Treatment of Combined Sewer Overflows Using Geotextile Baffle Contact Method

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Summary

This paper describes a new Best Management Practice (BMP) to remove and degrade organic pollutants from combined sewer overflows (CSOs). Combined sewers collect both sanitary and storm flow, which is then conveyed to central treatment plants through interceptors. When the hydraulic capacity of the latter is exceeded in wet weather, the excess flow is diverted to open waterways. While the wastewater component would appear to be diluted in streamflow, CSOs still adversely impact aesthetic and recreational value as well as raise concern about human and aquatic life health. Moreover, many diversion sites serve small upland watersheds and discharge into streams tributary to the main waterway and upstream of sites suitable for conventional solutions that temporarily store excess flow. These urban streams are often ecologically fragile and flow through parks. The problem is not the discharge volume per se, but the pollutants conveyed in it. The critical constituents are total suspended solids (TSS) and microorganisms that often attach to the TSS. End-of pipe treatment that removes such material before discharge is a class of BMPs appropriate to such locations.

The geotextile baffle contact system (GBCS) placed in compact subsurface chambers is a promising alternative. The system uses a chamber with suspended nonwoven geotextiles arranged as closely packed baffles that delineate a sinuous sequence of channels with pervious walls. Organic materials are removed by three mechanisms:

- Filtration from the flow seeping between channels through the porous baffles
- Sedimentation in the elongated channel pathway
- Sorption onto the baffle surfaces from tangential flow through channels

Intercepted organic material is degraded between overflow events by biomass growing in the thick porous geotextiles, innoculated by filtered microorganisms. The GBCS was developed with continuous flow of combined sewage, both raw and after primary treatment. The pilot plant reduced total suspended solids (TSS) and biochemical oxygen demand (BOD_5) to below secondary treatment standards for both types. Ammonia (NH_3) and nitrate (NO_3) were also reduced. It is thus expected that the method will treat similar material upgradient in the collection system, at individual diversion sites.

A. Introduction

The billions invested in facilities to remove pollutants from wastewater at continuous discharge or “point” sources since the Clean Water Act have improved water quality, but often not enough to meet receiving stream classification standards. The focus has shifted to wet weather discharges from "non-point" (agricultural or construction runoff) and dispersed "point" (urban runoff and CSO) sources. The goal is to comply with Total Maximum Daily Load (TMDL) allocations that limit pollution releases to a stream's assimilative capacity. Leading non-point discharge pollutants are identified as silt, nutrients and bacteria (Cushing C.E., Allan J.D., 2001). Microorganisms, including pathogens attached to suspended solids (TSS) are the main issue with CSOs. TSS values up to 500 mg/l are reported (Moffa P., 1997), resulting from scour of decomposing solids deposited on the pipe inverts in dry weather (Field R., Sullivan D., 2003). The dry weather flow deposition is the result of the collection piping being designed for street runoff, and thus oversized to convey the solids in sanitary flow.

Combined sewer systems serve over 40 million residents in nearly 1000 communities in the U.S., located primarily in the Northeast, Midwest and Northwest. The Association of Metropolitan Sewerage Agencies (1988) estimates that there are 15,000 to 20,000 individual outfalls. While combined sewers are considered an anachronism today, they were an appropriate solution to public health and drainage problems when installed in the 19th and early 20th century. However, diversions from combined sewer in wet weather are now the major untreated discharge in the cities where they exist. CSOs disrupt aquatic habitat in the receiving water by introducing competing species and turbidity, and a degradable substrate that contributes to oxygen depletion.

As watershed managers and sewage authorities search for innovative ways to achieve the standards of the United States Environmental Protection Agency (EPA) CSO Policy, it is clear that an array of solutions must be available. Reconstruction to separate sanitary and storm sewers may be cost-effective at some locations. However, this displaces the issue of treating the "first flush" of urban runoff, which can contain a wide array of pollutants accumulating on the surface between storms (Bannerman R.T. et al. 1993, Pitt R.E. et al., 1995). Another common solution is storing excess flow in either the pipe system itself (using weirs or inflatable dams) or off-line in surface or subsurface reservoirs. The stored water is released for treatment at central plants after a storm. However, storage requires topographic, geologic and pipe network characteristics that are often absent at the CSO locations along inland streams.

B. Combined Sewer Systems

A typical CS collection and interceptor system is shown on Figure 1. Local combined sewers (LCS) collect wastewater and runoff from buildings and street inlets. Tributary interceptors (TI) gather flow from LCS "sewersheds" and connect to regional interceptors (CSRI). The LCS piping is typically designed for storms of a five to ten year recurrence interval. When combined sewers were first installed, it was neither practical or nor thought necessary to treat the supposedly dilute wet weather flow. Thus, the interceptors that now convey flow to a publicly owned treatment works (POTW) are typically designed for sanitary flow. However, with customary factors of safety, they often can convey the first flush of runoff to treatment. Excess flow is then diverted to waterways at control chambers, noted on Figure 1 as LCSOs and CSRIOs. As many as 30 overflows can occur annually at some outfalls. The focus of this project is LCSO's, at the intersections of collectors and the interceptor system. Since most of the “sewersheds” where TIs discharge into streams are less than 100 acres, an end-of pipe solution appears feasible, as illustrated on Figure 2.

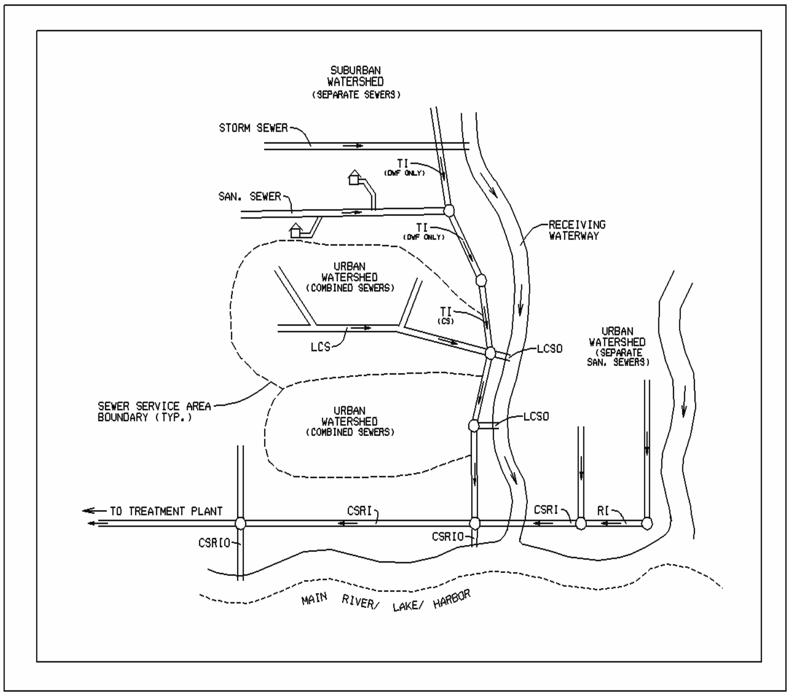

Figure 1: Layout of Combined Sewer System

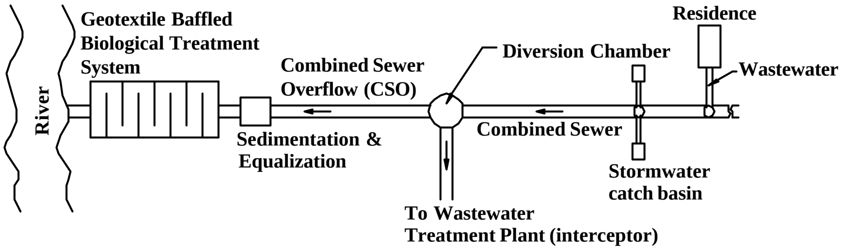

Figure 2: Local Combined Sewer (LCS) Sources, Diversion and Proposed Treatment Units

C. GBCS Experimental Program and Results

Table 1 illustrates typical ranges of combined sewer overflow quality.

Table 1: Typical CSO Quality (Moffa, 1997):

Parameter	Average	Range
TSS	370 mg/l	273-551 mg/l
VSS	140	109-182
BOD_5	115	59-222
COD	367	264-481
TKN	3.8	2.6-4.9
Fecal coliform (10^3/100ml)	670	201-1140

Other than the high TSS and the high ratio of TSS to BOD_5, which represents the decomposition of organic solids on the LCS pipe inverts, this is domestic wastewater. Thus, the GBCS is amenable to CSO treatment. A pilot plant study was run to study the capability of a geotextile to remove and degrade wastewater pollutants, as shown on Figure 3.

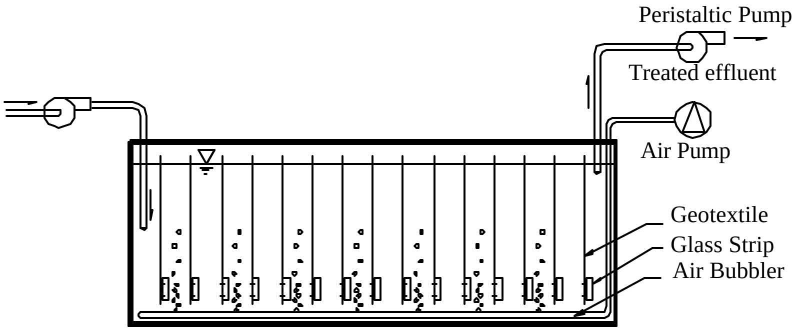

Figure 3: Side view of GBCS

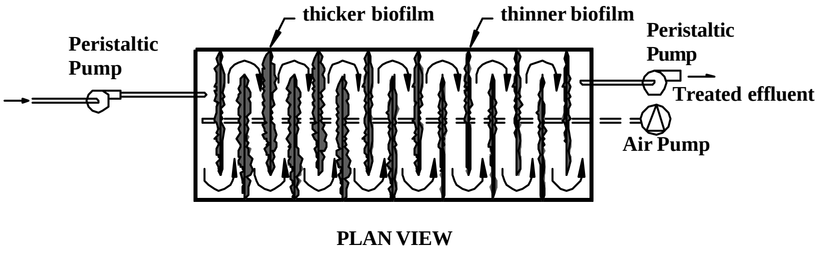

Figure 4: Plan view of GBCS with developing biofilm

To minimize the headloss that would occur with flow through filters that would gradually clog by captured and growing biomass, the geotextile baffles were placed in a zigzag pattern, transverse to the flow direction to form a sinuous channel bounded on both sides with the attachment material, as shown on Figure 4.

For two months, weekly samples of primary treatment effluent from a wastewater treatment plant that served a dense, urban combined sewer area were collected. Raw influent wastewater sample was collected in the first week. It was expected that solids would be removed by sedimentation, filtration and sorption. A portion of the flow in each channel short-circuited through each pervious, porous geotextile baffle, growing a biomass from captured microorganisms from the inside out, as is also shown on Figure 4. When the geotextile clogged, sorption of dissolved organics in the tangential flow past the biofilm could occur with sorption replacing filtration.

Figure 5: Photo of setup

Figure 5 shows two units in the pilot plant operation. Two 20 gallon glass tanks in sequence were used to provide an intermediate sampling point. Figure 6 illustrates the physical clarification, with flow entering from the right side of the first tank and exiting from the left side of the tank of the GBCS. The experiments used needle punched geotextiles that had both high permeability and high porosity to host the biomass. Eight runs of experiments were performed. A summary of the results for Runs 1-8 are presented in Figures 7 through 11, with the water quality at the end of the first tank (T1) and the second (T2) shown. Monitoring of the nitrogenous compounds did not commence until the second run, under the assumption that the acclimation time for both nitrifying and denitrifying bacteria would be well over a week.

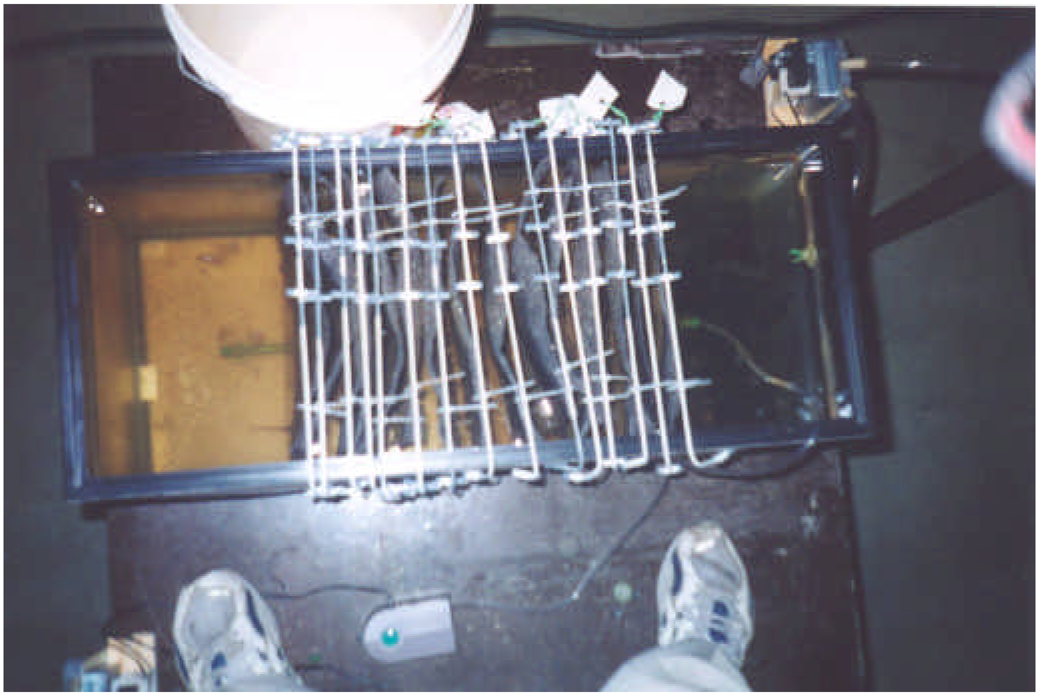

Figure 6: Water clarifying along GBCS

BOD_5 Removal:

The Run 1 sample was raw wastewater sampled from the entrance of the primary settlement tank of the treatment plant, such that the TSS and BOD_5 concentrations were high. Other samples (Runs 2-8) were collected at the end of the primary settlement tank of the same facility. For these samples, test influent raw BOD_5 varied between 33 to 73 mg/l. However, as of the end of the first treatment tank, at a loading of about 1.0 gpd/ft^2 of baffle area, the BOD_5 values decreased to the range of 2 to 11 mg/l in all runs. Hence, the ability of the second tank of geotextiles to provide a meaningful contribution to the system was diminished, such that its outflow BOD_5 ranged between 2-10 mg/l. The higher values were for the raw wastewater sample (10mg/l and 11mg/l). With a preceding primary sedimentation step, the GBCS consistently produced effluent BOD_5 below 10 mg/l. Doubling the detention time did not make a significant change. Thus, for both medium and low strength wastewater, it appears that a detention time of 22.5 hours, a nominal loading rate (cross section) of 20 gpd/ft^2 one tank, and a biofilm loading rate of 1.0 gpd/ft^2 geotextile is enough for the GBCS to remove excessive BOD_5. Influent and effluent values of BOD_5 are plotted on Figure 7.

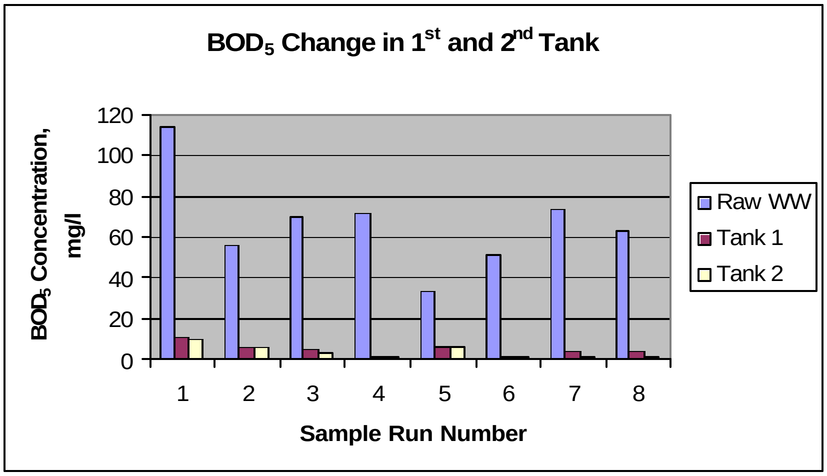

Figure 7: Influent and Effluent BOD_5 Concentrations

TSS Removal:

Influent and effluent concentrations of TSS are plotted on Figure 8. The results are even better than for the BOD reduction, with TSS effluent from the first tank consistently recorded in the single digits, even with the 300 mg/l raw wastewater for Run 1. This is a result of the three separate mechanisms of TSS removal, filtration, sedimentation and biofilm surface sorption. The capability for sedimentation, a result of the physical layout and the hydraulic loading rate, was constant through the two months of testing. The filtration phase decreased as the porosity of the upgradient baffles filled with biomass, thus reducing the permeability and the proportion of the flow short-circuiting through the baffles. However, it appears that this was compensated by the biofilm emergence on the baffle surfaces, allowing organic-organic sorption of colloids to occur. Again, TSS removal did not change significantly at the end of first and second treatment tanks because the effluent from the first tank (the influent to the second) had already been clarified to less than 10 mg/l of TSS. From the perspective of TSS removal, one GBCS tank was enough to remove excessive TSS.

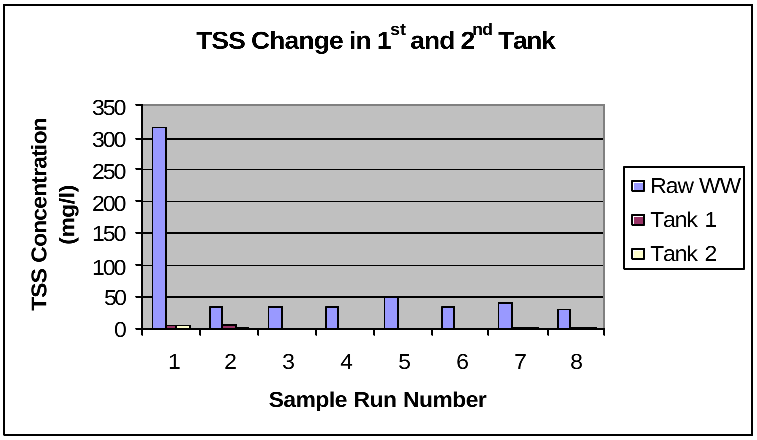

Figure 8: Influent and Effluent TSS Concentrations

Ammonia Removal:

Influent and effluent concentrations of NH_3-N are shown on Figure 9. As noted-Run 1 was not monitored for NH_3 as the sample was very concentrated. With a constant hydraulic loading, and a variation in influent ammonia by a factor of 2.5 (10.9 to 25 mg/l), the differences in conditions between Run 2 and Run 8 are biomass age and mass, which grew baffle by baffle as indicated on Figure 5. Other samples except for Run 1 were collected at end of primary settlement tank. Test influent raw NH_3 varied between 10.9 to 25 mg/l. As of the end of first treatment tank, NH_3 values decreased to the 0.08 to 0.93 mg/l range, an average of 95% removal. Again, doubling the detention time from 22.5 hours to 45 hours did not result in any significant change.

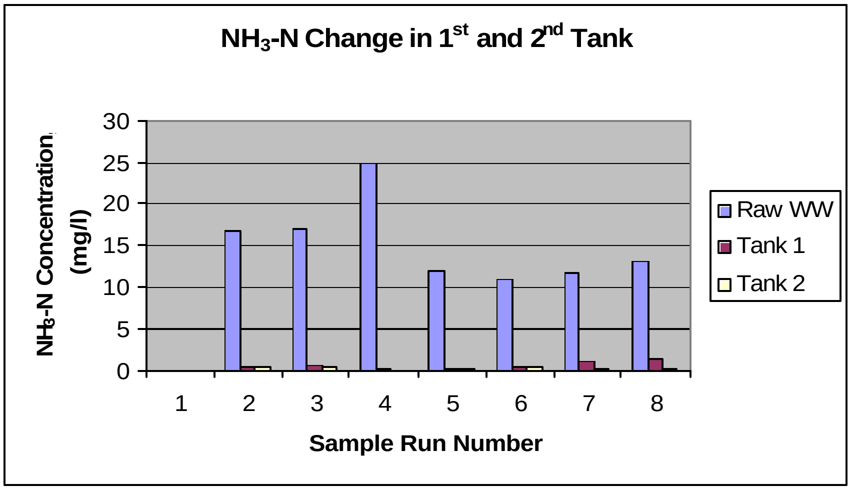

Figure 9: Influent and Effluent NH_3-N Concentrations

Nitrate Removal:

Influent and effluent concentrations of NO_3-N are plotted on Figure 10. The primary sedimentation influent NO_3 varied between 0 to 1, indicating that the ammonia had just been released from the organic nitrogen in the primary treatment, and thus had not yet the opportunity to convert ammonia to nitrate. After treatment in the first tank, its effluent NO_3 increased to the range of 6.4 to 23mg/l and between 5.6 to 22.8 mg/l at the end of the second tank. However, the ammonia reduction as indicated on Figure 9 exceeded the nitrate concentration by a factor of two in the last three runs, implying partial conversion to nitrogen gas. Figures 9 and 10 show stabilization of effluent concentrations start around the run 5 and run 6 and continued through the end of the run 8. This indicates acclimation of nitrifying and denitrifying microorganisms. Since the latter require anoxic conditions, it is presumed that they grew in the interior of the thick biomass in the porous baffles. In any case, it was demonstrated that only one tank, or alternatively, furnishing 1.0 gpd/ft^2 or less of baffle surface was sufficient to meet secondary treatment standards as well as ammonia removal.

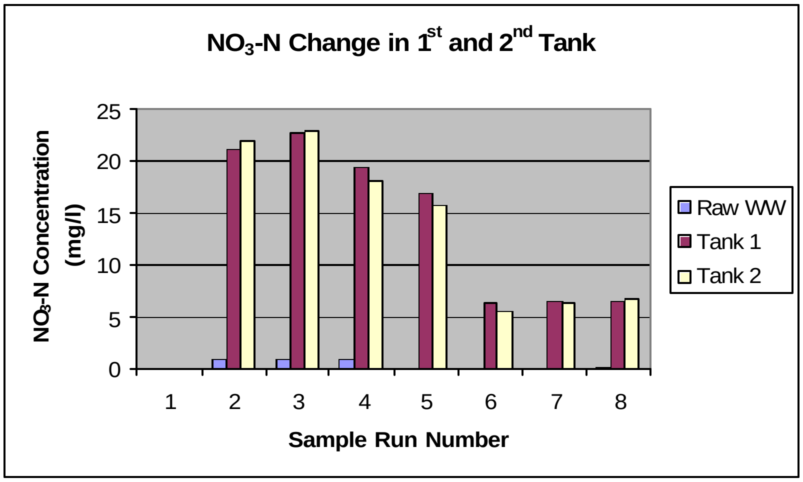

Figure 10: Influent and Effluent NO_3-N Concentrations

The residual biomass in the first tank was measured after two months of biological activity. The baffles were removed from the tank and air dried. The changes in dry biomass weights along Tank 1 are presented in Figure 11.

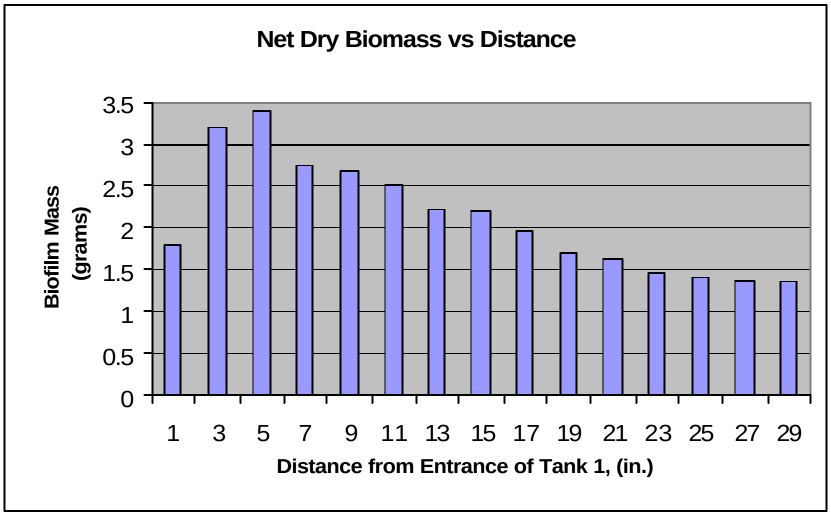

Figure 11: Dry biomass growth along the GBCS

The highest biofilm accumulation on the baffles was observed at the beginning of Tank 1 after the first baffle, which evidently served to dampen the inflow pumping effects. High biomass retention was visible from the second through the sixth baffle, with a slime coating that obscured the fabric, i.e, it grew out from the interior and coalesced on the surface to fully contact the flow through the channels. The baffles closer to the tank exit did not collect as much biomass and displaced a discontinuous surface slime layer. Since there had been sloughing off the first few baffles since Run 6, it can be concluded that the

3.4g maximum dry weight per 10in.x10in. baffle is the mechanically sustainable maximum biomass.

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