SIEMENS

TRIDENT® WATER TREATMENT SYSTEMS

PILOT STUDY REPORT

Georgetown Divide, CA

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INVESTIGATION DATES: March 19 to April 9, 2009

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Executive Summary

The following report evaluates the Trident and Trident HS process capabilities of treating the surface water source received from the Auburn Lake Trails Water Treatment Plant and it's ability of meeting the California Department of Public Health (CDPH) drinking water treatment standards. Siemens Water Technologies, in cooperation with the Georgetown Divide Public Utility District, conducted a pilot study using the Siemens Water Technologies' Microfloc Trident HS1 multi-barrier mobile demonstration plant.

The study objectives were to demonstrate the Trident and Trident HS process would meet or exceed the pilot study protocol as outlined by Georgetown Divide Public Utility District and Siemens Water Technologies.

Target Objectives:

- Filter effluent turbidity $\leq$ 0.10 Nephelometric Turbidity Units (NTU)
- Filter effluent color $\leq$ 5 Color Units (C.U.)
- Filter effluent aluminum $\leq$ 0.10 mg/l
- 2 log particle reduction (2-15 micron size range) across the treatment system
- $\geq$ 35 % TOC reduction (35% per USEPA's Stage 1 Disinfection By-Products Rule)

Additional Objectives:

- Evaluate net finish water production performance
- Evaluate optimum water treatment chemicals and dosage levels to meet the pilot study objectives
- Evaluate influent and Treated (clarifier and filter) water qualities
- Determine and optimize operational parameters to meet the pilot study objectives
- Demonstrate impact of elevated turbidity > 20 NTU
- Collect HAA5 and TTHM formation potential data
- Measure and evaluate AC flush and filter backwash waste settling characteristics

The test data collected concluded the following:

- The Trident and Trident HS systems are capable of successfully treating the source water for turbidity, color, metals, and total organic carbon (TOC)
- Filter effluent turbidity typically <0.05 NTU
- Filter effluent color typically $\leq$ 2 C.U.
- Filter effluent aluminum usage content typically $\leq$ 0.01 mg/l
- Filter effluent iron and manganese typically $\leq$ 0.01 mg/l
- Particle count log removal 3.7 – 4.3 log in the 2 – 5 micron size range and 3.7 – 4.8 log in the 5 – 15 micron size range
- Effluent TOC < 1.5 mg/l, and THMFP and HAA5FP below the MCL
- Net finish water production 95% to 96% with the Trident process
- Net finish water production 96% to 98% with the Trident HS process
- All the chemical treatment schemes evaluated achieved good to excellent effluent quality

Overall, Siemens Water Technologies' Trident and Trident HS process demonstrated acceptable treatment performance and versatility by treating the source water under various conditions, chemical treatment schemes, and process configurations (Trident versus Trident HS).

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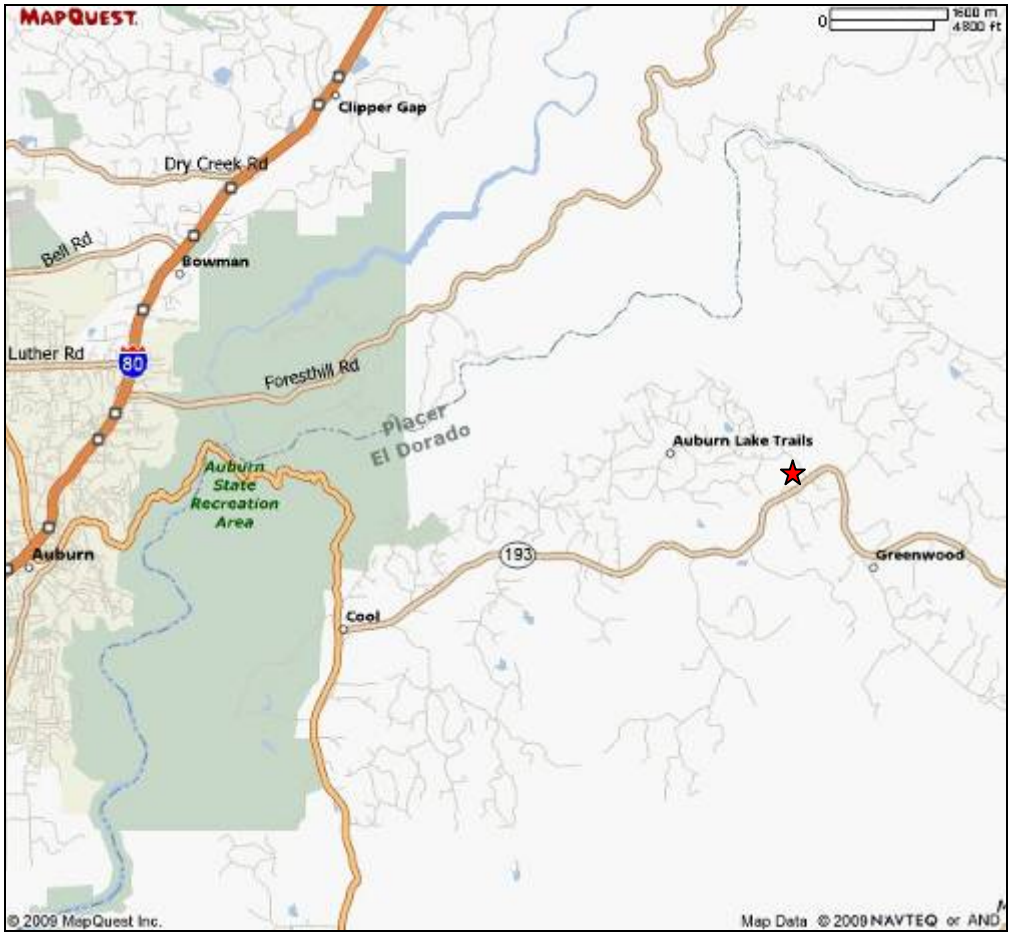
1.0 Introduction:

The Auburn Lake Trails Water Treatment Plant (ALT WTP) is located approximately 15 miles east of Auburn, CA and is operated by the Georgetown Divide Public Utility District (GDPUD). The Auburn Lake Trails WTP is located off Highway 193 near the town of Greenwood, CA. The ALT WTP utilizes runoff from the Sierra Mountains via Stumpy Meadows reservoir and a system of canals as its drinking water source. ALT WTP's existing water treatment facility utilizes an in-line filtration process. This process consists of in-line coagulation and pressure media filtration. The current chemical treatment regime consists of ProPAC 9890 as the primary coagulant and pre and post chlorination. Due to the age of the treatment system and difficulties in effectively handling water quality changes, the GDPUD is investigating new treatment system options. The GDPUD commissioned Siemens Water Technologies (SWT) to conduct a pilot study utilizing the Microfloc Trident and Trident HS package treatment processes. This pilot report presents data collected from the pilot testing conducted at ALT WTP during March 19 – April 09, 2009.

Auburn Lake Trails Water Treatment Plant - Site Map



2.0 Pilot Study Protocol:

The study objectives were to demonstrate the Trident and Trident HS Multi-barrier process would meet or exceed the following parameters as outlined by GDPUD and SWT:

Testing Objectives:

- Filter effluent turbidity ≤ 0.10 NTU
- Filter effluent color ≤ 5 C.U.
- Filter effluent aluminum ≤ 0.10 mg/l
- 2 log particle reduction (2-15 micron size range) across system
- ≥ 35 % TOC reduction (35% per USEPA's Stage 1 Disinfection By-Products Rule)
- Evaluate net finish water production performance
- Evaluate optimum water treatment chemicals and dosage levels to meet the pilot study requirements
- Evaluate influent and treated (clarifier and filter) water qualities
- Optimize operational parameters to meet the pilot study objectives
- Demonstrate the impact of elevated (simulated) turbidity > 20 NTU
- Collect HAA5 and TTHM formation potential data
- Measure AC flush and filter backwash waste settling characteristics

For the pilot study, pilot data was recorded via several formats. This included on-line data recording of turbidities, particle counts, clarifier and filter headlosses. Additional data was recorded by the operator for tests conducted on grab samples. Additionally samples were collected for outside lab analysis and validation. All data and associated documentation from the pilot study are presented in the appendices.

Measured Parameters:

- Turbidity – raw, tube effluent, AC effluent, and filter effluent
- Particle counts – raw, clarified (after AC only), and filter effluent
- Log removal from clarifier section, filter section, and system will be calculated
- pH – raw and coagulated
- Temperature – raw
- Flow/volume – tube, AC, and MMF
- AC pressure
- Filter headloss
- Coagulated streaming current
- Chemical feed rates
- Iron – raw, AC and filter effluent
- Manganese – raw, AC and filter effluent
- Aluminum – raw, AC, and filter effluent
- Color – raw, AC, and filter effluent
- Alkalinity – raw and filter effluent
- UV254 – raw, AC, and filter effluent

3.0 Process Description and Pilot Equipment:

The pilot study was conducted using the Trident and Trident HS Multi-barrier Demonstration Pilot Plant. The demonstration unit is a small scale replica of a complete treatment system. The plant includes complete raw water chemical feed capabilities, fully instrumented, and has an integral clearwell to provide water for backwash of the filter.

Similar performance and operational parameters of a full-scale plant based on the pilot plant performance can be expected assuming the raw water quality is comparable and chemical feeds are optimized. Coagulant was fed ahead of the 2.0" in-line static mixer. The static mixer is a six section PVC static in-line mixer, which provides effective mixing energy to produce a completely blended flow. Filter aid polymer was added prior to the Adsorption Clarifier® section, and sodium hypochlorite was added prior to the mixed media filter section.

In the Trident HS configuration (Figure 1, Photo 1) the first stage, tube clarifier section combines the functions of mixing of preformed flocs via an external recirculation pump (typically 2 - 5% of average of forward flow with a maximum of 10%); sludge blanket flocculation, and particle removal utilizing 60^0 inclined settling tubes. The sludge level within the tube clarifier and underflow concentration are maintained by intermittently wasting of the settled sludge, which is typically 1 to 2% of forward flow. A constant inventory of a high sludge blanket provides a "buffer" to potentially variable source water solids loading and helps in maintaining a consistent finish water quality. The tube section supernatant is then pumped to the second stage up flow Adsorption Clarifier® (AC). The up flow AC utilizes a packed bed NSF® approved buoyant media having an effective size of 2 mm. The buoyant media combines the functions of additional mixing, contact flocculation, and solids removal. The AC "polishes" non settleable solids and conditions any remaining solids prior to the stream entering the mixed media filter (MMF). In Trident mode the raw water is fed directly to the AC followed by the MMF (Figure 2).

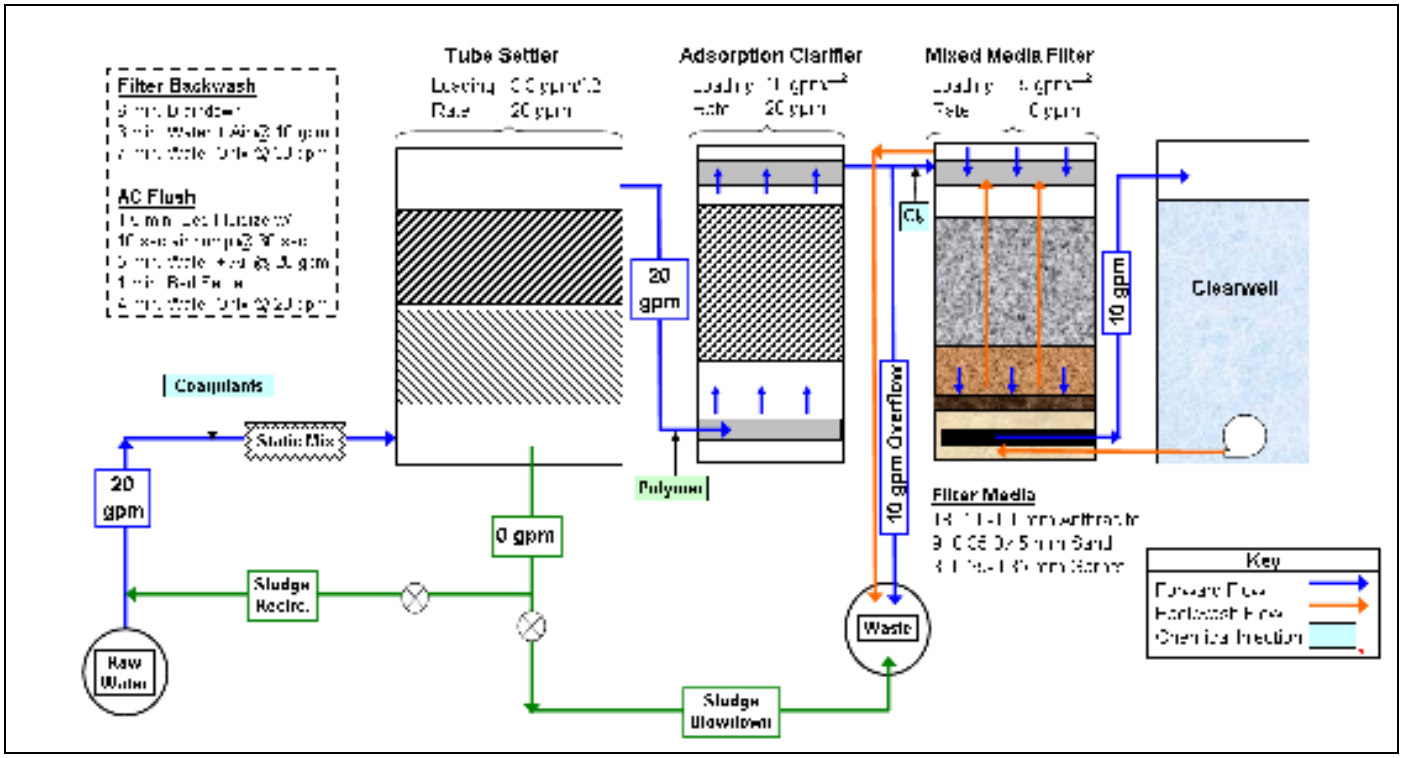


Figure 1: Trident HS Treatment Process Flow Scheme

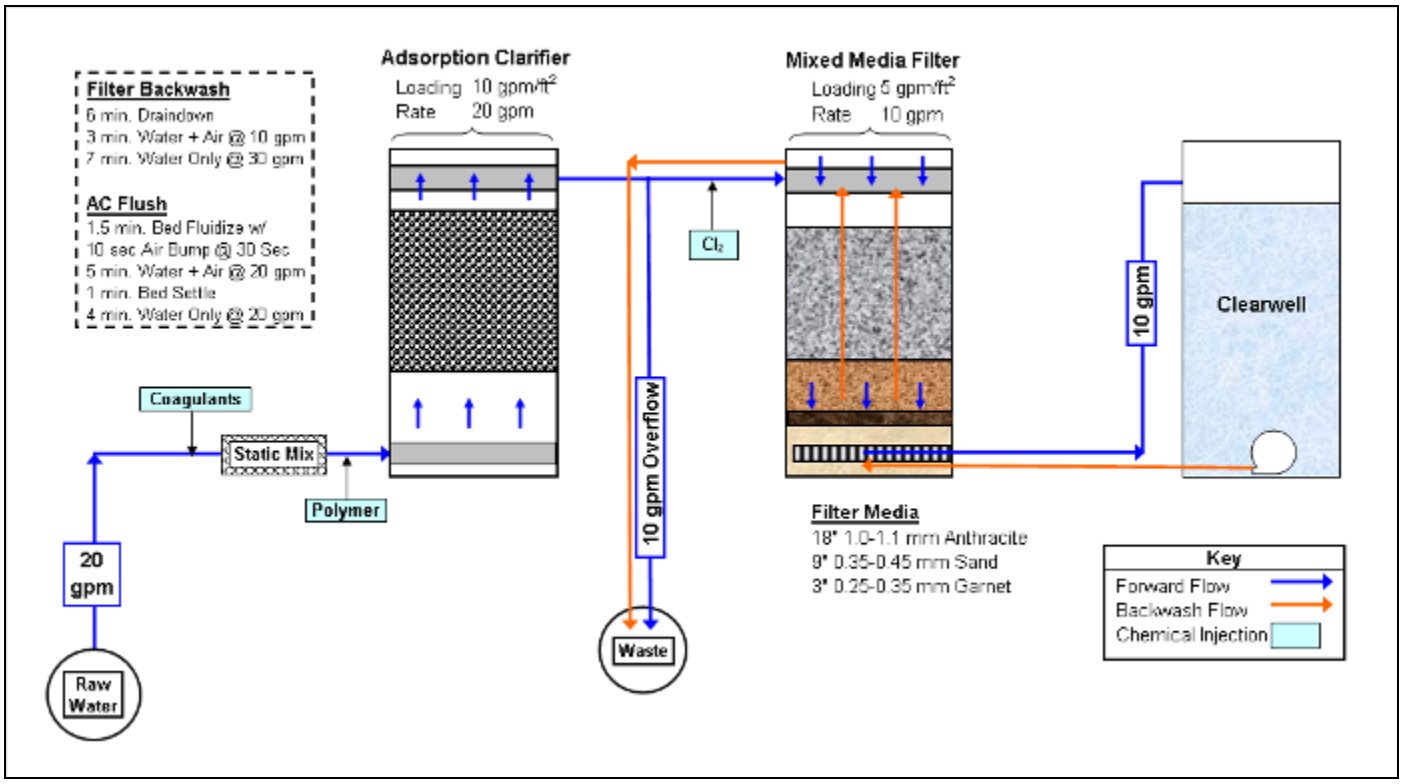


Figure 2: Trident Treatment Process Flow Scheme

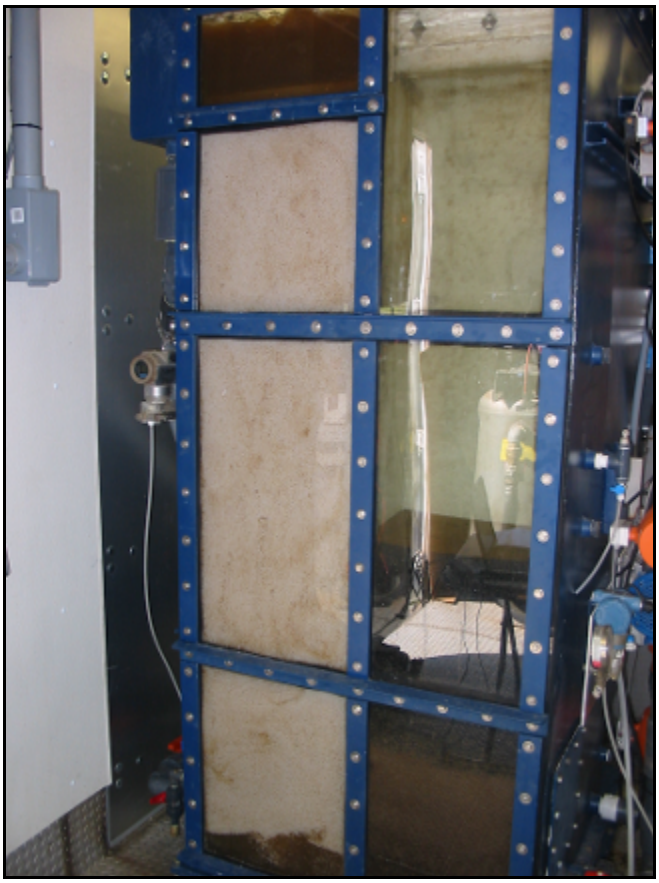
The Mixed Media Filter design consists of three media layers; 18 inches anthracite coal, 9 inches silica sand, and 3 inches high-density garnet. This media configuration provides a high media surface per volume allowing improved solids retention and improved filter run times. This multi-barrier clarification system provides well-conditioned clarified water to the third stage, a MMF. The flow is upward through the Tube Section (Trident HS only), upward through the AC, and downward through the MMF.

The coagulant feed was controlled manually. Automatic control is available on full-scale units with the Aquaritrol III® system which senses either the final turbidity or the surface charge on the coagulated particles (streaming current) and then regulates the coagulant to produce the desired set point. The Aquaritrol III® is a microprocessor based system which optimizes chemical dosages based upon water quality parameter inputs. It is a feed forward - feedback system with milli-second response time and solid-state assembly. The Aquaritrol III® system is available with three options: effluent turbidity control, raw water turbidity control with effluent turbidity control override, or streaming current control with effluent turbidity control override.

In the effluent turbidity control mode, the filter effluent turbidity is compared to the plant setpoint (for example 0.10 NTU) and primary coagulant dosage is adjusted based on the deviations observed. If the actual effluent turbidity is 5% higher than the setpoint, the coagulant dosage is appropriately increased. If the deviation is greater, for example, 15%, a greater increase in coagulant dosage would be made. If the effluent quality is better than required, dosages (and chemical consumption) are automatically reduced.

Photo 1: Trident HS Multi-barrier Pilot Unit

Photo 2: AC Flush



At the start of a run, the unit is initialized to the desired effluent and operation parameters. Turbidity setpoint, process time lag, baseline rate of dosage change, and dead band range are entered at the unit keyboard. A process time lag equivalent to the operating system detention time is programmed into the AQUARITROL III®. Under normal raw water conditions, the AQUARITROL III® will be acting a full lag time after changes in coagulation conditions occur. During periods when the raw water conditions are abnormal, the AQUARITROL III® will act more frequently and initiate greater dosage changes. This automated coagulant controller reacts to changing raw water conditions quicker than a plant operator. However, the AQUARITROL III® does not replace the plant operator but merely provides an addition tool for the optimization and control of the treatment process.

The Trident HS multi-barrier demonstration plant runs constant but at adjustable flow rates. For this study, the hydraulic loading rate **3.3 gpm/sq.ft**. on the tube section (Trident HS only), **10 gpm/sq.ft**. on the AC, and **5 gpm/sq.ft.** on the MMF. Because of scale considerations, the clarifier sections are larger than needed for flow to the filter. Part of the AC effluent is split off to waste and the other part is passed through the MMF. The raw feed and filter effluent flows are monitored with on-line magnetic flow meters. The AC and the MMF are each equipped with a pressure transmitter and recording device to monitor headloss development.

The AC automatic flush sequence is initiated via manual pushbutton, adjustable timer or accumulated headloss. The AC flush during this pilot study utilized the tube section effluent rather than finished filtered water. Photo 2 displays the AC during the **Flush** step. The buoyant media is completely fluidized allowing accumulated solids removal. The flush is accomplished in a multiple step process as follows:

- **Fluidization -** Forward flow stops, filtration stops, AC inlet valve closes, AC waste valve opens and the buoyant media fluidizes by injecting air at **3 to 4 scfm/sq.ft**. **1 – 1.5 minute**.
- **Optional Air Bump –** After 30 seconds of fluidization the air is shut-off for 10 seconds and restarted.
- **Flush -** Forward flow is resumed, AC inlet valve opens, flush rate automatically adjusts to **10 gpm/sq.ft**, air injection continues at **3 to 4 scfm/sq.ft**. **4 – 5 minutes**.
- **Bed Settle -** Forward flow stops, AC inlet valve closes, air injection stopped and the buoyant media settles. **1 minute**.
- **Flush to Waste -** Forward flow resumes, AC flow automatically adjusted to **15 gpm/sq.ft,** AC effluent is wasted. **4 – 6 minutes**.
- **Service-** AC waste valve closes diverting flow to the filter, filter starts; normal filtration resumes.

The MMF automatic backwash sequence is initiated via manual pushbutton, adjustable timer, accumulated headloss, or turbidity breakthrough. The MMF backwash utilizes filtered water stored in an integral clearwell. The backwash is accomplished in a multiple step process as follows:

- **Draindown** – Forward flow stops, filter continues to operate until the water level reaches the media's surface.
- **Combined Air/Water** – Backwash waste valve opens, filter effluent valves close, backwash supply valves open, air injection starts, backwash rate automatically set to **5 gpm/sq.ft** water and **3 scfm/sq.ft** air. **3 – 4 minutes**.
- **Air Purge/Re-stratification** – Air injection stopped, backwash rate automatically increased to **15 gpm/sq.ft**.
  4 – 6 minutes.
- **Service** – Backwash waste and supply valves close, filter effluent valves open, forward flow starts and filtration resumes.

The AC flush and MMF backwash sequence times can be adjusted, via the automatic plant control system; maximizing cleaning efficiency for given source water conditions. Full-scale Trident HS systems utilize Siemens Water Technologies' Multiwash® simultaneous air/water filter backwash process and a filter-to-waste step.

Reference Appendix A, Trident Pilot Technical Data, for complete documentation on the Trident HS treatment system.

4.0 Raw Water Characteristics:

Pilot testing was conducted at the Auburn Lake Trails WTP, which currently treats surface water from a retention pond next to the WTP. The raw water typically has turbidity < 5 NTU, and color < 15 cu, but historically during periods inclement weather turbidity spikes up to 30 NTU have been observed. During the pilot study, five runs were completed under natural conditions and two runs under induced elevated turbidity conditions. Table 1 presents raw water quality experienced during the study period.

Table 1: Average Raw Water Quality

Test Parameter	Natural	Turbidity Spike
pH - units	7	6.8
Turbidity – NTU	2.0 – 3.7	15 - 25
Color – C.U.	12	7
Iron - mg/l	0.11	0.45
Manganese - mg/l	0.018	0.147
Alkalinity - mg/l as CaCO3	10	12
Aluminum - mg/l	0.005	0.009
Temperature - ^{o}C	14	15
TOC - mg C/l	1.84	1.85

Reference Appendix B, Performance Runs – Summary, Data and Graphs and Appendix C, Outside Lab Results for complete details of raw water qualities.

5.0 Process Data and Discussion:

Following completion of the set-up of the Trident HS pilot unit, process optimization runs were conducted to identify an appropriate chemical treatment scheme. Aluminum based coagulants, specifically Aluminum Sulfate (Alum) and ProPAC 9890 (9890), were identified as a good primary coagulants for particle coagulation and turbidity reduction. A total of seven performance runs were conducted between March 23rd and April 9th; three with 9890, and four with Alum and 9890. Four of the runs were completed in Trident mode and three in Trident HS mode. Performance runs were typically conducted to filter terminal headloss of 8 feet or 24 hours. The Trident HS Multi-barrier pilot unit was operated at the flow rates of 3.3 gpm/sq.ft. on the tube section (Trident HS only), 10 gpm/sq.ft. on the adsorption clarifier and 5 gpm/sq.ft. on the mixed media filter.

Reference Appendix B, Performance Runs – Summary, Data and Graphs, and Appendix C, Outside Laboratory Results, for complete details of the data presented in Section 5.0.

5.1 Chemical Treatment:

Chemical treatment selection for the study was based on jar test results and pilot operator experience, effluent quality goals and process optimization. The chemical feed rates were adjusted during the process optimization runs and continually optimized to meet the study objectives. The ProPAC 9890 polyaluminum chloride and a combination of Alum and 9890 were

tested as coagulants. The coagulant(s) were dosed in the influent flow prior to a static mixer ahead of the tube or AC section.

During optimization several AC polymers were tested. Cytec Superfloc N-300 non-ionic polymer was found to provide the best treatment performance. The N-300 filter aid polymer provided good solids retention and reduction in the Adsorption Clarifier. All polymers utilized were NSF approved to a combined maximum dosage level of 1.0 mg/l as product. Sodium Hypochlorite (NaOCl) was dosed prior to the filter as an oxidant to aid particle removal. Dosage levels varied from 0.7 to 1.5 mg/l. Table 2 outlines the chemicals used during the study for each run.

Table 2: Chemical Treatment Schemes

Run	Start Date	Mode	Alum mg/L	ProPAC 9890 mg/L	AC Polymer N300 mg/L	NaOCl mg/L	Filter Run Length hours	AC Flush Interval hours	Comments
1	3/24/09	HS	---	3.2 – 3.5	0.1 – 0.18	1.0 – 1.4	44 (P)	8 (t)	
2	3/26/09	HS	7	1.0	0.12	0.7 – 1.4	60 (P)	9 - 10	
3	3/28/09	Trident	---	3.5	0.12	1.4	14.75	12 (t)	NaOCl Pump Fail
4	3/29/09	Trident	7	1.0	0.12	1.0	26.25	11	
5	3/30/09	Trident	---	3.5	0.12	1.0	17	15 (t)	
6	4/6/09	Trident	6 - 10	0.9 – 2.0	0.12 – 0.15	1.0	27.5	6 - 10	7.5 hour Turb Spike
7	4/7/09	HS	7	1.0 – 2.0	0.12 – 0.15	1.0	82 (P)	4 - 8	8.5 hour Turb Spike

Notes: (P) – Projected Run length based on headloss development
(t) – AC flushed based on time interval not headloss development
Alum – Aluminum Sulfate; Liquid
ProPAC 9890 – NTU Technologies; Polyaluminum Chloride (PACl); Liquid
Cytec Superfloc N-300 – Nonionic; floc/filter aid polymer; Dry
NaOCl – Sodium Hypochlorite; Liquid

Reference Appendix A, Trident HS1 Pilot Technical Data for MSDS data sheets

Overall, all the chemical treatment schemes evaluated achieved good effluent quality with low turbidity, particles, color, iron and manganese levels. Treatment with Alum and 9890 measured more favorable TOC and formation potential Trihalomethane (THM) and Haloacetic acids (five) (HAA5) reduction.

5.2 Turbidity Removal:

Turbidities were continuously monitored at four (4) points; raw, tube effluent, AC effluent, and MMF effluent using Hach 1720D on-line turbidimeters.

Source water turbidity reduction performance runs are presented below: Graphs 1 and 2 – Trident HS treatment under Alum and 9890 coagulation at natural and spiked turbidity conditions, Graphs 3 and 4 – Trident treatment under Alum and 9890 coagulation at natural and spiked turbidity conditions, and Graph 5 and 6 – Trident HS and Trident process treatment conditions with 9890 coagulation.

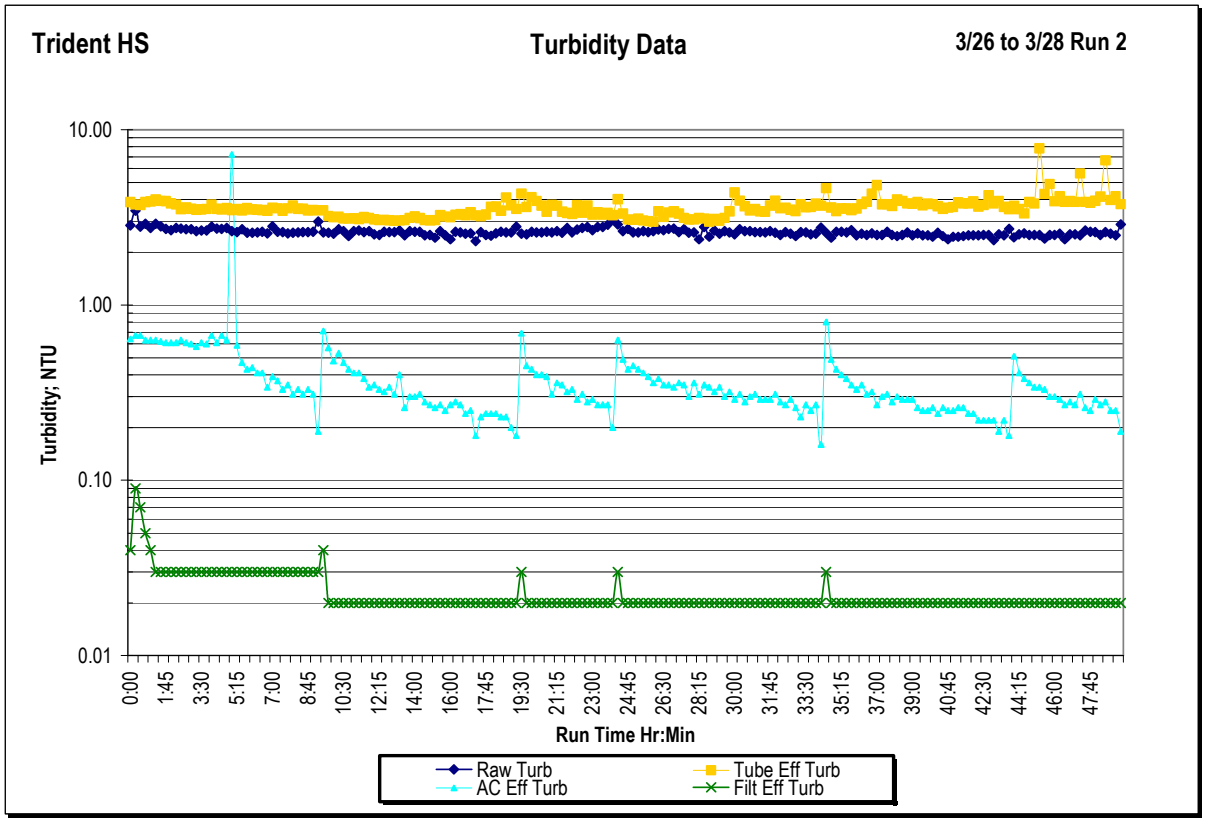
The raw water turbidities were ranged from 2.0 to 3.7 NTU during the testing period. Under the spiked turbidity runs, turbidities were increased in the range of 15 – 25 NTU. Note that spike conditions consisted of bentonite and area dirt. During normal turbidity conditions and at steady state conditions, the Trident HS multi-barrier and Trident treatment processes averaged the following turbidity performance:

- Tube Clarifier effluent turbidity:
  - 3.5 NTU – Alum and 9890 (Trident HS simulation)
  - 4.6 NTU – 9890 (Trident HS simulation)

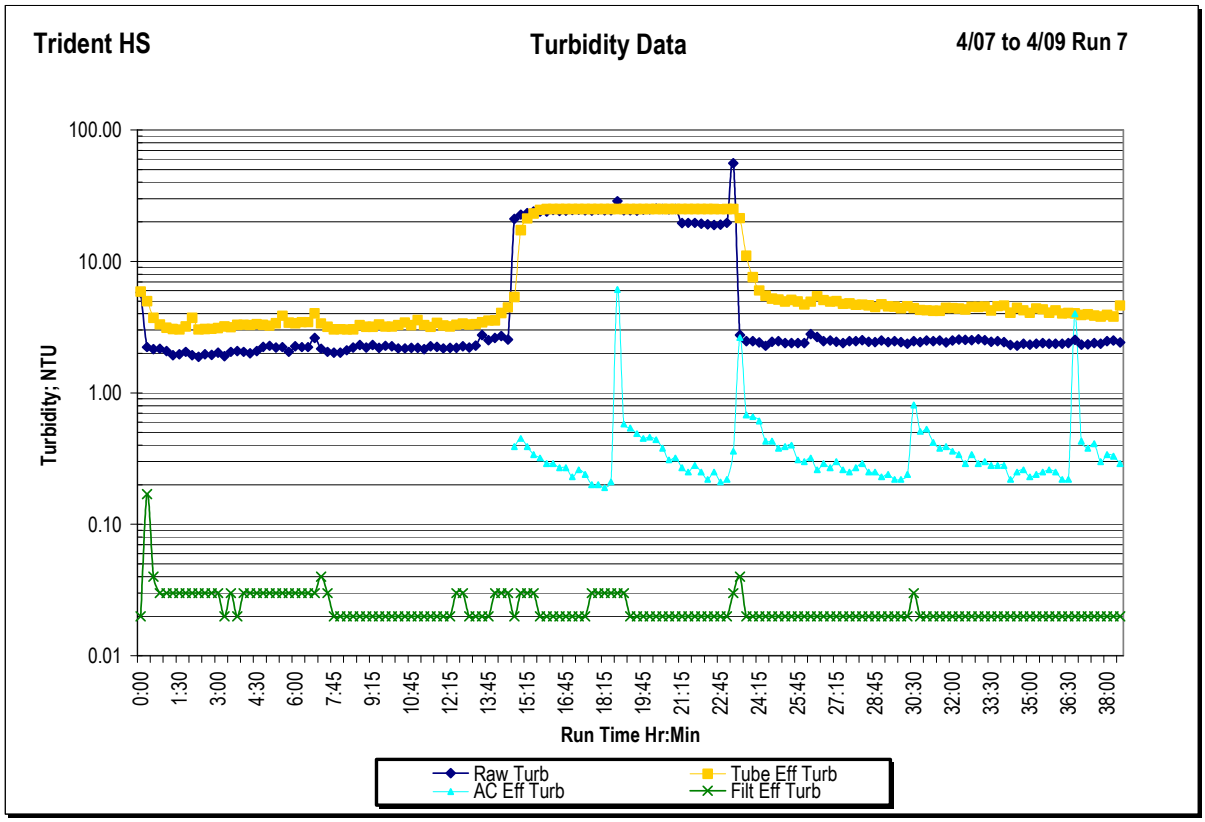
- Adsorption Clarifier effluent turbidity:
  - 0.4 NTU – Alum and 9890 (Trident HS simulation)
  - 1.1 NTU – 9890 (Trident HS simulation)
  - 0.6 NTU – Alum and 9890 (Trident simulation)
  - 1.2 NTU – 9890 (Trident simulation)

- Mixed Media Filter effluent turbidity:
  - 0.02 NTU – Alum and 9890 – Trident HS
  - 0.02 NTU – 9890 – Trident HS
  - 0.02 NTU – Alum and 9890 – Trident
  - 0.02 NTU – 9890 – Trident

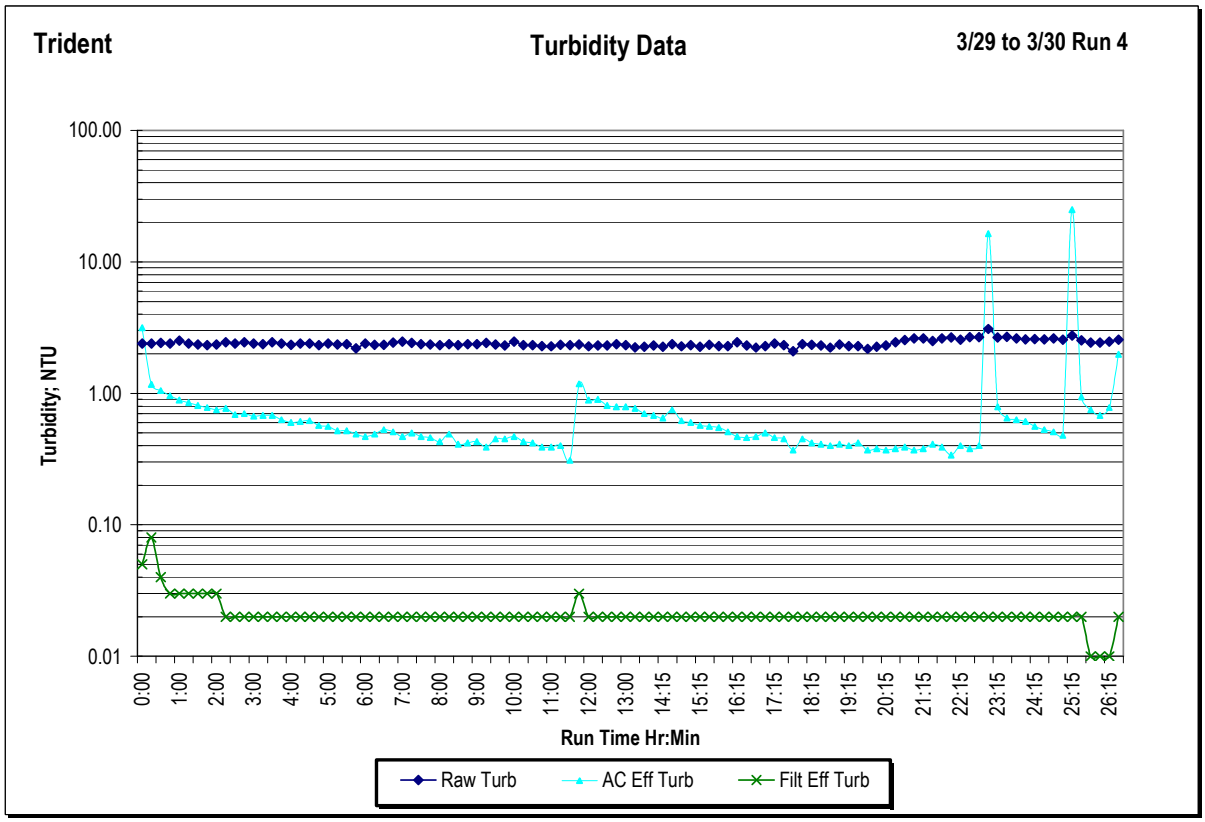
Under the turbidity spike events, Runs 6 and 7, raw turbidities increased up to 25 NTU. No impact to filter effluent turbidities were measured during the high solids events.



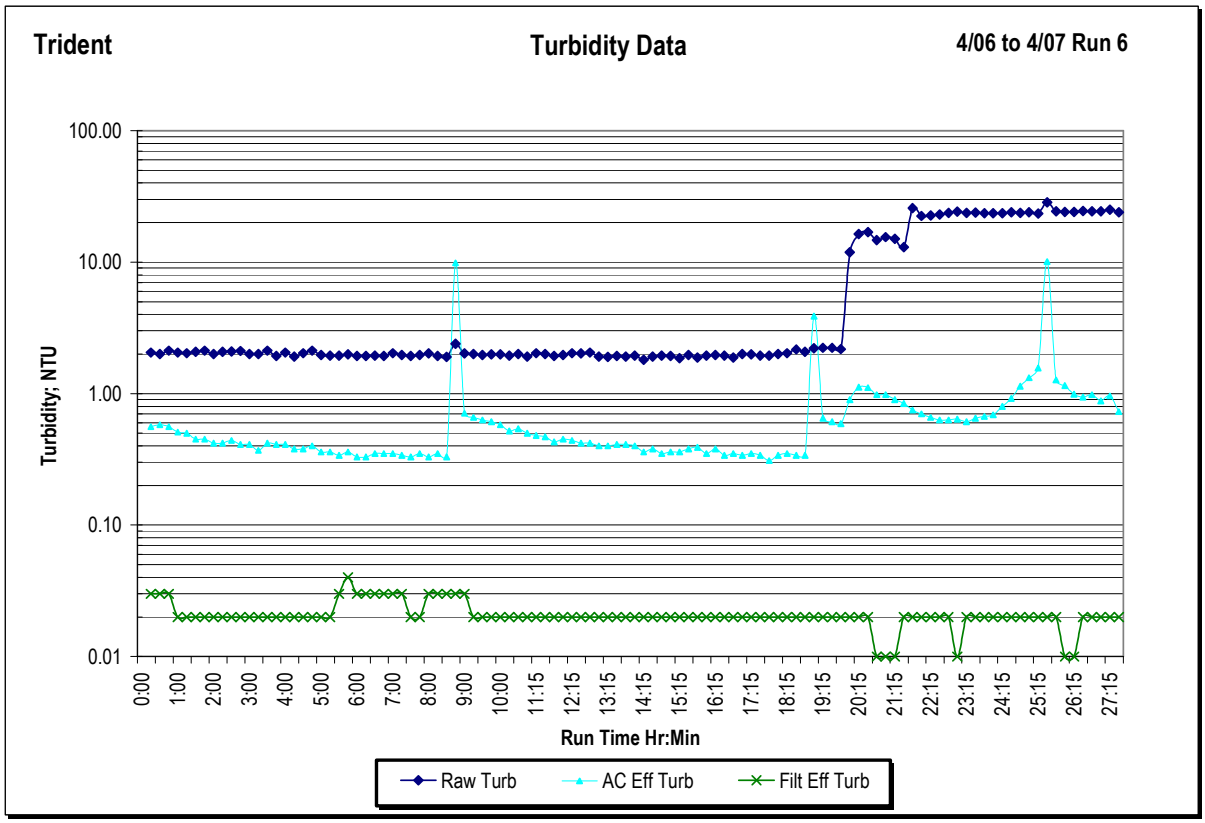
Graph 1: Trident HS – Alum and ProPAC 9890 Coagulation



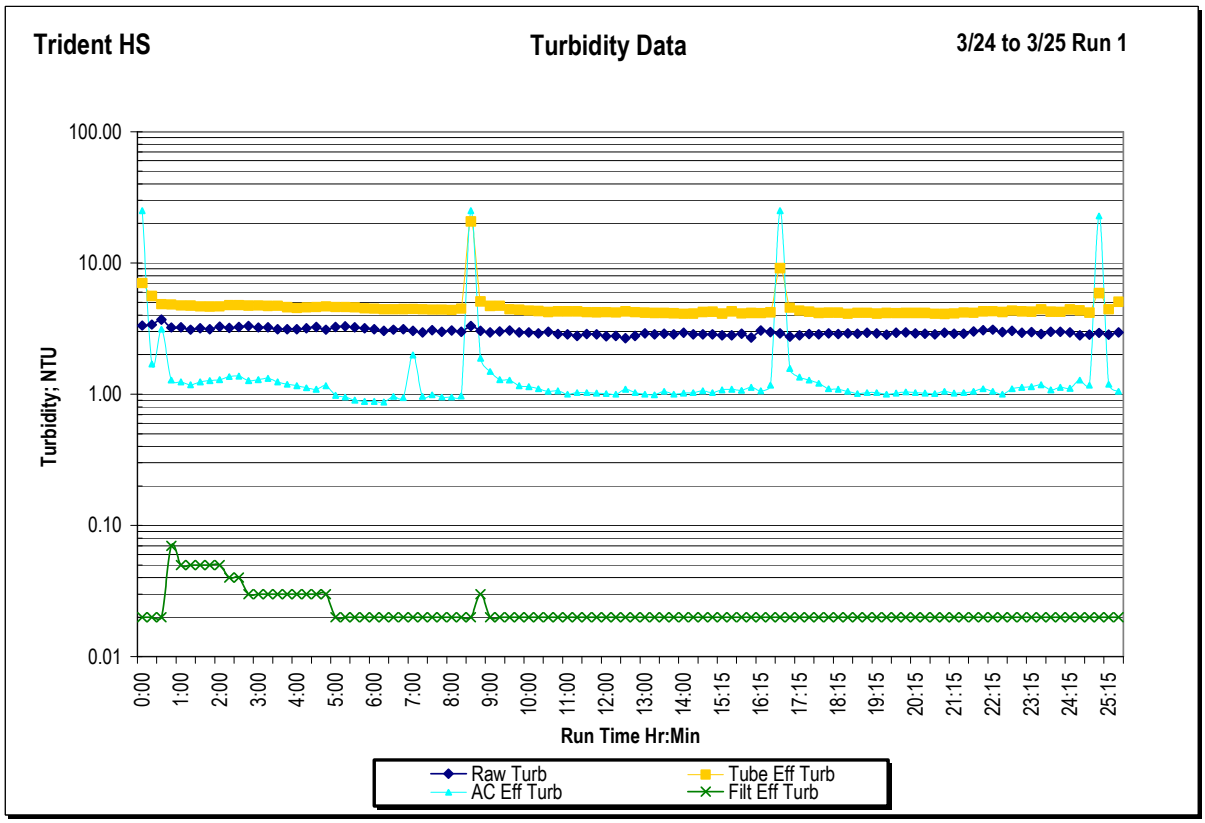
Graph 2: Trident HS – Alum and ProPAC 9890 Coagulation – Turbidity Spike



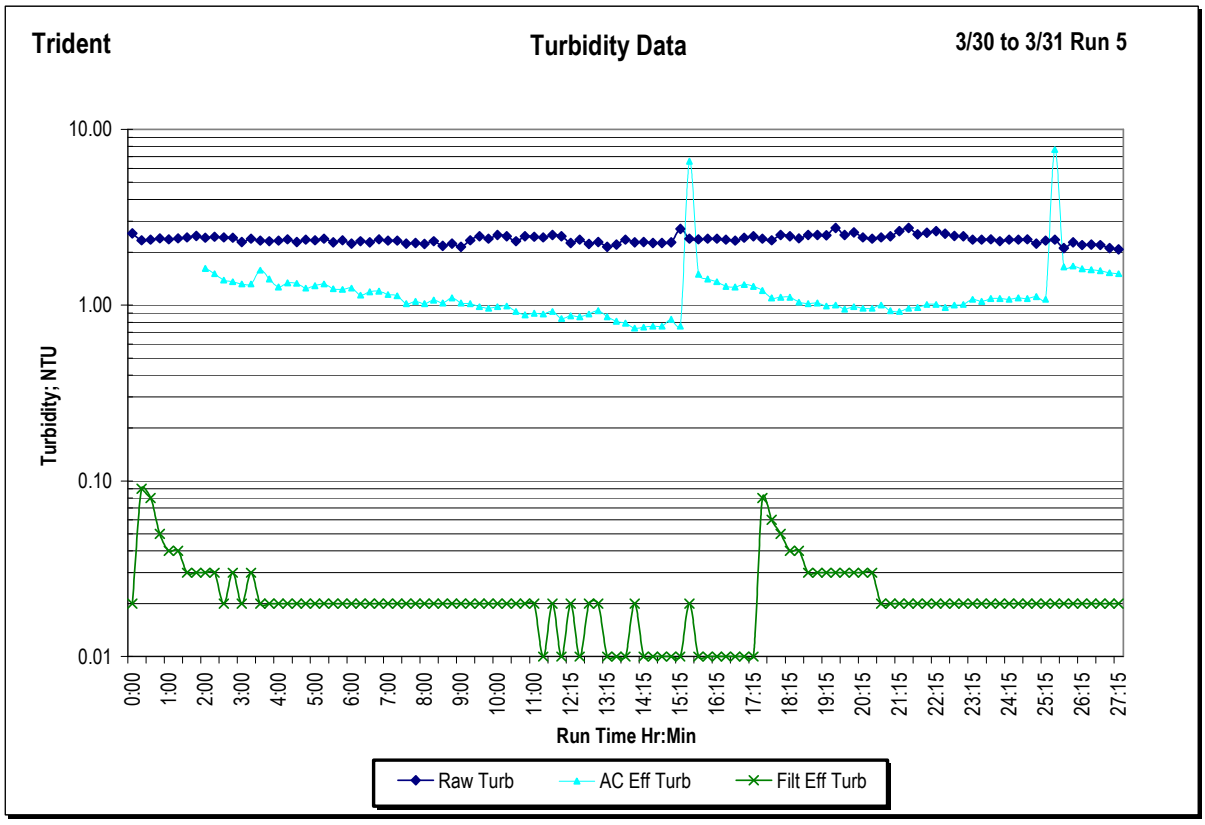
Graph 3: Trident – Alum and ProPAC 9890 Coagulation



Graph 4: Trident – Alum and ProPAC 9890 Coagulation – Turbidity Spike



Graph 5: Trident HS – ProPAC 9890 Coagulation



Graph 6: Trident – ProPAC 9890 Coagulation

5.3 Color Removal and UV 254:

During the testing period raw true color ranged from 3 to 26 C.U. The raw and AC effluent samples were filtered through 0.45 micron filter paper before analysis to determine the true color value. The filter effluent apparent color for the study period measured ≤ 1 C.U., meeting the protocol goal and USEPA's National Secondary Maximum Contaminant Level (SMCL) of <15 cu. Table 3 displays the color levels and UV 254 % Transmittance for Trident HS and Trident test conditions.

Table 3: Average Raw, AC, and Mixed Media Filter Effluent Color and UV 254

Run #	Raw		AC Effluent		Mixed Media Filter Effluent	
	True Color, cu	UV 254, %T	True Color, cu	UV 254, %T	App Color, cu	UV 254, %T
1	16	90	13	87	0	98
	26	90	4	85	0	98
2	22	89	2	96	4	98
	18	90	2	98	0	99
	11	90	2	97	3	98
3	5	90	2	94	0	98
4	7	90	1	96	0	98
	8	90	0	96	0	98
5	17	90	0	94	0	98
	3	90	0	94	0	97
6	15	79	1	96	0	98
	9	77	0	96	0	98
7	11	76	0	97	0	98
	3	78	1	97	0	98

Average	12	86	2	95	0.5	98

5.4 Metals – Iron, Manganese, and Aluminum:

Iron in the raw water measured well below the SMCL of 0.30 mg/l. Filter effluent levels never exceeded the SMCL and were typically < 0.01 mg/L total iron. Manganese in the raw water was typically measured below the SMCL of 0.05 mg/l except during the turbidity spike runs. The filter effluent levels were < 0.01 mg/l total manganese. The water quality easily achieved the USEPA National Secondary Drinking Water Standards. Table 4 provides average iron, manganese and aluminum concentrations.

USEPA's recommends a filtrate effluent aluminum level of less than 0.2 mg/l. Siemens Water Technologies' pilot operators regularly measure filter effluent aluminum residual when dosing an aluminum based coagulant. Under optimized conditions, filter effluent aluminum levels typically measured <0.010 mg/L.

Table 4: Raw and Effluent Iron and Manganese; mg/L

Run #	Raw			AC Effluent			Mixed Media Filter Effluent		
	Fe, mg/l	Mn, mg/l	Al, mg/l	Fe, mg/l	Mn, mg/l	Al, mg/l	Fe, mg/l	Mn, mg/l	Al, mg/l
1	0.01	0.016	0.018	0.17	0.026	0.066	0	0.001	0.003
	0.10	0.019	0.012	0.18	0.026	0.046	0.01	0.002	0.012
2	0.12	0.014	0.001	0.02	0.006	0.034	0.01	0.006	0
	0.10	0.019	0.001	0.02	0.009	0.006	0	0.008	0
	0.13	0.018	0	0.06	0.008	0.020	0	0.008	0
3	0.11	0.020	0	0.04	0.012	0.021	0	0.008	0.023
4	0.13	0.018	0.002	0.02	0.010	0.049	0	0.009	0.007
	0.11	0.018	0	0.03	0.010	0.034	0	0.009	0
5	0.13	0.018	0.012	0.06	0.012	0.024	0	0.007	0.008
	0.11	0.020	0	0.02	0.013	0.010	0.01	0.008	0.002
6	0.43	0.136	0.010	0.04	0.009	0.026	0.01	0.004	0.001
	0.49	0.169	0.007	0.04	0.008	0.047	0	0.007	0
7	0.44	0.150	0.015	0	0.008	0.018	0	0.008	0.001
	0.44	0.133	0.005	0.02	0.009	0.007	0	0.007	0.003
Average	0.20	0.055	0.006	0.05	0.012	0.029	0.003	0.007	0.004

5.5 Particle Counts Log Removals:

During the pilot study, particle count data was collected using the Stranco WTC 1028 continuous water particle counting system. Data was collected on the raw and filter effluent for particle size ranges of 2-5 µm, 5-15 µm, 15-50 µm, 50-100 µm and 2 – 200 µm on a 15 minute interval. The primary focus was on the 2-5 µm and 5-15 µm size ranges, based on the fact that bacterial pathogens of Cryptosporidium (Crypto) fall in the 2-5 µm range and Giardia fall in the 5-15 µm range. Reference Appendix B, Performance Runs – Summary, Data, and Graphs, for completed particle count/log data.

Typical particle counts and log removals are presented in Table 5.

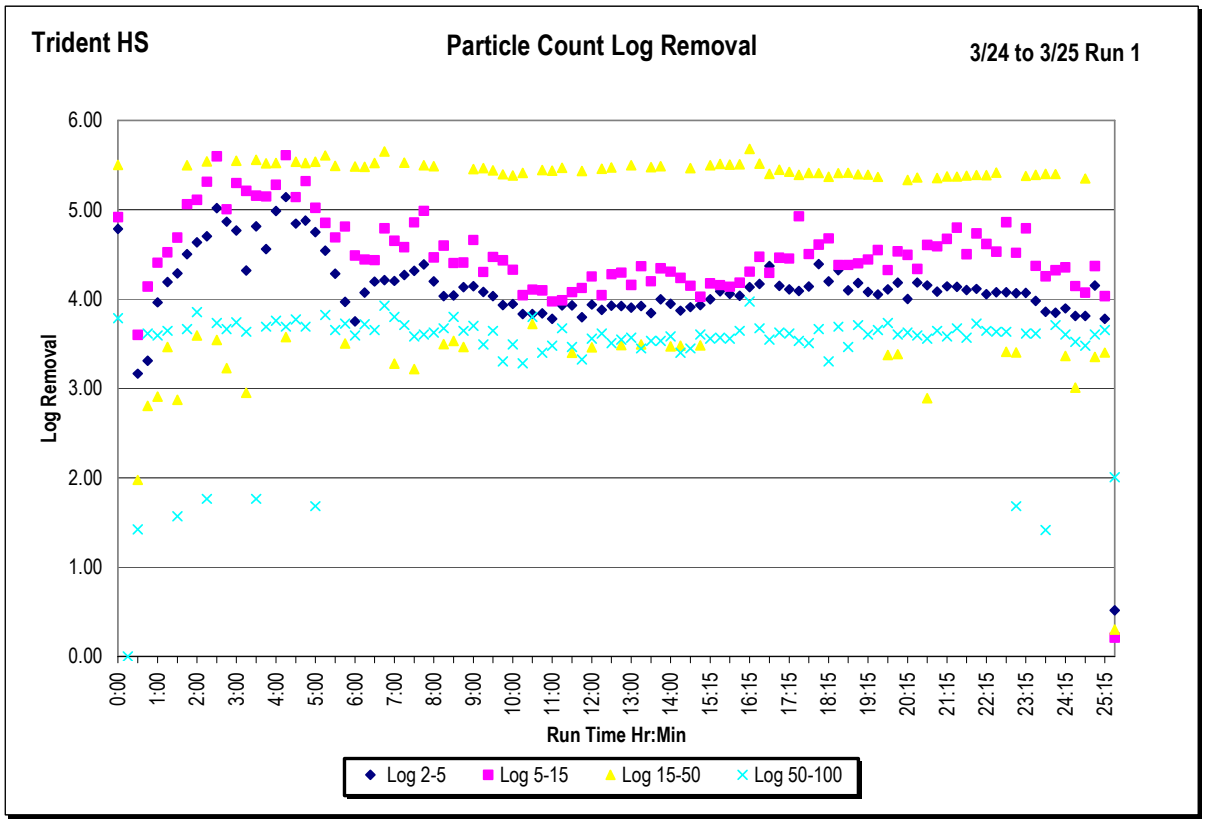
Table 5: Average Particle Count and Log Removals

Run #	2-5 µm counts/ml			5-15 µm counts/ml		
	Raw	Media Filter	Log Removal	Raw	Media Filter	Log Removal
1	5998	0.6	4.0	4699	0.2	4.4
2	5227	1.1	3.7	1738	0.4	3.7
3	4889	0.4	4.3	1199	0.7	3.9
4	4848	0.7	3.8	2403	0.7	3.9
5	4742	0.9	4.3	4062	0.3	4.8
6	6395	1	3.8	6891	0.4	4.2
7	6262	1.1	3.7	7596	0.4	4.3
Average	5480	0.8	3.9	4084	0.4	4.2

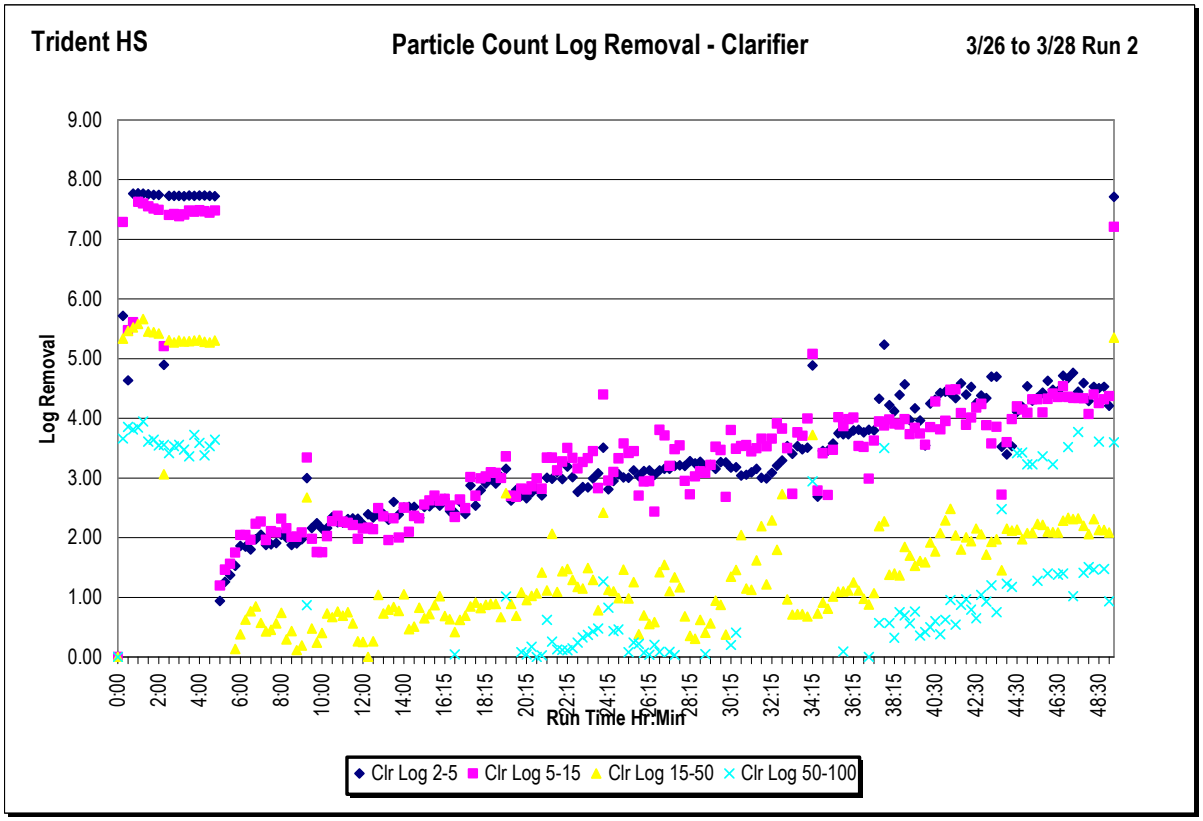
The particle count and log removal data indicated:

- Log removal in the 2 – 5 µm size measured 3.7 – 4.3 and in the 5 – 15 µm size at 3.7 – 4.8.
- Coagulation with 9890 generally measured slightly better log removals compared to treatment under the Alum and 9890 coagulation conditions.
- No significant differences in particle count removal were observed for the Trident and Trident HS system.

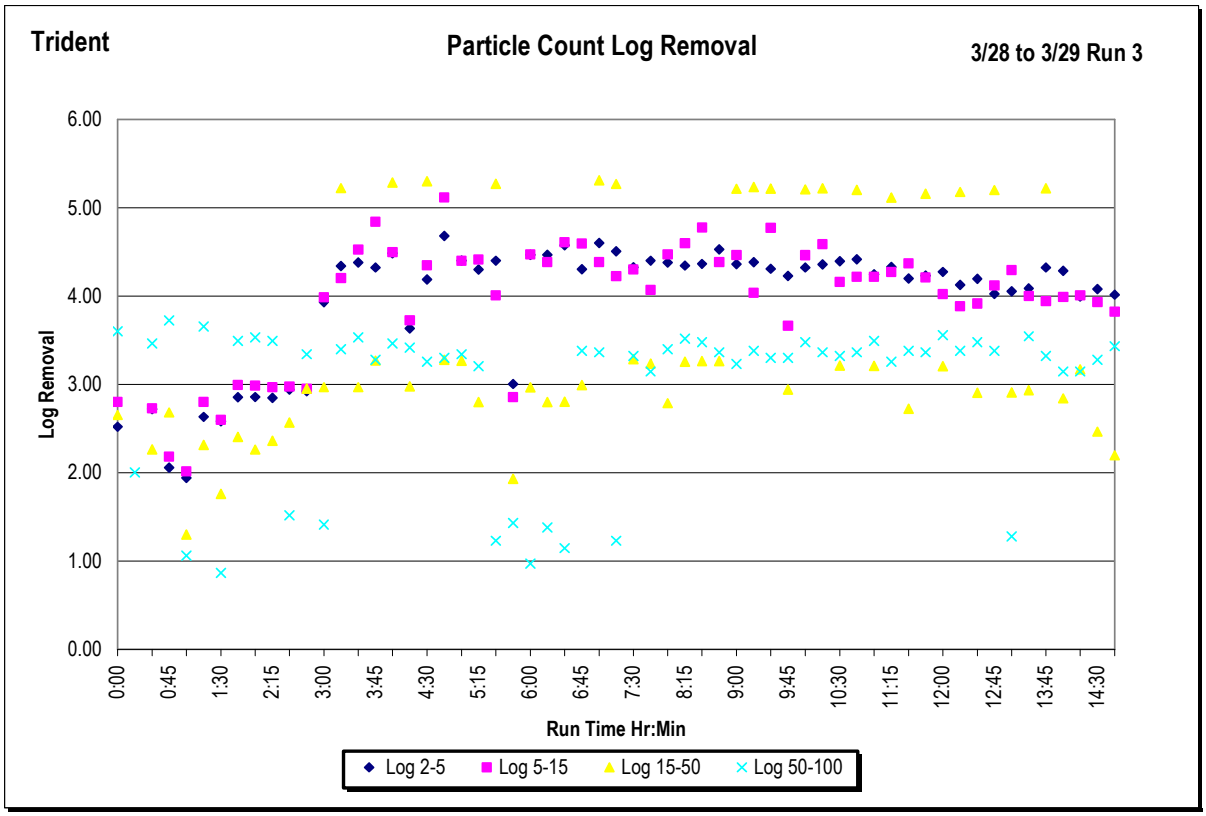
Graphs 7 – 13 illustrate particle log removal performance for the treatment conditions under Alum and 9890, and 9890 for the Trident HS process and treatment under the Trident process.



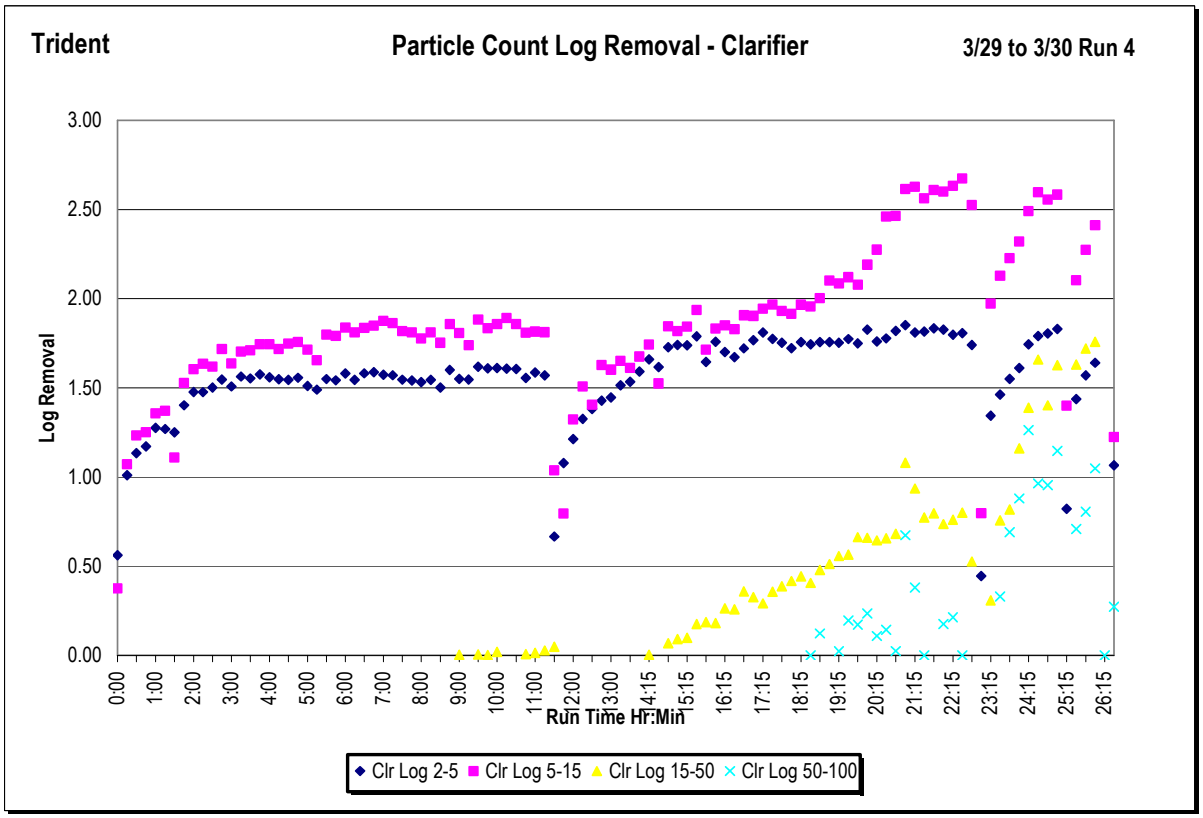
Graph 7: Log Removals Trident HS – ProPAC 9890 Coagulation



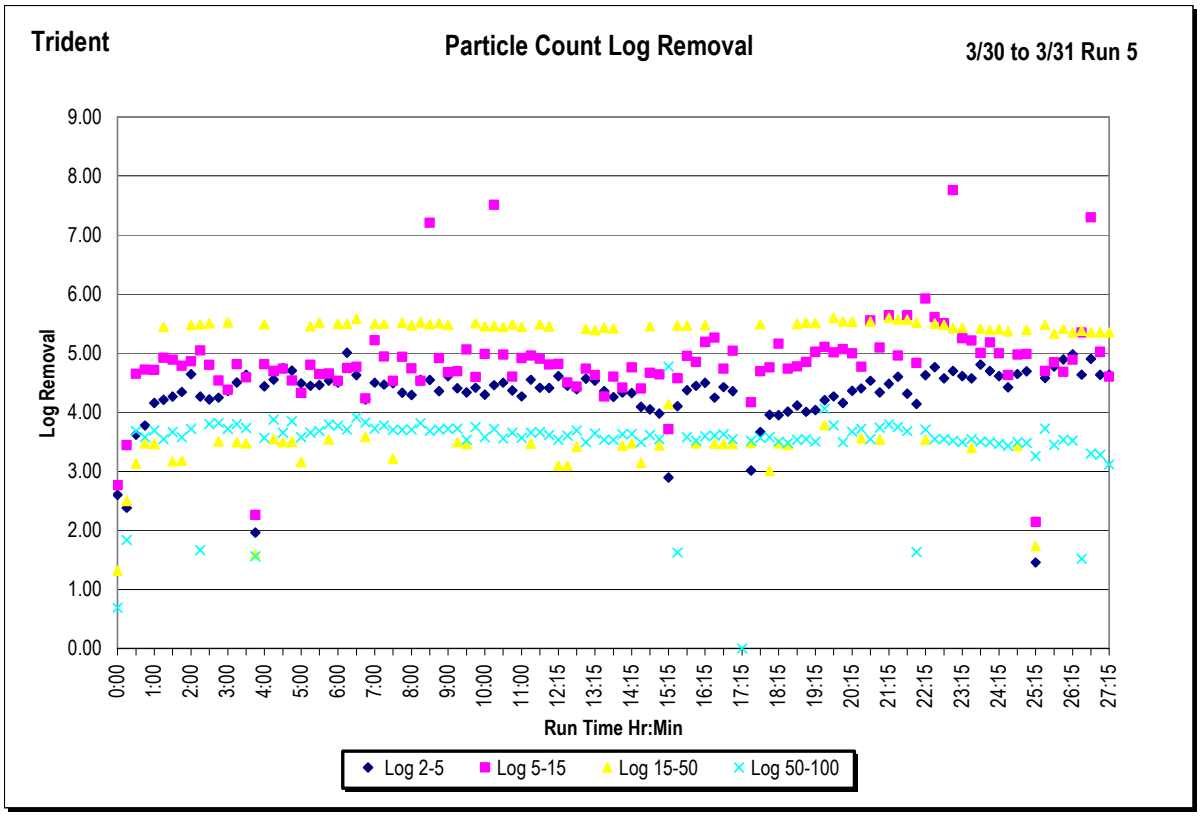
Graph 8: Log Removals Trident HS – Alum and ProPAC 9890 Coagulation



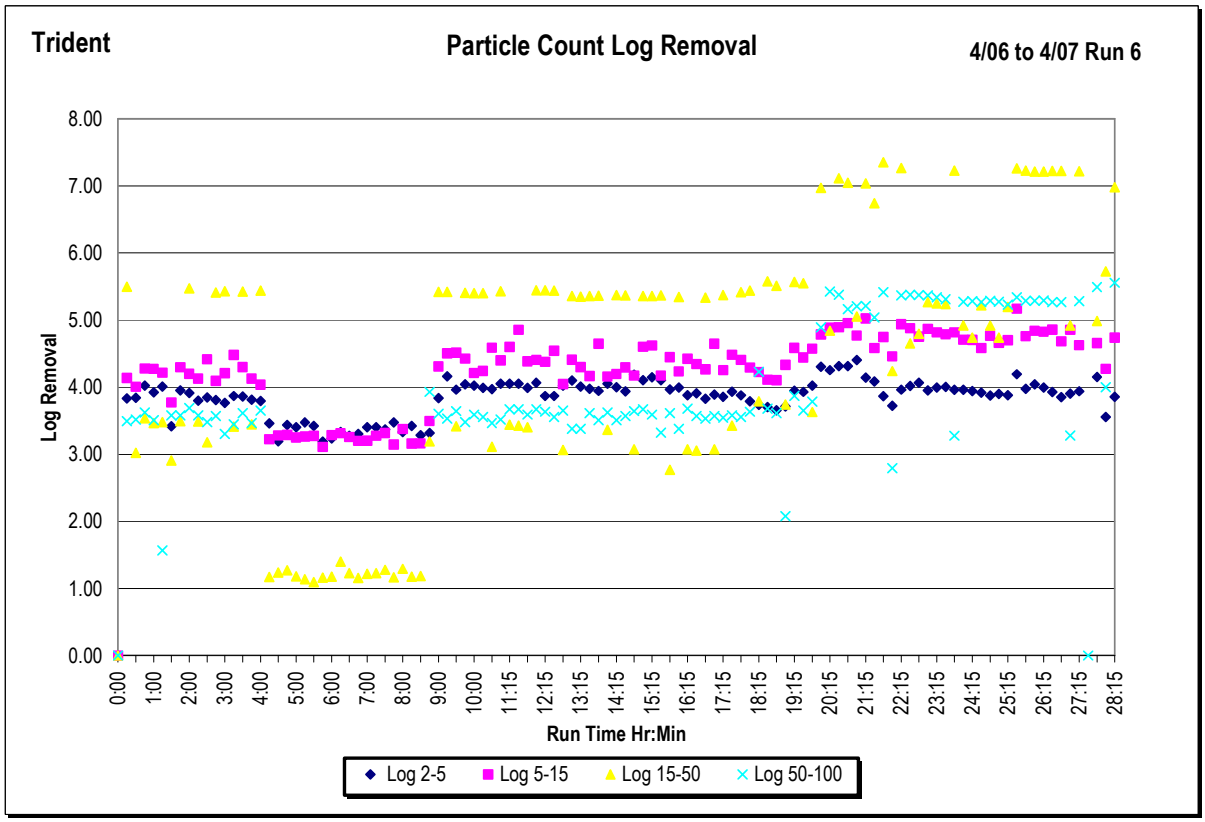
Graph 9: Log Removals Trident – ProPAC 9890 Coagulation



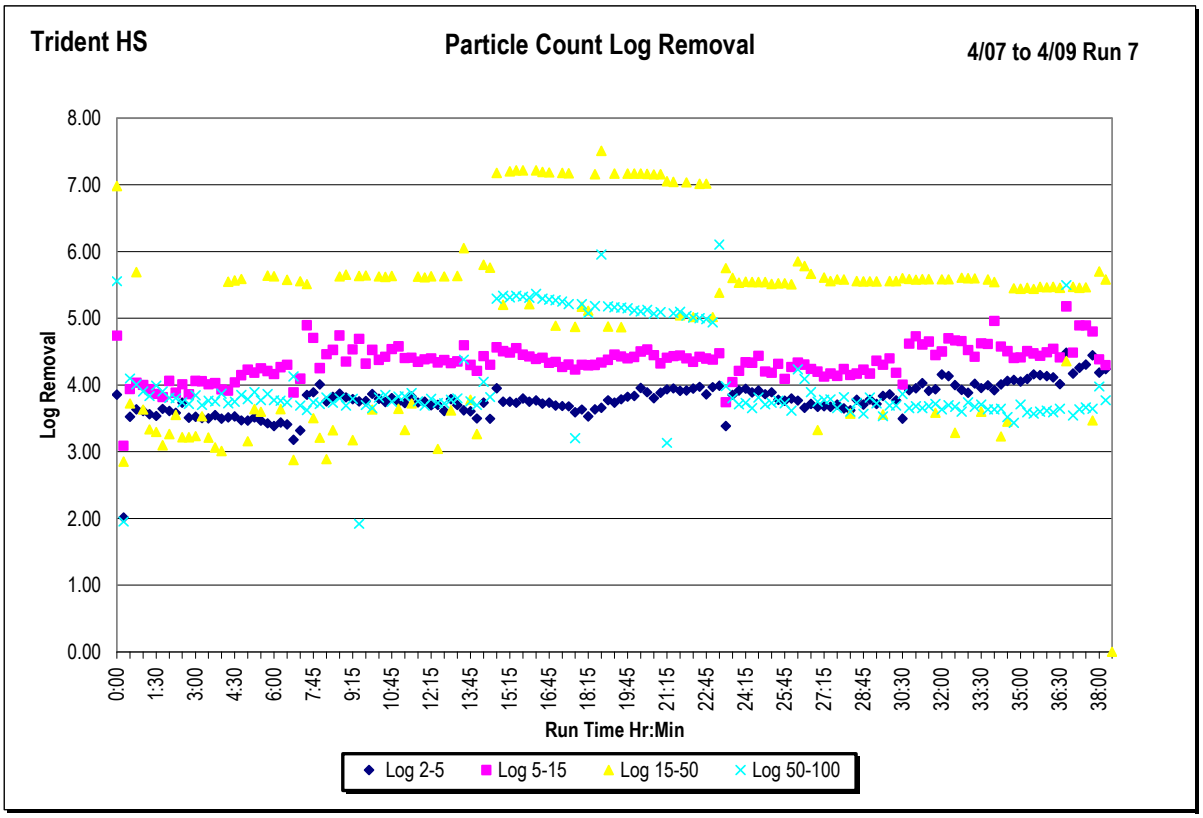
Graph 10: Log Removals Trident – Alum/ProPAC 9890 Coagulation



Graph 11: Log Removals Trident – ProPAC 9890 Coagulation



Graph 12: Log Removals Trident – Alum/ProPAC 9890 Coagulation – Turb. Spike



Graph 13: Log Removals Trident HS – Alum and ProPAC 9890 Coagulation – Turb. Spike

5.6 Total Suspended Solids:

During the pilot study the total suspended solids (TSS) were analyzed for several AC flushes and Filter backwashes. The TSS analysis was performed to characterize the waste streams produced. The TSS samples were collected continuously for the duration of the flush or backwash cycle. Overall, the AC flush waste TSS averaged 390 mg/l, and the filter backwash waste averaged 62 mg/l. Independent lab data for TSS concentrations are presented in Table 6. Settling tests of the AC flush waste found that 98% of the solids were settled after 5 minutes for Runs 2 and 4 using Alum and 9890, and 90% settled after 20 minutes for Run 1 using 9890. The filter backwash solids did not show visible settling after 20 minutes. Reference Appendix C, Outside Laboratory Results, for completed settling test results.

Table 6: TSS Concentrations

Run	Sample Date	Mode	Coagulant	AC Flush TSS mg/L	Filter Backwash TSS mg/L
1	3/25/09	HS	9890	340	77
2	3/28/09	HS	Alum/9890	390	48
4	3/30/09	Trident	Alum/9890	440	60

5.7 Organic Reduction

USEPA's Stage 1 Disinfection By-Products Rule requires surface water treatment systems to reduce TOC in order to minimize the formation of DBP's. The required reduction is determined by the source water TOC and alkalinity levels per Table 7. This reduction is typically achieved by enhanced coagulation. Generally enhanced coagulation requires slightly higher metal salt coagulant dosages and lower pH of coagulation than would be required for turbidity removal alone. The Stage 1 Disinfection By- Products Rule does provide alternative compliance criteria for system source water TOC that is less than 2.0 mg/L which was experienced at ALT WTP.

Table 7: Required Percent Removals of TOC per Stage 1 Disinfection By-Products Rule

	Source Water Alkalinity (mg/l as CaCO3)		
Source TOC (mg/l)	0- 60	>60 - 120	>120
> 2 – 4	35%	25%	15%
> 4 – 8	45%	35%	25%
>8	50%	40%	30%

Removing as much of the organic precursors (TOC) as possible reduces the potential to form harmful Trihalomethanes (THM) and Haloacetic Acids (five) (HAA5) in the distribution system. Current regulations limit THM levels at 80 ppb and HAA levels at 60 ppb.

THM and HAA5 Formation Potential is an estimate of the eventual THM concentration in the complete water system. The THMFP and HAAFP test attempts to predict the final concentrations in the distribution system, however it cannot calculate them precisely. The test, therefore, is considered by many to be the "worst case" condition of final THM or HAA levels assuming that ideal conditions of temperature, time, pH, and chlorine dose and residual are present. It is very rare that an actual system would see these levels in the distribution system.

Samples were collected throughout the study and analyzed by an independent laboratory. Evaluation of the results indicates:

- TOC removal was slightly better with Alum and 9890 than with 9890 only.
- TOC results were similar for both the Trident and Trident HS system.
- Effluent DOC levels measured higher than the TOC levels, indicating that the remaining TOC is soluble.
- THMFP and HAAFP levels were significantly lower with Alum and 9890 compared to 9890 only.
- The Trident and Trident HS process had comparable THMFP results for the same chemical treatment schemes. The Trident HS process had lower HAAFP results than the Trident process.

Detailed results are presented in Table 8 and 9.

Table 8: Independent Laboratory THM and HAA Formation Potential Analysis

Run	Sample Date	Sample Time	Mode	Coagulant	THM FP µg/L	HAA FP µg/L
1	3/24/09	16:00	HS	9890	75.6	67.4
2	3/27/09	7:45	HS	Alum/9890	51.6	45.0
	3/28/09	9:45			47.1	36.9
4	3/29/09	16:30	Trident	Alum/9890	57.0	47.5
5	3/31/09	10:30	Trident	9890	76.2	81.5
6	4/7/09	16:00	Trident	Alum/9890	52.1	50.2
7	4/7/09	15:30	HS	Alum/9890	52.0	45.4

Table 9: Independent Laboratory TOC and DOC Analysis

Run	Sample Date	Sample Time	Mode	Coagulant	TOC mg/L			DOC mg/L
					Raw	Effluent	% Removal	Effluent
1	3/24/09	16:00	HS	9890	2.9	1.6	44.8	1.7
2	3/27/09	7:45	HS	Alum/9890	1.1	1.3	-18.2	ND
	3/28/09	9:45			1.7	1.0	41.2	1.2
4	3/29/09	16:30	Trident	Alum/9890	1.6	1.1	31.3	1.4
5	3/31/09	10:30	Trident	9890	1.9	1.3	31.6	1.6
6	4/7/09	16:00	Trident	Alum/9890	1.5	1.9	-26.7	1.9
7	4/7/09	15:30	HS	Alum/9890	2.2	1.8	18.2	2.0

Reference Appendix C, Outside Laboratory Results, for completed test results.

6.0 Tube/Clarifier/Filter Hydraulic Performance and Net Production:

Hydraulic performance of the Trident or Trident HS Multi-barrier treatment system is qualified by the following criteria:

- Tube Section (Trident HS only) – Sludge re-circulation and sludge waste rates.
- Adsorption Clarifier – Run length in hours to terminal pressure, pre-determined time interval or contaminant breakthrough.
- Mixed Media Filter - Run length in hours to terminal pressure, pre-determined time interval or contaminant breakthrough.

The Net Production, expressed as a percentage, is calculated based upon; generated waste volume and time out of service. Reference Appendix B, Performance Runs – Summary, Data, and Graphs, for clarifier and filter headloss data and profiles

6.1 Tube Section Performance

The Tube section was utilized during Trident HS performance testing and operated at a loading rate of 3.3 gpm/sq.ft (of plan surface area). Effluent is then pumped to the Adsorption Clarifier. During standard Trident HS operation the settled solids are recirculated prior to the static mixer or intermittently wasted. Due to the low solids content of the water experienced during the pilot, the tube section was utilized to provide an additional 16 minutes of detention time only. The sludge recirculation and blowdown pump was not operated during the pilot.

The added detention time through the tube section provided significantly longer filter runs compared to the performance of the Trident system alone. Table 2 compared the filter and AC run lengths at each of the chemical treatment schemes for both the Trident and Trident HS system. Section 6.3 discusses filter performance during the pilot test.

6.2 Adsorption Clarifier Hydraulic Performance and Run Lengths:

The Adsorption Clarifier was operated at a clarification rate of 10 gpm/sq.ft. The AC is automatically flushed at 60 inches (water) of differential pressure, accumulated run time (operator adjusted) or contaminant breakthrough. AC run lengths varied based on the operating mode and chemical treatment scheme. In general, under the ProPAC 9890 treatment scheme the AC run lengths were longer, and flushed based on accumulated time, due to reduced solids capture through the AC resulting in higher AC effluent turbidities (Graphs 5 – 6). With the Alum and 9890 treatment scheme the AC provided better solids removal resulting in shorter AC runs but lower effluent turbidities (Graphs 1 – 4).

Typical AC Run Lengths:

Run #1 ProPAC 9890 Trident HS Run:	8 hours (flushed on time)
Run #2 Alum/9890 Trident HS Run:	9 -10 hours
Run #3 ProPAC 9890 Trident Run:	12 hours (flushed on time)
Run #4 Alum/ProPac 9890 Trident Run:	11 hours
Run #5 ProPac 9890 Trident Run:	15 hours
Run #6 Alum/ProPac 9890 Trident Run – Turbidity Spike:	6 – 10 hours
Run #7 Alum/ProPac 9890 Trident HS Run – Turbidity Spike:	4 – 6 hours

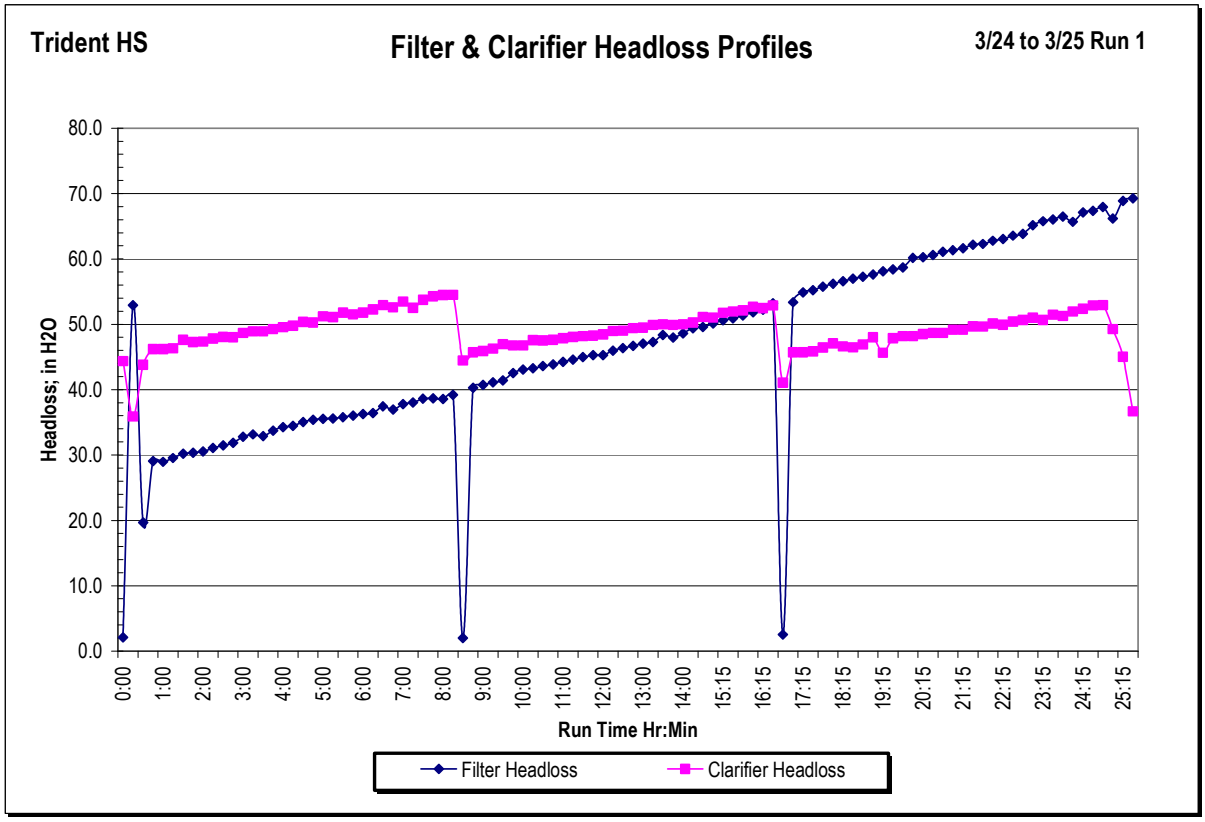
6.3 Mixed Media Filter Hydraulic Performance and Run Lengths:

The MMF is operated at a filtration rate of 5 gpm/sq.ft. Run termination is defined by 100 inches (water) total headloss, run time (operator defined), or contaminant breakthrough. Filter run lengths varied based upon operating mode and chemical treatment scheme. The longest filter runs occurred using the Trident HS mode, which provided an additional 16 minutes of detention time ahead of the AC section. Filter run lengths were projected to be 2 – 3 times longer at every condition tested for the Trident HS compared to the Trident system.

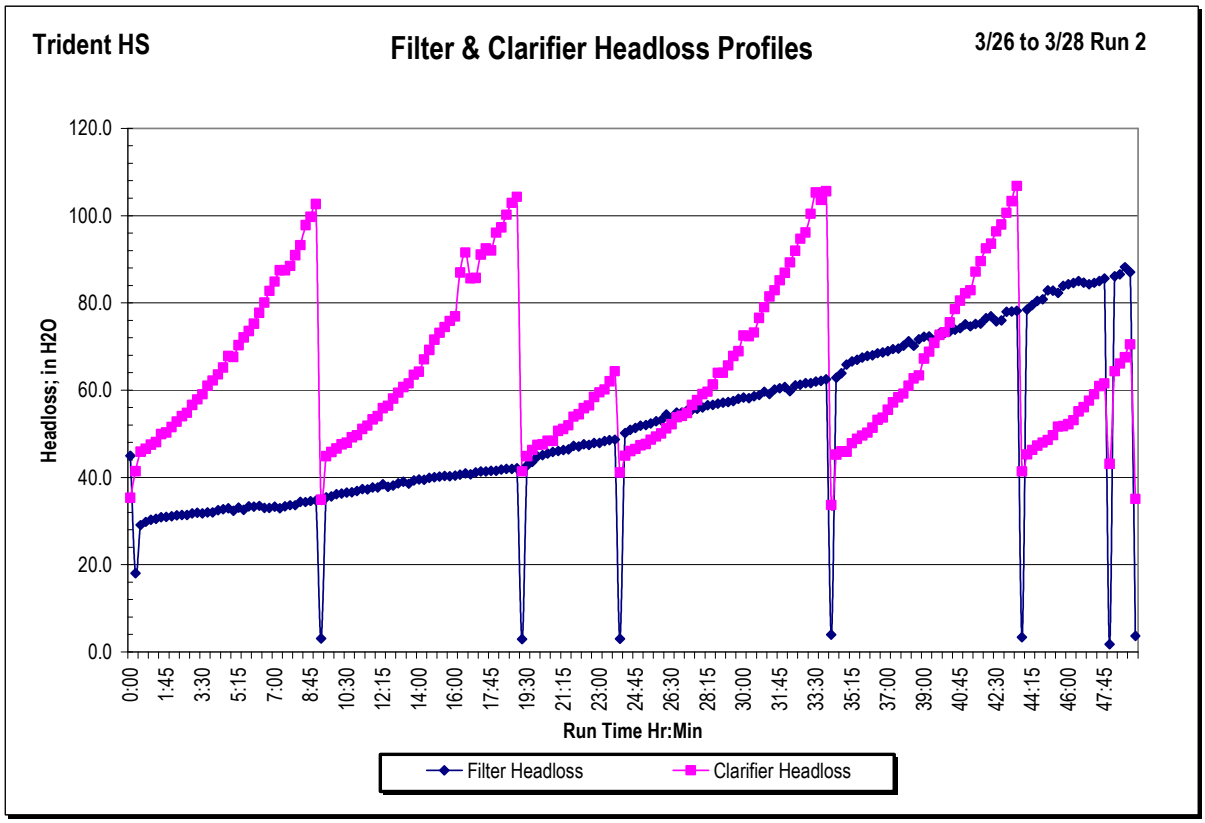
Typical Mixed Media Filter Run Lengths:

Run #1 ProPAC 9890 Trident HS Run:	44 hours
Run #2 Alum/ProPAC 9890 Trident HS Run:	60 hours (projected)
Run #3 ProPAC 9890 Trident Run:	14 hours
Run #4 Alum/ProPAC 9890 Trident Run:	26 hours
Run #5 ProPAC 9890 Trident Run:	17 hours
Run #6 Alum/ProPAC 9890 Trident Run – Turbidity Spike:	27 hours
Run #7 Alum/ProPAC 9890 Trident HS Run – Turbidity Spike:	82 hours (projected)

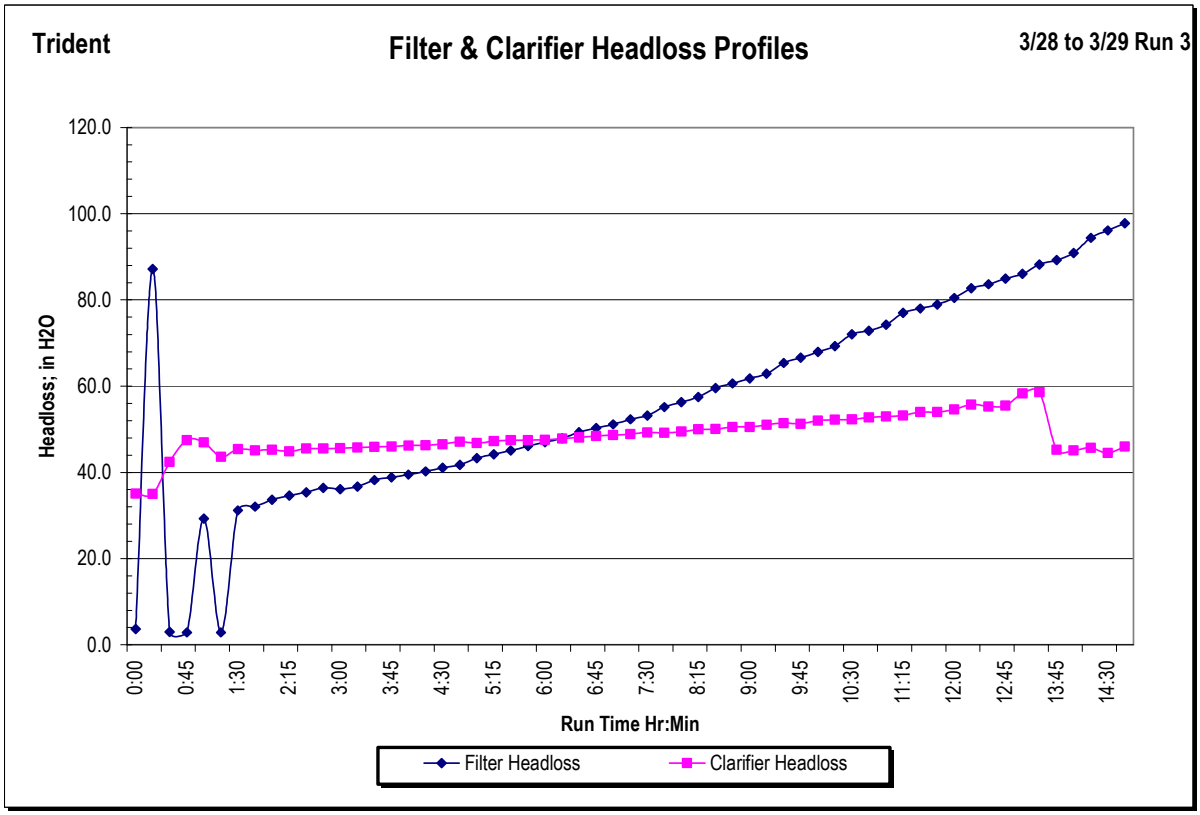
Graphs 14 – 20 illustrate AC and Mixed Media Filter hydraulic performance profiles



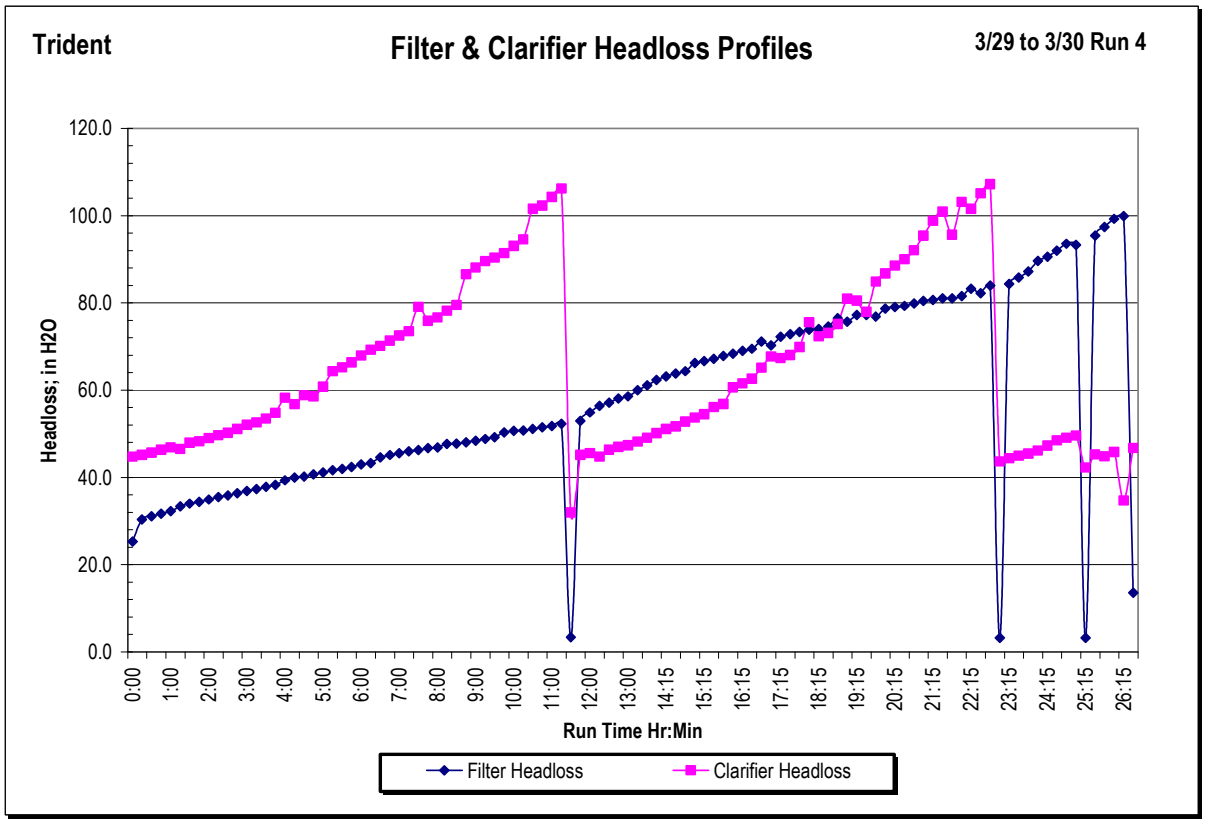
Graph 14: Headloss Trident HS – ProPAC 9890 Coagulation



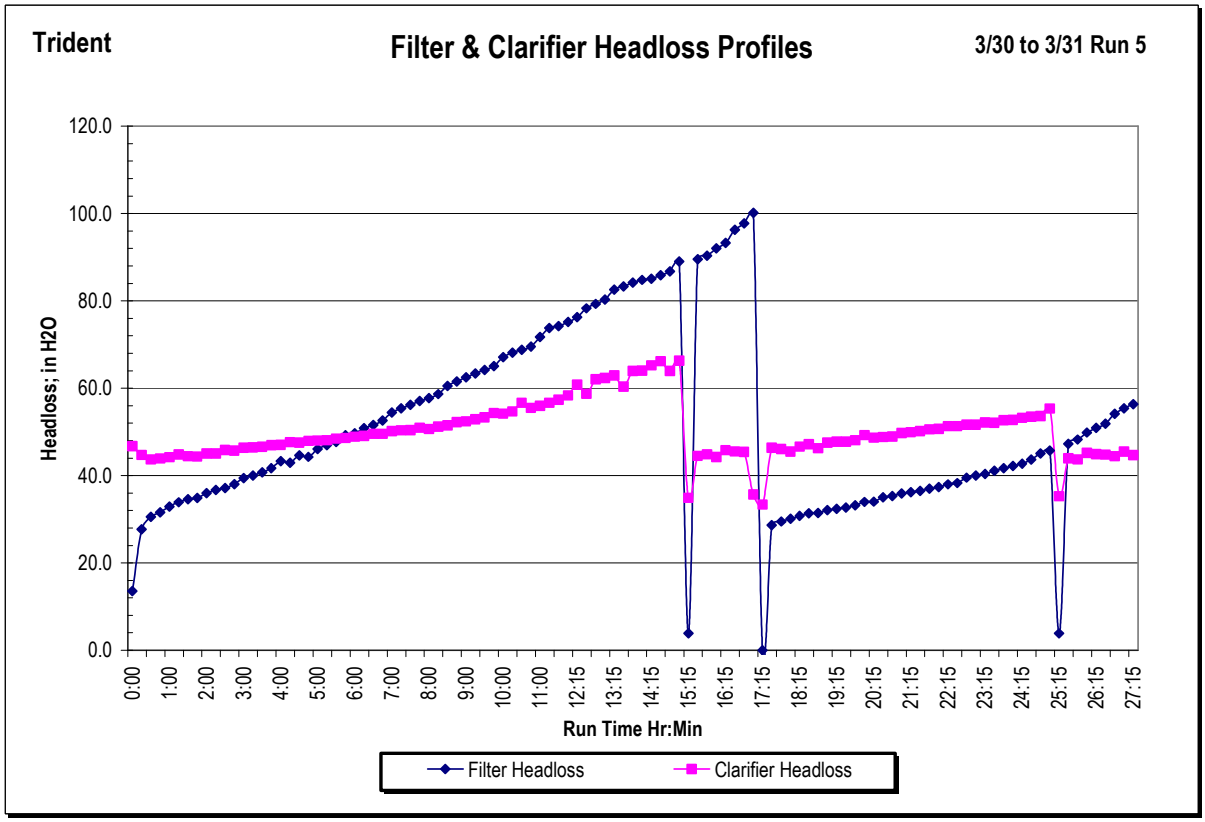
Graph 15: Headloss Trident HS – Alum and ProPAC 9890 Coagulation



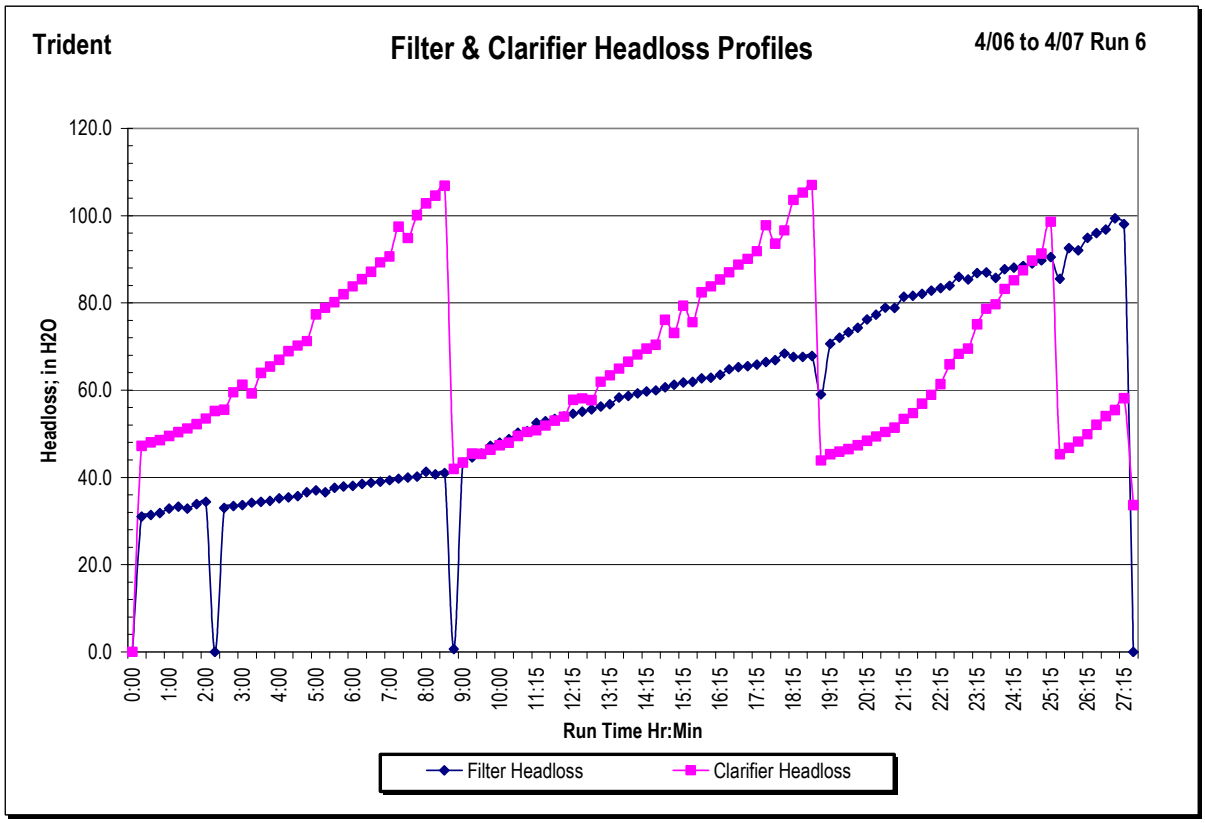
Graph 16: Headloss Trident – ProPAC 9890 Coagulation



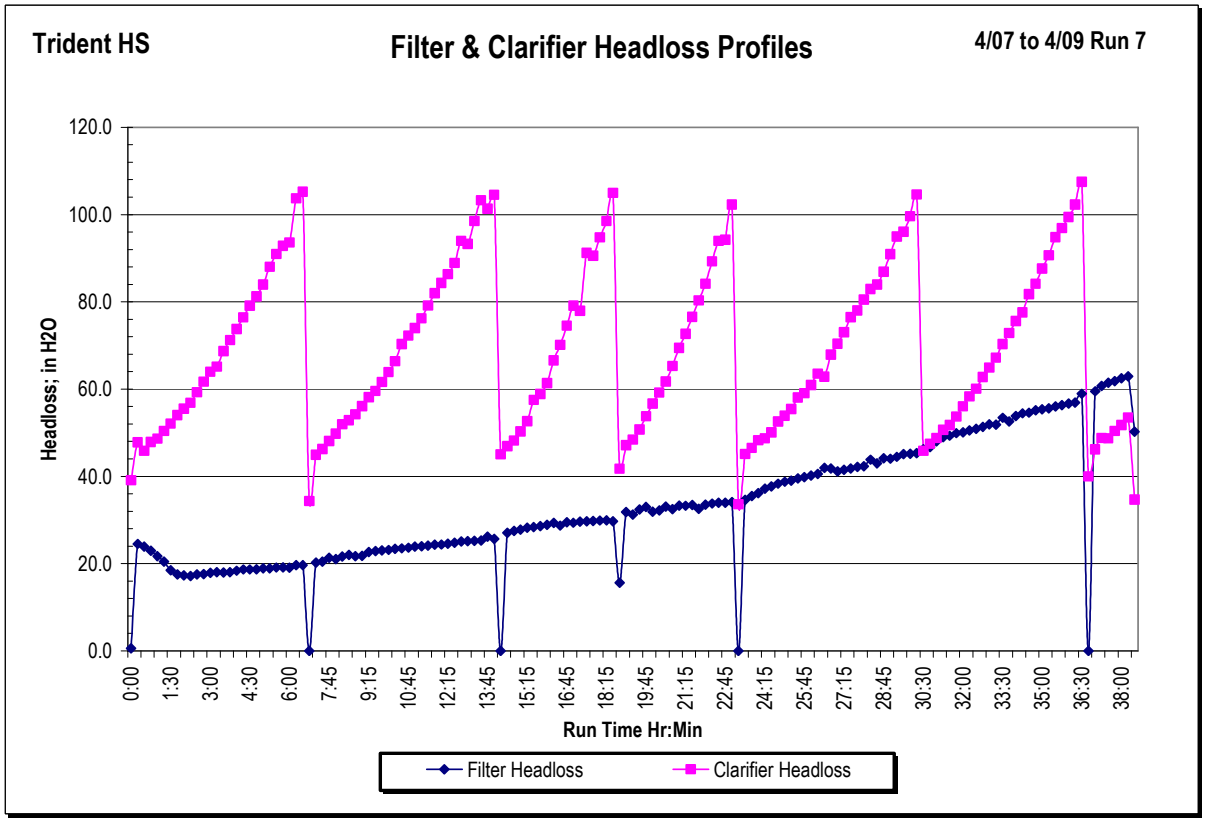
Graph 17: Headloss Trident – Alum and ProPAC 9890 Coagulation



Graph 18: Headloss Trident – ProPAC 9890 Coagulation



Graph 19: Headloss Trident – Alum and ProPAC 9890 Coagulation – Turb. Spike



Graph 20: Headloss Trident HS – Alum and ProPAC 9890 Coagulation – Turb. Spike

6.4 Net Production:

Net yield is the percent of the rated capacity that is available to the distribution system after backwash water, out of service time for backwash and clarifier flush have been subtracted. AC flush waste water used is not included in the Net Yield calculation since the AC flush is completed with unfinished influent water.

Table 10 displays net yield results that were achieved during the study period under the various conditions tested.

Table 10: Typical Net Productions

Run	% Net Yield	% Filter Backwash Waste	% Time Out of Service	% AC Flush Waste
1	97.1	0.9	2.0	1.7
2	97.6	0.7	1.7	1.5
3	95.9	2.7	1.4	1.2
4	96.9	1.5	1.6	1.4
5	96.6	2.4	1.1	1.0
6	95.7	1.5	2.8	2.5
7	96.7	0.5	2.8	2.4

7.0 Summary and Conclusions:

From the data trends of the two unit processes, Trident and Trident HS performed satisfactorily in all categories and are summarized below. The real point to glean from this data is the ability of the added detention time and external mixing of the tube clarifier section for the Trident HS process to maximize filter run times, minimize waste, and ability to handle flashier water.

Kelly of GPUD noted that waste minimization was important to this study as there were no access lines to a sewer system and therefore waste generated from the treatment systems has to be held on-site and pumped periodically for disposal. Therefore, the respective system should be evaluated closely to determine waste minimization. Table 11 summarizes the Trident process results.

Table 11: Trident Process Summary

Unit Process	Trident	Trident HS
Filter effluent turbidity, NTU	<0.05	<0.05
Filter effluent turbidity, C.U.	≤ 2	≤ 2
Filter effluent aluminum, mg/L	≤ 0.01	≤ 0.01
Filter effluent TOC, %	32	18 to 45
Filter effluent iron and manganese, mg/L	≤ 0.01	≤ 0.01
Particle count log removal 2 to 5 microns, log	3.7 to 4.3	3.7 to 4.3
Particle count log removal 5 to 15 microns, log	3.7 to 4.8	3.7 to 4.8
Filter TOC (THM and HAA5 FP), mg/L	<1.5	<1.5
Net treated water production, %	95 to 96	96 to 98
Filter run, hours	17 to 27	45 to 82

Note: All the chemical treatment schemes evaluated achieved good effluent quality. Treatment with Alum and 9890 had significantly lower AC effluent turbidities and had lower organics in the filter effluent (TOC, THMFP, and HAA5FP).

Appendix D illustrates the Operations cost of each treatment system.

Siemens would like to thank GPUD for opportunity to test at their site and the support that was provided during the pilot trial.