MICRO-PARTICLES IN RECIRCULATING AQUACULTURE SYSTEMS

by

Richard Neil Patterson

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TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

NOMENCLATURE

A	'Pre-swirl" tap, bottom flow from culture tanks	
A	Area	
ADC	Apparent digestibility coefficient for the feed (fish feeding)	m^2
AFR	Air flow rate	m^3/s
B	'Midwater' tap, upper flow from culture tanks	
Bd	Bubble diameter	m
$BF_{A,B}$	Sample points, post biofilters, lines A and B.	
C	Flow from top of swirl separator	m^3/s
D	Flow from the mixer/standpipe, before drum filter	m^3/s
D	Diameter	m
DDW	De-ionized, distilled water	
DGM	Density gradient medium; in this study mixtures of Percoll and sucrose.	
DE	Digestible energy	
dfm	Distance from meniscus	mm
DP	Digestible protein	
DW	Solids waste - undigested food excreted as faeces	
e	Base of natural logarithm	
E	Outflow from drum filter to settle deck	m^3/s
E_g	Gas hold up	
EPA	Environmental Protection Agency	
f	fraction of total ammonia that is NH_3	
FDDW	De-ionized, distilled water filtered through a 0.45 μm Type HVLP filter	
FW	Feed waste - uneaten feed	
g	acceleration due to gravity	m/s^2
$G_{A,B}$	Flow from the degasser/oxygenator to the culture tanks, lines A and B	
h	Distance across tube	m
hr	Hour	
HF	High Frequency	
I	Tap, wash water from drum filter	
I	Filterability of water	L/m^2
J	Outflow from biofilter wash water to ditch.	
L	Litre	
L	Length of settling zone	
l_i	PSA: lower class boundary	
l_{i+1}	PSA: upper class boundary	
l_i*	PSA: class median; nominal particle size for that class; $(l_i+l_{i+1})/2$	
m	Constant	
M	Molarity	
min	Minutes	

MUW	Make-up water	
MUW_A	Make-up water from the largest well	
MUW_B	Direct well water	
n	Constant	
n	Refractive index; suffix denotes source	
Oflow	Overflow from settle deck	
OFH	Foam overflow height	m
ORP	Oxygen reduction potential	millivolts
p	driving pressure	Pa, kPa, psi, ft of water
PC	Protein content	
PCX	Hach particle size counter, 2200 PCX	
Percoll™	Density gradient material produced by Amersham Pharmacia Biotech; lot 2.78493, density 1.1319 g/mL	
pK_a	-log K_a, the acid disassociation constant of the NH_4^+ ion	
PSA	Particle size analysis (the detecting of the particles size distribution in a sample and sorting those particles into size classes by number of counts per class, number of counts per unit volume per class (normalized count) or by percentage of particles per class.	
PSD	Particle size distribution (see PSA)	
Q	Flow	L/s or m^3/s
R	Resistance	
Re	Reynolds number	
f	Ratio of underflow to overflow	
RR	Removal rate	
R^2	Correlation Coefficient	
s	Seconds	
s	Speed of strainer	m^2/min
SIP	Standard Isotonic Percoll; in this study 1 part 2.5 M sucrose/ 9 parts Percoll, v/v	
SS	Suspended solids	
S Dk	Settle deck, 2nd (outflow) side	
SEM	Scattering electron microscope	
SIP	Standard isotonic Percoll: in this study, 1 part 2.5 M sucrose (certified A.C.S. (Saccharose) $C_{12}H_{22}O_{11}$ F.W. 342.30) in 9 parts Percoll, v/v.	
Swirl	Outflow from the swirl separator on flushing	
t	Time	seconds
T	Temperature	°C
TAN	Total ammonia nitrogen	mg/L
TDS	Total suspended solids	mg/L
TKN	Total Kjeldahl nitrogen; organic plus ammonia nitrogen	mg/L
TP	Total phosphorus	mg/L

TSS	Total suspended solids	mg/L
TSW	Estimate of total solid waste - feed consumed x (1-ADC) + FW	
TW	Total waste (fish feeding) = DW+SW+FW	
u	Velocity through the tube	m/s
U_g	Superficial gas velocity	m/s
UIA	Un-ionized ammonia	
USGPM	US gallons per minute	
UWFM	Ultrasonic Waste Flowmeter	
v	Velocity	m/s
V	Volume and Volume equivalents	m^3, parts, mL
VS	Volatile solids	
W	Width	m

Greek Symbols

α	Inlet velocity loss coefficient	
Θ	Angle of the tube relative to the plate	
ϵ	Void fraction of media in sand filters	
μm	micron; 1/1000th of a millimeter.	
μ	Dynamic or absolute viscosity	kg/m.s
ρ	Density	kg/m^3 or g/mL
rho	In spreadsheets: density	kg/m^3 or g/mL
ψ	Waddell's sphericity	

Subscripts

D	drag
f	fluid
h	horizontal (velocity)
H	hydraulic retention
i	inlet
l	liquid
o	overflow
p	particle
s	settling or particle
sc	critical settling (velocity)
u	underflow

vs	volatile solids
50	50 percent chance of being in underflow or overflow

Superscripts

n	power of cyclone performance

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ABSTRACT

This study examined micro-particles in a commercial aquaculture recirculating water system that produces Atlantic salmon smolts. The goal was to determine their abundance, size and physical properties of these particles with a view to eventually removing them.

Over a period of months, samples of the system waters were taken along the flow path after each major equipment in the water system. Using a field titrator, a spectrophotometer and meters, the samples were tested for water quality parameters: pH, temperature, ORP, TDS, TSS, alkalinity, hardness, nitrites, nitrates, ammonia, TKN and phosphorus. The last three parameters were digested to isolate the amount of the nutrient associated with the solids. Feed input and water flows were monitored. Samples were also studied for particle size distributions (PSD) and TSS obtained gravimetrically. The PSDs were processed to determine their proximity to a hyperbolic function. Selected samples were processed with density gradient material (DGM) (Percoll™) to determine particle densities. Microscopy was employed to assist in learning the nature and source of the particles. Where required, feed-in-water samples were produced and examined gravimetrically, for PSD and for DGM density determination.

Flow metering determined that the plant was not operating as a recirculation plant in the classic sense. Whereas the make-up water was only 10% of the circulation flow rate, between 100 and 200 % of the total system water capacity was replaced per day. Thus the expected build-up of micro particles did not occur.

As expected, the feed was the main source of the solids in the system. DGM studies showed that there was a larger, heavier fraction at about 1160 kg/m^3 based on the heavy cellulose fraction from whole wheat portion of the feed, which was not digested. Also there was a light fraction, about 1050 kg/m^3 consisting of small particles (3-5 μm) that tended to gather into loose flocs with a binding of viscid material, probably mucopolysaccharide based. There were also a few flocs above the upper band and between the two density bands. These appeared to be of the same floc make-up as the upper band particles but with lighter or heavier components.

The hyperbolic nature of the PSD was confirmed. Gravimetric testing proved not to be useful in this environment due to the introduction and production of the viscid material clogging the meshes before sufficient weight of solids can be collected. This was a mucus-based material which also clogs drum filters in active systems.

It was concluded that most of the heavier band particles can be removed by screening. For the lighter band, of the systems reviewed, flocculation appears to offer the greatest chance of success. The implementation of this is an area for future work.

CHAPTER 1 - INTRODUCTION

1.1 RECIRCULATING SYSTEMS

Once thought of as only a research vehicle, too expensive for commercial operations, water recirculation systems[1] are now entering the realm of commercial production for many aquatic species. Leading this movement in Atlantic Canada are the producers of Atlantic salmon (*Salmo salar*); many of the major producers of this over $200 Million industry are using recirculation plants to grow these fish through the freshwater stages (hatchery to smolt).

The commercial drive is to speed up and optimize (intensify) production for a given plant. Recirculating systems have distinct advantages in:

- optimizing the use of limited high quality water supplies
- conserving energy in temperature-growth enhancement
- controlling diseases
- conserving additives (e.g. salt, therapeutics)

The problems with such systems are that they require considerable capital outlay, operating expenses are generally higher that flow-through systems and system breakdowns, biological or mechanical, can result in disastrous loss of the complete culture stock.

Due to the latter three advantages, recirculation is now being considered for shellfish hatcheries and the potential cultivation of demersal marine species, such as the Winter Flounder (*Pseudopleuronectes americanus*) and Halibut (*Hippoglossus hipppoglossus*). In the latter case, land-based facilities are often considered as these bottom-dwellers suffer from wave motion in surface cages.

This study will focus on the juvenile phases (parr to smolt) of Atlantic salmon (*Salmo salar*) rearing in recirculating systems as practised in Atlantic Canada. In order for the water

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[1] Although definitions vary, recirculation has generally come to mean the replacement of less than 10% of the total system water per day. (Losordo, 1991, page 1).

to be reconditioned for reuse, the metabolic wastes and the uneaten food have to be removed or neutralized. The metabolic wastes are ammonia (NH_3) and faeces. The most of the ammonia is excreted via the gills and is in a highly soluble gaseous form. It is highly toxic to the fish; with 0.02 mg/L generally being considered the toleration threshold for this species. Ammonia ionizes to ammonium (NH_4^+) to a degree mediated by the temperature and the pH of the water, especially the latter. Although there are other methods, the common commercial method of removing/controlling the ammonia is by bio-conversion via the ionized form to relatively benign nitrate (NO_3^-), which in turn is controlled by dilution through the make-up water.

The feed, usually in the form of pellets, the size varying with the size of the animals, comes in dry or moist forms, with a recent tendency to move to the former. A typical formula for moist feed would be: protein, 46%; fat, 20%; fibre, 1%; moisture, 10%; ash, 10%[2].

The faeces can be small and pellet-like, or long strings, depending on the feed formula and the rearing conditions. Little work has been done on their chemical composition; it has been generally assumed that it will be similar to the original feed, with phosphorus and nitrogen as significant components.

If these suspended solids are not readily removed, a third type of solid is formed; aerobic heterotrophic and autotrophic bacteria which add to both the solids and the ammonia loads.

Both the pellets and the faeces tend to break down in the rearing system to a range of particles from soluble organics to 300 μm particles, depending on the shear forces and the time these forces have to act on the particles. Particles over about 50 - 60 μm can be readily

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[2] EWOS Vextra Smolt 1.5 mm feed. (bag label)

removed by screening but those under that, which range down to 1 μm and are usually termed suspended solids, cannot to date be economically removed. (Westers, 1992).[3]

Fines tend to accumulate in the recirculation system. They promote gill damage and reduce fish resistance to disease (Stickney, 1979; Wickens, 1980). Chapman *et al.* (1987) showed that particulate toxicity was responsible for rainbow trout deaths, and the associated particles were in the 5 - 10 μm range. In addition, suspended solids can potentially clog biofilters and can mineralize to become ammonia sources themselves. Bacterial growth on the particle substrate may be disease-causing in themselves. These observations were reinforced in a discussion on water treatment and reuse at the 124th AGM of the American Fisheries Association, in Halifax, NS, August, 1994. In that discussion aquacultural engineers from USA and Canada noted that these fines can build up to the point of system collapse, although the exact mechanism of collapse is not established, and that there is presently no economical method of removing them.

In Atlantic Canada, the present method of coping with fines is to close down the system and empty it for a season. At the present time this protocol suits the growth cycle of the species cultured. However, more growers are coming to realize that an idle plant is not an economical use of capital-expensive resources. As biological manipulation of spawning time is becoming more practical, and considering the economical advantages of a constant, year-round supply of product, the growers are moving to continuous operation of these plants with several year-classes being grown concurrently. At this juncture the problem of fines accumulation, along with that of nitrates and dissolved organics, will become limiting.

1.2 EFFECTS OF PARTICLES ON FISH

Chen *et al.* (1993), in the introduction to his paper on suspended solids in recirculating systems cites Stickney (1979) and Wickins (1980) in support of a statement that suspended solids promote gill damage and reduce fish resistance to disease. Stickney, in ***Warm Water***

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[3] Particles below 1 μm are considered by some as dissolved, but this definition is not universally held.

Aquaculture noted that suspended solids in aquatic systems generally are made up of sediment particles, organic material (detritus, waste food particles and faecal material) as well as plankton cells and other microorganisms. He goes on to say that inorganic particles can have a detrimental effect on aquatic organisms, citing Cairns (1967). Stickney continues, "The mechanical action of such particles can lead to clogging of the gills or the irritation of gill filaments and other membranes."

Cairn's (1967) paper discussed the ecological effects of suspended solids in natural aquatic systems. He wrote of six topics of which three are pertinent to finfish culture:

1 mechanical or abrasive action (e.g., clogging of gills, irritation of tissue),
2 availability as a surface for the growth of microorganisms (bacteria, fungi), and
3 carrier, by adsorption or absorption, of various chemicals.

However, in the data summary, only fatal, not stress-inducing, levels where given (2,600 to 270,000 mg/L) and these for non-aquaculture, freshwater species. Wickins (1981) is a review paper on water quality given at a EIFAC/FAO symposium which mainly notes that there are few data on the tolerance of fish to suspended solids but concludes that the levels of suspended solids should not exceed 15 mg/L dry weight.

Chen *et al.* (1993) also stated that "Bioassays with two separate solid wastes showed that particulate toxicity was responsible for rainbow trout deaths and the particles associated with the lethal effects were approximately 5 to 10 μm in diameter" (Chapman *et al.*, 1987). Chen also mentioned that gill damage can occur at moderate TSS (total suspended solids) levels of 44 mg/L as reported by Magor (1988).

Chapman *et a*l. (1987) exposed rainbow trout to 1000 mg/L and 100 mg/L concentrations of inorganic sludge and of dust (in separate tests) produced by an aluminum plant. At 1000 mg/L the sludge killed all 30 test fish, while the dust killed only one. At 100 mg/L a survival rate of 80% for sludge was noted. There was no indication of stress below lethal levels. The cause of death was respiratory failure due to the breakdown of the respiratory tissue in the gills. Physical blockage of the gills may have also occurred. The dust particle size was larger (10 to 40 µm) than the sludge, where particle sizes 5 to 10 µm were determined to be particularly lethal.

Magor (1988) had exposed juvenile Coho salmon to waterborne wood debris that he first made chemically inert. Again, physical damage to the gills was the pathology. However the smallest size particle that he was dealing with was 150 µm, and hence his results are not particularly apropos to the present study.

In an unpublished work, Krise *et al.* (1994) subjected rainbow trout to three levels of organic solids: 7.0, 10.6 and 11.8 mg/L. All levels were below the recommended limit of 15 mg/L (see Muir below), but the 11.8 mg/L solids treatment did indicate that the fish were stressed and their immune systems reduced. Averaged particle sizes only were reported, but later Patterson *et al.* (1999) re-examined the particle size distribution and found all streams to be dominated by fine particles (1 to 10 µm volume equivalent diameters[4]). Krise *et al.*(1994) is one of the few studies of the effects of organic particles but, unfortunately, the researchers had too limited a range of concentrations. TSS values of 15, 20, 25 and 30 mg/L, say , would have been interesting.

Muir (1982) in reviewing recirculating aquaculture systems noted that suspended solids caused mucus production and were implicated in bacterial gill disease. The recommended limit suggested was 20-40 mg/L. Chen *et al.* (1997) repeat the generally recommended suspended solids concentration limit of 15 mg/L, which, they say, is often exceeded. They also note that "research on the adverse effects of TSS upon fish in intensive culture systems is scarcely available."

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[4] an artificial parameter = the diameter of a sphere of the equivalent volume of the particle.

1.3 PROBLEM DEFINITION

Research on suspended solids in aquaculture systems to date is limited and has concentrated on the quantity of solids in the system (usually based on averaged values or mean size), the effect on fish physiology, and, to a lesser degree, particle size distribution.[5] There is little definitive data on the exact nature of the particles. None of the chemical and few of the physical characteristics of the particles have been determined. A protein-based, hydrophilic composition is (reasonably) assumed. On the work done to date on particle size distribution, a spherical shape is assumed as the present particle counters and sizers produce a volume value, and the artificial parameter 'equivalent volume diameter' (diameter of a sphere of equivalent volume to the particle) is used in sizing. Lastly, there is no data on the effect of the high fluid flow energy environment to which the particles are subjected, especially with respect to the length of system operating time which is in the order of months.

Considerable work has been done on particle distribution theory (e.g. Bader (1970), Beddow (1984), Allen (1981), McCave and Syvitski (1991), Singer *et al.* (1988)) but that work is primarily in the field of minerals. It is not known how much of that theory applies to particles in aquaculture systems, although present work suggests that the power law as developed by Kavanaugh *et al.* (1980) does apply.

1.4 TRIAL SITE

Merlin's Fish Farm s, RR#2, Wentworth Valley, Cumberland County, NS, B0M 1Z0, consented to be the trial site (details in Section 3.1). The study focussed on the recirculating water plant at the site.

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[5] See: Chapman *et al.* (1987), Chen and Malone (1991), Chen *et al.* (1993), Easter and Novak (1996), Ebeling *et al.* (1997), Han *et al.* (1996), Krise et al. (1994), Muir (1982), Allen, (1981), Beddow (1984), Singer *et a*l. (1988) and others.

CHAPTER 2 - LITERATURE REVIEW

2.1 FEED

Feed is the fuel for the production of fish. It is also usually the greatest cost input and the source of all solid or dissolved inputs the water quality, hence waste. From the end of the yolk sac absorption to harvesting, cultured Atlantic salmon are raised on manufactured feed. Typical formulations are shown in Table 2.1.[5]

Feed manufacturers supply overlapping ranges of feed sizes and a variety of formulations to suit the growers preference (or biases). From Table 2.5 it is possible to deduce that nutritionists concentrate on high protein diets for the early growth stages (greater that 50% protein), and shift towards higher energy diets as the fish mature by the substitution of oils for protein.

The salmonids are relatively easy to ween to artificial food. They are born of large eggs with large yolk sacs in a fairly developed form, much more developed than marine fish larvae. At the end of the yolk sac phase (swim-up or first feeding) their digestive systems are largely developed.

The feed comes in two forms. Small feed is in crumbles of an assorted size within a range. At 2 mm and larger it is most often in the form of an extruded pellet. The manufacture must be such that the food particle has low 'fines' associated with it and holds together in either freshwater or seawater, where it is being used, at least long enough that it has a reasonable chance of being consumed. The rule of thumb for fish feeds is that the feed size should be about 20 to 22 % of the extended mouth opening of the animal (D. Menton, 1998, email to Aqua-L).

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5. (NFE stands for Nitrogen free extract or total carbohydrate. This value does not include fiber in feeds. Often it is estimated by difference. NFE = 100-(protein+fat+ash+fibre) (S. Lall, NRC. pers. comm.)).

***Table 2.1**: EWOS VEXTRA Salmon Feed Sizes and Compositions*

NAME	FORM	SIZE mm	FOR FISH OF g	COMPOSITION %						GROSS ENERGY MJ/kg	REMARKS
				PROTEIN	OIL	NFE	ASH	MOIST.	FIBRE		
Start-Salmon	Crumb 0	0.3-0.5	< 0.2	55.0	12.0	14.0	10.0	8.0	1.0	20.3	Size 0 for small fry. Normally use # 1 at swim-up and move to 2 and 3.
	Crumb 1	0.5-0.9	0.2-1.2	55.0	14.0	12.0	10.0	8.0	1.0	20.7	
	Crumb 2	0.9-1.5	1.2-5.0	53.0	18.0	10.0	10.0	8.0	1.0	21.5	
	Crumb 3	1.5-2.0	5.0-12.0	53.0	18.0	10.0	10.0	8.0	1.0	21.5	
Smolt -Crumb	Crumb 4	2.0-3.0	12-40	53.0	18.0	9.0	10.0	9.0	1.0	21.3	An intermediate diet to use between fry and transfer feeds a diet with a controlled sinking rate
Salmon Classic 2mm	Extruded Pellet	2.0	20-75	51.0	20.0	9.0	10.0	9.0	1.0	21.7	Used after the Smolt Crumb diet to introduce expanded pellets to the fish for the first time
Mini	Extruded Pellet	2.0	20-75	54.0	19.0	8.0	10.0	8.0	1.0	21.8	Used after smolt diet to introduce fish to expanded pellets
Alpha	Extruded Pellet	2	20-75	52.0	20.0	8.0	10.0	9.0	1.0	21.0	Used after transfer to seawater. Has FinnStimm. High digestibility (90%).
		3	50-250	52.0	20.0	8.0	10.0	9.0	1.0	21.0	
Salmon Gold	Extruded Pellet	3	50-250	48.0	20.0	14.2	8.0	8.0	1.8	22	Highly palatable to salmon, even in cold months, 90% digestible.
		4	150-350	46.0	24.0	12.2	8.0	8.0	1.8	22.7	
		5	300-450	44.0	26.0	11.2	8.0	9.0	1.8	22.9	
		6	350-1000	42.0	28.0	10.2	10.0	8.0	1.8	23	
		8	1000-2200	40.0	28.0	13.0	10.0	8.0	1.0	22.9	
		10	> 2200	40.0	28.0	13.0	10.0	8.0	1.0	22.9	
Omega	Extruded Pellet	7	500-1500	42.0	31.0	9.5	7.5	9.0	1.0	24.0	Highest energy diet. New pellet shape. Use after Gold @ 500 g.
		9	1500-2500	38.0	33.0	12.0	7.0	9.0	1.0	24.2	
		11	>2500	38.0	33.0	12.0	7.0	9.0	1.0	24.2	
Salmon Classic	Extruded Pellet	3	50-250	46.0	24.0	10.0	10.0	9.0	1.0	22.2	Proven high performance diet. Can be fed to smolts with transfer weight LT of 50 g. Lowest feed-to-fish costs.
		4	150-350	46.0	24.0	10.0	10.0	9.0	1.0	22.2	
		5	300-450	45.0	24.0	11.0	10.0	9.0	1.0	22.2	
		6	350-1000	45.0	24.0	11.0	10.0	9.0	1.0	22.2	

The general strategy on feeding salmonids is to feed to satiation. Initially this is based on manufacturers' recommended rates, a percent of biomass per day, adjusted to temperature and animal size. A typical table is shown in Table 2.2. Such tables are for average situations and do not account for normal or stress induced swings in appetite. Refinements to this strategy to reducing waste in feed, and the amount of waste to be disposed of have been proposed which fall under three categories: feed period, excess feed detection and feed formulation.

***Table 2.2**: Recommended feed rates for EWOS Salmon Gold feed. (EWOS handout)*

Water Temperature °C	**Feeding rates (% biomass/day for fish size ranges (g) as follows**									
	50 **100**	**100** **200**	**200** **300**	**300** **500**	**500** **750**	**750** **1000**	**1000** **1250**	**1250** **1500**	**1500** **2200**	**2200** **10000**
6-7	1.01	0.99	0.96	0.92	0.84	0.62	0.57	0.53	0.44	0.35
7-8	1.17	1.16	1.12	1.09	1.03	0.76	0.70	0.66	0.54	0.38
8-9	1.33	1.32	1.28	1.26	1.21	0.90	0.83	0.78	0.63	0.42
9-10	1.58	1.58	1.55	1.51	1.42	1.04	0.98	0.96	0.81	0.49
10-11	1.82	1.84	1.80	1.75	1.16	1.16	1.13	1.12	0.98	0.55
11-12	1.96	2.00	1.95	1.89	1.76	1.26	1.20	1.16	0.98	0.61
12-13	2.09	2.15	2.10	2.04	1.09	1.36	1.26	1.18	0.98	0.67
13-14	2.19	2.17	2.17	2.18	2.04	1.48	1.34	1.24	1.00	0.68
14-15	2.33	2.22	2.28	2.36	2.21	1.62	1.45	1.32	1.04	0.71
15-16	2.24	2.22	2.27	2.37	2.26	1.64	1.48	1.36	1.11	0.73

2.1.1 Feeding Period.

The use of feeding regime to maximize feed consumption and thus minimize waste feed has been looked at by several authors (e.g.Bergheim and Forsberg, 1993; Cho *et al*., 1994; Hankins *et al*, 1995; Westers, 1995) The conclusions are mixed if not exactly contradictory. Most authors suggest that regimes should aim at reducing water quality impact, without actually specifying how. Bergheim and Forsberg found that feeding frequencies concentrated into 2 to 4 feedings versus spreading the feeding out over the 24 hour period) had no effect on total daily production of waste solids and nutrients. Hanks *et al.* found (and Zeigler and Johnson (1998) suggest) that spreading out the feeding did not result in any more feed being consumed, but the spread-out feeding regime meant that the production of waste products was more evenly distributed over the 24-hour period, thus avoiding post-feed peaks in nutrients that could challenge the biofilters, and associated oxygen troughs that could stress the fish. Near continuous feeding requires near continuous lighting in order for the fish to visually detect the feed.

2.1.2 Excess Feed Detection.

For maximum feed conversion, it has been desirable to be able to determine when the fish are at a satiation level and then stop the feeding. The original idea, from the Norway experience, was to watch the outflow standpipe for pellets (Hankins *et al.* 1995). Hand feeding is considered the best method for maximum feed conversion, but is impractical in today's large production plants where automatic feeders are necessary. There are now available a few devices that detect excess feed and can be used as a signal to stop an automatic feeder.

A slight improvement on the 'watch the outflow' idea was developed by AquaOptima from Norway who incorporated a glass sided swirl separator on the outflow of their patented recycle system, through which an observer can distinguish feed pellets from faeces.

Derrow *et al.* (1996) describe an ultrasonic waste feed monitor (UWFM) that detects feed in the drain pipe of a culture tank stand pipe of 38 mm (1.5") diameter or larger. The UWFM generates HF acoustic pulses (1 MHz) 5-50 pulses/sec in a 14° cone-shaped beam (Figure 2.1).

The signal is used via a microcontroller to stop the feeder. A signal threshold algorithm can be set up to eliminate the lower strength echo from faeces and the higher strength echo from scales. Air bubbles are a problem, but can be eliminated from the flow by other means.

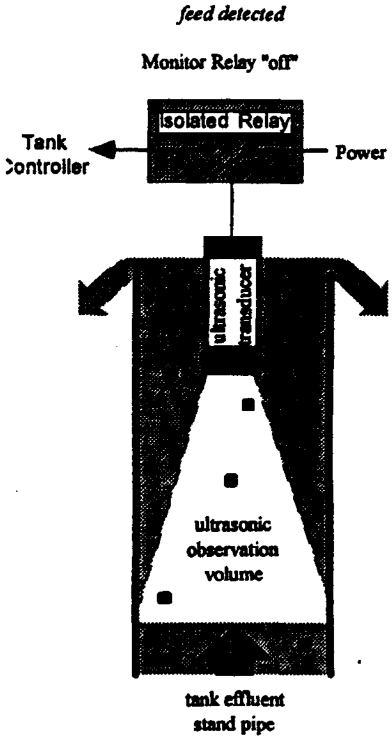


Figure 2.1: Ultrasonic waste feed monitor (Derrow et al. 1996)

There is a system by Aquasmart on the market for sea cages (Figure 2.2), which consists of a conical bag, open base up, with a sensor suspended in the lower, centre of the cage. The system can be set to stop the feeder after a given number of particles are collected and sensed, and restart the feeder, with a time interval, if desired, after pellets cease to be detected. The Aquasmart can detect feed from 2 to 14 mm size to a depth of 30 m. These controllers have been used in New Zealand, Scotland, Chile Canada and Norway for a few years. Growth increases of 30%, with fewer small fish and an improved feed conversion ratio (FCR) are claimed.

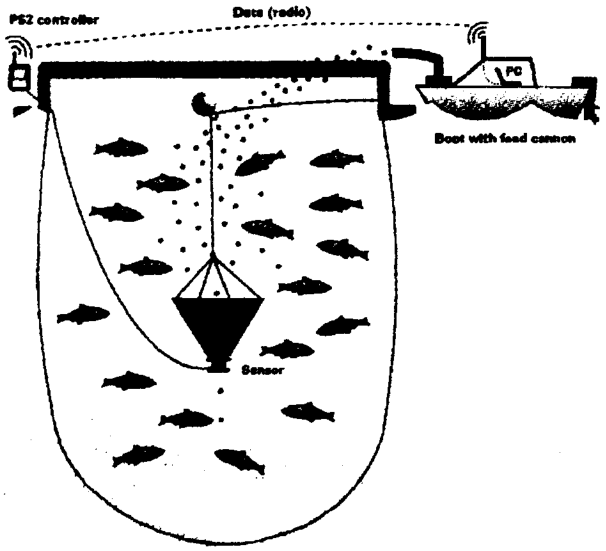


Figure 2.2: Aquasmart feed sensing system

The drawback with such systems is cost as one system per rearing unit (tank or cage) is required. The Aquasmart system runs about $5,000 per cage.

2.1.3 Feed Manufacture

There are two aspect to feed manufacturing that have an effect on waste production: manufacturing method and the formulation of the components of the feed, and they are linked. Ideally the feed should be of a nutrient dense, highly digestible, high energy formulation produced in a form that hold together well (is physically stable) in transportation, storage and in the water (sea- or freshwater) in which it is being used, thus producing few fines.

Several workers, of which Dr C.Y. Cho, (now Dr D. Bureau), of the University of Guelph is probably a leader, have been working on the nutritional approach to waste management. This includes (Cho *et al.* (1994)):

1. careful selection of feed ingredients based on digestibility
2. balanced formulation to ensure maximum energy and protein utilization
3. avoidance of excess nutrients
4. strict feeding regimes.

Cho and co-workers have experimented with high-nutrient-dense diets for trout for several years. His MNR-91H diet for example, was an improvement over a previous MNR-89G diet as shown in Table 2.3 (Cho *et al.* (1994)):

***Table 2.3**: Comparison of diet formulae from Cho et al. (1994)*

ITEM	MNR-89G	MNR-91H
Digestible Energy (DE) MJ/kg min.	17	20
Digestible Protein (DP) g/MJ DE	22	22
[DE as % formula]	37.4	44
Digestible Fat g/kg	160 [16%]	200 [20%]
Total Phosphorus (TP) g/kg max.	9	8
Expected FCR <	1	0.83
Estimated Wastes, kg/tonne fish produced		
Total Solids	240	190
Nitrogen: solid	10	6
soluble	40	33
Phosphorus: solid	4	3
soluble	2	1.5
Fines	1.5	1%

The 21% reduction in solids waste by recipe alone is significant. It is interesting to look back at Table 2.1 and see where improved formulation is going.

Factors of feed manufacturers' concern are cost, fines, size, digestibility, buoyancy, nutrient content, shelf life, water stability, durability, palatability and shape. There are three feed production processes current today; steam pelleting, extruded feed and expanded feed. Steam pelleting , the first method, was created by adding steam to a ground mash for about 35 seconds or less. Such pellets are cylindrical, length about 0.5 to 2 times the diameter, have a glazed look and are fairly dense and will sink. Extruded feed is the product of the 90's. The mash is introduced to an extruder barrel where moisture is added. The mash is then exposed to pressure, heat (300° C) and friction, gelatinizing most of the starches. After the mash is forced through the die, the pellets expand in the lower pressure and potentially can be made to sink, sink slowly or float. Expanded feed is similar to extruded, except the expanded mash is sent to a pellet mill. A comparison of the feed processed by these three methods is shown in Table 2.4 (Robinson (1998)).

Extruded is the most expensive but growth returns off-set the additional cost. A 2 % increase in growth rate will off-set a 10% increase in feed cost. (Powless (1998)). Extruded feed appears to be almost universally used in the production of salmon in the Canadian Maritimes.

***Table 2.4**: Comparison of feed manufacturing processes (Robinson (1998))*

Comparison of Feed Manufacturing Techniques			
	COMPRESSED PELLETS	EXTRUDED	EXPANDED
Initial feed cost	lowest	highest	intermediate
Starch gelatinization %	<40	>80	60-80
Max. temp. (F)	180	300	300
Max. fat level	20	40	30
Digestibility	good	best	better
Sinking available	yes	yes	yes
Floating available	no	yes	possibly
Slow sink available	no	yes	possibly
*Fines upon receipt, %	1 to 6	<1	<1
Vitamin and nutrient degradation	lowest	highest	intermediate
Feed conversions	worst	best	intermediate
Uniformity of feed	variable	excellent	good
Availability	most mills	some mills	few mills
* Fines can result from poor handling of finished feed or minimal grinding			

2.2 CHARACTERISTICS OF FISH WASTES

The possible range of solid particles in aquaculture systems is suggested in Figure 2.1. As discussed in Chapter 1, the primary sources of solids are fish metabolic wastes and uneaten food particles. Microorganisms, such as algae and bacteria will grow in the system as the system matures, barring any disinfection processes that the system may have. Most smolt systems do not have on-line disinfection components.

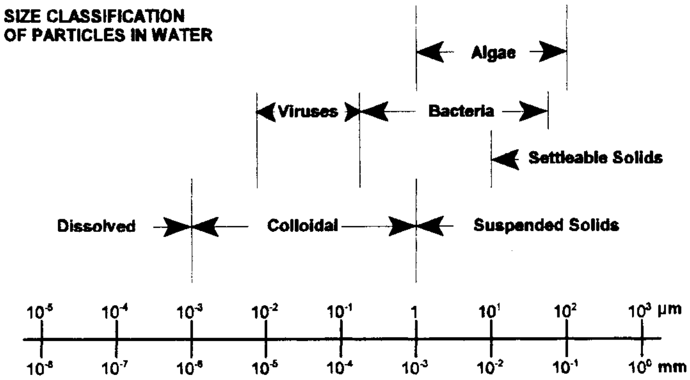


***Figure 2.3**: Size classification of possible particles in aquaculture waters (from Lawson, 1995)*

Due to the relatively low loadings of suspended solids in such systems, generally less than 500 mg/L (0.05% solids (Camp (1946) as cited by Chen *et al.* (1997)), particles in aquaculture systems are considered discrete, in that they are far enough apart that the settling of any one particle is unaffected ('unhindered') by the presence of any other.

2.2.1 Shape of Fish Faeces.

There appears to be little or no published information on the shape of fish faeces. The information that is available is largely anecdotal. Particle size distribution studies used machines that recorded a particle volume, from which an artificial parameter, the volume equivalent diameter (diameter of a sphere of equivalent volume) was calculated. Cho and Slinger (1979) used a test tank that collected Rainbow trout wastes and analyzed the chemical composition, but reported nothing on the size and shape of the faeces themselves. Cripps (1995) noted that, under a microscope, Atlantic salmon faeces particles were 'decidedly not round'. In response to a personal query, he has replied that he recalls them as fibrous,'shortish, hair-like structures'.

Aquaculturist and diver Phillip Drinnan (pers. comm. 1998) who has dived under his salmon and trout cages reported:

- "The faeces seem to be about the same size as the food pellet the fish are being fed on.
- The faeces have a number of rings, like a compressed cylinder.
- Even though the faeces seem solid they dissipate easily into a course particulate matter if you move your hand near it.
- With healthy fish the faeces are a greenish brown colour. Under cages that are "poor do'ers" you will find a large percentage of white stools. Under cages that are having vibrio problems you will find a large percentage of bright yellow stools and this is not related to the use of oxytetracycline. I am quite sure that you can develop a method of assessing the health of the fish on site by looking at the faeces underneath the cages.
- The faeces don't last very long, i.e. they don't pile up.
- Shortly after the fish are removed the bottom turns to white, with a thin layer of black underneath. These two layers are very fragile and gossamer-like, and are easily disturbed.
- These observations are for a site that has a lot of current on a hard bottom, having up to 900,000 fish. There was very little if any variation in temperature or oxygen from top to bottom. The depth of observation varied between 30 and 80 feet.
- On a site that has little current and has a very soft bottom with low oxygen and a lot of stratification in temperature and oxygen, the process seems to go almost directly to faecal break-up with very little solid faeces found."

Dr K.C.Watts (Thesis Supervisor) and this observer have seen rainbow trout faeces casts in a rearing pond which were about 2 to 3 mm in diameter and 80-100 mm long, tube-like structures. We were told at the time that this type of faeces was connected to a particular diets.

Dr Neil Auchterlonie, (pers, comm. 1998) Aquaculture Centre, University of Stirling speaking of marine species, commented:

> "You may be interested to know that my total faecal recapture experiments utilising faecal traps designed along the lines of those used by Cho [ed.: Cho *et al.* (1982)] for rainbow trout were singularly unsuccessful in accumulating halibut waste. My figures suggest that <10% of the total faecal matter voided was collected in the traps. The trial fish were c. 150g and fed a commercial dry pelleted diet. The consistency of the faeces gives some clue to why the traps didn't work. The matter appeared to have a very high water content (sorry no figures here - I couldn't trap enough), and because of this it didn't deposit within the system. My supervisor has likened this to hippopotamus faecal matter, which apparently is "sprayed" out the back end and covers a wide area......!
>
> Also, on occasion when much larger halibut have been handled and held in large holding tanks, I have noticed a quantity of what I initially considered to be mucus, but now think is faecal matter near the floor of the tank. This faecal matter appeared to be suspended within the lower part of the water column, but was not sufficiently dense to accumulate on the floor of the tank. I have worked for a few years with salmon and trout, and the faecal matter of these fish is much more dense, and holds together (has greater friability?) better in water - hence (probably) why Cho's traps worked for him, but not for me!"

Muir (1982) notes "Faecal material typically comprises undigested dietary materials bound together in a mucus coat[7], frequently produced in long strings". Beverage et al. (1991) state that the undigested food, together with mucus, sloughed intestinal cells and bacteria, is voided as faeces.

This anecdotal information suggests that faeces from salmonids are deposited in a semi-pelletized , mucus-coated form which is easily broken up into smaller particles. Marine species probably do not produce pellets, but produce solid/liquid suspensions.

---

[7] Mucus: a slimy solution of mucin, a mucoprotein, secreted by goblet cells of vertebrates (Abercrombie *et al.*, 1980)

2.2.2 Nature of the Particles

Physical Nature

Particles in an aquaculture system can remain as discrete entities with little change in size or composition, agglomerate into larger particles, or break down into smaller particles. Para 2.2 suggests that they are most probably of an organic nature, largely proteins with some carbohydrates, fats and inorganic matter.

As for agglomeration, it has been noted that particles in natural waters, which are largely inorganic, but with a varying degree of organic substances, tend to form flocs or aggregates when allowed to settle. The mechanism of contact appears to be that the larger particles, having a greater terminal velocity catch up to and contact the smaller particles. For inorganic particles the flocculation has been thought to be due to molecular attraction between crystal surfaces, but more recently biological factors such as organic coatings and extracellular polymer strands have been implicated (Krank, 1980).

Regardless of the method of flocculation, the resultant floc appears to be unstable in a high energy situation, such as aquaculture. Gibbs (1981) produced several typical flocs, allowed them to age to obtain maximum cohesion, and then ran them through three pumps, axial, centrifugal and peristaltic. In each case the particle size distributions were reduced from mean sizes of 80 to 250 μm to about 20 μm, indicating the instability of flocs in such situations.

It is considered that agglomeration is not a factor in recirculation aquaculture. On the contrary, it is probable that high energy situations such as passage through pumps will break up faecal "pellets" and water-logged uneaten food. The first two stages of waste control in local recirculation systems have an opportunity to remove pellets, the over-and-underflow tank outlets, where the underflow sweeps the tank bottom, and the swirl separator which follows. Neither of these can be expected to be 100% as there will be turbulent zones in the tanks (e.g. water inlet flow and swimming actions of fish) and in the plumbing that are expected to be of sufficient energy to break mucus bonds.

It is expected that the particle size distribution (PSD) will shift towards the fine particle end of the spectrum with each pass of the water around the system. The solids removal operations will remove most of the larger particles, the pump energy will reduce the mean size of those left, the fines will remain in the system, and more solids will be added with each pass though the culture tanks.

A review of particle size data from some current systems has supported such a view. Chen *et al.* (1993), using two species of trout in three experimental recirculating systems with differing large particle removal, investigated particle size distribution and the specific gravity in the culture water. Using the Electrozone method (specifically the Elzone Model 180XY particle counter) they found that fine particles dominate the distribution in numbers with 95% of the particles under 20 μm and 71% under 10 μm. The lower threshold for this equipment was 6.5 μm. The mean specific gravity was determined to be 1.19. However, this figure was arrived at using the APHA (Anon. 1995a) sludge test. It is suggested that, as there would be water still associated with the particles, the true in-water density of the particles is still in doubt.

Generally, the suspended solids load on an aquaculture system will remain below that considered bordering on the discrete/hindered boundary (approximately 500 mg/L (Camp, 1946)). Discrete suspensions tend not to flocculate. There could be some particle growth if microfauna were allowed to take hold in the system and grow on the larger particles, but that would be deleterious for the culture in general and should be otherwise controlled through disinfection.

In summary, it is believed that the suspended solids will be composed primarily of small organic particles, which will diminish in mean size as the system ages.

The Power Law Nature of Particle Distribution

In the introduction to his paper on the hyperbolic distribution of particle sizes, Bader (1970) noted that the equation,

$$N = K\left(\frac{x}{x_o}\right)^{-c} \tag{2.1}$$

(where N is the number of particles larger than a given size, x the particles size parameter , and K and c are positive constants), is a good approximation of many natural families of particles, such as fine sediments, airborne dust, cosmic dust and suspended particles in seawater, to cite a few. He further notes that this distribution can be approximately derived from an analysis of brittle fracture (Gaudin and Meloy, 1962), but that it "also sometimes characterizes low-density organic particles suspended in waters".

Gaudin and Meloy worked out a equation for a single fracture based on probability which accorded with experimental data:

$$\frac{M(x)}{M_o} = 1 - \left(1 - \frac{x}{x_o}\right)^{r} \tag{2.2}$$

where $M(x)$ is the weight of undersize contained, x is the size considered, M_0 is the total weight of the crushed sample, x_o is the feed size and r is the size ratio. Bader (1970) did not try to explain the phenomenon further but continued with his main thrust, the use of the then-new Coulter Counter for particle size distribution analysis.

Bagnold and Barndorff-Nielsen (1980) in a review in *Sedimentology* which dealt with the pattern of natural size distributions of granular material laid down by the action of wind and water flows, spoke of the long-established convention of integrating measured frequencies to yield a curve relating grain size, D, to a quantity representing the percentage of all grains smaller that D, which they suggested had the doubtful advantage of smoothing out inaccuracies, but avoiding the "best evidence" rule. In short, expressing doubt about normalizing.

These authors were looking mainly at near-Gaussian (normal) distributions, and their version of hyperbolic distribution referred to a "log-probability (density) function p(x)", plotted against log D, which showed a highly hyperbolic curve, but the asymptotes were not the x and y axes, as in the distributions under study.

There is an interesting discussion at the end of the Bagnold and Barndorff-Nielsen paper that speaks of a "diffusion" process: given that the probability p of a chance of departure from the mode value of the variate by one unit step is a^{-1}, where a is the constant,

$$p = a^{-n} \tag{2.3}$$

then the probability of a larger departure by n unit steps is a hyperbola with the axes as asymptotes which, on a log-log plot, is a straight line, slope $-n$.

The only theory discovered as to the why of the near-hyperbolic distributions uncovered so far has to do with inorganic substances in a fluid, wind or water, or on comminutation of the same type of particle, and is based on probability. Authors (Bader, 1970, Kavanaugh *et al.*, 1980) note the existence of such distributions in organic particles in water and use the experimental fact without offering an explanation as to the theoretical source. Probability is the probable source.

2.3 CURRENT METHODS OF SOLIDS REMOVAL

In solids control, the two most important physical characteristics are particle size distribution and the density of the particles. There are now available several sets of data on the particle size distribution (PSD) of suspended solids (e.g. Patterson *et al.*, 1999, Appendix J). It has been found that the PSD in such systems is closely hyperbolical, with an increasing, and very great number of fine particles, down to the 1 μm size. Density of the particles is another matter. There is presently only one figure available for the density of faeces and waste food and that is an averaged one of 1,190 kg/m^3 determined by Chen *et al.* (1993) for wastewater from Rainbow trout (*Onchorynchus mykiss*) in two recirculating systems. It is generally believed that the density of these particles will vary with species and composition of the feed, among other factors, but there are no other data on this subject to date.

While there are several cases where solid particles, settleable and suspended, have to be removed from aquaculture systems, this discussion will focus on the case at hand; that is the removal of suspended solids from food and fish faeces that will pass through a 40 μm screen, thus are in the suspended solids range.

The removal of suspended solids is a solid/liquid separation process. The methods of removal of solids from such systems include gravity separation (sedimentation), including devices in which the gravitational force is enhanced by centrifugal motion, screening and filtration, and floatation. Three mechanisms predominate: sedimentation, interception and diffusion.

2.3.1 Sedimentation

In sedimentation, the laden water is moved through a slow-moving area to allow the suspended solids to sink to the bottom under the force of gravity, which is off-set by the buoyant forces of the liquid acting on the particle, and the drag force on the particle moving through the fluid.

Considering a discrete particle (Figure 2.4), the resultant vertical velocity, termed the terminal settling velocity, is the algebraic sum of the gravitational force (based on the difference in density between the water and the particle) and the drag force on the particle.

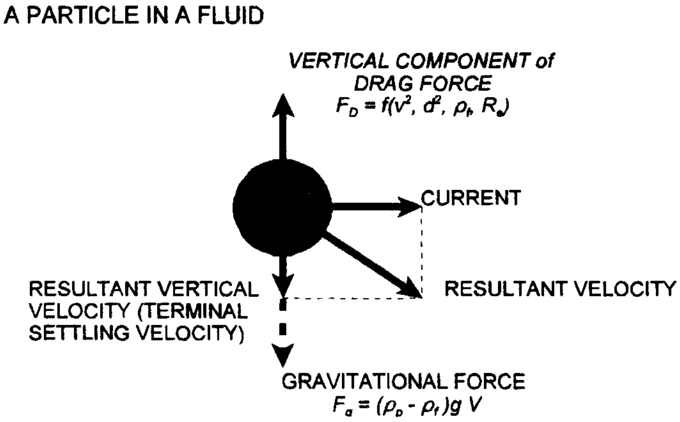


Figure 2.4: *Forces on a discrete particle in suspension*

The gravitational force is

$$F_g = (\rho_p - \rho_f)gV \tag{2.4}$$

where: ρ_p = particle density

ρ_f = fluid density

V = particle volume

The buoyant force is represented by the difference in densities. In the static (no-flow) condition, the drag force opposing the fall of the particle to the bottom is:

$$F_D = f(v_s^2 d^2 \rho_f R_e) \tag{2.5}$$

where: v_s = particle settling velocity
d = particle diameter
R_e = Reynold's Number = $\rho d v_s / \mu$

where μ is the dynamic viscosity of the fluid. For Reynolds Numbers < 0.3, (laminar flow) these formulae can be combined into a form of Stokes' Law:

$$v_s = \frac{g(\rho_p - \rho_w)d_p^2}{18\mu} \tag{2.6}$$

The Reynold's Number, R_e, for a 100 μm particle of fish waste in fresh water is in the order of 1×10^{-4}, indicating that Stoke's Law is valid for this system.

Settling Tanks or Basins

In the idealized sedimentation basin, there are four distinct zones: *inlet zone*, to be designed to reduce velocity and evenly distribute flow; *settling zone*, designed for quiescence; *sludge zone*, to provide sufficient space for temporary storage of the sludge; and outlet zone: to be designed for low exit velocities. (Figure 2.5)

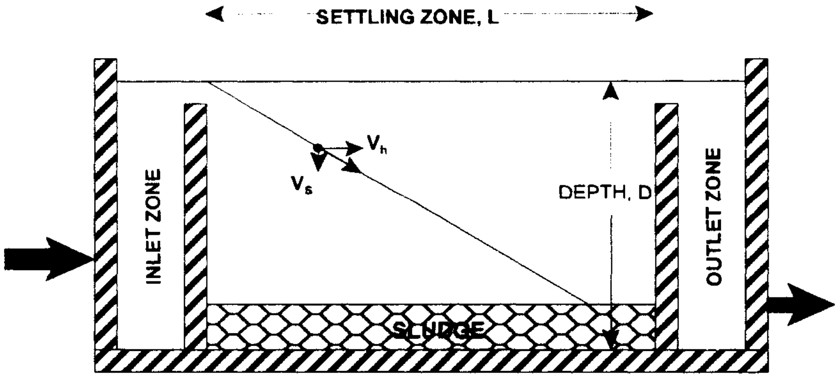


***Figure 2.5**: Idealized settling basin*

Assuming ideal (straight line) flow, the horizontal velocity, v_h, and the length of the flow path should be such that critical- or design-sized particle can reach the sludge line and therefore go out of the fluid. Theoretically all particles larger and denser will have dropped out earlier.

The settling velocity is proportional to the density difference and the square of the particle size. Tchobanoglous and Schroeder (1985) note that organic materials (bacteria, food particles and fecal matter) usually have densities in the 1030 to 1100 kg/m^3 range, chemical flocs produced in precipitation reactions have densities in the 1400 to 2000 kg/m^3 range, and mineral particles usually have densities around 2500 kg/m^3.

A comparison of the idealized still water settling velocities based on Equation 3 for three materials, sand (ρ_p = 2,650 kg/m^3), fish waste (ρ_p = 1,190 kg/m^3 (Chen *et al.*, 1993)) and silt (ρ_p = 1,009 kg/m^3) is shown in Figure 2.6. Note that both scales are logarithmic. Settling becomes very slow as the size diminishes.

Stokes law was developed for spheres. Cripps (1995) noted that casual observation under a microscope informed him that the particles were far from spherical, although he did not elaborate on the shapes he saw. Irregular shapes slow the falling velocity by increasing the drag. Quiescent settling tests can be used to determine the actual terminal velocities.

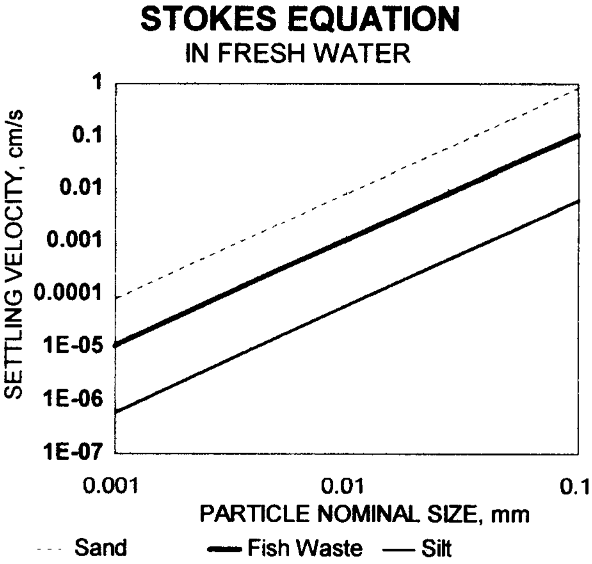


***Figure 2.6**: Theoretical settling or terminal velocities versus spherical particle diameter for three materials of differing specific gravities.*

A defining term in the design of settling basins is the overflow rate, *Q/WL*, based on the terminal velocity of a particular particle size, termed the critical settling velocity, v_{sc}. Complete settling occurs when :

$$v_{sc} > Dv_h/L \tag{2.7}$$

where: v_h is the horizontal fluid velocity, *L* is the length of the settling zone and *W* is the width. Also,

$$v_h = Q/DW \tag{2.8}$$

Combining Equations (2.4) and (2.5),

$$v_{sc} = Q/WL + Q/\ basin\ surface\ area \tag{2.9}$$

Particles having terminal velocity $v_s > v_{sc}$ will be removed in the proportion v_s / v_{sc} (Lawson, 1997). The *overflow rate* (*Q/WL*) has units of m^3/day/m^2 (GPD/ft^2).

In actual settling basins, there are several phenomena that cause serious deviations from the ideal. Poor inlet design (often a single pipe) causes short circuiting such that a plume of flow passes through too quickly and the remainder of the basin volume lies dormant, unused for settling. Turbulence is often present which causes the flow to deviate from laminar flow, slowing settling, and causing scouring, or the resuspension of material from the sludge zone. Poor outlet design can cause stronger currents to develop in that area increasing scour near the outlet.

However, considering the ideal basin and using Equation (2.6) for an arbitrary basin depth of 0.5 m to settle fish waste (Figure 2.7), under perfect conditions it would take nearly one hour for 40 μm particles to settle out, and over 13 hours for 10 μm particles to do so. As noted above, even the best designed settling tank is not ideal. Hence, while useful and economical for the reduction of large, settleable solids, even if the large area required is available and the tank is well designed (see Camp, 1946), the settling tank cannot be considered efficient enough to remove fine feed and faeces particles from recirculating systems.

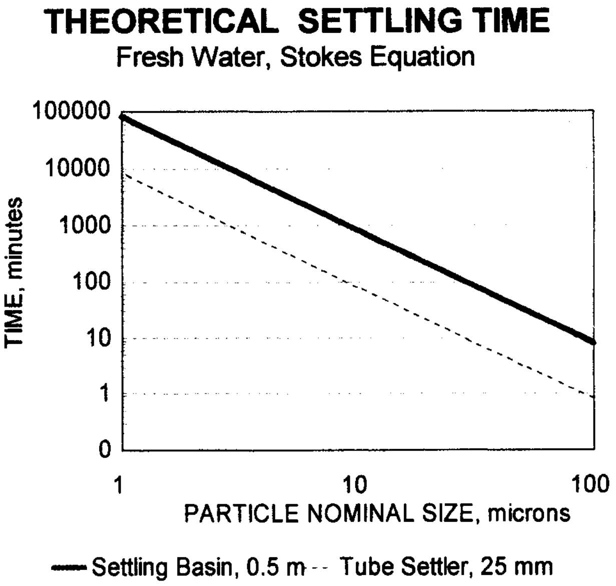


Figure 2.7: *Time required for a spherical particle, S.G = 1.19, to settle 0.5 m in still water.*

Laminar Plate or Tube Settlers

These devices were developed to enhance the settling characteristics of basins while reducing the basin footprint. They normally consist of modules of flat plates or tubes of several configurations set at an angle in a tank. The flow is directed up the tube or plate, thus increasing the residence time per horizontal length of tank. In addition, the plates or tubes have limited distance between them (in the order of 25-50 mm), thus creating laminar flow conditions and reducing the distance to drop out to millimetres. The material that drops out generally slides down the sloped plate or tube to be collected in the tank bottom. A slope angle from 45 to 60 degrees is recommended (Lawson, 1995). Below 40°, sludge will collect and the the self-cleaning characteristic will be lost. Above 60°, the removal efficiency drops.

The critical settling velocity is defined in a similar manner to that for the settling basin:

$$v_{sc} > h/t_H = hu/L \qquad (2.10)$$

and

$$v_{sc} = v_s Cos\Theta \qquad (2.11)$$

where: h = distance across the tube/plate space
u = velocity through the tube
t_H = detention time
L = length of tube/plate path
Θ = angle of tube/plate to horizon.

A theoretical indication of the improvement in clarification can be obtained from a laminar clarifier with 25 mm plate distance, angle 60°, is suggested by the dotted line in Figure 2.7 and annotated for several particle sizes in Table 2.5. There is a considerable improvement in terms of size to settle in a given time in every size. The plate clarifier will greatly improve the speed and degree of removal down to about 10 μm, when the residency time would again become such that the clarifier would take on a large size. They are reasonably space efficient and can be gravity fed. Thus this method is a valuable tool for the larger settleable solids and the high end of the suspended solids, but is incapable of handling the fine suspended solids in an economical fashion.

***Table 2.5**: Stoke's Law comparison of theoretical retention times to settle a given sized particle of fish waste between a 0.5 m deep basin and a tube or plate laminar clarifier with 25 mm between plates.*

Particle size, µm	100	50	10	5	1
Retention Time, 500 cm deep basin, min	7.97	31.89	797.19	3188.78	79719.39
Retention Time, 25 cm laminar settler, min	0.80	3.19	79.72	318.88	7971.94

Hydrocyclones

Hydrocyclones are stationary devices that seek to enhance the gravitational effects of settling by swirling the flow to add a centrifugal element. The hydrocyclone is represented diagrammatically in Figure 2.8. In the classic design, the flow enters tangentially at the top of a cylindrical section. The swirl creates a centrifugal force on the particles which tend to move to the wall, the velocity of movement being a function of the 'g' force caused by the swirling, the difference in density between the particle and the fluid, and the size of the particle. Particles impinge on the wall and slide down to be collected in the cone or continuously flow out of the bottom of the cone. Once a particle enters the boundary layer, it is out of the flow.

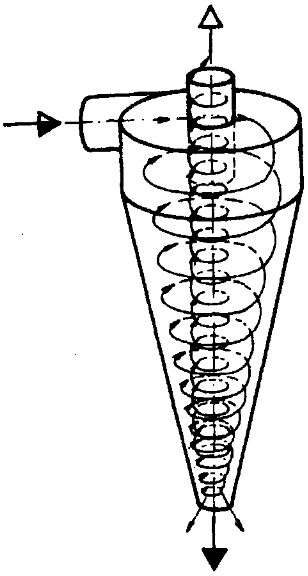


***Figure 2.8**: Vortices in a hydrocyclone*

The swirl also creates a low-pressure zone in the core of the device, setting up an axial flow downward near the wall, and upward in the centre, the path of the overflow of clarified liquid. Normally, there is a 'vortex finder' (downward extension of the outlet) to contain the central vortex and guide the overflow.

Hydrocyclones are designed to a certain ‘cut size’, the most common of which is d_{50}, the particle diameter which has a 50/50 chance of being either in the underflow or the overflow, In these devices, there are always some larger particles in the overflow and smaller particles in the underflow.

Wheaton (1977) repeats Bradley’s (1965) d_{50} design equation:

$$\frac{d_{50}D}{D_i^2} = \frac{3\,(038)^n}{\alpha}\left[\frac{\mu D(1-R_f)}{Q(\rho_s-\rho_i)}\tan\frac{\Theta}{2}\right] \tag{2.12}$$

where: D = internal diameter of the cylindrical portion

D_i = diameter of the inlet

Q = the influent flow rate

R_f = the ratio of the underflow/overflow

μ = the liquid absolute viscosity

ρ_s = density of the particle

ρ_l = density of the liquid

Θ = inclusive cone angle

n = the power of cyclone radius, r in vr^n = *const.* (conservation of momentum, vr = *const.*, modified for fluid friction; see Trawinski (1986) and Svarovsky (1984) who found $n = 0.5$ to 0.9)

α = inlet velocity loss coefficient = v_c/v_i

v_c = tangential velocity at the wall of the cylindrical portion

vi = tangential velocity of the inflow, considered a mean value.

As noted above, hydrocyclones can be operated in a continuous or periodic flush mode. This is reflected in the term, R_f. In the periodic mode this term would be zero (no underflow), and the cut size would be larger for a given set of conditions.

Rietma (1961) developed a set of optimal hydrocyclone proportions for solid/liquid separation:

D_i = 0.28 D
D_o = Overflow diameter
= 0.34 D
D_u = Underflow diameter
= 0.20 D
L = Overall length
≈ 5 D
Cone angle = 20°

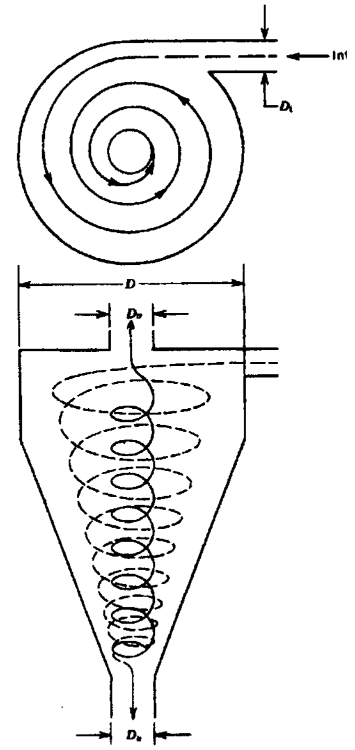


Figure 2.9: Hydrocyclone dimensions (from Wheaton (1977))

In the aquaculture field, the author has seen only one hydrocyclone that came near Rietma's optimum proportions. Common in the industry is the Swirl Separator of which the AquaTech version (Figure 2.10) is typical.

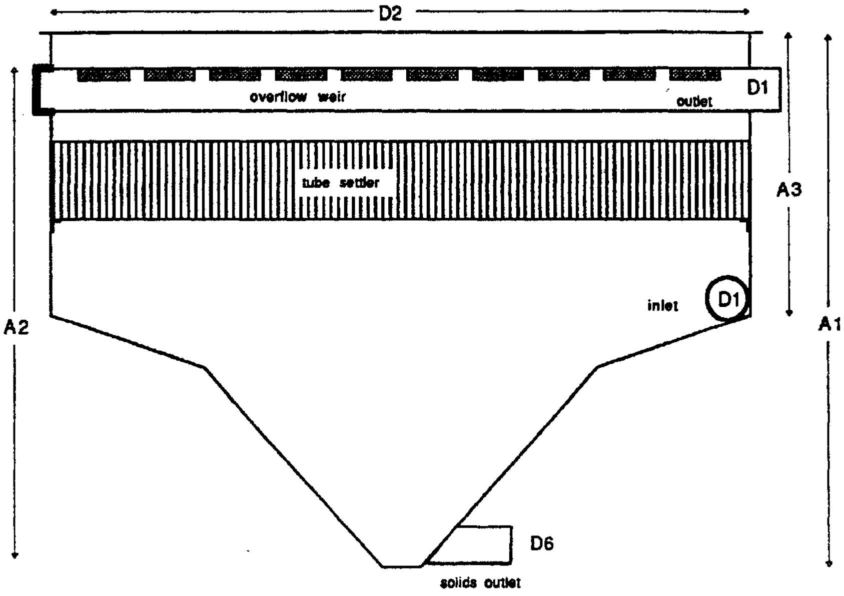


Figure 2.10: AquaTech swirl separator

Table 2.6: Swirl separator data from AquaTech

SWIRL SEPARATOR SIZES AND CAPACITIES

	MOD	**320P**	**MOD**	**270C**	**MOD**	**180P**	**MOD**	**120C**
CAPACITY	L/MIN	GPM	L/MIN	GPM	L/MIN	GPM	L/MIN	GPM
	4,800	1,270	3,200	847	1,200	317	400	106
DIMENSIONS	MM	IN.	MM	IN.	MM	IN.	MM	IN.
AI	4,080	160.6	1,950	76.8	2,300	90.6	855	33.7
A2	3,600	141.7	1,490	58.7	1,975	77.8	620	24.4
A3	1,080	42.5	910	35.8	600	23.6	400	15.7
D2	3,200	126.0	2,700	106.3	1,800	70.9	1200	47.2
D1	406.4	16	355.6	14	203.2	8	152.4	6
D6	101.6	4	101.6	4	101.6	4	76.2	3

The capacity indicated is operating capacity, which is about 80% of peak capacity.
"C" indicates models designed for continuous sludge removal (at about 10% of flow).
"P" indicates models designed for periodic or continuous sludge removal.

A comparison of these separators with Rietma's optimum proportions is given in Table 2.7. In the last column an estimate of the d_{50} cut size from equation (2.12) is offered. The cut size uses $\alpha = 0.45$, a reasonable figure for efficient hydrocyclone (Svarovsky (1984)), and the results can be said to be optimistic estimates. The true cut size can be expected to be larger, given the deviations from Rietma's optimum. Obviously these designs are not optimized for fine particle removal. The location of the inlet at the bottom of the cylindrical section is also contrary to good practice (e.g. Svarovsky (1984), Rietma (1961)) and the reason for it being so located is unknown.

***Table 2.7**: Comparison of Rietma's optimum solid/liquid hydrocyclones proportions with Swirl Separator proportions, plus calculated d_{50} cut sizes for the separators for fish waste in fresh water.*

	D_i/D	D_o/D	D_u/D	L/D	Cone Angle, °	d_{50}, µm
Rietma (1961)	0.28	0.34	0.2	5	20	
Model 120C	0.127	0.127	0.064	0.71	144/84	116
Model 180P	0.113	0.113	0.056	1.28	144/84	103
Model 270C	0.132	0.132	0.038	0.72	144/84	108
Model 320P	0.127	0.127	0.032	1.28	144/84	103

However swirl separators are relatively inexpensive pre-clarifiers for removing the larger particles and hence saving wash time on the drum filters. As they are usually set in the ground and fed by the gravity head from the culture tanks, they require no power.

2.3.2 Mechanical Filtration

Fixed Media

Mechanical filters operate on a form of Ohm's Law:

$$Q = \frac{p \times A}{R} \tag{2.13}$$

where: Q = rate of flow, in units like L/min

p = driving pressure; could be gravitational (open flow), vacuum (rare in aquaculture) or upstream pressure.

A = effective area of screen/filter (∟ to flow)

R = resistance to the flow

Note that while Q is analogous to I in Ohm's Law, p(N/m^2)xA(m^2) is the force driving the flow, or V, and R is resisting the flow. For a given situation, $R \propto$L, the depth of the media.

R is a function of several factors; the material and opening size of the screen or filter, its depth, and the variables: the type and build-up of the material being removed. As the filter loads up, the head loss increases. In some configurations, the pressure drop across the screen or filter can be used as an indicator of the degree of clogging taking place, and can trigger a cleaning cycle.

There are essentially three categories of filter as suggested in Table 2.8. Although these categories were developed originally to cartridge filtration media, they apply generally.

***Table 2.8**: Mechanical Filtration Classifications*

CLASS	METHOD	PRO	CON
Screen or Membrane	● Single layer, 'go, no-go' e.g. sieves, ● Woven metal, Dacron mesh, cast polymeric membranes (size determination, polishing)	● Absolute; no particles greater than the opening size will pass ● Some smaller particles will be retained as filter cakes. ● Efficiency independent of flow rate, Δp. ● No tendency for media slough-off downstream, no grow-thru. ● Low retention of solute constituents.	● Low load capacity; clogs easily, rapid build-up of head loss. ● Flow rates limited by surface area ● Relatively costly.
Surface	● Multiple layers, usually glass or polymeric micro fibres. ● Polypropylene, cellulose/resin-bonded paper, fiberglass/paper, often pleated ● Larger particles retained on surface, smaller in the matrix.	● Characteristics of both screen and depth filters. ● Higher dirt handling capacity than mesh. ● High efficiency if absolute rating not required. ● Flow rates considerably higher that screen filters ● Less expensive.	● Nominal rating only (not absolute, 99%). ● Grow-through: in extended service trapped microorganisms may grow thru to the filtrate side.
Depth	● Relatively thick, random porous structure. Particles become trapped in the network of flow channels. ● Mechanism: random adsorption and mechanical entrapment thru-out matrix. ● Some media: *Wound:* cotton, rayon, polypropylene. *Resin-bonded laminates:* cellulose, acrylic, rayon, fibreglass	● Highest dirt-holding capacity. ● Will retain a large amount of particles < rated. ● Less expensive than both above.	● Nominal rating (95%), no definite upper limit on particle size. ● Grow-through possible.

Cartridge Filters

Cartridge filters are used in aquaculture in situations where fine filtration and relatively low flow rates are required, such as in shellfish hatcheries. They are often used in parallel banks, not only to obtain the desires flow rate, but also to allow the operators to take one or more out of service for cartridge cleaning or replacement. They are not generally used at the flow rates required for finfish rearing, although there are some self-cleaning screen cartridge filters the may be of value on influent water, especially from surface sources, they have not shown up in the industry.

Microscreens

Microscreens are large, self-cleaning devices used to remove solids from culture effluent. A common practice in Atlantic Canada is to place a microscreen in the effluent stream after the swirl separator. There are three self-cleaning types; the *Triangl* filter, disc filter and drum filter.

The *Triangl* filter (Figure 9) was one of the early self-cleaning screen filters. It came from Norway, and as with many Norwegian developments early in the salmon farming industry, was embraced locally. In this filter, the flow washes over a screen fixed at an angle and falls through, leaving the solids on top. From the action of the unfiltered water, aided by a wash jet sweeping the screen area, the debris is washed into a trough for disposal. The screen being two-dimensional, its size versus flow rate is a limitation. It is largely unused in this area now.

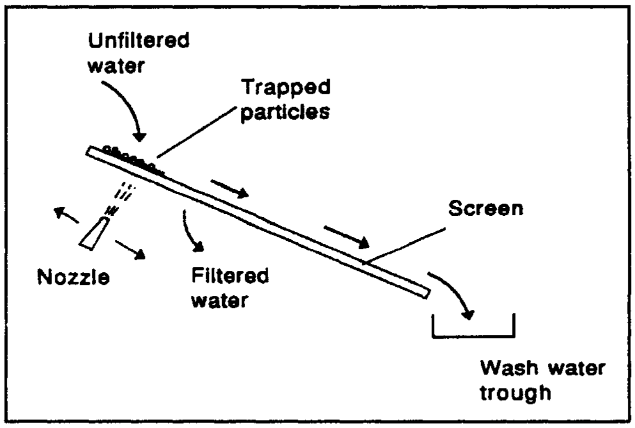


***Figure 2.11**: Diagram of the mechanics of the Triangl filter (Lawson, 1995)*

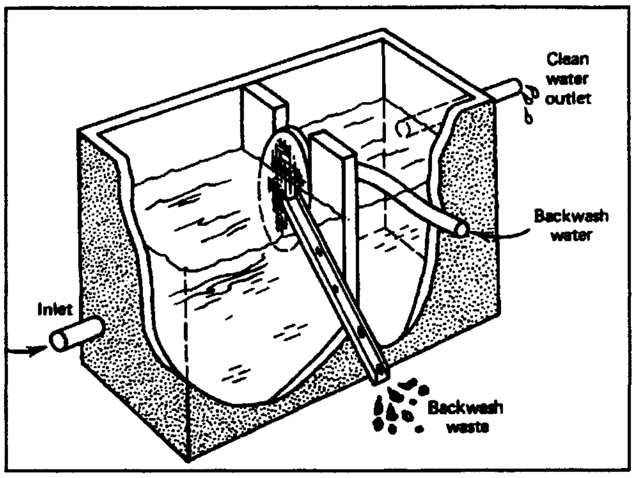


Figure 2.12: Operation of an axial rotary screen (Wheaton, 1977)

Disc Filters, also referred to as axial flow rotary screens (Figure 2.12), consist of a tank in which one or several disc screens are placed such that the water flows axially through them. The trapped solids are lifted up and pushed into a collection trough by a high-pressure back spray. This system has the advantage that progressively fine discs can be put in the flow but suffers from the disadvantage that the only way to increase the capacity is to increase the diameter of the disc. Multiple discs in tandem in descending mesh sizes can be utilized, however.

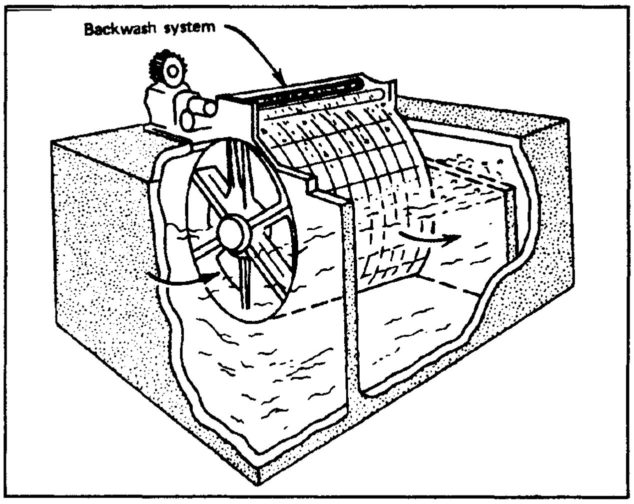
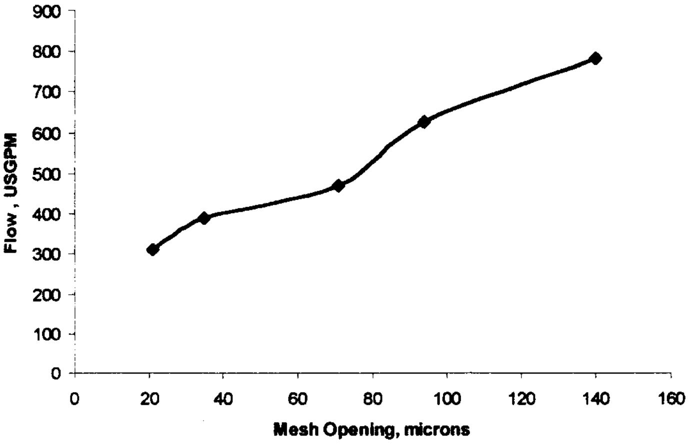


Figure 2.13: Drum filter operation (Wheaton, 1977)

Drum Filters or radial flow rotary screens (Figure 2.13) are common as culture water effluent clarifiers in recirculating aquaculture systems and they have generally taken on the generic name of 'microscreens' although that category really includes the two previous devices. The screen is placed on a drum, thus adjustments to capacity can be made both to the diameter of the drum ($\propto$ d) and length of the drum ($\propto$ l). In many installations they have replaced the pressurized sand filter (see later) as being easier to operate and maintain.

The normal upper load limit for drum filters is about 60 mg/L. The operating head across the screen is relatively low (the height of water inside the drum (influent) to the height of water outside the drum (effluent)) and is generally gravity fed. The resistance is an inverse function of screen size. Typical clean water flow rates for one manufacturer's drum filter (4 ft diameter x 2 ft long drum) is given in Figure 2.14.



Figue 2.14: *Lyco 4x2 microscreen flow rate vs screen mesh size, raw water, clean screen.*

The screen initially is about 40% submerged. Solids build up on the back (inside) of the screen forming a mat, which, while reducing the flow rate, will trap particles smaller that screen size. As the solids mat forms, the level inside the drum rises (10-30 cm). This can be used to trigger the wash cycle. Backwashing is performed by a jet flow from a high pressure pump, usually a turbine pump, taking water from the cleaned side. Backwater pressure is a design factor. Higher pressures (up to 345 kP) are more efficient cleaners and lead to lower wash water consumption (Chen *et al.* (1997).

The resistance increases, hence the capacity of microscreens diminishes with reduced mesh size. In addition, small mesh screens clog much more rapidly requiring a more frequent wash cycle, with the subsequent loss of water from recycling systems, plus the pumping energy. In one installation the author has seen the wash cycle running continuously in a salmon hatchery at a peak period.

Rotational speed is usually fixed (4.6 to 26 m/min, tangentially) and based on the allowable head loss across the screen, although Chen *et al.* (1997) suggest that the whole field is one that is not yet well investigated. Practically, about 50 to 60 µm is considered the lower limit for microscreening Chen *et al.* (1997), and pers. obsn.). The mesh is usually made out of stainless steel or polyester, although the latter will flatten and reduce porosity in service. Dawes (1986) noted that, despite backwashing, organic and inorganic slimes can progressively build up on the surface of the fabric, gradually reducing pore size. Periodic maintenance cleaning must be allowed to correct for this.

Wheaton (1977) discusses Boucher' (1947) design equation for microscreens:

$$h = \frac{mQh_o}{A} e^{\frac{nIQ}{s}} \tag{2.14}$$

where: e = base of the natural logarithm

h = head loss across the screen (cm water)

Q = flow through the screen (L/min)

h_o = initial head loss across screen (m) for an approach velocity of 1 ft/s

A = effective submerged area of the screen (m^2)

I = filterability index of raw water (L/m^2)

s = speed of strainer: area of filter entering the water per unit time (m^2/min)

m = constant = 1.1×10^{-4}

n = constant = 1.86×10^{-6}

The constants obviously have a dimension adjustment factor in them. The filterability index, I, is a function of the particular mesh in question, based on the minimal design particle size, and the desired rate of flow per unit area. It is the most difficult parameter to find.

Dawes (1986) describes Boucher's method and the Filtester by Mather and Platt. As the submerged screen area, *A*, is a function of drum dimensions and rotational speed, the process of finding the correct values for these parameters will be an iterative one.

Drums filters process large quantities of effluent in aquaculture facilities in a space and energy efficient manner. They have a lower practical limit of about 40 μm, require periodic out-of-service maintenance and, being mechanical, can break down. In practice, they are reliable enough that regional operators do not back them up.

Granular Media Filters

Granular media filtration is the passage of the waste water through a fixed bed of granular material, in most cases sand or plastic beads. The action transferring solids to the media involve sedimentation, straining, interception and diffusion. In the range of primary interest, interception and sedimentation are the primary modes. (Figure 2.15). These are essentially depth filters. As solids are captured on the media the interstices are constricted, hence smaller particles are captured. However the hydraulic rate (flow rate) is also reduced and at some point the media will have to be cleansed.

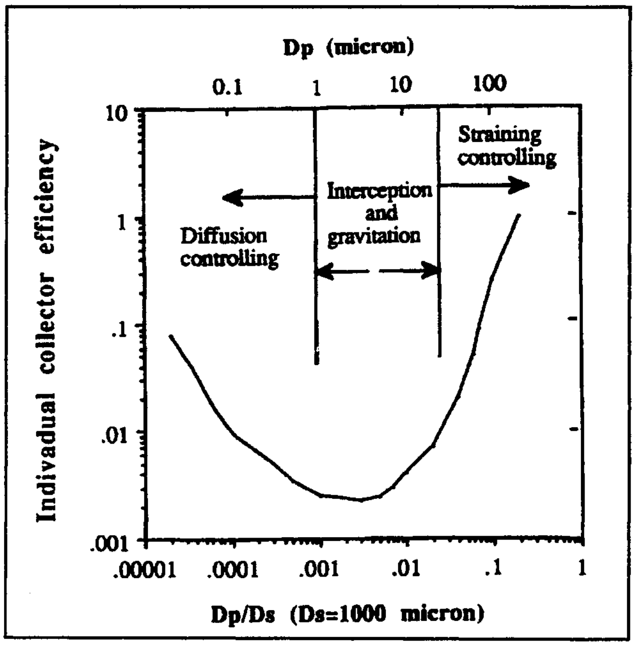


Figure 2.15: *Effects of particle size on particle removal efficiency. D_p = particle diameter; D_s = media size. Chen et al. (1997)*

Currently there are three versions using sand as a media, and a number of versions of floating bead media as discussed in biofiltration.

Sand Media Filters

These have been developed in three modes: gravity fed, pressurized down flow and pressurized upflow.

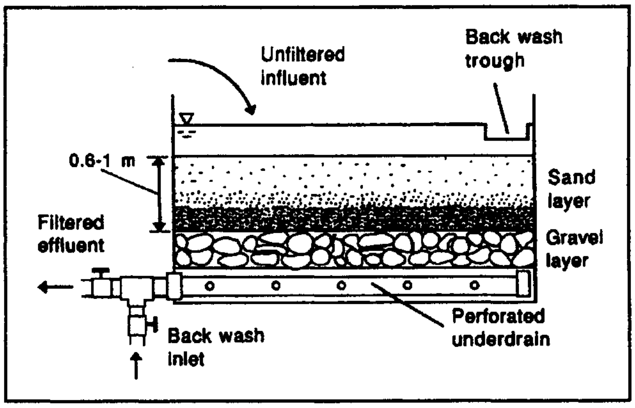


Figure 2.16: Gravity sand filter (from Timmons and Losordo (1997))

Gravity flow sand filters (Figure 2.16) are not used commercially. With a Δp limited to one atmosphere, they require a large surface area to achieve a reasonable flow rate. They will be invaded by bacterial colonies which can 'gel' them, blocking flow and so do need a method of breaking up the bed and cleansing it, normally by taking it out of service and backwashing it.

Pressurized sand filters (Figure 2.17), often referred to as the rapid sand filters, were common in experimental labs in the early days of research facilities and are still evident in local facilities. The pressurization, of which the energy costs must be paid, increases the hydraulic rate (flow rate) considerably, but, besides the sand filter tendency to turn into biofilter, they also tend to cake on the upstream side as the bed is compressed with the load. This requires the use of coarser sand and frequent backwashing.

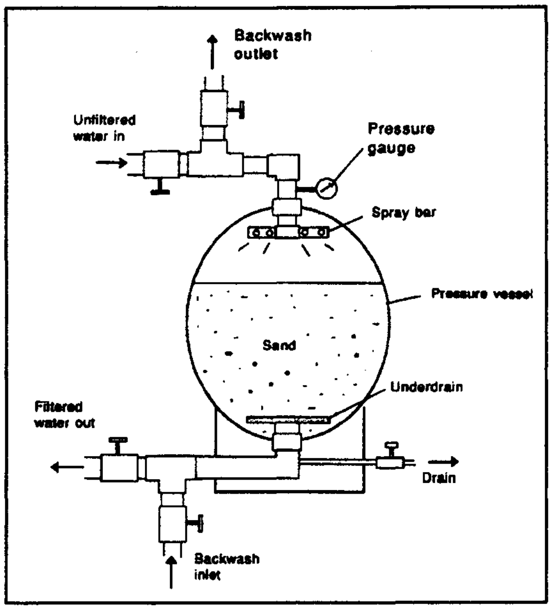


***Figure 2.17**: Downflow pressurized sand filter (Chen et al (1997))*

The upflow version of the pressurized sand filter are designed to eliminate the caking problem. Typically using 2 - 5 mm sand, the bed is designed at a flow rate just below fluidization. As the bed clogs or biofilm develops, localized fluidization zones occur. Back pressures are relieved and compression of the bed is prevented. However, the Δp is limited to avoid fluidizing the bed completely, and back washing water loss rates are high (Chen *et al.* (1997)).

Wheaton (1977) discusses a Hulbert and Feben (1933) equation for estimating the head loss through the filter versus flow rate, but these data can be supplied by the manufacturer for the particular filter of interest. Note that the data is for a clean filter and clean water. The in-service conditions, especially the particle size distribution (PSD) and load of suspended solids in the filtrate will dictate the actually effectiveness, backwash cycle and hence water loss of the filter. To estimate this will require a laboratory filterability test as described by Ives (1986)

Also Wheaton gives an expression for the velocity required to fluidize the sand bed for backwashing which is based on Stoke's Law. The author of this study suggests that the expression is too simplistic to describe the pre-expansion flow regime, and that one developed by Patterson and Watts (unpublished) based on Egun's (1951) work is more appropriate:

$$0.29\rho\left(\frac{6}{\psi d_p}\right)v_{mf}^2 + 4.17(1-\epsilon)\mu\left(\frac{6}{\psi d_p}\right)^2 v_{mf} - \epsilon^3(\rho_p-\rho)g = 0 \qquad (2.15)$$

where			CGS	SI Units
d_p	=	diameter of a sphere of the same volume as the particle	cm	m
ψ	=	Waddell's sphericity		
ρ	=	fluid density	g/cm^3	kg/m^3
ρ_p	=	particle density	g/cm^3	kg/m^3
v_{mf}	=	minimum fluidization velocity	cm/s	m/s
ϵ	=	void fraction of media		
μ	=	absolute viscosity,	g/cm.s	kg/m.s
g	=	gravitational constant,	981 cm/s^2	9.81 m/s^2

Wheaton (1977) states that pressurized sand filters remove particles consistently only down to about 30 μm without reference to removal efficiency. These are not absolute filters.

Bead Filters (Figure 2.18) although designed initially as biofilters, are purported to have the benefits of sand filters with high hydraulic rates but without the high water losses from backwashing. The most common media is 3 to 5 mm low density polythene beads, normally used as feed stock for plastic injection molding processes. The waste water flows up through the floating media which is packed in the top of the filter. Mechanical filtration as described takes place along with

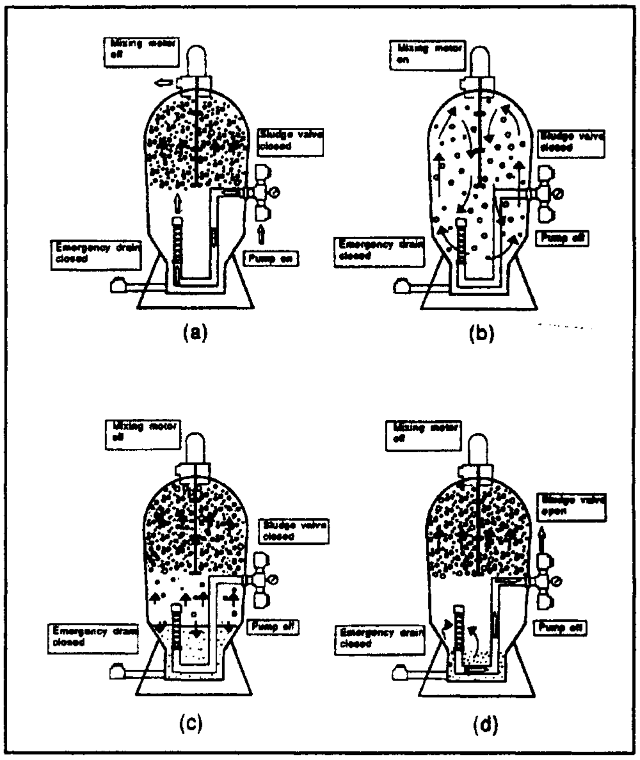


***Figure 2.18**: Bead filter cycle (Lawson, 1995)*

biofiltration, although the former appears to be the predominant effect.

On a timed or pressure differential basis the machine goes into a cleansing cycle. The flow is stopped and the beads agitated by air, mechanical stirring or water jetting, and the dislodged solids are allowed to sink to the bottom of the vessel, thus concentrating the solids for removal. High flow rates can be accommodated with low water loss during solids rejection. These devices appear to be more in evidence in warm water aquaculture. For continuous flow applications, at least two are required, each of which to be capable of taking the complete flow.

The reports on bead filters generally concentrate on the amount of SS removed, with little discussion of the size of particle.

2.3.3. Flotation

In the realm of chemical filtration, this report will concentrate on the use of bubble floatation. As Wheaton (1977) points out there are three forms of separation by flotation: foam fractionation, bubble fractionation and flotation. In each case fine bubbles of (normally) air are releases to rise up through a contained water column, carrying with it a portion of the substance to be removed.

Foam Fractionation separates dissolved solutes(organic acids, dissolved organic carbon) and some particulates from the culture water. The dissolved substances removed are surfacants, dipolar compounds with a hydrophilic end and a hydrophobic end (Figure 2.19). These molecules tend to collect at the air-water interface and get carried to the surface, where a foam is produced which can be physically removed. A simple version of such a device is shown in Figure 2.20. Foam fractionation is beneficial to culture systems as it maintains pH and lowers BOD, COD and nitrates.

Generally the only particulates removed are those which are entrapped in the bubbles, or have an electrostatic attraction (Wheaton (1977)).

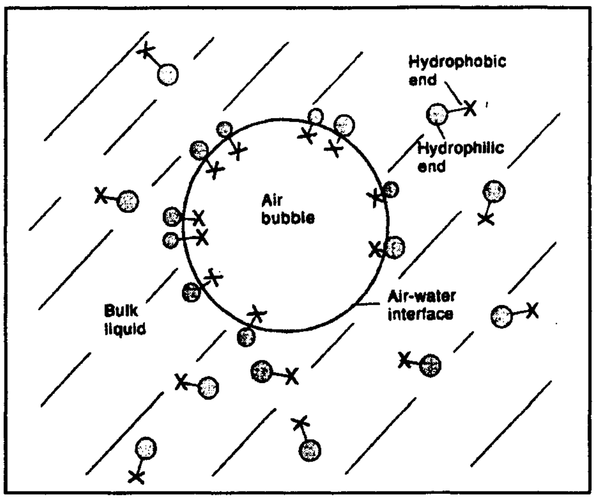


***Figure 2.19**: Diagram of air-water interface (from Lawson (1995))*

Bubble Fractionation is similar to foam fractionation where there is some surface activity present, but for various reasons, a foam does not form. In this case, the water near to surface becomes enriched in the solutes and must be drawn off.

Flotation is an industrial process, similar to foam fractionation, but aimed at removing hydrophobic suspended solids from the liquid by attaching the solids to air bubbles until the apparent, or bulk, specific gravity is less that the liquid and rises to the top to be skimmed off. In the context of this study, flotation would appear to offer the most useful approach. Stevenson (1986) advises that the central feature of this process is the generation of fine bubbles (50 to 100 μm versus 800 μm recommended as ideal in Lawson, 1995).

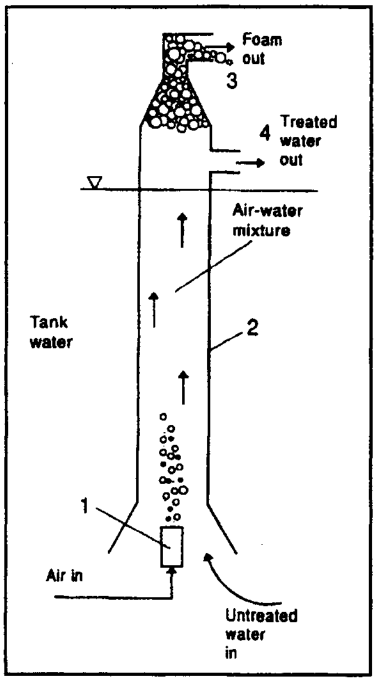


***Figure 2.20**: Basic co-current foam fractionator (after Lawson, (1995))*

Timmons (1997) produces an interesting review of the use of foam fractionation in aquaculture recirculating systems in which, while acknowledging the three types mentioned above, states that, for the purposes of the review, foam fractionation refers to a combined process of removal of dissolved molecules and suspended solids. This review and the models it contains is largely based on the work of Weeks *et al.* (1993) and Chen *et al.* (1994a, 1994b). Weeks' work is empirical, working on a commercial system, rearing an unidentified trout. The fractionator is a counter-current model diagramed in Figure 2.21. Chen's is a basic principle mathematical model.

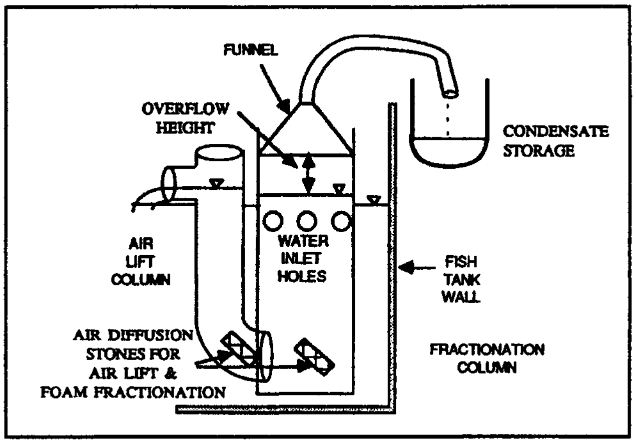


***Figure 2.21**: Counter-current foam fractionator as discussed in Timmons (1997)*

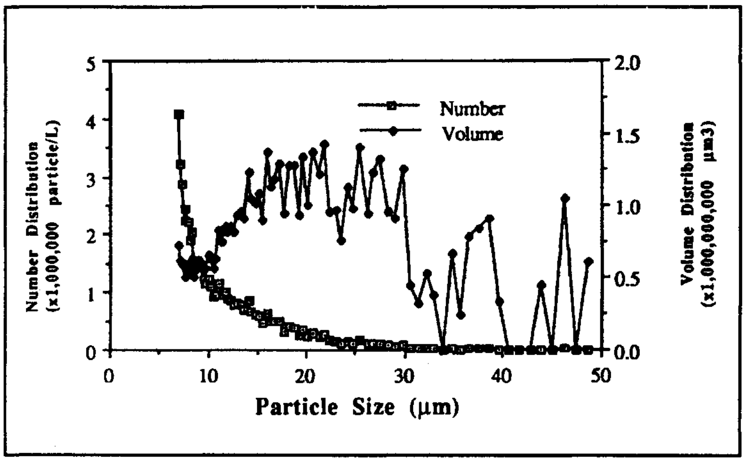


***Figure 2.22**: Particle distribution curves for a sample of foam condensate (from Chen et al. 1992b)*

Weeks *et al* (1993). concentrated on dissolved organics, suspended solids, and total Kjeldahl nitrogen (TKN) in the foam. It was determined that foam fractionation is very efficient at removing fine particles. The greatly reduced low-range particles as shown in Chen *et al.* (1992b) was cited (Figure 2.22). A reduction of the number of particles in the culture water ($4.1x10^6$ to $2.1x10^6$) through fractionation was reported. The mean particle 'volume equivalent sphere' diameter was noted as 10.6 µm. The PSD curve suggests that the particle sensing range ended at 6.5 µm, as with Chen's previous Elzone work. The paper states that "apparently, fine solids removal are not biased towards the finer solids". This author would like to suggest that they probably are well biased towards very fine particles, and slide smoothly into the dissolve range. The plot certainly looks hyperbolic. The problem is the limitation on the detection range of the apparatus used (see Appendix J).

Foam fractionation needs a surfactant to assist in removal of attracted molecules and particles and producing the foam. In fish culture systems the proteins in the feed and faeces supply the surfactants. This was particularly evident in Weeks *et al.* (1993) when extremely variable foaming rates were related to feeding. It later was determined that the feed had been top-dressed with fish oil, which acted as an anti-surfacant. It is of interest to note that the airstones used to generate bubbles in these tests were rated as coarse.

The major design parameters in performance of foam fractionators are:

- chemistry of the liquid and solute/particles
- surface tension
- temperature
- viscosity
- pH
- salinity
- bubble size
- air-to-liquid ratio
- contact time

The first six parameters are dictated to the designer by the rearing requirements of the animal, leaving three parameters to work with.

a. Bubble Size, B_d (Timmons *et al.*(1993))

Timmons starts by describing a superficial gas velocity, U_g such that:

$$U_g = \frac{Q}{A} \tag{2.16}$$

where: Q = air flow rate through the column, m^3/s

A = cross-sectional area of the column, m^2

He notes that there is a practical range for U_g, since a continuing increase in air flow rate will lead to bubble coalescence and slugs, seriously degrading performance.

A related parameter is gas holdup, E_g, which is the increase in column height above still water due to aeration. It is in the order of 10 to 20% but can go higher in fish culture water due to increased surface tension caused by the solutes. Chen (1991) obtained the following relationship between E_g and U_g:

$$E_g = 4.1\,U_g^{0.83}, \quad R^2 = 0.98 \tag{2.17}$$

Protein concentration (PC) affects bubble size with its effect on surface tension. Timmons regressed some of Chen's data to come up with the following expression for bubble size relating to the last two factors, for PC concentrations up to 137 mg/L.

$$B_d(mm) = 2.58 + 28.1\,U_g(m/s) - 0.0098\,PC(mg/L) \tag{2.18}$$

Mass transfer is based on a bubble swarm, and the smaller the bubbles size, the greater the surface area for adsorption. The bubble diameter is of course, based on the generator pore size and will increase as the bubbles rises up in the column. Lawson (1995) quotes a study by Wace and Banfield (1966) which purports to determine that the ideal bubble size of 0.8 mm. Unfortunately, this citing is not included in Lawson's references. As mentioned, Chen, Timmons and Weeks' works use air stones rated as coarse giving relatively large bubbles (2.5 to 3.5 mm in diameter) and claim little control over the generated bubble size. Figure 2.23 from Timmons (1997) is particularly telling. The $C_d(t)/C_d(t{=}0)$ for solutes and $C_d(t)/C_d(t{=}0)$ for particles (Figure 2.24) clearly show that small particles are particularly efficient at reducing micro-bubbles of 50 to 100 μm to remove hydrophobic particles such as finely crushed minerals. The industry appears to have methods of producing such bubbles.

There is now available in the aquaculture industry ceramic diffusers for oxygen transfer that have a 0.3 μm pore size. Generally a 100 μm bubble is now readily available, with increased pumping costs, of course. This may be an area of fruitful study.

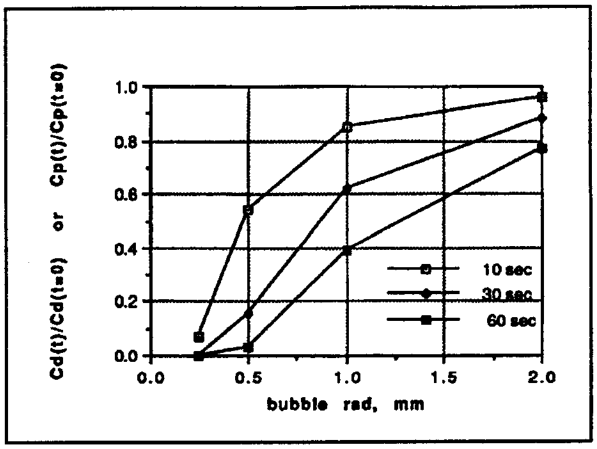


***Figure 2.23**: Theoretical reduction in concentration of solutes (C_d) and particles (C_p) in the bulk solution versus bubble size with time (from Timmons (1997))*

b. Air Flow Rate

As the air flow rate increases the specific efficiency of solids removal is reduced and becomes more variable (Figure 2.24). However the removal rate is increased overall due to the greater air velocity sweeping the foam, still wet, into the removal funnel Timmons (1997)). Lawson (1995) again citing Wace and Banfield (1966) suggests that an 'ideal' air-to-liquid can be obtained with a gas flow rate of 1.8 cm^3/cm^2.

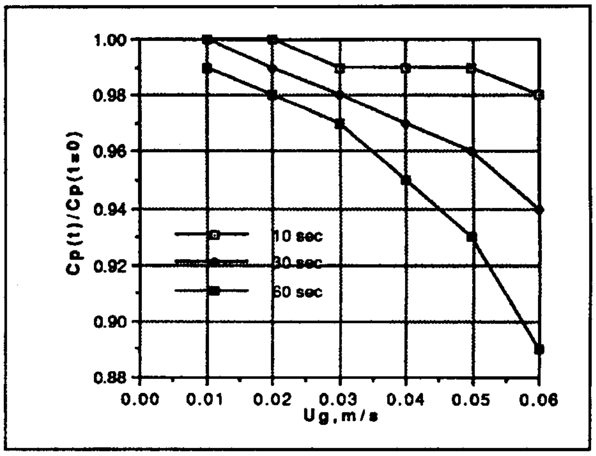


***Figure 2.24**: Theoretical reduction of solids concentration in bulk solution versus gas velocity (from Timmons (1997))*

Weeks *et al.* (1992) presents some empirical predictive models linking removal rates with airflow rates, AFR, (L/min) and foam overflow heights, OFH (cm) for a limited range of operating conditions:

Q = 11 to 33 L/min
AFR = 33 to 66 L/min
OFH = 0 to 8 cm
E_g = 0.22 to 0.40 (actually the upper limit is 0.25; above this, slug flow is liable)
U_g = 0.03 to 0.06 m/s

Condensate volatile solids, C_{VS} (mg/L):

$$C_{vs} = 1100 - 14\,AFR + 83\,OFH, \quad R^2 = 0.75 \tag{2.19}$$

Condensate production, P_{cond} (ml/min):

$$P_{cond} = -9.2 + 0.97AFR - 4.2OFH, \quad R^2 = 0.65 \tag{2.20}$$

Volatile solids removal rate, RR_{VS} (mg/min):

$$RR_{vs} = -2.9 + 0.39AFR - 0.81\,OFH, \quad R^2 = 0.81 \tag{2.21}$$

Weeks *et al.*(1993) determined a correlation between volatile solids, VS, and total suspended solids, TSS:

$$TSS(mg/L) = 0.27\,VS(mg/L), \quad R^2 = 0.81 \tag{2.22}$$

The Chen *et a*l (1994a) mathematical models, which are more complex, are discussed in Timmons (1997) and Timmons offers two correction factors. They will not be discussed at this time.

c. Contact Time

The references generalize that a longer contact time improves transfer efficiency, and that is why workers use the counter-current fractionator shown in Figure 2.21, popular because it extends the contact time between the bubbles and the solution. To date, no mathematical relationship has been found by this author.

Foam fractionation in Maritime aquaculture is focused on solutes removal and is valuable in aquacultural systems for removal of pH-lowering organic acids and some noxious ions such as nitrate. It is less efficient at removing suspended solids, but is the only method of those examined that does remove fine particles. Perhaps with emphasis on 'flotation' design versus fractionation, this method would hold promise.

2.4 BIOLOGICAL FILTERS

2.4.1 Method of Filtration

Biological filters are used in recirculating water aquaculture systems to remove the soluble metabolic wastes from the effluent of contained cultures, either for cleaning the water for recycling or to meet environmental laws. The target is the metabolic product ammonia (NH_3) a soluble gas which is highly toxic to all cultivated species. Ammonia in aqueous solutions is in equilibrium with its ionized form, ammonium (NH_4^+) depending on temperature and pH. Bacteria of the *Nitrosomonas* ssp. convert ammonium to less toxic nitrites (NO_2^-), and *Nitrobactors* ssp. convert the nitrites to least harmful nitrates (NO_3^-) by the process of growing of nitrifying bacteria on a solid substrate.

$$NH_3 \rightleftharpoons NH_4^+ \quad [f(pH,\ T)] \tag{2.23}$$

The simplified equations are, for conversion of ammonium to nitrite:

$$NH_4^+ \;+\; 1.5\,O_2 \xrightarrow{Nitrosomonas} NO_2^- \;+\; 2H^+ \;+ H_2O \tag{2.24}$$

and from nitrite to nitrate:

$$NO_2^- \;+\; 0.5\,O_2 \xrightarrow{Nitrobacters} NO_3^- \tag{2.25}$$

This is a fixed-film process; a thin layer of biofloc coats a hard substrate. The process has an inherently slow response characteristic for changing loads. Start-up to steady-state, even with inoculation of the bacteria, is in the order of two weeks to a month.

The term 'biofilter' is somewhat misleading, suggesting mechanical separation. Whereas some types of biofilter do contain an element of mechanical separation, the primary task is normally one of biological conversion of molecules, specifically nitrification.

2.4.2 Factors Affecting Biofilter Performance

It would be appropriate at this juncture to discuss the factors that affect performance, as they affect all types of biofilters. These factors were summarized efficiently in Lawson (1995) and in Timmons and Losordo (1997).

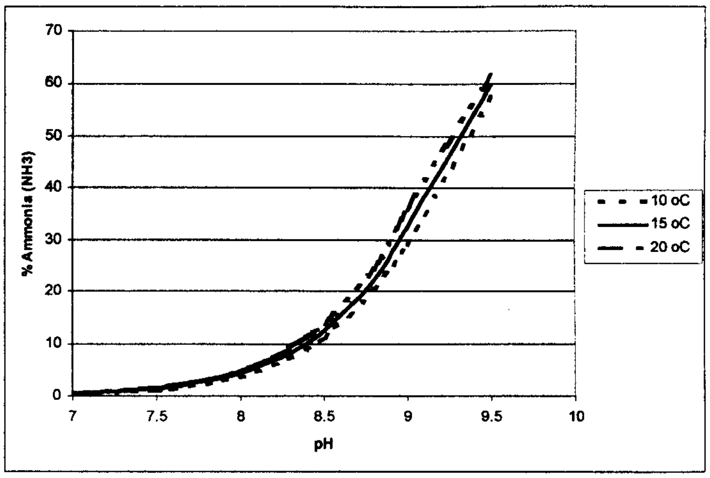


***Figure 2.25**: Percentage of un-ionized ammonia as a function of pH and temperature*

pH.

The un-ionized (UIA) form of ammonia, a dissolved gas, and the ionized form (referred to as ammonium) exist in an equilibrium in a relationship, for any given concentration, that is driven strongly by the pH. Figure 2.26 is a graphical version of the chart from Burrows (1964) shown in Wheaton ((1977) and relates to Table 2-10 and Figure 2-12 in Lawson (1995). The NH_4^+ ammonium form is the only form that *Nitrosomonas* can convert to nitrite. Thus to aid this process a low pH moves the NH_3 - NH_4^+ balance in favour of the former. But the nitrifying bacteria optimum growth pH is in the order of 7 to 9 (Lawson (1995), summarizing several sources). A pH of about 7 to 8 is a compromise target value.

Temperature.

In addition to the effect on percentage NH_3 mentioned above, temperature also affects the microorganisms directly. Although optimal growth temperatures of 28 - 35°C have been reported for the nitrifying bacteria, these organisms will adapt to slow changes in temperature. Generally the water temperature is dictated by the water source, for flow-through systems, and by the optimum growth temperature of the cultured species, in recirculating systems.

Wortman and Wheaton found a linear relationship between ammonia removal and temperature:

$$AMR = 140 + 8.5T \qquad R^2 = 0.89 \tag{2.24}$$

Thus cold water systems will require a greater amount of substrate on which to develop the same conversion rate as for warm water systems.

Alkalinity.

This is a process that produces hydrogen ions that consume alkalinity and lower pH. For each gram of NH_4-N oxidized, 7.14 g of alkalinity (as $CaCO_3$) are consumed and must be replaced, if the process is to continue The lower limit is indefinite (20-50 mg/l) but the rule is to replace that alkalinity consumed to maintain pH at the target level.

Oxygen.

In addition to alkalinity consumption, for each gram of NH_4-N oxidized, 4.57 g of oxygen are consumed. Common filter design practice is to ensure that the biofilter effluent has an oxygen level $\nless$ 2 mg/l to ensure sufficient O_2 availability in the biofilter for conversion (Timmons and Losordo, 1997). This suggests that the influent water oxygen concentration must be $\nless$ 5-6 mg/l as a rule.

Salinity.

The nitrifying bacteria can adapt to almost any range, if acclimatized slowly, but a constant promotes optimum conversion rates. Abrupt changes (> 5 g/l (‰)) will shock and decrease conversion efficiency until the adjustment is made.

Solids.

Suspended solids from waste food and the metabolic processes can clog some biofilters, hence increase head loss, and cause short circuiting (producing anaerobic areas). They can also mineralize and add to the biofilters' load. Particles in the 1.4 to 2.7 μm range provide substrate for bacteria. Some nitrification can be carried out on particles in the flow system, but the particles also provide substrate for competing heterotrophic bacteria. Overall, heavy organic loadings were found to inhibit biofilter efficiency. Particles can also shield disease organisms from the effects of disinfecting agents. The rule is to remove solids as quickly as possible from the system but definitely before biofiltration.

Light.

The nitrifying bacteria function best in total darkness. Light intensities as low as natural daylight inhibits nitrification, with *Nitrobacter* ssp being the more sensitive.

Ammonia and Nitrite Levels.

Excessively high levels of ammonia or nitrite levels are toxic to the converting bacteria. In the latter case, it is the aqueous product, nitrous acid that is the inhibiting agent. At the other end of the scale, low concentrations of the two nutrients, ammonium and nitrite can be the rate-limiting factor in the conversion processes in biofilters.

2.4.3 Media.

The task of the biofilter media is to provide the substrate on which the bacteria can grow. Ideally the system will provide the bacteria with a substrate that exposes them efficiently to the nutrient, water and oxygen and with sufficient surface area for all the ammonia to be converted.

Attributes of Column Packing *(Media)*

(from Fabco Systems TRI-PACK Brochure)

- *High specific surface area (SSA)*: m^2 of active surface/ m^3 of bulk volume of media: sufficient is required to covert the target amount of nutrient for the operating conditions. E.g. cold water biofilters require more surface area than warm water as the conversion is less efficient (see 'Temperature' above).
- *High void space, %, or void fraction, %/100*, [portion of empty space per unit volume of the packing]. A high void fraction indicates a low pressure drop and a tendency not to clog. It also suggests a bulkier filter to obtain the necessary total surface area.
- *Minimal packing*. Another non-clogging feature.
- *Stable material* Inert material that does not affect bacteria or fish.
- *Light in weight*, For ease of construction.

Tri-Pack is one of several manufactured packing materials, developed to maximize the above noted attributes. Almost any inert material can be used, including sand and gravel.

Specific Surface Area *(SSA)*

With solid media, there is an inverse relationship between the particle size and SSA. For spheres it is:

$$SSA = \frac{6}{d} \tag{2.27}$$

where d = the diameter of the sphere, in S.I. units, in meters.

For irregular particles (e.g. sand and gravel):

$$SSA = \frac{6}{\psi d} \tag{2.28}$$

where ψ is Waddell's sphericity, a measure of deviation from a sphere. For sand and gravel it is in the order of 0.7-0.8.

By way of example, Tri-pack quotes an SSA of 42 ft^2/ft^3 (138 m^2/m^3) for its 2 inch balls, versus 118 m^2/m^3 for a 2 inch solid sphere, whereas #1 sand has an SSA of about 8000 m^2/m^3.

Depth of Filter and Cross-sectional Area.

Depth of filter and cross-sectional area defines that part of the biofilter that is active, that is, where water, oxygen and nutrients meet. They are a function of the type of filter and the nutrient and hydraulic loading.

Biofloc.

Biofloc is a product of the nitrifying process. Too thick a biofloc will affect diffusion of the ammonium into the conversion sites and the product ions away from them. In some cases excessive biofloc will restrict flow, increasing head loss, and causing channelling leading

Hydraulic Loading Rate.

The hydraulic loading rate is defined as the volume of nutrient water flowing through the biofilter per unit of cross-sectional area. Its units are $m^3/m^2/day$ ($gal/ft^2/min$). It is also sometimes referred to as *flux rate* in $m^3/min/m^2$ ($gal/min/ft^2$). In some filters it is also referred to as the *superficial velocity*, the flow rate/the cross-sectional area, in such units as m/min or cm/s (ft/s). For rotating biological contactors (RBCs) (see later), the hydraulic loading has been expressed as the flow rate per media specific surface area per day.

The minimum loading is that which keeps all the filter media wet; below that level the bacteria will dry out and die. The maximum rate is generally considered one that excessively scours the bacteria off of the media, and/or leads to excessive head loss, hence increased energy costs.

2.4.4 Biological Filter Types

Fixed Bed Biofilters

The original biological filters were generally of the fixed or still bed type, in that a fixed bed of packed media was contained in a tank and the waste water applied to it. There are basically three configurations: submerged upflow, submerged downflow and trickling (downflow implied) filters.

Submerged Filters

In submerged filters, the media is completely submerged in the waste water. All the oxygen required for the bioconversion must be brought in in the influent water. They are simple, and a wide variety of media can be used. Early filters used gravel. They are prone to becoming gummed up with biofloc to the point that the bed becomes virtually a solid mass and ceases functioning completely. Therefore, large void fraction media, with related low to becoming gummed up with biofloc to the point that the bed becomes virtually a solid mass and ceases functioning completely. Therefore, large void fraction media, with related low SSA, are generally used which results in large, bulky filters. Total ammonium nitrogen (TAN) removal rates in the order of 0.6 g TAN/m^2/day of surface area could be expected.

Trickling Filters

In trickling filters, the water is applied by a spray bar on the top of the media and allowed to trickle down over the media. This oxygenates the flow and allows some degassing of the product carbon dioxide but the flow has to be carefully managed so that parts of the media do not dry out and kill bacteria. There is a low head requirement. These filters are now generally used only in aquaria or small research systems. Ammonium removal rates in the order of 0.75 g TAN/m^2/day of surface area at 12°C for trout has been estimated. (Timmons and Losordo, 1997)

Rotating Biological Contactors

Following the fixed bed filters, researchers developed a group of filters referred to as rotating biological contactors (RBC). They come in two forms, the biodrum and the biodisc. In either case, the media, formed into a drum shape or a series of discs, is mounted on a rotating horizontal shaft which is about 40% submerged in the waste water. As the RBC rotates the upward moving media carries water into the air, and the downwards moving media carries air into the water, and so oxygen-starvation is not a problem. These are open-to-atmosphere devices, and hence low head loss systems. Shear forces are sufficient to slough off excess biofloc, making them essentially non-clogging.

The rotational speed has to be gauged to ensure good conversion residence time without letting the media dry out. Conversion rates in the order of 0.86 g TAN/m^2/day have been reported. As various types of plastic media are used, these machines can be large; one seen by this author in Virginia for Tilapia was 10 ft in diameter and 25 ft long. Rotational power must be supplied and shaft strength and bearing wear has been a problem, especially in hand-made contactors. Commercial models are expensive.

Expandable Granular Media Filters

To overcome the clogging problems of the fixed bed filters using small sized media, the expandable bed granular media filters were developed, first the upflow sand filter and then the bead filter. In both cases, solids removal is combined with nitrification.

Upflowing Sand Filter

This is essentially a submerged upflowing filter using sand as the media. The flow rate is controlled so that the bed is maintained below expansion, and thus acts as a physical separation filter for solids, besides acting as the media for nitrification. Periodically, the valving is changed and an expansion rate of flow is provided. This allows the trapped solids and excess biofloc to be cleared out and sent to waste. Thus relatively cheap and high SSA sand can be used as the media. Pumping energy sufficient for expansion must be provided. The necessity to maintain normal flow below the expansion rate limits the hydraulic loading of the device and they are limited to low to moderate nutrient loading situations.

Bead filters

There are several variation of bead filters commercially available, derivatives of the original developed by Malone (1992) at LSU. This device is conical on the bottom and hemispherical on the top. The media are floating plastic beads < 3mm in diameter (SSA $\approx$2000 m^2/m^3). The flow is upward, trapping the beads in the dome. The beads are a nitrification substrate as well as trapping solids. In fact, the solids removal aspect has been noted to be the dominant effect. Periodically the flow is stopped and the beads agitated by air, water jet or paddles, sloughing off the solids and excess biofloc, which drops to the bottom of the cone, ready for purging. Pressure losses and hydraulic rates are moderate (420 - 840 kPa; 410 - 1,400 L/min/m^2) alleviating oxygen supply problems.

Bead sizing is based on areal nitrification rates. Rates of 0.10 to 0.15 g/m^2/day are suggested for broodstock and breeding, 0.20 t0 0.25 g/m^2/day for fingerlings and sensitive species, and 0.35 g/m^2/day for resistant species (catfish. tilapia, carp). To date, they have been used mostly in warm water systems.

Fluidized Beds

Fluidized beds originally were upwelling sand filters in which the hydraulic rate (flux rate, superficial velocity) was such that the media is maintained in an expanded condition in continuous service, not just for washing. Lately there has also appeared on the market some downflow filters that use a slightly buoyant media in an expanded condition

Fluidized Sand Beds

These biofilters consist of a bed of sand in which the upflowing water flows at a rate that the drag and buoyant forces maintain the grains in a fluidized state. This creates an ideal fixed film reactor: water, oxygen and the nutrients are presented to the substrate in a well-mixed soup, residency times are favourable and excessive biofloc is sloughed off by shear and abrasion.

Energy has to be expended to fluidize the bed, but this is not excessive. Superficial velocities of 0.25 to 5.33 cm/s (depending on sand size) only are required, and the head loss for a given flow rate and expansion can be readily calculated. Biofloc growth will change the bulk density of the sand, and loss of fine particles can be experienced. Flow rates are generally designed for 50% bed expansion of clean sand to allow for 100 % expansion when biofloc reduces the bulk density. There is no solids removal capability, which should be provided upstream of the biofilter.

These beds are self-cleaning, essentially immune to the expansion percentage, and require virtually no maintenance. The media is relatively cheap and the high SSA allows for a comparatively compact filter. Conversion rates of 0.25 to 0.35 g TAN/m^2/day are achievable (Timmons and Losordo, 1997). Because of these virtues, the fluidized sand bed filter is popular in cold water aquaculture. The common arrangement is to have one large biofilter (bed 2 to 2.5 m in diameter times 1 m deep) service a section of the aquaculture facility: one for the hatchery, one for each juvenile-to-smolt plant. This arrangement allows for reasonable economical solids removal, degassing, oxygenation and disinfection of the flow, with some protection from catastrophic disease attack.

A recent innovation to reduce the pumping energy input to fluidized sand bed biofilters is the Cycl-Bio™ biofilter. The essential difference is that where conventional fiters introduce the water through some type of distribution plate, the Cyclo-Bio introduces the water tangentially through a plenum at the base of the biofilter. Up to 50% reduction in expansion energy is claimed (Timmons *et al.*, 2000)

Fluidized Floating Media Biofilters

Waterline of PEI have produced a submerged downflow filter using buoyant, oblong plastic pellets about 3 mm long by 1 mm wide, density 750 kg/m^3, SSA $\approx$1500 m^2/m^3 (Patterson, 1997, unpublished). The normal arrangement is one biofilter per tank. The flow rate is maintained such that the bed downward expanded. Solids removal is first from an underflow/overflow arrangement on the tank outlet, where the solids heavy bottom flow goes to waste, and the relatively clear overflow is sent to the biofilter to be recycled. The biofilter also has a conical bottom in which, it is claimed, solids will collect as sludge to be periodically flushed. With this arrangement, disease attacks can be easily isolated, but full processing of the recycled water is not possible.

In 1995, at Cornell University, work was done through a company called Microgen on a micro-bead filter wherein polystyrene beads of a nominal 1 mm in diameter were used. Various configurations were used: in both an upflow and a downflow expanding bed and horizontal floating beds. The beads are those used a feed material for the Styrofoam industry and have an SSA of 6,000 m^2/m^3. Recently an article in Aquaculture (Losordo, 1998) described a new Canadian Tilapia farm, Northern Tilapia, based on the Cornell work, which employs two microbead filters per tank, plus a water conditioning system (drum filter, oxygenation, pH and alkalinity adjustment) per two tanks. The tanks have under and over outlets. The solids laden lower outlet water goes to the conditioning unit and the over outlet water goes through the biofilters.

2.5 MICROSCOPY

Microscopy is often used as an absolute method of particle size analysis as it is the only method in which individual particles are observed and measured. It is used for the examination of particles from 0.8 μm to 150 μm; smaller particles require electron microscopy.

2.5.1 The Optical Microscope

The microscopic image is two-dimensional, the particle often resting in the most stable position. The data that can be derived from microscopic examination are:

characteristic dimensions:

- Martins diameter (M)
- Feret's diameter (F)

- longest dimension
- maximum chord
- perimeter diameter
- projected area diameter (d_a)

Analysis

Particle size analysis can be done by hand with the assistance of calibrated ocular scales and graticules. It has the advantage of the operator being able to selectively choose and reject images. Binocular eyepieces are best for particle examination. For size analysis, a monocular eyepiece is better as the tube length can be varied to give step-wise magnification. Allen (1981) notes that most operators prefer direct viewing vs projection viewing, but the former is tiring to the eye. However, it is considered necessary to size about 600 particles in order to obtain a statistically accurate account.

Lately, computer programs have been developed to aid in the process (Allen, T. 1981, Ch 6). One such program is SigmaScan Pro, which will accept digitized images in most common formats. The data output includes counts plus perimeter, area, shape factor, compactness, Feret's diameter, number of pixels, centre of mass, major/minor axes length, slope, endpoints

Limitations

- Depth of field is limited. Reflected light can be used to 5 μm, but transmission microscopy (shadows) must be used below that.
- Image edges are blurred at lower sizes, leading to over-estimation of size.
- Limit of resolution:

$$d = \frac{f\lambda}{2NA} \tag{2.29}$$

where: d = limit of resolution

f = system inefficiency factor ($\approx$ 1.3)

λ = wavelength of the illuminant

NA = numerical aperture of the objective

e.g.: where:

λ = 0.6 μm

NA = 0.95 (dry); 1.40 (wet)

$$d_{\min} = \frac{f\lambda}{2NA} = \frac{1.3 \cdot 0.6}{2(0.95)} = 0.41\ \mu m \quad or = \frac{1.3 \cdot 0.6}{2(1.40)} = 0.28\ \mu m \qquad (2.30)$$

Particles having separation less than this merge to form a single image. Particles smaller that the limit appear as diffused circles and image broadening occurs, even for particles larger that $d_{\min}$. Allen (1981) gives 0.8 μm as the limit and limited accuracy up below 2.3 μm. Groves (1984) also suggests a realistic lower limit for light microscopy is about 2 μm, with a possible reduction of that limit through the use of differential interference contrast, but certainly not below 1 μm.

Sample Preparation

Allen (1981) notes that for light transmission microscopic examination, Millipore recommends that the sample be filtered through a 0.2 μm PTFE membrane filter which is then to be placed on a dry slide. The slide is inverted over a watch glass half filled with acetone, the vapours of which will render the filter material transparent in two to five minutes.

Millipore (Anon, 1998) for contaminants investigation, recommends a mixed esters of cellulose membrane, which is again rendered transparent by exposure to acetone fumes. The recommended procedure is a 25 mm filter, cut into quarters. One quarter is placed on a slide and exposed to acetone vapours. Once the membrane is clear, one to three drops of glycerol triacetate (Triacetin) are placed on the filter piece and a clean slip cover lowered over it immediately. This step is essential for particles under 5 μm.

The Millipore catalogue (1987) states that "for particle analysis by light microscopy, the standard MF-type filter has a refractive index of 1.51 and is easily rendered transparent when placed in standard immersion oil".

2.5.2 Electron Microscope

In this application, a stream of electrons from an electron gun is directed onto the specimen. In the scattering mode, the specimen is relatively thin and the beam is differentially scattered. An image is carried forward in the beam to be refocused in an electronic lens which is then received on a flourescent screen and photographed. The scattering electron microscope has two advantages: the resolving power is very much greater than the light microscope and the x-ray emission is characteristic of the elements illuminated. Thus a spectrum of the object's elements can be studied.

2.6 DENSITY GRADIENT CENTRIFUGING

As described in Section 2.3.1, a common mechanism for separating solid particles from a liquid is sedimentation which uses the density difference between the particles and the liquid they are suspended in.

Originating in the field of medicine and biology, a method of cell separation was devised using a density gradient medium, of which Percoll is one commercial example. Such media, when centrifuged the required rate for the necessary length of time, forms a density gradient from lightest at the top of the vial to densest at the bottom. Samples mixed into the original medium, if within the medium's final density range, will band out in the medium at their neutral buoyancy.

There are two types of density gradient centrifugation: rate zonal and isopycnic. These are illustrated in Figure 2.26 from Anon. (1995). The essential difference is that in the rate zonal mode, both density and size affect the banding out level. In isopycnic or equilibrium centrifugation the particles band out at their neutral buoyancy, regardless of size. Using this method, any flocculation that takes place will have no effect on the density determination (Anon. 1995, Sharpe, 1988).

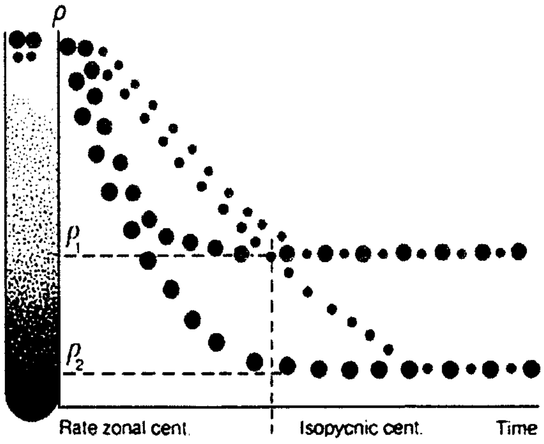


Figure 1. Diagrammatic representation of rate zonal and isopycnic centrifugation.

ρ_1 = buoyant density of the less dense (blue) particles
ρ_2 = buoyant density of the more dense (red) particles
(Courtesy of H. Pertoft, reproduced by kind permission.)

***Figure 2.26**: Diagram of the two types of density gradient centrifugation (from Anon. (1995)).*

The DGM is normally diluted with sucrose or sodium chloride solutions to an isotonic form called SIP: standard isotonic Percoll. It can then be further diluted to adjust the density range of the final solution, although this adjustment is limited.

CHAPTER 3 - OBJECTIVES

3.1 GOALS

From culture water samples from both research and commercial recirculation aquaculture sites in Nova Scotia, based primarily on the Atlantic salmon, *Salmo salar*, the candidate proposed to:

- determine the physical and chemical characteristics of food and faeces produced suspended solids vis-á-vis particle size and time in the system, using:
    - particle size analysis (size distribution),
    - gravimetric analysis (size distribution confirmation),
    - microscopic analysis: (size distribution, shape),
    - scanning electron microscope (shape analysis and chemical composition), and
    - density gradient centrifuging (density determination).
- concurrently, sample water quality parameters (flow rates, temperature, pH, alkalinity, salinity, nutrients: ammonia, nitrites, nitrates) and examine for correlations.
- compare culture water suspended solids particle characterization with current particle theory to determine that theory which applies to aquaculture systems.

From analysis of the data developed, the candidate further proposed to:

- determine the nature and change in the particles with respect to time, and
- examine optimal methods for removal from continuous systems.

3.2 DETAILED PLAN

3.2.1 Phase 1: Setup and Laboratory Examinations

a. Malvern Particle Size Analyser (laser diffraction) was to be modified and calibrated to test large samples (one litre) of finfish culture water.

b.. Samples of wastewater from a salmonid finfish system growing juvenile Atlantic salmon (*Salmo salar*), were to be obtained for proving systems and developing a data set.

c. Culture water samples were to be examined with a microscope with camera, looking for size related shape patterns.

d. In connection with c., staining analysis was to be carried out on particle samples and compared to feed samples.

e. Water quality analysis was to be concurrently carried out on all samples.

f. Gravimetric determination of mass concentration and density of particles, according to Standard Methods for the Examination of Water and Wastewater, APHA (Anon 1995a), was to be attempted.

g. Current particle size distribution theory for suspended solids in aqueous solutions was to be reviewed and applied to the culture water.

3.2.2 Phase 2: Field Data Collection and Analysis

Samples were to be collected from water at a commercial recirculating aquaculture site for *S. salar* and to be examined in accordance with items b. to g. above, for a field data set. This data collection was to start just after the introduction of fingerlings into a facility and continue until smoltification (approximately 6 months). Data would be examined for correlation patterns with water quality parameters and length of time in the system.

3.2.3 Phase 3: Fine Particle Removal Methods

Particle physical and chemical characteristics were used in conjunction with the principles governing present suspended solids removal methods with a view to selecting the most promising.

CHAPTER 4 - METHODOLOGY

PART A - TRIAL SITE, FLOW MEASUREMENT AND WATER QUALITY

4.1 SITE DESCRIPTION

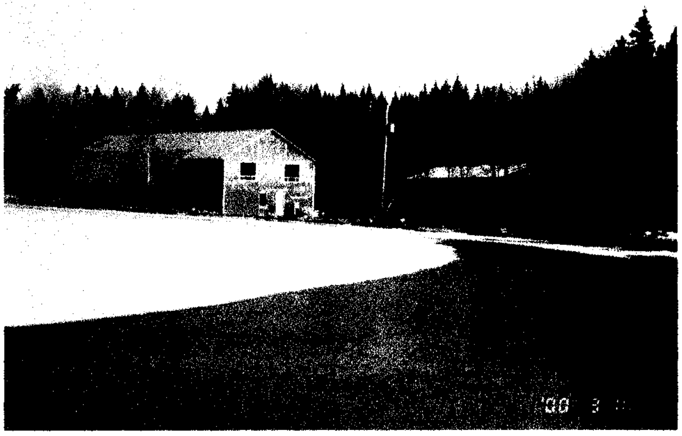


Figure 4.1: Merlins Fish Farm, Greenville Station, NS. Building to the left is the recirculation smolt production plant; building to the right is a hatchery and flow-through smolt production plant.

The trial site is the recirculating water Atlantic salmon smolt production plant of Merlins Fish Farms, located at Greenville Station, Nova Scotia (Figure 4.1). Merlin Fish Farms are owned by Paul Merlin in partnership with Gloria Merlin and their son, Forrest Merlin who manages the Greenville Station site. The recirculation plant is operated along side the original indoor hatchery and juvenile plant, plus an outdoor tank farm for smolt production. Except for the hatchery, the latter plants operate on flow-through surface water from a creek-fed pond.

The Merlins use the recirculation plant for growth enhancement through temperature to bring along those parr which are lagging behind in the outdoor tanks. In the summer of the year 2000, surface water temperature rose to and stayed at about 14 °C, optimum for growth of this species, and the move of the small fish indoors was delayed until early October. This was followed by a period of system adjustment including temperature changes, sorting and vaccination right up to March 2001.

The plant itself is laid out schematically in Figure 4.2. There are two lines, A and B, of six culture tanks each (Figure 4.3).

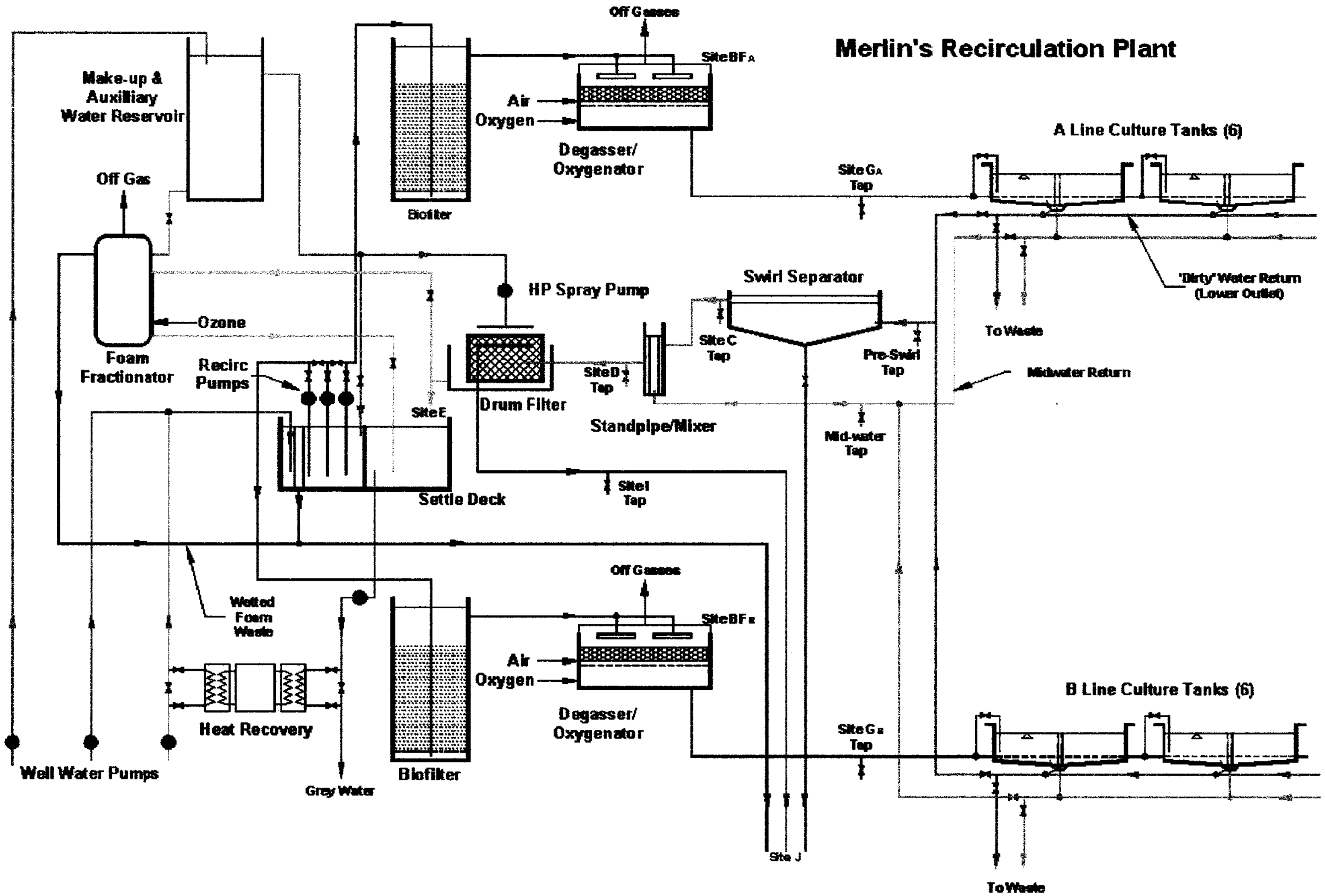


Figure 4.2: *Schematic of the water flows at Merlins Fish Farm recirculation plant*

The tanks are of the "Swedish" type, square with well rounded corners. This is a compromise between the superior self-cleaning properties of round tanks, in which settleable solids tend to get swept to the centre, and the greater rearing volume per floor area of square tanks where the corners tend to produce "dead zones" and self-cleaning is not as efficient (Klapsis and Burley, 1984)

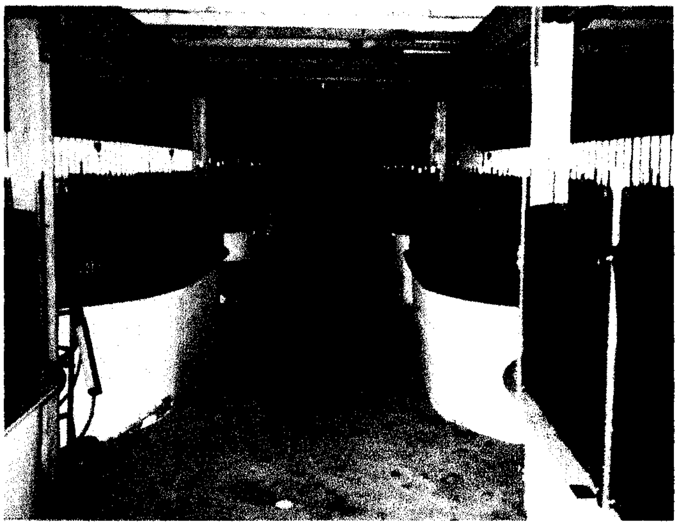


***Figure 4.3**: Recirculation plant production lines. Line A to the left, Line B to the right.*

These tanks have a double drain system; there is a midwater exit up in the culture tank water column to take off the cleaner water, and a central bottom drain that removes the bottom water, more heavily laden with solids. The bottom water is piped directly to a swirl separator (Figure 4.4; see Sect.2.3.1) and is referred to as 'pre-swirl' water. The cleaner water from the top of the swirl separator goes to a standpipe/mixer column where in joins the midwater. The ratio between these flows is about 1/3rd to the swirl separator.

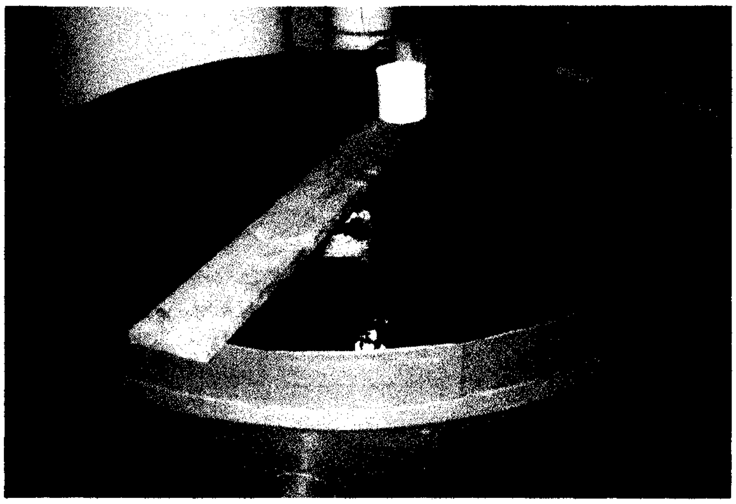


***Figure 4.4**: Swirl separator for removing larger waste particles from the tank bottom returns.*

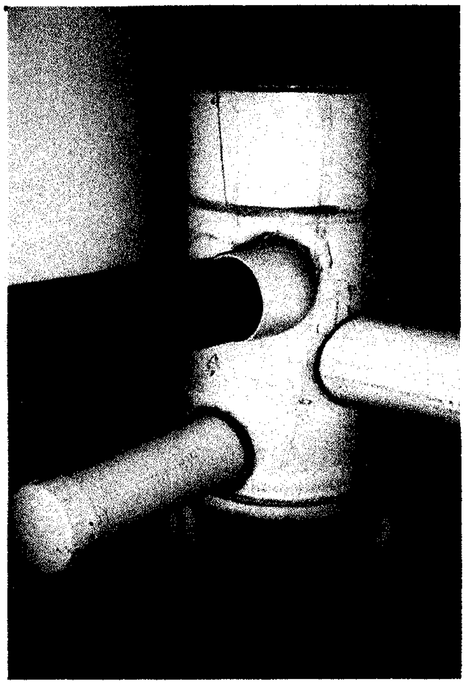


Figure 4.5: *Standpipe. The swirl overflow enters via the black pipe, the midwater return via a central stand pipe which controls the water depth in the culture tanks.*

The standpipe (Figure 4.5) is a 6-inch nominal PVC pipe vertical inside a 12-inch nominal PVC pipe, the latter receiving the post-swirl water. It is the height of the internal pipe that determines the depth of water in the culture tanks. This depth can be altered by changing the internal standpipe's length.

The mixed water flows to the internal cavity of a drum filter (Figure 4.6) with a nylon microscreen of 89 μm. As the water flows through the screen, it nominally traps particles above this size, which are then washed by a high-pressure jet of fresh water onto a drain tray and ducted out of the building. As much of the solid waste is soft and amorphous, some pushing-through of larger particles occurs.

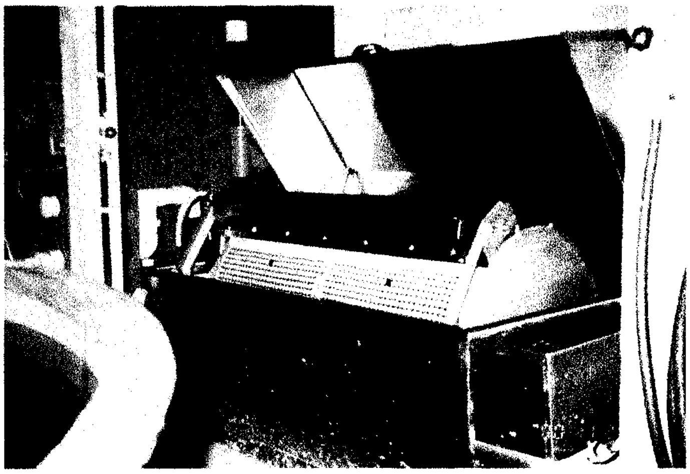


Figure 4.6: *Original drum filter (referred to as Drum Filter 1)*

Mid-April a second drum filter was installed in parallel with the first to cater for the increase in solids loading expected. However, this was taken back out of service mid-May and used to service the water from juvenile tanks installed in the plant loft.

From the drum filter(s) the water returns to the settle deck. (Figure 4.7). This is a concrete tank set in the floor and divided in two, an inlet bay and an outlet bay, by a concrete wall acting as a straight weir between the two parts. Primarily a sump for the system, there is an intention to settle out those solids that could be settled. The settle deck also plays a role in the temperature enhancement, which will be described later.


***Figure 4.7**: Settle deck (during construction) Note the central divider.*

Provision is made for water to be diverted from the drum filter outlet flow to a ozone based foam fractionator (Figure 4.8) for further polishing of the water as required. This water will be returned to the first bay of the settle deck, with the foam being ducted to the outside drain, when it is in service.

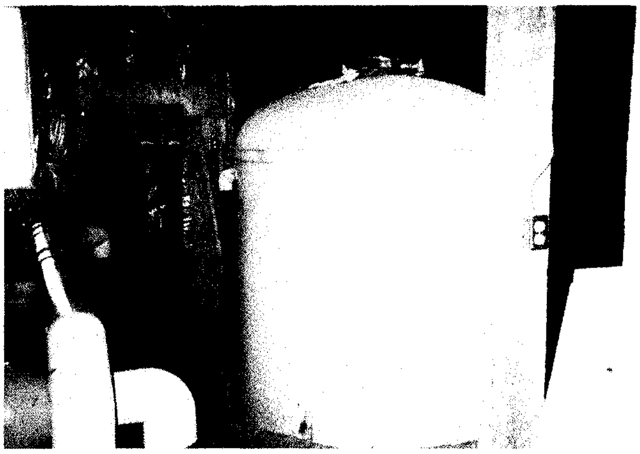


***Figure 4.8**: Foam fractionator*

Return pumping is from the outlet side of the settle deck by three Grundfos 10 HP 420 USGPM centrifugal pumps (Figure 4.9), two in service and one on standby at a time.

One pump supplies each A and B lines via upwelling fluidized sand-bed biofilters.

Gas stripping (CO_2) and oxygenation is done in locally designed aerators/oxygenator(Figure 4.10), one on each line. Two lines come out from near the top of each biofilter to rotary sprayers depositing the water over a grid media. Air is blown into this cavity.

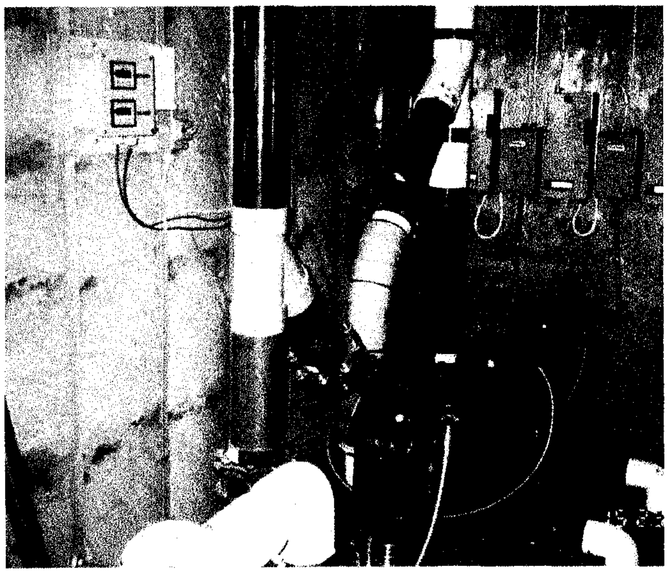


***Figure 4.9**: Supply pumps (one redundant)*

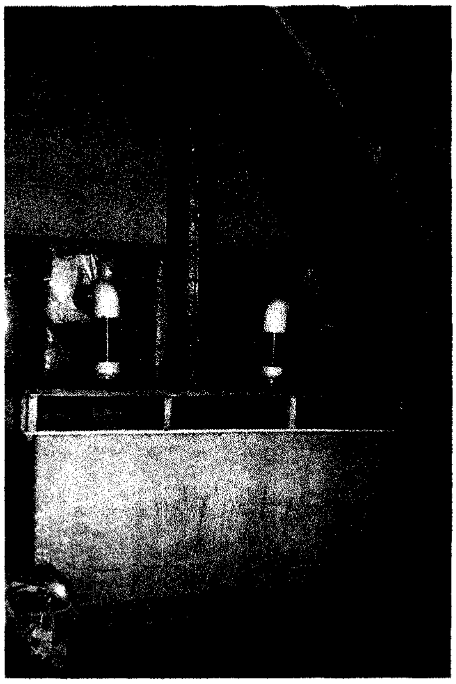


***Figure 4.10**: Gas stripper/oxygenator*

Below this is a perforated plate under which oxygen from a LOX supply is introduced. The gas exit hose is placed in a bucket of water to provide a back pressure for gas flow control (Figure 4.11). The flow water is such that the top of the plate has a head of water, sealing the oxygen below it. The water falls through the oxygen rich area and is

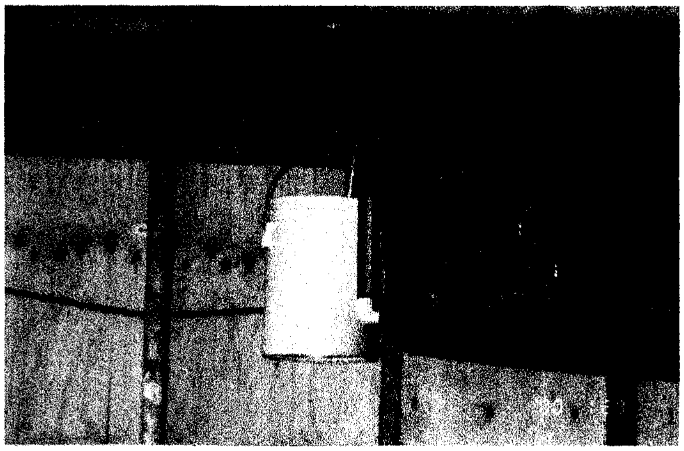


***Figure 4.11**: Oxygenation part of the aerator/oxygenator. Note oxygen back-pressure bucket.*

collected in the bottom of this double tank for distribution to the culture tanks. This level also supplies the head of water that drives the flow until it returns to the settle deck.

Temperature enhancement is achieved by heat recovery from a portion of the waste water ("grey water") pumped from the inlet side of the settle deck. Incoming water from the big well (Make-up Water A) is first passed by the grey water through two heat exchangers. Additional heat is extracted from the grey water as required, using two heat pumps. This system was changed several times throughout the test period in response for needs for warmer water in this plant and other parts of the farm. It will not be described further.

Sampling taps were already installed for the "midwater" and "pre-swirl" flows. For trial purposes, the owners permitted and assisted in the insertion of water sampling taps at several other points on the system. The primary sampling points are noted on Figure 4.2.

Unlike a "normal" recirculation water smolt production plant which usually stands alone, and where the fingerlings go in in the Fall and the smolts (less morts) go out in the Spring, this plant is integral to the overall production at this site. Due to higher flow-through water temperatures in the Fall of 2000, fish were not loaded into this plant until approximately 10 October. Then, during the growing period fish were often moved between the recirculation plant and the outdoor facilities. The aim was to produce the maximum number of smolts in the whole complex, hopefully as close to 100 g size as possible.

This is an economically sound strategy, but difficult from a study point of view. There were major changes to fish size and quantity, and to the water reconditioning system itself, almost for every visit. The system never did really go into a reasonably steady state until the last few weeks (see Section 3.2). Thus, instead of a continuum in which the system could be studied over the growth cycle, the observers were left with a series of snap-shots of a system in dynamic operation.

4.2 FLOW MEASUREMENT AND CAPABILITIES

4.2.1 Flow Measurement

Figure 4.12: Ultrasonic flowmeter on Site D pipe

It was realized early that, in order to look at the movement of nutrients, system flows would have to be determined. It was hoped that a portable non-intrusive apparatus would suffice and to this end a Ultrasonic Flowmeter Model FD-7000 was acquired from Omega Engineering, Inc. (Figure 4.12). This particular model is of the double transducer type and purported to be capable of measuring flows in pipes from 0.5 to 20 fps (0.15 to 6.2 m/s) containing suspended particles or gas bubbles. In this model, if sufficient reflectors were not present in the flow, the transducers were to be relocated into an area of non-symmetrical hydraulic turbulence, such as just downstream of an elbow.

The ultrasonic flowmeter was partially successful, working well on locations such as Site C (flow from the top of the swirl separator to the standpipe) and Site D (stand pipe to the first drum filter) once the best location was established. In other cases the following drawbacks were evident:

- the proper location was not always available, which included a sufficient run before and after the transducers to establish the flow front,
- the pipe had to be full,
- pump noise on the line distorted the readings.

The latter limitation precluded use of this meter on the supply pipes, which held flow values that were critical to the study. This author proposed that paddlewheel-type flowmeters be installed on the A and B line supply pipes and the Nova Scotia Department of Fisheries and Agriculture agreed to support this venture. A detailed report on the selection and installation of these flowmeters is included in Appendix B.

The sensors (Figure 4.13) were located on the long attic runs before the Biofilters. The displays, actually transmitters (Figure 4.14), were located near the supply pumps. They had both instantaneous and accumulative capability. While the instantaneous readout was useful to the plant manager for setting and balancing the flows, the flow rates for this study were taken by setting the transmitters to accumulation mode and timing the accumulated flow over 15 to 20 minutes, then dividing the accumulation by the time. This was an easier method to average the results.

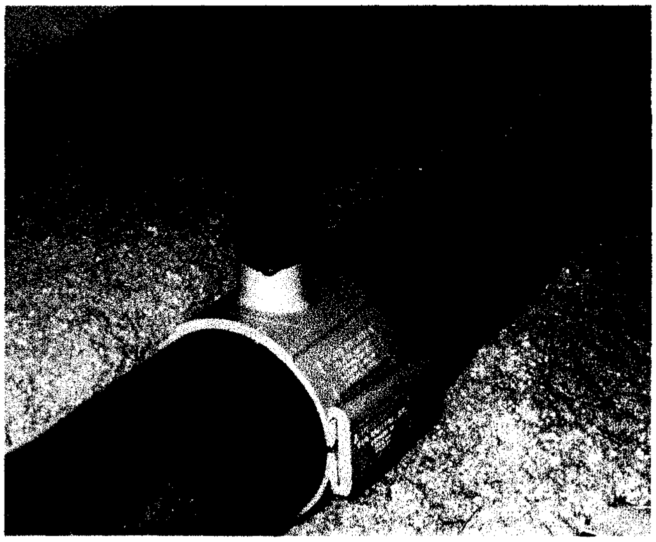


***Figure 4.13**: B line paddlewheel flowmeter sensor*

Transmitters were chosen to allow the flow to be monitored by a computer as part of a monitoring and control system some time in the future.

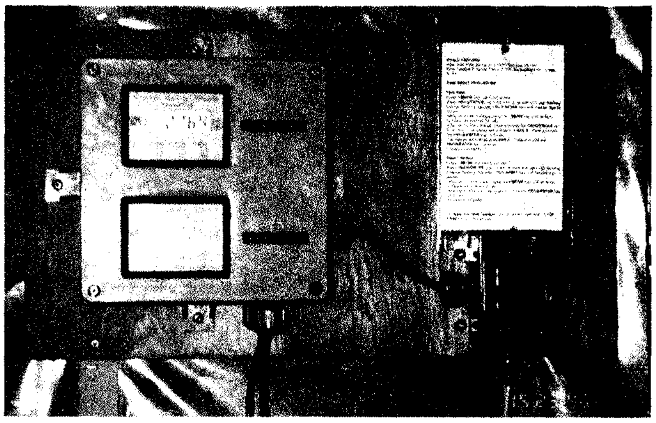


***Figure 4.14**: Flowmeter displays (near pumps)*

Where feasible, flow rates were also determined by the simple bucket-and-stopwatch method. Other flows were taken from manager estimates, which proved to be reasonable. The method of ascertainment is designated in the results spreadsheet.

4.2.2 Water Capacities

The water capacities of the complete system were determined from specifications and measurement and are contained in Appendix A.

4.3 FEED EVALUATION

The plant was using EWOS Transfer 2 and 3 mm feeds, the formula of which is in Table 4.1. Due to the strain of other activities, including a company expansion, a feed monitoring programme was not extant at the plant. This author devised such a scheme which was accepted with alacrity by the manager.

***Table 4.1**: Formulation of EWOS feed in use in the recirculating system*

Item	**Min/Max**	**2 mm %**	**3 mm %**
Crude Protein	Min	50	48
Crude Fat	Min	22	24
Crude Fibre	Max	1	1
Ash	Max	10	10
Moisture	Max	8	9
Ca	Actual	2.1	2.3
P	Actual	1.3	1.3

First, a weighing trial of known volumes of feed was conducted to determine the bulk density of these two feeds and a mix of 1/4 x 3 mm feed, 3/4 x 2 mm feed that was in use. These calculations are in Appendix D. Then 2-L plastic drink jugs with transparent sides and 1/4 L marks were provided along with clipboards were provided for every two tanks which held a two-tank tally (see Appendix D).

The feeder scored the amount by type and volume fed to each tank at each feeding. Generally feeding was done from 0800 hrs to 1700 hrs, once approximately every hour, although this was not strictly adhered to. Vaccinations, movement of fish and other company activities interfered with the schedule from time to time.

This author summed the tally sheet volumes. These were entered on spreadsheets contained in Appendix D which converted the volumes to weights using the bulk densities derived, and summed them by line and month. A bag feed record, on which the feeder was to score the date, the number of bags opened and the feed size was also instituted (also in Appendix D). This would have been used as a correction against minor errors accumulating in the daily feed records. This was not as successful in the long run as some feeders either forgot to score the bags on opening, or sometimes scored bags used to feed in other parts of the system. It did tend to confirm the individual tank counts in the early stages.

The plant had a primary feeder, who knew the fish well and fed in response to the fish. Alternate feeders were used on weekends and when the primary feeder was called away on other duties. Some were knowledgeable but other were new to the plant.

4.4 WATER QUALITY

4.4.1 Parameters and Sites

It was proposed to monitor several components of water quality in conjunction with particle size analysis to the ends of looking for correlations, determining the component of nutrients that are associated with the suspended solids and, with the flow rates, look at the distribution of these nutrients.

A Hach DR/2010 Aquaculture Laboratory (Cat. No. 26700-40) was purchased for water quality determinations, augmented by a dissolved oxygen meter from Royce (Model 900) with a Model 95 sensor. The basis of the Hach kit is the DR/2010 Spectrophotometer, the Model 16900 digital titrator and three of the sension ™ series of portable meters as noted in Table 4.2

***Table 4.2**: Water quality parameter test subjects and methods. All methods and meters are from Hach Company except the DO meter. A: initial list; B: additions.*

Parameter	Method
A	
Acidity: pH	sension1 pH meter, platinum electrode Model 51910-00
Temperature, °C	sension1 pH meter, platinum electrode Model 51910-00
Oxygen reduction potential, ORP, mV	sension2 pH/ISE meter, ORP electrode Model 50230
Total dissolved solids, TDS,, mg/L	sension5 conductivity meter, probe
Dissolved oxygen, DO, mg/L	Royce Model 900 and probe
Carbon dioxide, CO_2, mg/L	Method 8205, digital titrator
Alkalinity, mg/L as $CaCO_3$	Method 8203, digital titrator
Total hardness, mg/L as $CaCO_3$	Method 8213, digital titrator
Total ammonia nitrogen, TAN, mg/L	Method 8155, spectrophotometer
Nitrite nitrogen, NO_2-N, mg/L	Method 8507, spectrophotometer
Nitrate nitrogen, NO_3-N, mg/L	Method 8171, spectrophotometer
Total Suspended solids, mg/L	Method 8006, spectrophotometer
B	
Total iron, mg/L	Method 8008, spectrophotometer, Digestdahl
Total Kjeldahl nitrogen, TKN, mg/L	Method 8075, spectrophotometer, Digestdahl

Initially the 'A' group of parameters were to be monitored on each site visit. As experience was gained changes were made. First, due to the excessive work load per visit for this range of parameters, the DO and CO_2 parameters were dropped; both were peripheral to the study. Later, as the nutrient sampling was found to determine the dissolved fraction of the nutrient only, a Hach Digesdahl digestion apparatus was acquired and used to digest samples for TKN, TAN and phosphorus. The Digestdahl was also used for periodic determination on the total iron in the culture water as this element affects the results for TAN, enhancing the colour ('B' Group)

Digestion is required of the nutrient samples (TKN, TAN and phosphorus) in order to determine the proportion of the nutrient which is connected to the solid particles. One-half of a blended sample is filtered through a Millipore 0.45 µm Type HVLP filter, both halves are digested and the appropriate test run (Anon, 1997). The unfiltered sample half represents the total nutrient in the sample (mg/L) and the filtered portion the dissolved fraction. Subtraction of the latter from the former yields the fraction associated with the solids.

The Digestdahl method specifies the sample amount (B), the analysis amount (C) and a volume conversion factor (F). Noting the spectrophotometer reading as A, the nutrient determination from the reading is of the following form:

$$\mathit{Nutrient},\ \frac{mg}{L} = \frac{AxF}{BxC} \tag{4.1}$$

Once total iron in the culture water was determined, total ammonia nitrogen (TAN) results were adjusted for the influence of this iron on the TAN readings. A test was run on the effect of spiked iron samples on the reagents, the results plotted and the line regressed to yield the relationship:

$$\mathit{TAN\ subtraction},\ \frac{mg}{L} = 0.04864\cdot(Fe\ \frac{mg}{L})^{0.555150},\ R^2 = 0.98810 \tag{4.2}$$

which was subtracted from the readings before further processing. The mechanics of this process are laid out in Appendix E.

The un-ionized ammonia (UIA), i.e. ammonia gas, that fraction which is most toxic to the fish, is in an equilibrium in the solution with NH_4^+, ammonium. The fraction that is UIA is a function of temperature and pH. Determinations of the percentage UIA in sampled waters was computed from empirical formulae developed by Emerson *et al.* (1975):

$$pK_a = 0.09018 + \frac{2729.92}{T} \tag{4.3}$$

and

$$f = \frac{1}{10^{pK_a - pH} + 1} \tag{4.4}$$

where f = the fraction of the total ammonia that is NH_3 and T = temperature in °C.

Samples not tested on site were stabilized and renewed in accordance with Hach Table 10, 1B (Anon., 1997), a copy of which is in Appendix E. Sample sites are described in Table 4.3. The number varied from 13 to 16. Due to the large testing load this created, testing assistance was utilized for the majority of the water quality tests.

As experience was gained, the sampling was done in the afternoon in the order of the direction of flow and in as short a time as possible. Even so, the fluctuations, particularly in the discharge of solids from the bottom drains (see Appendix G) made a truly representative snapshot of a point in time nearly impossible.

***Table 4.3**: Sampling points for water quality (see also Figure 4.2)*

Site	Description	Remarks
A	'Pre-swirl" tap, bottom flow from culture tanks	
B	'Midwater' tap, upper flow from culture tanks	
C	Flow from top of swirl separator	
D	Flow from the mixer/standpipe, before drum filter	
E	Outflow from drum filter to settle deck	
S Dk	Settle deck, 2nd (outflow) side	from the surface near the overflow, latter near the pump intakes
$BF_{A,B}$	Post biofilters, lines A and B.	Originally from the top of the biofilters; later from the spray bar into the degasser/oxygenator
$G_{A,B}$	Flow from the degasser/oxygenator to the culture tanks, lines A and B	
I	Tap, wash water from drum filter 1	
J	Outflow from biofilter wash water to ditch.	
Swirl	Outflow from the swirl separator on flushing	Occasional
OFlow	Overflow from settle deck	Occasional
MUW_A	Make-up water from the largest well	later split into A1 and A2
MUW_B	Direct well water	

4.4.2 Water Quality Limits

Muir (1982) in his review recommends the following water quality limits for unstressed fish:

- Un-ionized ammonia (UIA:NH_3): 0.01-0.05 mg/L
- Nitrites (NO_2): 0.05-0.20 mg/L (although this can be mitigated with the presence of NaCl, hardness, and $CaCl_2$)
- Nitrates (NO_3): 400 mg/L
- Suspended solids (TSS): 20-40 mg/L (Wickins, 1980, recommended $\ngtr$ 15 mg/L)

Saunders (1995) suggests a temperature of 16-18 °C as the optimum temperature for feeding and growth. The New Brunswick Department of Fisheries and Aquaculture, in their publication AQUAFACTS, offer the following UIA limits, without source:

- Fry (< 35 mm): <0.003 mg/L
- Fingerlings (35-180 mm): <0.006 mg/L
- Fish > 180 mm: <0.012 mg/L

4.4.3 Oxygen Reduction Potential

In an attempt to look for correlations with other parameters, the oxygen reduction potential (ORP, mV) was determined in the water quality sampling. The measurement was simple; a **sension**™ Combination ORP probe, Model 50230, was attached to the BNC terminal of the **sension2**™ pH/ISE meter. In essence the ORP probe measures the combined millivolt (mV) electrical potential generated by the concentrations of chemicals in a solution. This is a function of the probe metal, filling solution, the chemicals in the solution and the solution temperature (M. Ross, 1996). In this case, the probe is platinum and the reference (filling) solution is 4 M KCl saturated with Ag/AgCl.

ORP probes do not normally require calibration; readings are absolute. However platinum electrodes can get dirty. A simple probe check using drug store iodine solution was obtained from C. Nelson (2001): make 1.25 mL tincture of iodine up to 100 mL with de-ionized distilled water. Probe should read between +440 and +455 mV.

PART B - RESEARCH METHODS

4.5 GRAVIMETRIC TESTS:

In an attempt to determine the suspended solids in the system at certain 'site visit' points of time, gravimetric tests were conducted on samples of the culture water taken from selective sites. The method used was APHA 2504 D (Anon. 1995a). The filters were 25-mm Spectra nylon meshes sizes 70, 41, 30,20,10,and 5 µm, plus 25-mm x 0.8 µm MSF mixed cellulose ester membrane filters for the last classification. On occasion, these last filters were replaced with 47-mm x 0.45 µm Durapore HV membrane filters, for reasons that will be explained later. The filters were originally weighed on a Mettler AB204-S scale (0.1 mg) and later on a Mettler M3 (0.001 mg). The samples were vacuum filtered, the vacuum being created by an Edwards 2 Stage high vacuum pump, Model E2M5. A similar gravimetric test was also performed on a sample of 2-mm EWOS Transfer feed for comparison.

4.6 PARTICLE SIZE ANALYSIS (PSA)

4.6.1 Power Law Study

As part of this work, the author reviewed 15 particle size distribution data sets from four aquaculture systems using three species, three data sets using recirculation and one set from a flow-through system (Chen *et al.* (1993), Ebeling, *et al.* (1997), Krise *et al.* (1994), Cripps (1995). The aim was to look at the viability of applying a two-parameter power law distribution function to suspended solids in aquacultural systems as per Kavanaugh *et al.* (1980), after the work of Bader (1970). For details refer to the paper, Patterson and *et al.*, 1999, "The Power Law in Particle Size Analysis for Aquaculture Facilities" published in *Aquacultural Engineering*, and which was given a "Superior Paper" award by the Aquacultural Engineering Society in January, 2001. A copy is reproduced in Appendix J.

4.6.2 Field Data Study

To study particle size distribution, a particle counter or a particle size analyser, as described in Appendix J, is required. The first attempt to obtain suitable equipment started with the acquisition of a discarded Coulter Counter Model Z_B Particle Counter. Many hours were spent on refurbishing this item and linking it to a data card in a computer so as to automate the counter's operation and data collection and processing. After a considerable effort, it was decided that this conversion was taking too long, and the results may be skewed through floccing caused by the necessity to increase the salinity of the samples to obtained the required electrolytic properties. (T. Milligan, pers comm,)

The next approach was to use a Malvern particle/droplet Sizer, Model 2600 and associated Sizer54 software (Figure 4.15). This is a laser sizer in which the beam is scattered by particles and the angle of the scatter is a measure of the particle size. A flow-through sampling cell was constructed and the samples were drawn through the cell by suction from a peristaltic pump from a stirred reservoir.

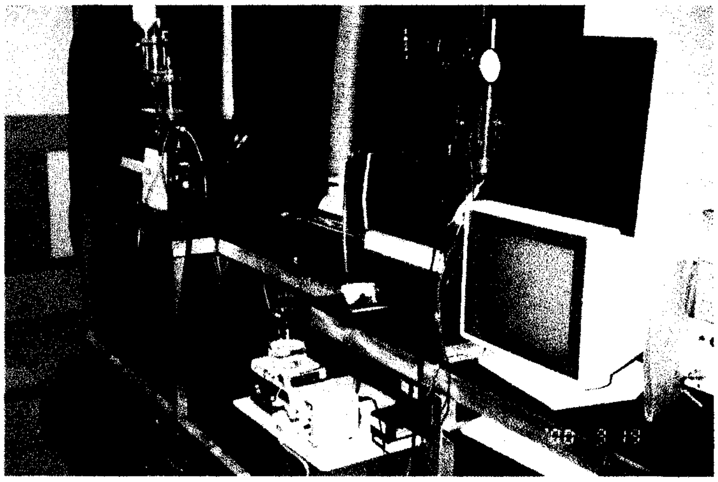


Figure 4.15: Malvern Laser Particle Sizer

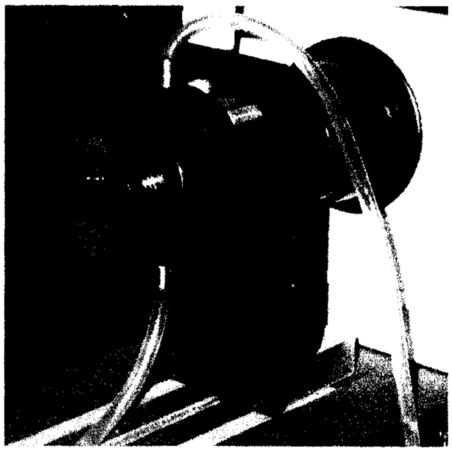


Figure 4.16: Flow-through sample cell

Classes as per Sheldon and Parsons (1975) (see Appendix J and Table 4.4) could be set up but had to be re-entered prior to each new trial. It was noted that the default class sizes fit the definition of a geometric progression required and so those class sizes were used. The sizing was done on samples that were cooled and transported on ice (about 5 °C) and stored in a 5 °C refrigerator. Samples were run with and without surfactant (Igepal CA-630 from Sigma). No appreciable difference was found between same source samples. Some results plotted well with good near-hyperbolic distributions but many showed very erratic plots (Figures 4.17 and 4.18).

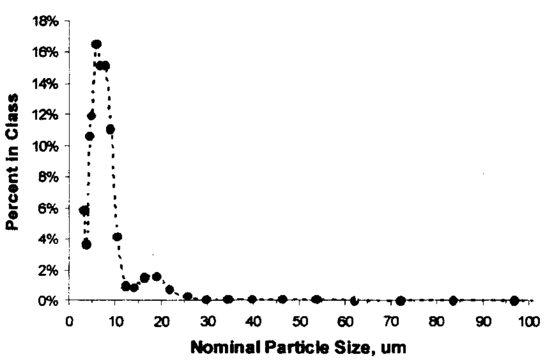


***Figure 4.17**: Plot of Malvern data, Ste A, 19 Mar sample*

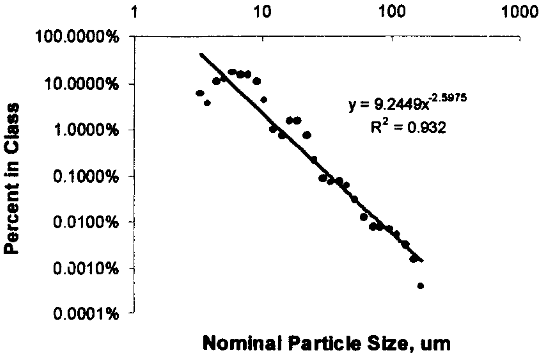


***Figure 4.18**: Log-log plot of Figure 4.17*

A test was run on crushed sand to prove the Malvern system. Loads (mg/L) were of the order recommended by the manufacturer. It was noticed that the power law held strongly for the sand trials (see Figures 4.19 and 4.20), but it was also noted from the signal strength as indicated on the computer signal page was a factor of fifty to one hundred times that indicated for the aquaculture samples.

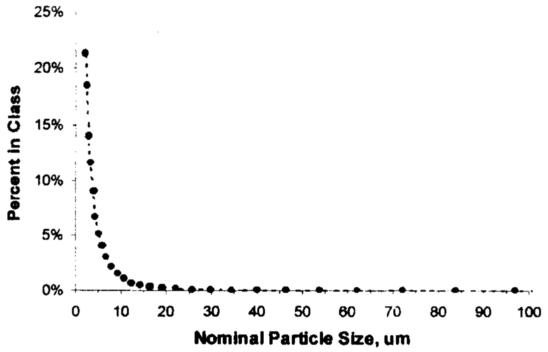


***Figure 4.19**: Malvern trial of crushed sand*

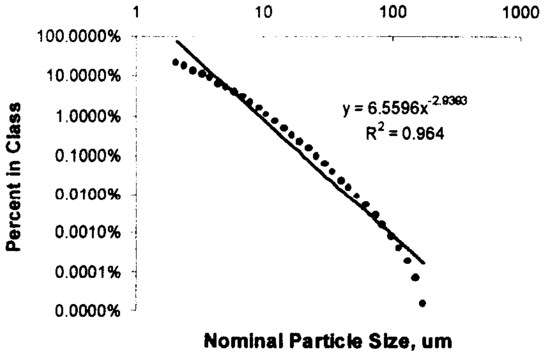


***Figure 4.20**: Log-log plot of sand trial*

After a large number of trials it was determined that the base noise of the Malvern equipment, including the sampling cell, was too high for the light solids loads in many of the aquaculture samples. The true operating zone of the Malvern is fifty to a hundred fold higher than the loads in most of the aquaculture samples, whose signals were in the noise. The instrument could not be relied upon to provide results for the complete sampling set. Therefore a more suitable particle sizer or particle counter was sought.

4.6.3 PCX Methodology

Setup

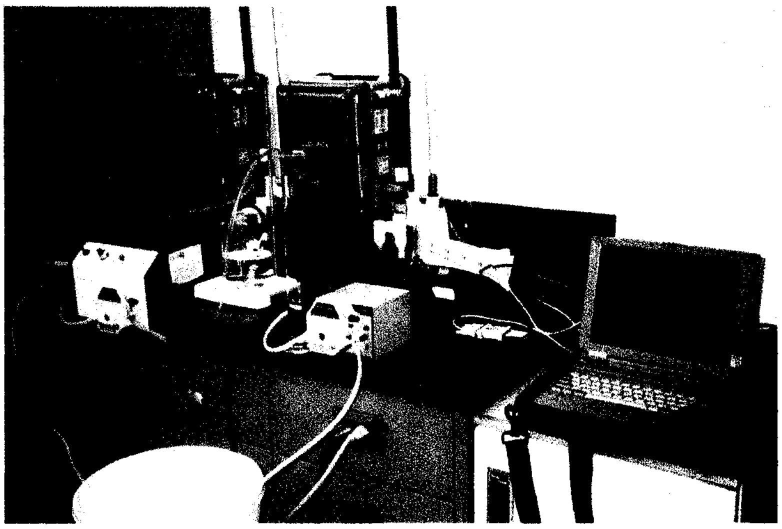


***Figure 4.21**: Double 2200 PCX setup*

Access to two Hach 2200 PCX optical particle counters (Figure 4.21) was gained for particle size analysis. These instruments use laser beam attenuation to count particles. The beam is collimated to illuminate a sample flowing past in a transparent (e.g. quartz) cell. An off-axis photodetector measures the amount of light scatter from a single particle by refraction, reflection and diffraction. Size and number of particles are measured simultaneously, the size being deduced by the intensity of the scattered light (Pashby *et al.* 1991).

The advertized capability of the 2200 PCX is 32 discrete channels from 2 to 750 microns, which is ideal for this application. Unfortunately the accompanying WQS Vista 1.1 software was designed for drinking water assessment according to US EPA standards and hence would only read and store eight channels. Technical assistance was sought from Hach to get around this problem and use the full capabilities of the PCXs but, while Hach technical support in all other areas was excellent, support was not forthcoming in this area. Several selections of size classifications were experimented with and will be noted in the results sheets in Appendix H. This was going on while the testing program was underway.

Classes Selection

The PCXs were controlled by a laptop computer using the aforementioned WQS Vista 1.1 software. After some experimentation and on the suggestion of a conferee (K. O'Leary, pers.comm), the two PCXs were eventually set up to operate in tandem (Figure 4.15) with the channels as shown in Table 4.4. The original calibration values for each PCX were converted to straight line equations and used to extended the calibration to suit the new ranges (see Appendix. H). This method gave 16 channels, considered sufficient for the purpose intended, and the best particle size analysis method available to the author.

***Table 4.4**: Class boundaries for PCXs in tandem compared to Sheldon and Parsons (1975) recommendations*

Sheldon & Parsons	PXC No.	Class Boundary	Class Interval (Δl_i)	Class Median (l_i^*)	Ratio $\Delta l_i/l_i^*$
2.00	1	2.0	0.5	2.25	0.2222
2.52		2.5	0.7	2.85	0.2456
3.18		3.2	0.8	3.60	0.2222
4.00		4.0	1	4.50	0.2222
5.04		5.0	1.3	5.65	0.2301
6.34		6.3	1.7	7.15	0.2378
8.00		8.0	2	9.00	0.2222
10.10		10	3	11.50	0.2609
12.70	2	13	3	14.50	0.2069
16.00		16	4	18.00	0.2222
20.20		20	5	22.50	0.2222
25.40		25	7	28.50	0.2456
32.00		32	8	36.00	0.2222
40.30		40	11	45.50	0.2418
50.80		51	13	57.50	0.2261
64.00		64	17	72.50	0.2345
80.60		81			

The channel selection mirrored the Sheldon and Parsons (1967) as closely as the software would allow. It reasonably followed the geometric progression criteria of that manual. Some earlier tests used a final bin of 51-81 μm. This was an error but one of little consequence as the count was very low in the higher classes.

In an attempt to compare count data, on occasion runs were done with one PCX set up as per the filter sizes used in the gravimetric tests.

Sampling

The apparatus was arranged with two peristaltic pumps drawing from one 2-L stirred beaker of sample. This gave four to five replicates over the sampling interval dictated by the software. The pumps drew the water from the supply beaker through the cells so the pumps had no effect on particle size.

Tap water was run to set the pumps at approximately the 100 mL/min flow rate required by the PCX readout and software. Thereafter periodic flow rate readings were taken during the test. A graduated cylinder and stopwatch were used for all flow rate evaluations. In some cases, filtered de-ionized distilled water (FDDW) was run through the PCXs to get a base count.

The output is normalized into counts/mL in the software, hence the requirement for flow rate data. With the measured flow rates, the results were adjusted for flow. In addition, it became the norm to run filtered distilled water through the PCXs and record a base or 'cell' set of readings, and then subtract these values from the recorded counts. This was especially important in low count samples. These techniques were also developed during the trials. The data connection between the two PCXs appeared seamless.

4.7 PARTICLE DENSITY DETERMINATION
Using the Density Gradient Medium (DGM) Percoll®.

4.7.1 Method

As described in Chapter 2, the DGM is normally diluted to an isotonic form called SIP: standard isotonic Percoll. It can then be further diluted to adjust the density range of the final solution, although this adjustment is limited. Two dilutants for the SIP are recommended: 1.5 M NaCl or 2.5 M Sucrose. This author chose the latter as it gave a higher final density, nearer the suspected range of the particles, which proved fortunate.

It was not considered that an isotonic solution was really needed in this case, but the Percoll procedure was a proven one and so was followed. Further dilution was done using 0.25 M Sucrose as recommended. Sucrose solution Brix Numbers (percentage), densities and refractive indices are tabulated in Weast (1975).

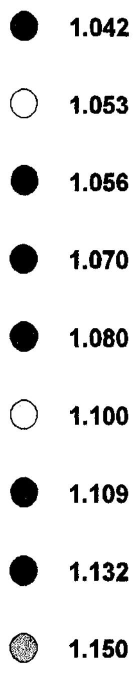


Figure 4.22. Density Marker Beads, Lot No. 253059 in 0.25 M sucrose, g/mL

The suppliers have available sets of coloured density marker beads (Figure 4.22) that band out at specific densities which, the suppliers suggest, should be centrifuged in a vial of the final media mix separate from the sample vials. Subsequently the band distance from the vial meniscus can be plotted against the bead densities, as denoted on the packaging. The bands in the samples can then be compared, visually or mathematically, with the bead curve for the determination of the band density.

As the suppliers, in their manual (Anon. 1995), produced a graph of refractive index versus density for Percoll in 0.25 M Sucrose, a version of which was also received from the supplier in a technical note (Anon. 1978) it was possible to determine the density of a layer by reading the refractive index of a small sample of the band. Both lines noted above were manually digitized and compared to bead extractions. The lowest variation (see

Appendix I) gave a relationship between the 0.25 M sucrose DGM refractive index and density of:

$$\rho = 7.0002n - 8.3815, \quad R^2 = 0.9969 \tag{4.5}$$

where ρ = the band density, g/mL and *n = the refractive index.*

Sampling was done by careful insertion of a thin pipette with bulb. It was suggested that an extraction cap be built with a long tube to the bottom for insertion of a pusher solution (heavier than the heaviest mix in the cell) and a short tube in the cap to lead to a sampling carousel. The pusher material is pushed in by a peristaltic pump. (T. Gill, CIFT, pers. comm.).

The cap was built, but the extraction system was not completed due to time restraints. If more work is done in this line, the 'pusher solution' method should be set up and used. It would have the advantages that the fractions would be isolated into separate vials for refractive index determinations and microphotography. The pipette method, though simpler, runs the risk of dragging in adjacent layers and, of course, the possibility of a spill destroying the entire sample.

In general, the refractive index method (vs the density marker beads) is more useful and is unaffected by any inadvertent differences in sample size, which affects the band-meniscus distance, but the beads were maintained as a check on the refractivity method.

DGM trials were carried out on both waste and feed samples. In connection with the Percoll trials, microphotographs were taken of selected bands for comparison and identity purposes.

DGM Development

Standard Isotonic Solution (SIP) was formulated using 1 part 2.5 M sucrose solution with 9 parts Percoll (Amersham Pharmacia Biotech, Lot. 278493, Density 1.1319 g/mL). As the density of this sucrose solution is 1.3164 (n = 1.4535 g/mL, BRIX , 65 (Weast, 1975)), a starting density of the SIP was determined from the ratios:

$$\rho_{SIP} = \frac{V_P\rho_P + V_s\rho_s}{V_P + V_s} = \frac{9\cdot 1.1319 + 1\cdot 1.13164}{9 + 1} = 1.1504\frac{g}{mL} \tag{4.6}$$

where V_P and V_s are volume equivalents (parts, mLs), and ρ_P and ρ_s are the densities of the Percoll and sucrose solution respectively. (Anon. 1995)

In actuality, the final 2.5 M sucrose solution was determined by refractive index on an Abbe Type 1T refractometer with associated temperature control bath (all measurements were done at 20 °C ± 0.5 °C) The actual sucrose solution may have varied 0.1 % from that calculated. This had no effect on the trials.

The SIP is now a 0.25 M sucrose solution DGM. In subsequent trials, the SIP was further diluted with 0.25 M sucrose to maintain the 0.25 M sucrose in Percoll combination. The density marker beads and the refractive index vs solution density line are therefore both valid for density determination.

In initial trials dilutions of 0, 20, 30, 40 and 50% 0.25 M sucrose in SIP were used in an attempt to obtain the right dilution for the suspended banding of whatever particles may be found.

Sample Preparation

For this trial, because the amounts of waste per litre in the main system were so light as to make it difficult to obtain a reasonable amount of solids in a small sample size, waste samples were taken from near the drain of a juvenile tank (Tank C1, 5000 x 20 g fish, EWOS 2 mm feed). The samples were dosed with sodium azide (0.02%) to kill microorganisms, and a surfactant, IGEPAL CA-630 (Lot 80K1048, Sigma Chemical Co.), one drop per litre of sample. They were transported in a cold box and stored over night in a refrigerator at 5 °C.

Feed samples were obtained by putting 20 g of 2 mm feed in 550 mL de-ionized, distilled water (DDW) for 60 minutes.

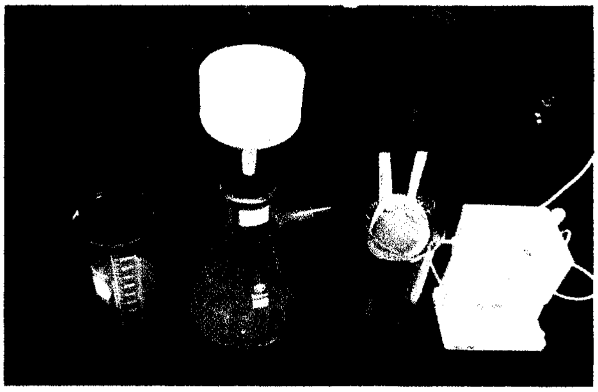


Figure 4.23: Sample filtration and filter wash set

In both cases, portions of the original samples were strained first through a 179 µm steel mesh, and then vacuum filtered through Spectra 90-mm nylon meshes, sequentially, at 41, 30, 20, 10 1nd 5 µm Figure 4.23). For the waste sample, an extra filtration was done on a Spectra 25-mmx70 µm nylon mesh. Meshes were placed on a 1/8th stainless steel mesh (for support only) on the inner lip of a tall 1-L beaker and washed off into the beaker with DDW using a WaterPik® jet. The aim was to get the most solids for the least expenditure of water, to keep the resultant samples as concentrated as possible[1]. The < 5 μm samples were taken from that remaining after the 5 μm screening. The washed meshes were microphotographed after use so that the residue could be examined later.

Centrifuge Preparation.

Isopycnic DGM procedures require the use of an ultracentrifuge with a fixed-angle rotor. The one used was a Beckman Model L2 with a Type 30 rotor. The rotor takes 12 x 38.5 mL tubes held at an angle of 26° to the vertical. (Bellis, 1966). Tubes were loaded with 2 mL of well-shaken sample and filled up with approximately 21 mL of DGM. It was found that restricting the load to 23 mL kept the meniscus to 25 mm from the top of the tube which prevented spillage during centrifugation as these tubes had no caps. The tubes were balanced with DGM to within 0.5 mg. The tubes for the density marker beads were first loaded with 2 mL DDW and beads, and then brought up to weight with the appropriate DGM. About 25-40 μL of each bead type were used per tube. The loadings are shown in Table 4.5. All samples were spun at 18,400 RPM (equivalent to a mean acceleration of 30,000 x g) for 60 minutes.

***Table 4.5**: Centrifugation tube loadings for site sample and feed trials (Sample Source refers to screen washed, except for <5' which was residue after 5 μm screening.)*

Site Sample (12 Aug 01)												
Tube >	1	2	3	4	5	6	7	8	9	10	11	12
Sample source (μm)	70	41	30	20	10	5	<5	179	41	<5	<5 F'	DMB
% 0.25 Sucrose	30	30	30	30	30	30	30	0	0	40	40	30
Feed Sample (30 Jun 01)												
Tube >	1	2	3	4	5	6	7	8	9	10	11	12
Sample source (μm)	DMB	DMB	41	41	30	30	20	10	5	5	<5	<5
% 0.25 Sucrose	40	20	40	20	40	20	40	40	40	20	40	20

---

[1] Initially, concentration of washed samples was attempted by both vacuum evaporation and oven evaporation at 45 °C. It proved just as effective to use heavy waste and feed sources.

Post Centrifugation

After centrifugation the tubes were immediately photographed with a digital camera on a special stand with a vertical scale in millimetres (Figure 4.24). This was critical as the sample bands had limited stability and two more activities followed which disturb the distances involved. These photographs were immediately printed and used in meniscus-to-band measurements, and as references for the refractive index determinations and microphotography that followed.

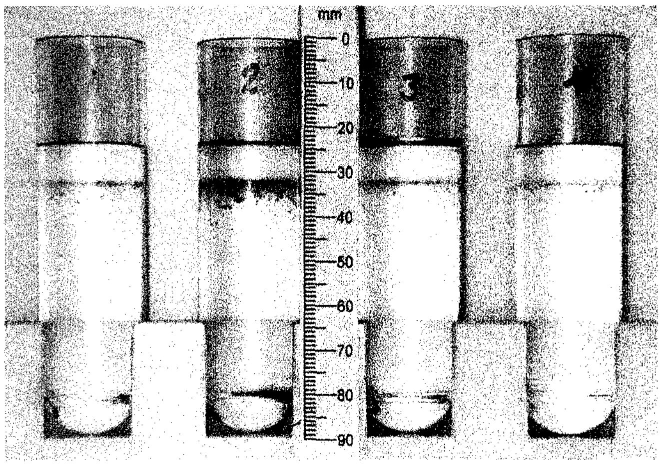


***Figure 4.24**: Digital photography of the Site Sample centrifuged tubes on a scaled stand.*

For each tube, sites were chosen for extraction for refractive index, starting at the upper layers. Approximately 0.5 mL were used in each extraction. Afterward samples were taken from the bands and placed on a hanging drop slide for microphotography. The microscope-camera system used was the Nikon Optiphot microscope with the Nikon FX-35A camera and Model HFX electronic exposure controller.

4.8 MICROSCOPIC EXAMINATION

4.8.1 Light Microscope

Equipment

As mentioned in Section 4.7.1, the microscope-camera system used was the Nikon Optiphot microscope with the Nikon FX-35A camera and Model HFX electronic exposure controller. Although the microscope had objective lenses x 4, x 10, x 40 and x 100, generally resolution below an objective lens of x 10 (total x 100 magnification) yielded little information due primarily, it is suspected, to the depth of field problem with samples often being liquids suspended in a small pool of water on the hanging drop slide. Few shots with the x 40 objective (x 400 total magnification) were thought to be worthwhile.

Objects

Besides the microphotography of the DGM results noted in Section 4.7.1, microphotography was used throughout the project. For example, photos were taken of selected screens used in the gravimetric tests and in sample concentration for the DGM studies.

Scaling

To provide a size scale for objects on the microphotographs, a 1 mm x 100 division graticule slide was also photographed at x 4, x 10 and x 40 objective lens (total magnifications x 40, x 100 and x 400). Selected distances (e.g. 1 division, 10, divisions) were measured and drawn in AutoCAD, divided by AutoCAD when necessary and printed on transparency material at a 1:1 scale. The appropriate scale line was then superimposed on the microphotograph and the photograph was scanned.

Staining

The use of stains in connection with microscopic work can be a useful to assisting the identification of solid waste components. The dyes described in Berg (1997) were used to assist in the identification of components of the solids viewed under the microscope, with fair success. The stains so used are those shown in Table 4.6.

***Table 4.6**: Stains used in microscopic work (Berg, 1997)*

Item	Stain	Solution	Effect
Protein	Eosin Y	5 mg/25 mL distilled water	will stain proteinaceous bits pink or read, depending on the level of protein
	Methylene blue	5 mg/25 mL distilled water	will stain proteinaceous bits blue
Carbohydrates	Thionin	50 mg/25 mL distilled water	will stain neutral polysaccharides (dextrins, starch grains) blue, acidic polysaccharides (gum arabic, alginates) pink
Oil	neutral red	5 mg/25 mL distilled water	will stain oils and waxes bright red

4.8.2 Electron Microscope

It was intended to use the scanning electron microscope (SEM) at the Sedimentary and Marine Geoscience Branch of the Geological Survey of Canada laboratory at the Bedford Institute of Oceanography, Dartmouth, Nova Scotia, to assist in particle identification. This instrument is an ElectroScan E3 model, running a lanthanum hexaboride source. Some preliminary work was done on early samples, which will be reported. Through time constraints, this work was not completed.

CHAPTER 5 - RESULTS

5.1 BIOMASS AND FISH DENSITY

As mentioned in the introduction, this plant works as part of a total system which included a large flow-through section. As the flow-through portion is gravity fed, it is much cheaper to grow fish in it, other considerations apart. This is reflected in what would be for any stand-alone recirculation plant, strange patterns in biomass and fish density. Figure 5.1 shows some of the changes in fish numbers and size, as does Figure 5.2 (data in Appendix C).

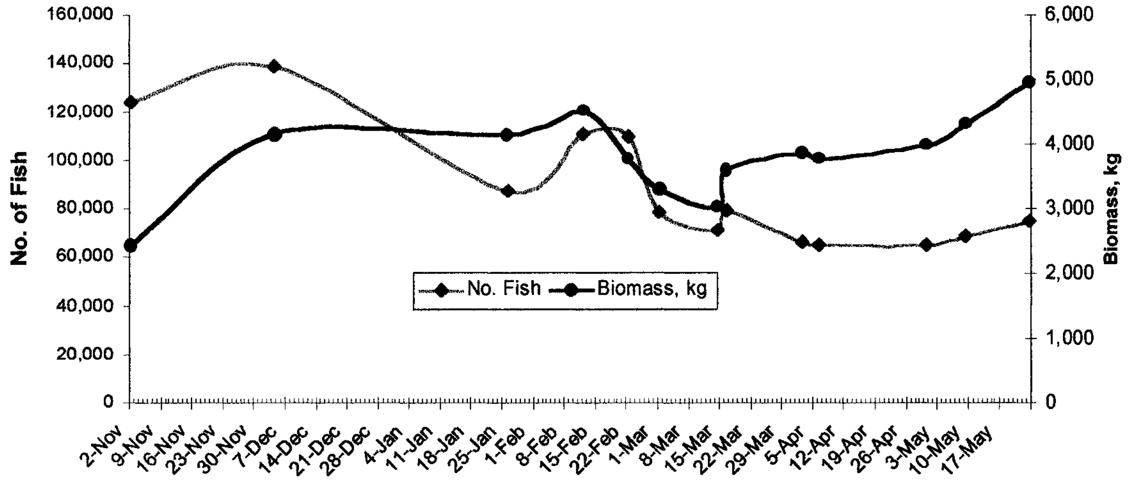


***Figure 5.1**: Record of biomass and fish numbers. Some figures are manager's estimates.*

The manager's original plan was to arrive at a density of about 40 kg/m^3 at smoltification. Due to imposed changes, only half that density was reached (Figure 5.2). It may be noted that, if reasonable records are kept, the regression line will be a useful predictor of the final overall weight on the shipping date.

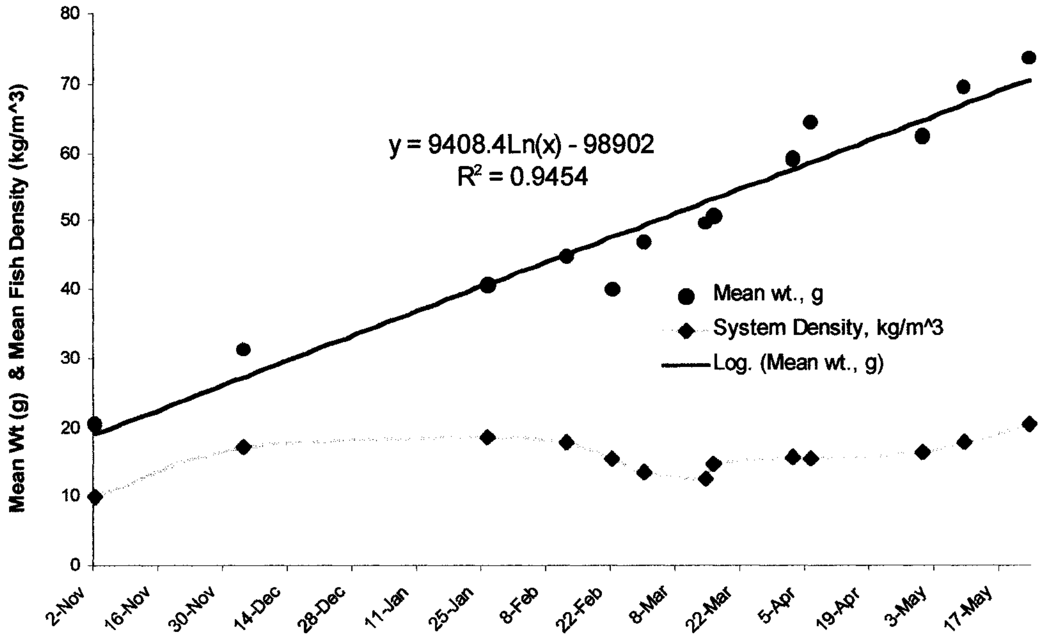


***Figure 5.2**: Record of mean fish weight and overall fish density (see Appendix C for tank densities)*

5.2 FLOW

5.2.1 Flow Rates

The results of the flow reading are compiled in Appendix B. Some significant plots are displayed in Figure 5.3. The major variations in flows (besides the power outage 12 Feb 01) were the bringing on line of a 2nd drum filter in the mid-March to late April period, and the changes in make-up water flows to feed the nursery set up in the loft in late April.

In the early data the only reliable values were those derived by the ultrasonic flowmeter on Sites C and D pipes, thus the total flow was by summation. The 30 Jan 01 total flow figures were derived by summations on the ultrasonic flowmeter readings for each tank inlet pipe on each line. The results were surprisingly good.

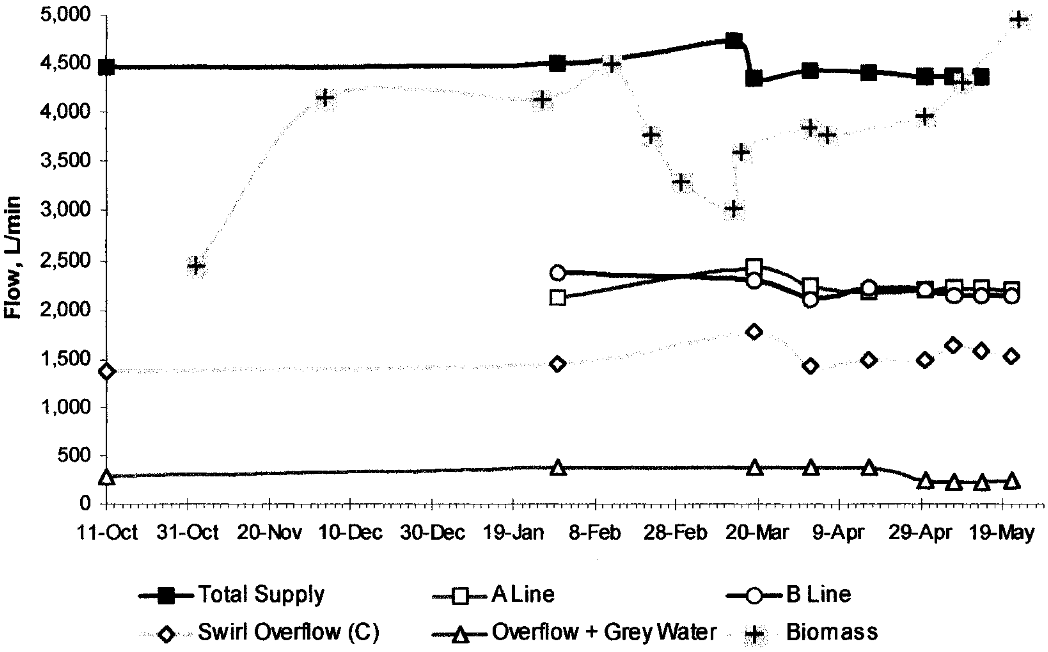


***Figure 5.3**: Flow record, total and A and B lines, plus the swirl separator overflow and the steady state outflow. Added on is the biomass estimates for the same period*

5.2.2 Recirculation

There are two conventions with respect to assessing the amount of recirculation of water in this type of plant, percentage of make-up water added to the recycled water per cycle and the percentage of the total system water capacity added per 24-hour day. Ten percent or less make-up water is often used as a criterion (Losordo, 1991). Appendix B contains the flow data in table form. In the recirculation block it is noted that, based on percent make-up water per cycle, the plant appears to be operating within the criterion off a recirculation plant at less than 10% make-up water per cycle. In fact, at 300 to 540 m^3 per day, the make-up water replaces 100 to 190% of the total water capacity of the plant in 24 hours. Inflow must equal the outflow. The outflow consists of:

- the swirl separator bottom drain, released once per day for approximately 3,500 L,
- the grey water, that water pumped from the inlet side of the settle deck through the heat exchangers and heat pumps for heat recovery, when needed,

- the overflow form the pump side of the settles deck, and
- the bottom line backwash (indeterminate, about once per week).

At the present rate of new water input, the flushing rate is very high. In the strictest sense this plant must be considered, not a true recirculating plant, but a hybrid. The interesting aspect is that, if the water reconditioning can be achieved to the degree necessary, this water supply could sustain considerably more fish. It is of interest to note that the flow rates bore no relationship to the biomass.

5.3 WATER QUALITY

Water quality testing presented particular challenges. The number of sites sampled per visit and the number of parameters sought per sample, coupled with the planned period of the visits, on top of the flow and particle size analysis which were primary, overwhelmed the author originally. When an assistant took over the water quality testing, he had to start from behind. Consequently, some results that were dubious could not be retested. In one case (16 April), where the imperative of the next interrupted the laboratory testing of the stored set, by the time the tester returned to the testing of that set, it was obvious from the results that the sample was no longer valid.

In addition, the system was constantly being adjusted in biomass, heat and flow between visits as has been described. The data set is obviously better near the end of the trial period. However, sufficient reliable evidence was collected overall to indicate some interesting, sometimes puzzling relationships. In general, Site B (tank midwater) may be considered to best represent an average of the culture water conditions, that in which the fish are actually swimming.

5.3.1 pH, Alkalinity and Hardness.

The culture water pH, alkalinity and total hardness for flows into and out of the culture tanks are plotted in Figure 5.4. Sites G_A and G_B sample the input water for lines A and B respectively, and Sites A and B sample the bottom and midwater outflows respectively.

In early February, the manager, concerned about both pH control and having sufficient calcium in the water for proper fish growth, added both $CaCl_2$ and $NaHCO_3$. While this had some effect on alkalinity, its greatest effect was on hardness. These additives were discontinued in a few weeks as noted in the return of alkalinity and hardness to the former levels (about 30 mg/L). The low pH controlled the level of un-ionized ammonia in the culture water (see Section)

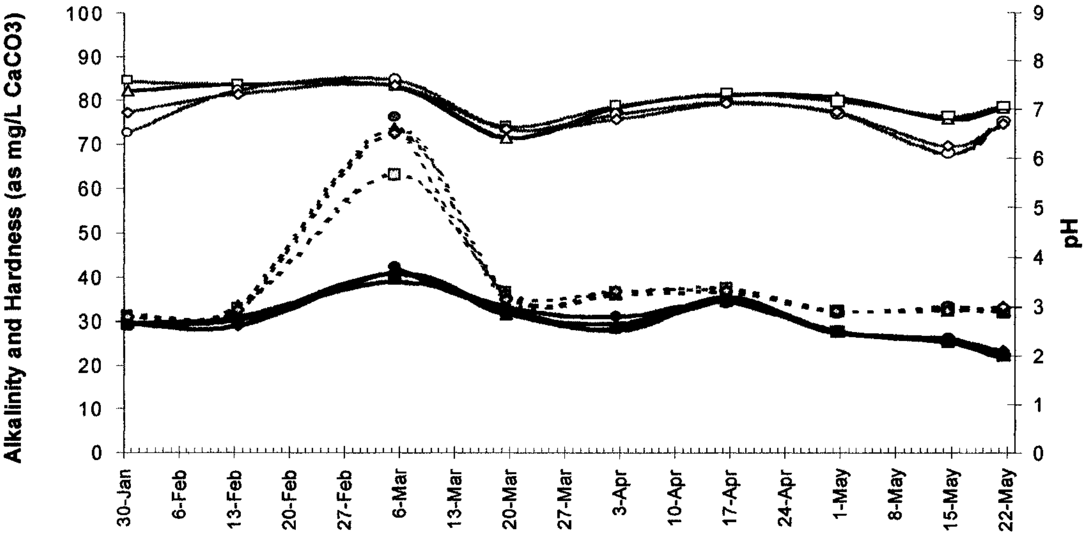


Figure 5.4: Plot of pH, alkalinity and total hardness for sites $G_{A,B}$, A and B from 30 Jan 01 to 21 May 01.

Figure 5.5 (note different time scale) portrays the estimated net flow of alkalinity in and out of the system for the dates shown, along with the inflow rate. Outflow equals inflow minus the swirl flush (about 3500 L/day), and the longer period 'A' line flush which is indeterminate (estimate at 5000 L/week), but will not be significant on a long scale when compared to the daily exchange rate. The details and assumptions are in Appendix E. The difference in alkalinity indicated would be that consumed primarily in the biological processes, the chief one being nitrification of ammonia.

The estimate shows a balance in alkalinity early in the reported period (5 March). This leaves no calcium for growth or carbonates for the reduction of ammonia in the biofilter from the incoming water. It was during this period that the $CaCl_2$ and $NaHCO_3$ additions were started.

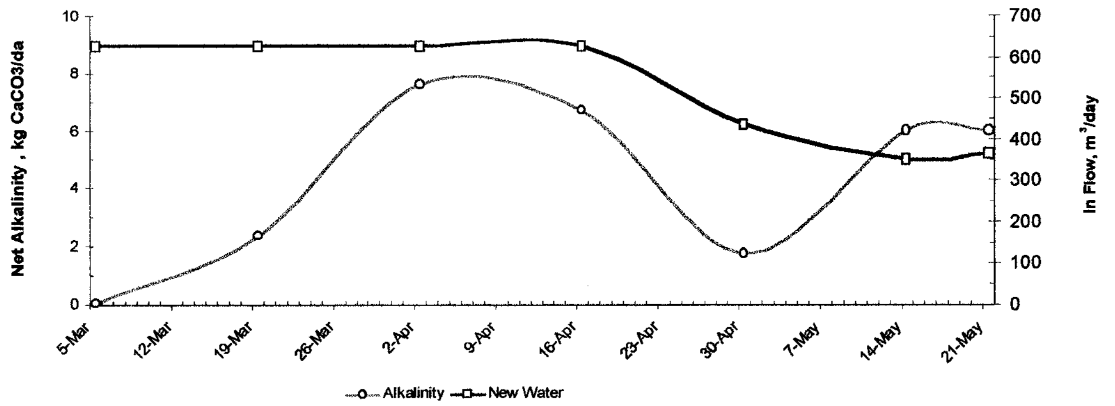


***Figure 5.5**: Net alkalinity (inflow water alkalinity minus outflow alkalinity) and daily rate of make-up water.*

By the 19 Mar 01 visit, the additions had been stopped and there was a drop in biomass through the exchange of large fish with small from the outside tanks, with a (TSS: Hach Method 8006) corresponding drop in feed input, hence ammonia production.

Thereafter the high rate of make-up water exchange provided the alkalinity required for pH maintenance until mid-April when the water exchange was reduced as warmer inflow water was diverted so as not to bring on the smoltification too soon. In early May the alkalinity deficit was again obvious as both biomass and hence feed in the system increased until the fish were being prepared for shipment. In this growth period, pH and alkalinity started to drop. pH recovered slightly as feeding was reduced preparatory for shipment

Preparation for shipments entailed, in part, curtailing feeding and lowering the water level in the tanks, one at a time, to stress the fish in order to eliminate the weaker fish. This plant guarantees its smolts for 45 days and thus it was essential to find and remove weak fish.

5.3.2 Temperature

At the end of January, 2001, the water temperature (Figure 5.6) was in the low end of the zone suggested as optimum for feeding and growth. After that, first the power was lost just prior to the visit 13 February, and then the heat pumps were closed down for cleaning, and finally the heat was required for the fingerlings and thus diverted.

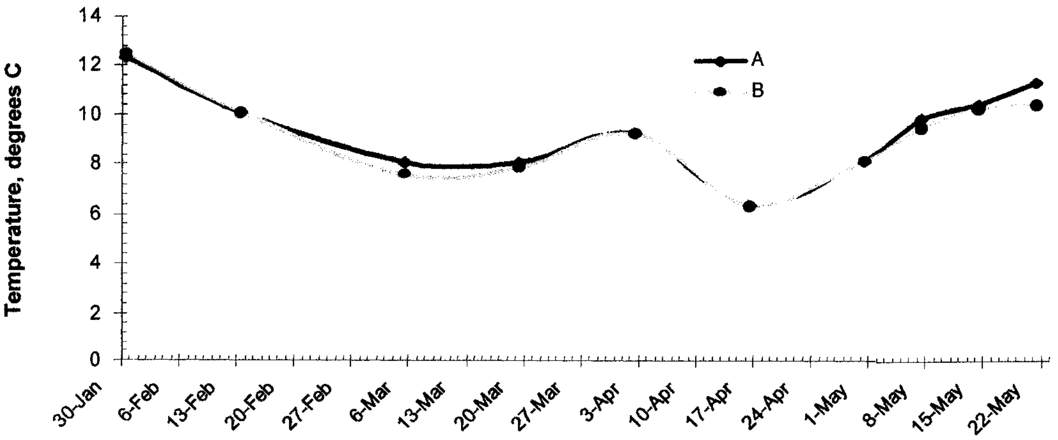


Figure 5.6: Temperatures recorded for sites A and B on visit dates.

The last rise in temperature after mid April was due to heat in the make-up water which was not wanted in the recirculating system as it would lead to premature smoltification. Thus, at this point, more make-up water was being diverted to waste.

5.3.3 Total Dissolved Solids

This parameter was derived from conductivity meter reading, a conversion that is done within the meter. Figure 5.7 shows the 'bulge' in TDS produced by the addition of $CaCl_2$ and $NaHCO_3$ from mid February to early March, after which the system settled out to a steady state in the mid to high 80 mg/L range.

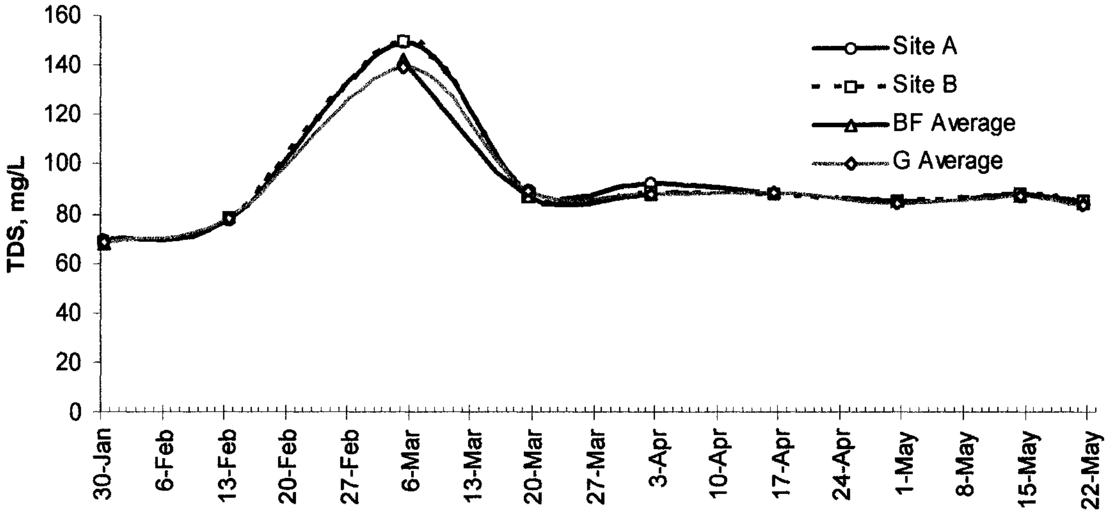


Figure 5.7: Total dissolved solids readings for sites A.B. BFA, BFB,GA, G_B, and MUW_A, plus temperature readings (site B).

Table 5.1: TDS culture water readings means and standard deviations for selected dates

Date	Mean	S.D
16 Apr	88.15	0.381
14 May	87.38	0.515
21 May	84.20	0.464

As with most dissolved constituents that were not being heavily produced or consumed within the system, the values were reasonable consistent throughout the system. For example, the means and standard deviations of the TDS readings from all culture water sites of selected dates are shown in Table 5.1 (see data in Appendix E). A high flow rate, thus a high level of mixing, can be considered to be the reason for such evenness of values.

5.3.4 Nutrients

As discussed in the Methods chapter, the nutrients in Table 5.2 were monitored. The results and comments are contained in the following paragraphs.

Table 5.2: *Nutrients measured and derived from the measurements*

Measured	Derived
Total Kjeldahl nitrogen (TKN)	Organic nitrogen
Total Ammonia Nitrogen (NH_3-N)	Total ammonia (NH_3), UIA
Nitrite Nitrogen (NO_2-N)	Nitrites (NO_2)
Nitrate NitrogenNO_3-N	Nitrates (NO_3)
Orthophosphate (PO_4^{-3})	Phosphate (P)

Total Kjeldahl Nitrogen

Total Kjeldahl nitrogen (TKN) measures the sum of the organic and ammonia related nitrogens. It was hoped that, by subtraction of the TAN, the organic portion of the samples, the portion of organic nitrogen associated solids could be found. This was not successful. The sample size determined by the method was simply too small. Full scale for the spectrophotometer test is 150 mg TKN/L. The test measurements were in the order of 10 mg/L, often lower. An error of 1 mg/L at this range translates into a 10 % error on the TKN value. This was evidenced by many of the organic nitrogen derivations (TKN - NH_3-N) coming out negative. A method is needed to concentrate more TKN in the test sample.; perhaps digesting two or more basic samples and then combining them would improve accuracy.

Total Ammonia

In Figure 5.8 the solid lines mark the total ammonia levels (after digestion) and the dotted, the percent. in the solids. Early records show both the changes in the system going on at that time, perhaps enhanced by the learning curve of the tester. The corresponding changes in feed rate, biomass and temperature are reflected in Figure 5.9.

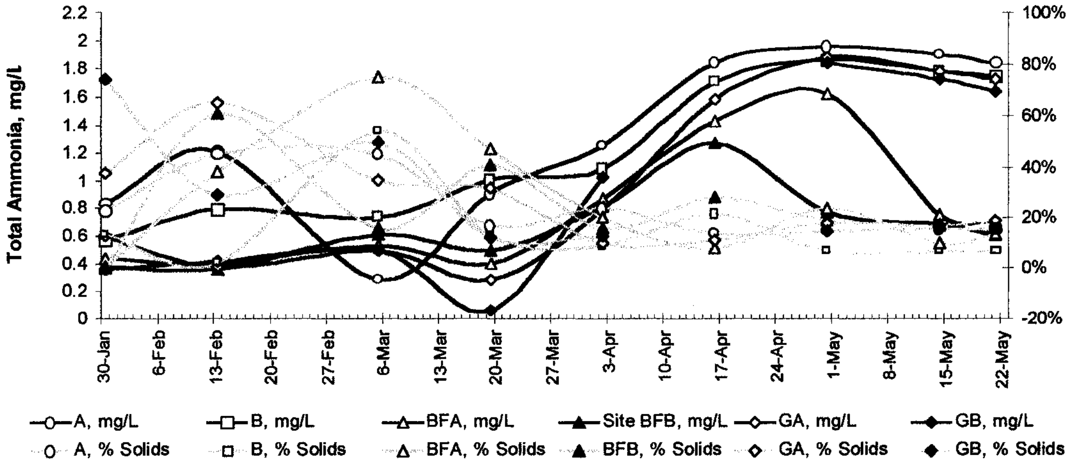


Figure 5.8: Total ammonia (solid lines) and % associated with solids (dash lines) from biofilter outlets and culture tank inputs and outputs.

In late March the system appeared to settle a little and the ammonia started to rise in the outlet lines. At first the biofilter outlet waters (BF_A and BF_B) reflected that change up to mid April when, obviously, they started working stronger and the ammonia levels dropped to a steady state as expected, albeit the A line biofilter took over a week longer than the B line biofilter.

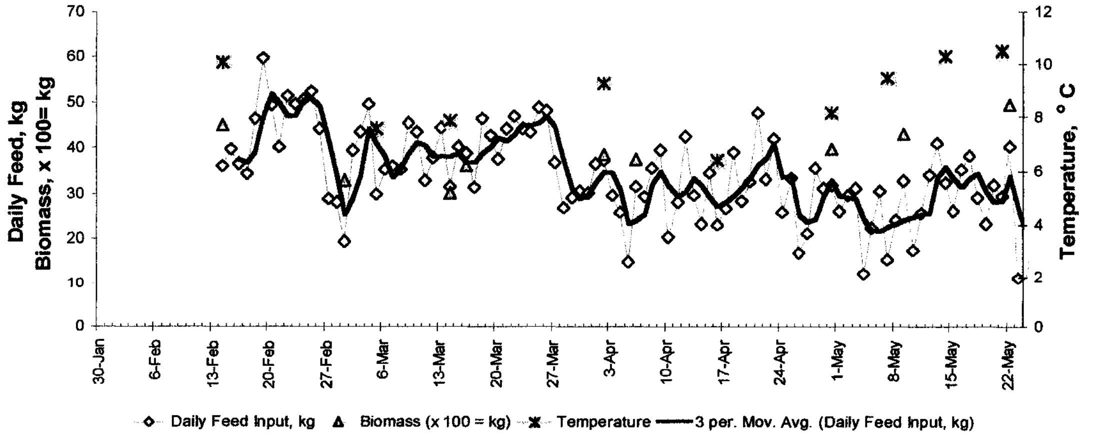


Figure 5.9: Plot of the 3-day average feed input, biomass changes and temperature changes.

The percent. ammonia that was associated with the solids appeared to vary early on but, if one looks at those data in absolute terms, as in Figure 5.10 (light lines), it would seem that the actual amount of ammonia in the solid fraction is reasonably independent of the total amount of ammonia being generated.

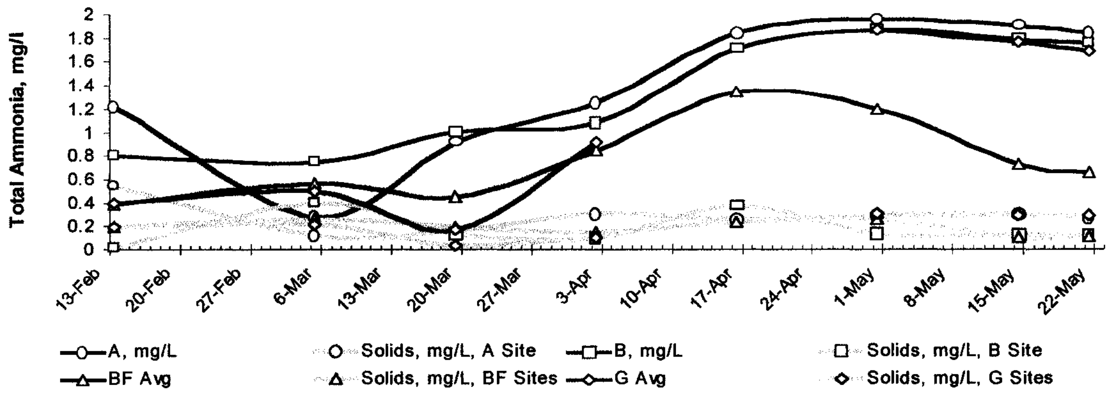


Figure 5.10: *Total ammonia for sites A and B and averaged values for Sites BF and G (solid lines), and total ammonia in the solids fraction of the water (dashed lines)*

The strangest phenomenon in these plots is that the level of ammonia coming out of the aerator/oxygenators is consistently higher than that entering from the biofilters (Figures 5.8 and 5.10) and, in fact, maintains a level of the same order as that leaving the culture tanks.

There are microorganisms that are able to aerobically convert organic nitrogen to NH_e. In fact this is a basic process in the system where food and faeces in the water are converted and adds to the TAN load.. The blown-in air for CO_2 stripping will supply both the oxygen and the nitrogen required and the carbon in the CO_2 in the water will supply the energy. The signature for such an activity would be a loss of organic nitrogen plus a gain in NH_3-N across the apparatus (A. Ghaly. Dalhousie University. pers.comm.). Although the difficulties with reading TKN have been discussed, several comparisons of values across the degasser/oxygenator support this hypothesis (Table 5.3).

The increase in particle count across the degasser/oxygenator noted in Section 5.4 could be explained by the increased microorganism load caused by this activity. Along with the improvement in TKN technique proposed, the water needs to be tested to detect and determine the type of microorganism involved.

***Table 5.3**: TAN and organic N across the degasser/oxygenators, mg/L, for 21 May 01 sampling*

Site	TAN	Total Organic N
A Line		
BF_A	0.578	0.922
G_A	1.422	0.219
Diff	0.844	-0.703
B Line		
BF_B	0.500	0.437
G_B	1.344	0.109

Un-ionized Ammonia (UIA)

Despite the high total ammonia levels, this fraction was maintained, by ph and temperature, well below even the very conservative NBDFA recommendation of < 0.006 mg/L.

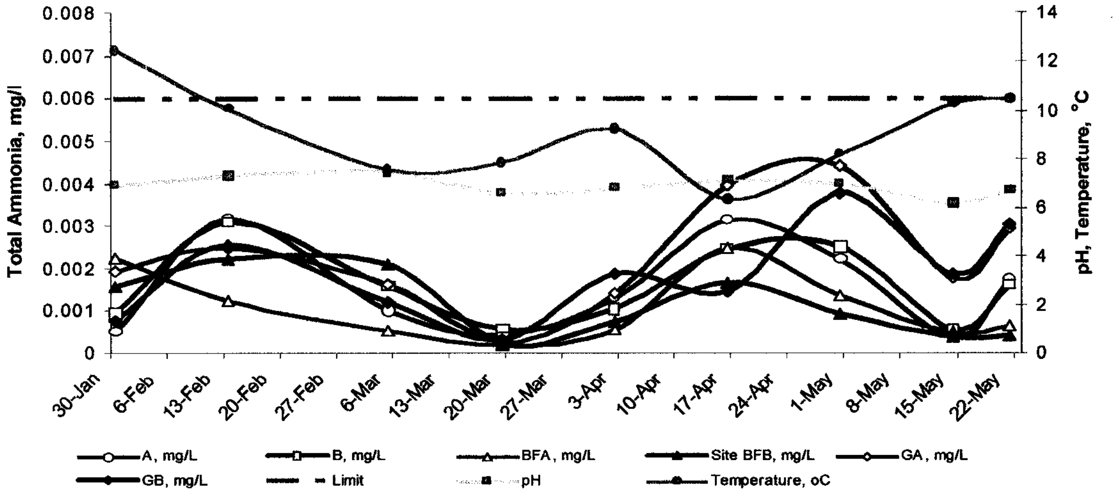


***Figure 5.11**: Un-ionized ammonia values for selected sites, plus ph and temperature.*

Nitrites and Nitrates

Both the nitrites and the nitrates (Figure 5.12 and 5.13) stayed within acceptable limits for the test period, although the nitrites rose toward the upper recommended limit in the last week , especially in the tank bottom water. At this time the stressing of the fish to weed out weak fish had begun.

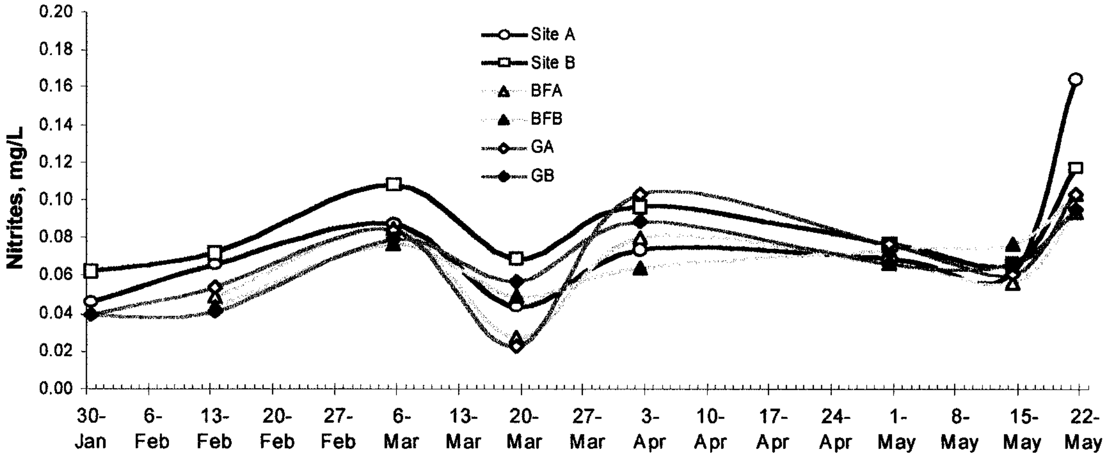


***Figure 5.12**: Nitrite readings from selected site.*

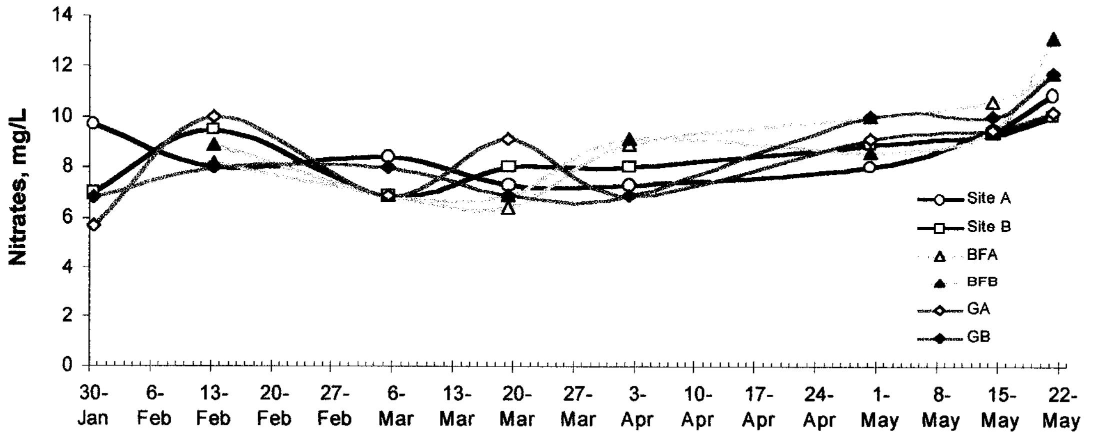


***Figure 5.13**: Nitrate readings from selected sites*

General Ammonia Comments

Site B (tank midwater) readings of NH_3, NO_2 and NO_3 in Figure 5.14 show the variations caused by the early period of changes in biomass and temperature. Then as the plant is loaded up the ammonia level in the tank rises until the system stabilizes in early May. The nitrates generally follow suit while the nitrites hardly change. It would appear that the *Nitrosomonas* spp. are reacting faster that the *Nitrobacter* spp.

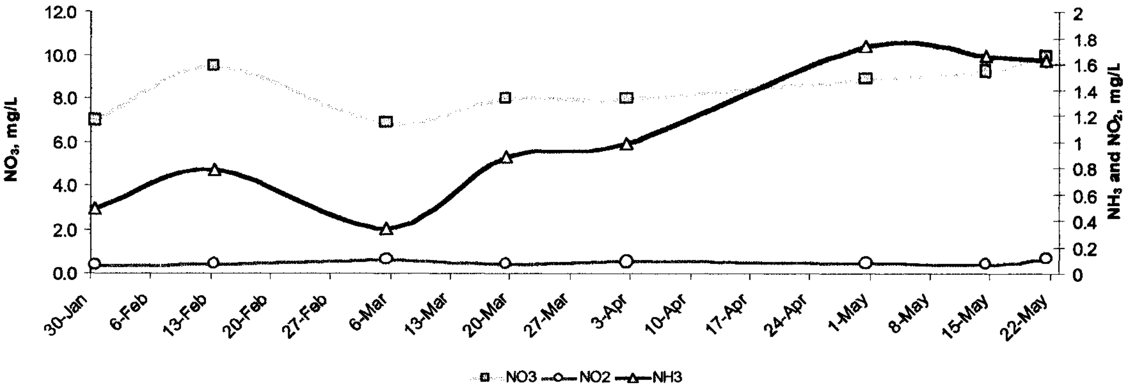


Figure 5.14: *Site B (midwater) readings of NH_3, NO_2, and NO_3*

Phosphorus

Phosphorus is an essential nutrient in fish food. There are only two sources of phosphorus input to the system; make-up water and feed. Figure 5.15 is the plot of total phosphorus along with the percent. associated with the solids. After operating at about 0.5 mg P/L in the water for the first part of the trial period, the phosphorus levels jumped to 2.5 mg/L. This large increase can almost completely answered by the phosphorus coming into the make-up waters as shown in Figure 5.16.

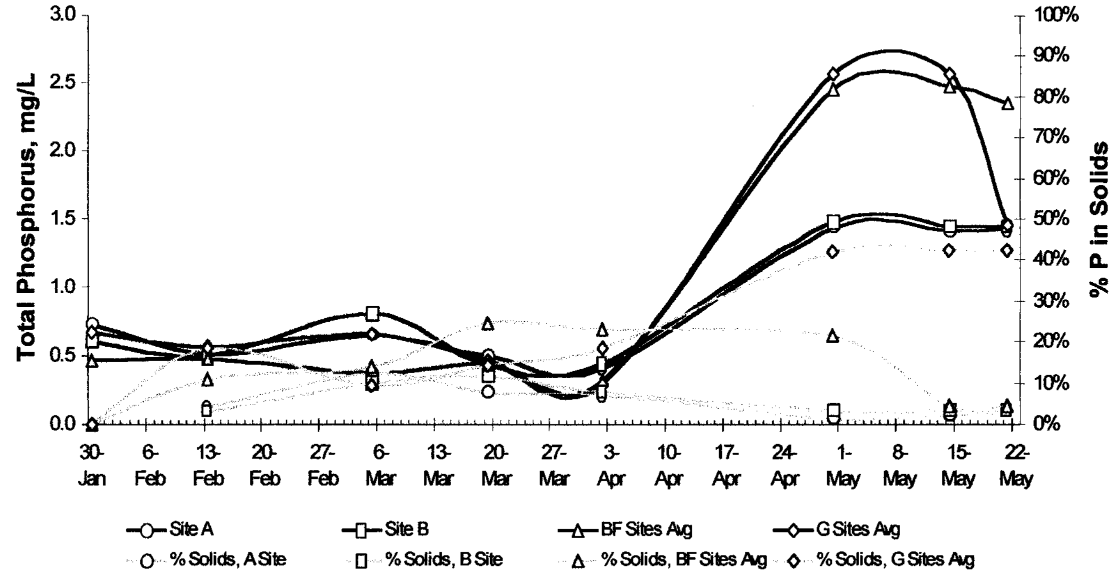


***Figure 5.15**: Total phosphorus (solid lines) and % in solids (dashed lines) for sites A and B, and BF and G averaged.*

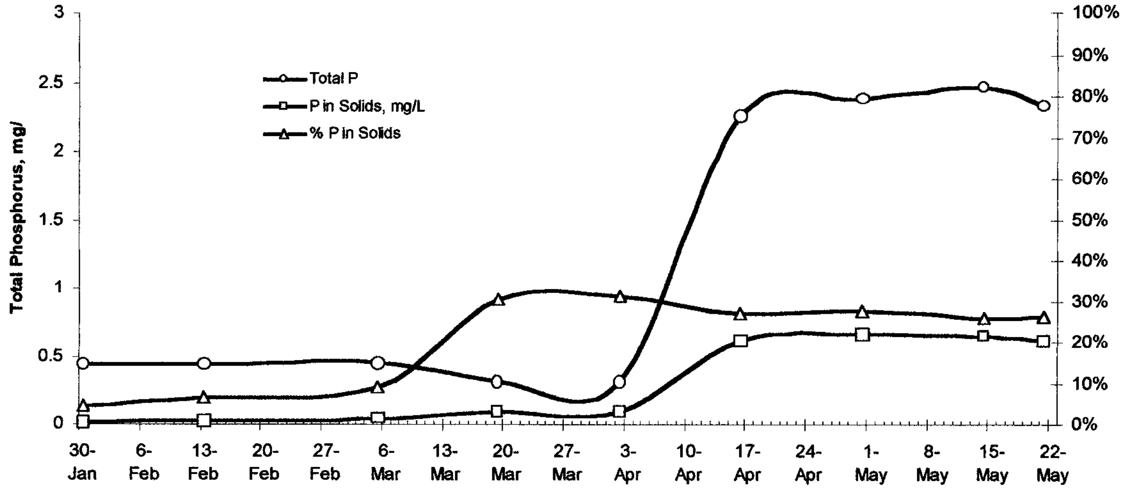


***Figure 5.16**: Total phosphorus, and P in solids levels, and % P in solids, for make-up water A (MUW$_A$)*

There are two anomalies in Figure 5.16. In the lesser one, there seems to be a response to the loading of $CaCl_2$ and $NaHCO_3$ around 6 March. Perhaps the salts were contaminated with some phosphorus.

The greater anomaly is that after about 10 April, the water exiting the culture tanks (A and B) show a large drop in phosphorus levels in spite of the fact that phosphorus is being inputted through feed waste and undigested P from fish excretion.

5.3.5 Oxygen Reduction Potential

The results of the ORP reading are plotted in Figure 5.17. In essence, the ORP value is registering the arithmetic sum of the inputted or produced ions in the sample.

The large drop in ORP after 16 April appears to coincide with the rise in TSS at the same time. This is an exciting correlation but, as the TSS test has insufficient precision (see Section 5.3.6), the true significance will have to await further study.

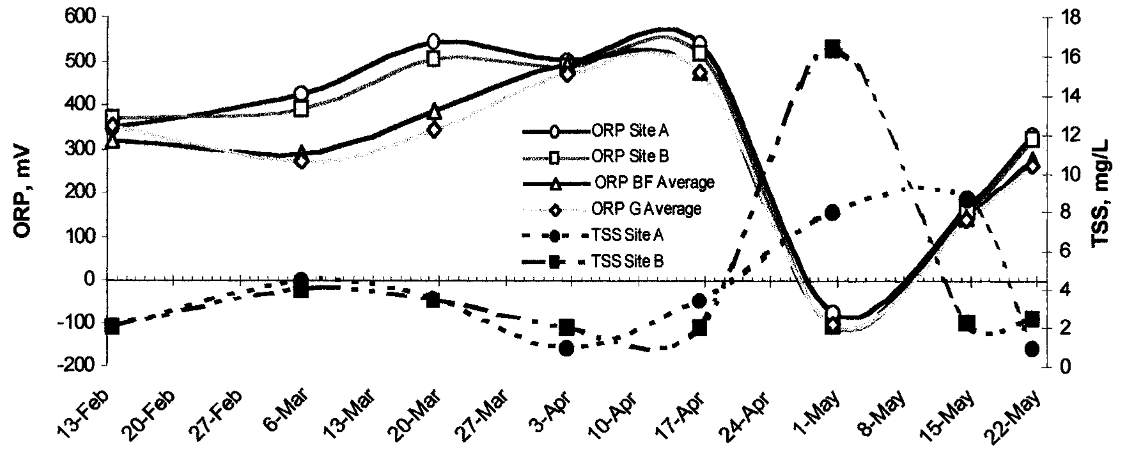


Figure 5.17: ORP data for sites A, B, G_A, G_B, BF_A, and BF_B plotted with water temperature

Interesting, also is the ORP value drops from the highest value in the A site culture bottom water to the lowest value as the water progresses through the system (Figure 5.18).

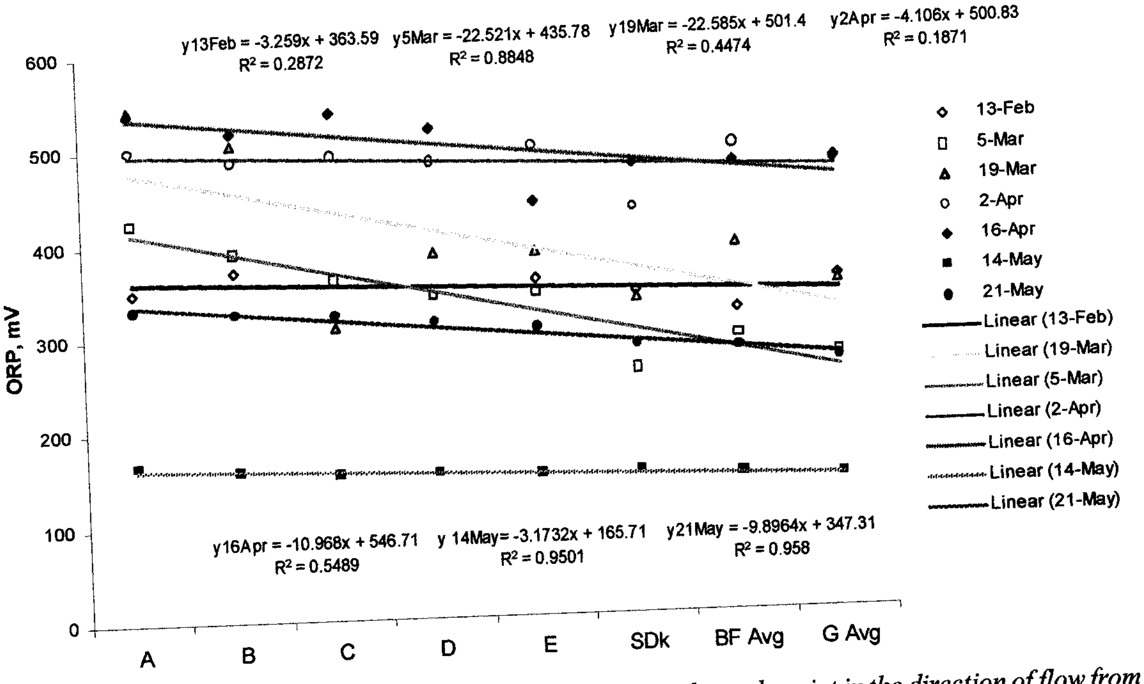


***Figure 5.18**: ORP values through the system. Abscissae indicated sample point in the direction of flow from the tank exits.*

This phenomenon, also a point of follow-up study, is almost linear especially in the last two samplings when the system was probably least unstable. As it starts with the bottom water having the highest value and what could be considered the cleanest water, the least value, it may be relatable to solids content.

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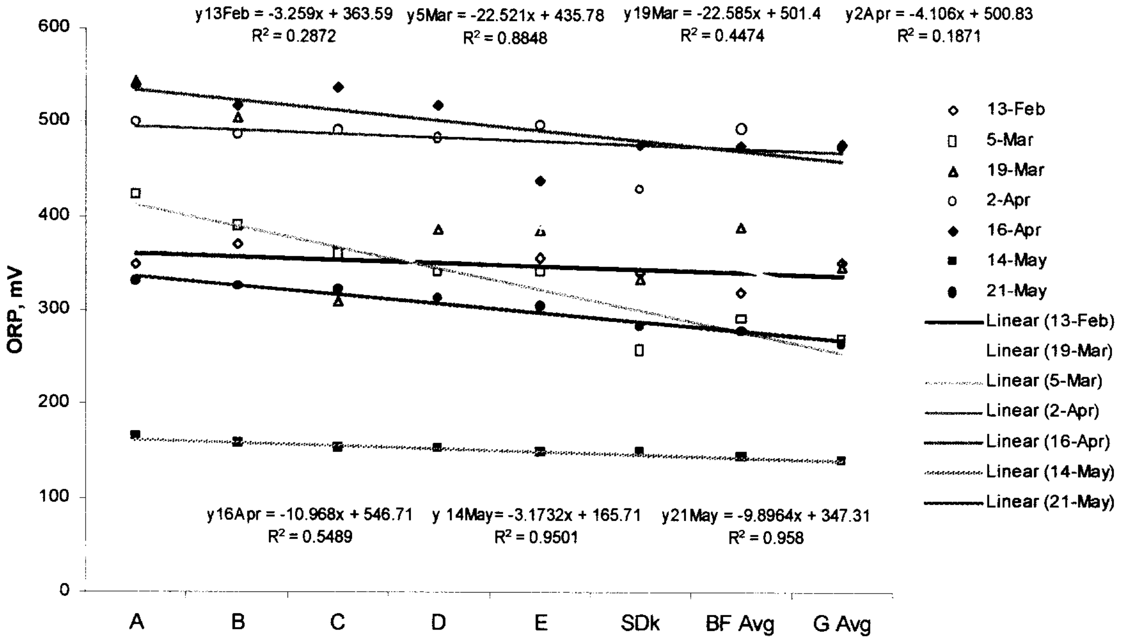

Figure 5.18: *ORP values through the system. Abscissae indicated sample point in the direction of flow from the tank exits.*

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5.3.6 Total Suspended Solids

Hach Method 8006 purports to read total suspended solids (TSS). In this method, 500 mL of sample is blended and then tested in the spectrophotometer at 810 nm against a DDW blank. Again because of the wide range of the test (0 - 705 mg/L) and the normally low concentration of solids in the system (1 - 10 mg/L), this method was never satisfactory. Also there are assumptions built into the results. As the reading is developed from the reduction of light intensity by the particles in the path of the beam, what really is being read is probably the shadow or cross-sectional area of the particles. It may be supposed that the program derives a diameter from a circle of equivalent area and converts it to a spherical volume. It would then have to have an assumes density in order to arrive at a mass, to read in mg/L.

If the loads were not so low this method could be used on a relative basis to compare loads. Hach does caution that this method should be compared to gravimetric and actually an early comparison showed up well (Hach: 2 mg/L; gravimetric: 1.7 mg/L) but the overall problem of small loads in the water still exist; small reading errors are exaggerated.

While testing on 25 Oct 00, a high TSS reading of 111 mg/L was obtained on the water from site A (tank bottom water). This site had previously read 3 mg/L. On subsequent readings this high petered out until it settled out at 7-8 mg/L. This author realized that the system solids were ‘pulse’ loaded and assumed that feeding was responsible; e.g. the TSS increases as the feed is distributed and the fish void, and then the TSS level drops until the next time.

A test was devised to take place over a feed period. 12 x 500 mL sample bottles were filled at site A every five minutes, hopefully giving a one-hour profile of the pulse. The results are plotted in Figure 5.19. A difference in 1 mg/L either way is within the experimental error and so it can be considered that the water was running at about 3 mg/L TSS. There is indeed a pulse from the feed, but a very minor one.

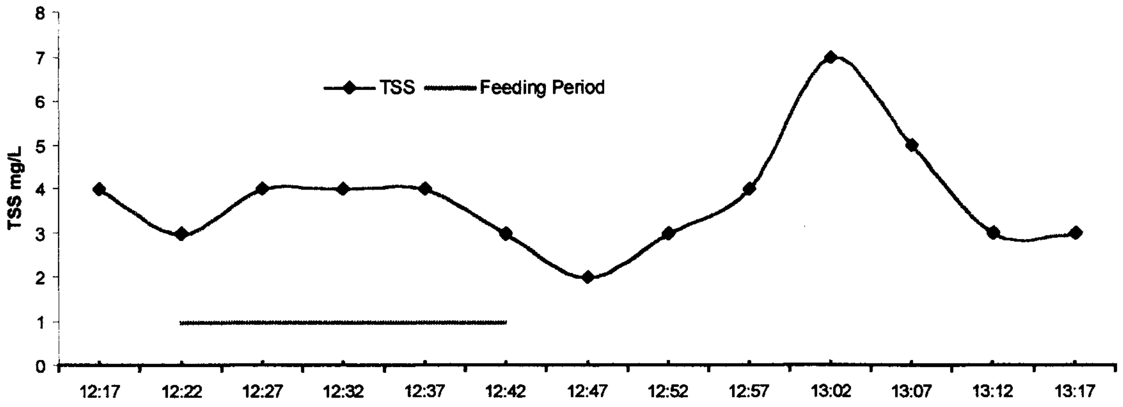

***Figure 5.19**: 25 Oct 00 feeding vs TSS trial results.*

Discussions with the manager elicited the fact that the return lines, and the bottom water line especially, were acting as settling basins clarifying the return water until the buildup became unstable and a large solids 'bloom' would pulse through the system. The management practice became back-flushing the lines about once per week. A detailed discussion on this phenomenon and how to avoid it is in Appendix G.

5.3.8 TSS of Dietary Origin

In Cho and Bureau (1997) and Cho et al. (1994) it is stated that wastes from feed input can be estimated from the following statements:

- Solid waste (DW) - undigested food excreted as faeces
- Dissolved waste (SW) - metabolism by-products (ammonia, urea, phosphate, etc.)
- Feed waste (FW) - uneaten feed.
- Total waste (TW) = DW + SW + FW
- Estimate of Total solid waste (TSW) = feed consumed x (1-ADC) + FW

where ADC is the apparent digestibility coefficient for the feed.

In this study the solid waste is of concern. D. Bureau of U Guelph (pers comm) suggested that, while ADC is difficult to determine, an estimate of the solids waste portion of eaten feed can be made through the following relationship:

$$Total\ Waste\ Solids\ =\ \%DS \times (1 - \%digestibility\ of DS) \qquad (5.1)$$

where DS = % dry solids in the feed.

J. Mann of EWOS (pers.comm.) offered that the feed in question had 92% dry solids content with 90-91% digestibility. From 14 February, 2001, good feed input data is available. Data that is not available is the percentage of that feed that is not eaten by the fish. Appendix D contains the mechanics of an estimate of the solids input of the feed, with a variable percentage wastage, in spreadsheet form. If one assumes a feed waste (uneaten) of 1% that breaks down, the contribution of feed to the solids load would be about 3.2 to 3.4 kg/day, as shown in Table 5.4.

***Table 5.4**: Estimate of the contribution of feed to the solids load based on sampling days. %feed uneaten set at 1%. 1-day and 3-day refer to feed input records .*

	1-Day Record			**3-Day Average**		
	SS Eaten	**SS Waste**	**TSS**	**SS Eaten**	**SS Waste**	**TSS**
14 Feb	3.28	0.33	3.62	3.29	0.33	3.62
5 Mar	2.72	0.27	2.99	3.74	0.38	4.12
14 Mar	2.88	0.29	3.18	3.46	0.35	3.81
2 Apr	3.41	0.34	3.75	3.17	0.32	3.49
16 Apr	2.12	0.21	2.34	2.47	0.25	2.72
30 Apr	2.91	0.29	3.20	3.00	0.30	3.30
16 May	3.22	0.32	3.54	2.86	0.29	3.15
21 May	2.69	0.27	2.96	2.58	0.26	2.84
Average	2.90	0.29	3.20	3.07	0.31	3.38
S.D	0.41	0.04	0.45	0.43	0.04	0.48

5.4 GRAVIMETRIC TRIALS

The results of the gravimetric tests are contained in Appendix F and are summarized in Figure 5.20. The major point to be shown by these tests is that recirculating systems culture water is not suitable for gravimetric analysis. The method (APHA 2540B (Anon. 1995a)) requires weighing to 1/10th of a milligram. On many filters there was not 1/10 th of a milligram residue. The results from the 30 Apr 01 sample even gave negative numbers though well within the margin of error.

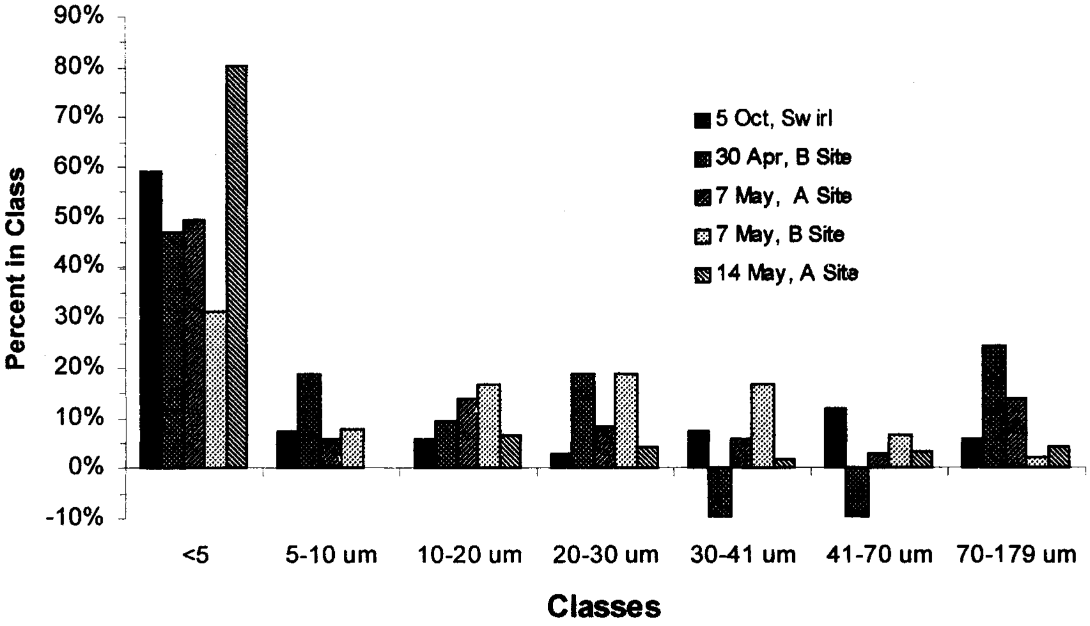

Figure 5.20: Summary of the results of gravimetric tests on some culture water samples

The normal way to correct for low solids in a solution is to filter more sample. This was attempted on later trials with limited success as several of the filters simply clogged. In addition, the weighing was moved to a more accurate scale and more care was taken with maintaining filter dryness, including excessive desiccant in the scale surround, with a filter waiting area in there also. This aided in maintaining positive results but the clogging still kept the resultant values very low. This was the first indication of the lightness of the particles in question.

On 7 Jun 01, 6 L samples taken from sites BF_B and G_B waters were filtered through the 25-mm series of filters noted above for further microscopic examination. It was noted during filtration that on the 20 um filter the filtration rate slowed after 4 L and, in the case of the G_B sample, clogged about 400 mL later. The 10 um mesh slowed after 2 to 3 L and, in the case of the G_B sample, clogged after 5 L. The BF_B sample passed the 5 um filter with little clogging, but not so with the G_B sample, which slowed after 4 L and clogged at 5 L.

Microscopic examination of the filters used showed a sheen on the finest filters and a clear, viscid material clinging to the meshes of which Figure 5.21 is an example. It was concluded that, due to the lightness of the major portion of the particles in question and the early clogging of the meshes, especially around 20 µm, gravimetric analysis is not a suitable vehicle for studying these suspended solids. The dominance of particles under five microns appears to be supported, however.

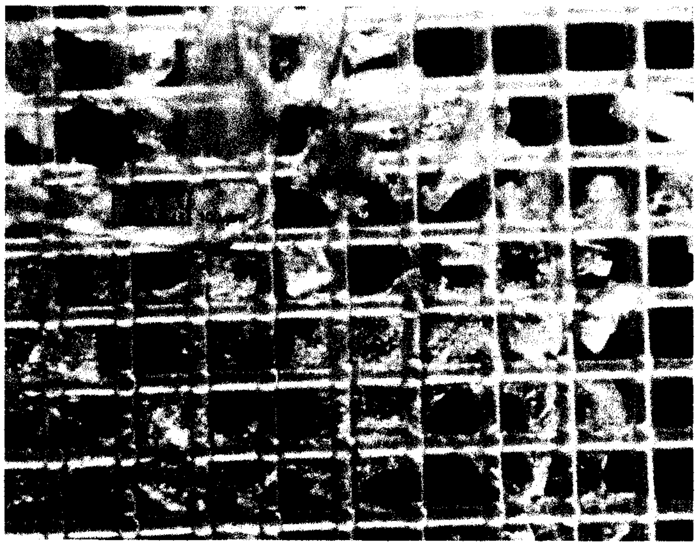

***Figure 5.21**: Viscid material on a 70 µm filter*

5.5 PARTICLE SIZE ANALYSIS

5.5.1. Field Samples

The analysis of particle size distribution of the field samples using the PCX sensors (plotted in Figures 5.22 and 5.23, with 5.23 expanded in 5.24) evolved during the test period. The near-hyperbolic nature of the distributions was evident while the fines did not build up as anticipated, as will be shown in Section 5.5 (Beta Values). The individual analyses are in Appendix H.

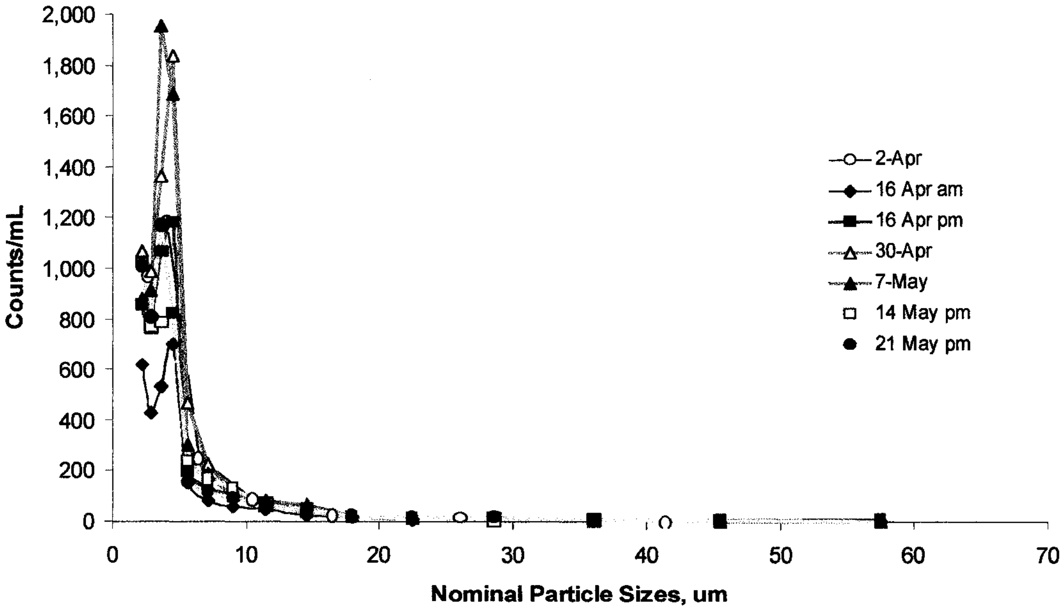

Figure 5.22: Collective plot of A site particle size distributions over the PCX test period

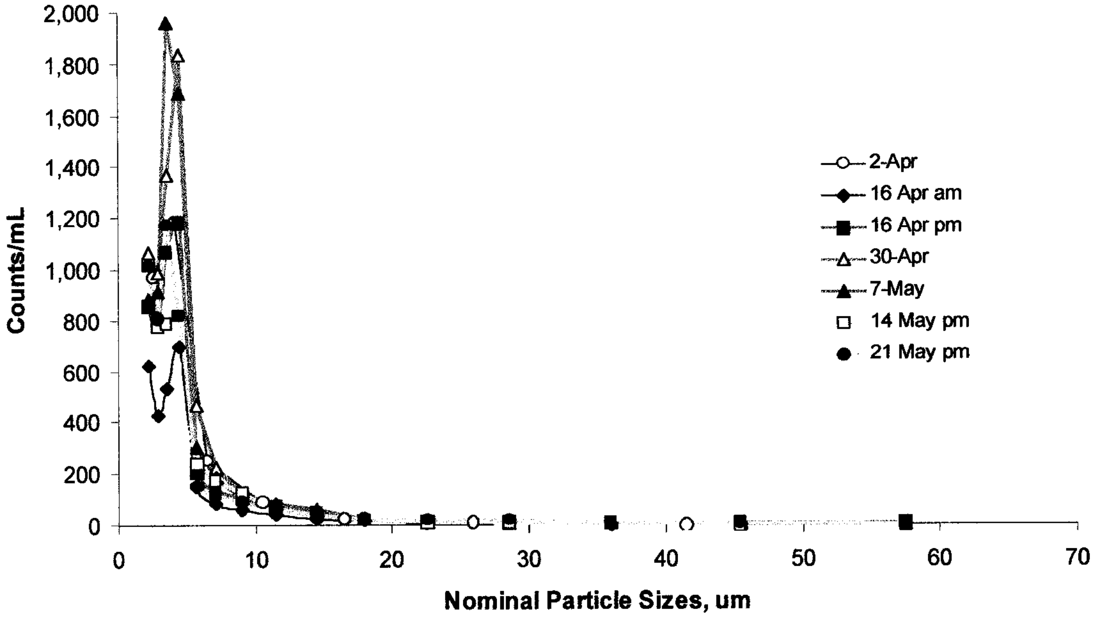

Figure 5.23: Collective plot of B site particles size distributions over the PCX test period

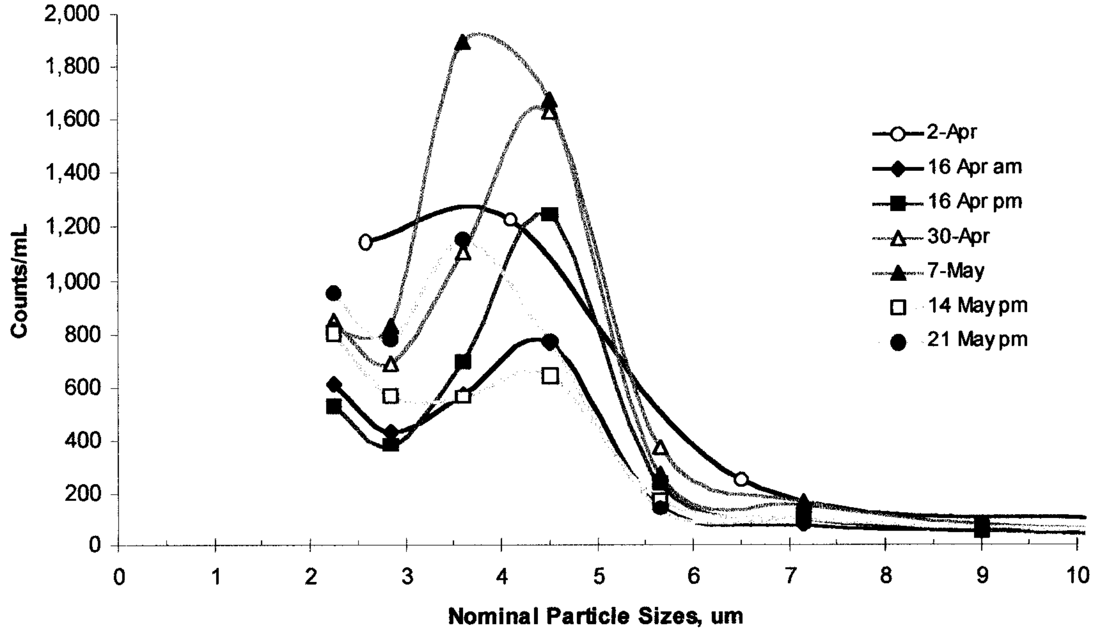

Figure 5.24: Expanded low end of Figure 5.23, collective B site PSDs.

The most striking feature of the particle size analysis (PSA) was a spike in the culture water between 3 and 5 µm. A and B sites are taken as typical for the culture water in general as all culture water sampling sites recorded similar spikes. A strict comparison of the spikes at sample times is not available as the data processing techniques changed (improved) as experience was gained. Never-the-less, the superimposed plots (Figures 5.22 and 5.23) , with the fine particle end of the B site samples plot (Figure 5.24) will show this phenomenon.

Although, as mentioned, the peaks cannot be rigidly compared due to differences in data processing as techniques evolved, general comparison is valid as those differences are not great. Note that the peak increased in height from 2 April until 30 April, after which it diminished again until it was minor by 21 May. Also the recorded peak varied between the nominal classes '3.2-4 µm' and '4-5 µm'. Thus the range of these peaks is 3.2 to 5 µm. The feed records also show that the use of 2 mm feed was discontinued on 26 April.

A review of the data sheets in Appendix H will show that these peaks are throughout the culture water but there is just a suggestion of them in the make-up waters and that in MUW_A which is reused water, having been through the hatchery, versus MUW_B which is well water direct flow (Figures 5.25 and 5.26) . The conclusion must be that these peaks are being generated within the recirculation plant.

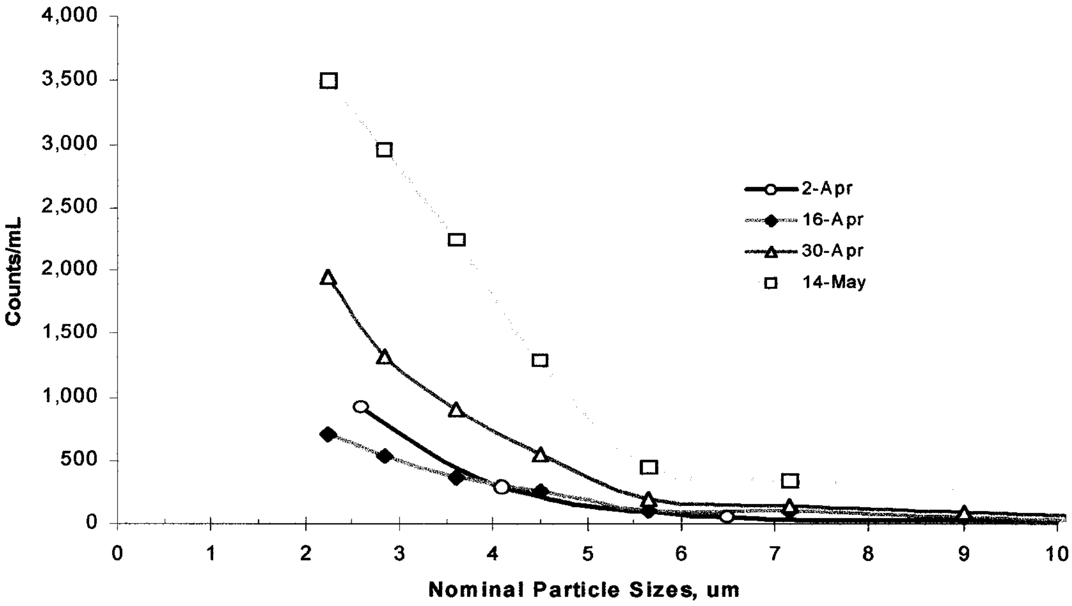

Figure 5.25: *Collective plot of the PSA of make-up Water A.*

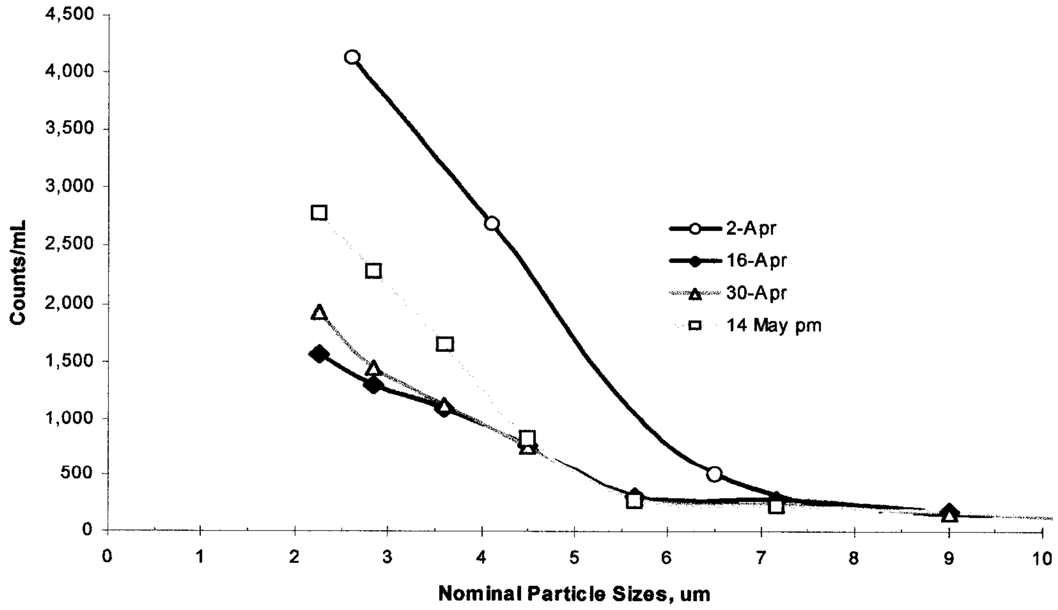

Figure 5.26: *Collective plot of the PSA of make-up water B*

5.5.2 Feed Trial

To determine the contribution of the feed to the 3-5 μm peaks, PSA trials were conducted on 2 and 3 mm EWOS Transfer feed being used in the plant. In all, three trials were done. The sample development was similar to that used for the density gradient media trials (see Section 3.8); samples of feeds were stirred in filtered distilled water for varying periods of time. The weights, water volumes, stir times and some observations are noted in Table 5.5 and the lower classes of the plots are shown in Figure 5.27.

Table 5.5*: Production of feed particle samples for PSA study. Time refers to stirring time.*

Feed >	2 mm		3 mm		Time	
Date	Wt mg	FDDW L	Wt mg	FDDW L	hr	Remarks
11/12 Apr	20	0.860	21	0.903	20	3-mm particles completely broken down 2-mm particles retained form but shed particles
19 Apr	10	0.9	10	0.9	1	3-mm pellets still had form but showed signs of breaking up. Particles in water. 2-mm pellets showed less deterioration
6 Jun	520	2.0	530	2.0	3	Samples heavy in solids; had to be diluted 50% for PCX

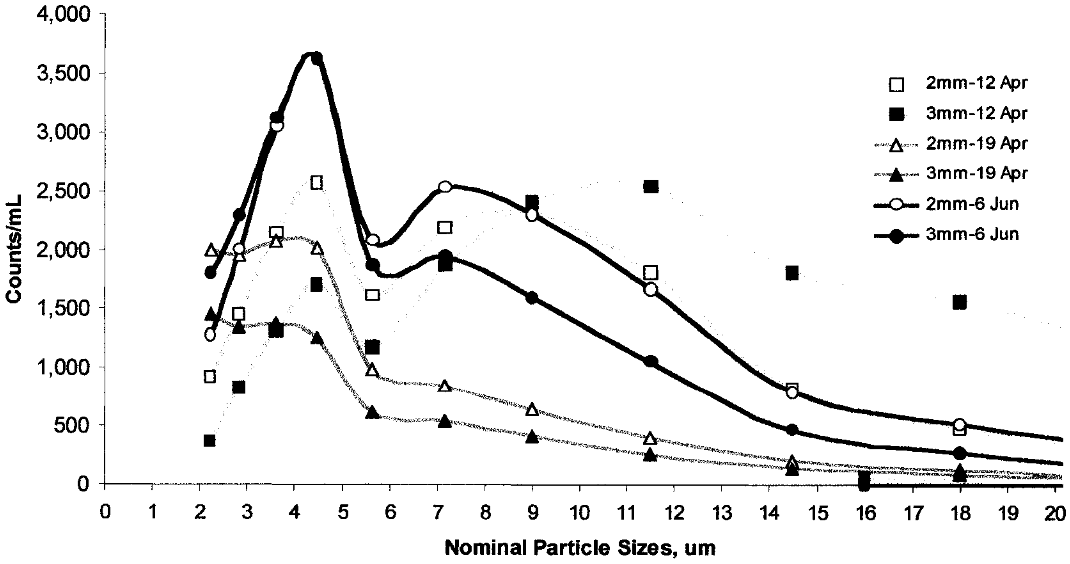

Figure 5.27*: Collective plot of feed PSA trials*

The first factor to note is that there is a distinct major peak in the 4-5 μm class, with a lesser 'hump' at varying distances in the seven to twelve micron range. The peak is not as distinct in the 19 April trial, that had the shortest stirring time, but it is evident, although spread into the lower classes. Thus this peak is caused by the feed and is not affected by the feed being digested by the fish.

The plug flow residency time in the culture tanks is approximately one hour. There will be corners and eddies in the tanks and in the return pipes (see Appendix G) where waste feed can linger and disintegrate.

5.5.3 Beta Values

A summary of the Beta values of the log-log plots of the particle size trials on the 2200 PCX, with corresponding regression coefficients, is shown in Table 4.10 (from Appendix H). Selected plots are Figures 5.29, 5.30 and 5.31.

The Beta values were expected to increase as the season progressed, thus showing a buildup of fine particles in the recirculating system. This did not occur. In general, the values remained low, between 2 and 3, indicating the continuing dominance of large particles in the system. The reason for this lies in the degree of circuit water replacement as discussed in Section 5.2. Essentially a large portion of the fines generated were being flushed from the system via the overflow in the settle deck, which removed surface and near-surface water.

The bottom return line (Sample A Site) samples were also expected to show Beta values much lower than the midwater (B Site) return, but it shows only a minor increase (Figure 5.28). In fact, the difference is not statistically significant (P(T<=t, two-tail) = 0.090) at 95% probability. This can be explained by the efficiency of the bottom water return lines in settling out larger solids (see Appendix G).

***Table 5.6**: Summary of the Beta values for the PCX trials on samples from various sites on visit dates with corresponding regression coefficients, R. (for details, see Appendix H)*

SITE		2-Apr-01		16-Apr-01		30-Apr-01			7-May-01		14-May-01	21-May-01
		Wide Range	**Low Range**	**am**	**pm**	**Surf.**	**No Surf.**	**(-) FDDW**	**Surf.**	**No Surf.**	**(-)FDDW**	**(-)FDDW**
		a	b	c	d	e	f	g	h	I	j	k
A	Beta	2.764	2.524	2.213	1.829	2.241	2.363	2.231	2.154	2.289	2.077	2.048
	R	0.9848	0.9941	0.9864	0.9706	0.9762	0.9790	0.9731	0.9647	0.9735	0.9802	0.9806
B	Beta	2.754	2.554	2.218	1.834	2.392	2.447		2.286	2.540	2.123	2.268
	R	0.9890	0.9954	0.9864	0.9707	0.9786	0.9776		0.9710	0.9742	0.9872	0.9812
C	Beta	2.635	2.055	2.413	1.567	2.396					2.079	
	R	0.9876	0.9895	0.9875	0.9641	0.9758					0.9829	
D	Beta	2.794	2.335	2.278		2.505					2.163	
	R	0.9843	0.9869	0.9863		0.9764					0.9873	
E	Beta	3.042	2.464	2.541		2.396					2.635	
	R	0.9856	0.9893	0.9871		0.9758					0.9855	
Settle Deck	Beta	2.832	2.541	2.282		1.299					1.383	
	R	0.9916	0.9919	0.9746		0.9675					0.9730	
BF$_A$	Beta	2.632	2.134	1.829		2.489					2.550	
	R	0.9858	0.9782	0.9706		0.9691					0.9844	
G$_A$	Beta	3.014	2.636	2.243		2.546					2.194	
	R	0.9824	0.9796	0.9706		0.9757					0.9919	
BF$_B$	Beta	2.738	2.281	2.035		2.500					2.404	
	R	0.9939	0.9799	0.9829		0.9730					0.9897	
G$_B$	Beta	2.492	2.335	2.326		2.414					2.420	
	R	0.9955	0.9887	0.9759		0.9672					0.9897	
I/J	Beta	2.129	1.956			1.308					2.022	
	R	0.9727	0.9841			0.9896					0.9947	
MUW$_A$	Beta	3.544	3.183	2.067		2.164					2.841	
	R	0.9906	0.9912	0.9961		0.9966					0.9939	
MUW$_{A1}$	Beta										3.139	
	R										0.9898	
MUW$_B$	Beta	3.142	2.196	2.495		2.454					2.797	
	R	0.9924	0.9925	0.9832		0.9978					0.9914	
Over Flow	Beta					2.326						
	R					0.9856						

Notes:
Surf. = surfactant, (-) FDDW = a base run of filtered, de-ionized, distilled water was subtracted. This was also done to the 7 May results.
2 Apr: Wide range; 2 - >256 µm. Low Range; 2-51 µm., 8 classes. Remaining trials, 2 - >65, 16 classes.

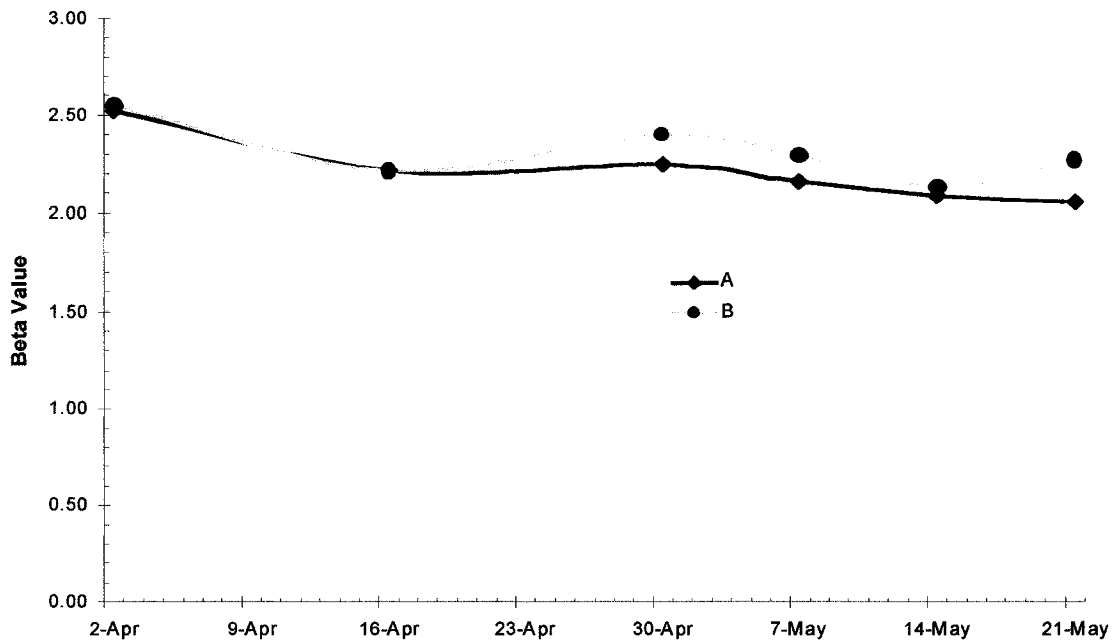

***Figure 5.28**: Sites A and B return water Beta values*

Similar consistency is observed in all the return waters and in the feed waters (Figures 5.29 and 5.30 respectively) except the settle deck water in Figure 5.29. The Beta value drops sharply in the last two samples. This can be explained by the fact that, originally, sampling was done near the surface of the settle deck water, but for the last two samples a pipe probe with a pump was used which could reach to the bottom of the settle deck. These samples were dark and laden with solids.

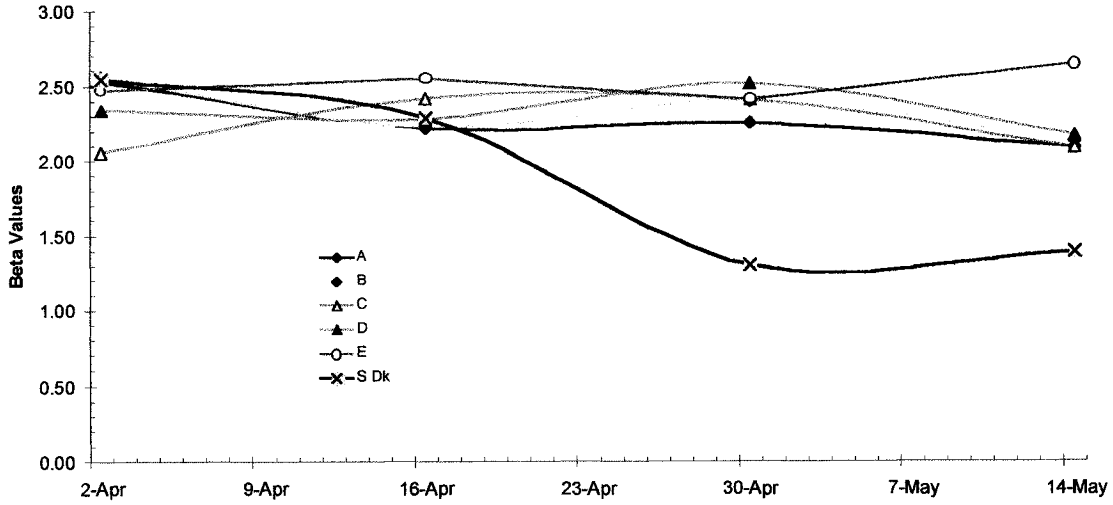

Figure 5.29*: All return water Beta values "A, B...." refer to sampling sites.*

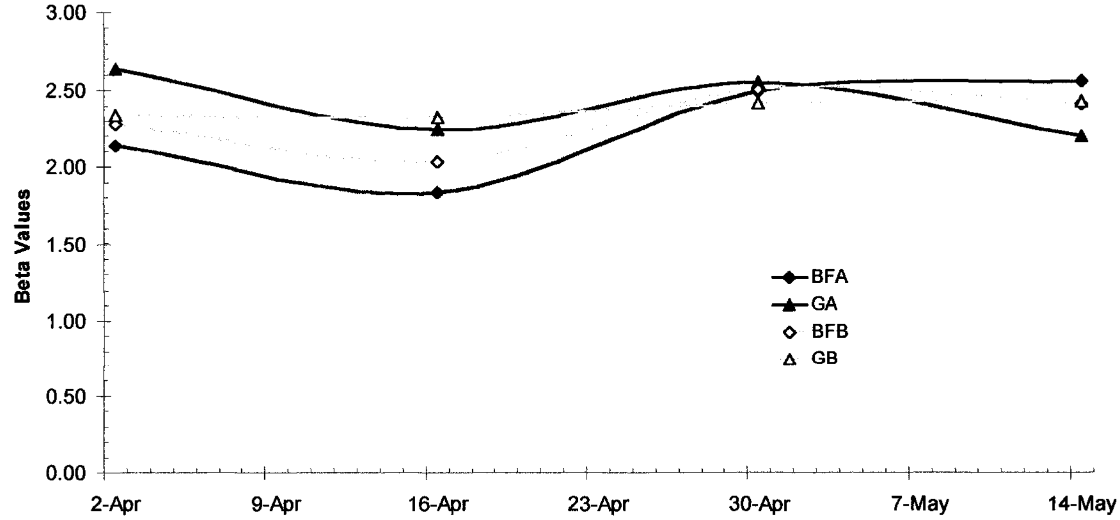

Figure 5.30*: Biofilter and aerator/oxygenator exit water*

Surfactants

In Table 5.6 it appears at first look that the application of a surfactant to inhibit electrostatic floccing (thus retaining smaller particles) was in fact increasing flocculation, as indicated by lower Beta values in the treated samples. In fact there is no significant statistical difference between the two sets (P(T<=t, two-tail) = 0.102) at 95% probability. The use of surfactants was discontinued.

Correlation Coefficients

The R values are generally above 0.98. Where the 3-4 µm spike is high the R values are weaker. The correlation coefficients for the make-up water (MUW) are particularly strong as this water did not have a 3-4 µm spike. The power law holds for this data set.

5.5.4 Power Law Study

Table 5.6 confirms that the power law appears valid, i.e. suspended particles in all the aquaculture systems closely follow a hyperbolic distribution with a large number of fine particles, but that, in confirmation of Chen *et al.* (1993), very small particles appear to completely dominate all types of recirculating water systems (see Patterson *et al.* (1999) Appendix J). In this case the dominance of very small particles (< 10 µm) is much less than that in the data sets used in the paper. This can be explained by the fact that the latter data sets were primarily from laboratory systems studying solids in waster and in this system , the local practice of high turn-over rates, thus high rates of flushing which would carry the fine particles out of the system, was used.

5.5.4 Degasser/Aerator Trial

In response to anomalies noted in the water quality tests, on 4 June 01 samples were taken of the water entering and leaving the B line degasser/aerator (sites BF_B and G_B) and processed through the PCXs the next day. The results are plotted in Figure 5.31.

This testing was done almost too late as fish were being moved and feeding was cut back severely. While the feed 'hump' is reduced severely, both samples show the small but evident increase in particle numbers of the same water in the degasser/oxygenator.

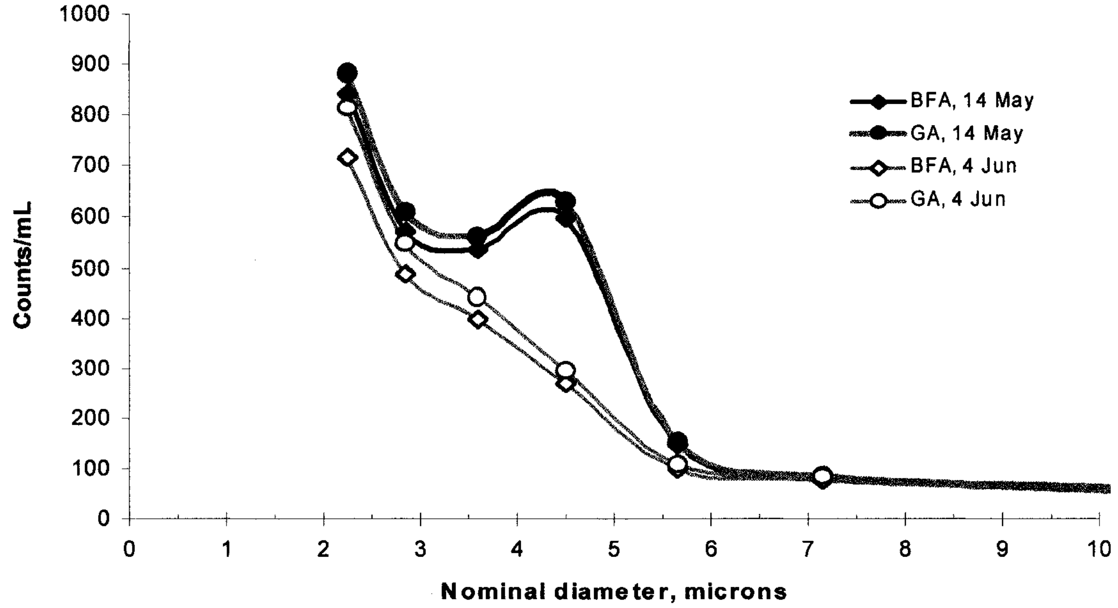

Figure 5.31: PSA results for sites G_A and BF_A for two dates.

5.6 PARTICLE DENSITY DETERMINATION

5.6.1 Pre-trial Observations

Feed Sample Preparation

The feed samples, when stirred in DDW, produced fines in a very short order as indicated in Figure 5.33. The sample was dark with brown fines after a few minutes. However the structure of the pellets, though sodden, remained even after one hour of stirring.

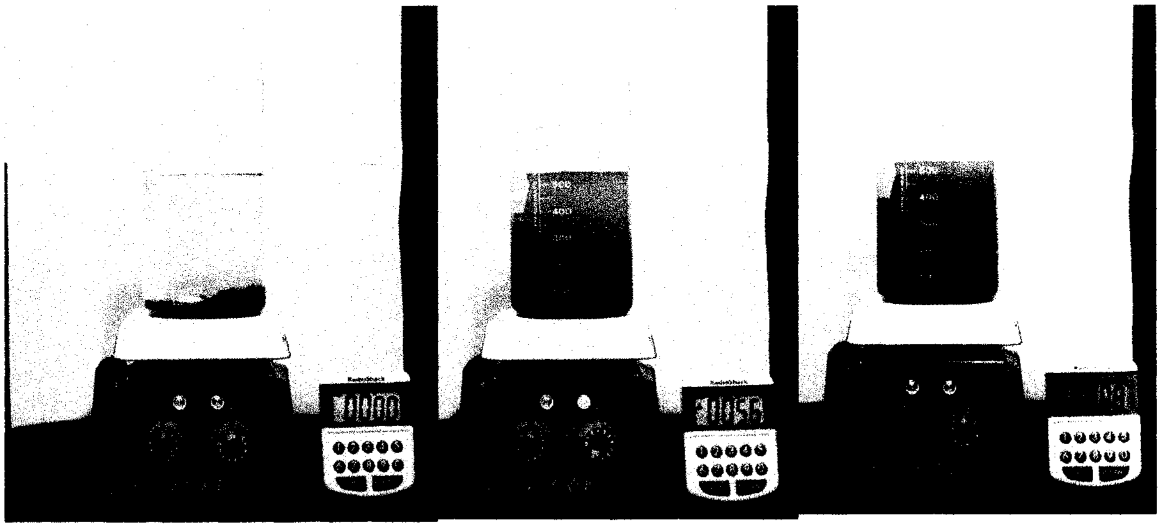

***Figure 5.33**: Sample preparation for feed trials, time in minutes and seconds. Brown fines were produced almost immediately.*

The filter wash samples from the site and the feed are shown in Figures 5.34 and 5.35. The shading is some indication of the amount of solids in the fraction but only approximately. The amount recovered per unit volume was also influenced by the degree of screen clogging and the amount of wash waster used in cleaning the screens. It does correspond reasonably well with the Gravimetric observations discussed in Section 5.4.

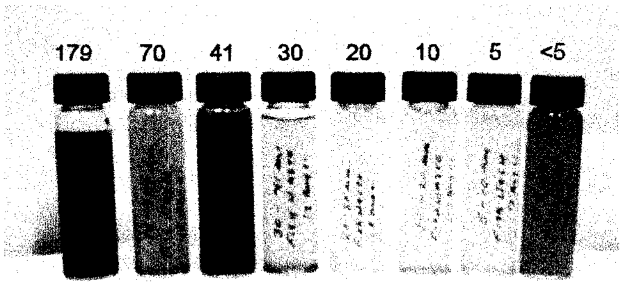

***Figure 5.34:** 12 Aug site samples after washing from screens, except '<5' which is from residue. Values are screen sizes in microns.*

Flocculation

It was noticed that the samples tended to floc while resting after preparation but little shaking effort was needed to break up the flocs, especially when the samples were fresh. Floculation continued as the samples set and seemed more difficult to break down.

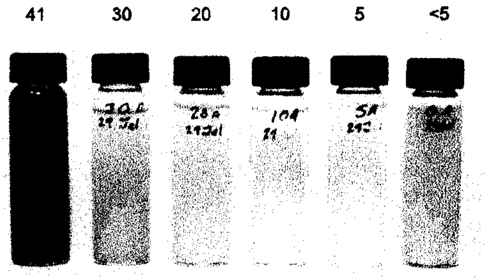

***Figure 5.35:** 29 Jun feed samples after washing from screens, except <5 which is from residue. Values are screen sizes in μm.*

5.6.2 Density Marker Beads

Bead runs with 30 % and 40 % of 0.25 M sucrose dilutions of SIP for the 12 Aug 01 site sample and the 30 Jul 01 feed test are shown in Figure 5.36 and the centrifuges tube (30,000 x g for 60 min) in Figure 4.40.

***Figure 5.36:** Density marker beads for 30% dilution of SIP*

Regressions to the sixth power (Figure 5.37) rendered very good interpolation curves (equations(5.2) and (5.3)). This is to be taken with caution as the degree of the exponent is approaching the number of data points. A comparison with the refractometer results (see check in Appendix I) are diagrammed in Figure 5.38. It shows that the variation is normally about 1% or less (good, considering the sample extraction problem) down to about 1.04 g/mL (the first blue bead), thereafter it does not hold at all. The figures in the appendix give a result less than 1 g/mL at low distances from the meniscus and that is clearly not so. Therefore, while interpolation holds, extrapolation, especially in the low density beyond the 1.042 g/mL blue bead, is not valid.

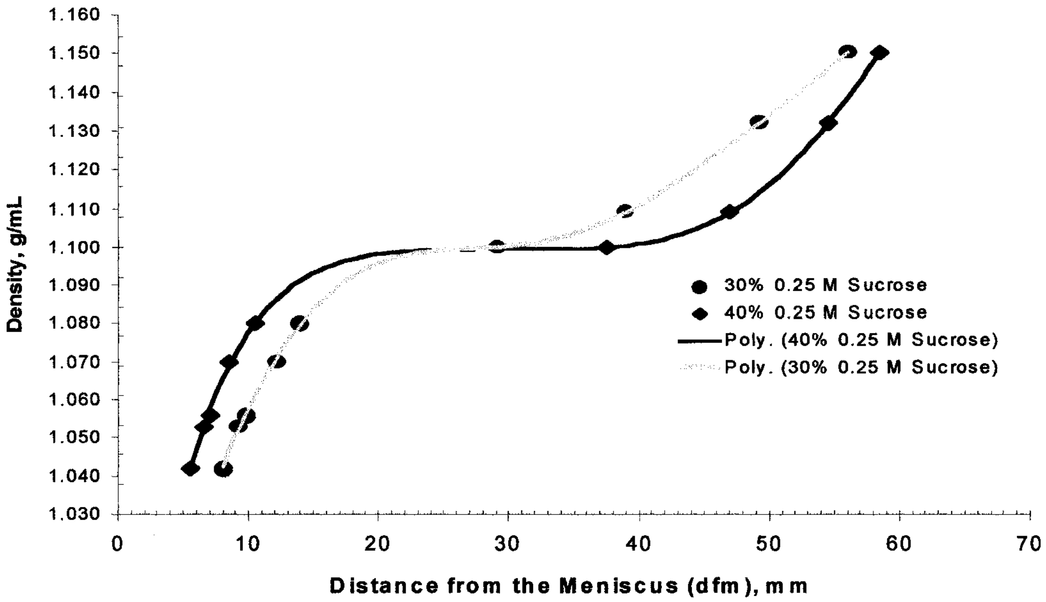

Figure 5.37: Plots of density marker beads (symbols) vs distance from the meniscus for 30% and 40% dilutions of SIP with 0.25 M sucrose, with regression lines.

$$\begin{aligned} y_{30\%} &= 1.0970\cdot10^{-10}x^6 - 2.1033\cdot10^{-8}x^5 + 1.4789\cdot10^{-6}x^4 \\ &\quad - 4.2899\cdot10^{-5}x^3 + 2.6986\cdot10^{-4}x^2 + 9.4159\cdot10^{-3}x + 9.6638\cdot10^{-1} \\ R^2 &= 0.99977 \end{aligned} \tag{5.2}$$

$$\begin{aligned} y_{40\%} &= -9.9791\cdot10^{-11}x^6 + 2.1299\cdot10^{-8}x^5 - 1.8221\cdot10^{-6}x^4 \\ &\quad + 8.1913\cdot10^{-5}x^3 - 2.0716\cdot10^{-3}x^2 + 2.8200\cdot10^{-2}x + 9.3732\cdot10^{-1} \\ R^2 &= 0.99975 \end{aligned} \tag{5.3}$$

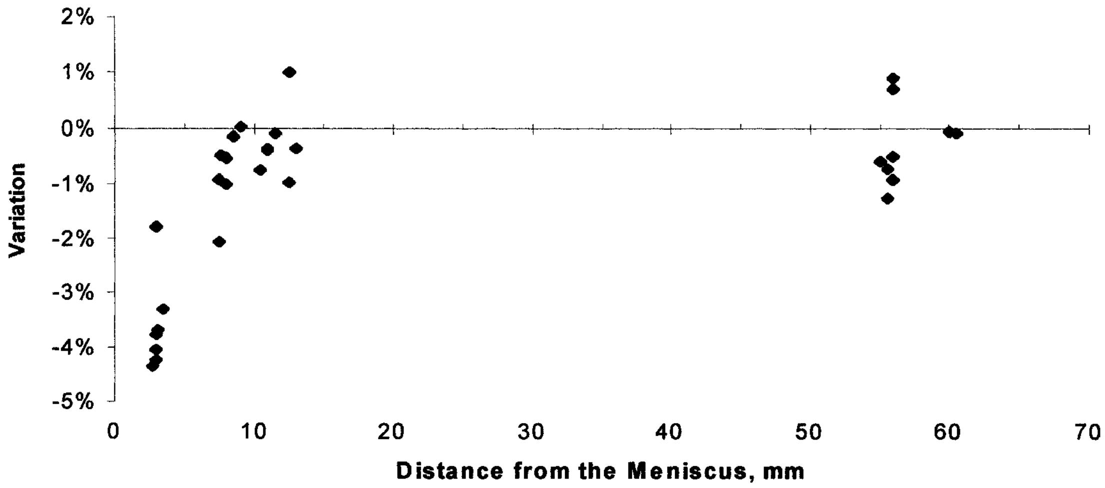

***Figure 5.38**: A comparison between the density values for the Site Sample derived from equation (4.2) and those recorded from refractometry.*

5.6.3 Refractive Index Versus Marker Beads

Appendix I also contains a comparison between the density marker beads and the refractometry readings directly. In adjunct to the feed trial, samples were extracted from the 20% and 40 % dilution bead runs as close to bead bands as possible (Figure 5.39). These were converted to densities via the selected line:

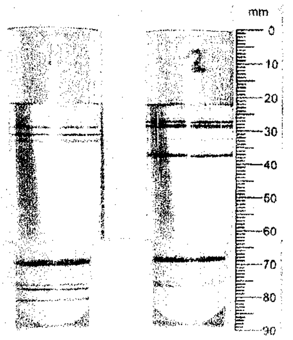

***Figure 5.39**: Density marker bead trials for 40% (1) and 20% (2) dilutions of SIP*

$$\rho = 7.0002 \cdot n - 8.3815 \quad (5.4)$$

where ρ = the density, g/mL and n = the refractive index of the sample, as described earlier.

A summary of the results of this trial are shown in Table 5.7. Despite the problem of exact level extraction with the Pasteur pipette, the results prove both the efficiency of the conversion line and the extraction/refraction method.

***Table 5.7**: Comparison of densities from refractive index sampling to density marker beads (using $\rho = 7.0002\,n - 8.3815$)*

		REFRACTIVE INDEX DENSITY RESULTS			
BEAD	**Density**	**40% Dilution**		**20% Dilution**	
COLOUR	**ρ g/mL**	**ρ g/mL**	**% Variation**	**ρ g/mL**	**% Variation**
Blue	1.080	1.0933	1.23%	-	-
Orange	1.100	1.0975	-0.23%	1.1073	0.66%
Green	1.109	1.1073	-0.15%	1.1073	-0.15%
Red	1.132	1.1325	0.04%	1.1248	-0.64%
Violet	1.150	1.1451	-0.43%	1.1500	0.00%

5.6.4 Site Sample DGM Trial Results

The DGM trial results for the 12 Aug 01 samples as shown pictorially in Figures 5.39 and 5.40 which follow. Letters on cells are referenced in Table 5.8.

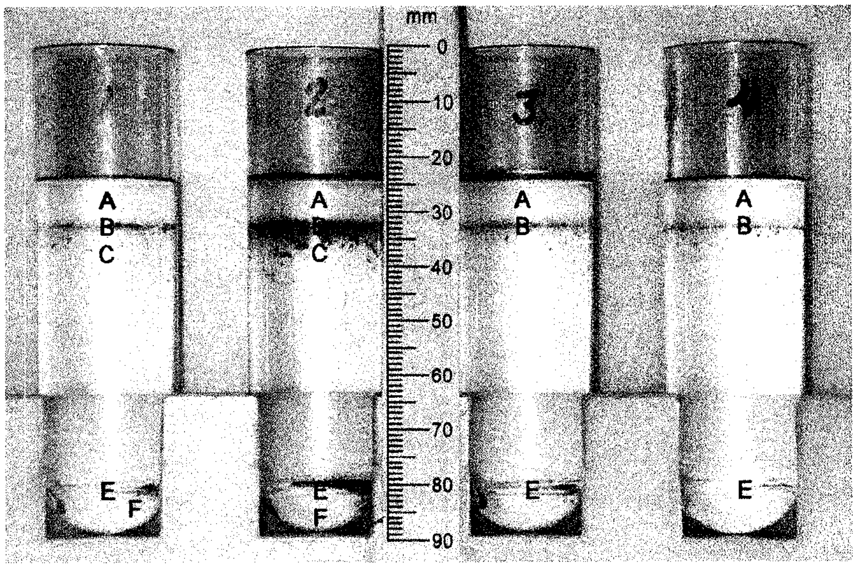

Figure 5.40*: Post-centrifuge tubes 1-4. 30% dilution of SIP with 0.25 M sucrose. 1: 70-179 µm, 2: 41-179 µm, 3: 30-41 µm, 4: 20-30 µm (letters and tubes refer to Table 5.8)*

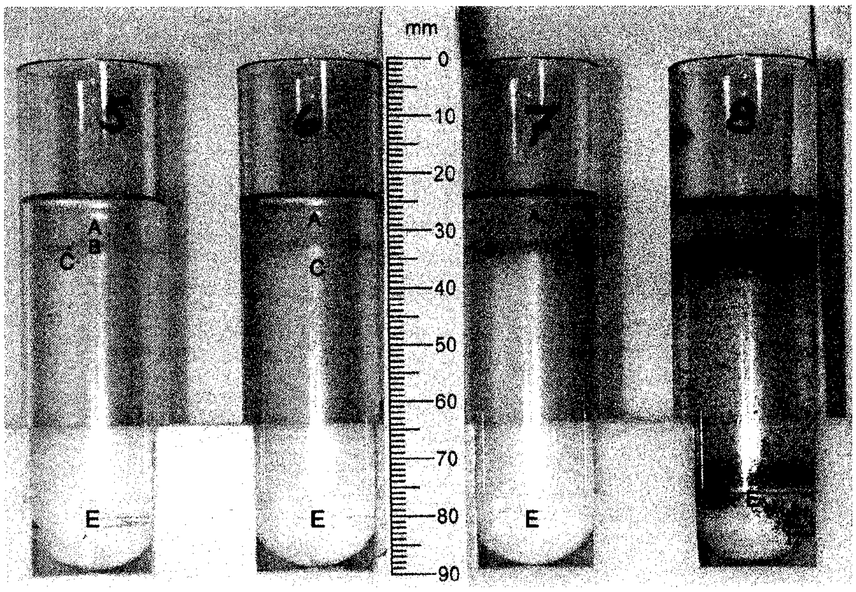

Figure 5.41*: Post-centrifuge tube 5-8. 5-7; 30% dilution of SIP with 0.25 M sucrose. 5: 10-20 µm, 6: 5-10 µm, 7: < 5 µm; 8: no dilution, > 179 µm (letters and tubes refer to Table 5.8)*

Table 5.8: *Densities (Rho) and descriptions for vertical locations in the 30% dilution centrifuge tubes of the 12 Aug 01 site samples. (dfm = distance from the meniscus)*

	Tube 7: <5 um			Tube 6: 5-10 um			Tube 5: 10-20 um			Tube 4: 20-30 um		
	dfm	**Rho**	**Description**	**dfm**	**Rho**	**Description**	**dfm**	**Rho**	**Description**	**dfm**	**Rho**	**Description**
Loc	mm	g/mL		mm	g/mL		mm	g/mL		mm	g/mL	
A	3.1	1.035	haze	3.5	1.035	haze	3.0	1.035		3.0	1.041	
B	9.0	1.050	light floc	8.0	1.053	floc, lt tan	8.5	1.048	yellow floc	7.6	1.044	floc line
C	11.0	1.068		11.5	1.068		10.5	1.069	scattered particles	12.5	1.062	fewer flocs
D												
E	55.5	1.154	very lt red-brown	56.0	1.161	very lt red-brown	56.0	1.156	lt red-brown	55.5	1.157	brown floc
F												

	Tube 3: 30-41 um			Tube 2: 41-179 um			Tube 1: 70-179 um		
	dfm	**Rho**	**Description**	**dfm**	**Rho**		**dfm**	**Rho**	
Loc	mm	g/mL		mm	g/mL		mm	g/mL	
A	2.7	1.038		3.0	1.038		3.0	1.040	
B	7.5	1.048	floc line	7.5	1.060	hy yellow-brown floc	8.0	1.048	hy green-brown floc
C	12.5	1.083	fewer flocs	13.0	1.079	large flocs	13.5	1.083	large flocs
D						scattered sm flocs			scattered sm flocs
E	55.5	1.163	brown floc	56.0	1.142	red-brown floc	56.0	1.140	red-brown floc
F				60.5	1.170		60.0	1.167	

Figures 5.39 and 5.40, and Table 5.8 indicate that there are main two bands of solids in the samples, one at B at about 1.05 g/mL and a second at E at 1.15 g/mL, plus a scattering of particles between these bands. Table 5.9 gives the averages and standard deviations of the readings in these two bands. Again, despite the difficulty of restricting the sample to the target layer with a Pasteur pipette, the results show good repeatability.

***Table 5.9**: Bands B and E derived densities for 12 Aug 01, Site C1 samples*

Class\Zone	**B**	**E**
< 5 µm	1.050	1.154
5-10 µm	1.053	1.161
10-20 µm	1.048	1.156
20-30 µm	1.044	1.157
30-41 µm	1.048	1.163
41-179 µm	1.060	1.142
70-179 µm	1.048	1.140
Average	1.050	1.153
Std Deviation	0.005	0.009

As one moves to the finer screens the E bands get smaller until in the final < 5 µm tube it is barely detectable. The B bands show in approximately the same relative strengths as in the washed-filter samples (Figures 5.33 and 5.34). There is a scattering of particles between the two bands. A reason for this phenomenon is suggested in Section 5.7.

5.6.5 Feed Trial

An earlier feed trial results are given in Table 5.10 and Figures 5.41, 5.42 and 5.43. A summation of two bands is presented in Table 5.10. To remind, the dilutions (e.g. '40%') refer to the dilution of SIP with 0.25 M sucrose solution.

***Table 5.10**: Bands A/B and E/F derived densities for 30 Jul 01 feed samples*

	40% Dilution		20% Dilution	
Class\Zone	**A/B**	**E/F**	**A/B**	**E/F**
< 5 µm	1.060		1.077	
5-10 µm	1.077		1.098	
10-20 µm	1.076	1.149		
20-30 µm	1.076	1.146		
30-41 µm	1.084	1.135	1.097	1.160
41-179 µm	1.076	1.139	1.102	1.159
Average	1.076	1.142	1.094	1.160
Std Deviation	0.006	0.006	0.011	0.001

The upper bands were generally hazes but the 'brown' particles band appeared in the E/F range. In the 40% dilution, the average density was read at 1.142 g/mL (S.D = 0.006), although two runs of the larger particles did give a value close to that of the site samples. The technique could have influenced the outcome as this was an earlier trial.

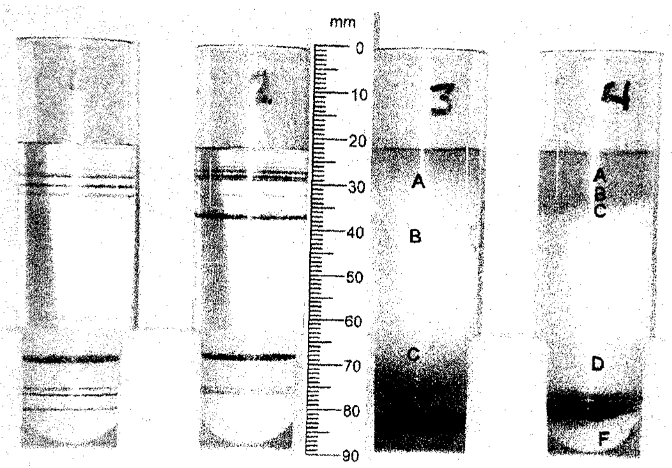

***Figure 5.41**: 1:Beads in 40% 0.25 M sucrose; 2: Beads in 20%; 3; wash from 41 μm screen in 40%; 4: wash from 41 μm screen in 40%*

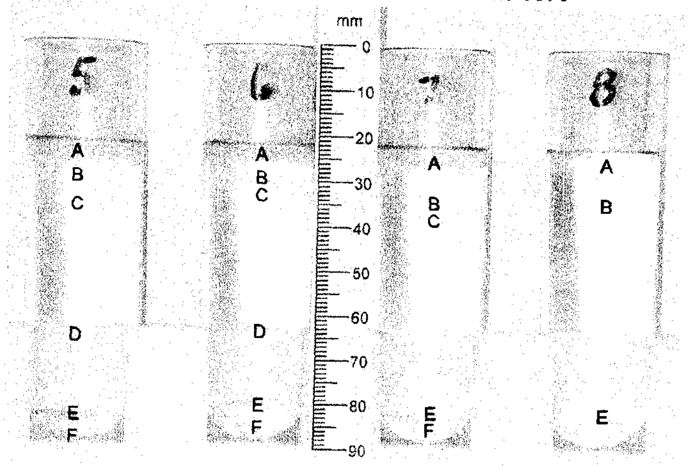

***Figure 5.42**: Wash from 30 μm screen on 40 % 0.25 M sucrose; 6: wash from 30 μm screen in 20%; 7: wash from 20 μm screen in 40%; 8; wash from 10 μm screen on 40%*

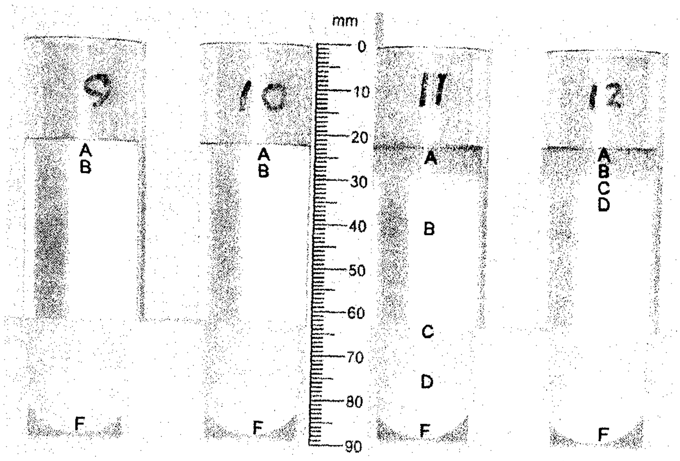

***Figure 5.43**: 9: wash from 5 μm screen in 40 % 0.25 M sucrose; 10: wasn from 5 μm screen in 20 %; 11: wash from 0,45 μm filter in 40 %, 12: wash from 0.45 μm filter in 20%*

Table 5.11: DGM feed trial results. Tube numbers and letters refer to Figures 5.41, 5.42 and 5.43

40 % 0.25 Sucrose dilution of SIP

	Tube 11: <5 um			Tube 9: 5-10 um			Tube 8: 10-20 um		
	dfm	Rho	Description	dfm	Rho	Description	dfm	Rho	Description
Loc	mm	g/mL		mm	g/mL		mm	g/mL	
A	0.5	1.060	light haze	1.5	1.077	haze	1.5	1.076	band white haze
B	17.5	1.062	scattered particles	4.5	1.114	haze line	11.5	1.088	thin white line
C	42.5	1.070							
D	52.5	1.076							
E							59.5	1.149	brown flecks
F	65.0	1.160		64.5	1.153				

	Tube 7: 20-30 um			Tube 5: 30-41 um			Tube 3: 41-179 um		
	dfm	Rho	Description	dfm	Rho	Description	dfm	Rho	Description
Loc	mm	g/mL		mm	g/mL		mm	g/mL	
A	2.5	1.076	haze	2.0	1.084	light haze band	0.5	1.076	light haze band
B	11.5		few flecks	7.5		light floc	17.5	1.097	scattered particles
C	15.5	1.090	haze	13.0	1.095	specks	42.5	1.110	light particles
D				43.0	1.110	specks, generally	52.5	1.123	more brown particles
E	59.5	1.146	few brown flecks	60.0	1.135	band brown flecks	59.5	1.139	brown layer
F	64.5	1.160		65.5	1.149		64.0	1.139	clearer, particles

20 % 0.25 Sucrose dilution of SIP

	Tube 12: <5 um			Tube 10: 5-10 um			Tube 6: 30-41 um			Tube 4: 41-179 um		
	dfm	Rho	Description	dfm	Rho	Description	dfm	Rho	Description	dfm	Rho	Description
Loc	mm	g/mL		mm	g/mL		mm	g/mL		mm	g/mL	
A	0.5	1.077	surface	1.5	1.098	haze	1.0	1.097	light haze band	1.0	1.102	haze
B	2.5	1.090	haze	5.0	1.114	haze line	6.0		floc	4.0	1.103	clearer band
C	7.0	1.097	thin line of specks				8.5	1.107	haze	9.0	1.118	light floc
D	10.5	1.112					41.0	1.114		43.0	1.131	some particles
E							58.0	1.160	brown flecks	56.0	1.159	heavy brown flecks
F	65.5	1.191		65.0	1.167		65.0	1.174		66.0	1.201	Some particles

5.7 MICROSCOPY

5.7.1 Light Microscope

General Nature Of Aquaculture Particles

Figures 5.44.and 5.45 show the variety of shapes and sizes of solid particles that can be expected in culture waters such as at the Merlin plant. The shapes vary from long spicule-like particles that appeared to be in evidence at all levels to sand-like particles. The 'spiculas' seem to be able to slip through screens, perhaps end-on.

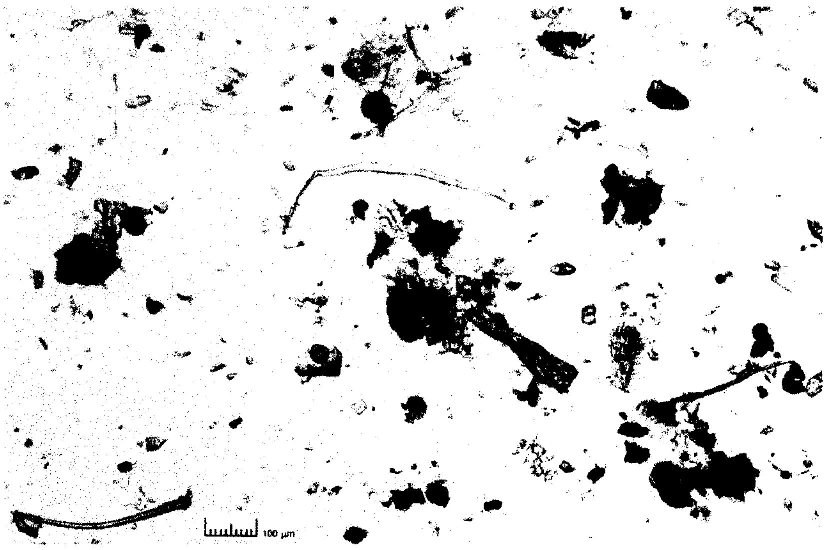

***Figure 5.44**: Particles in aquaculture waters*

The white, light and dark brown, sand-like particles also appear at all levels, although in continuously reduced sizes. These are not sand as will be shown later.

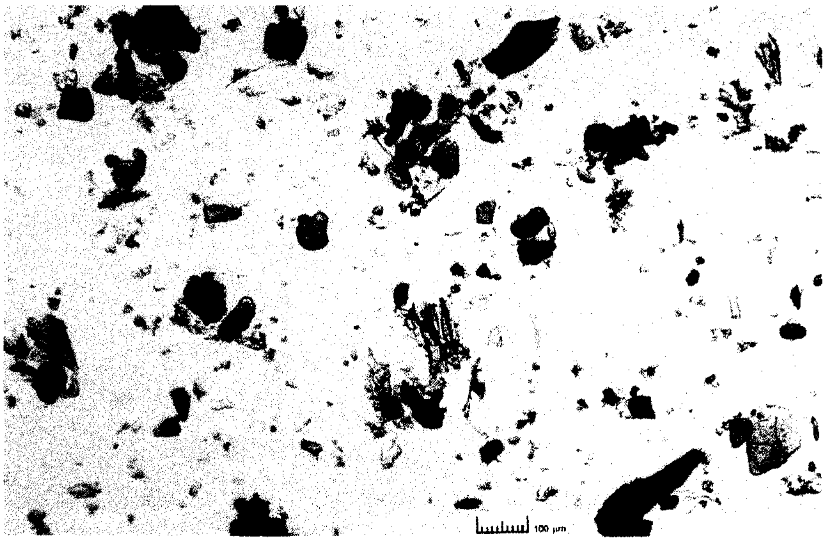

***Figure 5.45**: Particles in aquaculture waters*

A more concentrated view of the range and typed of larger particles is shown in Figures 5.46 and 5.47 which have been captured on a 70 μm screen from water coming from the B Line aerator/degasser.

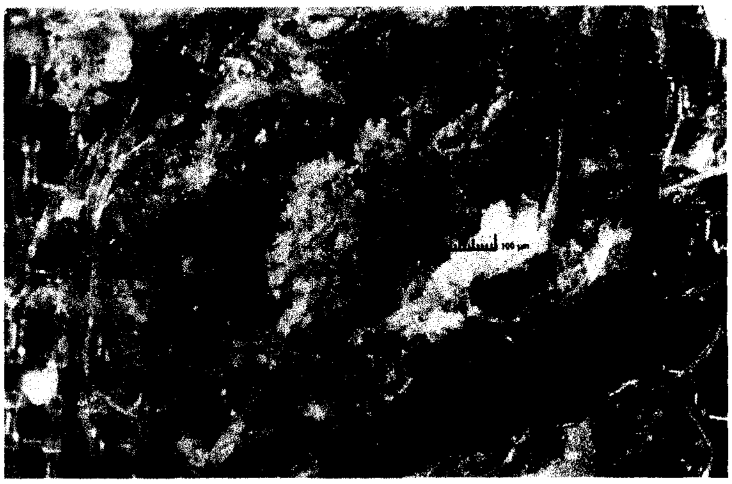

***Figure 5.46**: G_B sample, 70 μm screen, 11 Jun*

***Figure 5.47**: G_B sample, 70 μm screen, 11 Jun*

Figure 5.48 is a photo of some of the smaller particles captured on a 0.8 μm filter from water in the juvenile tanks.

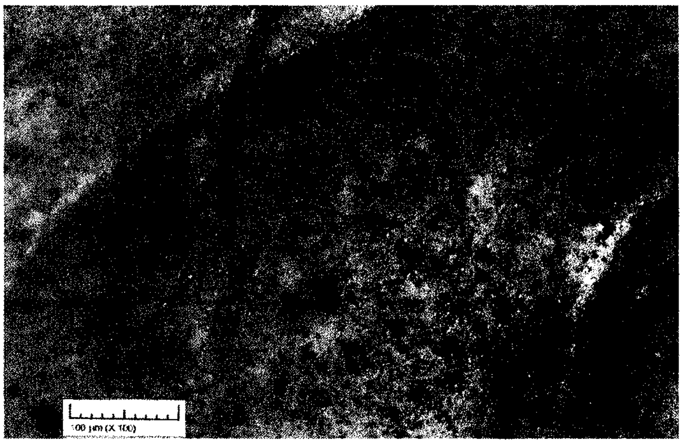

***Figure 5.48**: Site sample on a 0.8 μm filter, 11 Jun*

Site Sample Screens

As mentioned in Section 5.4, the wash screens of the site samples appear to be coated with a viscid material. This can be seen as a glaze on the fine filter in Figure 5.48 and is shown again in the webs of Figure 5.49 In many photos, this material traps particles of a size that normally would pass through. When the stain Thionin is applied to the mesh (Figure 5.50) this material tends to take on the stain, indicating that the material is of a carbonate nature. Lighting conditions and rendition do vary somewhat in the photography and processing, but the colour could be said to tend to the pink versus the blue.

***Figure5.49**: 70 µm screen, 12 Aug 01 site sample, showing viscid material, trapped brown particles*

***Figure 5.50**: 70 µm screen after Thionin staining*

This may be more evident in the next set, Figures 5.51, 5.52 and 5.53. In Figure 5.51, the clogging is evident on an unstained 41 µm screen. In Figure 5.52, the screen has been stained and the 'pink' is definitely

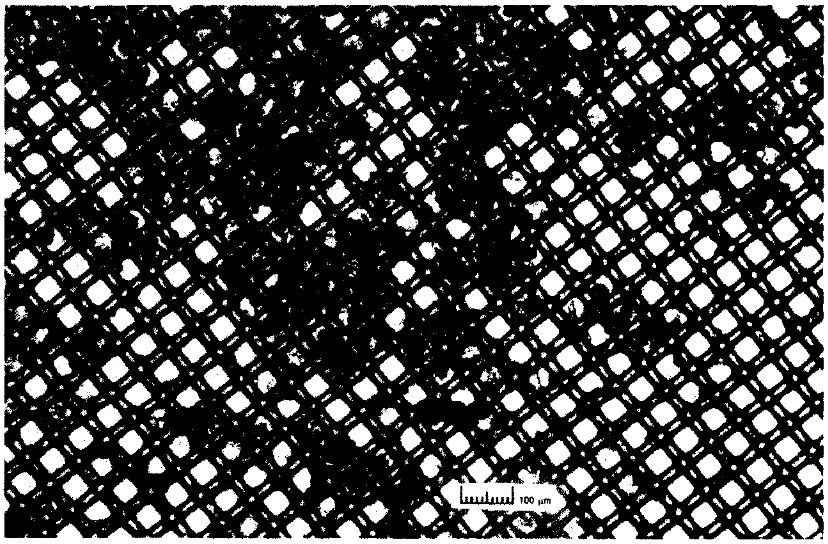

***Figure 5.51**: 41 µm screen, 12 Aug 01 site samples*

noticeable. Figure 5.53 is a magnification of Figure 5.52 (pink mark in the lower right of Figure 5.53 is that just above the centre in 5.52). In Figure 5.53 both pink and blue are evident. The blue sites are most probably starches and the pink materials are acidic polysaccharides as discussed in Subsection 4.8.1. Further comment on this will be made later.

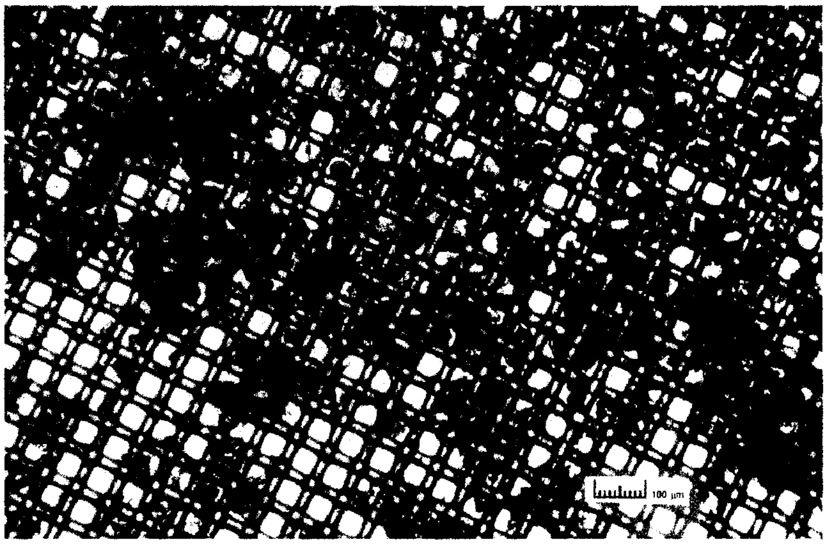

***Figure 5.52**: Figure 5.51 stained with Thionin.*

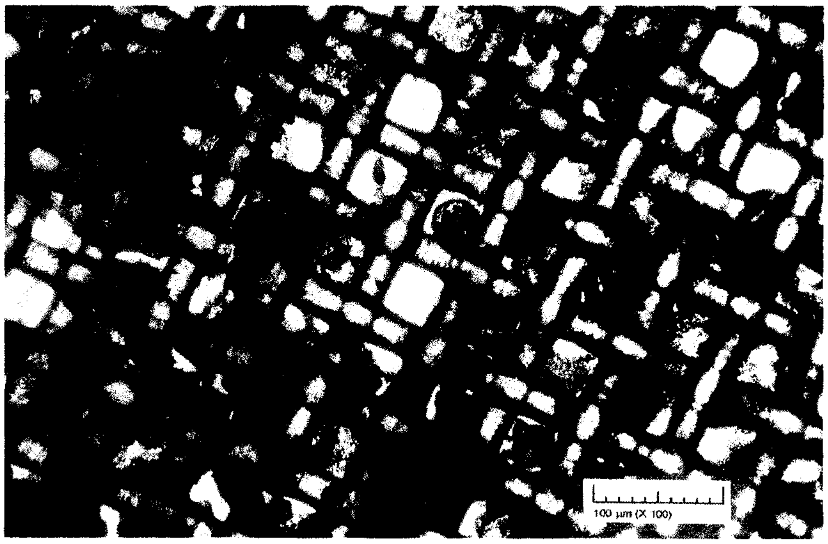

***Figure 5.53**: Magnification of Figure 5.52.*

Feed Sample Screens

Figures 5.54 to 5.55 are views of screens used in separations. Figure 5.54 is the general 'rubble' collected after stirring feed in DDW (see Subsection 5.6.1). Figure 5.55 is another part of the same mesh after an application of Thionin. In this case the application was excessive. However, generally the dark brown particles did not stain but the lighter particles did. The overwhelming colour appears to be a deep shade of blue.

***Figure 5.54**: 'Rubble' from feed stirred in DDW on a 70 µm mesh.*

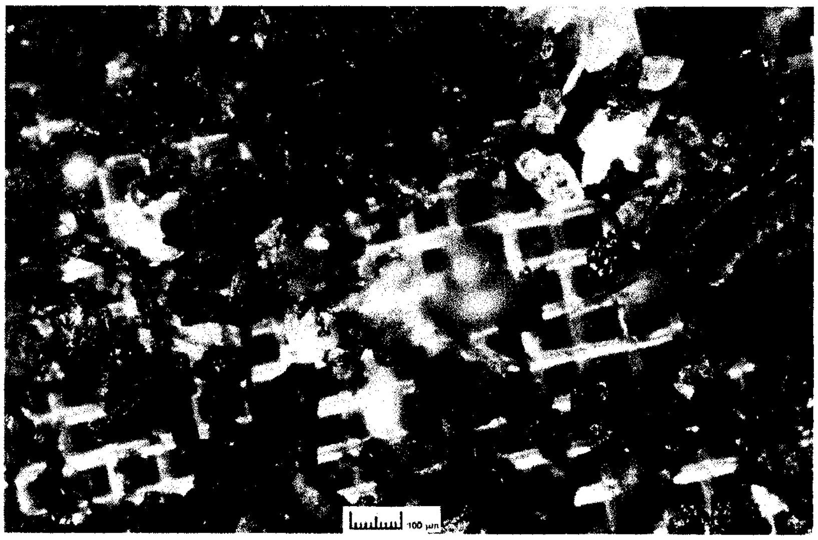

***Figure 5.55**: Same mesh as for Figure 5.54, stained with Thionin.*

Figure 5.56 is a top-lit shot of another area of the same mesh. (Ignore the blue tinge; it is caused by the lighting). On it the viscid 'web' clogging the mesh can be seen clearly holding particles which are smaller that the mesh size and would normally pass through. Figure 5.57 is a photo of the same area after the application of Thionin. The web appears to be made of a carbohydrate, probably modified starch.

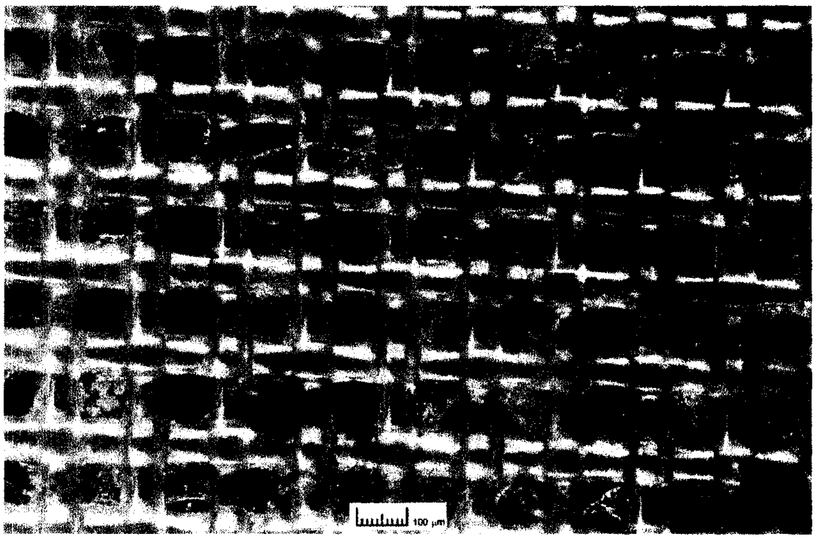

***Figure 5.56**: Feed sample 70 μm mesh.*

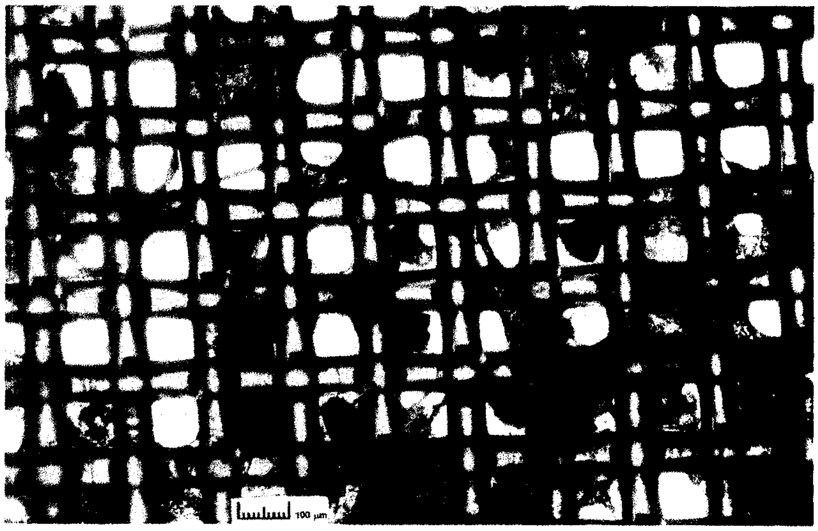

***Figure 5.57**: Same area as Figure 5.56 after Thionin application.*

Post-DGM Microphotography

E Band

Figures 5.58 to 5.60 are microphotographs of E band fractions for 41-179 µm, 30-41 µm and 10-20 µm respectively. The particles are mainly similar brown bits which get smaller and fewer as the fraction size diminishes, as would be expected. Figure 5.61 shows a sample of the feed which settled out in the E band. The similarity is evident.

***Figure 5.58**: E band particles in the 41-179 µm fraction*

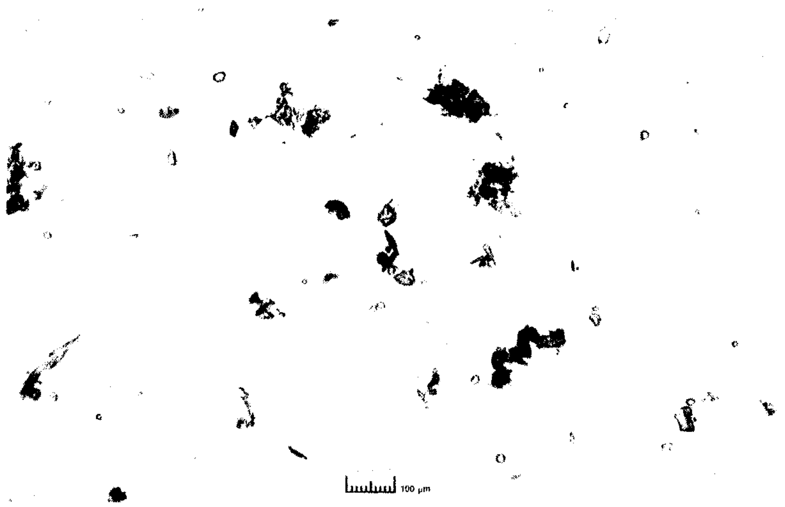

***Figure 5.59**: E band particles in the 30-41 µm fraction.*

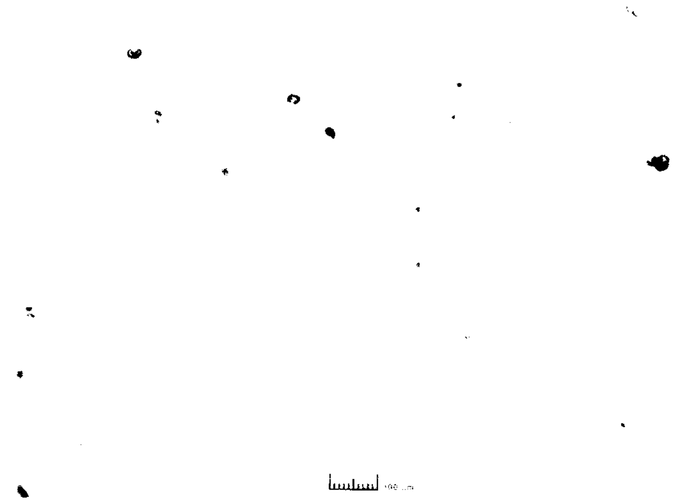

***Figure 5.60**: E band particles in the 10-20 μm fraction of the 12 Aug site sample.*

***Figure 5.61**: E band particles in the 41-179 μm fraction of a feed sample.*

B Band Site Samples

Representational B band flocs are shown in Figure 5.62 to 5.64. Figure 5.62, although stained with Neutral Red also represents an unstained sample as there was no reaction to the stain. No oils or waxes appear present. It is expected that, by this stage, oils will have percolated off to the surface of the culture water and washed away.

The flocs are loose collections of very fine particles held in a mat of viscid material. Bonds seem to be weak as stirring disturbs them. Some discrete particles are observed not in flocs.

Figure 5.63 has had Thionin applied and 5.64 has been stained with Methylene Blue. The bonding material reacts in both cases, in the former case, more pink that blue. The stains suggesting that both acidic polysaccharides and proteins make up the bonding material.

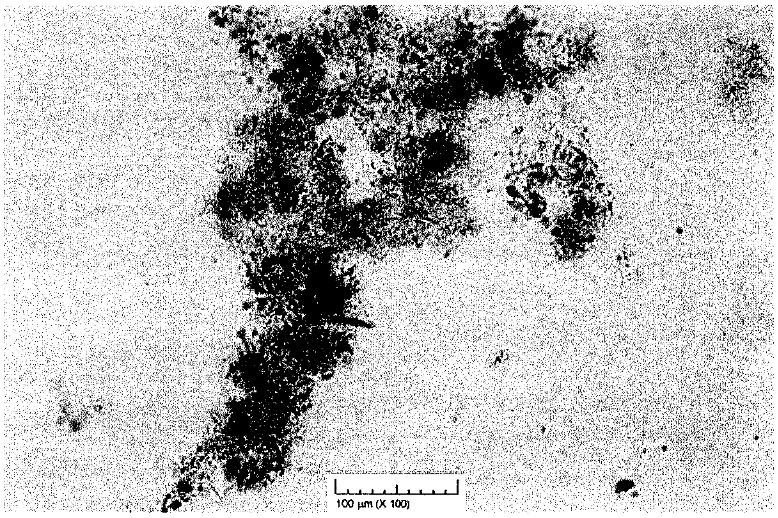

***Figure 5.62**: B band floc from the 41-179 µm fraction of 12 Aug sample. Neutral red stain applied.*

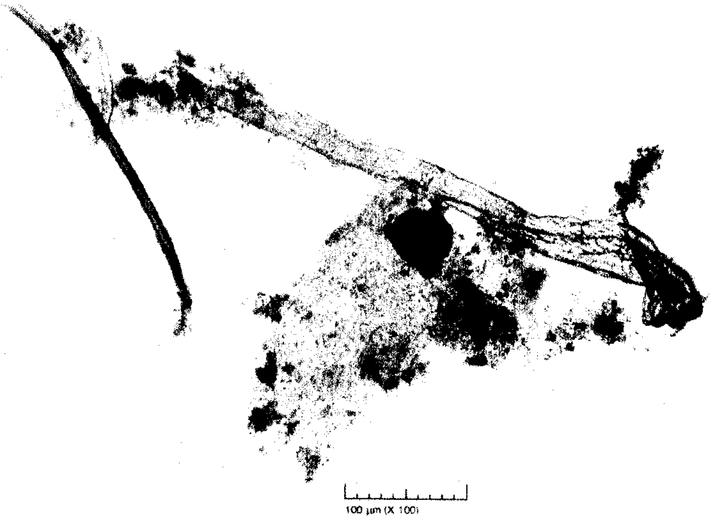

***Figure 5.63**: B Band floc from the 41-179 µm fraction of 12 Aug sample. Thionin stain applied.*

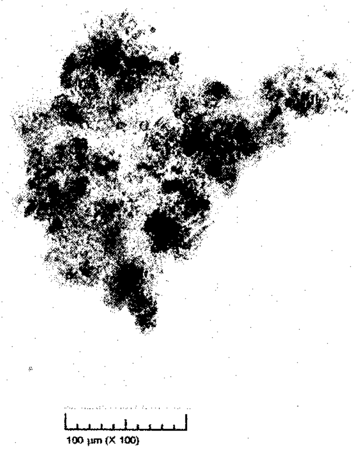

***Figure 5.64**: B band floc from the 41-179 µm fraction of 12 Aug sample. Methylene blue stain applied.*

There are flocs present below and above this band but in much lower quantities. The major portion is concentrated in the band (see Figures 5.39 and 5.40). These 'errant' flocs look the same. It is surmised that minor differences in the type and quantity of particles a given floc collects determines its final density.

B Band Feed Samples

Selected examples of flocs from feed samples from the DGM trial are shown in Figures 5.65 and 5.66 They are very similar to those in the previous subsection except that in Figure 5.66 the Neutral Red stain took, indicating that these flocs hold some oils. Figure 5.65 has had a Thionin application and shows that acidic polysaccharides are present.

***Figure 5.65**: Feed test floc site 7B with Thionin applied.*

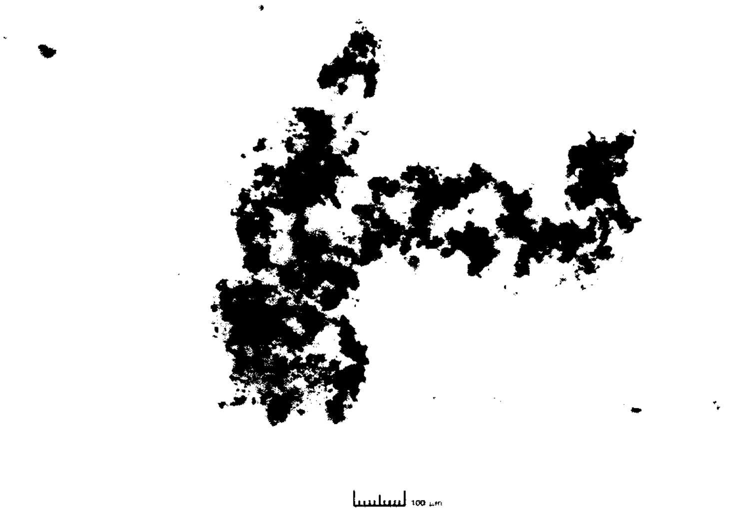

***Figure 5.66**: Feed test floc site 7B with Neutral Red applied.*

5.7.2 Electron Microscope

As discussed in Subsection 4.8.2, the scanning electron microscope examinations could not be completed. The following is offered to show potential. Figure 5.67 is a scan of particles from aquaculture waste water captured on a 0.8 μm cellulose filter. This scan is shown at two different scales, inputted in the controlling software.

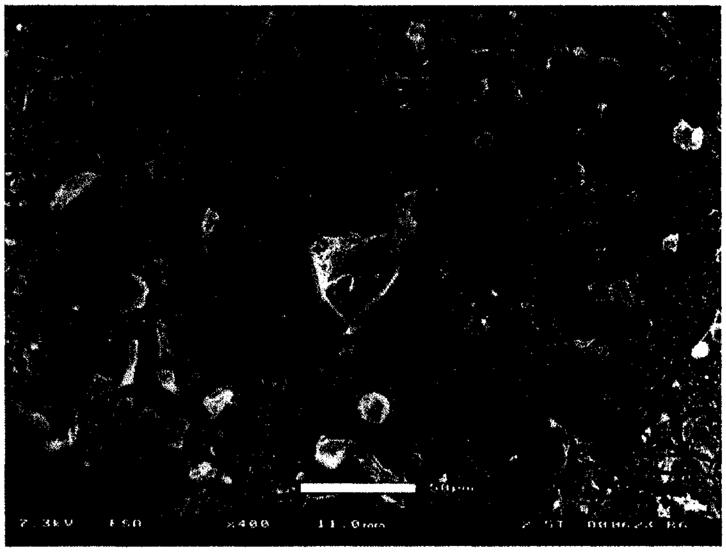

***Figure 5.67**: SEM photo of a grain particle on a 0.8 μm mixed esters of cellulose filter.*

The coating of the filtering material with a viscid material has been mentioned several times previously. Figure 5.67 is of a filtered that has been dried at 105 °C for a minimum of one hour. The viscid coating is clearly shown, including areas where it experienced heat/drying cracking.

***Figure 5.68**: SEM scan of the grain in Figure 4.n.1 at an increased magnification*

Figure 5.68 is a second scan of the grain in the centre of Figure 5.67 at an increased magnification. Figure 5.69 is the associated elemental spectrum for the grain shown above. A scan of a clean filter is required so that the background can be discounted and this was not done

In any event, this specimen, appears to be carrying considerable phosphorus and calcium. The carbon and oxygen could reflect the carbohydrates in the particle. This is an area of interesting future work.

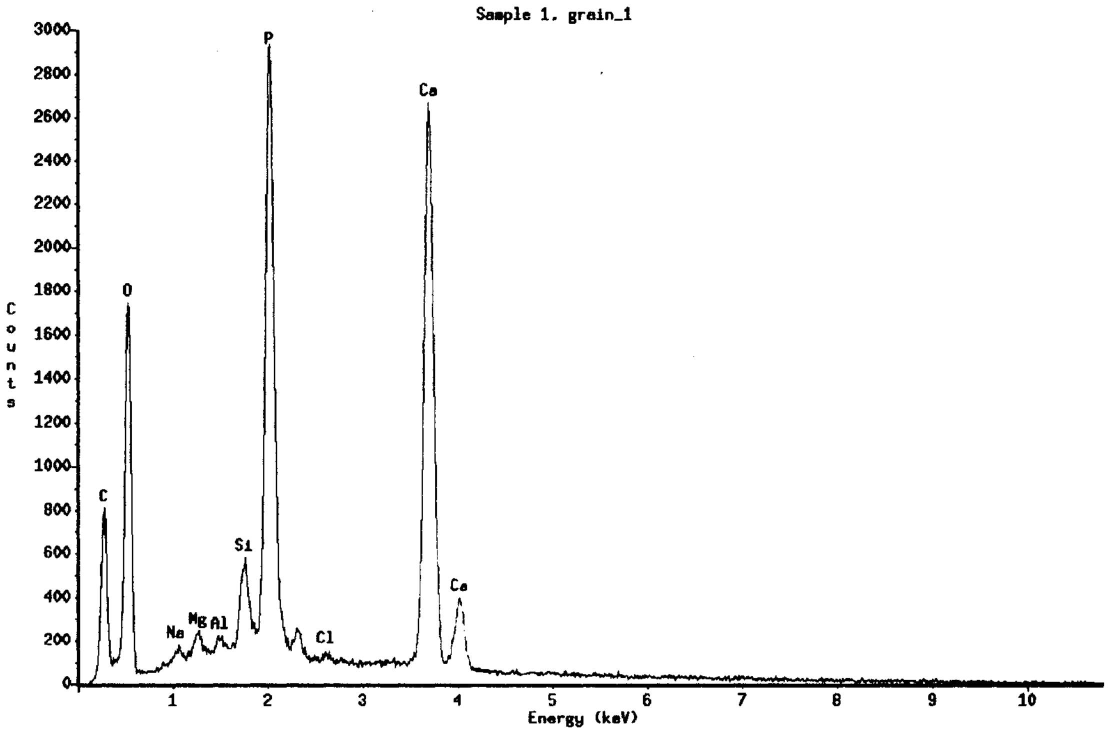

***Figure 5.69**: The SEM spectrum for the grain particle pictured in Figure 5.68.*

CHAPERT 6 - DISCUSSION

6.1 RELATED INFORMATION ON MUCUS AND FEED

The nature of the observations in Chapter 5 caused the author to investigate further into mucus and the nature of the feed. Discussions were held with Dr. Santosh Lall of NRC and Mr. J. Mann of EWOS Canada Ltd of Surrey, BC, suppliers of feed to the site under study.

6.1.1 Mucus

Mucus is usually a clear, viscid[1] secretion. It is a protein-zoopolysaccharide complex. (Pigman and Platte, 1957). The carbonate component is a mucopolysaccharide, also called a glycoaminoglycan (Abercrombie *et al.* 1985) or proteoglycan. Hyaluronic acid is involved which binds large amounts of water and forms gels (Hodge and Osman, 1976).

Sources of mucus in this aquaculture system include that naturally produced by the fish and used to sheath faecal casts (probably the primary source), and that in the fish meal used to make the feed (about 50% of the feed composition (J. Mann, EWOS, pers. comm.)).

6.1.2 Nature of the Feed

Beyond the composition of the EWOS Transfer feed used in this plant, given in Table 4.1, EWOS (J. Mann, EWOS, pers. comm.) informed the author that this feed is an extruded feed (see Section 2.1) which included whole wheat ground to a mean particle size of 300 to 400 μm. With 50% fish meal being used in its production, the ash portion includes bone fragments which are only partiality utilized by the fish. The extrusion process gelatinizes over 90% of the starches.

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[1] Viscid: sticky or adhesive; mucilaginous, viscous. Standard College Dictionary, Cdn Ed. Funk & Wagnalls

Dr. Lall (S.P. Lall, NRC. pers. comm.) advised that the whole wheat component introduces a heavy cellulose component that does not break down in the digestive tract, is not altered in the fish digestion and does not stain. The predominant colour of the particles would probably be brown. The gelatinized form of the starches would be viscid.

6.2 THE NATURE OF THE PARTICLES

The above statements lead the author to conclude that the heavier particles in the culture waters (about 1150 kg/m^3) are composed mainly of wheat-related heavy cellulose particles in the feed, primarily from the undigested portion of the feed that passed through the fish, with a small, variable portion coming from the disintegrating uneaten feed in the system waters.

The lighter material (about 1050 kg/m^3) is composed of fine particles which tend to form weak flocs when undisturbed.

The viscid material that clogs screens is primarily mucus produced by the fish to sheath faeces , with secondary sources of that undigested in the fish meal portion of the feed, and undigested portion of the feed gelatinized starches. It is composed of protein-polysaccharide complexes. It also forms the binding material for the lighter material flocs.

In support of these views, the following comments are noted:

Westers (1992) stated that particulate removal below about 40 µm are not now removable economically (Section 1.1). That was the inspiration for this study. Recently Vinci *et al.* (2001) noted that drum filters have a finite pore size limit in the 60-100 µm range "beyond [read 'below'] which increased filtration effort no longer improves solids removal".

It would appear that, besides the natural increased resistance of smaller meshes (Section 5.4), these devices suffer clogging due to the viscid matter in the water.

Based on the above observations, the following question was put to the Merlin site manager:

> "Do you find your drum filters screens coated after a season and requiring some heavy duty cleaning?"

Answer:

> "Yes, we do need to give our drum filters an extra cleaning each season because of the mucus on the screens." (F. Merlin, pers. comm)

6.3 PARTICLE REMOVAL

As a results of this study, it is considered that the heavier fraction can continue to be removed by mechanical means such as the drum filter down to the present economical size of 50 µm. In the gravimetric trials, though the 70 and 41 µm screens collected a mucus web, they did not clog.

Of the methods reviewed, only flocculation, in one of its forms, holds any promise of success in economically removing the lighter particles. In this, the glycoprotein mucus with its tendency to floc, should be particularly valuable.

CHAPTER 7 - CONCLUSIONS, CONTRIBUTIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

It turned out that the Merlin Fish Farms recirculating aquaculture site at Greenville station is not a recirculating aquaculture plant in the strictest sense. Whereas normally under 10% of the water in a cycle is make-up water, the flow rate is such that between 100 and 200% of the total plant water capacity was replaced in 24 hours.

The main source of particles in the Merlin recirculating plant is from the feed, primarily from the undigested portions thereof, and secondarily from the breakdown of waste feed particles. The particles display in two modes. The heavier mode has a density of 1160 kg/m^3 and is composed of undigested feed particles, mostly the heavy cellulose fraction of the whole wheat ingredient but also containing some undigested bone matter. In the lighter mode (1060 kg/m^3) fine particles are easily and loosely flocculated.

There is a viscid component to the waste which appears to be mucus with an small component of gelatinized starches.. The mucus is a glycoprotein (protein-polysaccharide complex) which coats screens. Screens 40 μm and above appear to be able to cope with this material and function until cleaned at the season's end, but smaller screens easily clog completely. It is for this reason that gravimetric analysis of solids is unsuitable for this water. This material also forms the bonding agent for the light particle flocculation. There are heavier and lighter flocs of lower quantities, probably based on the nature of the particles picked up in the floc, but 1060 kg/m^3 is the mean of the majority. These particles seem to be associated with a feed-related peak in the particle size distribution between 3 and 5 μm.

Normal mechanical separation methods such as the drum filter will suffice for the heavier particles down to and somewhat below screen mesh size, due to the viscid material capturing smaller particles. For the lighter particles, flocculation appears to be the only solution now available to remove them. The protein nature of the viscid material in the water should assist this method. The ozone-based, in-house designed, foam fractionator on site has yet to be put into service.

Nutrients associated with solids appeared to vary as a percent of the total from between 10 and 60% of the total load, but in absolute terms (e.g. mg/L), the solids remain relatively stable regardless of the changes in total load.

The near-hyperbolic nature of the particle size distributions in this water, postulated in Patterson *et al.* (1999), holds despite the feed-induced spike at 3-5 µm noted above. Due to the flushing of the system noted in the first paragraph, the fines never built up to the point of moving the Beta values up to 3, let alone beyond.

The return lines from the tanks, especially the bottom water line, act as settling troughs for larger solids such as faecal casts. After a build-up period the flow path restriction increases the flow rate to a point where the build-up waste randomly lets go, pushing a plume of solid wastes through the system at approximately 30 times the normal loading. This phenomenon could probably have been avoided with better waste line pipe size selection so as to keep the flow rate up in each section.

There is a suggestion of a relationship between ORP and TSS, but the TSS test as used is too imprecise at these loading levels to be conclusive.

Due to the generally low loadings of solids, the use of the Hach Digestdahl for TKN assessments was unsuccessful as the technique now stands.

7.2 CONTRIBUTIONS

In this study, this author contributed to the sum of knowledge in this field in the following ways;

- carried out a comprehensive study of a commercial Atlantic salmon smolt recirculating plant in Atlantic Canada,
- determined the density, source and description of the major micro-particles load in the culture water of such a plant and related this data to feed input,
- determined and confirmed the near-hyperbolic nature of the particle size distribution in finfish aquacultural systems,
- produced information and data on:
    - the methodology for density determination in culture waters:
        - actual flows, feed input, a dn related biomass,
        - associated water quality data: nutrients, solids streams; details on solids associated nutrients, pH, ORP.
        - system particle size distributions, and
- produced a large quantity of microphotographs of waste and feed particles in system waters.

7.3 RECOMMENDATIONS FOR FURTHER WORK

- Carry out a trial using the in-house foam fractionator and a commercial fractionator to determine the relative effectiveness on small particles in this plant.
- Model the processes of the fractionators.
- Repeat the DGM experiments to confirm the densities derived.
- Complete the particle make-up investigations, including
    - the electrostatic nature of the particles
    - scattering electron microscope analysis of selected, common particles.
- Further study leading to modelling of individual, selected components of the system.
- Determine why the water exiting the culture tanks has a lower phosphorus load than that entering.

- Study of the relationship of the ORP to the conditions existing at each stage of the culture water circuit.
- Conduct an experiment to test the relationship between ORP and TSS.
- Devise a technique to obtain valid determinations of TKN using the Digesdahl apparatus.

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APPENDIX A

SYSTEM CAPACITIES

MERLIN FISH FARMS
GREENVILLE STATION, NS

Capacities, Merlin's Recirc Plant
With 2nd Drum Filter out of the Circuit

Major Items

Item	No.	Vol ea, L	Total, L
Culture Tanks	12	22054	264653
Swirl Separator	1	12723	12723
Stand Pipe	1	237	237
Drum Filter 1	1	656.3	656
Drum Filter 2	0	378.8	0
Settle Deck	1	11165	11165
Biofilter	2	11451	22902
Oxgenator	2	624	1248
Total			313585

Piping **Sch. 40**

Item	No.	Nom.Dia	ID, in	Area, m^2	Length, m	Fill	Vol, m^3	Vol, L	Remarks
Supply, pump - biofilter, A Line	1	6	6.065	0.0186	24.00	1	0.447	447.2	from sump water surface
Supply, pump - biofilter, B Line	1	6	6.065	0.0186	18.00	1	0.335	335.4	from sump water surface
Biofilter Out, Short	2	6	6.065	0.0186	1.00	0.9	0.034	33.5	
Biofilter Out, Long	2	6	6.065	0.0186	2.00	0.9	0.067	67.1	
Tank Feed Manifolds from Aerator, A,B	2	8	7.981	0.0323	29.23	0.6	1.132	1131.8	not full
Tank Feed, per tank	12	4	4.026	0.0082	2.81	1	0.277	276.9	
Midwater return feed, per tank	12	4	4.026	0.0082	5.00	1	0.493	492.7	
Midwater return trunk, A	1	8	7.981	0.0323	24.99	1	0.806	806.5	
Midwater return trunk, B	1	8	7.981	0.0323	24.99	1	0.806	806.5	
Midwater Jcn to Standpipe	1	8	7.981	0.0323	2.99	1	0.096	96.4	
Bottom water return feed	12	4	4.026	0.0082	3.42	1	0.337	337.0	
Bottom water return trunk, A	1	8	7.981	0.0323	30.39	1	0.981	980.6	
Bottom water return trunk, B	1	8	7.981	0.0323	29.20	1	0.942	942.2	
BW Return, junction to swirl separator	1	8	7.981	0.0323	2.74	1	0.089	88.5	
Swirl Separator to standpipe	1	8	7.981	0.0323	1.80	1	0.058	58.2	
Standpipe to drum filter 1	1	10	10.02	0.0509	3.62	1	0.184	184.1	
Standpipe to drum filter 2	0	10	10.02	0.0509	1.07	1	0.000	0.0	
Drum Filter 1 to Settle Deck	1	12	11.938	0.0722	1.00	0.5	0.036	36.1	1/2 full
Drum Filter 2 to Settle Deck	0	8	7.981	0.0323	2.06	0.5	0.000	0.0	
Total, Piping								7120.6	

TOTAL SYSTEM ESTIMATE **320706 L**

Capacities, Merlin's Recirc Plant
With 2nd Drum Filter Online

Major Items

Item	No.	Vol ea, L	Total, L
Culture Tanks	12	22054	264653
Swirl Separator	1	12723	12723
Stand Pipe	1	237	237
Drum Filter 1	1	656.3	656
Drum Filter 2	1	378.8	379
Settle Deck	1	11165	11165
Biofilter	2	11451	22902
Oxgenator	2	624	1248
Total			313964

Piping **Sch. 40**

Item	No.	Nom.Dia	ID, in	Area, m^2	Length, m	Fill	Vol, m^3	Vol, L	Remarks
Supply, pump - biofilter, A Line	1	6	6.065	0.0186	24.00	1	0.447	447.2	from sump water surface
Supply, pump - biofilter, B Line	1	6	6.065	0.0186	18.00	1	0.335	335.4	from sump water surface
Biofilter Out, Short	2	6	6.065	0.0186	1.00	0.9	0.034	33.5	
Biofilter Out, Long	2	6	6.065	0.0186	2.00	0.9	0.067	67.1	
Tank Feed Manifolds from Aerator, A,B	2	8	7.981	0.0323	29.23	0.6	1.132	1131.8	not full
Tank Feed, per tank	12	4	4.026	0.0082	2.81	1	0.277	276.9	
Midwater return feed, per tank	12	4	4.026	0.0082	5.00	1	0.493	492.7	
Midwater return trunk, A	1	8	7.981	0.0323	24.99	1	0.806	806.5	
Midwater return trunk, B	1	8	7.981	0.0323	24.99	1	0.806	806.5	
Midwater Jcn to Standpipe	1	8	7.981	0.0323	2.99	1	0.096	96.4	
Bottom water return feed	12	4	4.026	0.0082	3.42	1	0.337	337.0	
Bottom water return trunk, A	1	8	7.981	0.0323	30.39	1	0.981	980.6	
Bottom water return trunk, B	1	8	7.981	0.0323	29.20	1	0.942	942.2	
BW Return, junction to swirl separator	1	8	7.981	0.0323	2.74	1	0.089	88.5	
Swirl Separator to standpipe	1	8	7.981	0.0323	1.80	1	0.058	58.2	
Standpipe to drum filter 1	1	10	10.02	0.0509	3.62	1	0.184	184.1	
Standpipe to drum filter 2	1	10	10.02	0.0509	1.07	1	0.054	54.3	
Drum Filter 1 to Settle Deck	1	12	11.938	0.0722	1.00	0.5	0.036	36.1	1/2 full
Drum Filter 2 to Settle Deck	1	8	7.981	0.0323	2.06	0.5	0.033	33.2	
Total, Piping								7208.1	

TOTAL SYSTEM ESTIMATE **321172 L**

APPENDIX B

FLOW DATA

Recirculating System Flows

Total Plant Capacity

Oct-00	to	4-Mar-01	320705.589	L
4-Mar-01	to	16-Apr-01	321171.841	L *
16-Apr-01	to	21-May-01	320705.589	L

* 2nd drum filter was on line for approx. this period.

Legend:

Manager's Estimate	E
Ultrasonic Flowmeter	U
Paddlewheel Flowmeter	F
Bucket & Stopwatch	B

Recirculated water

Date	Supply			Site C			% C	Site D		
	USgpm	L/min		USgpm	L/min			USgpm	L/min	
11-Oct-00	1178	4460	U	366	1385	U	31.1%	1099	4161	U
30-Jan-01	1191	4507	U	320	1456	U	32.3%	868	3946	U
19-Mar-01	1250	4730	F	473	1790	U	37.8%	1101	4166	U
2-Apr-01	1150	4352	F	380	1439	U	33.1%	1127	4265	U
16-Apr-01	1167	4419	F	392	1485	U	33.6%	1157	4379	U
30-Apr-01	1165	4410	F	396	1499	U	34.0%	1186	4491	U
7-May-01	1155	4371	F	434	1643	U	37.6%	1272	4815	U
14-May-01	1153	4363	F	419	1585	U	36.3%	1153	4363	U
21-May-01	1153	4364	F	407	1540	U	35.3%	1173	4442	U
					Average>		34.6%			
					SD		2.4%			

New Water

Date	Big well/MUWa			House Well/MUWa1			3rd well/MUWb			Total In	Total In
	USgpm	L/min		USgpm	L/min		USgpm	L/min		L/min	L/day
11-Oct-00	75	284	E			E			E	283.9	408,823
30-Jan-01	75	284	E	20	75.7	E	20	75.7	E	435.3	626,862
19-Mar-01	75	284	E	20	75.7	E	20	75.7	E	435.3	626,862
2-Apr-01	75	284	E	20	75.7	E	20	75.7	E	435.3	626,862
16-Apr-01	75	284	E	20	75.7	E	20	75.7	E	435.3	626,862
30-Apr-01	59	222	B				21	81	B	303.0	436,320
7-May-01	40	151	E	20	75.7	E	10	37.9	E	265.0	381,568
14-May-01	22	83	B	40	151.4	E	3	10	B	244.4	351,959
21-May-01	24	90	B	40	151.4	E	3	12	B	253.4	364,919

% Recirculation

Recirc as	Recirc as
%Flow	%Cap/day
6.4%	127.3%
9.7%	195.2%
9.2%	195.2%
10.0%	195.5%
9.9%	195.5%
6.9%	136.1%
6.1%	119.0%
5.6%	109.7%
5.8%	113.8%

Outflow

Swirl	Grey/Overflow	
L/day	L/day	L/min
3500	405323	281
3500	623362	433
3500	623362	433
3500	623362	433
3500	623362	433
3500	432820	301
3500	378068	263
3500	348459	242
3500	361419	251

Notes;

1 "...a closed (recirculating) system as production unit that replace less than 10% of the total system volume on a daily basis." Losordo (1991)
2 Swirl separator flush; 1211 L/min (320 USgpm) for approximately 3 min for about 3500 L/day
3 Bottom return lines (B site) flushes were intrmiitent and indeterminant.
4 On an average, 35% of the return flow went through the swirl separator.
5 Flowmeters installed on supply lines, 8 Mar 01.
6 In the newwater, originally all water was from one or more of three wells; later some make-up water was circulated through heat exchangers to the loft nursery first, in varying amounts depending primarily on temperature requrements

Data for Flow Record Plot

Supply Lines

Date	A Line	B Line
30-Jan-01	2125	2382
19-Mar-01	2432	2298
2-Apr-01	2238	2114
16-Apr-01	2189	2230
30-Apr-01	2209	2202
7-May-01	2228	2144
14-May-01	2215	2148
21-May-01	2211	2153

Date	Total
11-Oct-00	4460
30-Jan-01	4507
14-Mar-01	4829
19-Mar-01	4730
2-Apr-01	4352
16-Apr-01	4419
30-Apr-01	4410
7-May-01	4371
14-May-01	4363
21-May-01	4364

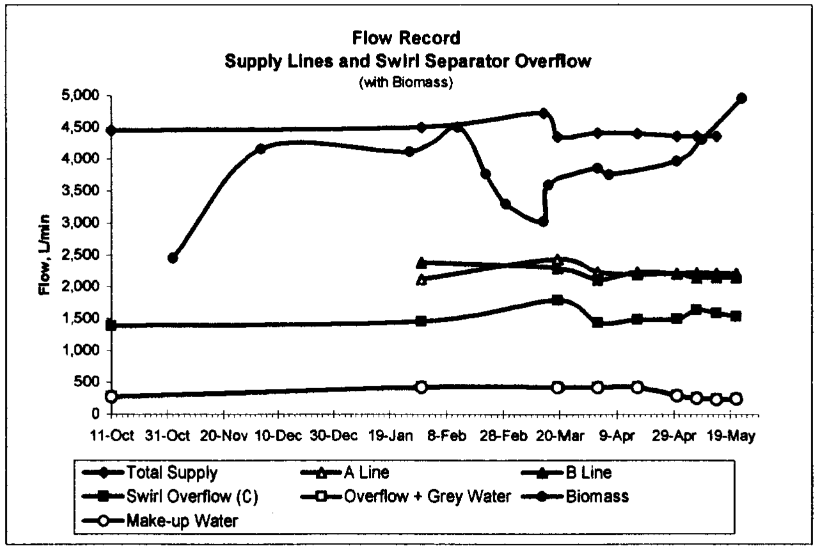
Flow, Site C

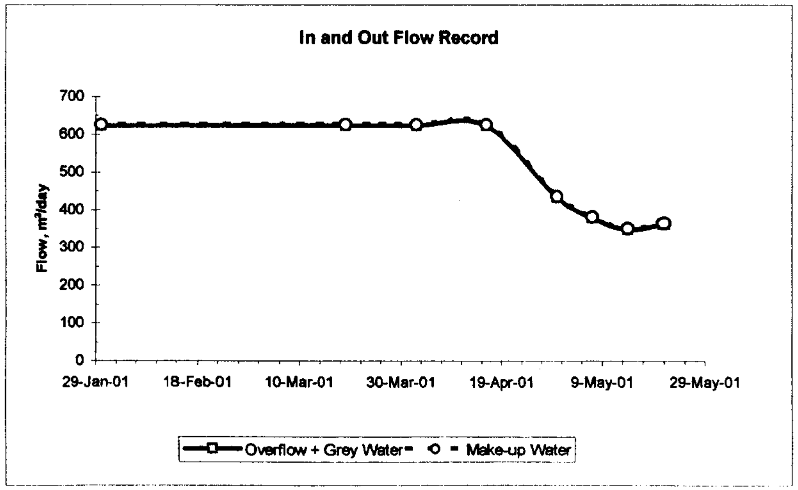
Date	C	%
36810	1385	31.1%
36921	1456	32.3%
36969	1790	37.8%
36983	1439	33.1%
36997	1485	33.6%
37011	1499	34.0%
37018	1643	37.6%
37025	1585	36.3%
37032	1540	35.3%
	Avg >	34.6%
	SD >	2.2%

Biomass

Date	kgs
2-Nov-00	2451
4-Dec-00	4162
26-Jan-01	4129
12-Feb-01	4506
22-Feb-01	3778
1-Mar-01	3301
14-Mar-01	3024
16-Mar-01	3606
2-Apr-01	3859
6-Apr-01	3765
30-Apr-01	3973
9-May-01	4312
23-May-01	4957

	In Flow		Out Flow	
Date	L/min	m^3/day	L/min	m^3/day
30-Jan-01	435	627	433	623
19-Mar-01	435	627	433	623
2-Apr-01	435	627	433	623
16-Apr-01	435	627	433	623
30-Apr-01	303	436	301	433
7-May-01	265	382	263	378
14-May-01	244	352	242	348
21-May-01	253	365	251	361


Flow Record
Supply Lines and Swirl Separator Overflow
(with Biomass)


In and Out Flow Record

PUMP DATA

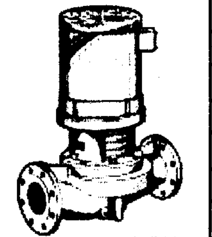
Grundfos Pumps; 3.0LM6, 4.0LP5

GRUNDFOS

In-Line, Single Stage Centrifugal Pumps

Series L
3.0LM6

Submittal Data 1750 RPM 60 Hertz



JOB or CUSTOMER:
ENGINEER:
CONTRACTOR:
SUBMITTED BY: DATE:
APPROVED BY: DATE:
ORDER NO DATE:
SPECIFICATION REF:

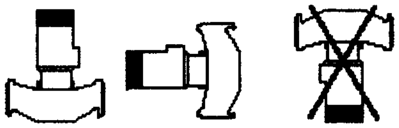
QUANTITY	TAG NO.	MODEL NO.	GPM	FEET	VOLT	PHASE	COMMENTS

Technical Data

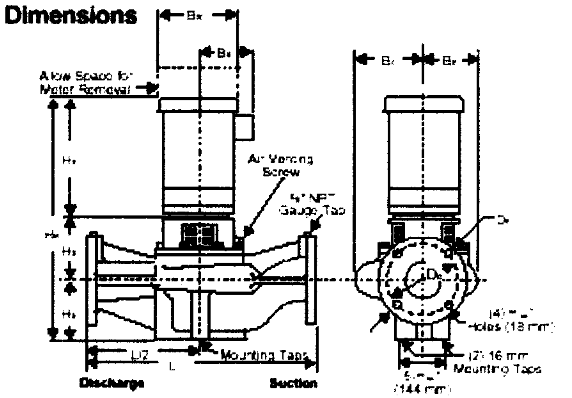
FLOW RANGE: 60 - 340 U.S. GPM
MINIMUM PUMPING RATE: 25 U.S. GPM
HEAD RANGE: 20 - 46 Feet
MOTORS: ODP (Standard), TEFC (Optional)
TEMPERATURE RANGE: 5° - 250°F (-15° - 121°C)
MAXIMUM WORKING PRESSURE: 175 PSI
FLANGES: 3" ANSI 125 lb. F.F.

MOTORS ARE UL/CSA RATED

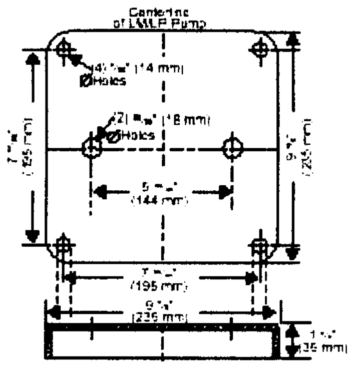
Mounting Positions



Dimensions



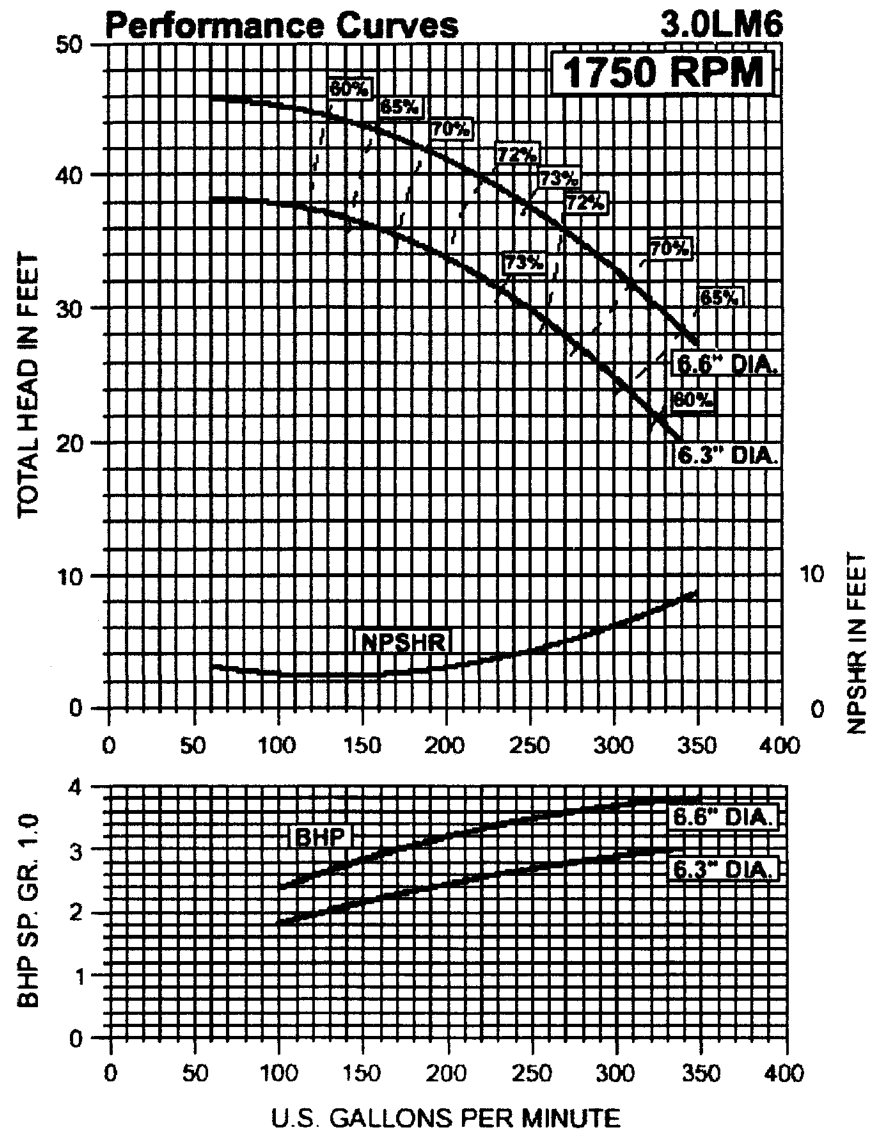
Baseplate Dimensions (Baseplate Optional)



Electrical Data, Dimensions, and Weights①

Pump Type	HP	Mtr. S.F.	PH	Volts	NEMA Frame Size	Suc./Disc. Size	DIMENSIONS IN INCHES									Net Wt. (Lbs.)	Ship. Wt. (Lbs.)	Ship. Vol. (Cu.Ft.)
							H₁	H₂	H₃	H₄	B₁	B₂	B₃	B₄	L			
3.0LM6/6.3	3.0	1.15	1	115/230	184TC	3"	26 [illegible]	5 [illegible]	7 [illegible]	13 [illegible]	8 [illegible]	5 [illegible]	7	6	21	180	190	9
	3.0	1.15	3	208 230/460	182TC	3"	25 [illegible]	5 [illegible]	7 [illegible]	12 [illegible]	8 [illegible]	5 [illegible]	7	6	21	158	168	9
3.0LM6/6.6	5.0	1.15	1	230	215TC	3"	29 [illegible]	5 [illegible]	9	15 [illegible]	10 [illegible]	6 [illegible]	7	6	21	200	210	9
	5.0	1.15	3	208 230/460	184TC	3"	26 [illegible]	5 [illegible]	9	14	7 [illegible]	6 [illegible]	7	6	21	175	185	9

NOTES: ① Above data for Baldor ODP motors. D₁: Flange O.D. - 7 [illegible]"; D₂: Bolt circle diameter - 6"



Materials of Construction

DESCRIPTION	MATERIAL	DESCRIPTION	MATERIAL
Pump Shaft	AISI 431 SS	Housing O-rings	EPDM Rubber
Impeller, Impeller Wear Ring, Coupling Guards, Impeller Seal Ring, Impeller Locking Nut and Washer	AISI 304 SS	Air Vent Screw	Brass
Pump Housing, Motor Stool and Coupling	Cast Iron	Mechanical Shaft Seal Rubber Bellows Stationary Seal Face Rotating Seal Face Mechanical Seal Spring	 EPDM Carbon Tungsten Carbide AISI 304 SS

GRUNDFOS

Leading in Pump Technology

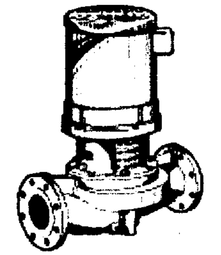
GRUNDFOS Pumps Corporation • 2555 Clovis Avenue • Clovis, CA 93612
Area Centers: Allentown, PA • Atlanta, GA • Chicago, IL • Clovis, CA • Dallas, TX • Seattle, WA
Phone: (800) 333-1366 • **Fax:** (800) 333-1363
Canada: Mississauga, Ontario • **Phone:** (800) 644-9599 • **Fax:** (800) 265-9862
Mexico: Apodaca, N.L.

GRUNDFOS

In-Line, Single Stage Centrifugal Pumps

Series L
4.0LP5

Submittal Data 3450 RPM 60 Hertz



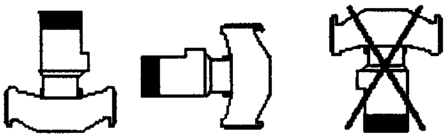
JOB or CUSTOMER:
ENGINEER:
CONTRACTOR:
SUBMITTED BY: DATE:
APPROVED BY: DATE:
ORDER NO: DATE:
SPECIFICATION REF:

QUANTITY	TAG NO.	MODEL NO.	GPM	FEET	VOLT	PHASE	COMMENTS

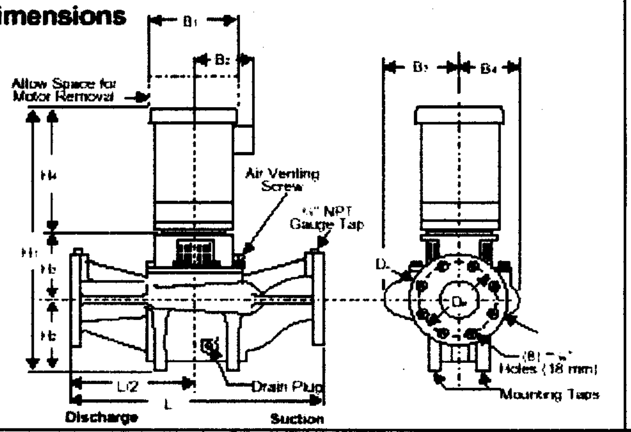
Technical Data

FLOW RANGE: 110 – 600 U.S. GPM
MINIMUM PUMPING RATE: 50 U.S. GPM
HEAD RANGE: 35 – 125 Feet
MOTORS: ODP (Standard), TEFC (Optional)
TEMPERATURE RANGE: 5° – 250°F (-15° – 121°C)
MAXIMUM WORKING PRESSURE: 175 PSI
FLANGES: 4" ANSI 125 lb. F.F.
MOTORS ARE UL/CSA RATED

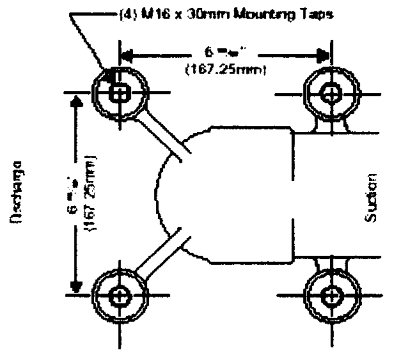
Mounting Positions



Dimensions



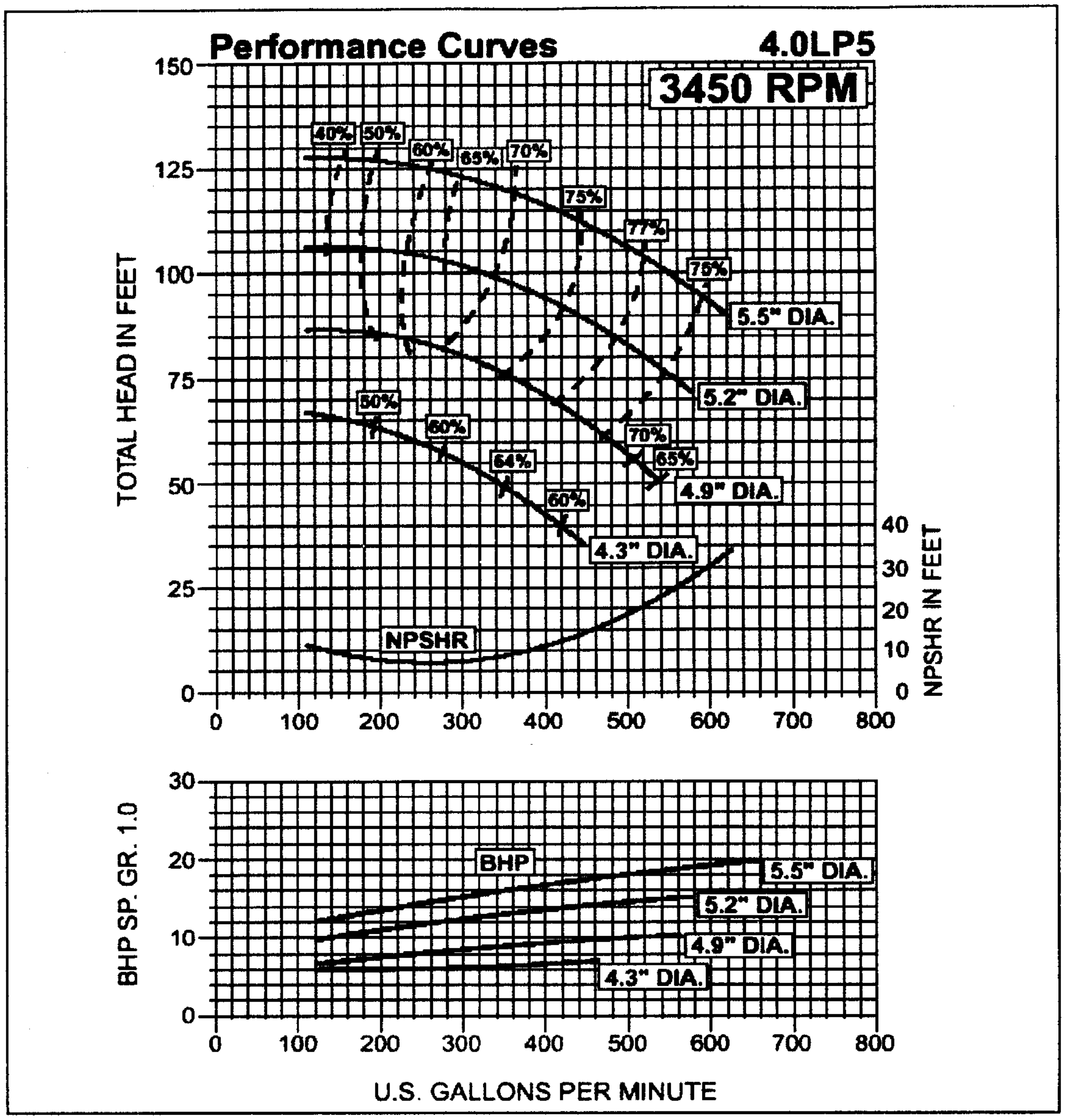
Base Dimensions



Electrical Data, Dimensions, and Weights ①

Pump Type	HP	Mtr. S.F.	PH	Volts	NEMA Frame Size	Suc./Disc. Size	DIMENSIONS IN INCHES H1	H2	H3	H4	B1	B2	B3	B4	L	Net Wt. (Lbs.)	Ship. Wt. (Lbs.)	Ship. Vol. (Cu. Ft.)
4.0LP5/4.3	7.5	1.15	1	208-230	213TC	4"	30 ½	5 ⅛	10	15 ⅜	10 ¼	8 ⅜	6 ½	5 ⅜	21	225	235	9
	7.5	1.15	3	208-230/460	215TC	4"	28 ½	5 ⅛	10	13 ¾	10 ¼	7 ⅜	6 ½	5 ⅜	21	195	205	9
4.0LP5/4.9	10	1.15	1	230	215TC	4"	31 ⅜	5 ⅛	10	16 ½	10 ¼	7 ⅜	6 ½	5 ⅜	21	227	237	9
	10	1.15	3	208-230/460	215TC	4"	30 ½	5 ⅛	10	15 ⅜	10 ¼	7 ⅜	6 ½	5 ⅜	21	197	207	9
4.0LP5/5.2	15	1.15	3	208-230/460	254TC	4"	30 ½	5 ⅛	10	15 ⅜	10 ¼	7 ⅜	6 ½	5 ⅜	21	220	230	9
4.0LP5/5.5	20	1.15	3	230/460	284TSC	4"	34 ½	5 ⅛	9 ¼	20 ½	11 ½	9	6 ½	5 ⅜	21	320	330	9

NOTES: ① Above data for Baldor ODP motors. D1: Flange O.D. = 9"; D2: Bolt circle diameter = 7 ½"



Materials of Construction

DESCRIPTION	MATERIAL
Pump Shaft	AISI 431 SS
Impeller, Impeller Wear Ring, Coupling Guards, Impeller Seal Ring, Impeller Locking Nut and Washer	AISI 304 SS
Pump Housing, Motor Stool and Coupling	Cast Iron

DESCRIPTION	MATERIAL
Housing O rings	EPDM Rubber
Air Vent Screw	Brass
Mechanical Shaft Seal	
Rubber Bellows	EPDM
Stationary Seal Face	Carbon
Rotating Seal Face	Tungsten Carbide
Mechanical Seal Spring	AISI 304 SS

GRUNDFOS Pumps Corporation • 2555 Clovis Avenue • Clovis, CA 93612
Area Centers: Allentown, PA • Atlanta, GA • Chicago, IL • Clovis, CA • Dallas, TX • Seattle, WA
Phone: (800) 333-1366 • **Fax:** (800) 333-1363
Canada: Mississauga, Ontario • **Mexico:** Apodaca, N.L.

B9

REPORT ON

THE INSTALLATION OF FLOWMETERS ON THE SUPPLY LINES AT MERLINS FISH FARM

FINAL REPORT
ON THE
INSTALLATION OF FLOWMETERS
ON THE SUPPLY LINES
OF AN EXISTING AQUACULTURE FACILITY

Prepared by

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for

Forrest Merlin, Manager
Merlins Fish Farms, Greenville Station, Nova Scotia
and
The Nova Scotia Department of Agriculture and Fisheries

April 20, 2001

SUMMARY

With the assistance of funding from the Nova Scotia Department of Agriculture and Fisheries, paddlewheel-type flow sensors were inserted into the supply lines of the recirculating water aquaculture plant at Merlin Fish Farms, Greenville Station, Nova Scotia. The aim was to enable the manager to better control and balance his flows to the two culture water supply lines.

Readout was provided in transmitters versus displays so that, besides giving an immediate display of flow rate and total flow, there is the capability of sending the signal to a computer where, with an appropriate card and software, this data can be monitored constantly, worked into an alarm system and stored for future consideration.

With a reasonable amount of preplanning, the installation was carried out in one afternoon and with little difficulty. The system was relatively easy to calibrate and was functional immediately

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Recently, Merlins Fish Farms added a recirculating water plant to their flow-through smolt production plant at Greenville Station, NS. The system is set up with two supply lines to two rows of culture tanks. A Schematic of the plant is shown in Figure 1.

Controlling the flow rates to each line and balancing the flows was problematic. It was proposed that two flowmeters with associated readouts, be installed, one on each line, so that the flow rate could be determined at will and a visual balancing of the lines could be achieved. Nova Scotia Department of Agriculture and Fisheries provided financial assistance to make the project possible.

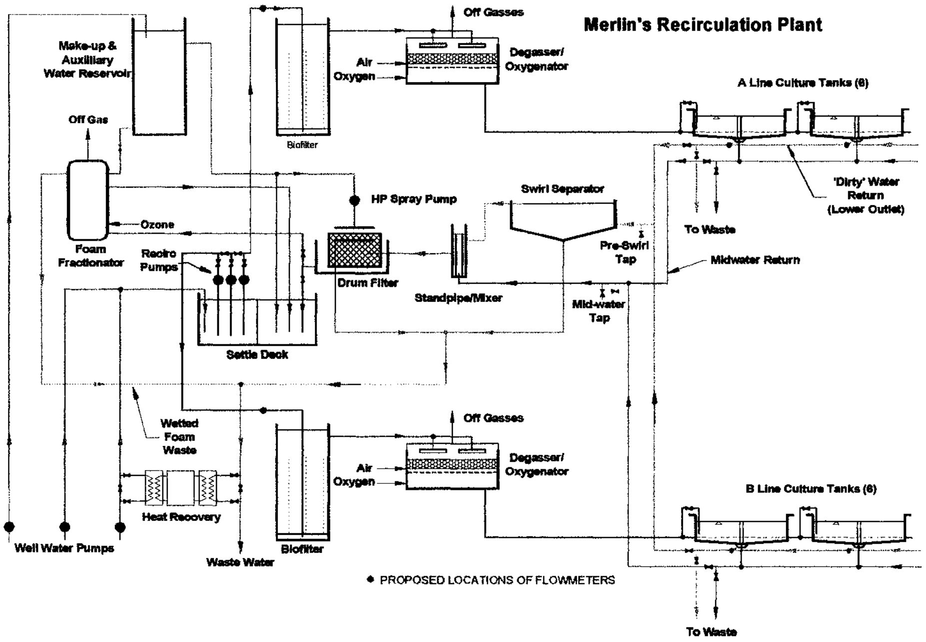


Figure 1: *Schematic of Merlins Fish Farm Recirculating Aquaculture plant, Greenville Sation, NS*

METHODOLOGY AND MATERIALS

Sensor Selection

Aquaeng Consulting reviewed the flow measurement instruments available. The most cost effective type of sensor for this application was determined to be the paddlewheel flow sensor.

This device inserts a multi-bladed paddle wheel into the flow. The individual paddles each have an embedded magnet which is picked up by a

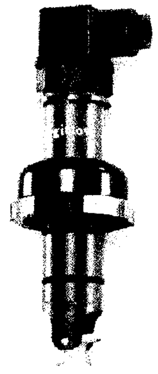


Figure 2: *Paddlewheel flow sensor*

Hall-effect transducer in the body, producing a pulse. An electronic chip in the sensor body converts this pulse to a square wave output frequency which is linearly proportional to the rate of rotor rotation, hence to the flow velocity. Flow rate is calculated from the flow velocity and the internal cross-sectional area of the pipe.

The signal can be terminated in either a display readout or a transmitter, to give an immediate visual representation of the flow rate and cumulative flow when calibrated for the size and type of pipe (see Appendix A). The transmitter was chosen in this instance as it has the capability of sending the signal on to a computer where, with an appropriate card and software, it can used for computer monitoring and eventual integration into a monitoring and control system. It order to have this capability, the transmitters must have an independent power supply.

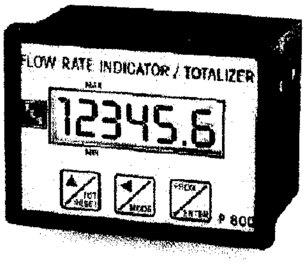


Figure 3: Panel-mounted transmitter

Special mounting arrangements have to be made to ensure the sensor in inserted at the appropriate depth and is facing in the correct direction. In this, on nominal 6-inch diameter Schedule 40 PVC pipe, clamp-on saddles were recommended.

Major Equipment

There are a number of similar equipments available at comparable prices. The following items were selected, based on cost and delivery:

Sensors:	(2)	Chemline	Cat. No. SA100E Digiflow Paddlewheel
Transmitters	(2)	Chemline	Cat. No. P500XFT Panel Mount
Saddles	(2)	Chemline	Cat. No. SAA060 for PVC 6" Sch 40 pipe
Power supply	(1)	Condor Linear	Cat. No. 279-2006-ND 24 VDC @ 0.5 amps.

The Chemline products were supplied by Northeast Equipment, Ltd., 135 Joseph Zatzman Drive, Dartmouth, NS, and the power supply by Digikey (mail order) 1-800-344-4539 or FAX: 218-681-3380 or www.digikey.com

Installation

The sensor installation must be on a full pipe to read correctly and there are manufacturer's restrictions on how far after and before an obstruction that the sensor can be located, to ensure a fully developed flow pattern (see Figure 4). With these restrictions, it was

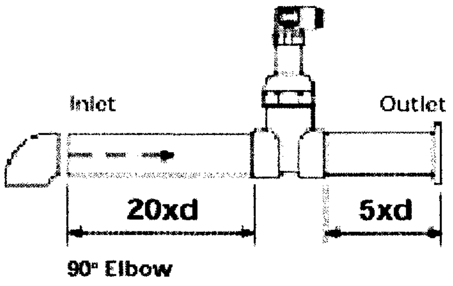


Figure 4: Chemline's sensor mounting advice. "d" = pipe diameters.

decided to install them on the horizontal pipe passing through the attic to feed the fluidized sand bed biofilters.

Recommended practice is to install the sensors as per "Figure 3" in Chemline's instructions (see Figure 5), but they were installed near-vertically (Figure 6) as entrapped air was not considered a problem. This method reduced the shut-down, drain and refill time required in this active plant.

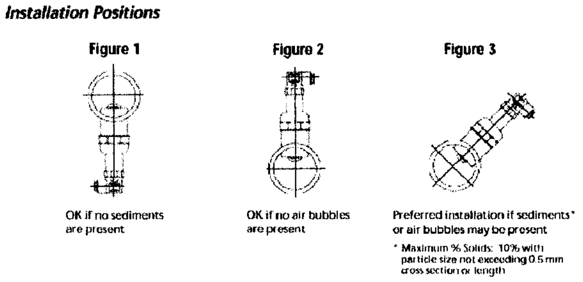


Figure 5: *Chemline's recommended mounting practice.*

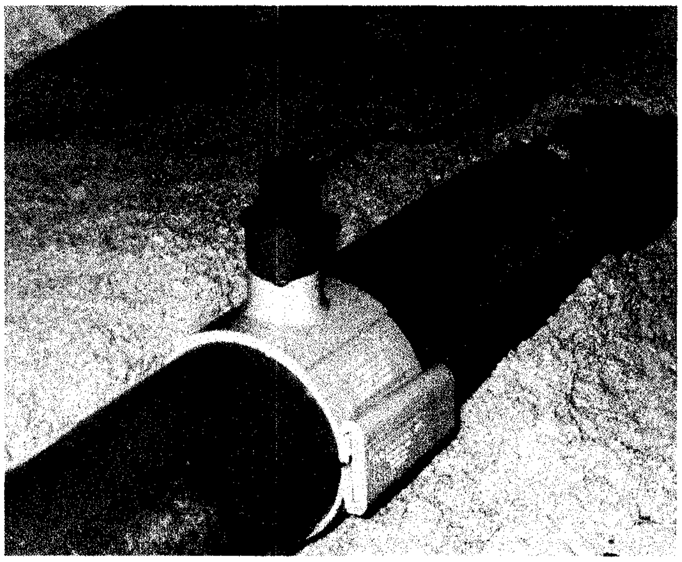


Figure 6: *B Line sensor installed using the appropriate saddle.*

Chemline advised that three-wire copper conductor with a cross-sectional area on 0.5 mm^2 or better (a European specification) was required for the sensor to transmitter linkage. That translates into 20 AWG in North America. 18 AWG 3-conductor thermostat wire, available in some building supply stores in Nova Scotia was used satisfactorily.

Transmitter Mounting

The transmitters and the power supply were mounted in an 8"x8" plastic waterproof box. Wires were run into the box using waterproof box connectors. Plastic mounting boxes, connectors and waterproof switch covers are all available at electrical suppliers and some building supply stores and Canadian Tire stores.

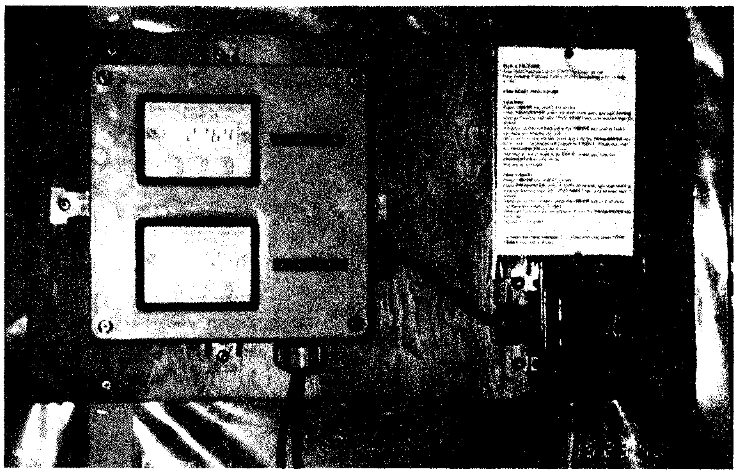


Figure 7: *Transmitter mounting box with waterproof power switch. Note calibration instructions.*

The transmitters and power supply were mounted in the box, the box and switch mounted on the board and pre-wired, following the manufacturers' directions, at the Department of Biological Engineering, Dalhousie University, Halifax, NS, prior to delivery to the site.

The transmitters were mounted close to the pumps to facilitate flow adjustments (Figure 8).

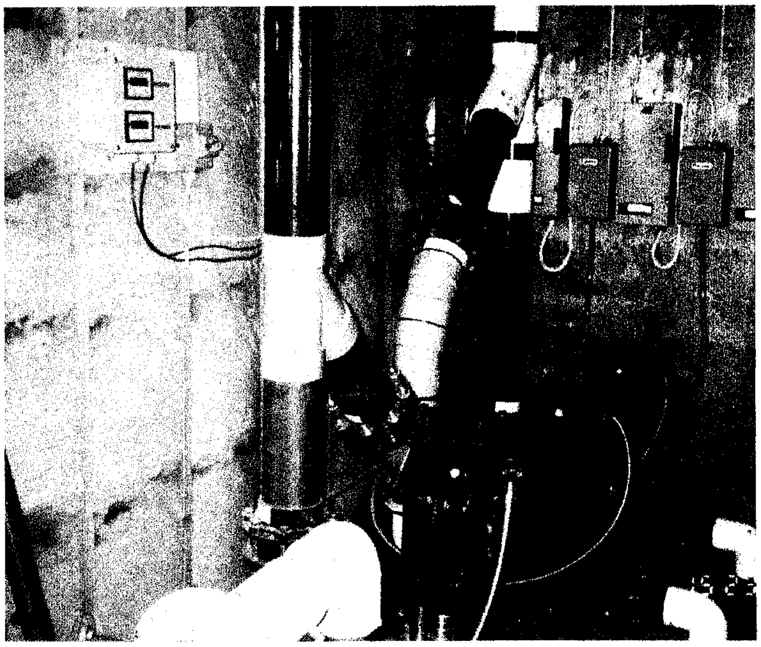


Figure 8: Transmitter Box - supply pumps location

The sensor installation, which consisted of drilling an appropriate hole in the pipe, mounting the saddle and inserting the sensor, was carried out by the site manager and an assistant with no difficulty. They also completed the wiring.

Installation of the sensors, mounting the board and wiring was completed in a few hours. Calibration of the transmitters (as per manufacturer's instructions) was completed in minutes and the system was running according to specification.

Any technical assistance requested was willingly given by Hach (www.hach.com) technicians by email and telephone.

CONCLUSIONS

Paddle wheel flowmeters are appropriate for this type of installation. They are the least expensive but of sufficient accuracy for the role. Installation is relatively straight-forward and ancillary supplies were obtainable from local suppliers. The flowmeters are performing as expected and giving the level of control anticipated. Total project price was under $3,500.

RECOMMENDATIONS

To aid in servicing a sensor plug, obtainable from the manufacturer, should be purchased. This plug can replace a sensor taken out for repair, and allow the flow to resume.

Further automation of water parameter sensing should be undertaken. This plant could be used by NSDAF as a demonstration site for computer monitoring and control of a recirculating aquaculture system.

APPENDIX A

Calibration

P500 Reset Procedure for the Merlin Fish Farms Installation

SCALE FACTORS:
Flow Rate Prescale Factor (FRPF) for L/min: 25.105
Flow Totalizer Prescale Factor (FTPF) for reading x 10 = Litres: 4.1841

P500 RESET PROCEDURE:

Flow Rate:
Press **</MODE** key until F 0.0 shows
Press **PROG/ENTER** until F XX.XXX show with right digit flashing.
Change flashing digit with **^/TOT RESET** key until desired digit (5) shows.
Advance up the numbers using the **</MODE** key until all factor numbers are entered (25.105).
When all numbers are set, press and hold the **PROG/ENTER** key for 5+ sec. The display will change to **4 XXX.X**. Press and hold the **PROG/ENTER** key for 5+ sec.
The display will change to **2o XXX.X**. Press and hold the **PROG/ENTER** key for 5+ sec.
Procedure complete.

Flow Totalizer:
Press **</MODE** key until 0.0 shows
Press **PROG/ENTER** until c X.XXXX show with right digit flashing.
Change flashing digit with **^/TOT RESET** key until desired digit (1) shows.
Advance up the numbers using the **</MODE** key until all factor numbers are entered (4.1841).
When all numbers are set, press and hold the **PROG/ENTER** key for 5+ sec.
Procedure complete.

To reset the Flow Totalizer to 0, press and hold down **^/TOT RESET** key until 0 shows

APPENDIX C

BIOMASS

BIOMASS Summary

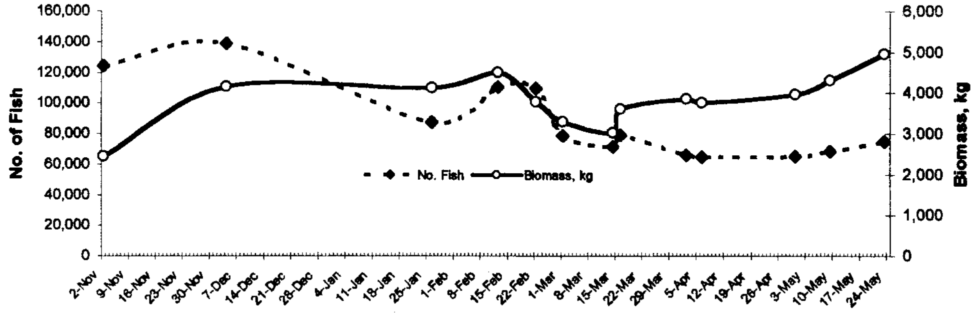
Some size and numbers values are Manager estimates.

Date	No. Fish	Mean wt., g	Biomass, kg	System Density, kg/m^3
2-Nov-00	124207	20.6	2451	10.1
4-Dec-00	139207	31.2	4162	17.2
26-Jan-01	87480	40.6	4129	18.6
12-Feb-01	110775	44.7	4506	18.0
22-Feb-01	109665	40.1	3778	15.5
1-Mar-01	78686	46.9	3301	13.6
14-Mar-01	71620	49.6	3024	12.6
16-Mar-01	79200	50.8	3606	14.8
2-Apr-01	66200	59.1	3859	15.8
6-Apr-01	64860	64.5	3765	15.5
30-Apr-01	65180	62.5	3973	16.4
9-May-01	68888	69.4	4312	17.9
23-May-01	75152	73.4	4957	20.6

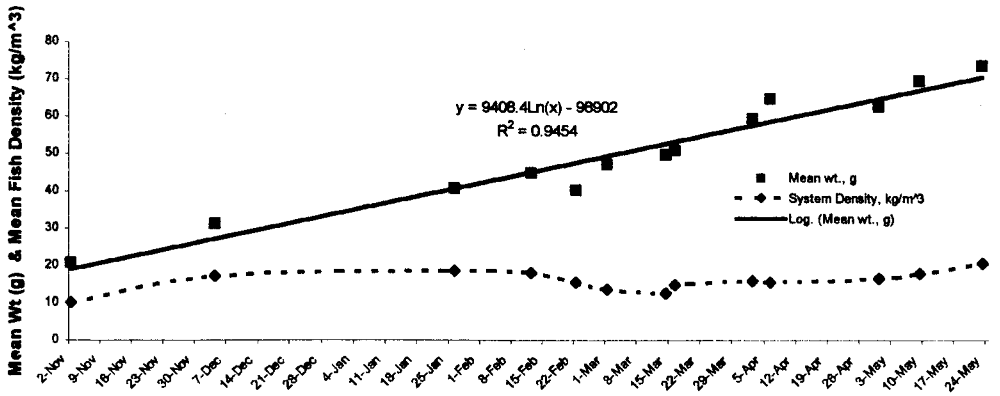
Date for Mean size
Forecast from trend line

Wt, g	Date
60	11-Apr-01
70	20-May-01
80	29-Jun-01
90	7-Aug-01
100	16-Sep-01

Number of Fish and Biomass



Mean Weight and Mean Density



APPENDIX D

FEED RECORDS

FEED INPUT TO WASTE PRODUCTS

FEED REGISTER for the Month of **February 01**
LINE A

FEED

Type	mm	kg/L	
A	3	0.706	
B	2/3	0.708	50/50
C	2	0.709	

S - Saturday, Sunday

Tk No>		1				2				3				4				5				6			
		Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt
DAY		A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg
1					0.00				0.00				0.00				0.00				0.00				0.00
2					0.00				0.00				0.00				0.00				0.00				0.00
3	S				0.00				0.00				0.00				0.00				0.00				0.00
4	S				0.00				0.00				0.00				0.00				0.00				0.00
5					0.00				0.00				0.00				0.00				0.00				0.00
6					0.00				0.00				0.00				0.00				0.00				0.00
7					0.00				0.00				0.00				0.00				0.00				0.00
8					0.00				0.00				0.00				0.00				0.00				0.00
9					0.00				0.00				0.00				0.00				0.00				0.00
10	S				0.00				0.00				0.00				0.00				0.00				0.00
11	S				0.00				0.00				0.00				0.00				0.00				0.00
12					0.00				0.00				0.00				0.00				0.00				0.00
13					0.00				0.00				0.00				0.00				0.00				0.00
14			1.25		0.88			0.50	0.35	7.50			5.30	7.50			5.30			4.50	3.19		4.25		3.01
15			4.50		3.18			3.75	2.66	5.00			3.53	5.25			3.71			3.25	2.30		4.00		2.83
16			3.25		2.30			2.75	1.95	6.75			4.77	6.50			4.59			3.00	2.13		3.00		2.12
17	S		2.75		1.95			2.75	1.95	6.50			4.59	6.50			4.59			2.25	1.60		3.25		2.30
18	S		3.50		2.48			4.25	3.01	7.30			5.15	7.20			5.08			4.25	3.01		5.65		4.00
19			6.00		4.25			4.75	3.37	10.50			7.41	9.75			6.88			4.00	2.84		5.50		3.89
20			4.25		3.01			4.25	3.01	7.75			5.47	8.50			6.00			4.55	3.23		6.00		4.25
21			3.75		2.65			2.75	1.95	6.50			4.59	6.50			4.59			3.75	2.66		4.50		3.18
22			5.75		4.07			4.50	3.19	7.00			4.94	6.90			4.87			4.65	3.30		5.40		3.82
23			6.10		4.32			3.75	2.66	8.50			6.00	7.00			4.94			4.30	3.05		4.25		3.01
24	S		5.00		3.54			3.50	2.48	8.00			5.65	7.00			4.94			3.75	2.66		5.75		4.07
25	S		5.25		3.71			3.75	2.66	10.50			7.41	9.00			6.35			5.25	3.72		6.00		4.25
26			4.75		3.36			4.25	3.01	7.25			5.12	6.50			4.59			4.75	3.37		6.00		4.25
27			4.25		3.01			3.50	2.48	2.25			1.59	3.25			2.29			2.50	1.77		3.75		2.65
28			4.25		3.01			2.50	1.77	3.50			2.47	3.25			2.29			2.00	1.42		3.25		2.30
																								Total>	

Daily Feed Summary	
kg	Day
0.00	1
0.00	2
0.00	3
0.00	4
0.00	5
0.00	6
0.00	7
0.00	8
0.00	9
0.00	10
0.00	11
0.00	12
0.00	13
18.03	14
18.21	15
17.85	16
16.97	17
22.74	18
28.64	19
24.96	20
19.62	21
24.19	22
23.97	23
23.34	24
28.11	25
23.69	26
13.80	27
13.26	28
317.38	kg

Running Totals

Vol, L		0.00	64.60	0.00		0.00	0.00	51.50		104.80	0.00	0.00		100.60	0.00	0.00		0.00	0.00	56.75		0.00	70.55	0.00	
Sum wt, kg>	kg				45.70				36.51				73.99				71.02				40.24				49.91
2mm	kg				22.85				36.51				0.00				0.00				40.24				24.96
3mm	kg				22.85				0.00				73.99				71.02				0.00				24.96
Check wt					45.70				36.51				73.99				71.02				40.24				49.91
Wt	kg	0.00	45.70	0.00	45.70	0.00	0.00	36.51	36.51	73.99	0.00	0.00	73.99	71.02	0.00	0.00	71.02	0.00	0.00	40.24	40.24	0.00	49.91	0.00	49.91

Totals to Date	
kg	Bags
124.56	5.0
192.82	7.7
317.38	
317.38	

D3

FEED REGISTER for the Month of **February 01**
Line B

FEED

Type	mm	kg/L	
A	3	0.706	
B	2/3	0.708	50/50
C	2	0.709	

S - Saturday, Sunday

Tk No>		1				2				3				4				5				6					
		Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Daily Sum	
DAY		A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	kg	Day
1					0.00				0.00				0.00				0.00				0.00				0.00	0.00	1
2					0.00				0.00				0.00				0.00				0.00				0.00	0.00	2
3	S				0.00				0.00				0.00				0.00				0.00				0.00	0.00	3
4	S				0.00				0.00				0.00				0.00				0.00				0.00	0.00	4
5					0.00				0.00				0.00				0.00				0.00				0.00	0.00	5
6					0.00				0.00				0.00				0.00				0.00				0.00	0.00	6
7					0.00				0.00				0.00				0.00				0.00				0.00	0.00	7
8					0.00				0.00				0.00				0.00				0.00				0.00	0.00	8
9					0.00				0.00				0.00				0.00				0.00				0.00	0.00	9
10	S				0.00				0.00				0.00				0.00				0.00				0.00	0.00	10
11	S				0.00				0.00				0.00				0.00				0.00				0.00	0.00	11
12					0.00				0.00				0.00				0.00				0.00				0.00	0.00	12
13					0.00				0.00				0.00				0.00				0.00				0.00	0.00	13
14			1.25		0.88	2.50			1.77	8.00			5.65		4.00		2.83			5.25	3.72		4.50		3.18	18.03	14
15			4.50		3.18	8.00			5.65	6.75			4.77		4.25		3.01			4.00	2.84		3.00		2.12	21.56	15
16			3.25		2.30	5.50			3.88	6.75			4.77		4.50		3.18			3.75	2.66		2.75		1.95	18.74	16
17	S		2.75		1.95	6.50			4.59	7.00			4.94		2.50		1.77			2.50	1.77		3.25		2.30	17.32	17
18	S		3.75		2.65	8.00			5.65	8.25			5.82		4.20		2.97			4.30	3.05		5.25		3.71	23.86	18
19			5.50		3.89	10.50			7.41	10.25			7.24		6.00		4.25			5.50	3.90		6.50		4.60	31.28	19
20			4.00		2.83	7.75			5.47	7.50			5.30		4.75		3.36		2.50	2.50	3.54		5.75		4.07	24.57	20
21			4.25		3.01	6.00			4.24	7.00			4.94		4.00		2.83			3.50	2.48		4.50		3.18	20.68	21
22			4.50		3.18	8.50			6.00	9.50			6.71		5.25		3.71			5.50	3.90		5.25		3.71	27.22	22
23			5.00		3.54	8.00			5.65	8.25			5.82		4.75		3.36			5.25	3.72		5.25		3.71	25.81	23
24	S		5.50		3.89	9.25			6.53	8.30			5.86		5.00		3.54			4.75	3.37		5.75		4.07	27.25	24
25	S		4.50		3.18	7.75			5.47	8.00			5.65		4.60		3.25			4.75	3.37		4.75		3.36	24.29	25
26			5.00		3.54	6.00			4.24	5.75			4.06		4.25		3.01			4.25	3.01		4.00		2.83	20.68	26
27			4.25		3.01	5.50			3.88	4.00			2.82		2.50		1.77			2.50	1.77		2.50		1.77	15.02	27
28			3.75		2.65	4.75			3.35	3.25			2.29		3.25		2.30			3.00	2.13		3.25		2.30	15.03	28
																									Total>	331.34	KG

Running Totals

Vol, L		0.00	61.75	0.00		104.50	0.00	0.00		108.55	0.00	0.00		0.00	63.80	0.00		0.00	2.50	61.30		0.00	66.25	0.00		Totals to Date	
Sum wt, kg	kg				43.69				73.78				76.64				45.14				45.23				46.87	kg	Bags
2mm	kg				21.84				0.00				0.00				22.57				44.35				23.44	112.20	4.49
3mm	kg				21.84				73.78				76.64				22.57				0.88				23.44	219.15	8.77
Check wt					43.69				73.78				76.64				45.14				45.23				46.87	331.34	
Wt	kg	0.00	43.69	0.00	43.69	73.78	0.00	0.00	73.78	76.64	0.00	0.00	76.64	0.00	45.14	0.00	45.14	0.00	1.77	43.46	45.23	0.00	46.87	0.00	46.87	331.34	

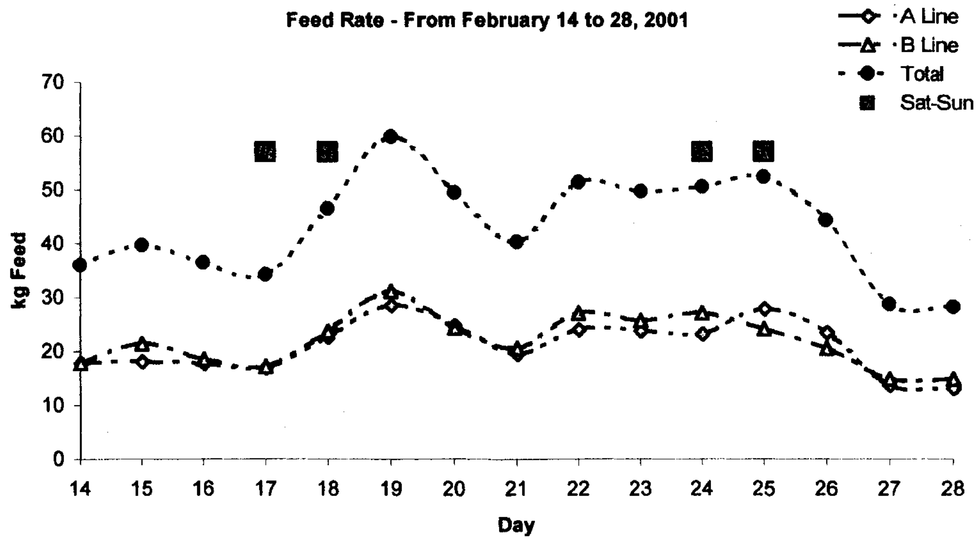
Feb-01	Daily Feed Summary, kg					Daily Bags Tally		
	Day	A Line	B Line	Total	Wkend	3mm	2mm	
	1	0.00	0.0	0.0				
	2	0.00	0.0	0.0				
	3	0.00	0.0	0.0				
	4	0.00	0.0	0.0				
	5	0.00	0.0	0.0				
	6	0.00	0.0	0.0				
	7	0.00	0.0	0.0				
	8	0.00	0.0	0.0				
	9	0.00	0.0	0.0				
	10	0.00	0.0	0.0				
	11	0.00	0.0	0.0				
	12	0.00	0.0	0.0				
	13	0.00	0.0	0.0				
	14	18.03	18.0	36.1				
	15	18.21	21.6	39.8			1	
	16	17.85	18.7	36.6		3		
	17	16.97	17.3	34.3	57			
	18	22.74	23.9	46.6	57	1	1	
	19	28.64	31.3	59.9				
	20	24.96	24.6	49.5		1	1	
	21	19.62	20.7	40.3		1	1	
	22	24.19	27.2	51.4		1	1	
	23	23.97	25.8	49.8				
	24	23.34	27.3	50.6	57	2	1	
	25	28.11	24.3	52.4	57	1	1	
	26	23.69	20.7	44.4		1		
	27	13.80	15.0	28.8		2		
	28	13.26	15.0	28.3		1	1	
	Totals	317.4	331.3	648.7	kg			
						14	8	Bags

Bags from Daily Reckoning

	A Bags	B Bags		Running	Totals
2mm	5.0	4.5	>		9
3mm	7.7	8.8	>	16	

25 kg bags

Monthly Average 43.2 kg/day


Feed Rate - From February 14 to 28, 2001

FEED REGISTER for the Month of March 01

LINE A

FEED

Type	mm	kg/L	
A	3	0.706	
B	2/3	0.708	50/50
C	2	0.709	

S - Saturday, Sunday

Tk No>		1				2				3				4				5				6			
		Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt
DAY		A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg
1			3		2.12			1.75	1.24	3.25			2.29	3.25			2.29			1.25	0.89		3.25		2.30
2			4.5		3.18		0.25		0.18	6.50			4.59	4.75			3.35		2.25		1.59		5.25		3.71
3	S	5.00			3.53		4.25		3.01	5.75			4.06	5.50			3.88		3.00		2.12	5.50			3.88
4	S	5.75			4.06		4.75		3.36	6.50			4.59	6.75			4.77		4.75		3.36	6.00			4.24
5			2.7		1.91		2.75		1.95	4.30			3.04	4.00			2.82		1.25		0.88		3.25		2.30
6			4		2.83		4.25		3.01	5.85			4.13	5.85			4.13		2.50		1.77		2.75		1.95
7			4.1		2.90		4.50		3.18	5.65			3.99	4.75			3.35		3.50		2.48		4.00		2.83
8			3.25		2.30		2.75		1.95	4.50			3.18	4.25			3.00		4.50		3.18		5.50		3.89
9			5.25		3.71		6.75		4.78	5.75			4.06	6.25			4.41		4.25		3.01		5.25		3.71
10	S		5		3.54		5.00		3.54	5.00			3.53	5.00			3.53		5.25		3.71		4.25		3.01
11	S		4		2.83		4.00		2.83	4.00			2.82	4.00			2.82		3.25		2.30		4.00		2.83
12			4.25		3.01		4.25		3.01	5.00			3.53	5.00			3.53		3.15		2.23		4.50		3.18
13			4.5		3.18		5.50		3.89	5.00			3.53	6.80			4.80		3.75		2.65		5.50		3.89
14			3.5		2.48		3.25		2.30	0.50			0.35	3.70			2.61		4.50		3.18		4.00		2.83
15			5.5		3.89		5.50		3.89	2.65			1.87	4.75			3.35		3.95		2.79		5.25		3.71
16			4.5		3.18		4.50		3.18	2.75			1.94	5.25			3.71		4.25		3.01		5.00		3.54
17	S		3.25		2.30		3.50		2.48	2.50			1.77	4.00			2.82		4.00		2.83		3.75		2.65
18	S		5		3.54		5.00		3.54	5.75			4.06	5.75			4.06		5.50		3.89		6.00		4.25
19			6		4.25		6.00		4.25	2.90			2.05	4.75			3.35		4.65		3.29		6.00		4.25
20			4		2.83		4.75		3.36	3.25			2.29	4.50			3.18		4.75		3.36		4.50		3.18
21			5.25		3.71		6.00		4.25	4.00			2.82	5.50			3.88		5.50		3.89		6.00		4.25
22			6		4.25		6.25		4.42	4.75			3.35	5.25			3.71		5.75		4.07		6.00		4.25
23		4.25	1		3.71	4.75	1.00		4.06	4.25			3.00	5.25			3.71		5.74		4.06	4.75			3.35
24	S	5.00			3.53	5.00			3.53	5.00			3.53	5.25			3.71		4.75		3.36	5.00			3.53
25	S	5.25			3.71	5.25			3.71	6.00			4.24	6.00			4.24		5.80		4.10	6.00			4.24
26		6.50			4.59	6.00			4.24	5.75			4.06	6.25			4.41		5.50		3.89	5.25			3.71
27		4.00			2.82	4.00			2.82	4.50			3.18	6.10			4.31		4.75		3.36	4.00			2.82
28					0.00				0.00	3.75			2.65	4.50			3.18		4.50		3.18	4.00			2.82
29					0.00				0.00	4.60			3.25	6.50			4.59		4.50		3.18	5.50			3.88
30		0.50			0.35	1.50			1.06	4.75			3.35	6.50			4.59		6.00		4.25	4.00			2.82
31	S	0.90			0.64	0.65			0.46	4.00			2.82	5.50			3.88		5.75		4.07	7.00			4.94
																								Total>	

Daily Feed Summary	
kg	Day
11.14	1
16.61	2
20.48	3
24.37	4
12.90	5
17.81	6
18.73	7
17.50	8
23.68	9
20.86	10
16.44	11
18.49	12
21.95	13
13.75	14
19.52	15
18.56	16
14.85	17
23.33	18
21.43	19
18.21	20
22.80	21
24.04	22
21.89	23
21.19	24
24.22	25
24.89	26
19.32	27
11.83	28
14.90	29
16.42	30
16.81	31
588.93	kg

Running Totals

Vol, L		37.15	88.55	0.00		27.15	94.75	1.75		138.70	0.00	0.00		161.45	0.00	0.00		0.00	131.54	1.25		57.00	94.00	0.00	
Sum wt, kg>	kg				88.88				87.44				97.92				113.98				93.95				106.75
2mm	kg				31.32				34.76				0.00				0.00				47.42				33.25
3mm	kg				57.55				52.69				97.92				113.98				46.53				73.49
Check wt					88.88				87.44				97.92				113.98				93.95				106.75
Wt	kg	26.23	62.65	0.00	88.88	19.17	67.04	1.24	87.44	97.92	0.00	0.00	97.92	113.98	0.00	0.00	113.98	0.00	93.06	0.89	93.95	40.24	66.51	0.00	106.75

Totals to Date	
kg	Bags
146.75	5.9
442.17	17.7
588.93	
588.93	

FEED REGISTER for the Month of **March 01**

LINE B

FEED

Type	mm	kg/L	
A	3	0.706	
B	2/3	0.708	50/50
C	2	0.709	

S - Saturday, Sunday

Tk No>		1				2				3				4				5				6			
		Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt
DAY		A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg
1			2.00		1.42		2.50		1.77	1.75			1.24		1.75		1.24			1.00	0.71		2.75		1.95
2			4.50		3.18	5.50			3.88	7.50			5.30		5.25		3.71		4.50		3.18		5.25		3.71
3	S	4.50			3.18	6.25			4.41	7.00			4.94	5.00			3.53		4.25		3.01	5.75			4.06
4	S	5.75			4.06	6.50			4.59	6.25			4.41	5.75			4.06		5.50		3.89	6.25			4.41
5			3.50		2.48	4.25			3.00	4.75			3.35	3.50			2.47		4.00		2.83		4.00		2.83
6			4.10		2.90	5.50			3.88	5.75			4.06	3.50			2.47		2.50		1.77		3.50		2.48
7			3.75		2.65	4.75			3.35	4.25			3.00	4.25			3.00		3.45		2.44		4.00		2.83
8			3.25		2.30	4.00			2.82	5.00			3.53	4.25			3.00		4.50		3.18		4.25		3.01
9			4.75		3.36	4.75			3.35	5.75			4.06	4.00			2.82		5.25		3.71		6.25		4.42
10	S		4.75		3.36	5.25			3.71	6.70			4.73	5.00			3.53		5.00		3.54		5.25		3.71
11	S		4.00		2.83	4.00			2.82	4.00			2.82	4.00			2.82		3.25		2.30		4.00		2.83
12			4.25		3.01	5.00			3.53	4.50			3.18	4.75			3.35		3.75		2.65		5.25		3.71
13			4.50		3.18	6.40			4.52	5.70			4.02	5.25			3.71		4.25		3.01		5.75		4.07
14			3.00		2.12	5.95			4.20	6.15			4.34		2.75		1.95		4.00		2.83		3.50		2.48
15			5.00		3.54	5.00			3.53	5.50			3.88		5.50		3.89		4.25		3.01		4.00		2.83
16			4.00		2.83	5.00			3.53	5.25			3.71		4.75		3.36		4.50		3.18		5.25		3.71
17	S		3.50		2.48	4.00			2.82	4.50			3.18		3.25		2.30		4.50		3.18		3.75		2.65
18	S		5.50		3.89	5.50			3.88	5.25			3.71		5.00		3.54		5.50		3.89		6.00		4.25
19			4.50		3.18	4.25			3.00	4.75			3.35		5.25		3.71		5.00		3.54		6.50		4.60
20			4.00		2.83	5.00			3.53	6.00			4.24		3.50		2.48		5.00		3.54		4.00		2.83
21			5.50		3.89	5.00			3.53	4.50			3.18		4.50		3.18		5.00		3.54		5.80		4.10
22			4.75		3.36	4.50			3.18	6.00			4.24		5.75		4.07		5.50		3.89		6.00		4.25
23		3.75	1.00		3.36	5.25			3.71	5.75			4.06	4.75			3.35		6.20		4.39	5.00			3.53
24	S	5.00			3.53	5.75			4.06	6.00			4.24	5.00			3.53		5.00		3.54	5.00			3.53
25	S	5.75			4.06	6.00			4.24	6.00			4.24	5.50			3.88		5.80		4.10	6.00			4.24
26		5.50			3.88	6.25			4.41	5.50			3.88	4.25			3.00		6.25		4.42	5.25			3.71
27		3.00			2.12	5.25			3.71	6.00			4.24	3.00			2.12		4.50		3.18	3.25			2.29
28					0.00	4.00			2.82	5.00			3.53	2.50			1.77		4.75		3.36	5.25			3.71
29		5.20			3.67	0.75			0.53	6.25			4.41	1.75			1.24		6.25		4.42				0.00
30		0.50			0.35	6.00			4.24	7.50			5.30				0.00		6.25		4.42				0.00
31	S	1.10			0.78	5.75			4.06	6.00			4.24				0.00		6.00		4.25				0.00

Total>

Daily Sum	
kg	Day
8.31	1
22.97	2
23.13	3
25.42	4
16.96	5
17.56	6
17.28	7
17.84	8
21.73	9
22.58	10
16.43	11
19.43	12
22.51	13
17.92	14
20.68	15
20.33	16
16.61	17
23.15	18
21.39	19
19.44	20
21.42	21
22.98	22
22.39	23
22.42	24
24.75	25
23.31	26
17.66	27
15.19	28
14.27	29
14.31	30
13.32	31
603.70	KG

Running Totals

Vol, L		40.05	84.10	0.00		151.35	2.50	0.00		170.80	0.00	0.00		76.00	47.25	0.00		0.00	144.45	1.00		41.75	95.05	0.00	
Sum wt, kg>	kg				87.78				108.62				120.58				87.09				102.91				96.72
2mm	kg				29.75				0.88				0.00				16.71				51.81				33.62
3mm	kg				58.03				107.74				120.58				70.37				51.10				63.10
Check wt					87.78				108.62				120.58				87.09				102.91				96.72
Wt	kg	28.28	59.50	0.00	87.78	106.85	1.77	0.00	108.62	120.58	0.00	0.00	120.58	53.66	33.43	0.00	87.09	0.00	102.20	0.71	102.91	29.48	67.25	0.00	96.72

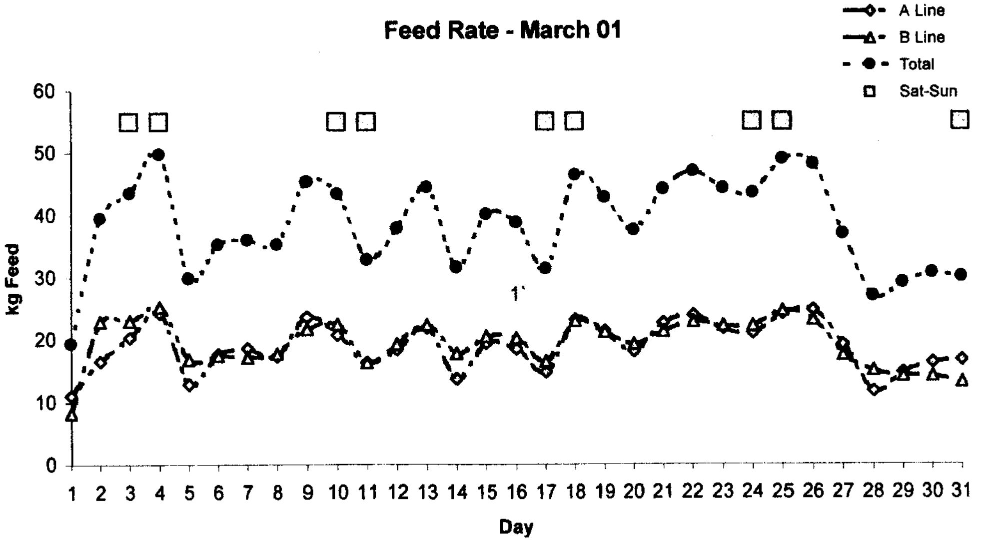
Totals to Date	
kg	Bags
132.78	5.31
470.92	18.84
603.70	
603.70	

Mar-01	Daily Feed Summary, kg					Daily Bags Tally		
	Day	A Line	B Line	Total	Wkend	3mm	2mm	
	1	11.14	8.3	19.4		1	1	
	2	16.61	23.0	39.6				
	3	20.48	23.1	43.6	55	2		
	4	24.37	25.4	49.8	55	2		
	5	12.90	17.0	29.9				
	6	17.81	17.6	35.4		2	1	
	7	18.73	17.3	36.0				
	8	17.50	17.8	35.3		3		
	9	23.68	21.7	45.4		1		
	10	20.86	22.6	43.4	55	1		
	11	16.44	16.4	32.9	55	1	1	
	12	18.49	19.4	37.9				
	13	21.95	22.5	44.5		1		
	14	13.75	17.9	31.7				
	15	19.52	20.7	40.2				
	16	18.56	20.3	38.9				
	17	14.85	16.6	31.5	55			
	18	23.33	23.2	46.5	55	1		
	19	21.43	21.4	42.8				
	20	18.21	19.4	37.6		2		
	21	22.80	21.4	44.2		3		
	22	24.04	23.0	47.0		1	1	
	23	21.89	22.4	44.3		3	1	
	24	21.19	22.4	43.6	55	1		
	25	24.22	24.8	49.0	55			
	26	24.89	23.3	48.2		3	1	
	27	19.32	17.7	37.0		3		
	28	11.83	15.2	27.0		1	1	
	29	14.90	14.3	29.2		2		
	30	16.42	14.3	30.7		2		
	31	16.81	13.3	30.1	55	1		
	Totals	588.9	603.7	1192.6	kg			
						37	7	Bags

Bags from Daily Reckoning

	A Bags	B Bags		Running	Totals	
2mm	5.9	5.3	>		11	25 kg bags
3mm	17.7	18.8	>	37		

Montly Average 38.5 kg/day



FEED REGISTER for the Month of **April 01**

LINE A

FEED

Type	mm	kg/L	
A	3	0.706	
B	2/3	0.708	50/50
C	2	0.709	

S - Saturday, Sunday

Tk No>		1				2				3				4				5				6			
		Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt
DAY		A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg
1	S	2.25			1.59	2.25			1.59	6.00			4.24	6.00			4.24		6.25		4.42	6.00			4.24
2		2.25			1.59	2.50			1.77	6.00			4.24	6.25			4.41		6.50		4.60	6.00			4.24
3		2.75			1.94	1.50			1.06	5.00			3.53	4.75			3.35		5.00		3.54	3.25			2.29
4		2.25			1.59	2.25			1.59	4.25			3.00	4.50			3.18		4.00		2.83				0.00
5		1.00			0.71	1.00			0.71	2.00			1.41	2.00			1.41		4.00		2.83				0.00
6		3.00			2.12	3.00			2.12	4.25			3.00	4.75			3.35		5.50		3.89				0.00
7	S	3.25			2.29	2.75			1.94	3.75			2.65	4.50			3.18		5.25		3.71				0.00
8	S	2.75			1.94	2.75			1.94	6.00			4.24	6.00			4.24		6.00		4.25				0.00
9		3.75			2.65	3.75			2.65	6.00			4.24	6.00			4.24		6.50		4.60				0.00
10		1.75			1.24	2.00			1.41	3.75			2.65	3.25			2.29		3.25		2.30				0.00
11		2.25			1.59	2.25			1.59	4.25			3.00	4.25			3.00		4.50		3.18				0.00
12		6.50			4.59	4.25			3.00	6.25			4.41	7.75			5.47		5.75		4.07				0.00
13		2.75			1.94	2.25			1.59	3.75			2.65	4.25			3.00		5.75		4.07				0.00
14	S	2.25			1.59	2.25			1.59	3.50			2.47	3.50			2.47		4.00		2.83				0.00
15	S	2.75			1.94	2.75			1.94	5.50			3.88	5.50			3.88		6.00		4.25				0.00
16		3.00			2.12	0.50			0.35	3.75			2.65	3.75			2.65		3.00		2.12				0.00
17		2.75			1.94	2.50			1.77	3.50			2.47	3.50			2.47		5.00		3.54				0.00
18		4.25			3.00	2.75			1.94	5.50			3.88	5.25			3.71		6.75		4.78				0.00
19		3.00			2.12	4.00			2.82	4.00			2.82	4.00			2.82		4.75		3.36				0.00
20		3.50			2.47	3.00			2.12	5.00			3.53	5.00			3.53		5.00		3.54				0.00
21	S	7.00			4.94	3.50			2.47	6.00			4.24	6.00			4.24		6.00		4.25				0.00
22	S	4.00			2.82	7.00			4.94	4.00			2.82	4.00			2.82		4.00		2.83				0.00
23		5.50			3.88	4.00			2.82	5.50			3.88	5.50			3.88		6.50		4.60				0.00
24		3.00			2.12	5.00			3.53	3.00			2.12	3.00			2.12		3.75		2.65				0.00
25		4.50			3.18	3.00			2.12	3.75			2.65	4.00			2.82		5.25		3.71				0.00
26		1.50			1.06	4.25			3.00	1.25			0.88	1.50			1.06		2.25		1.59				0.00
27		3.25			2.29	1.50			1.06	3.00			2.12	3.00			2.12	3.00			2.12				0.00
28	S	5.00			3.53	3.25			2.29	4.25			3.00	4.50			3.18	4.50			3.18	4.50			3.18
29	S	4.00			2.82	4.25			3.00	4.00			2.82	4.00			2.82	4.00			2.82	4.00			2.82
30		4.25			3.00	4.00			2.82	3.75			2.65	4.00			2.82	5.00			3.53	5.00			3.53
31					0.00	3.75			2.65				0.00				0.00				0.00				0.00
																								Total>	

Daily Feed Summary	
kg	Day
20.31	1
20.84	2
15.72	3
12.18	4
7.07	5
14.48	6
13.77	7
16.60	8
18.37	9
9.89	10
12.36	11
21.54	12
13.25	13
10.95	14
15.89	15
9.89	16
12.19	17
17.31	18
13.95	19
15.19	20
20.13	21
16.24	22
19.07	23
12.54	24
14.48	25
7.59	26
9.71	27
18.36	28
17.12	29
18.36	30
2.65	31
447.98	kg

Running Totals

Vol, L		100.00	0.00	0.00		93.75	0.00	0.00		130.50	0.00	0.00		134.25	0.00	0.00		16.50	130.50	0.00		28.75	0.00	0.00	
Sum wt, kg>	kg				70.60				66.19				92.13				94.78				103.98				20.30
2mm	kg				0.00				0.00				0.00				0.00				46.16				0.00
3mm	kg				70.60				66.19				92.13				94.78				57.81				20.30
Check wt					70.60				66.19				92.13				94.78				103.98				20.30
Wt	kg	70.60	0.00	0.00	70.60	66.19	0.00	0.00	66.19	92.13	0.00	0.00	92.13	94.78	0.00	0.00	94.78	11.65	92.33	0.00	103.98	20.30	0.00	0.00	20.30

Totals to Date	
kg	Bags
46.16	1.8
401.81	16.1
447.98	
447.98	

FEED REGISTER for the Month of **April 01**
LINE B

FEED

Type	mm	kg/L	
A	3	0.706	
B	2/3	0.708	50/50
C	2	0.709	

S - Saturday, Sunday

Tk No>		1				2				3				4				5				6			
		Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt
DAY		A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg
1	S	2.25			1.59	6.00			4.24	6.00			4.24	2.75			1.94		6.25		4.42				0.00
2		2.25			1.59	6.00			4.24	6.25			4.41	2.25			1.59		6.75		4.78				0.00
3		1.75			1.24	5.25			3.71	5.75			4.06	2.00			1.41		5.00		3.54				0.00
4		2.25			1.59	4.75			3.35	4.25			3.00	2.75			1.94		5.50		3.89				0.00
5		1.75			1.24	1.75			1.24	1.00			0.71	1.75			1.24		3.75		2.65	1.50			1.06
6		3.25			2.29	4.75			3.35	4.75			3.35	3.00			2.12		5.50		3.89	3.00			2.12
7	S	3.00			2.12	4.25			3.00	4.50			3.18	3.25			2.29		5.25		3.71	2.00			1.41
8	S	2.50			1.77	6.00			4.24	6.00			4.24	3.75			2.65		6.00		4.25	2.75			1.94
9		3.50			2.47	6.25			4.41	6.25			4.41	3.75			2.65		6.50		4.60	3.75			2.65
10		1.25			0.88	3.25			2.29	3.25			2.29	2.50			1.77		3.00		2.12	1.75			1.24
11		2.25			1.59	4.25			3.00	4.75			3.35	2.50			1.77		5.00		3.54	3.50			2.47
12		2.75			1.94	5.00			3.53	5.25			3.71	6.50			4.59		6.50		4.60	3.75			2.65
13		2.00			1.41	4.75			3.35	4.00			2.82	3.00			2.12		5.50		3.89	4.00			2.82
14	S	2.00			1.41	3.25			2.29	4.25			3.00	1.50			1.06		4.75		3.36	2.00			1.41
15	S	3.25			2.29	5.50			3.88	5.50			3.88	3.00			2.12		6.00		4.25	3.25			2.29
16		2.50			1.77	3.75			2.65	3.50			2.47	2.00			1.41		4.25		3.01	3.00			2.12
17		3.00			2.12	3.25			2.29	2.75			1.94	3.50			2.47		5.00		3.54	3.00			2.12
18		4.25			3.00	6.00			4.24	6.25			4.41	3.75			2.65		6.75		4.78	4.00			2.82
19		2.75			1.94	4.00			2.82	4.00			2.82	2.75			1.94		4.75		3.36	2.25			1.59
20		3.50			2.47	5.00			3.53	5.00			3.53	3.50			2.47		5.25		3.71	2.50			1.77
21	S	7.00			4.94	6.00			4.24	6.00			4.24	7.00			4.94		6.00		4.25	7.00			4.94
22	S	4.00			2.82	4.00			2.82	4.00			2.82	4.00			2.82		4.00		2.83	4.00			2.82
23		5.00			3.53	5.50			3.88	5.50			3.88	5.00			3.53		6.50		4.60	5.00			3.53
24		3.00			2.12	3.00			2.12	3.00			2.12	3.00			2.12		4.00		2.83	3.00			2.12
25		4.00			2.82	4.50			3.18	4.50			3.18	4.00			2.82		5.25		3.71	4.50			3.18
26		1.75			1.24	1.50			1.06	2.00			1.41	1.75			1.24		3.75		2.65	2.50			1.77
27		3.25			2.29	3.25			2.29	3.00			2.12	3.00			2.12				0.00	3.75			2.65
28	S	5.00			3.53	4.75			3.35	5.00			3.53	5.00			3.53				0.00	4.75			3.35
29	S	4.00			2.82	4.00			2.82	4.00			2.82	4.00			2.82				0.00	4.00			2.82
30		4.00			2.82	3.25			2.29	3.50			2.47	3.75			2.65				0.00	4.75			3.35
31					0.00				0.00				0.00				0.00				0.00				0.00

Daily Sum	
kg	Day
16.42	1
16.60	2
13.95	3
13.78	4
8.12	5
17.13	6
15.72	7
19.07	8
21.19	9
10.59	10
15.72	11
21.01	12
16.42	13
12.54	14
18.72	15
13.42	16
14.48	17
21.90	18
14.48	19
17.48	20
27.54	21
16.95	22
22.95	23
13.42	24
18.89	25
9.36	26
11.47	27
17.30	28
14.12	29
13.59	30
0.00	31
484.34	KG

Total>

Running Totals

Vol, L		93.00	0.00	0.00		132.75	0.00	0.00		133.75	0.00	0.00		100.25	0.00	0.00		0.00	136.75	0.00		89.25	0.00	0.00	
Sum wt, kg:	kg				65.66				93.72				94.43				70.78				96.75				63.01
2mm	kg				0.00				0.00				0.00				0.00				48.38				0.00
3mm	kg				65.66				93.72				94.43				70.78				48.38				63.01
Check wt					65.66				93.72				94.43				70.78				96.75				63.01
Wt	kg	65.66	0.00	0.00	65.66	93.72	0.00	0.00	93.72	94.43	0.00	0.00	94.43	70.78	0.00	0.00	70.78	0.00	96.75	0.00	96.75	63.01	0.00	0.00	63.01

Totals to Date	
kg	Bags
48.38	1.94
435.97	17.44
484.34	
484.34	

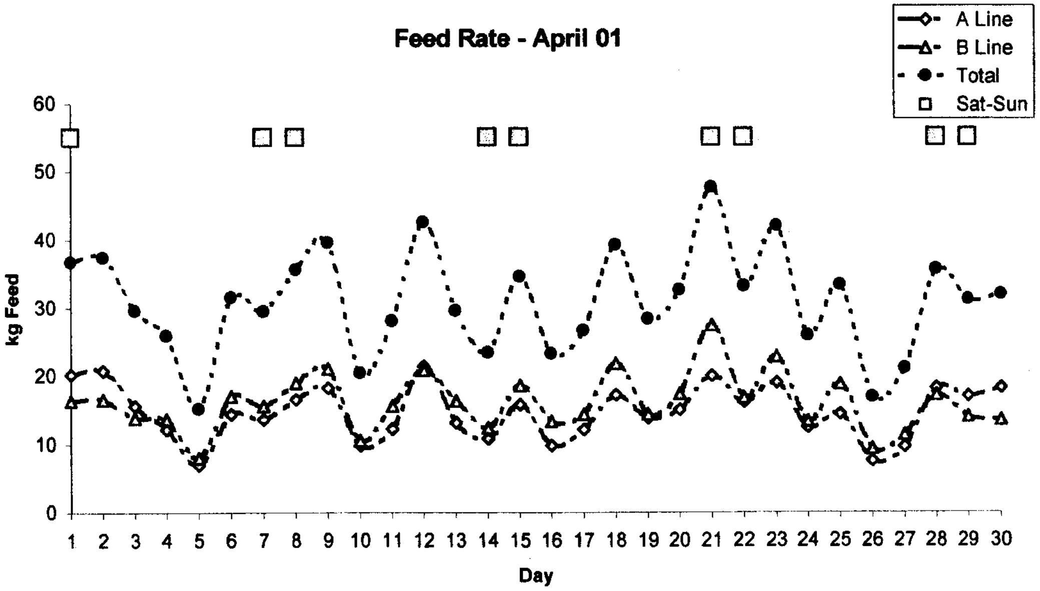
April 01	Daily Feed Summary, kg					Daily Bags Tally		
	Day	A Line	B Line	Total	Wkend	3mm	2mm	
	1	20.31	16.4	36.7	55	1		
	2	20.84	16.6	37.4		3	1	
	3	15.72	14.0	29.7				
	4	12.18	13.8	26.0		3		
	5	7.07	8.1	15.2		3		
	6	14.48	17.1	31.6		2		
	7	13.77	15.7	29.5	55	1	1	
	8	16.60	19.1	35.7	55			
	9	18.37	21.2	39.6		3		
	10	9.89	10.6	20.5				
	11	12.36	15.7	28.1		3	1	
	12	21.54	21.0	42.6			3	
	13	13.25	16.4	29.7		2	1	
	14	10.95	12.5	23.5	55			
	15	15.89	18.7	34.6	55		1	
	16	9.89	13.4	23.3			1	
	17	12.19	14.5	26.7		4		
	18	17.31	21.9	39.2		1		
	19	13.95	14.5	28.4				
	20	15.19	17.5	32.7				
	21	20.13	27.5	47.7	55	1		
	22	16.24	17.0	33.2	55	1		
	23	19.07	23.0	42.0		1		
	24	12.54	13.4	26.0		2		
	25	14.48	18.9	33.4		3		
	26	7.59	9.4	17.0		1		
	27	9.71	11.5	21.2				
	28	18.36	17.3	35.7	55	2		
	29	17.12	14.1	31.2	55	1		
	30	18.36	13.6	31.9				
	Totals	445.3	484.3	929.7	kg			
						38	9	Bags

Bags from Daily Reckoning

	A Bags	B Bags		Running	Totals
2mm	1.8	1.9	>		4
3mm	16.1	17.4	>	34	

Bags tally discontinued as counts missed and bags taken to feed outside fish recorded.

Monthly Average 31.0 kg/day



25 kg bags

FEED REGISTER for the Month of **May 01**

LINE A

FEED

Type	mm	kg/L	
A	3	0.706	
B	2/3	0.708	50/50
C	2	0.709	

S - Saturday, Sunday

Tk No>		1				2				3				4				5				6			
		Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt
DAY		A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg
1		3.00			2.12	3.00			2.12	2.25			1.59	2.75			1.94	4.00			2.82	2.00			1.41
2		3.75			2.65	3.75			2.65	3.25			2.29	3.00			2.12	5.00			3.53	3.50			2.47
3		4.00			2.82	4.00			2.82	3.75			2.65	3.75			2.65	3.75			2.65	3.75			2.65
4		2.00			1.41	2.00			1.41	1.25			0.88	1.25			0.88				0.00	1.00			0.71
5	S	3.00			2.12	3.00			2.12	2.75			1.94	3.00			2.12				0.00	3.25			2.29
6	S	4.25			3.00	4.25			3.00	4.25			3.00	4.75			3.35				0.00	4.25			3.00
7		2.00			1.41	2.00			1.41	2.00			1.41	2.00			1.41				0.00	2.00			1.41
8		3.75			2.65	4.00			2.82	3.00			2.12	3.00			2.12				0.00	3.50			2.47
9		4.50			3.18	4.25			3.00	4.00			2.82	4.25			3.00	4.00			2.82	4.50			3.18
10		2.00			1.41	2.00			1.41	2.00			1.41	2.00			1.41	2.00			1.41	3.25			2.29
11		3.00			2.12	3.00			2.12	3.00			2.12	3.00			2.12	3.00			2.12	4.75			3.35
12	S	4.75			3.35	3.75			2.65	3.00			2.12	3.00			2.12	5.00			3.53	4.75			3.35
13	S	6.50			4.59	5.00			3.53	4.00			2.82	3.75			2.65	5.00			3.53	5.25			3.71
14		5.25			3.71	5.50			3.88	2.00			1.41	2.00			1.41	2.75			1.94	3.75			2.65
15		5.00			3.53	4.00			2.82	1.75			1.24	2.00			1.41	2.00			1.41	2.00			1.41
16		4.00			2.82	4.00			2.82	3.50			2.47	3.75			2.65	5.00			3.53	5.00			3.53
17		4.00			2.82	4.25			3.00	3.75			2.65	3.75			2.65	6.50			4.59	6.25			4.41
18		3.75			2.65	3.75			2.65	2.75			1.94	2.75			1.94	4.50			3.18	4.50			3.18
19	S	3.25			2.29	3.40			2.40	2.00			1.41	2.00			1.41	2.00			1.41	2.00			1.41
20	S	3.75			2.65	4.00			2.82	3.50			2.47	3.50			2.47	3.00			2.12	3.00			2.12
21		3.00			2.12	2.75			1.94	2.25			1.59	2.00			1.41	4.75			3.35	5.25			3.71
22		4.75			3.35	4.75			3.35	4.50			3.18	4.75			3.35	5.50			3.88	5.50			3.88
23		2.00			1.41	2.50			1.77				0.00				0.00	1.75			1.24	2.00			1.41
24		2.50			1.77	3.00			2.12				0.00				0.00	2.50			1.77	2.50			1.77
25		6.00			4.24	6.00			4.24				0.00				0.00				0.00	6.50			4.59
26	S	4.00			2.82	4.00			2.82				0.00				0.00				0.00	3.50			2.47
27	S	5.90			4.17	5.90			4.17				0.00				0.00				0.00	1.00			0.71
28		6.00			4.24	6.00			4.24				0.00				0.00				0.00				0.00
29		2.00			1.41	2.00			1.41				0.00				0.00				0.00				0.00
30		4.00			2.82	4.00			2.82				0.00				0.00				0.00				0.00
31		3.00			2.12	3.00			2.12				0.00				0.00				0.00				0.00
																									Total >

Daily Feed Summary	
kg	Day
12.00	1
15.71	2
16.24	3
5.30	4
10.59	5
15.36	6
7.06	7
12.18	8
18.00	9
9.35	10
13.94	11
17.12	12
20.83	13
15.00	14
11.83	15
17.83	16
20.12	17
15.53	18
10.34	19
14.65	20
14.12	21
21.00	22
5.82	23
7.41	24
13.06	25
8.12	26
9.04	27
8.47	28
2.82	29
5.65	30
4.24	31
378.73	kg

Running Totals

Vol, L		118.65	0.00	0.00		116.80	0.00	0.00		64.50	0.00	0.00		66.00	0.00	0.00		72.00	0.00	0.00		98.50	0.00	0.00	
Sum wt, kg>	kg				83.77				82.46				45.54				46.60				50.83				69.54
2mm	kg				0.00				0.00				0.00				0.00				0.00				0.00
3mm	kg				83.77				82.46				45.54				46.60				50.83				69.54
Check wt					83.77				82.46				45.54				46.60				50.83				69.54
Wt	kg	83.77	0.00	0.00	83.77	82.46	0.00	0.00	82.46	45.54	0.00	0.00	45.54	46.60	0.00	0.00	46.60	50.83	0.00	0.00	50.83	69.54	0.00	0.00	69.54

Totals to Date	
kg	Bags
0.00	0.0
378.73	15.1
378.73	
378.73	

D11

FEED REGISTER for the Month of May 01
LINE B

FEED

Type	mm	kg/L	
A	3	0.706	
B	2/3	0.708	50/50
C	2	0.709	

S - Saturday, Sunday

Tk No>		1				2				3				4				5				6			
		Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt	Litres			Wt
DAY		A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg	A	B	C	kg
1		3.25			2.29	3.75			2.65	3.25			2.29	4.75			3.35				0.00	5.00			3.53
2		4.00			2.82	4.00			2.82	3.00			2.12	3.75			2.65				0.00	5.25			3.71
3		4.50			3.18	4.00			2.82	4.00			2.82	4.00			2.82				0.00	4.50			3.18
4		2.00			1.41	2.00			1.41	2.00			1.41	2.00			1.41				0.00	2.00			1.41
5	S	3.00			2.12	3.25			2.29	3.50			2.47	2.75			1.94	0.75			0.53	3.50			2.47
6	S	4.00			2.82	4.25			3.00	4.25			3.00	4.25			3.00	1.25			0.88	3.75			2.65
7		2.00			1.41	2.00			1.41	2.00			1.41	2.00			1.41	1.25			0.88	2.75			1.94
8		2.50			1.77	3.00			2.12	3.00			2.12	3.00			2.12	1.55			1.09	4.00			2.82
9		3.75			2.65	4.50			3.18	4.50			3.18	4.00			2.82	1.25			0.88	3.25			2.29
10		2.00			1.41	2.00			1.41	2.00			1.41	2.00			1.41	1.50			1.06	2.00			1.41
11		3.00			2.12	2.75			1.94	3.00			2.12	3.00			2.12	2.00			1.41	3.00			2.12
12	S	4.50			3.18	4.50			3.18	4.25			3.00	4.25			3.00	2.25			1.59	4.50			3.18
13	S	5.00			3.53	4.00			2.82	4.25			3.00	5.50			3.88	4.25			3.00	5.75			4.06
14		5.00			3.53	2.75			1.94	2.75			1.94	5.75			4.06	2.75			1.94	5.75			4.06
15		4.50			3.18	2.00			1.41	1.50			1.06	6.00			4.24	1.50			1.06	5.00			3.53
16		3.75			2.65	4.00			2.82	3.75			2.65	4.50			3.18	4.00			2.82	4.75			3.35
17		4.00			2.82	4.00			2.82	3.50			2.47	5.25			3.71	4.50			3.18	4.50			3.18
18		3.25			2.29	2.75			1.94	2.75			1.94	4.25			3.00	3.00			2.12	3.50			2.47
19	S	3.50			2.47	3.00			2.12	2.00			1.41	3.25			2.29	2.00			1.41	5.00			3.53
20	S	4.00			2.82	3.75			2.65	3.75			2.65	4.25			3.00	3.60			2.54	5.25			3.71
21		3.00			2.12	3.00			2.12	3.00			2.12	3.50			2.47	6.25			4.41	3.00			2.12
22		4.25			3.00	4.50			3.18	4.25			3.00	5.00			3.53	4.25			3.00	5.00			3.53
23		2.00			1.41				0.00				0.00	3.00			2.12	0.00			0.00	3.00			2.12
24		2.75			1.94				0.00				0.00	3.50			2.47	0.00			0.00	0.00			0.00
25		6.00			4.24				0.00				0.00	6.00			4.24	2.50			1.77	6.00			4.24
26	S	4.00			2.82				0.00				0.00	4.00			2.82	4.50			3.18	4.00			2.82
27	S	5.90			4.17				0.00				0.00	5.90			4.17	5.00			3.53	5.90			4.17
28		6.00			4.24				0.00				0.00	6.00			4.24	1.00			0.71	4.00			2.82
29		2.00			1.41				0.00				0.00	2.00			1.41				0.00	2.00			1.41
30		4.00			2.82				0.00				0.00	4.00			2.82				0.00	4.00			2.82
31		3.00			2.12				0.00				0.00	3.00			2.12				0.00	3.00			2.12

Daily Sum	
kg	Day
14.12	1
14.12	2
14.83	3
7.06	4
11.83	5
15.36	6
8.47	7
12.04	8
15.00	9
8.12	10
11.83	11
17.12	12
20.30	13
17.47	14
14.47	15
17.47	16
18.18	17
13.77	18
13.24	19
17.37	20
15.36	21
19.24	22
5.65	23
4.41	24
14.47	25
11.65	26
16.03	27
12.00	28
4.24	29
8.47	30
6.35	31
400.02	Kg

Total >

Running Totals

Vol, L		65.90	0.00	0.00		73.75	0.00	0.00		70.25	0.00	0.00		124.40	0.00	0.00		60.90	0.00	0.00		122.90	0.00	0.00	
Sum wt, kg>	kg				80.77				52.07				49.60				87.83				43.00				86.77
2mm	kg				0.00				0.00				0.00				0.00				0.00				0.00
3mm	kg				46.53				52.07				49.60				87.83				43.00				86.77
Check wt					46.53				52.07				49.60				87.83				43.00				86.77
Wt	kg	46.53	0.00	0.00	46.53	52.07	0.00	0.00	52.07	49.60	0.00	0.00	49.60	87.83	0.00	0.00	87.83	43.00	0.00	0.00	43.00	86.77	0.00	0.00	86.77

Totals to Date	
kg	Bags
0.00	0.00
365.78	14.63
365.78	
365.78	

May-01	Daily Feed Summary, kg					Daily Bags Tally		
	Day	A Line	B Line	Total	Wkend	3mm	2mm	
	1	12.00	14.1	26.1		1		
	2	15.71	14.1	29.8		3	1	
	3	16.24	14.8	31.1				
	4	5.30	7.1	12.4				
	5	10.59	11.8	22.4	55			
	6	15.36	15.4	30.7	55			
	7	7.06	8.5	15.5				
	8	12.18	12.0	24.2				
	9	18.00	15.0	33.0				
	10	9.35	8.1	17.5				
	11	13.94	11.8	25.8				
	12	17.12	17.1	34.2	55			
	13	20.83	20.3	41.1	55			
	14	15.00	17.5	32.5				
	15	11.83	14.5	26.3				
	16	17.83	17.5	35.3				
	17	20.12	18.2	38.3				
	18	15.53	13.8	29.3				
	19	10.34	13.2	23.6	55			
	20	14.65	17.4	32.0	55			
	21	14.12	15.4	29.5				
	22	21.00	19.2	40.2				
	23	5.82	5.6	11.5				
	24	7.41	4.4	11.8				
	25	13.06	14.5	27.5				
	26	8.12	11.6	19.8	55			
	27	9.04	16.0	25.1	55			
	28	8.47	12.0	20.5				
	29	2.82	4.2	7.1				
	30	5.65	8.5	14.1				
	31	4.24	6.4	10.6				
	Totals	378.7	400.0	778.8	kg			
						4	1	Bags

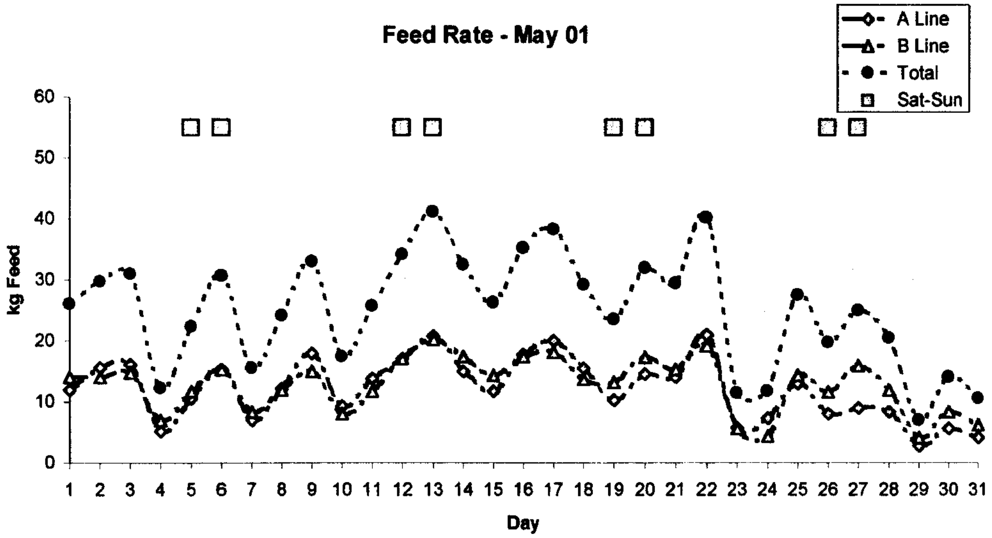
Bags from Daily Reckoning

	A Bags	B Bags		Running	Totals
2mm	0.0	0.0	>		0
3mm	15.1	14.6	>	30	

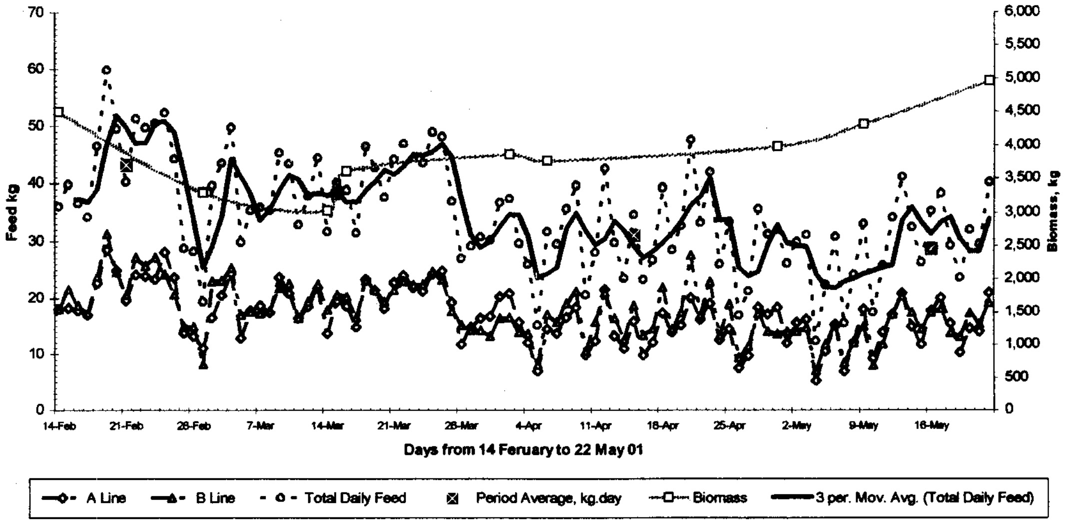
25 kg bags

Bag count discontinued as bags were sometimes not recorded and bags used for outside tanks were recorded.

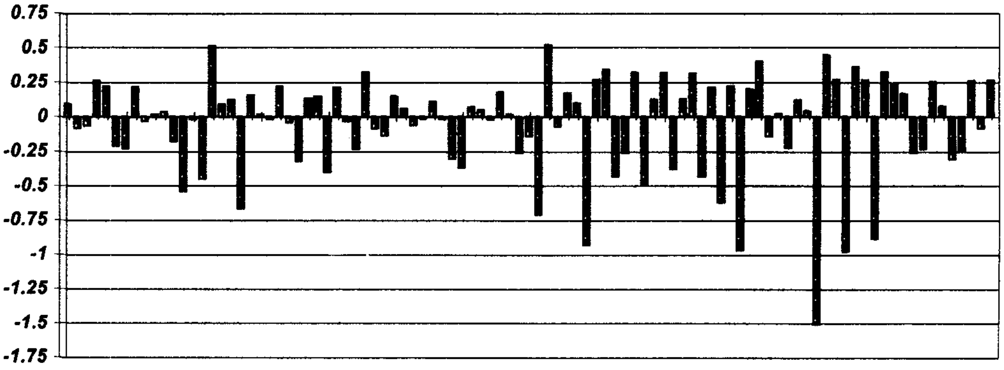
Monthly Average 25.1 kg/day



Daily Feed Record
14 February - 22 May 2001



Percent. Changes in Daily Total Feed Rate



FEED BULK DENSITY DETERMINATION

EWOS Vextra Transfer

3mm			2/3mm			2mm		
		Bulk Density	1/4 3mm, 3/4 2mm		**Bulk Density**			**Bulk Density**
Vol, mL	**Wt, g**	**kg/L**	**Vol, mL**	**Wt, g**	**kg/L**	**Vol, mL**	**Wt, g**	**kg/L**
92	63.87	0.694	95	67.35	0.709	87	62.21	0.715
100	70.53	0.705	100	71.63	0.716	95	67.77	0.713
95	67.82	0.714	98	71.11	0.726	93	65.67	0.706
94	66.58	0.708	98	70.51	0.719	86	61.09	0.710
99	69.97	0.707	96	66.83	0.696	91	64.1	0.704

Statistics	Mean	0.7057	Mean	0.713299	Mean	0.70986
	Standard Error	0.003214	Standard Error	0.0050602	Standard Error	0.002041
	Median	0.706768	Median	0.7163	Median	0.710349
	Mode	NA	Mode	NA	Mode	NA
	Standard Deviation	0.007186	Standard Deviation	0.011315	Standard Deviation	0.004565
	Variance	5.2E-05	Variance	0.000128	Variance	2.1E-05
	Range	0.019656	Range	0.0294664	Range	0.010662
	Minimum	0.694239	Minimum	0.6961458	Minimum	0.704396
	Maximum	0.713895	Maximum	0.7256122	Maximum	0.715057
	Sum	3.528499	Sum	3.5664952	Sum	3.549299
	Count	5	Count	5	Count	5

Use **0.71** kg/L

		Feed/tk Vol, L	**Wt, kg**	**No. of tanks**	**No. Feeds**	**Feed kg/day**
9 Jan	"large" fish tanks	2.07	1.5	4	5	29.4
	"small" fish tanks	1.64	1.2	8	5	46.6
					Total	76.0

Presently feeding about 100 kg/day EWOS Vextra Transfer

Estimate of 2mm feed :0.75*2mm + 0.25*3mm = 0.713299 kg/L
or 2mm = (0.713299 - 0.25*07057)/0.75
Bulk density 2mm = 0.716 kg/L

Estmated density, 50/50 ration = 0.50*0.7057 + 0.5*0.7158 = 0.711 kg/L

Sample Daily Tank Feed Record (tanks A1 and A2)

A1 **No Change: use “** **A2**

Date: No. Fish Wt.

Time	Feed, L				Feed type

No. Fish Wt.

Time	Feed, L				Feed type

Date: No. Fish Wt.

Time	Feed, L				Feed type

No. Fish Wt.

Time	Feed, L				Feed type

Date: No. Fish Wt.

Time	Feed, L				Feed type

No. Fish Wt.

Time	Feed, L				Feed type

Date: No. Fish Wt.

Time	Feed, L				Feed type

No. Fish Wt.

Time	Feed, L				Feed type

Sample: Feed Bag Record Sheet

FEED BAG RECORD

Record when a new bag is opened.

DATE	TYPE OF FEED			REMARKS
	2 mm	3mm		

Estimate of Feed Inputs to Waste Products (Digestibility 91%)

Total solids input = % dry solids x (1- % digestibility of dry solids) (D. Bureau, UGuelph. pers.comm)

EWOS Transfer

Item	% kg	% Digested
Dry Solids	92.0%	91.0%
Protein	49.0%	90.0%
N		
P	1.3%	0.5%
Ca	2.3%	
Na	0.9%	

Est. Waste Feed
1.00%

Data

Date	1-Day	3-Day Avg	Biomass, k	T
14-Feb	36.06	36.10	4506	10.1
5-Mar	29.86	41.09		7.6
14-Mar	31.67	38.02	3024	7.9
2-Apr	37.44	34.77	3859	9.3
16-Apr	23.31	27.14		6.4
30-Apr	31.95	32.95	3973	8.2
16-May	35.30	31.37		10.3
21-May	29.50	28.37	4957	10.5

% Biomass	
1-Day	3-Day
0.80%	0.80%
1.05%	1.26%
0.97%	0.90%
0.80%	0.83%
0.60%	0.57%

Estimates of Eaten Feed Input to Wastes

1-Day Feed Record			
	TSS	Protein	P
	2.96	1.75	0.46
	2.45	1.45	0.38
	2.60	1.54	0.41
	3.07	1.82	0.48
	1.91	1.13	0.30
	2.62	1.55	0.41
	2.89	1.71	0.45
	2.42	1.43	0.38
Average	2.61	1.55	0.41
S.D	0.37	0.22	0.06

3-Day Average Feed Record			
	TSS	Protein	P
	2.96	1.75	0.46
	3.37	1.99	0.53
	3.12	1.84	0.49
	2.85	1.69	0.45
	2.22	1.32	0.35
	2.70	1.60	0.42
	2.57	1.52	0.40
	2.33	1.38	0.36
Average	2.76	1.64	0.43
S.D	0.39	0.23	0.06

Estimates of Waste Feed Input to Wastes

1-Day Feed Record			
	TSS	Protein	P
	0.33	0.18	0.0047
	0.27	0.15	0.0039
	0.29	0.16	0.0041
	0.34	0.18	0.0049
	0.21	0.11	0.0030
	0.29	0.16	0.0042
	0.32	0.17	0.0046
	0.27	0.14	0.0038
Average	0.29	0.16	0.0041
S.D	0.04	0.02	0.0006

3-Day Average Feed Record			
	TSS	Protein	P
	0.33	0.18	0.0047
	0.38	0.20	0.0053
	0.35	0.19	0.0049
	0.32	0.17	0.0045
	0.25	0.13	0.0035
	0.30	0.16	0.0043
	0.29	0.15	0.0041
	0.26	0.14	0.0037
Average	0.31	0.17	0.0044
S.D	0.04	0.02	0.0006

Total Estimates of Feed Input to Wastes

1-Day Feed Record			
	TSS	Protein	P
	3.29	1.93	0.47
	2.72	1.59	0.39
	2.89	1.69	0.41
	3.41	2.00	0.48
	2.13	1.24	0.30
	2.91	1.71	0.41
	3.22	1.89	0.46
	2.69	1.58	0.38
Average	2.91	1.70	0.41
S.D	0.41	0.24	0.06

3-Day Average Feed Record			
	TSS	Protein	P
	3.29	1.93	0.47
	3.75	2.19	0.53
	3.47	2.03	0.49
	3.17	1.86	0.45
	2.47	1.45	0.35
	3.00	1.76	0.43
	2.86	1.68	0.41
	2.59	1.52	0.37
Average	3.07	1.80	0.44
S.D	0.43	0.25	0.06

Estimate of Feed Inputs to Waste Products (Digestibility 90%)

Total solids input = % dry solids x (1- % digestibility of dry solids) (D. Bureau, UGuelph. pers.comm)

EWOS Transfer

Item	% kg	% Digested
Dry Solids	92.0%	90.0%
Protein	49.0%	90.0%
N		
P	1.3%	0.5%
Ca	2.3%	
Na	0.9%	

Est. Waste Feed
1.00%

Data

Date	1-Day	3-Day Avg	Biomass, k	T
14-Feb	36.06	36.10	4506	10.1
5-Mar	29.86	41.09		7.6
14-Mar	31.67	38.02	3024	7.9
2-Apr	37.44	34.77	3859	9.3
16-Apr	23.31	27.14		6.4
30-Apr	31.95	32.95	3973	8.2
16-May	35.30	31.37		10.3
21-May	29.50	28.37	4957	10.5

% Biomass	
1-Day	3-Day
0.80%	0.80%
1.05%	1.26%
0.97%	0.90%
0.80%	0.83%
0.60%	0.57%

Estimates of Eaten Feed Input to Wastes

	1-Day Feed Record		
	TSS	Protein	P
	3.28	1.75	0.46
	2.72	1.45	0.38
	2.88	1.54	0.41
	3.41	1.82	0.48
	2.12	1.13	0.30
	2.91	1.55	0.41
	3.22	1.71	0.45
	2.69	1.43	0.38
Average	2.90	1.55	0.41
S.D	0.41	0.22	0.06

	3-Day Average Feed Record		
	TSS	Protein	P
	3.29	1.75	0.46
	3.74	1.99	0.53
	3.46	1.84	0.49
	3.17	1.69	0.45
	2.47	1.32	0.35
	3.00	1.60	0.42
	2.86	1.52	0.40
	2.58	1.38	0.36
Average	3.07	1.64	0.43
S.D	0.43	0.23	0.06

Estimates of Waste Feed Input to Wastes

	1-Day Feed Record		
	TSS	Protein	P
	0.33	0.18	0.0047
	0.27	0.15	0.0039
	0.29	0.16	0.0041
	0.34	0.18	0.0049
	0.21	0.11	0.0030
	0.29	0.16	0.0042
	0.32	0.17	0.0046
	0.27	0.14	0.0038
Average	0.29	0.16	0.0041
S.D	0.04	0.02	0.0006

	3-Day Average Feed Record		
	TSS	Protein	P
	0.33	0.18	0.0047
	0.38	0.20	0.0053
	0.35	0.19	0.0049
	0.32	0.17	0.0045
	0.25	0.13	0.0035
	0.30	0.16	0.0043
	0.29	0.15	0.0041
	0.26	0.14	0.0037
Average	0.31	0.17	0.0044
S.D	0.04	0.02	0.0006

Total Estimates of Feed Input to Wastes

	1-Day Feed Record		
	TSS	Protein	P
	3.62	1.93	0.47
	2.99	1.59	0.39
	3.18	1.69	0.41
	3.75	2.00	0.48
	2.34	1.24	0.30
	3.20	1.71	0.41
	3.54	1.89	0.46
	2.96	1.58	0.38
Average	3.20	1.70	0.41
S.D	0.45	0.24	0.06

	3-Day Average Feed Record		
	TSS	Protein	P
	3.62	1.93	0.47
	4.12	2.19	0.53
	3.81	2.03	0.49
	3.49	1.86	0.45
	2.72	1.45	0.35
	3.30	1.76	0.43
	3.15	1.68	0.41
	2.84	1.52	0.37
Average	3.38	1.80	0.44
S.D	0.48	0.25	0.06

APPENDIX E

WATER QUALITY ANALYSIS

SAMPLE PRESERVATION:

Anon. 1997. Water Analysis Handbook. Hach Co. Loveland CO.:Table 10, 1B, page 52:

Parameter	Cont	Preservation	Max Time	
Alkalinity	P,G	Cool, 4°C	24 hrs	Fill completely,cap, warm
Ammonia	P,G	Cool, 4°C, H_2SO_4 to pH <2	28 days	Cl wng., warm, neut with 5 N NaOH
CO_2	P,G	Cool, 4°C	24 hrs	Fill completely,cap, warm
Hardness	P,G	Cool, 4°C, H_2SO_4, HNO_3 to pH <2	6 mos	acid wash, neut to pH 3-8 w/ 5 N NaOH, corr for vol
Iron	P.G.	HNO_3 to pH <2	6 mos	acid wash, neut to pH 3-5 w/ 5 N NaOH, corr for vol
Nitrate	P,G	Cool, 4°C	48 hrs	warm
Nitrite	P,G	Cool, 4°C	48 hrs	warm
Orthophosphate	P,G	Cool, 4°C	48 hrs	acid wash, filter
Phosphorus, total	P,G	Cool, 4°C, H_2SO_4 to pH <2	28 days	acid wash, corr for vol
TKN	P,G	Cool, 4°C, H_2SO_4 to pH <2	28 days	warm
TSS	P,G	Cool, 4°C	7 days	warm
Turbidity	P,G	Cool, 4°C	48 hrs	warm

For pH <2: about 2 mL/L
Cont = container, Plastic , Glass
If low concentrations expected, analyse immediately

Acid wash:

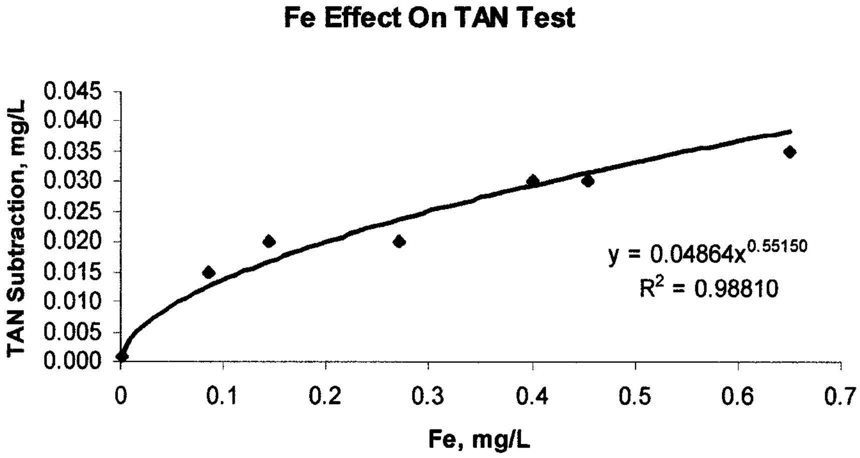
- Wash with P free detergent
- Rinse in tap water
- Rinse with 1:1 HCl or 1:1 HNO_3
- Rinse well with DDW
- Air dry

Correcting For Volume: Record additions.
Example:
Sample - 1 L, preserving acid 2 mL, neutralizing base, 5 mL
Total 1007 mL vs 1000 mL original sample.
Correction factor = 1007/1000 = 1.007
Multiply the result by 1.007.

Calculation of the effect of Culture Water Iron on the Hach Ammonia Nitrogen Test Method 8155 (Anon. 1997).

Site sample were check periodically for total iron (Hach Method 8112, Anon (1997)). It was noted in Method 8155 that iron is an interference with that method.

To determine an iron interference curve, samples of de-ionized, distilled water (DDW) were spiked with iron from a solution of $FeSO_4.7H_2O$. Diluted samples over the range of interest were tested for iron as per Method 8112, and second portions were run through the salicylate NH_3-N test (Method 8155) against a DDW blank. The resultant iron effect readings were plotted against the iron test results. For a reading of total iron, calculate the total ammonia nitrogen (TAN) value deduction from the curve or the equation.



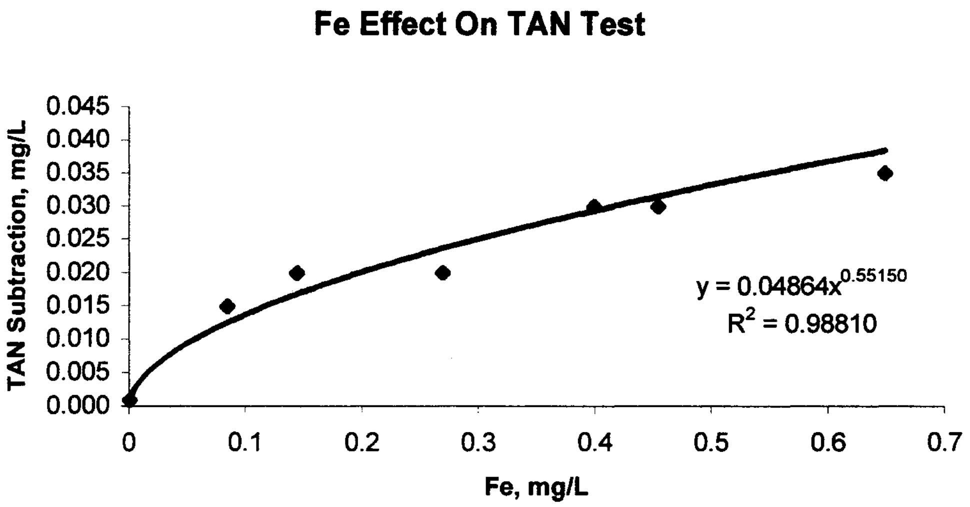
Effect of total iron on the salicylate NH_3-N test. Subtract TAN value from TAN readings

See spreadsheet model next page.

Spreadsheet Model - Fe Effect on Tan Test.

Trial

FE			TAN Test Effect			
1	**2**	**Avg**	**1**	**2**	**Avg**	
		0.001			0.001	(artificial 0,0)
0.08	0.09	0.085	0.01	0.02	0.015	
0.15	0.14	0.145	0.02	0.02	0.02	
0.27	0.27	0.27	0.02	0.02	0.02	
0.4	0.4	0.4	0.03	0.03	0.03	
0.45	0.46	0.455	0.03	0.03	0.03	
0.65	0.65	0.65	0.04	0.03	0.035	



Model

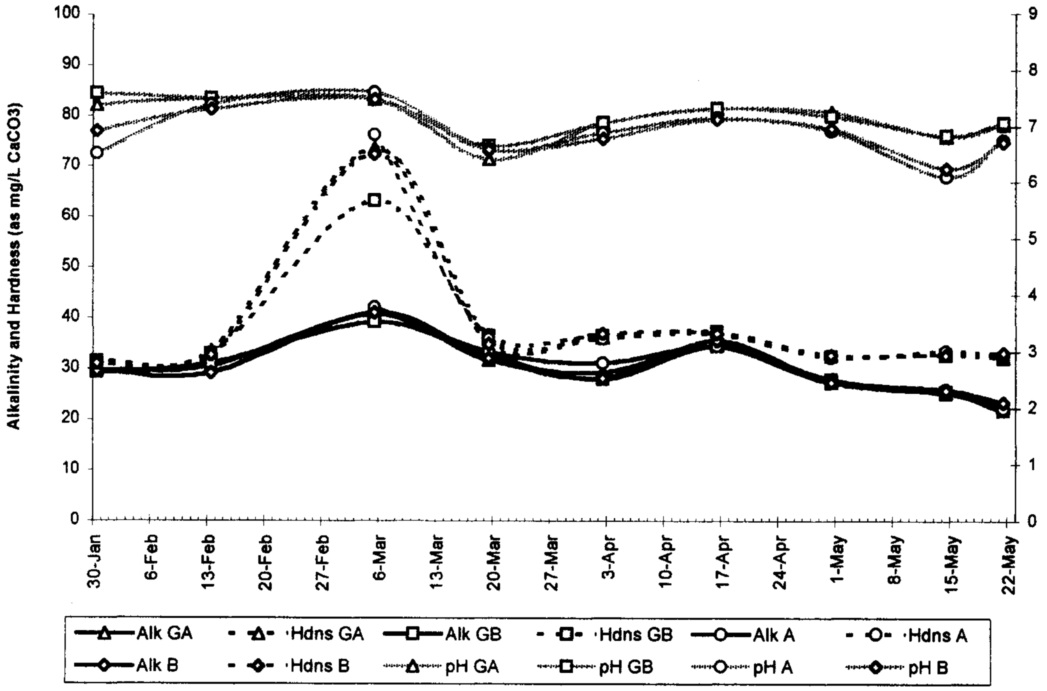
Enter Fe >	0.59	mg/L	
TAN Effect	0.036	mg/L	to be subtracted from TAN results

Historical Data

Data Pt	Date	mg/L	Method	Site	comp.
1	3-Aug-00	0.41	persulfate	Tk	0.030
2	14-Aug-00	0.25	persulfate	Tk	0.023
3	16-Aug-00	0.77	persulfate		0.042
4	10-Oct-00	0.16	persulfate		0.018
5	24-Oct-00	0.12	persulfate	GA	0.015
6	14-Jun-01	0.59	Digesdahl	S Dk	0.036

Plot of pH, Alkalinity and Hardness for Sites A, B, G_A, G_B, BF_A, BF_B

Date	pH G_A	Alk G_A	Hdns G_A	pH G_B	Alk G_B	Hdns G_B	pH A	Alk A	Hdns A	pH B	Alk B	Hdns B
30-Jan	7.4	29.8	30.7	7.61	29.4	31.5	6.53	30	30.9	6.94	29.6	31.1
13-Feb	7.52	30.6	33.6	7.52	31.1	33.1	7.41			7.33	29.2	32.8
5-Mar	7.5	40.8	73.6	7.49	39.2	63.2	7.62	42.2	76.2	7.5	41.2	72.4
19-Mar	6.43	31.8	36.4	6.66	32.6	36.6	6.6	33.4	36	6.6	32.2	35
2-Apr	7.05	29.4	36.2	7.08	28	36.6	6.89	31.2	35.9	6.79	28.2	37
16-Apr	7.31	34.6	36.8	7.33	34.6	37.4	7.16	34.4	36.8	7.13	35.6	37
30-Apr	7.26	27.4	32.6	7.18	27.8	32.4	6.92	27.4	32.2	6.96	27.4	32.6
14-May	6.81	25.2	32.6	6.84	25.4	32.8	6.1	26	33.4	6.24	25.8	32.6
21-May	7.03	22.6	32.2	7.06	21.8	32.2	6.74	22.2	32.6	6.71	23.4	33.2



SPREADSHEET - Alkalinity Mass Flow
kg of $CaCO_3$ per day

IN

	MUWA		MUWB		MUWC		Total Alkalinity In	
Date	L/min	mg/L	L/min	mg/L	L/min	mg/L	L/day	kg/da
5-Mar	284	35.2	76	57.4	76	57.4	626,839	26.9
19-Mar	284	30.8	76	54.4	76	54.4	626,839	24.5
2-Apr	284	33.4	76	55.0	76	55.0	626,839	25.6
16-Apr	284	34.8	76	52.2	76	52.2	626,839	25.6
30-Apr	284	34.0	76	35.0	76	35.0	626,839	21.5
14-May	284	36.0	76	35.8	151	35.8	735,271	26.4
21-May	284	35.2	76	32.0	76	35.8	626,839	21.8

OUT

	Swirl Separator		
Date	L/min	mg/L	kg/da
5-Mar	3600	83.6	0.30
19-Mar	3600	70	0.25
2-Apr	3600	51.8	0.19
16-Apr	3600	52	0.19
30-Apr	3600	52	0.19
14-May	3600	52	0.19
21-May	3600	52	0.19

Grey & Overflow		
L/min	mg/L	kg/da
623,239	42.6	27
623,239	35	22
623,239	28.6	18
623,239	30	19
623,239	31.4	20
731,671	27.6	20
623,239	22.8	14

Total Out
kg/da
26.9
22.1
18.0
18.9
19.8
20.4
14.4

DIFFERENCE

Date	kg/da
5-Mar	0.1
19-Mar	2.4
2-Apr	7.6
16-Apr	6.7
30-Apr	1.8
14-May	6.0
21-May	6.0

Notes

1. Generally flows are estimates
2. Swirl separator alkalinities, except 5 Mar and 2 Apr are estimates.
3. $CaCO_3$ and $NaHCO_3$ were added mid February to early March
4. Alkalinity was recorded in the drum filter wash water, but that was considered primarily wash water alkalinity;

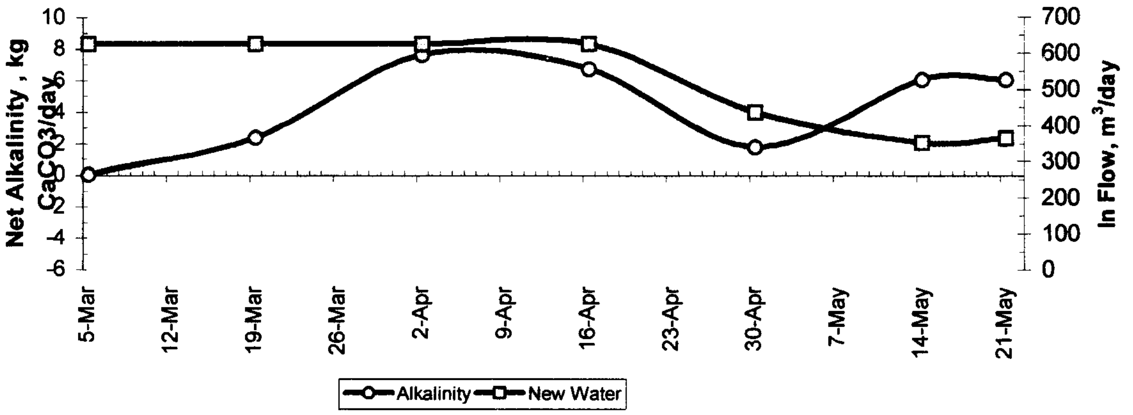
Plot of Difference in Alkalinity Between Make-up Waters and of Make-up Water Inflow

Alkalinity Difference

Date	kg/da
5-Mar	0.1
19-Mar	2.4
2-Apr	7.6
16-Apr	6.7
30-Apr	1.8
14-May	6.0
21-May	6.0

In Flow

Date	L/min	m^3/day
5-Mar	435	627
19-Mar-01	435	627
2-Apr-01	435	627
16-Apr-01	435	627
30-Apr-01	303	436
14-May-01	244	352
21-May-01	253	365



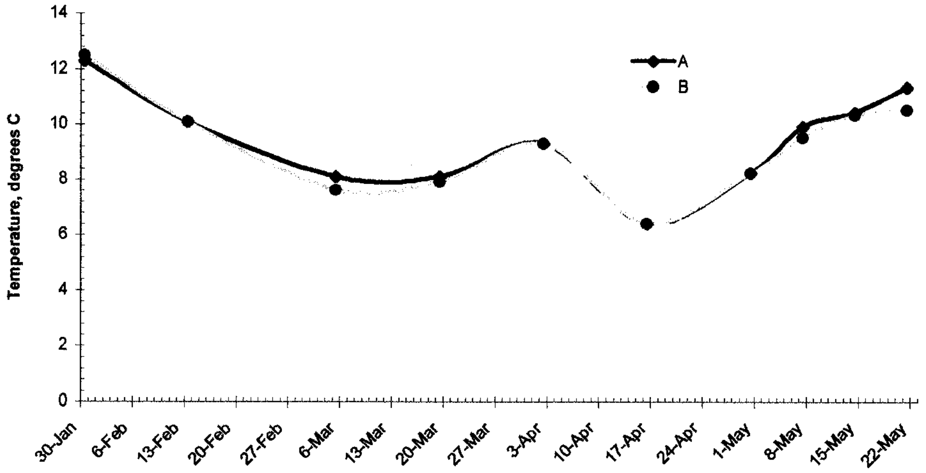
Collected Data 30 Jan 01 to 21 May 01

						***			
TSS	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
A	7	2	4.5	3.5	1	3.4	8	8.7	1
B	3	2	4	3.4	2	2	16.5	2.3	2.5
TDS									
A	69.3	77.6	149.2	89.1	92.5	87.6		88.1	84.8
B	68.8	78.4	149.6	88.1	88.6	88.1	85.1	87.8	84.5
BFA			143.2	87.3	88.8	88.2	84.8	86.9	83.5
BFB			141.1	87.4	86.2	88.5	84.8	86.8	84.5
Bfavg	68		142.15	87.35	87.5	88.35	84.8	86.85	84
GA	67.9	79.6	139.1	88.3	88.5	88.5	84.2	86.8	83.6
GB	69.1	77.1	139.9	90.6	86.9	88.5	84.2	86.8	83.7
Gavg	68.5	78.35	139.5	89.45	87.7	88.5	84.2	86.8	83.65
ORP									
A	304.5	349	424.3	544.2	500.2	538.9		165	332.1
B	190.3	370.6	391.8	504.9	488.9	518.4		158.3	324.9
BFA	382	322	291.6	389.5	495.7	473.8		146.2	282.1
BFB	408.2	317.9	289.1	387.3	491.2	477.3		143.3	274
Bfavg	395.1	319.95	290.35	388.4	493.45	475.55		144.75	278.05
GA		356.8	262.3	342.4	472.2	477.4		139.3	265.3
GB		345.4	278.2	349.7	474.7	474.2		139.1	264.4
Gavg		351.1	270.25	346.05	473.45	475.8		139.2	264.85
NH3									
A, mg/L	0.833	1.216	0.279	0.912	1.254	1.843	1.957	1.9	1.843
A, % Solids	0.23	0.45	0.45	0.17	0.24	0.14	0.15	0.16	0.15
B, mg/L	0.567	0.798	0.741	1.007	1.083	1.71	1.862	1.786	1.748
B, % Solids	0.13	0.02	0.54	0.13	0.09	0.22	0.07	0.07	0.07
BFA	0.434	0.399	0.532	0.399	0.874	1.425	1.615	0.76	0.703
%	0	0.38	0.75	0.47	0.2	0.08	0.24	0.1	0.14
BFB	0.377	0.361	0.608	0.494	0.817	1.273	0.779	0.684	0.608
%	0	0.61	0.16	0.41	0.16	0.28	0.19	0.17	0.19
Bfavg	0.4055	0.38	0.57	0.4465	0.8455	1.349	1.197	0.722	0.6555
% Avg	0	0.495	0.455	0.44	0.18	0.18	0.215	0.135	0.165
GA	0.605	0.38	0.494	0.285	0.798	1.577	1.881	1.786	1.729
%	0.38	0.65	0.35	0.32	0.1	0.11	0.18	0.17	0.19
GB	0.358	0.418	0.494	0.057	1.026	0.665	1.843	1.729	1.634
%	0.74	0.29	0.5	0.12	0.13	0.26	0.15	0.16	0.16
Gavg	0.4815	0.399	0.494	0.171	0.912	1.121	1.862	1.7575	1.6815
%avg	0.559938	0.47	0.425	0.22	0.115	0.185	0.165	0.165	0.175
P									
A	0.724	0.515	0.652	0.499	0.413	2.564	1.427	1.412	1.422
%		0.12	0.37	0.24	0.22	0.05	0.05	0.07	0.09
B	0.601	0.505	0.805	0.433	0.438	2.574	1.473	1.447	1.447
%		0.09	0.31	0.35	0.24	0.04	0.1	0.1	0.1
BFA	0.464	0.474	0.377	0.392	0.311	2.518	2.426	2.523	2.385
%		0.09	0.16	0.18	0.21	0.04	0.33	0.05	0.05
BFB	0.464	0.484	0.382	0.505	0.321	2.395	2.487	2.431	2.309
%		0.13	0.12	0.31	0.25	0.03	0.1	0.04	0.04
Bfavg	0.464	0.479	0.3795	0.4485	0.316	2.4565	2.4565	2.477	2.347
%avg	0	0.11	0.14	0.245	0.23	0.035	0.215	0.045	0.045
GA	0.744	0.443	0.423	0.448	0.296	2.324	2.482	2.513	1.488
%		0.1	0.11	0.11	0.13	0.43	0.4	0.4	0.4
GB	0.591	0.698	0.892	0.494	0.296	0.306	2.65	2.614	1.417
%		0.27	0.8	0.18	0.24	0.2	0.44	0.45	0.45
Gavg	0.6675	0.5705	0.6575	0.471	0.296	1.315	2.566	2.5635	1.4525
%avg	0	0.185	0.455	0.145	0.185	0.315	0.42	0.425	0.425

*** some values may be from too old samples
A,B,D,E,GB should be OK

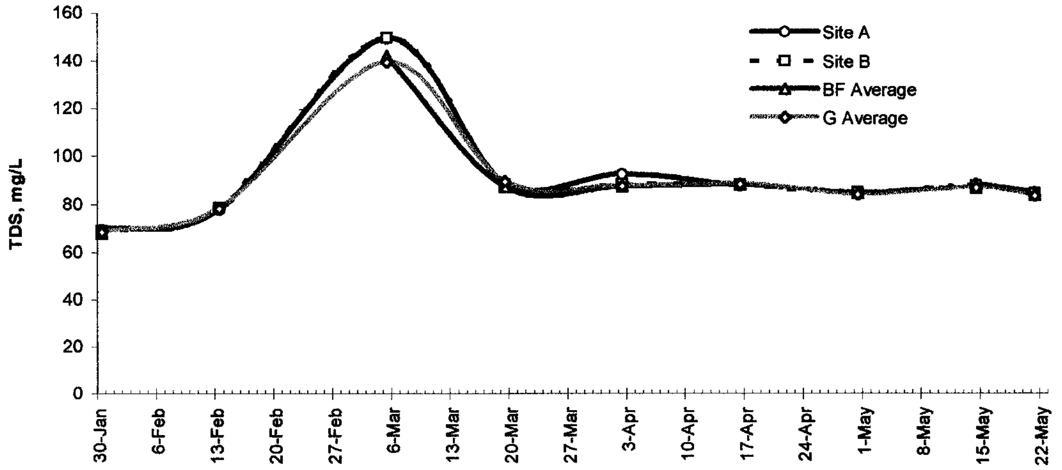
Data For Temperature Plots
°C

Site	30-Jan-01	13-Feb-01	5-Mar-01	19-Mar-01	2-Apr-01	16-Apr-01	30-Apr-01	7-May-01	14-May-01	21-May-01
A	12.3	10.1	8.1	8.1	9.3	6.4	8.2	9.9	10.4	11.3
B	12.5	10.1	7.6	7.9	9.3	6.4	8.2	9.5	10.3	10.5
C	11.8		8.2	7.9	9.4	6.3	8.2		10.3	10.5
D	11.8		7.3	7.9	9.4	6.3	8.3		10.2	10.4
E	11.4	10	7.3	7.9	9.4	6.3	8.2		10.2	10.5
SDk		11.3	7.3	7.9	9.5	6.5	9.5		10.7	10.7
BFA	12.7	10	6.9	7.9	9.7	6.3	8.3		10.3	10.5
BFB	13.5	10.2	6.9	7.9	9.4	6.3	8.4		10.1	10.6
GA	11.4	11	7.1	7.9	9.4	6.4	8.1		10.1	10.8
GB	11.4	10.1	8	7.9	9.4	6.4	8.3		10.2	10.7
MUW	11		8 ?		9.6	9.7	6.7		8.3	9.1
MUW		11	8	8.5	9.6	9.6			7.1	8.3
MUW							8		8.5	13.6
I/J	10.6	10.6	8		8.9	7.7	8.5		9	10.7
Swirl					8.4					
Over Flow							7.3			10.1

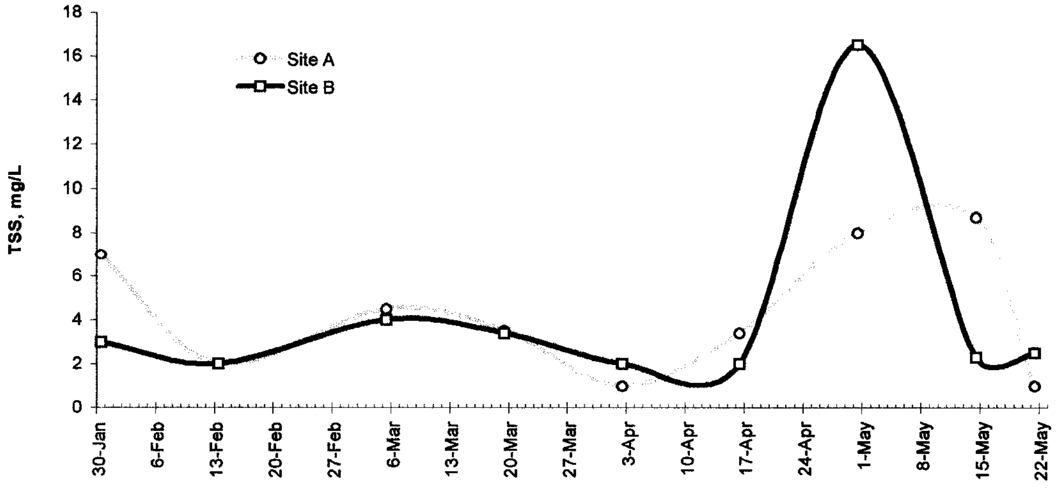


Plot Data for Total Dissolved Solids (TDS) and Total Suspended Solids (TSS)

TDS	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
A	69.3	77.6	149.2	89.1	92.5	87.6		88.1	84.8
B	68.8	78.4	149.6	88.1	88.6	88.1	85.1	87.8	84.5
BFA			143.2	87.3	88.8	88.2	84.8	86.9	83.5
BFB			141.1	87.4	86.2	88.5	84.8	86.8	84.5
Bfavg	68		142.15	87.35	87.5	88.35	84.8	86.85	84
GA	67.9	79.6	139.1	88.3	88.5	88.5	84.2	86.8	83.6
GB	69.1	77.1	139.9	90.6	86.9	88.5	84.2	86.8	83.7
Gavg	68.5	78.35	139.5	89.45	87.7	88.5	84.2	86.8	83.65

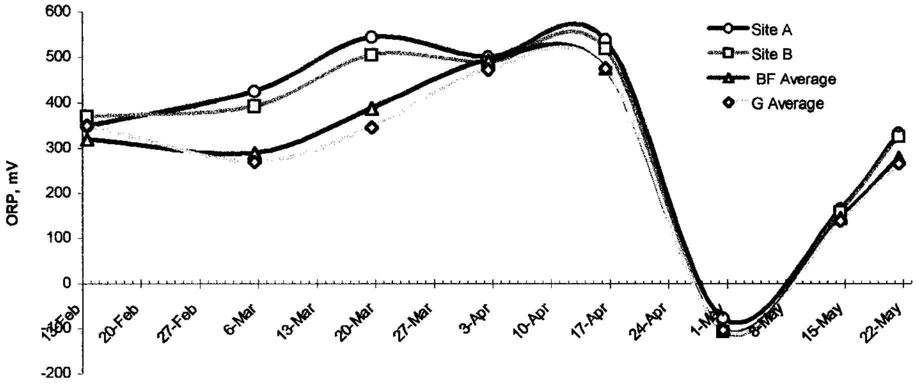


TSS	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
A	7	2	4.5	3.5	1	3.4	8	8.7	1
B	3	2	4	3.4	2	2	16.5	2.3	2.5

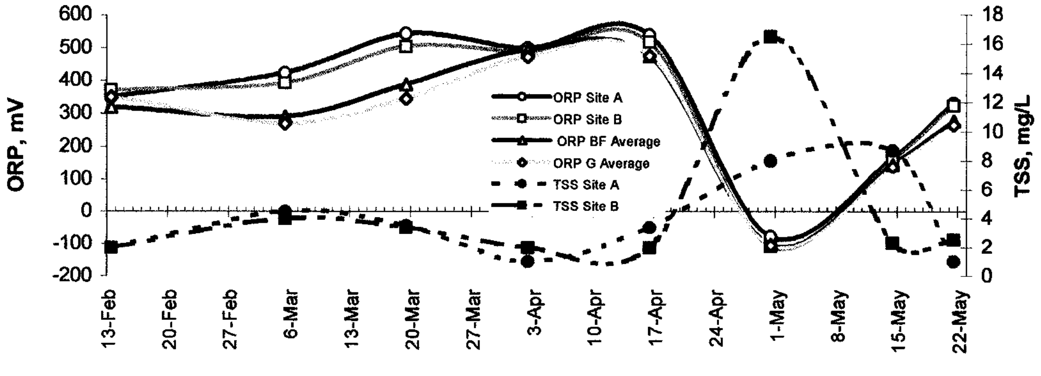


ORP Plot Data with Time

	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
Site A	304.5	349	424.3	544.2	500.2	538.9	-77.7	165	332.1
Site B	190.3	370.6	391.8	504.9	488.9	518.4	-107.7	158.3	324.9
BFA	382	322	291.6	389.5	495.7	473.8	-107.7	146.2	282.1
BFB	408.2	317.9	289.1	387.3	491.2	477.3	-96.5	143.3	274
BF avg	395.1	319.95	290.35	388.4	493.45	475.55	-102.1	144.75	278.05
GA		356.8	262.3	342.4	472.2	477.4	-103.4	139.3	265.3
GB		345.4	278.2	349.7	474.7	474.2	-103.5	139.1	264.4
G avg		351.1	270.25	346.05	473.45	475.8	-103.45	139.2	264.85

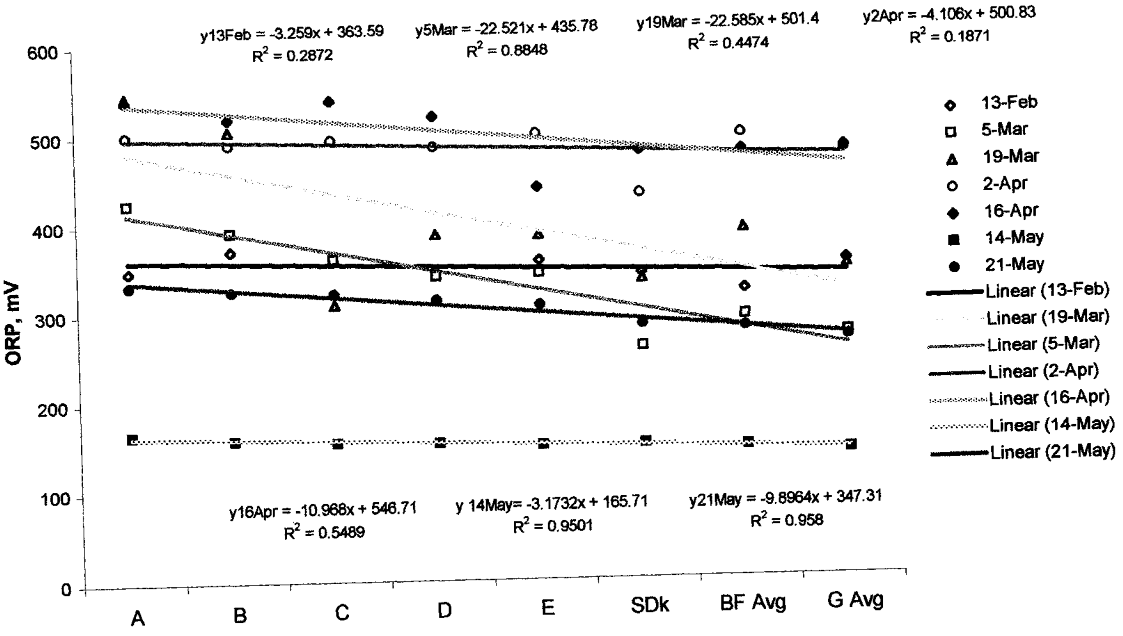


TSS	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
A	7	2	4.5	3.5	1	3.4	8	8.7	1
B	3	2	4	3.4	2	2	16.5	2.3	2.5



ORP Plots: ORP vs Flow Through The System

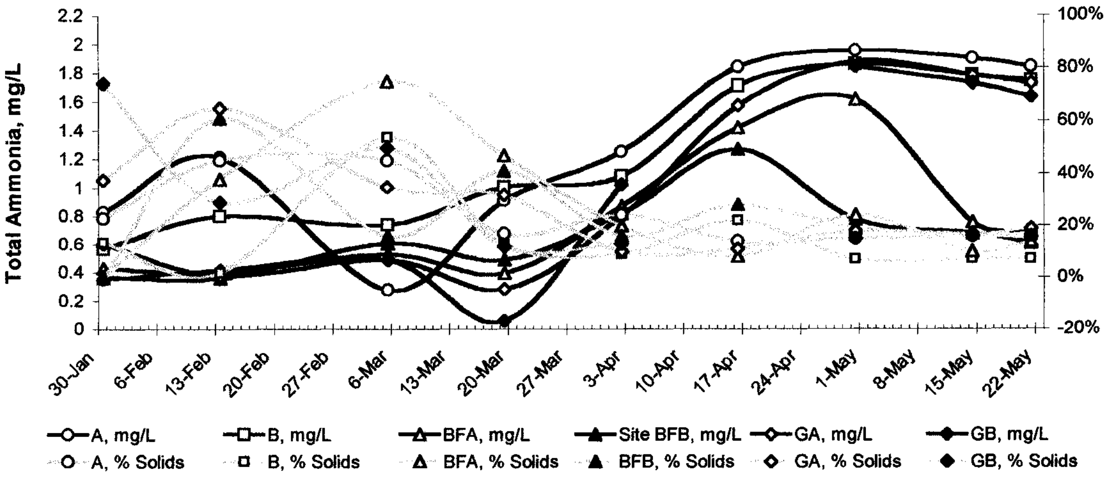
SITES	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	14-May	21-May
A	349	424.3	544.2	500.2	538.9	165	332.1
B	370.6	391.8	504.9	488.9	518.4	158.3	324.9
C		360.3	309.1	493	538	153.7	321.8
D		339.5	386.8	484.2	518.2	152.7	312.9
E	356.2	341.4	384.8	497	437.6	148.9	305.4
SDk	340.2	257.6	333.9	428.6	476.4	148.9	282.2
BF Avg	319.95	290.35	388.4	493.45	475.55	144.75	278.05
G Avg	351.1	270.25	346.05	473.45	475.8	139.2	264.85



Total Ammonia Data and Plots

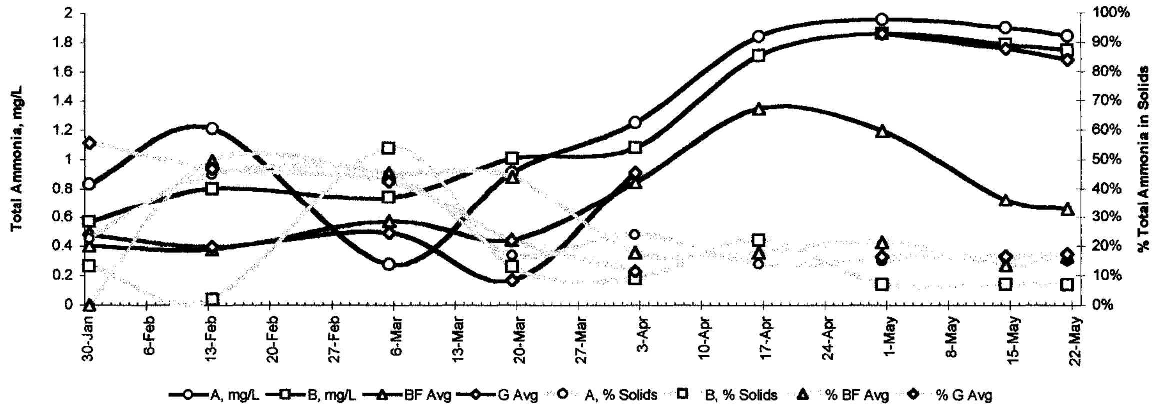
*** some 16 Apr values may be from too old samples
A, B, BFs, GA should be OK

	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
A, mg/L	0.833	1.216	0.279	0.912	1.254	1.843	1.957	1.9	1.843
A, % Solids	0.23	0.45	0.45	0.17	0.24	0.14	0.15	0.16	0.15
B, mg/L	0.567	0.798	0.741	1.007	1.083	1.71	1.862	1.786	1.748
B, % Solids	0.13	0.02	0.54	0.13	0.09	0.22	0.07	0.07	0.07
BFA, mg/L	0.434	0.399	0.532	0.399	0.874	1.425	1.615	0.76	0.703
BFA, % Solids	0	0.38	0.75	0.47	0.2	0.08	0.24	0.1	0.14
Site BFB, mg/L	0.377	0.361	0.608	0.494	0.817	1.273	0.779	0.684	0.608
BFB, % Solids	0	0.61	0.16	0.41	0.16	0.28	0.19	0.17	0.19
GA, mg/L	0.605	0.38	0.494	0.285	0.798	1.577	1.881	1.786	1.729
GA, % Solids	0.38	0.65	0.35	0.32	0.1	0.11	0.18	0.17	0.19
GB, mg/L	0.358	0.418	0.494	0.057	1.026		1.843	1.729	1.634
GB, % Solids	0.74	0.29	0.5	0.12	0.13		0.15	0.16	0.16



BF and G site data averaged

	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
A, mg/L	0.833	1.216	0.279	0.912	1.254	1.843	1.957	1.9	1.843
A, % Solids	0.23	0.45	0.45	0.17	0.24	0.14	0.15	0.16	0.15
B, mg/L	0.567	0.798	0.741	1.007	1.083	1.71	1.862	1.786	1.748
B, % Solids	0.13	0.02	0.54	0.13	0.09	0.22	0.07	0.07	0.07
BF Avg	0.4055	0.38	0.57	0.4465	0.8455	1.349	1.197	0.722	0.6555
% BF Avg	0	0.495	0.455	0.44	0.18	0.18	0.215	0.135	0.165
G Avg	0.4815	0.399	0.494	0.171	0.912		1.862	1.7575	1.6815
% G Avg	0.559938	0.47	0.425	0.22	0.115		0.165	0.165	0.175

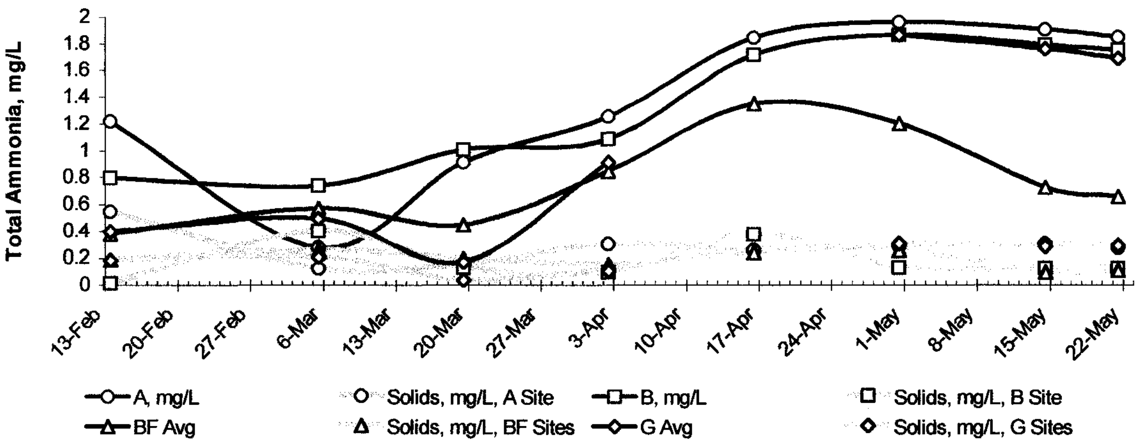


Total Ammonia Plots, cont'd. **Ammonia Related to Solids, mg/L**

	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
A, mg/L	1.216	0.279	0.912	1.254	1.843	1.957	1.9	1.843
B, mg/L	0.798	0.741	1.007	1.083	1.71	1.862	1.786	1.748
BF Avg	0.38	0.57	0.4465	0.8455	1.349	1.197	0.722	0.6555
G Avg	0.399	0.494	0.171	0.912		1.862	1.7575	1.6815

	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
Solids, mg/L, A S	0.5472	0.12555	0.15504	0.30096	0.25802	0.29355	0.304	0.27645
Solids, mg/L, B S	0.01596	0.40014	0.13091	0.09747	0.3762	0.13034	0.12502	0.12236
Solids, mg/L, BF	0.1881	0.25935	0.19646	0.15219	0.24282	0.257355	0.09747	0.108158
Solids, mg/L, G S	0.18753	0.20995	0.03762	0.10488		0.30723	0.289988	0.294263

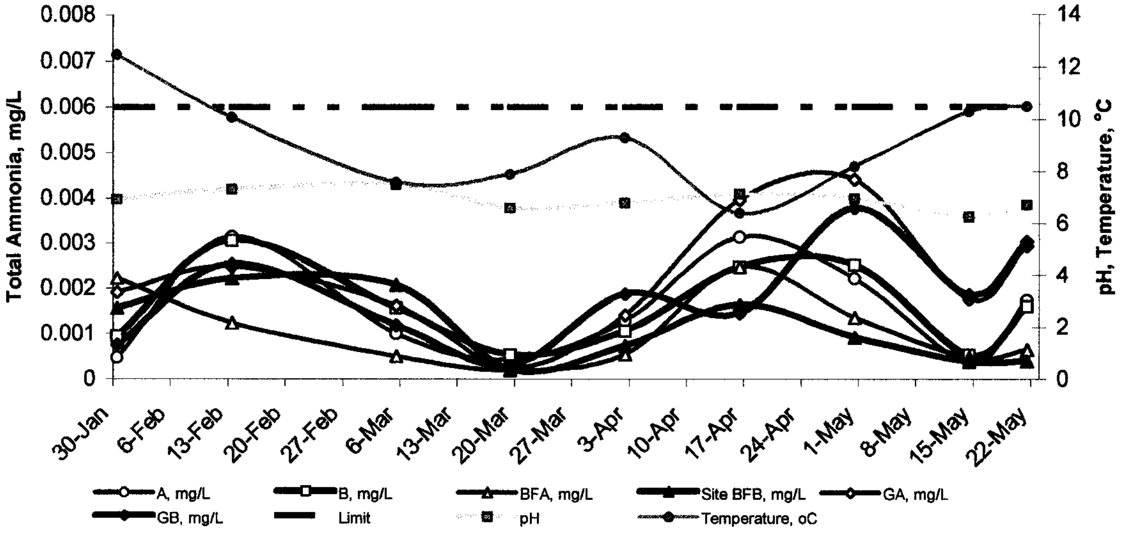
	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
A, % Solids	0.45	0.45	0.17	0.24	0.14	0.15	0.16	0.15
B, % Solids	0.02	0.54	0.13	0.09	0.22	0.07	0.07	0.07
% BF Avg	0.495	0.455	0.44	0.18	0.18	0.215	0.135	0.165
% G Avg	0.47	0.425	0.22	0.115	0.185	0.165	0.165	0.175



Un-ionized Fraction of Total Ammonia

Sites	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
A, mg/L	0.000477	0.003145	0.001001	0.000435	0.001278	0.003134	0.00221	0.00038	0.001736
B, mg/L	0.00095	0.003067	0.001567	0.00054	0.001056	0.002467	0.002505	0.000539	0.001597
BFA, mg/L	0.002229	0.001239	0.000511	0.000196	0.000549	0.002469	0.001356	0.000477	0.000652
Site BFB, mg/L	0.001568	0.002214	0.00207	0.000211	0.000737	0.00164	0.000914	0.000378	0.000396
GA, mg/L	0.001926	0.00248	0.001617	0.000254	0.001415	0.003944	0.004408	0.001767	0.002936
GB, mg/L	0.000758	0.002544	0.00119	0.000297	0.001875	0.001451	0.003773	0.001859	0.003036
Limit	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
pH	6.94	7.33	7.5	6.6	6.79	7.13	6.96	6.24	6.71
Temperature, °C	12.5	10.1	7.6	7.9	9.3	6.4	8.2	10.3	10.5

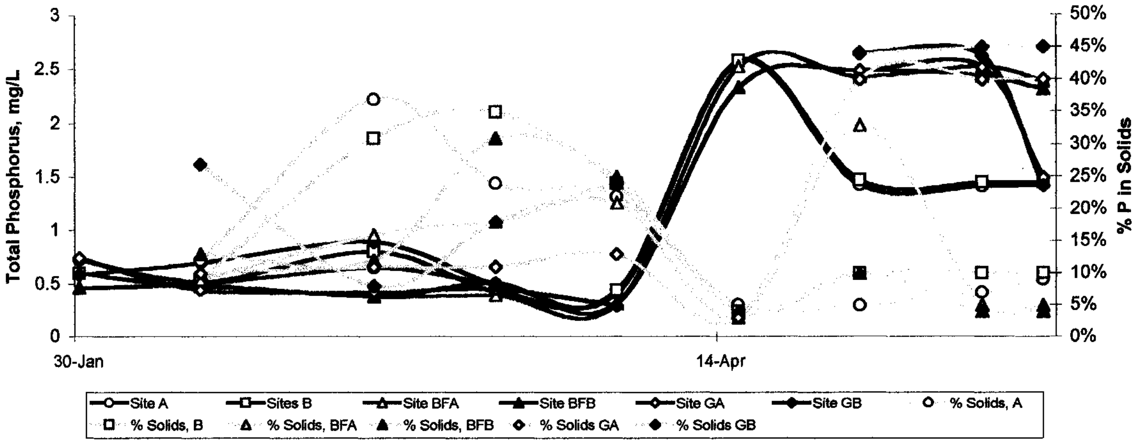
NBDFA recommended safe level 0.006 mg/L



Phosphorus: Total and % in Solids

16 Apr 01 data excluded as doubtful

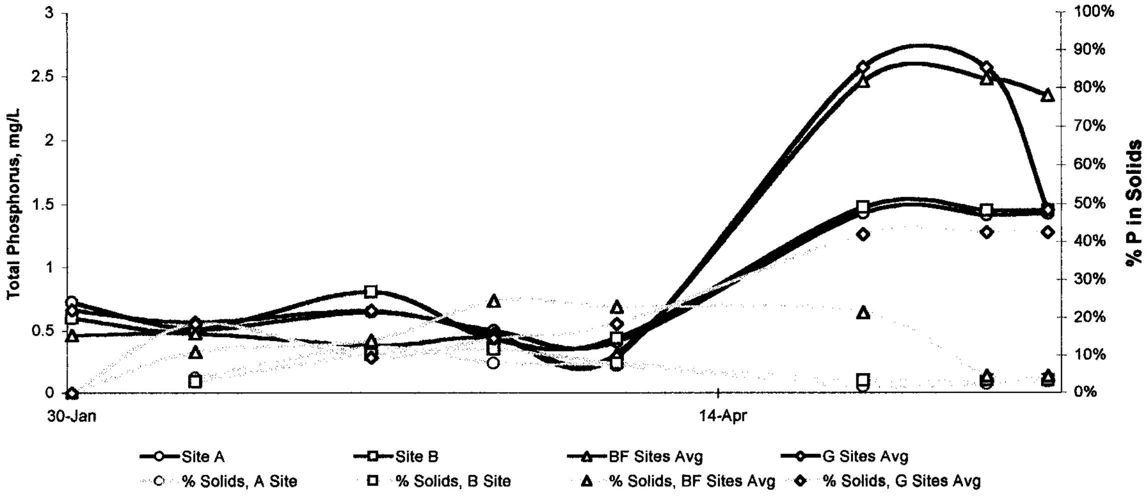
	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
Site A	0.724	0.515	0.652	0.499	0.413	2.564	1.427	1.412	1.422
Sites B	0.601	0.505	0.805	0.433	0.438	2.574	1.473	1.447	1.447
Site BFA	0.464	0.474	0.377	0.392	0.311	2.518	2.426	2.523	2.385
Site BFB	0.464	0.484	0.382	0.505	0.321	2.329	2.487	2.431	2.309
Site GA	0.744	0.443	0.423	0.448	0.296		2.482	2.513	1.488
Site GB	0.591	0.698	0.892	0.494	0.296		2.65	2.614	1.417
% Solids, A		0.12	0.37	0.24	0.22	0.05	0.05	0.07	0.09
% Solids, B		0.09	0.31	0.35	0.24	0.04	0.1	0.1	0.1
% Solids, BFA		0.09	0.16	0.18	0.21	0.03	0.33	0.05	0.05
% Solids, BFB		0.13	0.12	0.31	0.25	0.04	0.1	0.04	0.04
% Solids GA		0.1	0.11	0.11	0.13	0.03	0.4	0.4	0.4
% Solids GB		0.27	0.08	0.18	0.24		0.44	0.45	0.45
BF Avg	0.464	0.479	0.3795	0.4485	0.316	2.4235	2.4565	2.477	2.347
G Avg	0.668	0.571	0.658	0.471	0.296		2.566	2.564	1.453
% Solids, BF Avg	0.000	0.110	0.140	0.245	0.230	0.035	0.215	0.045	0.045
% Solids G Avg	0.000	0.185	0.095	0.145	0.185		0.420	0.425	0.425

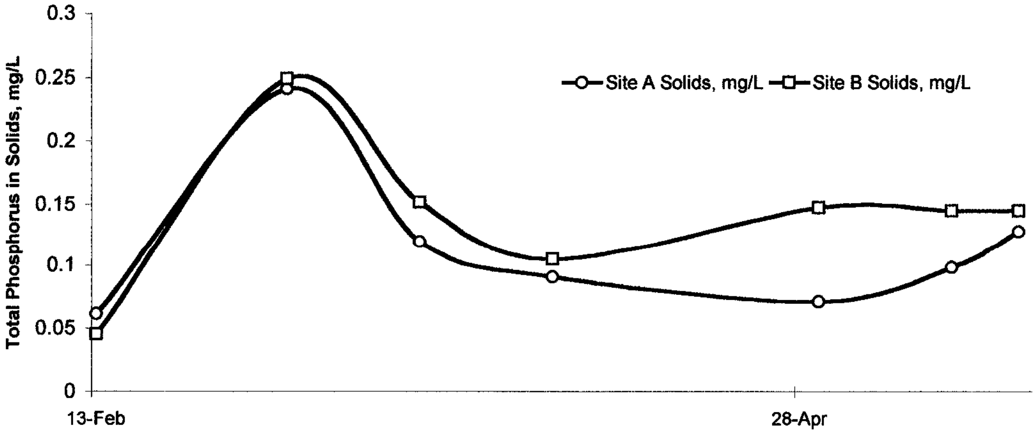


Phosphorus, BF and G Averaged

	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	30-Apr	14-May	21-May
Site A	0.724	0.515	0.652	0.499	0.413	1.427	1.412	1.422
Site B	0.601	0.505	0.805	0.433	0.438	1.473	1.447	1.447
BF Sites Avg	0.464	0.479	0.3795	0.4485	0.316	2.4565	2.477	2.347
G Sites Avg	0.6675	0.5705	0.6575	0.471	0.296	2.566	2.5635	1.4525
% Solids, A Site		0.12	0.37	0.24	0.22	0.05	0.07	0.09
% Solids, B Site		0.09	0.31	0.35	0.24	0.1	0.1	0.1
% Solids, BF Sites Avg	0	0.11	0.14	0.245	0.23	0.215	0.045	0.045
% Solids, G Sites Avg	0	0.185	0.095	0.145	0.185	0.42	0.425	0.425
BF Avg	0.464	0.479	0.3795	0.4485	0.316	2.4565	2.477	2.347
G Avg	0.668	0.571	0.658	0.471	0.296	2.566	2.564	1.453
% Solids, BF vgA	0.000	0.110	0.140	0.245	0.230	0.215	0.045	0.045
% Solids G Avg	0.000	0.185	0.095	0.145	0.185	0.420	0.425	0.425

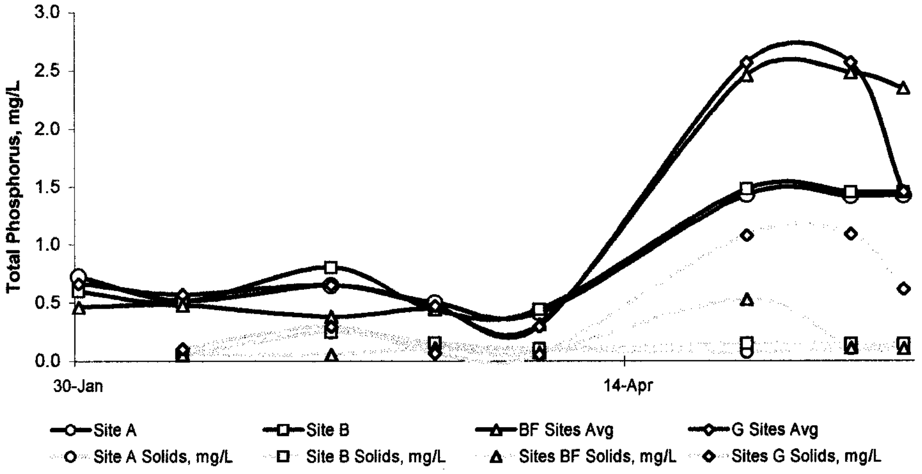
		13-Feb	5-Mar	19-Mar	2-Apr	30-Apr	14-May	21-May
Site A Solids, mg/L		0.0618	0.24124	0.11976	0.09086	0.07135	0.09884	0.12798
Site B Solids, mg/L		0.04545	0.24955	0.15155	0.10512	0.1473	0.1447	0.1447
Sites BF Solids, mg/L		0.05269	0.05313	0.109883	0.07268	0.528148	0.111465	0.105615
Sites G Solids, mg/L		0.105543	0.062463	0.068295	0.05476	1.07772	1.089488	0.617313
MUWA	0.443	0.443	0.413	0.316	0.321	2.38	2.553	2.324





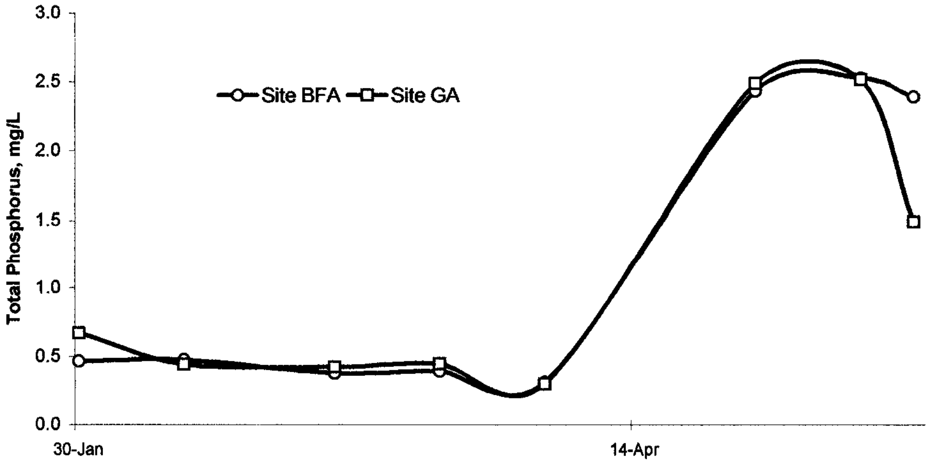
Phosphorus: Solids vs Total

	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	30-Apr	14-May	21-May
Site A	0.724	0.515	0.652	0.499	0.413	1.427	1.412	1.422
Site B	0.601	0.505	0.805	0.433	0.438	1.473	1.447	1.447
BF Sites Avg	0.464	0.479	0.380	0.449	0.316	2.457	2.477	2.347
G Sites Avg	0.668	0.571	0.658	0.471	0.296	2.566	2.564	1.453
Site A Solids, mg/L		0.062	0.241	0.120	0.091	0.071	0.099	0.128
Site B Solids, mg/L		0.045	0.250	0.152	0.105	0.147	0.145	0.145
Sites BF Solids, mg/L		0.053	0.053	0.110	0.073	0.528	0.111	0.106
Sites G Solids, mg/L		0.106	0.299	0.068	0.055	1.078	1.089	0.617
% Solids, A Site		0.12	0.37	0.24	0.22	0.05	0.07	0.09
% Solids, B Site		0.09	0.31	0.35	0.24	0.1	0.1	0.1
% Solids, BF Sites Avg	0	0.11	0.14	0.245	0.23	0.215	0.045	0.045
% Solids, G Sites Avg	0	0.185	0.455	0.145	0.185	0.42	0.425	0.425



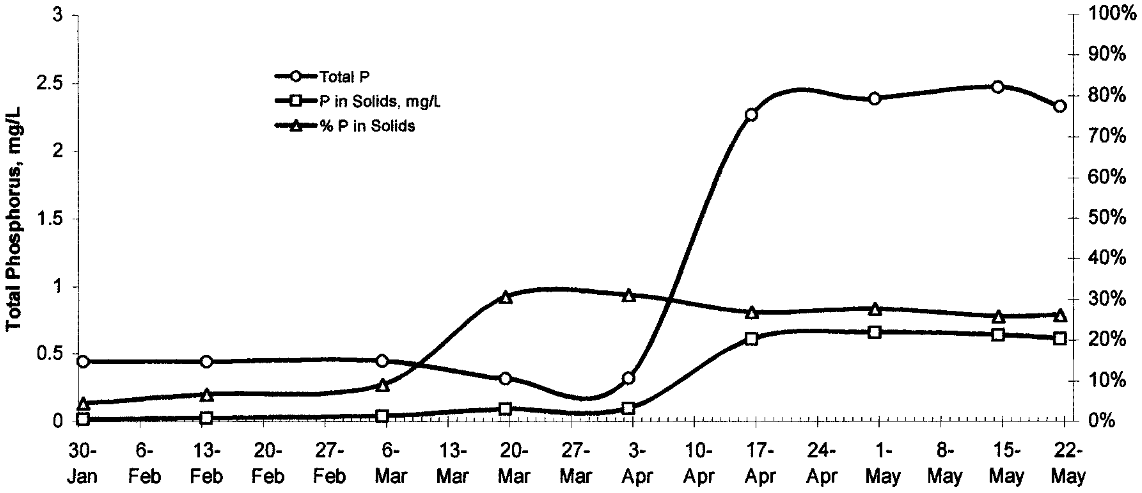
P

	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	30-Apr	14-May	21-May
Site BFA	0.464	0.474	0.377	0.392	0.311	2.426	2.523	2.385
Site GA	0.668	0.443	0.423	0.448	0.296	2.482	2.513	1.488



Make-up Water A Phosphorus Input

MUWA	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	16-Apr	30-Apr	14-May	21-May
Total P	0.443	0.443	0.448	0.316	0.321	2.268	2.38	2.467	2.324
P in Solids, m	0.02	0.03	0.041	0.097	0.1	0.61	0.66	0.64	0.61
% P in Solids	4.51%	6.77%	9.15%	30.70%	31.15%	26.90%	27.73%	25.94%	26.25%



Nitrite and Nitrate Data:

16 Apr removed. Late testing gave poor results

NO2

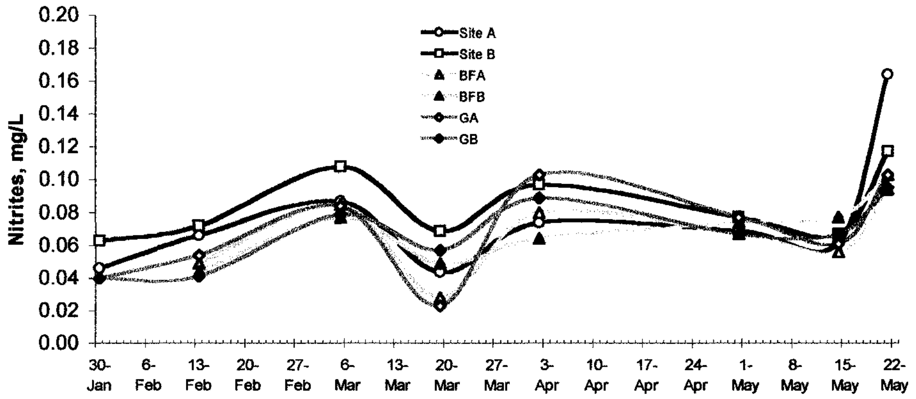
	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	30-Apr	14-May	21-May
Site A	0.046	0.066	0.087	0.044	0.074	0.069	0.062	0.164
Site B	0.063	0.072	0.108	0.069	0.097	0.077	0.067	0.117
BFA		0.049	0.085	0.028	0.080	0.067	0.056	0.094
BFB		0.044	0.077	0.049	0.064	0.074	0.077	0.103
GA	0.040	0.054	0.084	0.023	0.103	0.077	0.061	0.103
GB	0.040	0.041	0.079	0.057	0.089	0.067	0.067	0.095

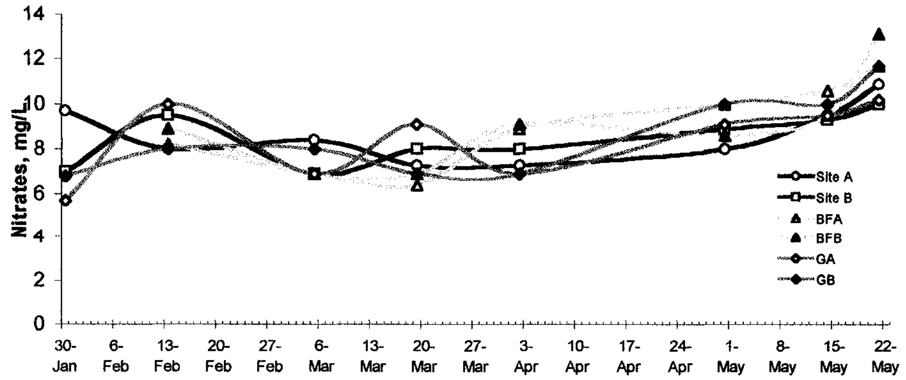
	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	30-Apr	14-May	21-May
Site A	0.046	0.066	0.087	0.044	0.074	0.069	0.062	0.164
Site B	0.063	0.072	0.108	0.069	0.097	0.077	0.067	0.117
BFA Sites Avg	0.000	0.047	0.081	0.039	0.072	0.071	0.067	0.099
G Sites Avg	0.040	0.048	0.082	0.040	0.096	0.072	0.064	0.099

NO3

	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	30-Apr	14-May	21-May
Site A	9.7	8.0	8.4	7.3	7.3	8.0	9.5	10.9
Site B	7.0	9.5	6.9	8.0	8.0	8.9	9.3	10.0
BFA		8.2	6.9	6.4	8.9	10.0	10.6	11.7
BFB		8.9	6.9	6.9	9.1	8.6	9.5	13.1
GA	5.7	10.0	6.9	9.1	6.9	9.1	9.5	10.2
GB	6.8	8.0	8.0	6.9	6.9	10.0	10.0	11.7

	30-Jan	13-Feb	5-Mar	19-Mar	2-Apr	30-Apr	14-May	21-May
Site A	9.7	8.0	8.4	7.3	7.3	8.0	9.5	10.9
Site B	7.0	9.5	6.9	8.0	8.0	8.9	9.3	10.0
BFA Sites Avg	0.0	8.6	6.9	6.7	9.0	9.3	10.1	12.4
G Sites Avg	6.3	9.0	7.5	8.0	6.9	9.6	9.8	11.0





Water Quality Data Summary

Date 30-Jan-01 Modified : where phosphorus filtered is higher that unfiltered, values switched NH3-N to NH3 1.215877

	pH	T	CO2	ORP	Alk	Hardn	NO_2	NO_3	TSS	TDS	Beta	R
Site		deg C	mg/L	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		
A	6.53	12.3	4.8	304.5	30.0	30.9	0.046	9.7	7	69.3	2.050	0.8510
B	6.94	12.5	5.4	190.3	29.6	31.1	0.063	7.0	3	68.8	2.000	0.7830
C	6.79	11.8	5.6	43.9	30.1	31.0	0.056	7.1	3	68.8	1.600	0.6830
D	7.46	11.8	4.4	15.0	30.8	31.3	0.064	7.2	2	68.7	1.760	0.9410
E	6.98	11.4	4.8	525.8	29.8	31.1	0.058	7.1	1	69.8	1.450	0.6560
SDeck							0.061		1	66.9		
Bio A	7.34	12.7	4.1	382.0	30.0	30.7						
Bio B	7.24	13.5	4.2	408.2	29.9	31.6						
GA	7.40	11.4	3.7	-67.7	29.8	30.7	0.040	5.7	3	67.9	1.990	0.9490
GB	7.61	11.4	3.9	3.9	29.4	31.5	0.040	6.8	2	69.1		
MUW	8.32	11	0.0	377.7	54.7	55.5	0.010	0.1	3	169.2		
I	7.65	10.6	2.1	469.6	49.7	50.3	0.036	1.6	10	146.4	1.810	0.9870
J									10	147.0		

	TKN			Ammonia NH3					Organic N			Phosphorus			
	UnFilt	Filt	Solids	UnFilt	Filt	Solids	% NH3	UIA	UnFilt	Filt	Solids	UnFilt	Filt	Solids	% In
Site	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		Solids
A	1.031	0.938	0.094	0.833	0.643	0.19	0.07%	0.000	0.346	0.409	-0.063	1.182	0.724	0.46	38.79%
B	0.750	0.750	0.000	0.567	0.491	0.076	0.19%	0.001	0.284	0.346	-0.063	0.673	0.601	0.07	10.61%
C	0.703	0.609	0.094	0.605	0.529	0.076	0.13%	0.001	0.206	0.175	0.031	0.999	0.714	0.29	28.57%
D	0.469	0.422	0.047	0.529	0.301	0.228	0.61%	0.002	0.034	0.175	-0.141	0.714	0.663	0.05	7.14%
E	2.906	1.031	1.875	0.415	0.377	0.038	0.20%	0.001	2.565	0.721	1.844	1.091	0.856	0.23	21.50%
SDeck	1.219	0.938	0.281	0.681	0.225	0.456			0.659	0.753	-0.094	0.454	0.408	0.03	5.62%
Bio A	0.469	0.281	0.188	0.434	0.453	-0.019	0.49%	0.002	0.112	-0.091	0.203	0.464	0.408	0.06	12.09%
Bio B	0.047	0.188	-0.141	0.377	0.377	0	0.42%	0.002	-0.263	-0.122	-0.141	0.464	0.392	0.07	15.38%
GA	0.609	0.422	0.188	0.605	0.377	0.228	0.51%	0.002	0.112	0.112	-0.000	0.856	0.744	0.11	13.10%
GB	0.750	0.563	0.188	0.358	0.092	0.266	0.83%	0.001	0.456	0.487	-0.031	0.591	0.561	0.03	5.17%
MUw	1.031	0.750	0.281	0.282	0.168	0.114	3.98%	0.007	0.800	0.612	0.187	0.433	0.418	0.02	3.53%
I/J	1.031	0.375	0.656	1.763	0.700	1.0639	0.85%	0.006	-0.419	-0.200	-0.219	1.254	1.198	0.06	4.47%

Nitrite & Nitrate

30 Jan 01

	At. Wt.		**N**	**O**	**Total**
N	14.0067	NO2	1	2	46.006
O	15.9994	NO2-N	1	0	14.007
		NO3	1	3.00	62.005
		NO3-N	1	0	14.007

NO_2 Reagent Factor	0	
NO_2 /NO2-N Factor	3.285	
NO_3 Reagent Factor	0.9	Factor not used after switch to Method 8171
NO_3 /NO3-N Factor	4.427	

	NITRITE				**NITRATE, mg/L**					
Site	**Rdg**	**R**	**NO2-N**	**NO2**	**Rdg**	**R**	**NO3-N**	**NO3**		
A	0.0135	2	0.0135	0.044	3.1	2	2.2	9.7	Using Test 8039	
B	0.0190	2	0.0190	0.062	1.6	2	1.6	7.1	Using Test 8171	No correction
C	0.0170	2	0.0170	0.056	1.6	2	1.6	7.1		
D	0.0195	2	0.0195	0.064	1.6	3	1.6	7.1		
E	0.0180	2	0.0180	0.059	1.6	2	1.6	6.9		
SDeck	0.0185	2	0.0185	0.061	1.50		1.5	6.6		
G$_A$	0.0125	2	0.0125	0.041	1.3	2	1.3	5.8		
G$_B$	0.0120	2	0.0120	0.039	1.6	2	1.6	6.9		

MUWB	0.0030	2	0.0030	0.010	0.00		0.0	0.0
J	0.0105	2	0.0105	0.034	0.4	2	0.4	1.8

R - repetitions

0.0000' - averaging

TKN, Ammonia and Phosphorus Data and Calculations, 30 Jan 01

TKN Calculations Digestion
Factor 75
Calc B 40
Reagent Correction 0

0.0 = average

		Unfiltered			Filtered			% in
Site	**C**	**Rdg**	**Rep**	**TKN**	**Rdg**	**Rep**	**TKN**	**Solids**
A	10	5.5	2	1.031	5	2	0.938	9.09%
B	10	4	2	0.750	4	2	0.750	0.00%
C	20	7.5	2	0.703	6.5	2	0.609	13.33%
D	20	5	2	0.469	4.5	2	0.422	10.00%
E	10	15.5	2	2.906	5.5	2	1.031	64.52%
SDeck	10	6.5	2	1.219	5	2	0.938	23.08%
BFa	20	5	2	0.469	3	2	0.281	40.00%
BFb	20	5	2	0.469	3	2	0.281	40.00%
Ga	20	6.5	2	0.609	4.5	2	0.422	30.77%
Gb	20	8	2	0.750	6	2	0.563	25.00%
MUWB	10	5.5	2	1.031	4	2	0.750	27.27%
I/J	20	11	2	1.031	4	2	0.375	63.64%

Averages

UnFilt	**Filt**	**Diff**	**%**
A-B	**A-B**	(1/3 proportional)	
0.844	0.813	0.031	3.70%
BF	**BF**		
0.469	0.281	0.188	40.00%
G	**G**		
0.680	0.492	0.188	27.59%

Ammonia Calculations Digestion
Factor 2500 Fe correction 0.034 mg/L
Calc B 40

TAN> NH3	At Wt	No	Tot				
N	14.01	1	14.008	H3-N x	1.216	=	NH3
H	1.01	3	3.024				
			17.032				

		Unfiltered				Filtered				% TAN
Site	**C**	**Rdg**	**Rep**	**TAN**	**NH3**	**Rdg**	**Rep**	**TAN**	**NH3**	**in Solids**
A	10	0.115	2	0.685	0.833	0.09	2	0.529	0.643	22.82%
B	10	0.08	2	0.466	0.567	0.07	2	0.404	0.491	13.41%
C	10	0.085	2	0.497	0.605	0.075	2	0.435	0.529	12.57%
D	10	0.075	2	0.435	0.529	0.045	2	0.247	0.301	43.13%
E	10	0.06	2	0.341	0.415	0.055	2	0.310	0.377	9.16%
SDeck	20	0.19		0.560	0.681	0.07	2	0.185	0.225	66.99%
BFa	20	0.125	2	0.357	0.434	0.13	2	0.372	0.453	-4.38%
BFb	20	0.11		0.310	0.377	0.11		0.310	0.377	0.00%
Ga	10	0.085	2	0.497	0.605	0.055	2	0.310	0.377	37.71%
Gb	20	0.105	2	0.294	0.358	0.035	2	0.075	0.092	74.37%
MUWB	20	0.085	2	0.232	0.282	0.055	2	0.138	0.168	40.47%
I/J	20	0.475	2	1.450	1.763	0.195	2	0.575	0.700	60.33%

Avg A,B
18.12%

Avg, BF
-2.19%
Avg, G
56.04%

Phosphorus Calculations
Factor 2500
Calc B 40
Reagent Correction 0.01

PO4>P	**At Wt**	**No**	**Tot**				
P	30.98	1	30.98	PO4 x	0.326	=	P
O	16.00	4	64				
			94.98				

		Unfiltered				Filtered				%
Site	**C**	**Rdg**	**Rep**	**PO4**	**P**	**Rdg**	**Rep**	**PO4**	**P**	**in Solids**
A	20	1.17	2	3.625	1.182	0.72	2	2.219	0.724	38.79%
B	20	0.67	2	2.063	0.673	0.6	2	1.844	0.601	10.61%
C	20	0.99	2	3.063	0.999	0.71	2	2.188	0.714	28.57%
D	20	0.71	2	2.188	0.714	0.66	2	2.031	0.663	7.14%
E	20	1.08	2	3.344	1.091	0.85	2	2.625	0.856	21.50%
SDeck	20	0.455	2	1.391	0.454	0.41	2	1.250	0.408	10.11%
BFa	20	0.465	2	1.422	0.464	0.41	2	1.250	0.408	12.09%
BFb	20	0.465	2	1.422	0.464	0.395	2	1.203	0.392	15.38%
Ga	20	0.85	2	2.625	0.856	0.74	2	2.281	0.744	13.10%
Gb	20	0.59	2	1.813	0.591	0.56	2	1.719	0.561	5.17%
MUWB	20	0.435	2	1.328	0.433	0.42	2	1.281	0.418	3.53%
I/J	20	1.24	2	3.844	1.254	1.185	2	3.672	1.198	4.47%

Water Quality Data Summary

Date 13-Feb-01 NH3-N to NH3 1.2159

	pH	T	CO2	ORP	Alk	Hardn	NO2	NO3	TDS	TSS	Beta	R
Site		deg C	mg/L	mV	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		
A	7.41	10.1	5.5	349.0			0.066	8.0	77.6	2	2.530	0.9058
B	7.33	10.1	5.6	370.6	29.2	32.8	0.072	9.5	78.4	2	2.113	0.8452
C					31.1		0.077	9.1	78.3	3		
D							0.074	9.7	78.1	7		
E	7.47	10.0	5.5	356.2	31.7	33.6	0.072	9.3	78.3	2		
SDeck	7.37	11.3	5	340.2	30.5	33.9	0.071	9.5	80.4	1		
Bio A	7.23	10.0	6.5	322.0		33.6	0.049	8.2				
Bio B	7.52	10.2	6.0	317.9		33.1	0.044	8.9				
GA	7.52	11.0	3.7	356.8	30.6	33.6	0.054	10.0	79.6	1.5		
GB	7.52	10.1	3.8	345.4	31.1	33.1	0.041	8.0	77.1	1		
MUWA					34.6	27.7	0.023	0.4	79.6	2		
MUWB	8.32	11.0	0.0	377.7	59.0	54.8	0.000	0.0				
I	7.65	10.6	2.1	469.6	54.9	50.8	0.076	2.7	150.8	34	1.927	0.9555
J												

	TKN				Ammonia NH3						Organic N			Phosphorus			
	UnFilt	Filt	Solids	% InSol	UnFilt	Filt	Solids	%	% UIA	UIA	UnFilt	Filt	Solids	UnFilt	Filt	Solids	% in
Site	mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	Solids		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Solids
A	2.203	0.656	1.547	70%	1.216	0.665	0.551	45%	0.47%	0.0031	1.203	0.109	1.094	0.515	0.454	0.06	12%
B	0.656	0.656	0.000	0%	0.798	0.779	0.019	2%	0.39%	0.0031	-0.000	0.016	-0.016	0.505	0.459	0.05	9%
C	1.125	0.938	0.188	17%	0.779	0.646	0.133	17%			0.484	0.406	0.078	0.448	0.433	0.02	3%
D	0.656	0.563	0.094	14%	0.741	0.646	0.095	13%			0.047	0.031	0.016	0.550	0.469	0.08	15%
E	0.938	0.516	0.422	45%	0.741	0.646	0.095	13%	0.54%	0.0035	0.328	-0.016	0.344	0.489	0.484	0.01	1%
SDeck	2.297	0.797	1.500	65%	1.368	0.950	0.418	31%	0.47%	0.0045	1.172	0.016	1.156	0.719	0.505	0.21	30%
Bio A	1.781	0.516	1.266	71%	0.646	0.399	0.247	38%	0.31%	0.0012	1.250	0.187	1.063	0.474	0.433	0.04	9%
Bio B	2.109	0.750	1.359	64%	0.589	0.361	0.228	39%	0.61%	0.0022	1.625	0.453	1.172	0.484	0.423	0.06	13%
GA	0.891	0.750	0.141	16%	0.513	0.380	0.133	26%	0.65%	0.0025	0.469	0.437	0.031	0.443	0.398	0.05	10%
GB	2.203	0.750	1.453	66%	0.589	0.418	0.171	29%	0.61%	0.0025	1.719	0.406	1.313	0.698	0.510	0.19	27%
MUWA	1.172	0.422	0.750	64%	0.323	0.285	0.038	12%			0.906	0.187	0.719	0.443	0.413	0.03	7%
I/J	3.891	1.688	2.203	57%	3.800	1.026	2.774	73%	0.85%	0.0087	0.766	0.844	-0.078	1.422	1.147	0.28	19%

Nitrite & Nitrate
13 Feb 01

	At. Wt.		N	O	Total
N	14.0067	NO2	1	2	46.0055
O	15.9994	NO2-N	1	0	14.0067
		NO3	1	3.00	62.0049
		NO3-N	1	0	14.0067

NO_2 Reagent Factor	0	
NO_2 /NO2-N Factor	3.285	
NO_3 Reagent Factor	0	Factor not used after switch to Method 8171
NO_3 /NO3-N Factor	4.427	

	NITRITE, mg/L				NITRATE, mg/L					
Site	**Rdg**	**R**	**NO2-N**	**NO2**	**Rdg**	**R**	**NO3-N**	**NO3**		
A	0.02	2	0.02	0.066	1.8	2	1.8	8.0	Using Test 8039	
B	0.022	2	0.022	0.072	2.2	2	2.2	9.5	Using Test 8171	No correct
C	0.0235	2	0.0235	0.077	2.1	2	2.1	9.1		
D	0.0225	2	0.0225	0.074	2.2	2	2.2	9.7		
E	0.022	2	0.022	0.072	2.1	2	2.1	9.3		
SDeck	0.0215	2	0.0215	0.071	2.15		2.2	9.5		
BFa	0.015	2	0.015	0.049	1.9	2	1.9	8.2		
BFb	0.0135	2	0.0135	0.044	2.0	2	2.0	8.9		
GA	0.0165	2	0.0165	0.054	2.3	2	2.3	10.0		
GB	0.0125	2	0.0125	0.041	1.8	2	1.8	8.0		
MUWA	0.007	2	0.007	0.023	0.10		0.1	0.4		
MUWB		2	0	0.000			0.0	0.0		
J	0.023	2	0.023	0.076	0.6	2	0.6	2.7		

R - repetitions
0.0005' and '0.05' - averaging

TKN, Ammonia and Phosphorus Data and Calculations, 13 Feb 01

TKNCalculations

Factor	75
Calc B	40
Reagent Correction	0

		Unfiltered			Filtered			% in
Site	**C**	**Rdg**	**Rep**	**TKN**	**Rdg**	**Rep**	**TKN**	**Solids**
A	20	23.5	2	2.203	7	2	0.656	70.2%
B	20	7	2	0.656	7	2	0.656	0.0%
C	10	6	2	1.125	5	2	0.938	16.7%
D	20	7	2	0.656	6	2	0.563	14.3%
E	20	10	2	0.938	5.5	2	0.516	45.0%
SDeck	20	24.5	2	2.297	8.5	2	0.797	65.3%
BFa	20	19	2	1.781	5.5	2	0.516	71.1%
BFb	20	22.5	2	2.109	5	2	0.469	77.8%
Ga	20	9.5	2	0.891	8	2	0.750	15.8%
Gb	20	23.5	2	2.203	8	2	0.750	66.0%
MUWA	20	12.5	2	1.172	4.5	2	0.422	64.0%
I/J	20	41.5	2	3.891	18	2	1.688	56.6%
Swirl Fl	0.5	35	2	131.3	18.5	2	69.4	47.1%

Sample size modified.

Effect of a one point error in B and C

Analytical Volume, mL		20		10
Rdgs	8	0.75	7	1.313
	7	0.656	6	1.125
Difference		0.094		0.188
% Error		14.33%		16.71%

Ammonia Calculations

Factor	2500	**Fe Formula**		0.04864	0.5515
Calc B	40	**Fe Rdg**	**Fe effect**		
		0.55	0.035 mg/L		(subtract from readings)

TAN> NH3		At Wt	No	Tot			
	N	14.01	1	14.008	NH3-N x	1.216 =	NH3
	H	1.01	3	3.024			
				17.032			

		Unfiltered				Filtered				%
Site	**C**	**Rdg**	**Rep**	**TAN**	**NH3**	**Rdg**	**Rep**	**TAN**	**NH3**	**in Solids**
A	20	0.355	2	1.000	1.216	0.21	2	0.547	0.665	45.31%
B	20	0.245	2	0.656	0.798	0.24	2	0.641	0.779	2.38%
C	20	0.24	2	0.641	0.779	0.205	2	0.531	0.646	17.07%
D	20	0.23	2	0.609	0.741	0.205	2	0.531	0.646	12.82%
E	20	0.23	2	0.609	0.741	0.205	2	0.531	0.646	12.82%
SDeck	20	0.395		1.125	1.368	0.285	2	0.781	0.950	30.55%
BFa	20	0.205	2	0.531	0.646	0.14	2	0.328	0.399	38.23%
BFb	20	0.19	2	0.484	0.589	0.13	2	0.297	0.361	38.70%
Ga	20	0.17	2	0.422	0.513	0.135	2	0.313	0.380	25.92%
Gb	20	0.19	2	0.484	0.589	0.145	2	0.344	0.418	29.03%
MUWA	20	0.12	2	0.266	0.323	0.11	2	0.234	0.285	11.76%
MUWB										
I/J	10	0.535	2	3.125	3.800	0.17	2	0.844	1.026	73.00%

Averages

UnFilt	**Filt**	**Diff**	**%**
A-B	**A-B**	(1:3 proportional)	
1.140	0.975	0.165	14.4%
BF	**BF**		
0.845	0.694	0.152	18.0%
G	**G**		
0.912	0.807	0.104	11.5%

Phosphate Calculations mg/L

Factor	2500
Calc B	40
Reagent Correction	0.01

PO4>P		At Wt	No	Tot			
	P	30.98	1	30.98	PO4 x	0.326 =	P
	O	16.00	4	64			
				94.98			

		Unfiltered				Filtered				P	%
Site	**C**	**Rdg**	**Rep**	**PO4**	**P**	**Rdg**	**Rep**	**PO4**	**P**	**in Solids**	**in Solids**
A	20	0.515	2	1.578	0.515	0.455	2	1.391	0.454	0.06	11.88%
B	20	0.505	2	1.547	0.505	0.46	2	1.406	0.459	0.05	9.09%
C	20	0.45	2	1.375	0.448	0.435	2	1.328	0.433	0.02	3.41%
D	20	0.55	2	1.688	0.550	0.47	2	1.438	0.469	0.08	14.81%
E	20	0.49	2	1.500	0.489	0.485	2	1.484	0.484	0.01	1.04%
SDeck	20	0.715	2	2.203	0.719	0.505	2	1.547	0.505	0.21	29.79%
BFa	20	0.475	2	1.453	0.474	0.435	2	1.328	0.433	0.04	8.60%
BFb	20	0.485	2	1.484	0.484	0.425	2	1.297	0.423	0.06	12.63%
Ga	20	0.445	2	1.359	0.443	0.4	2	1.219	0.398	0.05	10.34%
Gb	20	0.695	2	2.141	0.698	0.51	2	1.563	0.510	0.19	27.01%
MUWA	20	0.445	2	1.359	0.443	0.415	2	1.266	0.413	0.03	6.90%
I/J	20	1.405	2	4.359	1.422	1.135	2	3.516	1.147	0.28	19.35%

Data Summary

Date 05-Mar-01 Some data done 08-Mar NH3-N to NH3 1.2159

08-Mar Malvern Corr. Coeff.

	pH	T	CO2	ORP	Alk	Hardn	NO2	NO3	TSS mg/L		ORP mV		TDS mg/L		Beta	R
Site		deg C	mg/L	mV	mg/L	mg/L	mg/L	mg/L	Rdg	Rep	Rdg	Rep	Rdg	Rep		
A	7.623	8.1	5.7	424.3	42.2	76.2	0.087	8.4	4.5	11		2	149.2	1	2.78	0.877
B	7.482	7.6	5.6	391.8	41.2	72.4	0.108	6.9	4	8	306.6	2	149.6	1	2.66	0.819
C	7.49	8.2	5.8	360.3	42.6	74.4	0.089	7.1	3.4	8	308.8	2	148.6	1	2.55	0.937
D	7.512	7.3	5.8	339.5	42.4	75.6	0.103	7.7	3.4	2	309.7	2	148.3	1	3.42	0.921
E	7.575	7.3	5.9	341.4	42.4	75.2	0.223	7.3	3.4	8	314.7	2	148.9	1	2.30	0.961
SDeck	7.455	7.3	4.5	257.6	42.6	70.8	0.079	6.2	2.7	2	313	2	137.4	1		
Bio A	7.429	6.9	4.7	291.6	40.8	73.2	0.085	6.9	2	5	322.5	2	143.2	1		
Bio B	7.451	6.9	4.5	289.1	42.4	72.8	0.077	6.9	1.3	6	318.8	2	141.1	1		
GA	7.538	7.1	3.4	262.3	40.8	73.6	0.084	6.9		2	315.6	2	139.1	2		
GB	7.49	8.0	3.5	278.2	39.2	63.2	0.079	8.0	3.5	2	314.7	2	139.9	2		
MUW_A	7.49	8.0	3.4	315.9	35.2	31.2	0.018	0.0	1	2	351.6	2	54.5	1		
MUW_B	7.644	8.0	0	180.5	57.4	58.4	0.011	0.0								
I/J	7.792	8.0	3.7	284.5	65.2	66.8	0.223	3.3	17	2	298.6	2		2	1.89	0.996
Sw Flush				198.9	83.6		0.460	9.7	540		200.6	2	125.2		2.27	0.999

	TKN				Ammonia NH3						Organic N			Phosphorus			
	UnFilt	Filt	Solids	% InSol	UnFilt	Filt	Solids	%	% UIA	UIA	UnFilt	Filt	Solids	UnFilt	Filt	Solids	% in
Site	mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	Solids		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Solids
A	0.797	0.328	0.469	59%	0.279	0.152	0.127	45%	0.66%	0.001	0.568	0.203	0.365	0.652	0.413	0.240	37%
B	1.078	0.328	0.750	70%	0.741	0.342	0.399	54%	0.46%	0.002	0.469	0.047	0.422	0.805	0.556	0.250	31%
C	0.516	0.375	0.141	27%	0.494	0.190	0.304	62%	0.49%	0.001	0.109	0.219	-0.109	0.515	0.408	0.107	21%
D	1.266	0.516	0.750	59%	0.665	0.171	0.494	74%	0.48%	0.001	0.719	0.375	0.344	0.443	0.438	0.005	1%
E	1.313	0.516	0.797	61%	0.475	0.285	0.190	40%	0.55%	0.002	0.922	0.281	0.641	0.474	0.357	0.117	25%
SDeck	0.938	0.422	0.516	55%	0.817	0.323	0.494	60%	0.42%	0.001	0.266	0.156	0.109	0.561	0.545	0.015	3%
Bio A	0.797	0.328	0.469	59%	0.532	0.133	0.399	75%	0.38%	0.001	0.359	0.219	0.141	0.377	0.316	0.061	16%
Bio B	1.031	0.703	0.328	32%	0.608	0.513	0.095	16%	0.40%	0.002	0.531	0.281	0.250	0.433	0.382	0.051	12%
GA	0.703	0.375	0.328	47%	0.494	0.323	0.171	35%	0.50%	0.002	0.297	0.109	0.187	0.474	0.423	0.051	11%
GB	1.688	0.656	1.031	61%	0.494	0.247	0.247	50%	0.48%	0.001	1.281	0.453	0.828	0.968	0.892	0.076	8%
MUW_A	1.313	0.422	0.891	68%	0.627	0.190	0.437	70%	0.48%	0.001	0.797	0.266	0.531	0.448	0.408	0.041	9%
MUW_B	1.125	0.375	0.750	67%	0.152	0.000	0.152	100%	0.69%	0.000	1.000	0.375	0.625	0.413	0.408	0.005	1%
I/J	2.203	0.469	1.734	79%	2.622	1.444	1.178	45%	0.96%	0.014	0.047	-0.719	0.766	1.544	1.203	0.341	22%

pH, Alkalinity, Hardness
5 Mar 01

				Alkalinity mg/L as $CaCO_3$					Total Hardness mg/L as $CaCO_3$				
	pH												
Site	Rdg	Rep	T °C	Rdg	Rep	Fact.	Result	Avgs	Rdg	Rep	Fact.	Result	
A	7.62	2	8.1	106	2	0.4	42.2		186	2	0.4	74.4	
B	7.48	2	7.6	103	2	0.4	41.2		181	2	0.4	72.4	
C	7.49	2	8.2	107	2	0.4	42.6		186	2	0.4	74.4	
D	7.51	2	7.3	106	2	0.4	42.4		189	2	0.4	75.6	
E	7.58	2	7.3	106	2	0.4	42.4		188	2	0.4	75.2	
SDeck	7.46	2	7.3	107		0.4	42.6		177	2	0.4	70.8	
BFa	7.43	2	6.9	102	2	0.4	40.8	BF_{A-B}	183	2	0.4	73.2	
BFb	7.45	2	6.9	106	2	0.4	42.4	41.6	182	2	0.4	72.8	
G_A	7.54	2	7.1	102	2	0.4	40.8	G_{A-B}	184	2	0.4	73.6	
G_B	7.49	2	8	98	2	0.4	39.2	40.0	158	2	0.4	63.2	next day
MUW_A	7.49	2	8	88		0.4	35.2		78	2	0.4	31.2	
MUW_B	7.64	2	8	144		0.4	57.4		146	2	0.4	58.4	
J	7.79	2	8	163	2	0.4	65.2		167	2	0.4	66.8	
Swirl Bottom				209									

Cartridge 0.1600 N H_2SO_4 0.0800 N EDTA

Statistics, Culture Water Alkalinity

Mean	41.66
Standard Error	0.356589
Median	42.3
Mode	42.4
Standard Deviation	1.127633
Variance	1.271556
Kurtosis	1.1016
Skewness	-1.28075
Range	3.4
Minimum	39.2
Maximum	42.6
Sum	416.6
Count	10
Confidence Level(0.950000)	0.698901

Statistics, Culture Water Hardness

Mean	72.56
Standard Error	1.131685
Median	73.4
Mode	74.4
Standard Deviation	3.578702
Variance	12.80711
Kurtosis	6.097285
Skewness	-2.31859
Range	12.4
Minimum	63.2
Maximum	75.6
Sum	725.6
Count	10
Confidence Level(0.950000)	2.218062

Nitrite & Nitrate

5 Mar 01 Using Test 8171

	At. Wt.		N	O	Total
N	14.0067	NO_2	1	2	46.006
O	15.9994	NO_2-N	1	0	14.007
		NO_3	1	3.00	62.005
		NO_3-N	1	0	14.007

NO_2 Reagent Factor	0	
NO_2 /NO2-N Factor	3.285	
NO_3 Reagent Factor	0	Factor not used after switch to Method 8171
NO_3 /NO3-N Factor	4.427	

	NITRITE, mg/L				NITRATE, mg/L			
Site	Rdg	R	NO2-N	NO2	Rdg	R	NO3-N	NO3
A	0.0265	2	0.0265	0.087	1.9	2	1.9	8.4
B	0.033	2	0.033	0.108	1.6	2	1.6	6.9
C	0.027	2	0.027	0.089	1.6	2	1.6	7.1
D	0.0315	2	0.0315	0.103	1.8	2	1.8	7.7
E	0.068	2	0.068	0.223	1.7	2	1.7	7.3
SDeck	0.1395	2	0.024	0.079	1.40		1.4	6.2
BFa	0.026	2	0.026	0.085	1.6	2	1.6	6.9
BFb	0.0235	2	0.0235	0.077	1.6	2	1.6	6.9
GA	0.0255	2	0.0255	0.084	1.6	2	1.6	6.9
GB	0.024	2	0.024	0.079	1.8	3	1.8	8.0
MUWA	0.0055	2	0.0055	0.018	0.00		0.0	0.0
MUWB	0.0035	2	0.0035	0.011	0.00		0.0	0.0
J	0.068	2	0.068	0.223	0.8	2	0.8	3.3
Swirl Flsh	0.14	2	0.14	0.460	2.20	17	2.2	9.7

Using Tes

R - repetitions
0.0005' and '0.05' - averaging

Swirl Nitrate Reading Statistics

Mean	2.20588
Standard Error	0.0597
Median	2.3
Mode	2.3
Standard Deviation	0.24615
Variance	0.06059
Range	0.8
Minimum	1.8
Maximum	2.6
Sum	37.5
Count	17
Confidence Level(0.950000)	0.11701

Swirl Rdgs
1.9
2.2
2
2
1.9
2.6
2.5
2.5
2.3
2.4
2.3
2.3
2.4
2.3
2.2
1.9
1.8

TKN, Ammonia and Phosphorus Data and Calculations, 5 Mar 01

Results in mg/L

TKNCalculations

Factor	75
Calc B	40
Reagent Correction	0

		Unfiltered			Filtered			% in
Site	C	Rdg	Rep	TKN	Rdg	Rep	TKN	Solids
A	20	8.5	2	0.797	3.5	2	0.328	58.8%
B	20	11.5	2	1.078	3.5	2	0.328	69.6%
C	20	5.5	2	0.516	4	2	0.375	27.3%
D	20	13.5	2	1.266	5.5	2	0.516	59.3%
E	20	14	2	1.313	5.5	2	0.516	60.7%
SDeck	20	10	2	0.938	4.5	2	0.422	55.0%
BFa	20	8.5	2	0.797	3.5	2	0.328	58.8%
BFb	20	11	2	1.031	7.5	2	0.703	31.8%
Ga	20	7.5	2	0.703	4	2	0.375	46.7%
Gb	20	18	2	1.688	7	2	0.656	61.1%
MUWA	20	14	2	1.313	4.5	2	0.422	67.9%
MUWB	20	12	2	1.125	4	2	0.375	66.7%
I/J	20	23.5	2	2.203	5	2	0.469	78.7%

Averages

UnFilt	Filt	Diff	%
A-B	A-B	(1/3 proportional)	
0.984	0.328	0.656	66.67%
BF	BF		
0.914	0.516	0.398	43.59%
G	G		
1.195	0.516	0.680	56.86%

Ammonia Calculations

Factor	2500
Calc B	40

Fe Formula 0.04864 0.5515

Fe Rdg **Fe effect**

0.55 0.035 mg/L (subtract from readings)

TAN> NH3	At Wt	No	Tot				
N	14.01	1	14.008	NH3-N x	1.216	=	NH3
H	1.01	3	3.024				
			17.032				

		Unfiltered				Filtered				%
Site	C	Rdg	Rep	TAN	NH3	Rdg	Rep	TAN	NH3	in Solids
A	15	0.09	2	0.229	0.279	0.065	2	0.125	0.152	45.44%
B	20	0.23	2	0.609	0.741	0.125	2	0.281	0.342	53.84%
C	20	0.165	2	0.406	0.494	0.085	2	0.156	0.190	61.53%
D	20	0.21	2	0.547	0.665	0.08	2	0.141	0.171	74.28%
E	20	0.16	2	0.391	0.475	0.11	2	0.234	0.285	39.99%
SDeck	20	0.25		0.672	0.817	0.12	2	0.266	0.323	60.46%
BFa	20	0.175	2	0.438	0.532	0.07	2	0.109	0.133	74.99%
BFb	20	0.195	2	0.500	0.608	0.17	2	0.422	0.513	15.62%
Ga	20	0.165	2	0.406	0.494	0.12	2	0.266	0.323	34.61%
Gb	20	0.165	2	0.406	0.494	0.1	2	0.203	0.247	49.99%
MUWA	20	0.2	2	0.516	0.627	0.085	2	0.156	0.190	69.69%
MUWB	20	0.075	2	0.125	0.152	0.03	2	0.000	0.000	100.00%
I/J	10	0.38	2	2.156	2.622	0.225	2	1.188	1.444	44.92%
SwirlFlush				0.17	0.207					

Averages

UnFilt	Filt	Diff		%
A-B	A-B	(1/3 proportional)		
0.587	0.279	0.308		52.5%
BF	BF			
0.570	0.323	0.247		43.3%
G	G			
0.494	0.285	0.209		42.3%
	G	G		
	1.681	1.387	0.294	17.5%

Phosphate Calculations mg/L

Factor	2500
Calc B	40
Reagent Correction	0.01

PO4>P	At Wt	No	Tot				
P	30.98	1	30.98	PO4 x	0.326	=	P
O	16.00	4	64				
			94.98				

		Unfiltered				Filtered				P	%
Site	C	Rdg	Rep	PO4	P	Rdg	Rep	PO4	P	in Solids	in Solids
A	20	0.65	2	2.000	0.652	0.415	2	1.266	0.413	0.240	36.72%
B	20	0.8	2	2.469	0.805	0.555	2	1.703	0.556	0.250	31.01%
C	20	0.515	2	1.578	0.515	0.41	2	1.250	0.408	0.107	20.79%
D	20	0.445	2	1.359	0.443	0.44	2	1.344	0.438	0.005	1.15%
E	20	0.475	2	1.453	0.474	0.36	2	1.094	0.357	0.117	24.73%
SDeck	20	0.56	2	1.719	0.561	0.545	2	1.672	0.545	0.015	2.73%
BFa	20	0.38	2	1.156	0.377	0.32	2	0.969	0.316	0.061	16.22%
BFb	20	0.435	2	1.328	0.433	0.385	2	1.172	0.382	0.051	11.76%
Ga	20	0.475	2	1.453	0.474	0.425	2	1.297	0.423	0.051	10.75%
Gb	20	0.96	2	2.969	0.968	0.885	2	2.734	0.892	0.076	7.89%
MUWA	20	0.45	2	1.375	0.448	0.41	2	1.250	0.408	0.041	9.09%
MUWB	20	0.415	2	1.266	0.413	0.335	2	1.016	0.331	0.082	19.75%
I/J	20	1.525	2	4.734	1.544	1.19	2	3.688	1.203	0.341	22.11%

Averages

UnFilt	Filt	Diff	%
A-B	A-B	(1/3 proportional)	
0.754	0.508	0.246	32.7%
BF	BF		
0.405	0.349	0.056	13.8%
G	G		
0.721	0.657	0.064	8.8%

Water Quality Data Summary

Date 19-Mar-01 NH3-N to NH3 1.216 Rep - repetition

	pH	T	CO2	Alk	Hardn	NO2	NO3	TSS mg/L		ORP mV		TDS mg/L		Beta	R
Site		deg C	mg/L	mg/L	mg/L	mg/L	mg/L	Rdg	Rep	Rdg	Rep	Rdg	Rep		
A	6.56	8.1		33.4	36.0	0.044	7.3	3.45	11	544.2	1	89.1	1	2.989	0.9846
B	6.60	7.9	6.8	32.2	35.0	0.069	8.0	3.38	8	504.9	1	88.1	1	3.080	0.8386
C	6.60	7.9		32.2	35.0	0.044	7.1	4.14	14	309.1	1	89.6	2	2.759	0.9696
D	6.74	7.9		32.4	36.2	0.048	7.1	2.22	9	386.8	2	86.4	2	2.808	0.7726
E	6.72	7.9		32.6	36.4	0.041	7.1	1.50	6	384.8	3	87.0	2		
SDeck	6.76	7.9		32.0	36.6	0.079	7.3	2.40	10	333.9	5	87.7	3	2.573	0.9768
Bio A	6.50	7.9		31.6	34.6	0.028	6.4	1.50	8	389.5	3	87.3	2	4.330	0.9093
Bio B	6.44	7.9		31.8	36.0	0.049	6.9	1.42	7	387.3	4	87.4	4	2.712	0.966
GA	6.43	7.9		31.8	36.4	0.023	9.1	2.00	9	342.4	3	88.3	2	2.711	0.9372
GB	6.66	7.9		32.6	36.6	0.057	6.9	2.04	21	349.7	3	90.6	2	2.435	0.9624
MUWA		?		30.8	26.8	0.010	0.7	2.00	12	336.0	2	54.7	2	3.620	0.9664
MUWB	8.53	8.5		54.4	56.2	0.007	0.0	2.25	8	330.1	2	173.4	2	2.219	0.7402
I/J				51.4	54.2	0.057	2.7	18.70	10	329.0	2	152.1	2		
Sw Flush															

	TKN				Ammonia NH3						Organic N			Phosphorus			
	UnFilt	Filt	Solids	% InSol	UnFilt	Filt	Solids	%	% NH3	Unlon.	UnFilt	Filt	Solids	UnFilt	Filt	Solids	% in
Site	mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	Solids		NH3	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Solids
A	0.750	0.563	0.188	25%	0.912	0.760	0.152	17%	0.06%	0.0004	-0.000	-0.063	0.062	0.499	0.377	0.122	24%
B	1.031	0.844	0.188	18%	1.007	0.874	0.133	13%	0.06%	0.0005	0.203	0.125	0.078	0.433	0.280	0.153	35%
C	0.984	0.328	0.656	67%	1.444	0.779	0.665	46%	0.06%	0.0005	-0.203	-0.313	0.109	0.948	0.744	0.204	22%
D	0.938	0.750	0.188	20%	1.159	0.722	0.437	38%	0.09%	0.0006	-0.016	0.156	-0.172	0.505	0.341	0.163	32%
E	1.313	0.656	0.656	50%	1.767	1.083	0.684	39%	0.08%	0.0009	-0.141	-0.234	0.094	0.622	0.433	0.189	30%
SDeck	0.750	0.516	0.234	31%	0.912	0.779	0.133	15%	0.07%	0.0006	-0.000	-0.125	0.125	0.413	0.290	0.122	30%
Bio A	0.797	0.281	0.516	65%	0.760	0.399	0.361	47%	0.05%	0.0002	0.172	-0.047	0.219	0.392	0.321	0.071	18%
Bio B	0.703	0.422	0.281	40%	0.836	0.494	0.342	41%	0.04%	0.0002	0.016	0.016	-0.000	0.505	0.347	0.158	31%
GA	0.750	0.516	0.234	31%	0.893	0.608	0.285	32%	0.04%	0.0003	0.016	0.016	-0.000	0.448	0.398	0.051	11%
GB	1.313	0.891	0.422	32%	0.475	0.418	0.057	12%	0.07%	0.0003	0.922	0.547	0.375	0.494	0.408	0.087	18%
MUWA	0.609	0.469	0.141	23%	0.665	0.608	0.057	9%	0.00%	0.0000	0.062	-0.031	0.094	0.316	0.219	0.097	31%
MUWB	0.469	0.188	0.281	60%	0.133	0.057	0.076	57%	5.23%	0.0030	0.359	0.141	0.219	0.255	0.189	0.066	26%
I/J	1.828	0.797	1.031	56%	2.622	1.140	1.482	57%	0.00%	0.000	-0.328	-0.141	-0.188	1.539	1.356	0.183	12%

pH, Alkalinity, Hardness

19 Mar 01

	pH			CO_2 mg/L				Alkalinity mg/L as CaCO3				Total Hardness mg/L as CaCO3			
Site	**Rdg**	**Rep**	**T °C**	**Rdg**	**Rep**	**Fact.**	**Result**	**Rdg**	**Rep**	**Fact.**	**Result**	**Rdg**	**Rep**	**Fact.**	**Result**
A	6.56	2	8.1				0	84	2	0.4	33.4	90	2	0.4	36.0
B	6.60	2	7.9	34	2	0.2	6.8	81	2	0.4	32.2	88	2	0.4	35.0
C	6.60	2	7.9				0	81	2	0.4	32.2	88	2	0.4	35.0
D	6.74	2	7.9				0	81	2	0.4	32.4	91	2	0.4	36.2
E	6.72	2	7.9				0	82	2	0.4	32.6	91	2	0.4	36.4
SDeck	6.76	2	7.9				0	80		0.4	32.0	92	2	0.4	36.6
BFa	6.50	2	7.9				0	79	2	0.4	31.6	87	2	0.4	34.6
BFb	6.44	2	7.9				0	80	2	0.4	31.8	90	2	0.4	36.0
G_A	6.43	2	7.9				0	80	2	0.4	31.8	91	2	0.4	36.4
G_B	6.66	2	7.9				0	82	2	0.4	32.6	92	2	0.4	36.6
MUW_A		2	?				0	77		0.4	30.8	67	2	0.4	26.8
MUW_B	8.53	2	8.5				0	136		0.4	54.4	141	2	0.4	56.2
J		2					0	129	2	0.4	51.4	136	2	0.4	54.2

Cartridge 0.3636 N NaOH 0.1600 N H_2SO_4 0.0800 N EDTA

Statistics, Culture Water Alkalinity

Mean	32.26
Standard Error	0.1661
Median	32.2
Mode	31.8
Standard Deviation	0.5254
Variance	0.276
Kurtosis	1.3909
Skewness	1.0179
Range	1.8
Minimum	31.6
Maximum	33.4
Sum	322.6
Count	10
Confidence Level(0.950000)	0.3256

Statistics, Culture Water Hardness

Mean	35.88
Standard Error	0.233238
Median	36.1
Mode	35
Standard Deviation	0.737564
Variance	0.544
Kurtosis	-0.96273
Skewness	-0.82944
Range	2
Minimum	34.6
Maximum	36.6
Sum	358.8
Count	10
Confidence Level(0.950000)	0.457138

Nitrite & Nitrate

19 Mar 01		Using Tests 8507 & 8171			
	At. Wt.		**N**	**O**	**Total**
N	14.0067	NO2	1	2	46.0055
O	15.9994	NO2-N	1	0	14.0067
		NO3	1	3.00	62.0049
		NO3-N	1	0	14.0067

NO_2 Reagent Factor	0	
NO_2 /NO2-N Factor	3.285	
NO_3 Reagent Factor	0	Factor not used after switch to Method 8171
NO_3 /NO3-N Factor	4.427	

	NITRITE, mg/L				NITRATE, mg/L				
Site	Rdg	R	NO2-N	NO2	Rdg	R	NO3-N	NO3	
A	0.0135	2	0.0135	0.044	1.7	2	1.7	7.3	
B	0.021	4	0.021	0.069	1.8	4	1.8	8.0	*
C	0.0135	2	0.0135	0.044	1.6	2	1.6	7.1	
D	0.0145	2	0.0145	0.048	1.6	2	1.6	7.1	
E	0.0125	2	0.0125	0.041	1.6	2	1.6	7.1	
SDeck	0.011	2	0.024	0.079	1.65		1.7	7.3	
BFa	0.0085	2	0.0085	0.028	1.5	2	1.5	6.4	
BFb	0.015	2	0.015	0.049	1.6	2	1.6	6.9	
G_A	0.007	2	0.007	0.023	2.1	2	2.1	9.1	
G_B	0.0175	2	0.0175	0.057	1.6	3	1.6	6.9	
MUW_A	0.003	2	0.003	0.010	0.15		0.2	0.7	
MUW_B	0.002	2	0.002	0.007	0.00		0.0	0.0	
J	0.0175	4	0.0175	0.057	0.6	4	0.6	2.7	
Swirl Flsh									

* B sample was late pm, remainder early am

R - repetitions
0.0005' and '0.05' - averaging

TSS, TDS, ORP

Date: 19 Mar 01

	TSS mg/L		ORP mV		TDS mg/L		Beta	R
Site	**Rdg**	**Rep**	**Rdg**	**Rep**	**Rdg**	**Rep**		
A	3.45	11	544.2	1	89.1	1	2.989	0.98460
B	3.38	8	504.9	1	88.1	1	3.080	0.83860
C	4.14	14	309.1	1	89.6	2	2.759	0.96960
D	2.22	9	386.8	2	86.4	2	2.808	0.77260
E	1.50	6	384.8	3	87.0	2		
SDeck	2.40	10	333.9	5	87.7	3	2.573	0.97680
BFa	1.50	8	389.5	3	87.3	2	4.330	0.90930
BFb	1.42	7	387.3	4	87.4	4	2.712	0.96600
Ga	2.00	9	342.4	3	88.3	2	2.711	0.93720
Gb	2.04	21	349.7	3	90.6	2	2.435	0.96240
MUWA	2.00	12	336.0	2	54.7	2	3.620	0.96640
MUWB	2.25	8	330.1	2	173.4	2	2.219	0.74020
I/J	18.70	10	329.0	2	152.1	2		
Swirl Fl								

0.00 = averaging

Beta values using Malvern Particle Sizer

Results erratic

TKN, Ammonia and Phosphorus Data and Calculations, 19 Mar 01

Results in mg/L

TKNCalculations

Factor	75
Calc B	40
Reagent Correction	0

		Unfiltered			Filtered			% in
Site	**C**	**Rdg**	**Rep**	**TKN**	**Rdg**	**Rep**	**TKN**	**Solids**
A	20	8	2	0.750	6	2	0.563	25.0%
B	20	11	2	1.031	9	2	0.844	18.2%
C	20	10.5	2	0.984	3.5	2	0.328	66.7%
D	20	10	2	0.938	8	2	0.750	20.0%
E	20	14	2	1.313	7	2	0.656	50.0%
SDeck	20	8	2	0.750	5.5	2	0.516	31.3%
BFa	20	8.5	2	0.797	3	2	0.281	64.7%
BFb	20	7.5	2	0.703	4.5	2	0.422	40.0%
Ga	20	8	2	0.750	5.5	2	0.516	31.3%
Gb	20	14	2	1.313	9.5	2	0.891	32.1%
MUWA	20	6.5	2	0.609	5	2	0.469	23.1%
MUWB	20	5	2	0.469	2	2	0.188	60.0%
I/J	20	19.5	2	1.828	8.5	2	0.797	56.4%

Averages

UnFilt	**Filt**	**Diff**	**%**
A-B	**A-B**	(1/3 proportional)	
0.938	0.750	0.188	20.00%
BF	**BF**		
0.750	0.352	0.398	53.13%
G	**G**		
1.031	0.703	0.328	31.82%

Ammonia Calculations

Factor	2500
Calc B	40

Fe Formula 0.04864 0.5515

Fe Rdg **Fe effect**

0.55 0.035 mg/L (subtract from readings)

TAN> NH3		At Wt	No	Tot				
	N	14.01	1	14.008	NH3-N x	1.216 =		NH3
	H	1.01	3	3.024				
				17.032				

		Unfiltered				Filtered				%
Site	**C**	**Rdg**	**Rep**	**TAN**	**NH3**	**Rdg**	**Rep**	**TAN**	**NH3**	**in Solids**
A	20	0.275	2	0.750	0.912	0.235	2	0.625	0.760	16.67%
B	20	0.3	2	0.828	1.007	0.265	2	0.719	0.874	13.21%
C	20	0.415	2	1.188	1.444	0.24	2	0.641	0.779	46.05%
D	20	0.34	2	0.953	1.159	0.225	2	0.594	0.722	37.70%
E	20	0.5	2	1.453	1.767	0.32	2	0.891	1.083	38.71%
SDeck	20	0.275	2	0.750	0.912	0.24	2	0.641	0.779	14.58%
BFa	20	0.235	2	0.625	0.760	0.14	2	0.328	0.399	47.49%
BFb	20	0.255	2	0.688	0.836	0.165	2	0.406	0.494	40.91%
Ga	20	0.27	2	0.734	0.893	0.195	2	0.500	0.608	31.91%
Gb	20	0.16	2	0.391	0.475	0.145	2	0.344	0.418	12.00%
MUWA	20	0.21	2	0.547	0.665	0.195	2	0.500	0.608	8.57%
MUWB	20	0.07	2	0.109	0.133	0.05	2	0.047	0.057	57.11%
I/J	10	0.38	2	2.156	2.622	0.185	2	0.938	1.140	56.52%

Averages

UnFilt	**Filt**	**Diff**		**%**
A-B	**A-B**	(1/3 proportional)		
0.975	0.836	0.139		14.3%
BF	**BF**			
0.798	0.447	0.351		44.0%
G	**G**			
0.684	0.513	0.171		25.0%
	G	**G**		
	1.681	1.387	0.294	17.5%

Phosphate Calculations mg/L

Factor	2500
Calc B	40
Reagent Correction	0.01

PO4>P		At Wt	No	Tot				
	P	30.98	1	30.98	PO4 x	0.326 =		P
	O	16.00	4	64				
				94.98				

		Unfiltered				Filtered				P	%
Site	**C**	**Rdg**	**Rep**	**PO4**	**P**	**Rdg**	**Rep**	**PO4**	**P**	**in Solids**	**in Solids**
A	20	0.5	2	1.531	0.499	0.38	2	1.156	0.377	0.12	24.49%
B	20	0.435	2	1.328	0.433	0.285	2	0.859	0.280	0.15	35.29%
C	20	0.94	2	2.906	0.948	0.74	2	2.281	0.744	0.20	21.51%
D	20	0.505	2	1.547	0.505	0.345	2	1.047	0.341	0.16	32.32%
E	20	0.62	2	1.906	0.622	0.435	2	1.328	0.433	0.19	30.33%
SDeck	20	0.415	2	1.266	0.413	0.295	2	0.891	0.290	0.12	29.63%
BFa	20	0.395	2	1.203	0.392	0.325	2	0.984	0.321	0.07	18.18%
BFb	20	0.505	2	1.547	0.505	0.35	2	1.063	0.347	0.16	31.31%
Ga	20	0.45	2	1.375	0.448	0.4	2	1.219	0.398	0.05	11.36%
Gb	20	0.495	2	1.516	0.494	0.41	2	1.250	0.408	0.09	17.53%
MUWA	20	0.32	2	0.969	0.316	0.225	2	0.672	0.219	0.10	30.65%
MUWB	20	0.26	2	0.781	0.255	0.195	2	0.578	0.189	0.07	26.00%
I/J	10	0.765	2	4.719	1.539	0.675	2	4.156	1.356	0.18	11.92%

Averages

UnFilt	**Filt**	**Diff**	**%**
A-B	**A-B**	(1/3 proportional)	
0.455	0.313	0.143	31.3%
BF	**BF**		
0.448	0.334	0.115	25.6%
G	**G**		
0.471	0.403	0.069	14.6%

Water Quality Data Summary

Date 2 April 01 FE comp NH3-N to NH3 1.215877

	pH	T	Alk	Hardn	NO2	NO3	TSS mg/L	ORP mV	TDS mg/L	Beta	R
Site		deg C	mg/L	mg/L	mg/L	mg/L	Rdg	Rdg	Rdg		
A	6.89	9.3	31.2	35.9	0.074	7.3	1.0	500.2	92.5	2.524	0.9941
B	6.79	9.3	28.2	37.0	0.097	8.0	2.0	488.9	88.6	2.554	0.9954
C	6.83	9.4	29.8	37.2	0.103	6.2	1.0	493.0	89.6	2.055	0.9895
D	6.87	9.4	28.4	37.2	0.094	6.4	1.0	484.2	88.6	2.335	0.9869
E	6.82	9.4	29.0	37.4	0.102	7.3	1.3	497.0	89.0	2.464	0.9893
SDeck	6.87	9.5	28.6	36.4	0.079	8.9	1.4	428.6	88.8	2.541	0.9919
Bio A	6.64	9.7	29.8	37.0	0.080	8.9	1.0	495.7	88.8	2.134	0.9782
Bio B	6.79	9.4	30.4	36.8	0.064	9.1	1.0	491.2	86.2	2.281	0.9799
GA	7.05	9.4	29.4	36.2	0.103	6.9	1.0	472.2	88.5	3.014	0.9824
GB	7.08	9.4	28.0	36.6	0.089	6.9	1.3	474.7	86.9	2.492	0.9955
MUW$_A$	7.04	9.6	33.4	31.2	0.038	0.4	2.0	441.5	55.6	3.183	0.9912
MUW$_B$	6.75	9.6	55.0	59.6	0.007	0.0	1.7	256.5	176.3	2.196	0.9925
I/J	7.12	8.9	50.6	56.2	0.136	3.1	53.0	385.8	122.8	1.632	0.9921
Sw Flush	7.43	8.4	51.8	75.0	0.145	17.5	565.1	263.3	101.4		

	TKN				Ammonia NH3						Organic N			Phosphorus			
	UnFilt	Filt	Solids	% InSol	UnFilt	Filt	Solids	%	% UIA	UIA	UnFilt	Filt	Solids	UnFilt	Filt	Solids	% in
Site	mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	Solids		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Solids
A	1.172	0.834	0.338	29%	1.254	0.950	0.304	24%	0.13%	0.001	0.141	0.053	0.088	0.413	0.321	0.09	22%
B	0.984	0.609	0.375	38%	1.083	0.988	0.095	9%	0.11%	0.001	0.094	-0.203	0.297	0.438	0.331	0.11	24%
C	0.797	0.609	0.188	24%	1.368	0.988	0.38	28%	0.12%	0.001	-0.328	-0.203	-0.125	0.474	0.362	0.11	24%
D	0.797	0.609	0.188	24%	1.140	0.969	0.171	15%	0.13%	0.001	-0.141	-0.188	0.047	0.433	0.311	0.12	28%
E	1.172	0.750	0.422	36%	1.501	1.026	0.475	32%	0.12%	0.001	-0.063	-0.094	0.031	0.036	0.019	0.02	48%
SDeck	0.891	0.609	0.281	32%	1.045	0.931	0.114	11%	0.13%	0.001	0.031	-0.156	0.188	0.352	0.311	0.04	12%
Bio A	0.797	0.516	0.281	35%	0.874	0.703	0.171	20%	0.08%	0.001	0.078	-0.063	0.141	0.392	0.311	0.08	21%
Bio B	0.797	0.469	0.328	41%	0.817	0.684	0.133	16%	0.11%	0.001	0.125	-0.094	0.219	0.428	0.321	0.11	25%
GA	0.750	0.516	0.234	31%	0.798	0.722	0.076	10%	0.20%	0.001	0.094	-0.078	0.172	0.341	0.296	0.05	13%
GB	1.031	0.797	0.234	23%	1.026	0.893	0.133	13%	0.21%	0.002	0.187	0.062	0.125	0.387	0.296	0.09	24%
MUW$_A$	0.750	0.563	0.188	25%	0.817	0.608	0.209	26%	0.19%	0.001	0.078	0.062	0.016	0.321	0.219	0.10	32%
MUW$_B$	0.375	0.141	0.234	63%	0.323	0.190	0.133	41%	0.10%	0.000	0.109	-0.016	0.125	0.285	0.194	0.09	32%
I/J	9.047	1.969	7.078	78%	19.973	3.306	16.668	83%	0.22%	0.007	-7.380	-0.750	-6.630	1.952	0.984	0.97	50%
Sw Flush	131.3	69.4	61.9	47%	141.4	68.4	72.953	52%						154.9	141.5	13.45	9%

pH, Alkalinity, Hardness
2 Apr 01

	pH			Alkalinity mg/L as CaCO3				Total Hardness mg/L as CaCO3			
Site	**Rdg**	**Rep**	**T °C**	**Rdg**	**Rep**	**Fact.**	**Result**	**Rdg**	**Rep**	**Fact.**	**Result**
A	6.89	1	9.3	78	2	0.4	31.2	90	3	0.4	35.9
B	6.79	1	9.3	71	2	0.4	28.2	93	2	0.4	37.0
C	6.83	1	9.4	75	2	0.4	29.8	93	2	0.4	37.2
D	6.87	1	9.4	71	2	0.4	28.4	93	2	0.4	37.2
E	6.82	1	9.4	73	2	0.4	29.0	94	2	0.4	37.4
SDeck	6.87	1	9.5	72	2	0.4	28.6	91	2	0.4	36.4
BFa	6.64	1	9.7	75	2	0.4	29.8	93	2	0.4	37.0
BFb	6.79	1	9.4	76	2	0.4	30.4	92	2	0.4	36.8
G_A	7.05	1	9.4	74	2	0.4	29.4	91	2	0.4	36.2
G_B	7.08	1	9.4	70	2	0.4	28.0	92	2	0.4	36.6
MUW_A	7.04	1	9.6	84	2	0.4	33.4	78	2	0.4	31.2
MUW_B	6.75	1	9.6	138	2	0.4	55.0	149	2	0.4	59.6
J	7.12	1	8.9	127	2	0.4	50.6	141	2	0.4	56.2
Swirl Bottom	7.43	1	8.4	129.50	2	0.4	51.8	187.5	2	0.4	75

Cartridge 0.1600 N H_2SO_4 0.0800 N EDTA

Statistics, Culture Water Alkalinity

Mean	29.28
Standard Error	0.3269
Median	29.2
Mode	29.8
Standard Deviation	1.0337
Variance	1.0684
Kurtosis	-0.4823
Skewness	0.5522
Range	3.2
Minimum	28
Maximum	31.2
Sum	292.8
Count	10
Confidence Level(0.950000)	0.6407

Statistics, Culture Water Hardness

Mean	36.768
Standard Error	0.154782
Median	36.9
Mode	37
Standard Deviation	0.489462
Variance	0.239573
Kurtosis	-0.61264
Skewness	-0.59147
Range	1.52
Minimum	35.88
Maximum	37.4
Sum	367.68
Count	10
Confidence Level(0.950000)	0.303366

Nitrite & Nitrate

2 Apr 01 Using Tests 8507 & 8171

	At. Wt.		N	O	Total
N	14.0067	NO2	1	2	46.0055
O	15.9994	NO2-N	1	0	14.0067
		NO3	1	3.00	62.0049
		NO3-N	1	0	14.0067

NO_2 Reagent Factor	0	
NO_2 /NO2-N Factor	3.285	
NO_3 Reagent Factor	0	Factor not used after switch to Method 817
NO_3 /NO3-N Factor	4.427	

	NITRITE, mg/L				NITRATE, mg/L			
Site	**Rdg**	**R**	**NO2-N**	**NO2**	**Rdg**	**R**	**NO3-N**	**NO3**
A	0.0225	2	0.0225	0.074	1.7	2	1.6	7.3
B	0.0295	2	0.0295	0.097	1.8	2	1.8	8.0
C	0.0315	2	0.0315	0.103	1.4	2	1.4	6.2
D	0.0285	2	0.0285	0.094	1.6	2	1.4	6.4
E	0.031	2	0.031	0.102	1.6	2	1.6	7.3
SDeck	0.0215	2	0.0215	0.071	1.65	2	2.0	8.9
BFa	0.0245	2	0.0245	0.080	1.5	2	2.0	8.9
BFb	0.0195	2	0.0195	0.064	1.6	2	2.1	9.1
GA	0.0315	2	0.0315	0.103	2.1	2	1.6	6.9
GB	0.027	2	0.027	0.089	1.6	3	1.6	6.9
MUWA	0.0115	2	0.0115	0.038	0.15	2	0.1	0.4
MUWB	0.002	2	0.002	0.007	0.00	2	0.0	0.0
J	0.0415	4	0.0415	0.136	0.6	4	0.7	3.1
Swirl Fish	0.044	2	0.044	0.145	0.00		4.0	17.5

R - repetitions
0.0005' and '0.05' - averaging

TSS, TDS, ORP
Date: 2 Apr 01

	TSS mg/L		ORP mV		TDS mg/L		Beta	R
Site	**Rdg**	**Rep**	**Rdg**	**Rep**	**Rdg**	**Rep**		
A	1.0	6	500.2	3	92.5	3	2.524	0.9941
B	2.0	6	488.9	3	88.6	3	2.554	0.9954
C	1.0	6	493.0	3	89.6	3	2.055	0.9895
D	1.0	6	484.2	3	88.6	3	2.335	0.9869
E	1.3	9	497.0	3	89.0	3	2.464	0.9893
SDeck	1.4	7	428.6	3	88.8	3	2.541	0.9919
BFa	1.0	6	495.7	3	88.8	3	2.134	0.9782
BFb	1.0	6	491.2	3	86.2	3	2.281	0.9799
Ga	1.0	6	472.2	7	88.5	3	3.014	0.9824
Gb	1.3	9	474.7	3	86.9	3	2.492	0.9955
MUWA	2.0	6	441.5	3	55.6	3	3.183	0.9912
MUWB	1.7	9	256.5	3	176.3	3	2.196	0.9925
I/J	53.0	6	385.8	3	122.8	3	1.632	0.9921
Swirl Fl	565.1	7	263.3	3	101.4	3		

0.0 = averaging

TKN, Ammonia and Phosphorus Data and Calculations, 2 Apr 01

TKNCalculations

Factor	75
Calc B	40
Reagent Correction	0

		Unfiltered			Filtered			%
Site	C	Rdg	R	TKN	Rdg	R	TKN	in Solids
A	20	12.5	2	1.172	8.9	2	0.834	28.8%
B	20	10.5	2	0.984	6.5	2	0.609	38.1%
C	20	8.5	2	0.797	6.5	2	0.609	23.5%
D	20	8.5	2	0.797	6.5	2	0.609	23.5%
E	20	12.5	2	1.172	8	2	0.750	36.0%
SDeck	20	9.5	2	0.891	6.5	2	0.609	31.6%
BFa	20	8.5	2	0.797	5.5	2	0.516	35.3%
BFb	20	8.5	2	0.797	5	2	0.469	41.2%
Ga	20	8	2	0.750	5.5	2	0.516	31.3%
Gb	20	11	2	1.031	8.5	2	0.797	22.7%
MUWA	20	8	2	0.750	6	2	0.563	25.0%
MUWB	20	4	2	0.375	1.5	2	0.141	62.5%
I/J	20	96.5	2	9.047	21	2	1.969	78.2%
Swirl Fl	0.5	35	2	131.3	18.5	2	69.4	47.1%

Averages

UnFilt	Filt	Diff	%	
A-B	**A-B**			(1/3 proportional)
1.047	0.684	0.363	34.6%	
BF	**BF**			
0.797	0.492	0.305	38.2%	
G	**G**			
0.891	0.656	0.234	26.3%	

Ammonia Calculations

Factor 2500 **Fe Formula** 0.04864 0.5515

Calc B 40 **Fe Rdg :e effect**

0.55 0.035 mg/L (subtract from readings)

TAN> NH3		At Wt	No	Tot			
	N	14.01	1	14.008	\IH3-N x	1.216 =	NH3
	H	1.01	3	3.024			
	NH3			17.032			

		Unfiltered				Filtered				%
Site	C	Rdg	R	TAN	NH3	Rdg	R	TAN	NH3	in Solids
A	20	0.365	2	1.031	1.254	0.285	2	0.781	0.950	24.24%
B	20	0.320	2	0.891	1.083	0.295	2	0.813	0.988	8.77%
C	20	0.395	2	1.125	1.368	0.295	2	0.813	0.988	27.78%
D	20	0.335	2	0.938	1.140	0.290	2	0.797	0.969	15.00%
E	20	0.430	2	1.234	1.501	0.305	2	0.844	1.026	31.64%
SDeck	20	0.310	2	0.859	1.045	0.280	2	0.766	0.931	10.91%
BFa	20	0.265	2	0.719	0.874	0.220	2	0.578	0.703	19.56%
BFb	20	0.250	2	0.672	0.817	0.215	2	0.563	0.684	16.28%
Ga	20	0.245	2	0.656	0.798	0.225	2	0.594	0.722	9.52%
Gb	20	0.305	2	0.844	1.026	0.270	2	0.734	0.893	12.96%
MUWA	20	0.250	2	0.672	0.817	0.195	2	0.500	0.608	25.58%
MUWB	20	0.120	2	0.266	0.323	0.085	2	0.156	0.190	41.17%
I/J	10	2.66	2	16.427	19.973	0.470	2	2.719	3.306	83.45%
Flush	0.25	0.500	2	116.3	141.4	0.260	2	56.3	68.4	51.61%

* Dilution estimate, unfiltered

Averages

UnFilt	Filt	Diff	%	
A-B	**A-B**			(1/3 propc
1.140	0.975	0.165	14.4%	
BF	**BF**			
0.845	0.694	0.152	18.0%	
G	**G**			
0.912	0.807	0.104	11.5%	

Phosphate Calculations

Date:	2 Apr 01
Factor	2500
Calc B	40
Reagent Correction	0.01

PO4>P		At Wt	No	Tot			
	P	30.98	1	30.98	PO4 x	0.326 =	P
	O	16.00	4	64			
				94.98			

		Unfiltered				Filtered				P in Solids	%
Site	C	Rdg	R	PO4	P	Rdg	R	PO4	P	mg/L	in Solids
A	20	0.415	2	1.266	0.413	0.325	2	0.984	0.321	0.09	22.22%
B	20	0.44	2	1.344	0.438	0.335	2	1.016	0.331	0.11	24.42%
C	20	0.475	2	1.453	0.474	0.365	2	1.109	0.362	0.11	23.66%
D	20	0.435	2	1.328	0.433	0.315	2	0.953	0.311	0.12	28.24%
E	20	0.0455	2	0.111	0.036	0.029	2	0.058	0.019	0.02	47.89%
SDeck	20	0.355	2	1.078	0.352	0.315	2	0.953	0.311	0.04	11.59%
BFa	20	0.395	2	1.203	0.392	0.315	2	0.953	0.311	0.08	20.78%
BFb	20	0.43	2	1.313	0.428	0.325	2	0.984	0.321	0.11	25.00%
Ga	20	0.345	2	1.047	0.341	0.3	2	0.906	0.296	0.05	13.43%
Gb	20	0.39	2	1.188	0.387	0.3	2	0.906	0.296	0.09	23.68%
MUWA	20	0.325	2	0.984	0.321	0.225	2	0.672	0.219	0.10	31.75%
MUWB	20	0.29	2	0.875	0.285	0.2	2	0.594	0.194	0.09	32.14%
I/J	20	1.925	2	5.984	1.952	0.975	2	3.016	0.984	0.97	49.61%
Flush	0.25	1.91	2	475.0	154.9	1.745	2	433.8	141.5	13.45	8.68%

Averages

UnFilt	Filt	Diff	%	
A-B	**A-B**			(1/3 propc
0.430	0.328	0.102	23.7%	
BF	**BF**			
0.410	0.316	0.094	23.0%	
G	**G**			
0.364	0.296	0.069	18.9%	

Water Quality Data Summary

Date 16 April 01

NH3-N to NH3 1.215877

	pH	T	Alk	Hardn	NO2	NO3
Site		deg C	mg/L	mg/L	mg/L	mg/L
A	7.16	6.4	34.4	36.8	0.066	5.3
B	7.13	6.4	35.6	37.0	0.723	5.5
C	7.20	6.3	34.6	36.2	0.723	5.8
D	7.18	6.3	33.8	36.8	0.739	6.0
E	7.18	6.3	35.8	37.6	0.739	6.2
SDeck	7.17	6.5	34.0	37.4	0.061	5.8
Bio A	7.14	6.3	35.0	36.2	0.755	6.9
Bio B	7.12	6.3	34.0	36.6	0.624	7.1
GA	7.31	6.4	34.6	36.8	0.591	5.1
GB	7.33	6.4	34.6	37.4	0.805	11.5
MUW$_A$	7.13	9.7	34.8	30.2	0.018	0.9
MUW$_B$	6.95	9.6	52.2	55.8	0.007	0.4
I/J	7.22	7.7	41.4	43.8	0.218	6.2

TSS mg/L	ORP mV	TDS mg/L
Rdg	Rdg	Rdg
3.4	538.9	87.6
2.0	518.4	88.1
1.4	538.0	88.2
2.1	518.2	88.1
1.0	437.6	87.4
1.0	476.4	88.4
1.0	473.8	88.2
1.0	477.3	88.5
1.0	477.4	88.5
0.4	474.2	88.5
1.1	398.6	55.8
0.9	379.4	174.2
19.3	403.1	138.1

Beta	R
2.210	0.9864
2.210	0.9823
2.410	0.9874
2.280	0.9859
2.540	0.9869
2.280	0.9747
1.830	0.9706
2.030	0.9829
2.240	0.9706
2.330	0.9757
2.070	0.9960
1.050	0.8258

	TKN				Ammonia NH3						Organic N			Phosphorus			
	UnFilt	Filt	Solids	% InSol	UnFilt	Filt	Solids	%	% NH3	Unlon.	UnFilt	Filt	Solids	UnFilt	Filt	Solids	% in
Site	mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	Solids		NH3	mg/L	mg/L	mg/L	mg/L	mg/L		Solids
A	0.984	0.656	0.328	33%	1.843	1.577	0.266	14%	0.20%	0.003	-0.531	-0.641	0.109	2.564	2.446	0.12	5%
B	0.891	0.516	0.375	42%	1.710	1.330	0.38	22%	0.19%	0.002	-0.516	-0.578	0.063	2.574	2.472	0.10	4%
C	1.266	0.375	0.891	70%	2.481	1.539	0.9423	38%	0.22%	0.003	-0.775	-0.891	0.116	2.752	1.295	1.46	53%
D	0.797	0.731	0.066	8%	0.779	0.684	0.095	12%	0.21%	0.001	0.156	0.169	-0.012	0.464	0.301	0.16	35%
E	1.266	0.731	0.534	42%	0.779	0.646	0.133	17%	0.21%	0.001	0.625	0.200	0.425	0.433	0.306	0.13	29%
SDeck	1.219	0.984	0.234	19%	1.824	1.577	0.247	14%	0.21%	0.003	-0.281	-0.313	0.031	2.604	2.487	0.12	5%
Bio A	0.750	0.516	0.234	31%	1.425	1.311	0.114	8%	0.19%	0.002	-0.422	-0.563	0.141	2.518	2.416	0.10	4%
Bio B	0.703	0.375	0.328	47%	1.273	0.912	0.361	28%	0.18%	0.002	-0.344	-0.375	0.031	2.395	2.329	0.07	3%
GA	1.031	0.703	0.328	32%	1.577	1.406	0.171	11%	0.28%	0.004	-0.266	-0.453	0.188	2.324	1.330	0.99	43%
GB	1.078	0.656	0.422	39%	0.665	0.494	0.171	26%	0.29%	0.001	0.531	0.250	0.281	0.382	0.306	0.08	20%
MUW$_A$	0.891	0.703	0.188	21%	1.862	1.558	0.304	16%	0.24%	0.004	-0.641	-0.578	-0.062	2.268	1.656	0.61	27%
MUW$_B$	0.516	0.281	0.234	45%	0.703	0.608	0.095	14%	0.16%	0.001	-0.063	-0.219	0.156	2.431	2.293	0.14	6%
I/J					7.238	2.527	4.7115	65%									

pH, Alkalinity, Hardness
16 Apr 01

				Alkalinity				Total Hardness			
	pH			mg/L as CaCO3				mg/L as CaCO3			
Site	**Rdg**	**R**	**T °C**	**Rdg**	**R**	**Fact.**	**Result**	**Rdg**	**R**	**Fact.**	**Result**
A	7.16	1	6.4	86	2	0.4	34.4	92	2	0.4	36.8
B	7.13	1	6.4	89	2	0.4	35.6	93	2	0.4	37.0
C	7.20	1	6.3	87	2	0.4	34.6	91	2	0.4	36.2
D	7.18	1	6.3	85	2	0.4	33.8	92	2	0.4	36.8
E	7.18	1	6.3	90	2	0.4	35.8	94	2	0.4	37.6
SDeck	7.17	1	6.5	85	2	0.4	34.0	94	2	0.4	37.4
BFa	7.14	1	6.3	88	2	0.4	35.0	91	2	0.4	36.2
BFb	7.12	1	6.3	85	2	0.4	34.0	92	2	0.4	36.6
GA	7.31	1	6.4	87	2	0.4	34.6	92	2	0.4	36.8
GB	7.33	1	6.4	87	2	0.4	34.6	94	2	0.4	37.4
MUWA	7.13	1	9.7	87	2	0.4	34.8	76	2	0.4	30.2
MUWB	6.95	1	9.6	131	2	0.4	52.2	140	2	0.4	55.8
J	7.22	1	7.7	104	2	0.4	41.4	110	2	0.4	43.8

Cartridge 0.1600 N H_2SO_4 0.0800 N EDTA

R = replications

Statistics, Culture Water Alkalinity

Mean	34.64
Standard Error	0.210396
Median	34.6
Mode	34.6
Standard Deviation	0.665332
Variance	0.442667
Kurtosis	-0.42591
Skewness	0.641948
Range	2
Minimum	33.8
Maximum	35.8
Sum	346.4
Count	10
Confidence Level(0.950000)	0.412369

Statistics, Culture Water Hardness

Mean	36.88
Standard Error	0.152607
Median	36.8
Mode	36.8
Standard Deviation	0.482586
Variance	0.232889
Kurtosis	-0.92255
Skewness	0.004745
Range	1.4
Minimum	36.2
Maximum	37.6
Sum	368.8
Count	10
Confidence Level(0.950000)	0.299104

Nitrite & Nitrate

16 Apr 01 Using Tests 8507 & 8171

	At. Wt.		N	O	Total
N	14.0067	NO2	1	2	46.0055
O	15.9994	NO2-N	1	0	14.0067
		NO3	1	3.00	62.0049
		NO3-N	1	0	14.0067

NO_2 Reagent Factor	0	
NO_2 /NO2-N Factor	3.285	
NO_3 Reagent Factor	0	Factor not used after switch to Method 817
NO_3 /NO3-N Factor	4.427	

	NITRITE, mg/L				NITRATE, mg/L			
Site	**Rdg**	**R**	**NO2-N**	**NO2**	**Rdg**	**R**	**NO3-N**	**NO3**
A	0.02	2	0.02	0.066	1.2	2	1.2	5.3
B	0.22	2	0.22	0.723	1.3	2	1.3	5.5
C	0.22	2	0.22	0.723	1.3	2	1.3	5.8
D	0.225	2	0.225	0.739	1.4	2	1.4	6.0
E	0.225	2	0.225	0.739	1.4	2	1.4	6.2
SDeck	0.0185	2	0.0185	0.061	1.30	2	1.3	5.8
BFa	0.23	2	0.23	0.755	1.6	2	1.6	6.9
BFb	0.19	2	0.19	0.624	1.6	2	1.6	7.1
GA	0.18	2	0.18	0.591	1.2	2	1.2	5.1
GB	0.245	2	0.245	0.805	2.6	3	2.6	11.5
MUWA	0.0055	2	0.0055	0.018	0.20	2	0.2	0.9
MUWB	0.002	2	0.002	0.007	0.10	0.2	0.1	0.4
J	0.0665	4	0.0665	0.218	1.4	4	1.4	6.2
Swirl Flsh		2	0	0.000		2		0.0

R - repetitions

0.0005' and '0.05' - averaging

TSS, TDS, ORP
Date: 16 Apr 01

Time > **1000 hrs**

	TSS mg/L		ORP mV		TDS mg/L		Beta	R
Site	**Rdg**	**Rep**	**Rdg**	**Rep**	**Rdg**	**Rep**		
A	3.4	13	538.9	3	87.6	2	2.210	0.9864
B	2.0	6	518.4	2	88.1	2	2.210	0.9823
C	1.4	20	538.0	2	88.2	2	2.410	0.9874
D	2.1	7	518.2	2	88.1	2	2.280	0.9859
E	1.0	6	437.6	2	87.4	2	2.540	0.9869
SDeck	1.0	6	476.4	3	88.4	2	2.280	0.9747
BFa	1.0	6	473.8	3	88.2	2	1.830	0.9706
BFb	1.0	6	477.3	2	88.5	2	2.030	0.9829
Ga	1.0	6	477.4	2	88.5	2	2.240	0.9706
Gb	0.4	14	474.2	2	88.5	2	2.330	0.9757
MUW$_A$	1.1	7	398.6	2	55.8	2	2.070	0.9960
MUW$_B$	0.9	7	379.4	2	174.2	2	2.495	0.9667
I/J	19.3	6	403.1	2	138.1	2		

0.0 = averaging

1530 hrs

	TSS mg/L	
Site	**Rdg**	**Rep**
A	25.0	8
B	6.3	18
C	12.0	8

Note: these samples were teste
and had surfactant (1-2 drops/2

% Remove	**1000**	**1530**
	58.8%	52.0%
	(spurious)	

TKN, Ammonia and Phosphorus Data and Calculations, 16 Apr 01

TKNCalculations

Factor	75
Calc B	40
Reagent Correction	0

		Unfiltered			Filtered			% in
Site	**C**	**Rdg**	**Rep**	**TKN**	**Rdg**	**Rep**	**TKN**	**Solids**
A	20	10.5	2	0.984	7	2	0.656	33.3%
B	20	9.5	2	0.891	5.5	2	0.516	42.1%
C	10	13.5	2	1.266	7.5	2	0.375	70.4%
D	20	8.5	2	0.797	4	2	0.731	8.2%
E	20	13.5	2	1.266	7.8	2	0.731	42.2%
SDeck	20	13	2	1.219	10.5	2	0.984	19.2%
BFa	20	8	2	0.750	5.5	2	0.516	31.3%
BFb	20	7.5	2	0.703	4	2	0.375	46.7%
Ga	20	11	2	1.031	7.5	2	0.703	31.8%
Gb	20	11.5	2	1.078	7	2	0.656	39.1%
MUWA	20	9.5	2	0.891	7.5	2	0.703	21.1%
MUWB	20	5.5	2	0.516	3	2	0.281	45.5%
I/J	20							

Averages

UnFilt	Filt	Diff	%
A-B	**A-B**	(1/3 proportional)	
0.922	0.563	0.359	38.98%
BF	**BF**		
0.727	0.445	0.281	38.71%
G	**G**		
1.055	0.680	0.375	35.56%

Ammonia Calculations

Factor	2500
Calc B	40

Fe Formula 0.04864 0.5515

Fe Rdg	**Fe effect**	
0.55	0.035	mg/L

(subtract from readings)

TAN> NH3	At Wt	No	Tot				
N	14.01	1	14.008	NH3-N x	1.216	=	NH3
H	1.01	3	3.024				
			17.032				

		Unfiltered				Filtered				%
Site	**C**	**Rdg**	**Rep**	**TAN**	**NH3**	**Rdg**	**Rep**	**TAN**	**NH3**	**in Solids**
A	20	0.52	2	1.516	1.843	0.45	2	1.297	1.577	14.43%
B	20	0.485	2	1.406	1.710	0.385	2	1.094	1.330	22.22%
C	20	0.688	2	2.041	2.481	0.44	2	1.266	1.539	37.98%
D	20	0.24	2	0.641	0.779	0.215	2	0.563	0.684	12.19%
E	20	0.24	2	0.641	0.779	0.205	2	0.531	0.646	17.07%
SDeck	20	0.515	2	1.500	1.824	0.45	2	1.297	1.577	13.54%
BFa	20	0.41	2	1.172	1.425	0.38	2	1.078	1.311	8.00%
BFb	20	0.37	2	1.047	1.273	0.275	2	0.750	0.912	28.36%
Ga	20	0.45	2	1.297	1.577	0.405	2	1.156	1.406	10.84%
Gb	20	0.21	2	0.547	0.665	0.165	2	0.406	0.494	25.71%
MUWA	20	0.525	2	1.531	1.862	0.445	2	1.281	1.558	16.33%
MUWB		0.22	2	0.578	0.703	0.195	2	0.500	0.608	13.51%
I/J	10	1.94	2	5.953	7.238	0.7	2	2.078	2.527	65.09%

Averages

UnFilt	Filt	Diff	%
A-B	**A-B**	(1/3 proportional)	
1.754	1.412	0.342	19.5%
BF	**BF**		
1.349	1.111	0.237	17.6%
G	**G**		
1.121	0.950	0.171	15.3%

Phosphate Calculations mg/L

Factor	2500
Calc B	40
Reagent Correction	0.01

PO4>P	At Wt	No	Tot				
P	30.98	1	30.98	PO4 x	0.326	=	P
O	16.00	4	64				
			94.98				

		Unfiltered				Filtered				P	%
Site	**C**	**Rdg**	**Rep**	**PO4**	**P**	**Rdg**	**Rep**	**PO4**	**P**	**in Solids**	**in Solids**
A	20	2.525	2	7.859	2.564	2.41	2	7.500	2.446	0.12	4.57%
B	20	2.535	2	7.891	2.574	2.435	2	7.578	2.472	0.10	3.96%
C	20	2.71	2	8.438	2.752	1.28	2	3.969	1.295	1.46	52.96%
D	20	0.465	2	1.422	0.464	0.305	2	0.922	0.301	0.16	35.16%
E	20	0.435	2	1.328	0.433	0.31	2	0.938	0.306	0.13	29.41%
SDeck	20	2.565	2	7.984	2.604	2.45	2	7.625	2.487	0.12	4.50%
BFa	20	2.48	2	7.719	2.518	2.38	2	7.406	2.416	0.10	4.05%
BFb	20	2.36	2	7.344	2.395	2.295	2	7.141	2.329	0.07	2.77%
Ga	20	2.29	2	7.125	2.324	1.315	2	4.078	1.330	0.99	42.76%
Gb	20	0.385	2	1.172	0.382	0.31	2	0.938	0.306	0.08	20.00%
MUWA	20	2.235	2	6.953	2.268	1.635	2	5.078	1.656	0.61	26.97%
MUWB	20	2.395	2	7.453	2.431	2.26	2	7.031	2.293	0.14	5.66%
I/J	10		2	-0.063	-0.020		2	-0.063	-0.020	0.00	0.00%

Averages

UnFilt	Filt	Diff	%
A-B	**A-B**	(1/3 proportional)	
2.570	2.463	0.107	4.2%
BF	**BF**		
2.456	2.372	0.084	3.4%
G	**G**		
1.353	0.818	0.535	39.5%

Water Quality Data Summary

Date 30 April 01 NH3-N to NH3 1.2159

*

	pH	T	Alk	Hardn	NO2	NO3	TSS	ORP	TDS	Beta	R
Site		deg C	mg/L	mg/L	mg/L	mg/L	mg/L	mV	mg/L		
A	6.92	8.2	27.4	36.8	0.069	8.0	8.0	-77.7	604.0	2.240	0.9762
B	6.96	8.2	27.4	37.0	0.077	8.9	16.5	-107.7	85.1	2.392	0.9786
C	6.95	8.2	29.0	36.2	0.072	9.7	4.0	-98.9	85.4	2.396	0.9758
D	6.88	8.3	29.2	36.8	0.084	7.7	10.5	-106.9	85.8	2.505	0.9764
E	6.91	8.2	28.6	37.6	0.071	8.4	3.5	-106.7	85.2	2.396	0.9758
SDeck	6.93	9.5	30.6	37.4	0.053	9.5	27.0	-91.2	86.0	1.299	0.9675
Bio A	6.81	8.3	27.0	36.2	0.067	10.0	20.0	-107.7	84.8	2.489	0.9691
Bio B	6.93	8.4	26.6	36.6	0.074	8.6	17.0	-96.5	84.8	2.500	0.9730
GA	7.26	8.1	27.4	36.8	0.077	9.1	18.5	-103.5	84.2	2.546	0.9757
GB	7.18	8.3	27.8	37.4	0.067	10.0	18.7	-103.4	84.2	2.414	0.9673
MUWA1	7.71	6.7	34.0	30.2	0.010	0.9	4.0	-104.4	67.3	2.164	0.9966
MUWA2										2.454	0.9978
MUWB	7.38	8.0	35.0	55.8	0.020	0.9	26.5	-95.2	68.6		
I/J	7.48	8.5	47.2	43.8	0.112	2.7	12.0	-112.1	154.8	1.308	0.9896
Over Flow	7.08	7.3	31.4	222.3	0.049	5.8	25.5	-99.9	78.55	2.326	0.9856

Spurious:
All ORP
TDS A site

TKN, NH3 and P
all tested between
10-18 Jul. Appear OK.

All Beta values tested with
surfactant

	TKN				Ammonia NH3						Organic N			Phosphorus			
	UnFilt	Filt	Solids	% InSol	UnFilt	Filt	Solids	%	% NH3	Union.	UnFilt	Filt	Solids	UnFilt	Filt	Solids	% in
Site	mg/L	mg/L	mg/L		mg/L	mg/L	mg/L	Solids		NH3	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Solids
A	1.172	0.984	0.188	16%	1.957	1.672	0.285	15%	0.13%	0.0022	-0.438	-0.391	-0.047	1.427	1.351	0.08	5%
B	1.359	1.125	0.234	17%	1.862	1.729	0.133	7%	0.14%	0.0025	-0.172	-0.297	0.125	1.473	1.320	0.15	10%
C	1.781	0.656	1.125	63%	2.090	1.634	0.456	22%	0.14%	0.0023	0.062	-0.688	0.750	2.492	2.400	0.09	4%
D	0.891	0.563	0.328	37%	1.615	1.520	0.095	6%	0.12%	0.0018	-0.438	-0.688	0.250	2.548	2.472	0.08	3%
E	1.078	0.750	0.328	30%	1.710	1.425	0.285	17%	0.13%	0.0018	-0.328	-0.422	0.094	2.676	2.186	0.49	18%
SDeck	1.266	1.031	0.234	19%	1.558	1.178	0.38	24%	0.15%	0.0018	-0.016	0.062	-0.078	2.375	1.575	0.80	34%
Bio A	1.922	1.172	0.750	39%	1.615	1.311	0.304	19%	0.10%	0.0014	0.594	0.094	0.500	2.426	1.626	0.80	33%
Bio B	1.172	0.750	0.422	36%	0.779	0.665	0.114	15%	0.14%	0.0009	0.531	0.203	0.328	2.487	2.227	0.26	10%
GA	1.641	1.078	0.563	34%	1.881	1.539	0.342	18%	0.29%	0.0044	0.094	-0.188	0.281	2.482	2.390	0.09	4%
GB	1.688	1.266	0.422	25%	1.843	1.558	0.285	15%	0.24%	0.0038	0.172	-0.016	0.188	2.650	1.488	1.16	44%
MUWA	2.578	1.688	0.891	35%	1.919	1.691	0.228	12%	0.72%	0.0122	1.000	0.297	0.703	2.380	1.718	0.66	28%

MUWB	1.884	1.500	0.384	20%	0.760	0.684	0.076	10%	0.37%	0.0026	1.259	0.937	0.322	2.446	2.288	0.16	6%
I/J	6.469	1.641	4.828	75%	2.185	1.976	0.209	10%	0.49%	0.0097	4.672	0.016	4.656	2.594	1.876	0.72	28%
Over Flow	1.969	1.547	0.422	21%	1.710	1.444	0.266	16%	0.18%	0.0026	0.562	0.359	0.203	2.263	1.728	0.54	24%

pH, Alkalinity, Hardness
30 Apr 01

	pH			Alkalinity mg/L as CaCO3				Total Hardness mg/L as CaCO3			
Site	**Rdg**	**R**	**T °C**	**Rdg**	**R**	**Fact.**	**Result**	**Rdg**	**R**	**Fact.**	**Result**
A	6.92	1	8.2	69	2	0.4	27.4	81	2	0.4	32.2
B	6.96	1	8.2	69	2	0.4	27.4	82	2	0.4	32.6
C	6.95	1	8.2	73	2	0.4	29.0	80	2	0.4	31.8
D	6.88	1	8.3	73	2	0.4	29.2	83	2	0.4	33.0
E	6.91	1	8.2	72	2	0.4	28.6	82	2	0.4	32.6
SDeck	6.93	1	9.5	77	2	0.4	30.6	83	2	0.4	33.2
BFa	6.81	1	8.3	68	2	0.4	27.0	83	2	0.4	33.0
BFb	6.93	1	8.4	67	2	0.4	26.6	82	2	0.4	32.6
GA	7.26	1	8.1	69	2	0.4	27.4	82	2	0.4	32.6
GB	7.18	1	8.3	70	2	0.4	27.8	81	2	0.4	32.4
MUWA	7.71	1	6.7	85	2	0.4	34.0	74	2	0.4	29.4
MUWB	7.38	1	8.0	88	2	0.4	35.0	72	2	0.4	28.8
J	7.48	1	8.5	118	2	0.4	47.2	128	2	0.4	51.0
Overflow	7.08	1	7.3	79	2	0.4	31.4	80	2	0.4	31.8

Cartridge 0.1600 N H_2SO_4 0.0800 N EDTA

R = replications

Statistics, Culture Water Alkalinity

Mean	28.1
Standard Error	0.387872
Median	27.6
Mode	27.4
Standard Deviation	1.226558
Variance	1.504444
Kurtosis	0.337564
Skewness	0.906814
Range	4
Minimum	26.6
Maximum	30.6
Sum	281
Count	10
Confidence Level(0.950000)	0.760215

Statistics, Culture Water Hardness

Mean	32.6
Standard Error	0.129957
Median	32.6
Mode	32.6
Standard Deviation	0.410961
Variance	0.168889
Kurtosis	0.386427
Skewness	-0.48026
Range	1.4
Minimum	31.8
Maximum	33.2
Sum	326
Count	10
Confidence Level(0.950000)	0.254712

Nitrite & Nitrate

30 Apr 01 Using Tests 8507 & 8171

	At. Wt.		**N**	**O**	**Total**
N	14.0067	NO_2	1	2	46.0055
O	15.9994	NO_2-N	1	0	14.0067
		NO_3	1	3.00	62.0049
		NO_3-N	1	0	14.0067

NO_2 Reagent Factor	0	
NO_2 /NO2-N Factor	3.285	
NO_3 Reagent Factor	0	Factor not used after switch to Method 817
NO_3 /NO3-N Factor	4.427	

	NITRITE, mg/L				**NITRATE, mg/L**			
Site	**Rdg**	**R**	**NO2-N**	**NO2**	**Rdg**	**R**	**NO3-N**	**NO3**
A	0.021	2	0.021	0.069	1.8	2	1.8	8.0
B	0.0235	2	0.024	0.077	2.0	2	2.0	8.9
C	0.022	2	0.022	0.072	2.2	2	2.2	9.7
D	0.0255	2	0.026	0.084	1.8	2	1.8	7.7
E	0.0215	2	0.022	0.071	1.9	2	1.9	8.4
SDeck	0.016	2	0.016	0.053	2.15	2	2.2	9.5
BFa	0.0205	2	0.021	0.067	2.3	2	2.3	10.0
BFb	0.0225	2	0.023	0.074	2.0	2	2.0	8.6
GA	0.0235	2	0.024	0.077	2.1	2	2.1	9.1
GB	0.0205	2	0.021	0.067	2.3	3	2.3	10.0
MUWA	0.003	2	0.003	0.010	0.20	2	0.2	0.9
MUWB	0.006	2	0.006	0.020	0.20	0.2	0.2	0.9
J	0.034	4	0.034	0.112	0.6	4	0.6	2.7
OFlow	0.015	2	0.015	0.049	1.30	2	1.3	5.8

R - repetitions

0.0005' and '0.05' - averaging

TSS, TDS, ORP
Date: 30 Apr 01
Sampled 30 Apr; tests run 1 May

	TSS mg/L		ORP mV		TDS mg/L		Beta	R
Site	**Rdg**	**R**	**Rdg**	**R**	**Rdg**	**R**		
A	8.0	2	-77.7	2	604.0	2	2.240	0.9762
B	16.5	2	-107.7	2	85.1	2	2.392	0.9786
C	4.0	2	-98.9	2	85.4	2	2.396	0.9758
D	10.5	2	-106.9	2	85.8	2	2.505	0.9764
E	3.5	2	-106.7	2	85.2	2	2.396	0.9758
SDeck	27.0	2	-91.2	2	86.0	2	1.299	0.9675
BFa	20.0	2	-107.7	2	84.8	2	2.489	0.9691
BFb	17.0	2	-96.5	2	84.8	2	2.500	0.9730
Ga	18.5	2	-103.5	2	84.2	2	2.546	0.9757
Gb	18.7	3	-103.4	2	84.2	2	2.414	0.9673
MUWA1	4.0	2	-104.4	2	67.3	2	2.164	0.9966
MUWA2							2.454	0.9978
MUWB	26.5	2	-95.2	2	68.6	2		
I/J	12.0	2	-112.1	2	154.8	2	1.308	0.9896
Oflow	25.5	2	-99.9	2	78.55	2	2.326	0.9856

0.0 = averaging

Iodine test in range

TKN, Ammonia and Phosphorus Data and Calculations, 30 Apr 01

TKNCalculations

Factor	75	
Calc B	40	
Reagent Correction		0

		Unfiltered			Filtered			% in	
Site	C	Rdg	Rep	TKN	Rdg	Rep	TKN	Solids	Tested
A	20	12.5	2	1.172	10.5	2	0.984	16.0%	10 Jul
B	20	14.5	2	1.359	12	2	1.125	17.2%	10 Jul
C	20	19	2	1.781	7	2	0.656	63.2%	10 Jul
D	20	9.5	2	0.891	6	2	0.563	36.8%	10 Jul
E	20	11.5	2	1.078	8	2	0.750	30.4%	10 Jul
SDeck	20	13.5	2	1.266	11	2	1.031	18.5%	18 Jul
BFa	20	20.5	2	1.922	12.5	2	1.172	39.0%	17 Jul
BFb	20	12.5	2	1.172	8	2	0.750	36.0%	17 Jul
Ga	20	17.5	2	1.641	11.5	2	1.078	34.3%	17 Jul
Gb	20	18	2	1.688	13.5	2	1.266	25.0%	17 Jul
MUWA	20	27.5	2	2.578	18	2	1.688	34.5%	18 Jul
MUWB	20	20.1	2	1.884	16	2	1.500	20.4%	18 Jul
I/J	20	69	2	6.469	17.5	2	1.641	74.6%	17 Jul
OFlow	20	21	2	1.969	16.5	2	1.547	21.4%	18 Jul

Averages

UnFilt	Filt	Diff	%
A-B	A-B	(1/3 proportional)	
1.297	1.078	0.219	16.9%
BF	BF		
1.547	0.961	0.586	37.9%
G	G		
1.664	1.172	0.492	29.6%

Ammonia Calculations

Factor	2500	**Fe Formula**		0.04864	0.5515
Calc B	40	**Fe Rdg**	**Fe effect**		
		0.55	0.035 mg/L	(subtract from readings)	

TAN> NH3		At Wt	No	Tot			
	N	14.01	1	14.008	NH3-N x	1.216 =	NH3
	H	1.01	3	3.024			
				17.032			

		Unfiltered				Filtered				%
Site	C	Rdg	Rep	TAN	NH3	Rdg	Rep	TAN	NH3	in Solids
A	20	0.55	2	1.609	1.957	0.475	2	1.375	1.672	14.56%
B	20	0.525	2	1.531	1.862	0.49	2	1.422	1.729	7.14%
C	20	0.585	2	1.719	2.090	0.465	2	1.344	1.634	21.82%
D	20	0.46	2	1.328	1.615	0.435	2	1.250	1.520	5.88%
E	20	0.485	2	1.406	1.710	0.41	2	1.172	1.425	16.67%
SDeck	20	0.445	2	1.281	1.558	0.345	2	0.969	1.178	24.39%
BFa	20	0.46	2	1.328	1.615	0.38	2	1.078	1.311	18.82%
BFb	20	0.24	2	0.641	0.779	0.21	2	0.547	0.665	14.63%
Ga	20	0.53	2	1.547	1.881	0.44	2	1.266	1.539	18.18%
Gb	20	0.52	2	1.516	1.843	0.445	2	1.281	1.558	15.46%
MUWA	20	0.54	2	1.578	1.919	0.48	2	1.391	1.691	11.88%
MUWB	20	0.235	2	0.625	0.760	0.215	2	0.563	0.684	10.00%
I/J	20	0.61	2	1.797	2.185	0.555	2	1.625	1.976	9.56%
OFlow	20	0.485	2	1.406	1.710	0.415	2	1.188	1.444	15.55%

Averages

UnFilt	Filt	Diff	%
A-B	A-B	(1/3 proportional)	
1.894	1.710	0.184	9.7%
BF	BF		
1.197	0.988	0.209	17.5%
G	G		
1.862	1.548	0.313	16.8%

*Dilution estimate on unfiltered.

Phosphate Calculations mg/L

Factor	2500	
Calc B	40	
Reagent Correction		0.01

PO4>P		At Wt	No	Tot			
	P	30.98	1	30.98	PO4 x	0.326 =	P
	O	16.00	4	64			
				94.98			

		Unfiltered				Filtered				P	%
Site	C	Rdg	Rep	PO4	P	Rdg	Rep	PO4	P	in Solids	in Solids
A	20	1.41	2	4.375	1.427	1.335	2	4.141	1.351	0.08	5.36%
B	20	1.455	2	4.516	1.473	1.305	2	4.047	1.320	0.15	10.38%
C	20	2.455	2	7.641	2.492	2.365	2	7.359	2.400	0.09	3.68%
D	20	2.51	2	7.813	2.548	2.435	2	7.578	2.472	0.08	3.00%
E	20	2.635	2	8.203	2.676	2.155	2	6.703	2.186	0.49	18.29%
SDeck	20	2.34	2	7.281	2.375	1.555	2	4.828	1.575	0.80	33.69%
BFa	20	2.39	2	7.438	2.426	1.605	2	4.984	1.626	0.80	32.98%
BFb	20	2.45	2	7.625	2.487	2.195	2	6.828	2.227	0.26	10.45%
Ga	20	2.445	2	7.609	2.482	2.355	2	7.328	2.390	0.09	3.70%
Gb	20	2.61	2	8.125	2.650	1.47	2	4.563	1.488	1.16	43.85%
MUWA	20	2.345	2	7.297	2.380	1.695	2	5.266	1.718	0.66	27.84%
MUWB	20	2.41	2	7.500	2.446	2.255	2	7.016	2.288	0.16	6.46%
I/J	20	2.555	2	7.953	2.594	1.85	2	5.750	1.876	0.72	27.70%
OFlow	20	2.23	2	6.938	2.263	1.705	2	5.297	1.728	0.54	23.65%

Averages

UnFilt	Filt	Diff	%
A-B	A-B	(1/3 proportional)	
1.458	1.330	0.127	8.7%
BF	BF		
2.456	1.926	0.530	21.6%
G	G		
2.566	1.939	0.627	24.4%

Water Quality Data Summary

Date 14-May-01

NH3-N to NH3 1.2159

	pH	T	Alk	Hardn	NO2	NO3	TSS	ORP	TDS	Beta	R
Site		deg C	mg/L	mg/L	mg/L	mg/L	mg/L	mV	mg/L		
A	6.10	10.4	26.0	33.4	0.062	9.5	8.7	165.0	88.1	2.077	0.9802
B	6.24	10.3	25.8	32.6	0.067	9.3	2.3	158.3	87.8	2.123	0.9872
C	6.27	10.3	26.0	33.2	0.066	9.3	9.0	153.7	87.7	2.079	0.9829
D	6.43	10.2	26.2	32.0	0.071	9.3	15.5	152.7	87.4	2.163	0.9873
E	6.53	10.2	25.6	32.8	0.069	8.6	20.5	148.9	87.9	2.635	0.9855
SDeck	6.60	10.7	27.6	35.8	0.051	9.1	30.0	148.9	87.9	1.383	0.9730
Bio A	6.57	10.3	25.0	32.8	0.056	10.6	13.5	146.2	86.9	2.550	0.9844
Bio B	6.56	10.1	25.0	32.2	0.077	9.5	14.0	143.3	86.8	2.405	0.9897
G_A	6.81	10.1	25.2	32.6	0.061	9.5	3.5	139.3	86.8	2.194	0.9919
G_B	6.84	10.2	25.4	32.8	0.067	10.0	3.0	139.1	86.8	2.420	0.9897
MUW_{A1}	7.14	8.3	36.0	31.8	0.016	0.4	7.0	137.0	74.6	2.841	0.9939
MUW_{A2}	6.92	7.1	30.6	26.6	0.016	0.4	0.0	137.5	52.7	3.139	0.9898
MUW_B	7.05	8.5	35.8	30.6	0.011	0.4	20.5	136.6	70.4	2.797	0.9914
I/J	7.31	9.0	47.6	48.0	0.033	1.1	16.5	135.5	151.9	2.022	0.9947

	TKN				Ammonia NH3						Organic N			Phosphorus			
	UnFilt	Filt	Solids	% In	UnFilt	Filt	Solids	%	% UIA	UIA	UnFilt	Filt	Solids	UnFilt	Filt	Solids	% in
Site	mg/L	mg/L	mg/L	Solids	mg/L	mg/L	mg/L	Solids		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Solids
A	1.266	1.078	0.188	15%	1.900	1.596	0.304	16%	0.02%	0.0004	-0.297	-0.234	-0.063	1.412	1.310	0.10	7%
B	1.313	1.125	0.188	14%	1.786	1.653	0.133	7%	0.03%	0.0005	-0.156	-0.234	0.078	1.447	1.300	0.15	10%
C	1.688	0.609	1.078	64%	1.957	1.577	0.38	19%	0.03%	0.0005	0.078	-0.688	0.766	2.446	2.380	0.07	3%
D	0.984	0.609	0.375	38%	1.596	1.482	0.114	7%	0.05%	0.0007	-0.328	-0.609	0.281	2.533	2.451	0.08	3%
E	0.984	0.703	0.281	29%	1.501	1.406	0.095	6%	0.06%	0.0009	-0.250	-0.453	0.203	2.533	2.156	0.38	15%
SDeck	1.266	0.984	0.281	22%	1.577	1.254	0.323	20%	0.08%	0.0010	-0.031	-0.047	0.016	2.400	1.595	0.81	34%
BFa	1.734	1.031	0.703	41%	0.760	0.684	0.076	10%	0.07%	0.0005	1.109	0.469	0.641	2.523	2.406	0.12	5%
BFb	0.984	0.609	0.375	38%	0.684	0.570	0.114	17%	0.07%	0.0004	0.422	0.141	0.281	2.431	2.344	0.09	4%
Ga	1.547	0.984	0.563	36%	1.786	1.482	0.304	17%	0.12%	0.0018	0.078	-0.234	0.312	2.513	1.514	1.00	40%
Gb	1.547	1.125	0.422	27%	1.729	1.444	0.285	16%	0.13%	0.0019	0.125	-0.063	0.187	2.614	1.442	1.17	45%
MUW_{A1}	6.047	1.828	4.219	70%	1.938	1.748	0.19	10%	0.22%	0.0039	4.453	0.391	4.062	2.380	1.738	0.64	27%
MUW_{A2}	2.391	1.453	0.938	39%	2.375	2.261	0.114	5%	0.12%	0.0027	0.437	-0.406	0.844	2.553	2.462	0.09	4%
MUW_B	1.734	1.359	0.375	22%	0.817	0.760	0.057	7%	0.18%	0.0014	1.062	0.734	0.328	2.436	2.309	0.13	5%
I/J	6.281	1.547	4.734	75%	9.100	1.957	7.143	78%	0.34%	0.0068	-1.203	-0.063	-1.141	5.627	4.923	0.70	13%

pH, Alkalinity, Hardness
14 May 01

	pH			Alkalinity mg/L as CaCO3				Total Hardness mg/L as CaCO3			
Site	**Rdg**	**R**	**T °C**	**Rdg**	**R**	**Fact.**	**Result**	**Rdg**	**R**	**Fact.**	**Result**
A	6.10	2	10.4	65	2	0.4	26.0	84	2	0.4	33.4
B	6.24	2	10.3	65	2	0.4	25.8	82	2	0.4	32.6
C	6.27	2	10.3	65	2	0.4	26.0	83	2	0.4	33.2
D	6.43	2	10.2	66	2	0.4	26.2	80	2	0.4	32.0
E	6.53	2	10.2	64	2	0.4	25.6	82	2	0.4	32.8
SDeck	6.60	2	10.7	69	2	0.4	27.6	90	2	0.4	35.8 *
BFa	6.57	2	10.3	63	2	0.4	25.0	82	2	0.4	32.8
BFb	6.56	2	10.1	63	2	0.4	25.0	81	2	0.4	32.2
G_A	6.81	2	10.1	63	2	0.4	25.2	82	2	0.4	32.6
G_B	6.84	2	10.2	64	2	0.4	25.4	82	2	0.4	32.8
MUW_A	7.14	2	8.3	90	2	0.4	36.0	80	2	0.4	31.8
MUW_{A1}	6.92	2	7.1	77	2	0.4	30.6	67	2	0.4	26.6
MUW_B	7.05	2	8.5	90	2	0.4	35.8	77	2	0.4	30.6
J	7.31	2	9.0	119	2	0.4	47.6	120	2	0.4	48.0

Cartridge 0.1600 N H_2SO_4 0.0800 N EDTA

R = replications

Statistics, Culture Water Alkalinity

Mean	25.78
Standard Error	0.243036
Median	25.7
Mode	25
Standard Deviation	0.768548
Variance	0.590667
Kurtosis	3.094487
Skewness	1.504992
Range	2.6
Minimum	25
Maximum	27.6
Sum	257.8
Count	10
Confidence Level(0.950000)	0.476342

Statistics, Culture Water Hardness

Mean	33.02
Standard Error	0.335261
Median	32.8
Mode	32.8
Standard Deviation	1.060189
Variance	1.124
Kurtosis	6.259878
Skewness	2.302238
Range	3.8
Minimum	32
Maximum	35.8
Sum	330.2
Count	10
Confidence Level(0.950000)	0.6571

Nitrite & Nitrate

14 May 01 Using Tests 8507 & 8171

	At. Wt.		N	O	Total
N	14.0067	NO2	1	2	46.0055
O	15.9994	NO2-N	1	0	14.0067
		NO3	1	3.00	62.0049
		NO3-N	1	0	14.0067

NO_2 Reagent Factor	0	
NO_2 /NO2-N Factor	3.285	
NO_3 Reagent Factor	0	Factor not used after switch to Method 817
NO_3 /NO3-N Factor	4.427	

	NITRITE, mg/L				NITRATE, mg/L			
Site	**Rdg**	**R**	**NO2-N**	**NO2**	**Rdg**	**R**	**NO3-N**	**NO3**
A	0.019	2	0.019	0.062	2.2	2	2.2	9.5
B	0.0205	2	0.021	0.067	2.1	2	2.1	9.3
C	0.02	2	0.020	0.066	2.1	2	2.1	9.3
D	0.0215	2	0.022	0.071	2.1	2	2.1	9.3
E	0.021	2	0.021	0.069	2.0	2	2.0	8.6
SDeck	0.0155	2	0.016	0.051	2.05	2	2.1	9.1
BFa	0.017	2	0.017	0.056	2.4	2	2.4	10.6
BFb	0.0235	2	0.024	0.077	2.2	2	2.2	9.5
GA	0.0185	2	0.019	0.061	2.2	2	2.2	9.5
GB	0.0205	2	0.021	0.067	2.3	3	2.3	10.0
MUWA	0.005	2	0.005	0.016	0.10	2	0.1	0.4
MUWA1	0.005	2	0.005	0.016	0.10	0.2	0.1	0.4
MUWB	0.0035	2	0.004	0.011	0.10	0.2	0.1	0.4
J	0.01	4	0.010	0.033	0.3	4	0.3	1.1
OFlow								

R - repetitions

0.0005' and '0.05' - averaging

TSS, TDS, ORP
Sampling date: 14May 01
Tests run 15 May

	TSS mg/L		ORP mV		TDS mg/L		Beta	R	
Site	**Rdg**	**Rep**	**Rdg**	**Rep**	**Rdg**	**Rep**			
A	8.7	3	165.0	2	88.1	2	2.077	0.9802	Less FDD'
B	2.3	3	158.3	2	87.8	2	2.123	0.9872	
C	9.0	2	153.7	2	87.7	2	2.079	0.9829	
D	15.5	2	152.7	2	87.4	2	2.163	0.9873	
E	20.5	2	148.9	2	87.9	2	2.635	0.9855	
SDeck	30.0	3	148.9	2	87.9	2	1.383	0.9730	
BFa	13.5	2	146.2	2	86.9	2	2.550	0.9844	
BFb	14.0	2	143.3	2	86.8	2	2.405	0.9897	
Ga	3.5	2	139.3	2	86.8	2	2.194	0.9919	
Gb	3.0	2	139.1	2	86.8	2	2.420	0.9897	
MUW$_{A}$	7.0	3	137.0	2	74.6	2	2.841	0.9939	
MUW$_{A1}$	0.0	3	137.5		52.7	2	3.139	0.9898	
MUW$_{B}$	20.5	3	136.6	2	70.4	2	2.797	0.9914	
I/J	16.5	2	135.5	2	151.9	2	2.022	0.9947	

0.0 = averaging

R = replicate

TKN, Ammonia and Phosphorus Data and Calculations, 14 May 01

Results in mg/L

TKNCalculations

Factor	75
Calc B	40
Reagent Correction	0

		Unfiltered			Filtered			% in
Site	**C**	**Rdg**	**Rep**	**TKN**	**Rdg**	**Rep**	**TKN**	**Solids**
A	20	13.5	2	1.266	11.5	2	1.078	14.8%
B	20	14	2	1.313	12	2	1.125	14.3%
C	20	18	2	1.688	6.5	2	0.609	63.9%
D	20	10.5	2	0.984	6.5	2	0.609	38.1%
E	20	10.5	2	0.984	7.5	2	0.703	28.6%
SDeck	20	13.5	2	1.266	10.5	2	0.984	22.2%
BFa	20	18.5	2	1.734	11	2	1.031	40.5%
BFb	20	10.5	2	0.984	6.5	2	0.609	38.1%
Ga	20	16.5	2	1.547	10.5	2	0.984	36.4%
Gb	20	16.5	2	1.547	12	2	1.125	27.3%
MUWA1	20	64.5	2	6.047	19.5	2	1.828	69.8%
MUWA2	20	25.5	2	2.391	15.5	2	1.453	39.2%
MUWB	20	18.5	2	1.734	14.5	2	1.359	21.6%
I/J	20	67	2	6.281	16.5	2	1.547	75.4%

Averages

UnFilt	**Filt**	**Diff**	**%**
A-B	**A-B**	(1/3 proportional)	
1.297	1.109	0.188	14.5%
BF	**BF**		
1.359	0.820	0.539	39.7%
G	**G**		
1.547	1.055	0.492	31.8%

Ammonia Calculations

Factor	2500	**Fe Formula**		0.04864	0.5515
Calc B	40	**Fe Rdg**	**Fe effect**		
		0.55	0.035 mg/L		(subtract from readings)

TAN> NH3	At Wt	No	Tot			
N	14.01	1	14.008	NH3-N x	1.216 =	NH3
H	1.01	3	3.024			
			17.032			

		Unfiltered				Filtered				%	
Site	**C**	**Rdg**	**Rep**	**TAN**	**NH3**	**Rdg**	**Rep**	**TAN**	**NH3**	**in Solids**	
A	20	0.535	2	1.563	1.900	0.455	2	1.313	1.596	16.00%	
B	20	0.505	2	1.469	1.786	0.47	2	1.359	1.653	7.45%	
C	20	0.55	2	1.609	1.957	0.45	2	1.297	1.577	19.42%	
D	20	0.455	2	1.313	1.596	0.425	2	1.219	1.482	7.14%	
E	20	0.43	2	1.234	1.501	0.405	2	1.156	1.406	6.33%	
SDeck	20	0.45	2	1.297	1.577	0.365	2	1.031	1.254	20.48%	*
BFa	20	0.235	2	0.625	0.760	0.215	2	0.563	0.684	10.00%	
BFb	20	0.215	2	0.563	0.684	0.185	2	0.469	0.570	16.66%	
Ga	20	0.505	2	1.469	1.786	0.425	2	1.219	1.482	17.02%	
Gb	20	0.49	2	1.422	1.729	0.415	2	1.188	1.444	16.48%	
MUWA	20	0.545	2	1.594	1.938	0.495	2	1.438	1.748	9.80%	
MUWA1	20	0.66	2	1.953	2.375	0.63	2	1.859	2.261	4.80%	**
MUWB	20	0.25	2	0.672	0.817	0.235	2	0.625	0.760	6.98%	
I/J	20	2.43	2	7.484	9.100	0.55	2	1.609	1.957	78.50%	**

Averages

UnFilt	**Filt**	**Diff**	**%**
A-B	**A-B**	(1/3 proportional)	
1.824	1.634	0.190	10.4%
BF	**BF**		
0.722	0.627	0.095	13.2%
G	**G**		
1.757	1.463	0.294	16.8%

*Note: near bottom water

**Dilution estimate on unfiltered.

Phosphate Calculations mg/L

Factor	2500
Calc B	40
Reagent Correction	0.01

PO4>P	At Wt	No	Tot			
P	30.98	1	30.98	PO4 x	0.326 =	P
O	16.00	4	64			
			94.98			

		Unfiltered				Filtered				P	%
Site	**C**	**Rdg**	**Rep**	**PO4**	**P**	**Rdg**	**Rep**	**PO4**	**P**	**in Solids**	**in Solids**
A	20	1.395	2	4.328	1.412	1.295	2	4.016	1.310	0.10	7.22%
B	20	1.43	2	4.438	1.447	1.285	2	3.984	1.300	0.15	10.21%
C	20	2.41	2	7.500	2.446	2.345	2	7.297	2.380	0.07	2.71%
D	20	2.495	2	7.766	2.533	2.415	2	7.516	2.451	0.08	3.22%
E	20	2.495	2	7.766	2.533	2.125	2	6.609	2.156	0.38	14.89%
SDeck	20	2.365	2	7.359	2.400	1.575	2	4.891	1.595	0.81	33.55%
BFa	20	2.485	1	7.734	2.523	2.37	1	7.375	2.406	0.12	4.65%
BFb	20	2.395	2	7.453	2.431	2.31	2	7.188	2.344	0.09	3.56%
Ga	20	2.475	2	7.703	2.513	1.495	2	4.641	1.514	1.00	39.76%
Gb	20	2.575	2	8.016	2.614	1.425	2	4.422	1.442	1.17	44.83%
MUWA	20	2.345	2	7.297	2.380	1.715	2	5.328	1.738	0.64	26.98%
MUWA1	20	2.515	2	7.828	2.553	2.425	2	7.547	2.462	0.09	3.59%
MUWB	20	2.4	2	7.469	2.436	2.275	2	7.078	2.309	0.13	5.23%
I/J	10	2.77	2	17.250	5.627	2.425	2	15.094	4.923	0.70	12.50%

Averages

UnFilt	**Filt**	**Diff**	**%**
A-B	**A-B**	(1/3 proportional)	
1.436	1.303	0.133	9.2%
BF	**BF**		
2.477	2.375	0.102	4.1%
G	**G**		
2.564	1.478	1.086	42.3%

Water Quality Data Summary

Date 21-May-01

NH3-N to NH3 1.21588

	pH	T	Alk	Hardn	NO2	NO3
Site		deg C	mg/L	mg/L	mg/L	mg/L
A	6.74	11.3	22.2	32.6	0.164	10.6
B	6.71	10.5	23.4	33.2	0.117	10.0
C	6.84	10.5	17.8	31.8	0.112	10.0
D	6.75	10.4	21.4	31.8	0.112	10.0
E	6.75	10.5	22.6	32.0	0.105	11.3
SDeck	6.75	10.7	22.8	33.0	0.103	10.8
Bio A	6.75	10.5	22.2	32.6	0.094	11.7
Bio B	6.62	10.6	22.6	31.8	0.103	13.1
G_A	7.03	10.8	22.6	32.2	0.103	10.2
G_B	7.06	10.7	21.8	32.2	0.095	11.7
MUW_{A1}	7.09	9.1	35.2	29.0	0.030	0.4
MUW_{A2}	7.03	8.3	32.0	26.6	0.038	0.7
MUW_B	7.08	13.6	35.8	31.0	0.039	0.4
I/J	7.14	10.7	45.6	50.0	0.105	3.5
Over Flow	6.83	10.1	28.0	30.8	0.074	4.4

TSS	ORP	TDS
mg/L	mV	mg/L
1.0	332.1	84.8
24.5	324.9	84.5
14.5	321.8	84.6
33.0	312.9	84.0
2.7	305.4	84.5
0.0	282.2	84.3
23.5	282.1	83.5
19.5	274.0	84.5
0.0	265.3	83.6
1.0	264.4	83.7
25.0	283.4	68.9
25.5	279.9	54.5
0.5	285.0	73.7
23.5	287.7	156.9
26.7	279.5	63.9

Beta	R
2.048	0.9806
2.263	0.9812

	TKN				Ammonia NH3						Organic N			Phosphorus			
	UnFilt	Filt	Solids	% in	UnFilt	Filt	Solids	%	%	UIA	UnFilt	Filt	Solids	UnFilt	Filt	Solids	% in
Site	mg/L	mg/L	mg/L	Solids	mg/L	mg/L	mg/L	Solids	UIA	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	Solids
A	1.17	0.94	0.234	20%	1.843	1.558	0.285	15%	0.11%	0.0017	-0.344	-0.344	-0.000	1.422	1.289	0.13	9%
B	0.94	0.70	0.234	25%	1.748	1.634	0.114	7%	0.10%	0.0016	-0.500	-0.641	0.141	1.447	1.310	0.14	10%
C	1.08	0.75	0.328	30%	1.900	1.501	0.399	21%	0.13%	0.0020	-0.484	-0.484	-0.000	2.456	2.365	0.09	4%
D	0.94	0.61	0.328	35%	1.615	1.444	0.171	11%	0.11%	0.0015	-0.391	-0.578	0.187	2.528	2.441	0.09	3%
E	0.80	0.61	0.188	24%	1.463	1.349	0.114	8%	0.11%	0.0014	-0.406	-0.500	0.094	2.441	2.125	0.32	13%
SDeck	1.17	0.89	0.281	24%	1.596	1.292	0.304	19%	0.11%	0.0014	-0.141	-0.172	0.031	2.691	1.524	1.17	43%
BFa	1.50	0.94	0.563	38%	0.703	0.608	0.095	14%	0.11%	0.0007	0.922	0.437	0.484	2.518	2.385	0.13	5%
BFb	0.94	0.66	0.281	30%	0.608	0.494	0.114	19%	0.08%	0.0004	0.437	0.250	0.187	2.406	2.309	0.10	4%
Ga	1.64	0.98	0.656	40%	1.729	1.406	0.323	19%	0.21%	0.0029	0.219	-0.172	0.391	2.477	1.488	0.99	40%
Gb	1.45	1.08	0.375	26%	1.634	1.368	0.266	16%	0.22%	0.0030	0.109	-0.047	0.156	2.589	1.417	1.17	45%
MUW_{A1}	6.09	1.45	4.641	76%	1.900	1.653	0.247	13%	0.21%	0.0035	4.531	0.094	4.438	2.324	1.712	0.61	26%
MUW_{A2}	2.25	1.36	0.891	40%	2.166	2.109	0.057	3%	0.17%	0.0036	0.469	-0.375	0.844	2.497	2.477	0.02	1%
MUW_B	1.73	1.45	0.281	16%	0.760	0.665	0.095	12%	0.29%	0.0019	1.109	0.906	0.203	2.446	2.288	0.16	6%
I/J	6.14	1.45	4.688	76%	10.620	1.862	8.7581	82%	0.27%	0.0050	-2.594	-0.078	-2.516	NG	NG		
Over Flow	1.69	0.98	0.703	42%	1.748	1.520	0.228	13%	0.12%	0.0019	0.250	-0.266	0.516	-0.781	1.692	-2.47	317%

pH, Alkalinity, Hardness
21 May 01

				Alkalinity				Total Hardness			
	pH			mg/L as CaCO3				mg/L as CaCO3			
Site	Rdg	R	T °C	Rdg	R	Fact.	Result	Rdg	R	Fact.	Result
A	6.74	2	11.3	56	2	0.4	22.2	82	2	0.4	32.6
B	6.71	3	10.5	59	2	0.4	23.4	83	2	0.4	33.2
C	6.84	2	10.5	45	2	0.4	17.8	80	2	0.4	31.8
D	6.75	2	10.4	54	2	0.4	21.4	80	2	0.4	31.8
E	6.75	2	10.5	57	2	0.4	22.6	80	2	0.4	32.0
SDeck	6.75	2	10.7	57	2	0.4	22.8	83	2	0.4	33.0
BFa	6.75	2	10.5	56	2	0.4	22.2	82	2	0.4	32.6
BFb	6.62	2	10.6	57	2	0.4	22.6	80	2	0.4	31.8
G_A	7.03	2	10.8	57	2	0.4	22.6	81	2	0.4	32.2
G_B	7.06	2	10.7	55	2	0.4	21.8	81	2	0.4	32.2
MUW_A	7.09	1	9.1	88	2	0.4	35.2	73	2	0.4	29.0
MUW_{A1}	7.03	2	8.3	80	2	0.4	32.0	67	2	0.4	26.6
MUW_B	7.08	2	13.6	90	2	0.4	35.8	78	2	0.4	31.0
J	7.14	2	10.7	114	2	0.4	45.6	125	2	0.4	50.0
OFlow	6.83	2	10.1	70	2	0.4	28.0	77	2	0.4	30.8

Cartridge 0.1600 N H_2SO_4 0.0800 N EDTA

R = replications

Statistics, Culture Water Alkalinity

Mean	21.94
Standard Error	0.491754
Median	22.4
Mode	22.6
Standard Deviation	1.555063
Variance	2.418222
Kurtosis	6.839539
Skewness	-2.45507
Range	5.6
Minimum	17.8
Maximum	23.4
Sum	219.4
Count	10
Confidence Level(0.950000)	0.963821

Statistics, Culture Water Hardness

Mean	32.32
Standard Error	0.161107
Median	32.2
Mode	31.8
Standard Deviation	0.509466
Variance	0.259556
Kurtosis	-0.91802
Skewness	0.611035
Range	1.4
Minimum	31.8
Maximum	33.2
Sum	323.2
Count	10
Confidence Level(0.950000)	0.315764

Nitrite & Nitrate

21 May 01 Using Tests 8507 & 8171

	At. Wt.		N	O	Total
N	14.0067	NO2	1	2	46.0055
O	15.9994	NO2-N	1	0	14.0067
		NO3	1	3.00	62.0049
		NO3-N	1	0	14.0067

NO_2 Reagent Factor	0	
NO_2 /NO2-N Factor	3.285	
NO_3 Reagent Factor	0	Factor not used after switch to Method 817
NO_3 /NO3-N Factor	4.427	

	NITRITE, mg/L				NITRATE, mg/L			
Site	Rdg	R	NO2-N	NO2	Rdg	R	NO3-N	NO3
A	0.05	4	0.050	0.164	2.4	2	2.4	10.6
B	0.0355	2	0.036	0.117	2.3	2	2.3	10.0
C	0.034	2	0.034	0.112	2.3	2	2.3	10.0
D	0.034	2	0.034	0.112	2.3	2	2.3	10.0
E	0.032	2	0.032	0.105	2.6	2	2.6	11.3
SDeck	0.0315	2	0.032	0.103	2.45	2	2.5	10.8
BFa	0.0285	2	0.029	0.094	2.7	2	2.7	11.7
BFb	0.0315	2	0.032	0.103	3.0	2	3.0	13.1
G_A	0.0315	2	0.032	0.103	2.3	2	2.3	10.2
G_B	0.029	2	0.029	0.095	2.7	3	2.7	11.7
MUW_A	0.009	2	0.009	0.030	0.10	2	0.1	0.4
MUW_{A1}	0.0115	2	0.012	0.038	0.15	0.2	0.2	0.7
MUW_B	0.012	2	0.012	0.039	0.10	0.2	0.1	0.4
J	0.032	4	0.032	0.105	0.8	4	0.8	3.5
OFlow	0.0225	2	0.023	0.074	1.95	2	1.0	4.4

R - repetitions

0.0005' and '0.05' - averaging

TSS, TDS, ORP
Sampling date: 21May 01
TSS tested: 22 May Remainder on site.

	TSS mg/L		ORP mV		TDS mg/L		Beta	R
Site	**Rdg**	**Rep**	**Rdg**	**Rep**	**Rdg**	**Rep**		
A	1.0	3	332.1	2	84.8	2	2.048	0.9806
B	24.5	2	324.9	2	84.5	2	2.263	0.9812
C	14.5	2	321.8	2	84.6	2		
D	33.0	2	312.9	3	84.0	2		
E	2.7	3	305.4	2	84.5	2		
SDeck	0.0	3	282.2	2	84.3	2		
BFa	23.5	2	282.1	2	83.5	2		
BFb	19.5	2	274.0	2	84.5	2		
Ga	0.0	3	265.3	2	83.6	2		
Gb	1.0	3	264.4	2	83.7	2		
MUWA	25.0	2	283.4	2	68.9	2		
MUWA1	25.5	3	279.9	2	54.5	2		
MUWB	0.5	4	285.0	2	73.7	2		
I/J	23.5	2	287.7	2	156.9	2		
Oflow	26.7	2	279.5	2	63.9	2		

0.0 = averaging

TKN, Ammonia and Phosphorus Data and Calculations, 21 May 01

Results in mg/L

TKNCalculations

Factor	75
Calc B	40
Reagent Correction	0

		Unfiltered			Filtered			% in
Site	C	Rdg	Rep	TKN	Rdg	Rep	TKN	Solids
A	20	12.5	2	1.17	10	2	0.94	20.0%
B	20	10	2	0.94	7.5	2	0.70	25.0%
C	20	11.5	2	1.08	8	2	0.75	30.4%
D	20	10	2	0.94	6.5	2	0.61	35.0%
E	20	8.5	2	0.80	6.5	2	0.61	23.5%
SDeck	20	12.5	2	1.17	9.5	2	0.89	24.0%
BFa	20	16	2	1.50	10	2	0.94	37.5%
BFb	20	10	2	0.94	7	2	0.66	30.0%
Ga	20	17.5	2	1.64	10.5	2	0.98	40.0%
Gb	20	15.5	2	1.45	11.5	2	1.08	25.8%
MUWA1	20	65	2	6.09	15.5	2	1.45	76.2%
MUWA2	20	24	2	2.25	14.5	2	1.36	39.6%
MUWB	20	18.5	2	1.73	15.5	2	1.45	16.2%
I/J	20	65.5	2	6.14	15.5	2	1.45	76.3%
OFlow	20	18	2	1.69	10.5	2	0.98	41.7%

Averages

UnFilt	Filt	Diff	%
A-B	**A-B**	(1/3 proportional)	
1.016	0.781	0.234	23.1%
BF	**BF**		
1.219	0.797	0.422	34.6%
G	**G**		
1.547	1.031	0.516	33.3%

Ammonia Calculations

Factor	2500	**Fe Formula**		0.04864	0.5515
Calc B	40	**Fe Rdg**	**Fe effect**		
		0.55	0.035 mg/L	(subtract from readings)	

TAN> NH3	At Wt	No	Tot				
N	14.01	1	14.008	NH3-N x	1.216 =	NH3
H	1.01	3	3.024			
			17.032			

		Unfiltered				Filtered				%	
Site	C	Rdg	Rep	TAN	NH3	Rdg	Rep	TAN	NH3	in Solids	
A	20	0.520	2	1.516	1.843	0.445	2	1.281	1.558	15.46%	
B	20	0.495	2	1.438	1.748	0.465	2	1.344	1.634	6.52%	
C	20	0.535	2	1.563	1.900	0.43	2	1.234	1.501	21.00%	
D	20	0.460	2	1.328	1.615	0.415	2	1.188	1.444	10.59%	
E	20	0.420	2	1.203	1.463	0.39	2	1.109	1.349	7.79%	
SDeck	20	0.455	2	1.313	1.596	0.375	2	1.063	1.292	19.05%	**
BFa	20	0.220	2	0.578	0.703	0.195	2	0.500	0.608	13.51%	
BFb	20	0.195	2	0.500	0.608	0.165	2	0.406	0.494	18.75%	
Ga	20	0.490	2	1.422	1.729	0.405	2	1.156	1.406	18.68%	
Gb	20	0.465	2	1.344	1.634	0.395	2	1.125	1.368	16.28%	
MUWA	20	0.535	2	1.563	1.900	0.47	2	1.359	1.653	13.00%	
MUWA1	20	0.605	2	1.781	2.166	0.59	2	1.734	2.109	2.63%	*
MUWB	20	0.235	2	0.625	0.760	0.21	2	0.547	0.665	12.50%	
I/J	20	2.830	2	8.734	10.620	0.525	2	1.531	1.862	82.47%	*
OFlow	20	0.495	2	1.438	1.748	0.435	2	1.250	1.520	13.04%	

Averages

UnFilt	Filt	Diff	%
A-B	**A-B**	(1/3 proportional)	
1.780	1.609	0.171	9.6%
BF	**BF**		
0.656	0.551	0.104	15.9%
G	**G**		
1.681	1.387	0.294	17.5%

**Note: near bottom water

*Dilution estimate on unfiltered.

Phosphate Calculations mg/L

Factor	2500
Calc B	40
Reagent Correction	0.01

PO4>P	At Wt	No	Tot			
P	30.98	1	30.98	PO4 x	0.326 =	P
O	16.00	4	64			
			94.98			

		Unfiltered				Filtered				P	%
Site	C	Rdg	Rep	PO4	P	Rdg	Rep	PO4	P	in Solids	in Solids
A	20	1.405	2	4.359	1.422	1.275	2	3.953	1.289	0.13	9.32%
B	20	1.43	2	4.438	1.447	1.295	2	4.016	1.310	0.14	9.51%
C	20	2.42	2	7.531	2.456	2.33	2	7.250	2.365	0.09	3.73%
D	20	2.49	2	7.750	2.528	2.405	2	7.484	2.441	0.09	3.43%
E	20	2.405	2	7.484	2.441	2.095	2	6.516	2.125	0.32	12.94%
SDeck	20	2.65	2	8.250	2.691	1.505	2	4.672	1.524	1.17	43.37%
BFa	20	2.48	1	7.719	2.518	2.35	1	7.313	2.385	0.13	5.26%
BFb	20	2.37	2	7.375	2.406	2.275	2	7.078	2.309	0.10	4.03%
Ga	20	2.44	2	7.594	2.477	1.47	2	4.563	1.488	0.99	39.92%
Gb	20	2.55	2	7.938	2.589	1.4	2	4.344	1.417	1.17	45.28%
MUWA	20	2.29	2	7.125	2.324	1.69	2	5.250	1.712	0.61	26.32%
MUWA1	20	2.46	1	7.656	2.497	2.44	1	7.594	2.477	0.02	0.82%
MUWB	20	2.41	2	7.500	2.446	2.255	2	7.016	2.288	0.16	6.46%
I/J	10	NG	2	-0.063	-0.020	NG	2	-0.063	-0.020	0.00	0.00%
OFlow	20	2.25	2	7.000	2.283	1.67	2	5.188	1.692	0.59	25.89%

Averages

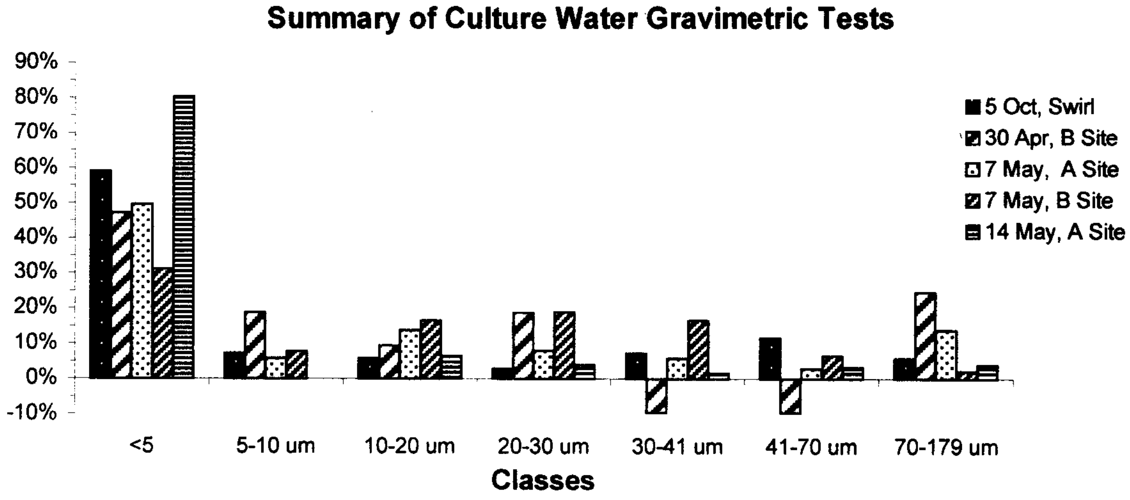
UnFilt	Filt	Diff	%
A-B	**A-B**	(1/3 proportional)	
1.439	1.303	0.136	9.4%
BF	**BF**		
2.462	2.347	0.115	4.7%
G	**G**		
2.533	1.452	1.080	42.7%

APPENDIX F

GRAVIMETRIC TESTS DATA AND RESULTS

Summary of Gravimetric Tests on Water Samples

Class	5 Oct, Swirl	30 Apr, B Site	7 May, A Site	7 May, B Site	14 May, A Site
<5	59.06%	47.17%	49.64%	31.11%	80.33%
5-10 um	7.31%	18.87%	5.84%	7.78%	0.00%
10-20 um	5.85%	9.43%	13.87%	16.67%	6.56%
20-30 um	2.92%	18.87%	8.03%	18.89%	4.10%
30-41 um	7.31%	-9.43%	5.84%	16.67%	1.64%
41-70 um	11.70%	-9.43%	2.92%	6.67%	3.28%
70-179 um	5.85%	24.53%	13.87%	2.22%	4.10%



Gravimetric Test of a Swirl Separator Sample 5 Oct 00

Size	Mark	Initial Wt	Final Wt		Vol	Conc
µm		mg	mg	Net	L	mg/L
70	i	8.2	8.4	0.1	2	0.1
41	ii	11.7	12.1	0.25	2	0.2
30	iii	18.1	18.35	0.6	2	0.125
20	iv	21.2	21.3	0.7	2	0.05
10	v	17.7	17.9	0.6	2	0.1
5	vi	28.7	28.95	0.3	2	0.125
0.8	vii	22.3	22.75	0	0.445	1.01
0.45	s11	127.4	127.9	0.5	1.79	0.28

Filters

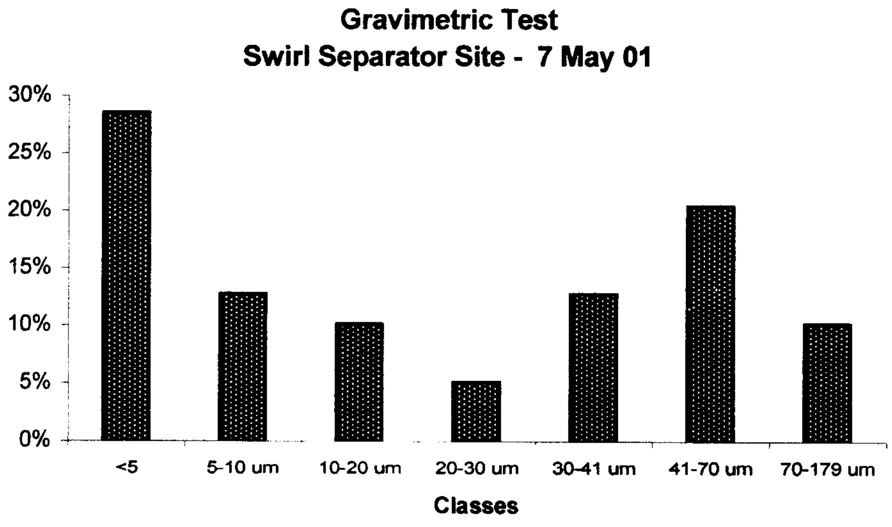
Pre-strained on a 179 um screen
5 - 70 um; 25-mm Spectra nylon mesh
0.8 um: 25-mm MFS membrane filters
0.45 um: 47-mm Durapore membrane filters, Type HVLP

Notes:

Note:
This was a system flushing of the biofilters.
No fish present.

Plot data

<5	0.28	28.57%
5-10 um	0.125	12.76%
10-20 um	0.1	10.20%
20-30 um	0.05	5.10%
30-41 um	0.125	12.76%
41-70 um	0.2	20.41%
70-179 um	0.1	10.20%
	0.98	100.00%



Gravimetric Test
Swirl Separator Site - 7 May 01

Gravimetric test of a B site sample - 30 Apr 01

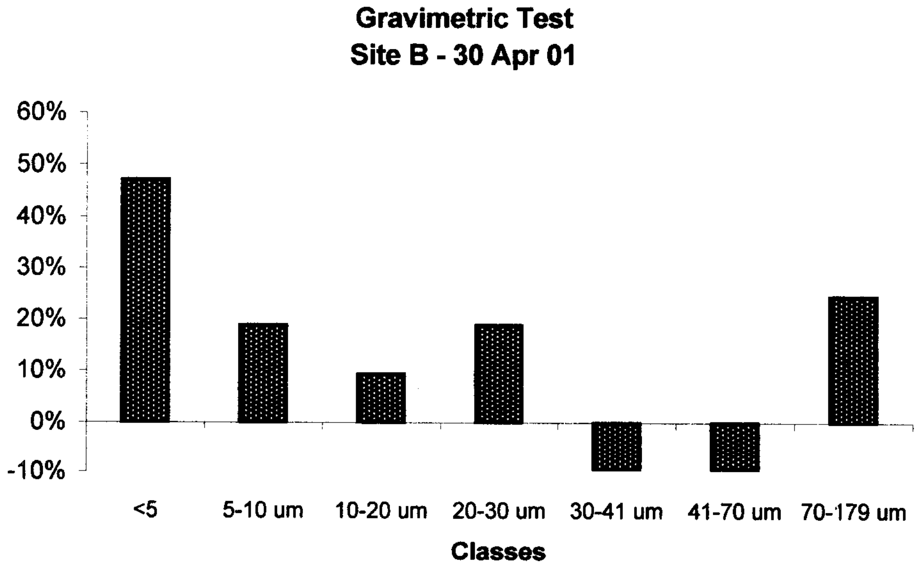
Size	Mark	Initial Weight, mg			Final Weight, mg				Vol	Conc
µm	Red*	1	2	Avg	1	2	Avg	Net	L	mg/L
70	Rd i	8.3	8	8.15	8.4	8.4	8.4	0.25	1.945	0.13
41	Rd ii	12.2	12.2	12.2	12.1	12.2	12.15	-0.1	1.945	-0.05
30	Rd iii	18.4	18.5	18.45	18.3	18.3	18.3	-0.1	1.945	-0.05
20	Rd iv	21.2	21.4	21.3	21.4	21.2	21.3	0.2	1.945	0.1
10	Rd v	17.4	17.4	17.4	17.5	17.5	17.5	0.1	1.945	0.05
5	Rd vi	29.5	29.4	29.45	29.7	29.5	29.6	0.2	1.945	0.1
0.8	Rd *	22.6	22.4	22.5	22.7	22.7	22.7	0.1	0.394	0.25
										0.54

Filters
Pre-strained on a 179 um screen
5 - 70 um; 25-mm Spectra nylon mesh
0.8 um: 25-mm MFS membrane filters

Notes;
0.8 um filter reduced flow after a few minutes then clogged

Plot Data

<5	0.25	47.17%
5-10 um	0.1	18.87%
10-20 um	0.05	9.43%
20-30 um	0.1	18.87%
30-41 um	-0.05	-9.43%
41-70 um	-0.05	-9.43%
70-179 u	0.13	24.53%
	0.53	100.00%



Gravimetric Test of Site A Sample 7 May 01.

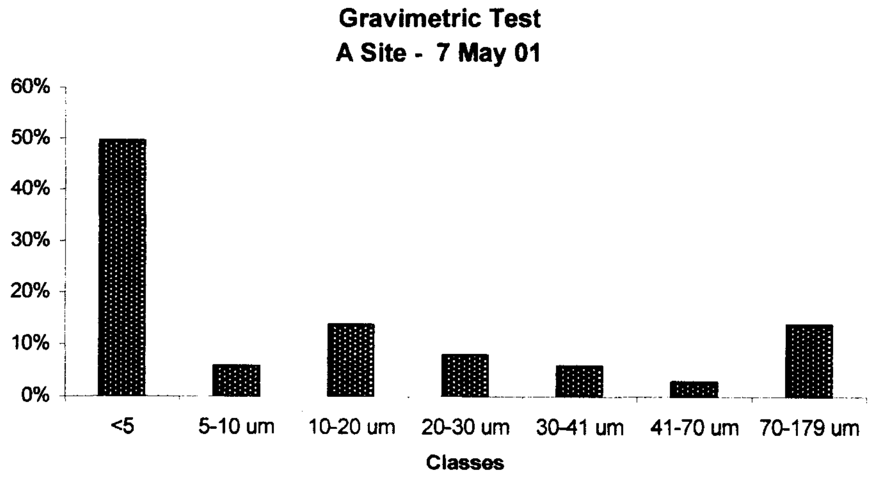
Size	Mark	Initial Weight, mg			Final Weight, mg				Vol	Conc
µm	Blue *	1	2	Avg	1	2	Avg	Net	L	mg/L
70	i	8.3	8.3	8.3	9.1	9.1	9.1	0.8	4.19	0.19
41	ii	12.2	12.3	12.25	12.5	12.3	12.4	0.15	4.19	0.04
30	iii	18.2	18.3	18.25	18.6	18.6	18.6	0.35	4.19	0.08
20	iv	21.2	21.2	21.2	21.7	21.6	21.65	0.45	4.19	0.11
10	v	16.7	16.7	16.7	17.6	17.4	17.5	0.8	4.19	0.19
5	vi	29.1	29.2	29.15	29.7	29.3	29.5	0.35	4.19	0.08
0.8	vii	23.1	22.9	23	23	23.1	23.05	0.05	0.35	0.14
0.45	s11	126.7	126.6	126.65	127.9	127.8	127.85	1.2	1.76	0.68

Filters
Pre-strained on a 179 um screen
5 - 70 um; 25-mm Spectra nylon mesh
0.8 um: 25-mm MFS membrane filters
0.45 um: 47-mm Durapore membrane filters, Type HVLP

Notes:
Both the 0.8 and 0.45 um filters clogged quickly

Plot data

<5	0.68	49.64%
5-10 um	0.08	5.84%
10-20 um	0.19	13.87%
20-30 um	0.11	8.03%
30-41 um	0.08	5.84%
41-70 um	0.04	2.92%
70-179 um	0.19	13.87%
	1.37	100.00%



C-J, 30-48

Gravimetric Test of Site A Sample 7 May 01.
Using the greatest difference in weights as values

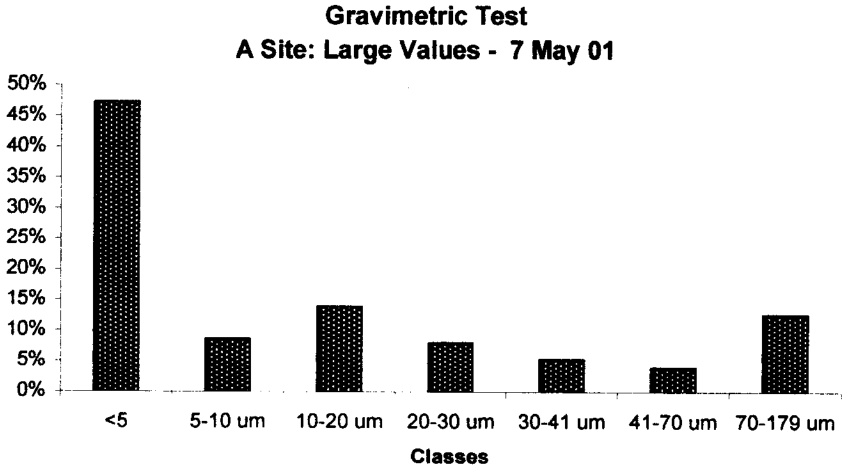
Size	Mark	Initial Weight, mg			Final Weight, mg				Vol	Conc
µm	Blue	1	2	Avg	1	2	Avg	Net	L	mg/L
70	i	8.3	8.3	8.3	9.1	9.1	9.1	0.8	4.19	0.19
41	ii	12.2	12.3	12.25	12.5	12.5	12.5	0.25	4.19	0.06
30	iii	18.2	18.3	18.25	18.6	18.6	18.6	0.35	4.19	0.08
20	iv	21.2	21.2	21.2	21.7	21.7	21.7	0.5	4.19	0.12
10	v	16.7	16.7	16.7	17.6	17.6	17.6	0.9	4.19	0.21
5	vi	29.1	29.2	29.15	29.7	29.7	29.7	0.55	4.19	0.13
0.8	vii	23.1	22.9	23	23	23	23	0	0.35	0
0.45	s11	126.7	126.6	126.65	127.9	127.9	127.9	1.25	1.76	0.71

Filters
Pre-strained on a 179 um screen
5 - 70 um; 25-mm Spectra nylon mesh
0.8 um: 25-mm MFS membrane filters
0.45 um: 47-mm Durapore membrane filters, Type HVLP

Notes:
Both the 0.8 and 0.45 um filters clogged quickly

Plot data

<5	0.71	47.33%
5-10 um	0.13	8.67%
10-20 um	0.21	14.00%
20-30 um	0.12	8.00%
30-41 um	0.08	5.33%
41-70 um	0.06	4.00%
70-179 um	0.19	12.67%
	1.5	100.00%


Gravimetric Test
A Site: Large Values - 7 May 01

Gravimetric Test of Site B Sample 7 May 01.

Size	Mark	Initial Weight, mg			Final Weight, mg				Vol	Conc
µm	Green *	1	2	Avg	1	2	Avg	Net	L	mg/L
70	i	8.2	8.3	8.25	8.4	8.3	8.35	0.1	4.04	0.02
41	ii	12.0	12.1	12.05	12.3	12.3	12.3	0.25	4.04	0.06
30	iii	17.4	17.2	17.3	17.7	18.1	17.9	0.6	4.03	0.15
20	iv	21.1	21.1	21.1	22.2	21.4	21.8	0.7	4.04	0.17
10	v	17.4	17.3	17.35	18.2	17.7	17.95	0.6	4.03	0.15
5	vi	29.1	29.2	29.15	29.4	29.5	29.45	0.3	4.04	0.07
0.8	vii	22.6	22.6	22.6	22.8	22.4	22.6	0	0.29	0
0.45	s11	127.9	126.9	127.4	128.1	127.7	127.9	0.5	1.79	0.28

Filters

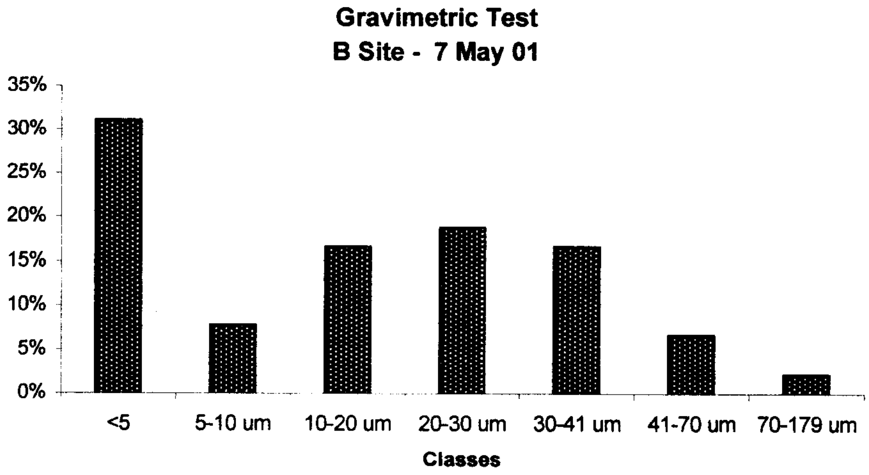
Pre-strained on a 179 um screen
5 - 70 um; 25-mm Spectra nylon mesh
0.8 um: 25-mm MFS membrane filters
0.45 um: 47-mm Durapore membrane filters, Type HVLP

Notes:

Both the 0.8 and 0.45 um filters clogged quickly

Plot data

<5	0.28	31.11%
5-10 um	0.07	7.78%
10-20 um	0.15	16.67%
20-30 um	0.17	18.89%
30-41 um	0.15	16.67%
41-70 um	0.06	6.67%
70-179 um	0.02	2.22%
	0.9	100.00%


Gravimetric Test
B Site - 7 May 01

C-J, 30-48

Gravimetric Test of Site B Sample 7 May 01.

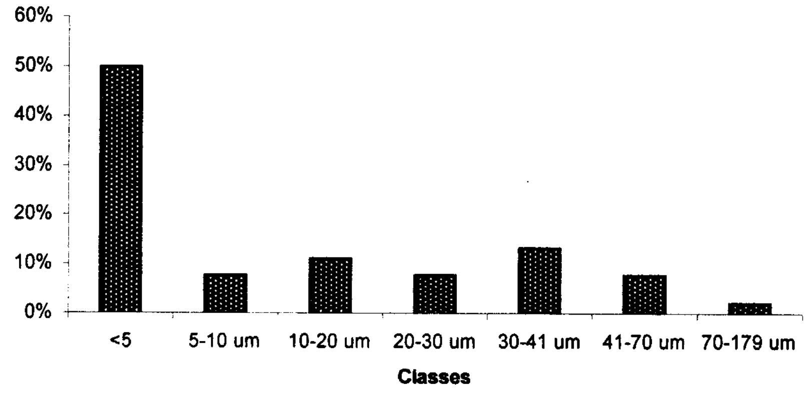
Size	Mark	Initial Weight, mg			Final Weight, mg				Vol	Conc
µm	Green	1	2	Avg	1	2	Avg	Net	L	mg/L
70	i	8.2	8.3	8.2	8.4	8.3	8.3	0.1	4.04	0.02
41	ii	12	12.1	12	12.3	12.3	12.3	0.3	4.04	0.07
30	iii	17.4	17.2	17.2	17.7	18.1	17.7	0.5	4.03	0.12
20	iv	21.1	21.1	21.1	22.2	21.4	21.4	0.3	4.04	0.07
10	v	17.4	17.3	17.3	18.2	17.7	17.7	0.4	4.03	0.1
5	vi	29.1	29.2	29.1	29.4	29.5	29.4	0.3	4.04	0.07
0.8	vii	22.6	22.6	22.6	22.8	22.4	22.4	-0.2	0.29	
0.45	s11	127.9	126.9	126.9	128.1	127.7	127.7	0.8	1.79	0.45

Filters
Pre-strained on a 179 um screen
5 - 70 um; 25-mm Spectra nylon mesh
0.8 um: 25-mm MFS membrane filters
0.45 um: 47-mm Durapore membrane filters, Type HVLP

Notes:
Both the 0.8 and 0.45 um filters clogged quickly
Using smaller of the two weighings
Final 1: dried 3 hrs
Final 2: dried overnight

Plot data

<5	0.45	50.00%
5-10 um	0.07	7.78%
10-20 um	0.1	11.11%
20-30 um	0.07	7.78%
30-41 um	0.12	13.33%
41-70 um	0.07	7.78%
70-179 um	0.02	2.22%
	0.9	100.00%


Gravimetric Test
B Site - 7 May 01

Gravimetric Test of Site B Sample 7 May 01.

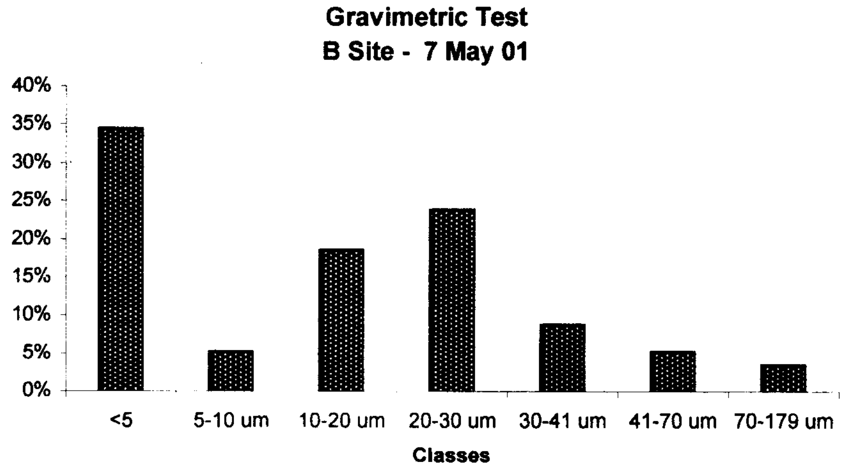
Size	Mark	Initial Weight, mg			Final Weight, mg				Vol	Conc
µm	Green	1	2	Avg	1	2	Avg	Net	L	mg/L
70	i	8.2	8.3	8.25	8.4	8.4	8.4	0.15	4.04	0.04
41	ii	12	12.1	12.05	12.3	12.3	12.3	0.25	4.04	0.06
30	iii	17.4	17.2	17.3	17.7	17.7	17.7	0.4	4.03	0.1
20	iv	21.1	21.1	21.1	22.2	22.2	22.2	1.1	4.04	0.27
10	v	17.4	17.3	17.35	18.2	18.2	18.2	0.85	4.03	0.21
5	vi	29.1	29.2	29.15	29.4	29.4	29.4	0.25	4.04	0.06
0.8	vii	22.6	22.6	22.6	22.8	22.8	22.8	0.2	0.29	0.68
0.45	s11	127.9	126.9	127.4	128.1	128.1	128.1	0.7	1.79	0.39

Filters
Pre-strained on a 179 um screen
5 - 70 um; 25-mm Spectra nylon mesh
0.8 um: 25-mm MFS membrane filters
0.45 um: 47-mm Durapore membrane filters, Type HVLP

Notes:
Both the 0.8 and 0.45 um filters clogged quickly
Second weighing

Plot data

<5	0.39	34.51%
5-10 um	0.06	5.31%
10-20 um	0.21	18.58%
20-30 um	0.27	23.89%
30-41 um	0.1	8.85%
41-70 um	0.06	5.31%
70-179 um	0.04	3.54%
	1.13	100.00%



Gravimetric Test
B Site - 7 May 01

Gravimetric Test of I/J sample taken 4 Jun.
Site: I/J Green**

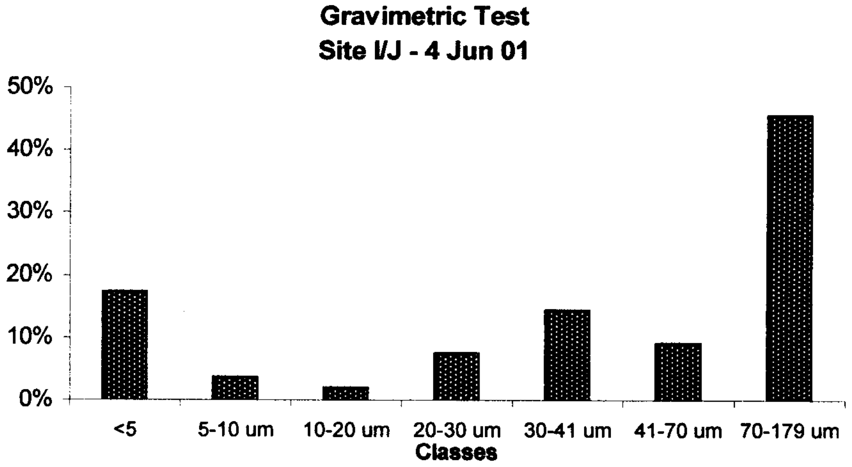
Size	Mark	Initial Weight, mg			Final Weight, mg				Vol	Conc
µm		1	2	Avg	1	2	Avg	Net	L	mg/L
70	i	8.2	8.3	8.2	17.64	17.63	17.64	9.44	4.24	2.23
41	ii	12	12.1	12	13.9	13.92	13.91	1.91	4.24	0.45
30	iii	17.4	17.2	17.2	20.22	20.19	20.21	3.01	4.24	0.71
20	iv	21.1	21.1	21.1	22.62	22.66	22.64	1.54	4.19	0.37
10	v	17.4	17.3	17.3	17.46	17.46	17.46	0.16	1.53	0.1
5	vi	29.1	29.2	29.1	29.6	29.57	29.59	0.49	2.73	0.18
0.8	vii	22.6	22.6	22.6	22.81	22.78	22.8	0.2	0.26	0.74
0.45	vii	127.9	126.9	126.9	127.68	127.68	127.68	0.78	0.89	0.88
						sum	0.8 + 0.47	0.98	1.15	0.85

Filters:
Pre-strained on a 179 um screen
5 - 70 um; 25-mm Spectra nylon mesh
0.8 um: 25-mm MFS membrane filters
0.45 um: 47-mm Durapore membrane filters, Type HVLP

Notes:
20 um filter started clogging at 3.7 L
10 um filter clogged at 1.5 L
Remainer of sample put through a 90 mm x 10 um mesh
5 um filter clogged at 2.7 L
Both the 0.8 and 0.45 um filters clogged quickly

Plot Data

<5	0.85	17.38%
5-10 um	0.18	3.68%
10-20 um	0.1	2.04%
20-30 um	0.37	7.57%
30-41 um	0.71	14.52%
41-70 um	0.45	9.20%
70-179 um	2.23	45.60%
	4.89	100.00%



Gravimetric Test
Site I/J - 4 Jun 01

Gravimetric Test of Feed Sample 7 Jun.
2 mm Feed Red**

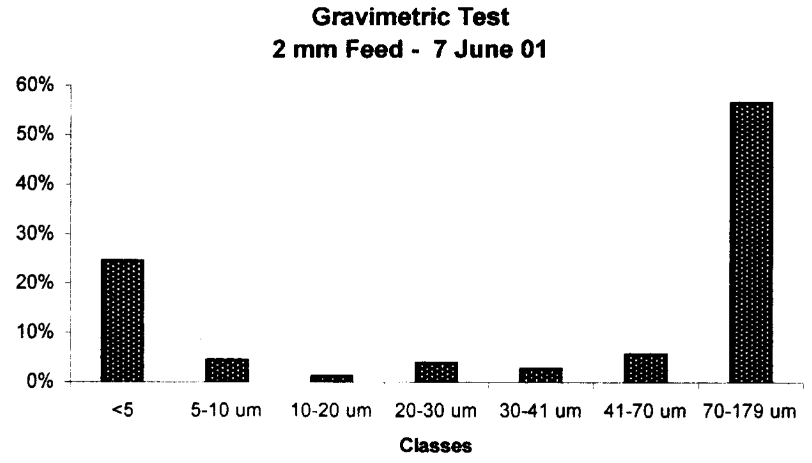
Size	Mark	Initial Weight, mg			Final Weight, mg				Vol	Conc
µm		1	2	Avg	1	2	Avg	Net	L	mg/L
70	i	8.08	8.09	8.08	15.58	15.51	15.55	7.46	0.97	7.69
41	ii	12.02	11.91	11.96	12.72	12.74	12.73	0.77	0.97	0.79
30	iii	18.32	18.33	18.32	18.67	18.71	18.69	0.36	0.97	0.38
20	iv	21.16	21.17	21.17	21.71	21.69	21.7	0.53	0.97	0.55
10	v	17.27	17.29	17.28	17.46	17.48	17.47	0.19	0.97	0.2
5	vi	29	28.99	28.99	29.63	29.58	29.6	0.61	0.97	0.63
0.8	vii	22.57	22.55	22.56	23.94	23.89	23.91	1.36	0.39	3.52
0.47	s11	123.11	123.11	123.11	125.06	125.03	125.04	1.94	0.6	3.23
						sum	0.8 + 0.47	3.29	0.99	3.34

Filters
Pre-strained on a 179 um screen
5 - 70 um; 25-mm Spectra nylon mesh
0.8 um: 25-mm MFS membrane filters
0.45 um: 47-mm Durapore membrane filters, Type HVLP

Notes:
Flow through the 5 um filter slowed severely
Both the 0.8 and 0.45 um filters clogged quickly

Plot data

<5	3.34	24.59%
5-10 um	0.63	4.64%
10-20 um	0.2	1.47%
20-30 um	0.55	4.05%
30-41 um	0.38	2.80%
41-70 um	0.79	5.82%
70-179 um	7.69	56.63%
	13.58	100.00%



C-J, 30-48

APPENDIX G

SPREADSHEET FOR

BOTTOM WATER RETURN LINE FLOW STUDY

SOLIDS IN THE RETURN LINES

As stated in the body of the report, the system is dynamic. Feeding variations and the return system contribute to large fluctuations in values that run through the system. A particular difficulty is caused by the return pipes, especially the bottom water line. These lines are 30 meters long with the tank outlets joining them approximately every five meters. The bottom water lines end pipe also has a short rise before it enters the swirl separator.

In a condition that is not peculiar to this plant, while the solids load is relatively low (1-10 mg/L), larger settleable solids will settle out in the culture water return lines, especially in the lines carrying the more heavily loaded water from the tank bottom outlet.

The range of solids that may settle in these lines can be estimated by Stokes' Law, described in section 2.3.1. Starting at the farthest tank (No. 6) in each line, and considering that the lines are 200 mm in diameter (nominal 8 inch), in a clean pipe the farthest particle from the 'sludge line' has to fall 20 cm before settling out. This has to be accomplished before the flow reaches the next inlet (Tank No. 5, etc.) where more flow will be added, increasing the flow velocity and reducing the settling time available. Particles nearer the bottom will require less time to move to the sludge line.

Several authors have determined values for the settling velocities of aquaculture waste solids. Vinci et al. (2001) reviewed some of these which are condensed in Table G.1.

***Table G.1**: Settling velocities for aquaculture wastes, m/s.*

Author	Item	Low end	High end
Idaho Waste Management Guidlines for Aquaculture Operations (Sharpnack (ed.) 1998)	Fine particles	0.000457	0.000914
	Faecal casts	0.0201	0.0500
Warrer-Hansen (1982)	Rainbow trout faeces	0.0168	0.0418
Wong and Piedrahita (2000)	Rainbow trout waste	0.0171 (median)	

As discussed in Section 2.5, Stokes' law can be used to estimate the settling velocities, v_s, of particles sedimenting out in these pipes. These determinations are shown in Figure 4.23 and are comparable to those given in Table 4.5 which correlate well with Stokes' estimates.

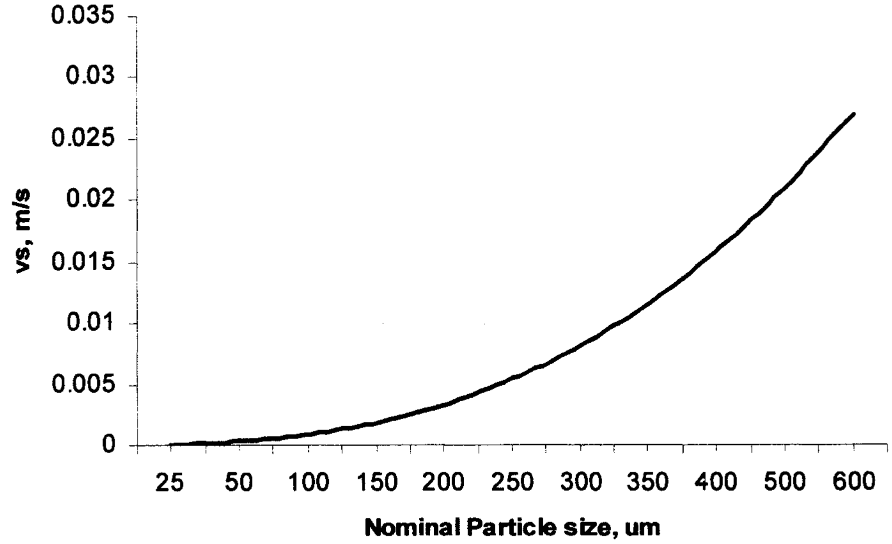


***Figure G.2**: Stokes' law estimate of the settling velocity of particles of density 1160 kg/m^3.*

Assuming a line flow rate of 2300 L/min, even distribution (nearly always true), and 5 meters between tank outlet junctions, and using the Law of Conservation of Mass, the time for a particle to travel between each junction of the return pipe (residency time) is determinable and is given in Table G.2.

***Table G.2**: Superficial velocities in the bottom water return line and residency times, assuming a total flow in the line of 766.7 L/min (1/3rd of input 2300 L/min), even distribution of the flow to tanks, and 5 m between tank outlet junctions.*

Tank No. >		**1**	**2**	**3**	**4**	**5**	**6**
Flow out	L/min	127.8	127.8	127.8	127.8	127.8	127.8
Flow, Return Line	L/min	766.7	638.9	511.1	383.3	255.6	127.8
	m^3/s	0.0128	0.0106	0.0085	0.0064	0.0043	0.0021
Superficial Velocity	m/s	0.3959	0.3299	0.2639	0.1979	0.1320	0.0660
	cm/s	39.6	33.0	26.4	19.8	13.2	6.6
Distance	m	5	5	5	5	5	5
Time	s	12.6	15.2	18.9	25.3	37.9	75.8

It can be assumed that the line is full despite the low flow rates as the line terminates in the swirl separator which is full, with a head approximately that of the culture tanks themselves.

The Stokes' Law results ($N_R < 3$, for a spherical body of density = 1160 kg/m3. This density selection will be explained later) were used to determine the time it would take particles of varying sizes to fall to the sludge line in the pipe from several heights, from the top of the pipe (20 cm) to 1/4 the pipe diameter (5 cm). When the Stokes' results are combined with particle residency times for each pipe section, an estimate of the probability of a particle of a given size and depth sedimenting out of the stream at succeeding points in the return line can be determined. Such an estimate is illustrated in Figure G.3. The larger particles are especially prone to sedimentation in all runs, but particles under 100 μm near the pipe bottom are also liable in the first run.

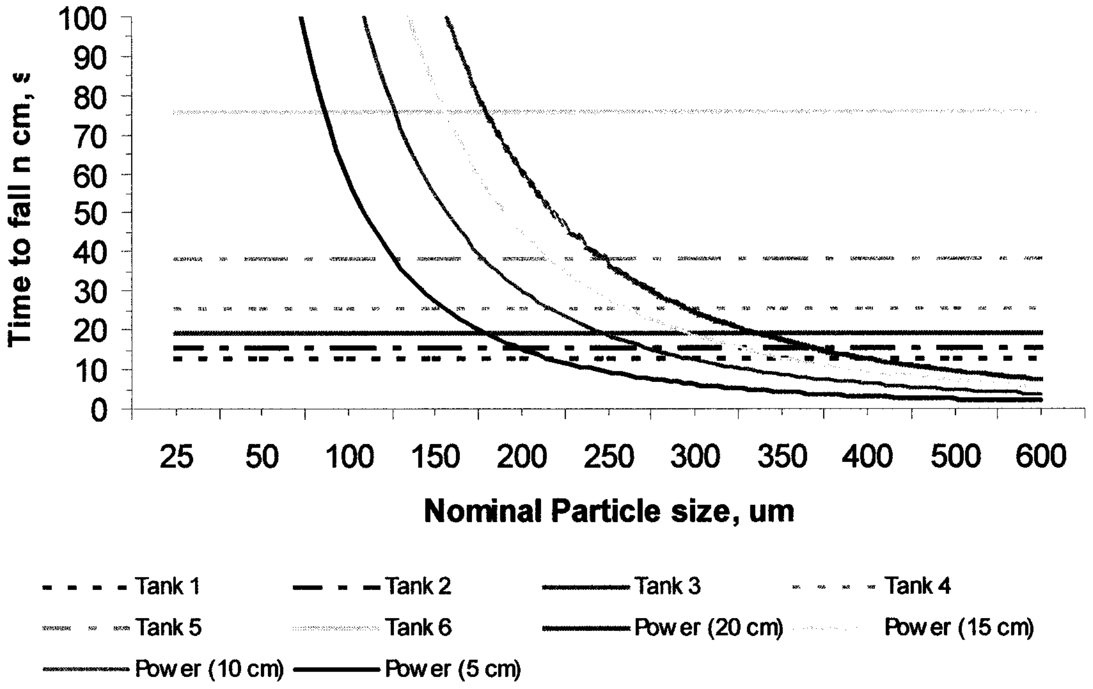


Figure G.3: Tank bottom line residency times (dashed) and Stokes' equation estimates of fall times from selected heights (solid lines)

The fall distance will decrease as the pipe fills with sediment, shortening the settling time, but that will also increase the flow velocity through restriction of the flow cross-sectional area. It has been observed by the Manager that after a certain build-up, the sludge lets go, pushing a pulse of solids through the system at random periods. These heavy, random pulse loadings of solid wastes in the system are difficult to manage.

Turbulence and scouring reduce settling but the theory behind the observation is demonstrated. The analysis is detailed in a spreadsheet in following this study. This analysis can also be used to determine a solution, albeit not a retro fit one. It can be shown (Table G.3) that, had the return pipe diameters per section been better matched to flow rate, the flow velocity could have been kept higher, hence the residency time shorter (not to mention probable increased turbulence) to the degree that sedimentation would be very much less and the build-up of solids probably reduce to insignificance.

***Table G.3**: Modified return pipe diameters to maintain higher velocities and thus shorter residency times (flow rate = 2300 L/min)*

Pipe ID	**Nom**	**8"**	**6"**	**6"**	**5"**	**4"**	**3"**
	in	7.981	6.065	6.065	5.017	4.026	3.068
	m	0.2027	0.1541	0.1541	0.1274	0.1023	0.0779
Cross-sectional Area	m^2	0.0323	0.0186	0.0186	0.0128	0.0082	0.0048
Run Length	m	5					
Flows:							
Tank No. >		**1**	**2**	**3**	**4**	**5**	**6**
Flow out	L/min	127.8	127.8	127.8	127.8	127.8	127.8
Flow Return Line	L/min	766.7	638.9	511.1	383.3	255.6	127.8
	m^3/s	0.0128	0.0106	0.0085	0.0064	0.0043	0.0021
Superficial Velocity	m/s	0.40	0.57	0.46	0.50	0.52	0.45
	cm/s	39.59	57.13	45.70	50.09	51.86	44.65
Res. Time	s	12.6	8.8	10.9	10.0	9.6	11.2

Estimate of Flow Velocities in Bottom Water Return Pipe.

	Date	21-May-01	**Total A line Flow Rate**	2300 L/min		
	Line	A	**Bottom Return Flow rate**	766.7 L/min	1/3 total to bottom line	
Pipe ID	in	7.981			Assume evenly split flow	
	m	0.2027				
X Area	m^2	0.0323				

Flows:

Tank No. >		1	2	3	4	5	6	
Flow out	L/min	127.8	127.8	127.8	127.8	127.8	127.8	
Flow, RL	L/min	766.7	638.9	511.1	383.3	255.6	127.8	
	m^3/s	0.0128	0.0106	0.0085	0.0064	0.0043	0.0021	
Superficial	m/s	0.3959	0.3299	0.2639	0.1979	0.1320	0.0660	
Velocity	cm/s	39.6	33.0	26.4	19.8	13.2	6.6	
Distance	m	5	5	5	5	5	5	
Time	s	12.6	15.2	18.9	25.3	37.9	75.8	for a particle to go the 5 m length

Stokes vs = (g(Rhop-Rhow)dp^2)/18 mu

Rhop	1160	kg/m^3
Rhow	1000	kg/m^3
dp ***	25	um
dp	0.000025	m
mu	0.001	kg/m.s
g	9.81	m/s^2
vs	5.45E-05	m/s

*** This cell to be changed to the required particle size

Sch 40 Pipe	**8"**	**6"**	**5"**	**4"**	**3"**
ID, in	7.981	6.065	5.017	4.026	3.068

Stokes' Plot Data Time to hit bottom

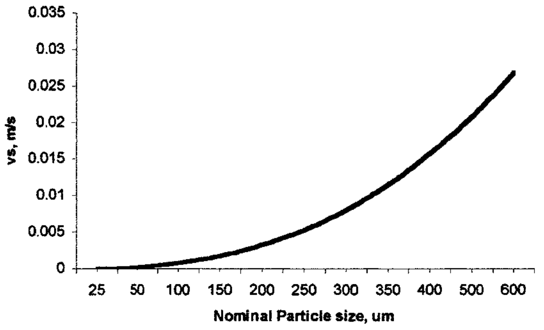
		Particle Initial Vertical Height				Line Residency Times, s					
dp, um	**vs, m/s**	**20 cm**	**15 cm**	**10 cm**	**5 cm**	**Tank 1**	**Tank 2**	**Tank 3**	**Tank 4**	**Tank 5**	**Tank 6**
25	5.45E-05	3669.7	2752.3	1834.9	917.4	12.6	15.2	18.9	25.3	37.9	75.8
50	0.000218	917.4	688.1	458.7	229.4	12.6	15.2	18.9	25.3	37.9	75.8
100	0.000872	229.4	172.0	114.7	57.3	12.6	15.2	18.9	25.3	37.9	75.8
150	0.001962	101.9	76.5	51.0	25.5	12.6	15.2	18.9	25.3	37.9	75.8
200	0.003488	57.3	43.0	28.7	14.3	12.6	15.2	18.9	25.3	37.9	75.8
250	0.00545	36.7	27.5	18.3	9.2	12.6	15.2	18.9	25.3	37.9	75.8
300	0.007848	25.5	19.1	12.7	6.4	12.6	15.2	18.9	25.3	37.9	75.8
350	0.010682	18.7	14.0	9.4	4.7	12.6	15.2	18.9	25.3	37.9	75.8
400	0.013952	14.3	10.8	7.2	3.6	12.6	15.2	18.9	25.3	37.9	75.8
500	0.0218	9.2	6.9	4.6	2.3	12.6	15.2	18.9	25.3	37.9	75.8
600	0.031392	6.4	4.8	3.2	1.6	12.6	15.2	18.9	25.3	37.9	75.8

Regression Lines > y20 = 244.65*x^-2 y15=183.49*x^-2 y10=122.32*x^-2 y5=61.162*x^-2

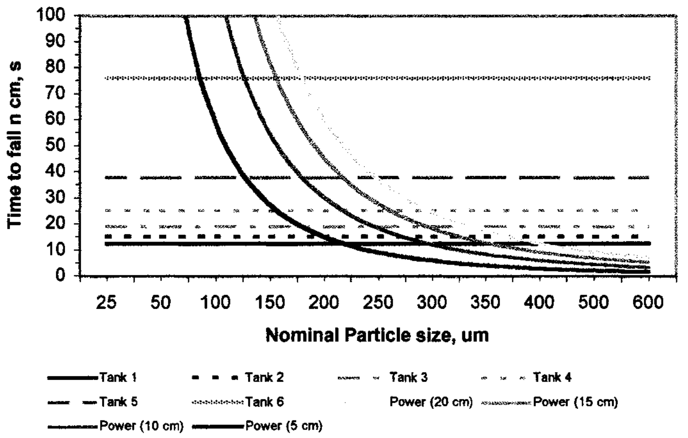
Hypothetical Flows with varying pipe diameter

Line	A	**Flow**	2300	L/min	Assume evenly split flow
Bottom Return Flow rate			766.7	L/min	1/3 total to bottom line

	Nom	**8"**	**6"**	**6"**	**5"**	**4"**	**3"**
Pipe ID	in	7.981	6.065	6.065	5.017	4.026	3.068
	m	0.2027	0.1541	0.1541	0.1274	0.1023	0.0779
X Area	m^2	0.0323	0.0186	0.0186	0.0128	0.0082	0.0048
Length	m	5					
Flows:							
Tank No. >		**1**	**2**	**3**	**4**	**5**	**6**
Flow out	L/min	127.8	127.8	127.8	127.8	127.8	127.8
Flow Return	L/min	766.7	638.9	511.1	383.3	255.6	127.8
Line	m^3/s	0.0128	0.0106	0.0085	0.0064	0.0043	0.0021
Superficial	m/s	0.40	0.57	0.46	0.50	0.52	0.45
Velocity	cm/s	39.59	57.13	45.70	50.09	51.86	44.65
Res. Time	s	12.6	8.8	10.9	10.0	9.6	11.2



y20	Log y	a	Log a	Power	Logx	x
75.8	1.8796692	1124.6	3.050998	-2.6278	0.5857	2.791
						2.791



APPENDIX H

PARTICLE SIZE ANALYSIS RESULTS

A and B Test Site Data
Collective A and B Site Results
2 April 01 Site Samples Results
16 April 01 Site Samples Results
30 April 01 Site Samples Results
7 May 01 Site Samples Results
14 May 01 Site Samples Results
21 May 01 Site Samples Results
4 June 01 Site Samples Results

Feed Test Data
12, 19 Apr 01 and 6 Jun 01

Sampling Sites

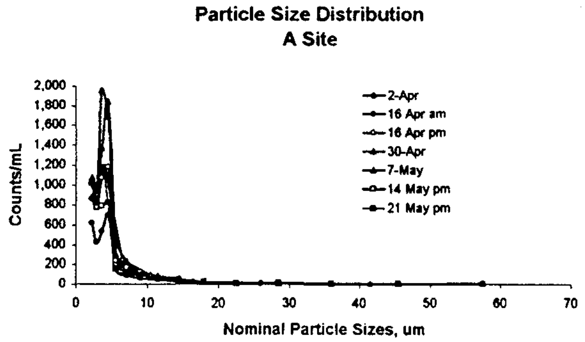
SITE	DESIGNATION
A	culture tanks bottom drain return line
B	culture tanks midwater drain return line
C	line from swirl separator to standpipe
D	line from standpipe to drum filter 1
E	outflow from drum filter 1
SD	settle deck near the pump inlets
BF_A, BF_B	outflow from biofilters on lines A and B
G_A, G_B	flow from degasser/oxygenators on lines A and B
I/J	wash water outflow from drum filter(s)
D2	inlet/outlet drum filter 2 (when in the circuit)
MW, MUW_{A1}	make-up water from main supply
MW, MUW_{A2}	make-up water from secondary supply
MW, MUW_B	make-up water from tertiary supply
OF	settle deck overflow

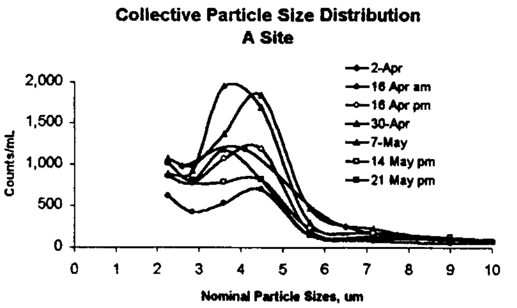
Particle Size Analysis

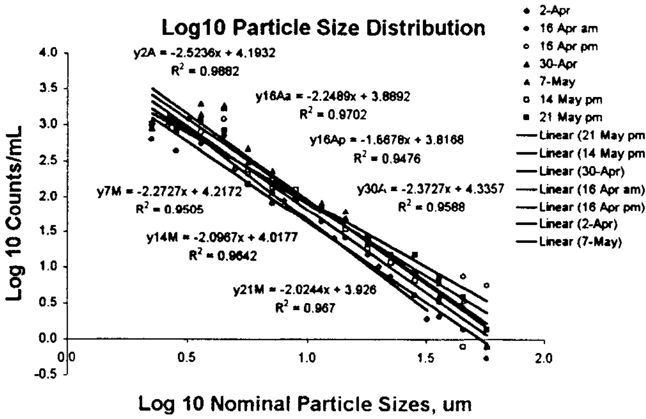
Collective Sites A and B PCX Results 2 April 01 - 21 May 01.

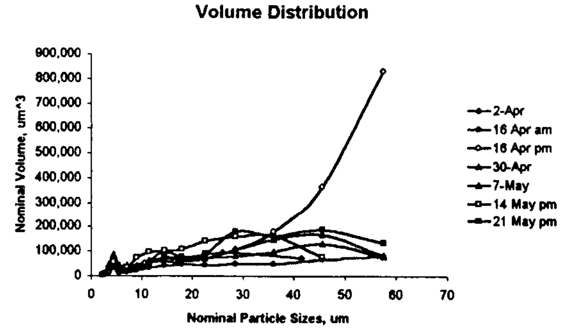
PCX Test of all A Data (lessFDDW)

		<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>									
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est	
	# >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64		256
	r* >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	160		
	Log10 r*	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967			
2-Apr	r* >	2.6	4.1	6.5	10.5	16.5	26	41.5											
	Log10 r*	0.41497	0.60615	0.69897	0.90309	1.11394	1.30103	1.60615											
Average		970.22	1162.16	247.06	80.27	25.24	10.36	1.90											
Volume, um^3		8,929	42,661	35,529	53,502	59,360	96,306	71,104											
Log10 PSD		2.98687	3.07268	2.39284	1.94581	1.40205	1.01520	0.27875											
16 Apr am																			
Average		617.39	423.80	531.76	693.64	146.86	81.39	58.47	43.14	26.11	15.11	7.61	4.13	2.05	1.37	0.54	0.12		
Flow Ajusted		620.65	426.97	534.49	697.19	147.61	81.80	58.77	43.36	25.92	15.00	7.46	4.10	2.03	1.36	0.54	0.11		
Volume, um^3		3,701	6,163	13,057	33,265	13,940	15,656	22,433	34,630	41,376	45,791	44,466	49,636	49,595	66,835	80,698	285,981		
Log10 PSD		2.79270	2.62938	2.72794	2.84335	2.16912	1.91276	1.76916	1.63710	1.41365	1.17596	0.87248	0.61227	0.30753	0.13197	-0.27077			
16 Apr pm																			
Average		853.43	764.28	1060.91	1175.75	203.26	134.09	103.49	69.96	46.80	19.63	11.59	8.97	7.47	7.49	5.55	0.72		
Flow Ajusted		857.81	768.20	1066.35	1181.78	204.30	134.77	104.02	70.31	46.46	19.48	11.51	8.90	7.41	7.43	5.51	0.71		
Volume, um^3		5,116	9,311	26,050	56,386	19,294	25,794	39,704	55,994	74,163	59,493	68,645	107,921	181,132	366,616	629,401	1,787,382		
Log10 PSD		2.93339	2.88547	3.02790	3.07254	2.31028	2.12961	2.01711	1.84705	1.66709	1.28965	1.06107	0.94957	0.87009	0.87118	0.74113			
30-Apr																			
Average		1031.01	955.975	1320.12	1774.48	451.331	217.68125	111.85	79.3375	61.3	25.7563	12.425	6.675	4.03125	2.69375	0.7875	0.2		
Flow Ajusted		1067.35	989.673	1366.65	1837.03	467.241	225.364573	115.7927	82.134168	61.2149	25.7205	12.40775	6.56587	4.0256543	2.690011	0.7864069	0.1997224		
Volume, um^3		6365.8	11995.7	33386	87649.9	44125	43130.364	44198.5	65406.762	97714.7	78540.8	74001.3	79684	98342.808	132674.3	78279.757	92520.733		
Log10 PSD		3.02831	2.99549	3.13566	3.26412	2.66954	2.35286638	2.063681	1.9145239	1.78686	1.41028	1.093693	0.81729	0.6048365	0.429764	-0.104353			
7-May																			
Average		834.23	866.98	1655.09	1600.33	286.09	173.85	98.35	61.37	45.37	21.59	11.07	8.34	5.70	3.23	0.79	0.19		
Flow Ajusted		879.53	914.05	1955.81	1687.22	301.62	183.29	103.69	64.70	47.83	22.76	11.67	8.79	6.00	3.40	0.83	0.20		
Volume, um^3		5,246	11,079	47,779	80,602	28,484	35,080	39,579	51,520	76,346	69,491	69,606	106,577	146,677	167,697	82,382	92,796		
Log10 PSD		2.94425	2.96097	3.29133	3.22717	2.47946	2.26314	2.01574	1.81088	1.67968	1.35711	1.06711	0.94413	0.77846	0.53149	-0.08217			
14 May pm	r* >	2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5				
		Log10 r*	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967			
Average		998.09	762.74	773.38	804.58	233.47	167.01	124.04	60.83	33.48	17.91	11.61	6.52	3.26	0.78	0.29			
Flow Ajusted		1014.80	775.51	786.33	818.05	237.38	169.80	124.85	61.23	33.70	18.03	11.68	6.56	3.28	0.78	4,062			
Volume, um^3		6,052	9,400	19,209	39,031	22,417	32,498	75,674	97,731	102,901	107,524	141,589	160,278	161,952	77,644	1,053,901			
Log10 PSD		3.00638	2.88969	2.89560	2.91278	2.37544	2.22994	2.09638	1.78693	1.52760	1.25596	1.06749	0.81697	0.51635	-0.10790				
21 May pm																			
Average		1029.89	827.03	1193.11	834.46	153.22	113.95	92.37	67.36	44.39	25.92	15.13	14.96	6.71	3.86	1.37	0.57		
Flow Ajusted		1010.39	811.37	1170.52	818.66	150.32	111.79	90.62	66.06	43.94	25.66	14.97	14.81	6.64	3.82	1.35	0.56		
Volume, um^3		6,026	9,834	28,595	39,061	14,196	21,396	34,590	62,622	70,138	78,347	89,296	179,527	162,324	188,274	134,871	1,207,460		
Log10 PSD		3.00449	2.90922	3.06838	2.91310	2.17701	2.04841	1.95722	1.82008	1.64265	1.40921	1.17529	1.17060	0.82248	0.58176	0.13192			


Particle Size Distribution
A Site


Collective Particle Size Distribution
A Site


Log10 Particle Size Distribution

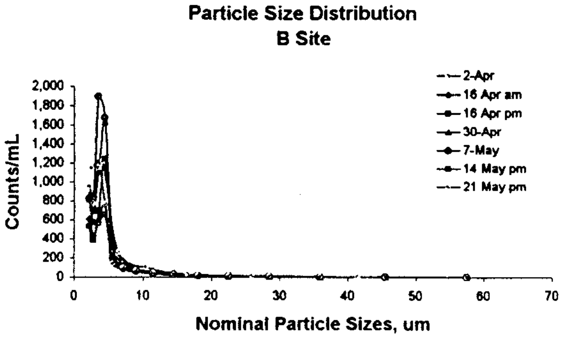

Volume Distribution

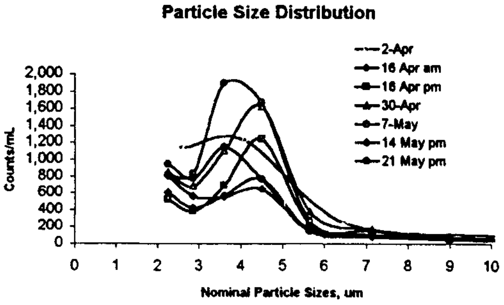
Correlatiopn Coefficients

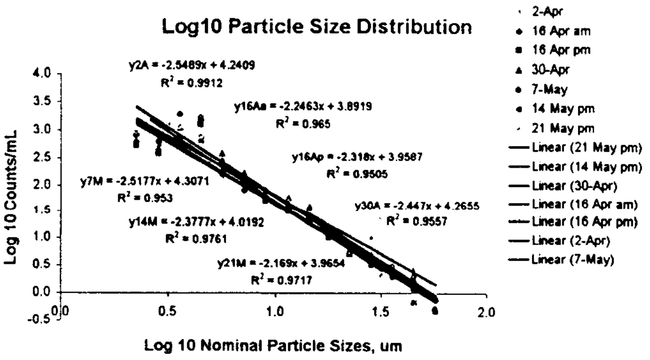
Date	R^2	R
2-Apr	0 9882	0 99408
16 Apr am	0 9702	0.98499
16 Apr pm	0.9476	0.97345
30-Apr	0.9588	0.97918
7-May	0 9505	0.97494
14-May	0 9642	0 98194
21-May	0.967	0 98336

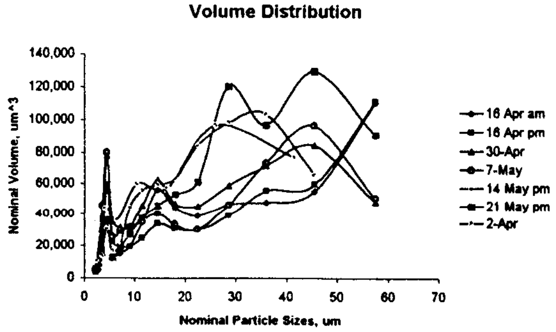
PCX Test of all B Data (lessFDDW)

		<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>							<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>										
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est	
	# >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64		256
	l* >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	160		
	Log10 l*	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967			
2-Apr	l* >	2.6	4.1	6.5	10.5	16.5	26	41.5											
	Log10 l*	0.41497	0.50515	0.69897	0.90309	1.11394	1.30103	1.50515											
Average		1146.61	1222.13	251.04	99.13	24.54	10.49	2.06											
Volume, um^3		10,552	44,103	36,098	60,063	57,714	96,514	76,952											
Log10 PSD		3.05942	3.08712	2.39975	1.99618	1.38983	1.02067	0.31308											
16 Apr am																			
Average		605.06	427.78	567.43	760.55	146.85	79.15	51.35	43.46	35.24	14.49	6.52	3.85	1.96	1.12	0.73			
Flow Ajusted		608.16	429.97	570.34	764.44	147.61	79.56	51.61	43.69	35.42	14.56	6.56	3.87	1.97	1.12	0.73			
Volume, um^3		3,627	5,212	13,933	36,474	13,940	15,226	19,699	34,788	56,536	44,466	39,090	46,955	48,188	55,358	110,326			
Log10 PSD		2.78402	2.63344	2.75614	2.88335	2.16911	1.90067	1.71273	1.64034	1.54923	1.16321	0.81652	0.58815	0.29503	0.05014	-0.13495			
16 Apr pm																			
Average		523.38	379.32	688.57	1235.88	234.90	101.52	50.50	31.06	21.21	10.11	5.05	3.19	2.27	1.21	0.74			
Flow Ajusted		526.06	381.26	692.10	1242.21	236.10	102.04	50.75	31.21	21.32	10.16	5.07	3.20	2.28	1.21	0.74			
Volume, um^3		3,138	4,621	16,907	59,270	22,297	19,529	19,373	24,857	34,030	31,030	30,243	38,803	66,615	69,737	111,209			
Log10 PSD		2.72104	2.58122	2.84017	3.09420	2.37310	2.00877	1.70547	1.49435	1.32876	1.00697	0.70506	0.50533	0.35729	0.08321	-0.13149			
30-Apr																			
Average		822.344	662.281	1067.14	1572.29	360.756	159.03125	79.9625	66.8375	39.3063	15.6875	7.6875	4.8625	2.93125	1.7125	0.4875			
Flow Ajusted		851.332	685.627	1104.76	1627.72	373.473	164.637145	82.7812	57.805787	39.2517	15.5659	7.676829	4.85575	2.9271812	1.710123	0.4868233			
Volume, um^3		5077.44	8310.38	26988.2	77663.2	35269.8	31509.7221	31597.87	46032.383	62655.8	47532.4	45785.51	58855.8	71508.182	84345.16	48458.897			
Log10 PSD		2.9301	2.83609	3.04327	3.21158	2.57226	2.21652783	1.917932	1.7619713	1.59386	1.19217	0.885182	0.68626	0.4664496	0.233027	-0.312629			
7-May																			
Average		775.88	789.76	1795.69	1584.75	258.48	144.70	78.29	42.32	24.04	10.51	4.86	3.64	2.85	1.85	0.49	0.20		
Flow Ajusted		818.00	832.64	1893.19	1670.80	272.51	152.56	82.54	44.61	25.35	11.08	5.12	3.84	3.00	1.95	0.51	0.21		
Volume, um^3		4,879	10,092	46,249	79,719	25,735	29,198	31,504	35,526	40,458	33,820	30,559	46,515	73,403	96,198	50,899	97,680		
Log10 PSD		2.91275	2.92046	3.27719	3.22292	2.43538	2.18343	1.91664	1.64946	1.40390	1.04436	0.70960	0.58406	0.47781	0.29013	-0.29130			
14 May pm																			
	l* >	2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5				
	Log10 l*	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967				
Average		793.71	567.07	549.90	634.81	169.35	103.48	72.68	34.68	19.29	10.43	6.84	3.95	2.07	0.66				
Flow Ajusted		806.99	566.40	559.11	645.44	172.18	105.21	73.90	35.26	19.61	10.60	6.95	4.02	2.10	0.67				
Volume, um^3		4,813	6,865	13,658	30,796	16,260	20,137	44,791	66,285	59,891	63,247	84,233	98,110	103,553	66,291				
Log10 PSD		2.90687	2.75312	2.74749	2.80985	2.23598	2.02207	1.86863	1.54729	1.29254	1.02550	0.84195	0.60381	0.32213	-0.17655				
21 May pm																			
Average		949.40	775.84	1149.49	769.70	140.57	101.28	72.66	48.39	29.28	17.59	10.38	10.05	3.99	2.66	0.92	0.36		
Less Fddw		949.40	775.84	1149.49	769.70	140.57	101.28	72.66	48.39	29.28	17.59	10.38	10.05	3.99	2.66	0.92	0.36		
Flow Ajusted		931.42	761.15	1127.72	755.12	137.91	99.36	71.28	47.47	28.98	17.41	10.27	9.94	3.95	2.63	0.91	0.35		
Volume, um^3		5,555	9,226	27,549	36,029	13,024	19,017	27,208	37,801	46,259	53,171	61,253	120,525	96,488	129,625	90,653	753,667		
Log10 PSD		2.96915	2.88147	3.05220	2.87802	2.13959	1.99722	1.85296	1.67641	1.46209	1.24086	1.01158	0.99754	0.59657	0.41966	-0.04062			





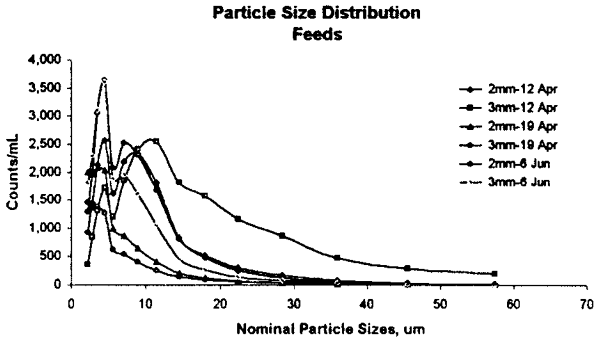


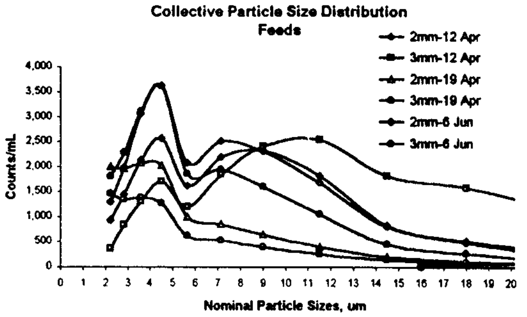


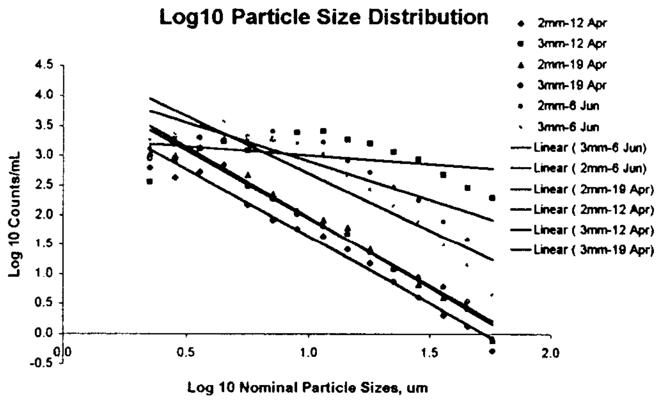
Date	Beta	R^2	R
2-Apr	2.55	0.9912	0.99558
16 Apr am	2.25	0.965	0.98234
16 Apr pm	2.32	0.9505	0.97494
30-Apr	2.45	0.9557	0.97760
7-May	2.58	0.953	0.97622
14-May	2.38	0.9761	0.98798
21-May	2.17	0.9717	0.98575

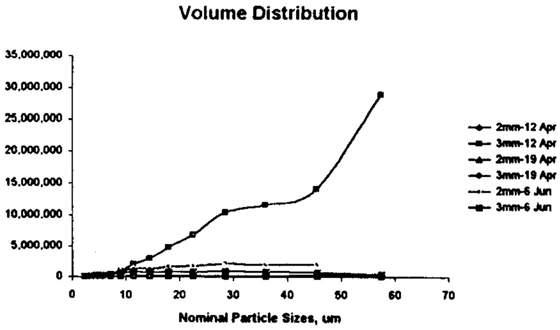
Collective PCX Test of all Feed Trials (lessFDDW)

	<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
l >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	256
l' >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	160	
Log10 l'	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
2mm-12 Apr																	
Average	924.73	1447.76	2132.81	2566.84	1612.00	2167.46	2321.41	1813.36	824.20	482.15	246.89	127.26	51.66	25.39	13.86	2.14	
Volume, um^3	3,701	5,163	13,057	33,265	13,940	15,666	22,433	34,630	41,376	45,791	44,466	49,636	49,595	66,835	80,696	285,981	
Log10 PSD	2.79278	2.62938	2.72794	2.84335	2.16912	1.91276	1.76915	1.63710	1.41365	1.17596	0.87248	0.61227	0.30753	0.13197	-0.27077		
3mm-12 Apr																	
Average	358.86	833.33	1305.49	1705.16	1189.40	1850.21	2410.44	2539.25	1815.38	1568.26	1154.39	857.48	474.91	285.38	191.94	48.75	
Volume, um^3	2,140	10,101	31,892	81,358	112,324	364,110	920,072	2,022,077	2,897,804	4,788,890	6,884,902	10,393,329	11,601,649	14,075,011	28,892,842	29,126,768	
Log10 PSD	2.55493	2.92081	3.11677	3.23177	3.07533	3.26722	3.38210	3.40471	3.25897	3.19542	3.06235	2.93322	2.67661	2.45542	2.28316	1.68797	
2mm-19 Apr																	
Average	2022.11	1987.84	2101.98	2052.26	1001.13	866.1625	655.8	407.2375	197.6125	120.1875	66.5375	35.7875	15.125	7.65	3.6625	0.5125	
Flow Ajusted	1994.59	1960.78	2073.36	2024.31	987.498	854.372164	646.8732	401.69412	200.917594	122.19765	66.633623	36.38605053	15.37796757	7.676274719	3.723765783	0.5210716	
Volume, um^3	6365.8	11996.7	33386	87649.9	44125	43130.364	44198.5	65405.762	97714.6888	78540.836	74001.296	79583.99006	98342.80841	132674.3137	78279.75697	92520.733	
Log10 PSD	3.02831	2.99549	3.13566	3.26412	2.66954	2.35286638	2.063681	1.9145239	1.78665722	1.4102794	1.0936931	0.817292507	0.604836482	0.429754037	-0.104352688		
3mm-19 Apr																	
Average	1475.46	1366.83	1397.09	1283.53	623.40	541.86	411.55	260.49	134.41	67.19	62.38	33.15	17.26	10.01	6.01	0.51	
Flow Ajusted	1455.38	1348.22	1378.07	1266.05	614.91	534.49	405.95	256.94	136.66	68.65	63.25	33.70	17.55	10.18	6.11	0.52	
Volume, um^3	5,246	11,079	47,779	80,502	28,484	35,080	39,579	51,520	76,346	69,491	69,606	106,577	146,677	167,697	82,382	92,796	
Log10 PSD	2.94425	2.96097	3.29133	3.22717	2.47946	2.26314	2.01574	1.81088	1.67968	1.35711	1.06711	0.94413	0.77846	0.53149	-0.08217		
2mm-6 Jun																	
Average	1323.82	2002.36	3029.69	3573.05	2037.11	2472.88	2264.04	1641.58	843.73	547.00	309.66	183.79	82.55	39.81	14.78	6.96	
Less FDDW	1251.45	1940.18	2972.39	3533.06	2018.51	2452.72	2244.85	1626.24	832.47	539.42	305.36	181.59	81.81	39.62	14.74	6.95	
Flow Ajusted	1286.31	1994.22	3055.18	3631.47	2074.74	2521.04	2307.38	1671.54	803.11	520.39	294.58	175.18	78.92	38.22	14.22	6.72	
Volume, um^3	7,672	24,172	74,635	173,268	196,933	482,498	880,736	1,331,095	1,281,963	1,589,071	1,756,935	2,123,352	1,927,997	1,885,208	1,416,836	116,244	
Log10 PSD	3.10935	3.29977	3.48504	3.56008	3.31696	3.40158	3.36312	3.22312	2.90477	2.71633	2.46921	2.24349	1.89720	1.58233	1.15295	0.82717	
3mm-6 Jun																	
Average	1826.07	2287.03	3082.86	3549.97	1832.43	1914.41	1575.41	1038.30	485.26	284.83	148.91	81.07	32.80	14.70	4.69	1.84	
Less FDDW	1753.70	2224.85	3025.55	3509.98	1813.83	1894.25	1556.22	1022.97	474.00	277.24	144.61	78.87	32.06	14.51	4.66	1.83	
Flow Ajusted	1802.55	2286.82	3109.82	3607.75	1864.35	1947.02	1599.57	1051.46	457.28	267.46	139.51	76.09	30.93	14.00	4.50	1.78	
Volume, um^3	10751	27718	75970	172136	176064	372638	610561	837308	729931	816728	832024	922234	755527	690324	447538	30518	
Log10 PSD	3.26	3.36	3.49	3.56	3.27	3.29	3.20	3.02	2.66	2.43	2.14	1.88	1.49	1.15	0.65	0.25	



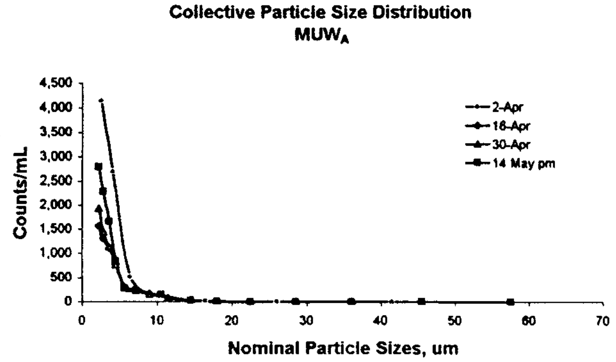


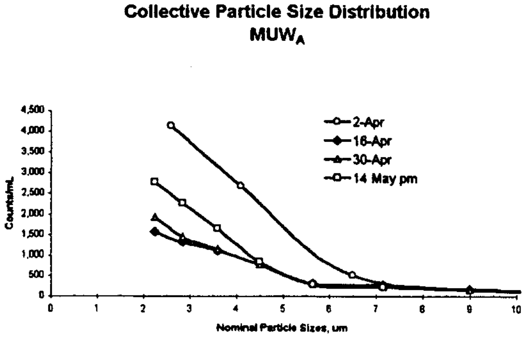


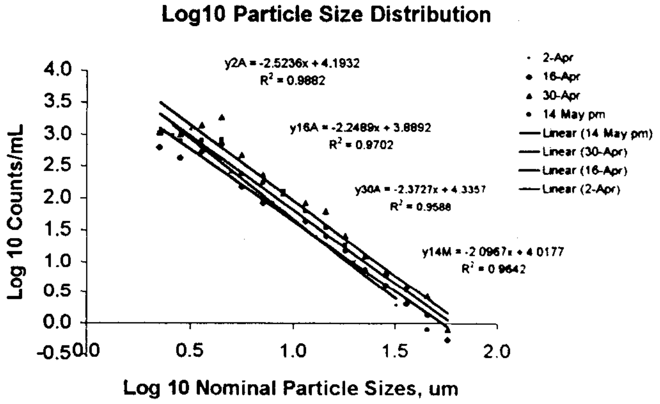


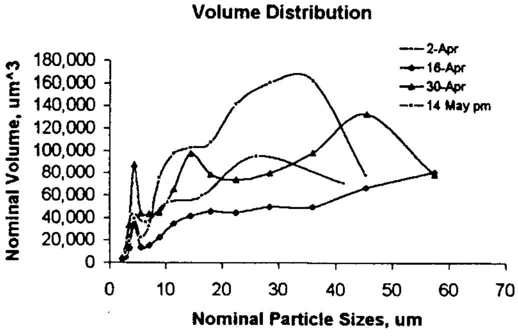
Collective PCX Test Data of all MUW_A Data (less FDDW)

2-Apr	r* >	2.6	4.1	6.5	10.5	16.5	26	41.5											
	Log10 r*	0.41497	0.50515	0.69897	0.90309	1.11394	1.30103	1.50515											
Average		4140.79	2692.81	511.32	124.33	12.20	2.41	0.93	0.37										
Volume, um^3		8,929	42,661	35,529	53,502	59,360	95,306	71,104											
Log10 PSD		2.99687	3.07268	2.39284	1.94581	1.40205	1.01520	0.27875											
		<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>									
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est	
	li >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64		179
	r* >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	121.5		
	Log10 r*	0.35218	0.45484	0.55630	0.65321	0.75206	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967			
16-Apr																			
Average		1558.37	1305.09	1096.79	772.72	304.00	280.13	168.75	84.00	43.11	29.46	18.55	12.34	7.06	4.64	2.25	0.31		
Flow Ajusted		1566.36	1311.78	1104.42	776.68	306.55	281.56	169.62	84.43	43.33	29.61	18.65	12.40	7.09	4.66	2.26	0.31		
Volume, um^3		3,701	5,163	13,057	33,265	13,940	15,656	22,433	34,530	41,376	45,791	44,466	49,636	49,595	66,835	80,696			
Log10 PSD		2.79278	2.62938	2.72794	2.84335	2.16912	1.91276	1.76915	1.63710	1.41365	1.17596	0.87248	0.61227	0.30753	0.13197	-0.27077			
30-Apr																			
Average		1862.78	1403.69	1095.24	738.85	282.155	228.89	153.72	79.93	41.615	27.185	17.24	12.76	7.585	4.19	1.705	0.93		
Flow Ajusted		1928.44	1453.17	1133.84	764.895	292.101	236.95843	159.1387	82.74755	41.557	27.147	17.2161	12.742	7.574471	4.18418	1.702633			
Volume, um^3		6365.8	11995.7	33386	87649.9	44125	43130.364	44198.5	65405.76	97715	78541	74001.3	79584	98342.81	132674	78279.76			
Log10 PSD		3.02831	2.99549	3.13566	3.26412	2.66954	2.3528664	2.063681	1.914524	1.7869	1.4103	1.09369	0.8173	0.604836	0.42975	-0.104353			
14 May pm	r* >	2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5				
		Log10 r*	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967			
Average		2857.41	2336.85	1704.07	672.29	291.60	234.50	156.56	31.39	14.08	6.22	3.06	1.73	1.14	0.47	0.29			
Flow Ajusted		2786.97	2279.53	1655.73	641.02	278.98	221.52	148.53	28.65	12.57	5.57	2.76	1.62	1.07	0.47	4,062			
Volume, um^3		6,052	9,400	19,209	39,031	22,417	32,498	75,674	97,731	102,901	107,524	141,589	160,278	161,952	77,644	1,053,901			
Log10 PSD		3.00638	2.88959	2.89560	2.91278	2.37544	2.22994	2.09638	1.78693	1.52760	1.25596	1.06749	0.81697	0.51635	-0.10790				


Collective Particle Size Distribution
MUW_A


Collective Particle Size Distribution
MUW_A


Log10 Particle Size Distribution


Volume Distribution

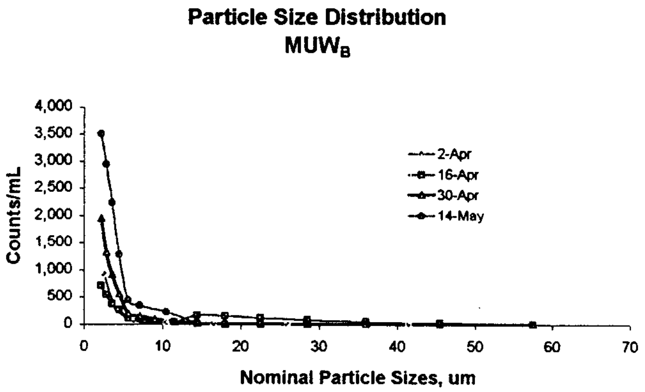
Correlation Coefficients

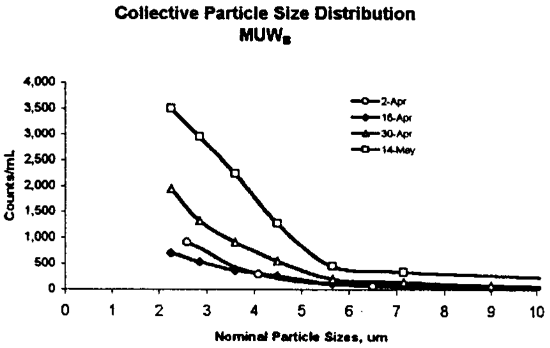
Date	R^2	R
2-Apr	0.9882	0.99408
16-Apr	0.9702	0.98499
30-Apr	0.9588	0.97918
7-May	0.9505	0.97494
14-May	0.9642	0.98194

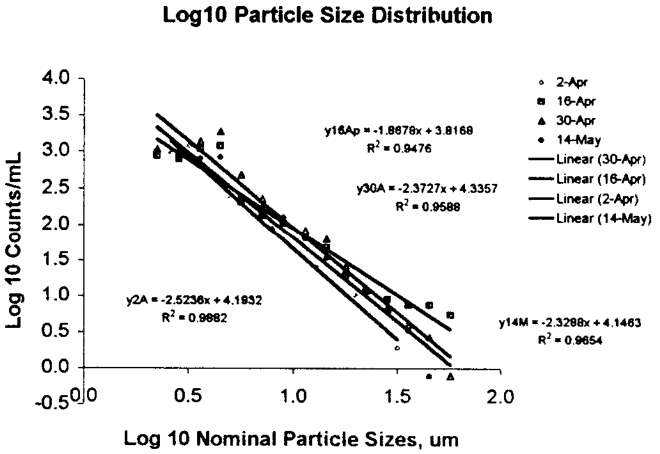
Collective PCX Test of all MUW$_B$ Data (less FDDW)

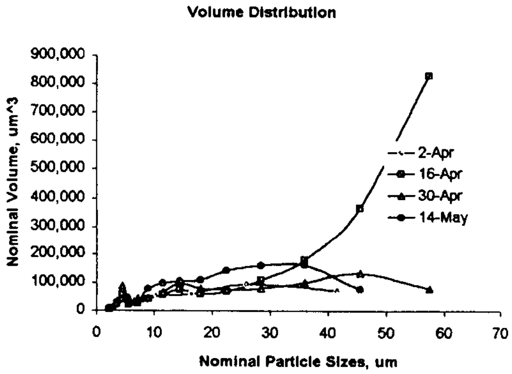
2-Apr	r' >	2.6	4.1	6.5	10.5	16.5	26	41.5	
	Log10 r'	0.41497	0.50515	0.69897	0.90309	1.11394	1.30103	1.50515	
Average		911.96	291.03	56.78	22.64	8.06	3.83	1.43	0.77
Volume, um^3		8,929	42,661	35,529	53,502	59,360	95,306	71,104	
Log10 PSD		2.98687	3.07268	2.39284	1.94581	1.40205	1.01520	0.27875	

		<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
	I >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	256
	r' >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	160	
	Log10 r'	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
16-Apr																		
Average		700.40	531.36	361.09	255.73	105.72	98.95	50.76	30.40	161.63	157.37	119.31	88.07	45.31	18.21	4.23	0.45	
Flow Ajusted		703.99	534.08	362.94	257.04	106.26	99.46	51.02	30.56	162.46	158.18	119.92	88.52	45.54	18.30	4.25	0.45	
Volume, um^3		5,116	9,311	26,050	56,386	19,294	25,794	39,704	55,994	74,163	59,493	68,645	107,921	181,132	366,615	829,401	1,787,382	
Log10 PSD		2.93339	2.88547	3.02790	3.07254	2.31028	2.12961	2.01711	1.84705	1.66709	1.28965	1.06107	0.94957	0.87009	0.87118	0.74113		
30-Apr																		
Average		1881.33	1278.58	877.531	536.375	194.069	144.18125	87.7375	42.975	20.9625	13.4375	8.33125	5.525	3.3375	1.61875	0.64375	1.46875	
Flow Ajusted		1947.65	1323.65	908.464	555.282	200.91	149.263678	90.83027	44.48988	20.9334	13.4188	8.319686	5.51733	3.3328673	1.616503	0.6428564	1.4667113	
Volume, um^3		6365.8	11995.7	33386	87649.9	44125	43130.364	44198.5	65405.762	97714.7	78540.8	74001.3	79584	98342.808	132674.3	78279.757	92520.733	
Log10 PSD		3.02831	2.99549	3.13566	3.26412	2.66954	2.35286638	2.063681	1.9145239	1.78686	1.41028	1.093693	0.81729	0.6048365	0.429754	-0.104353		
14-May	r' >	2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5			
		Log10 r'	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801			
Average		3570.22	3005.61	2280.97	1308.18	456.76	354.23	228.21	36.77	17.94	9.30	5.84	3.63	2.06	0.43			
Flow Ajusted		3499.78	2948.30	2232.63	1276.90	444.15	341.25	220.18	34.03	16.43	8.65	5.54	3.52	2.00	0.43			
Volume, um^3		6,052	9,400	19,209	39,031	22,417	32,498	75,674	97,731	102,901	107,524	141,589	160,278	161,952	77,644			
Log10 PSD		3.00638	2.88959	2.89560	2.91278	2.37544	2.22994	2.09638	1.78693	1.52760	1.25596	1.06749	0.81697	0.51635	-0.10790			


Particle Size Distribution
MUW$_B$


Collective Particle Size Distribution
MUW$_B$


Log10 Particle Size Distribution


Volume Distribution

Correlation Coefficients

Date	R^2	R
2-Apr	0.9882	0.99408
16-Apr	0.9702	0.98499
30-Apr	0.9588	0.97918
14-May	0.9642	0.98194

Particle Size Analysis

PCX Results for samples taken 2 April 01.

The PCX particle counters were set up in separately in two x eight channels spans:

Wide span (A): 2-4, 4-8, 8-16, 16-32, 32-64, 64-128, 128-256, >256 µm

and

Narrow span (B): 2-3.2, 3.2-5, 5-8, 8-13, 13-20, 20-32, 32-51, >51 µm

and

Low span (C): 1-2, 2-4, 4-8, 8-16, 16-32, 32-64, 64-128, >128 µm

There was adjustment for variation in flow rates but no adjustment for cell noise.

Results log:

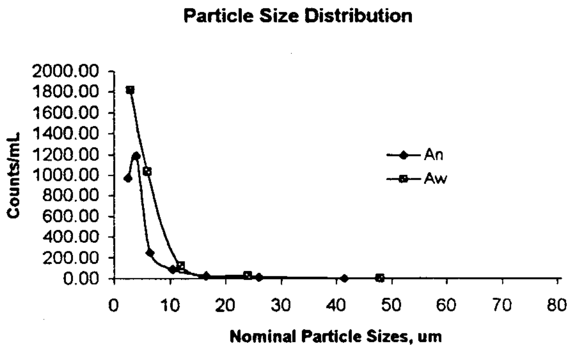
Site>	**A**	**B**	**C**	**D**	**E**	**SD**	**BF$_A$**	**BF$_B$**	**G$_A$**	**G$_B$**	**MW$_A$ 1**	**MW$_A$ 2**	**MW$_B$**	**I/J**	**D2**
A	√	√	√	√	√	√	√	√	√	√	√		√	√	
B	√	√	√	√	√	√	√	√	√	√	√		√		
C						√									√

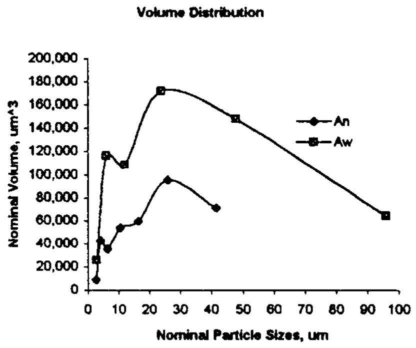
PCX Test of A Data, 2-51 & 2-256 Ranges

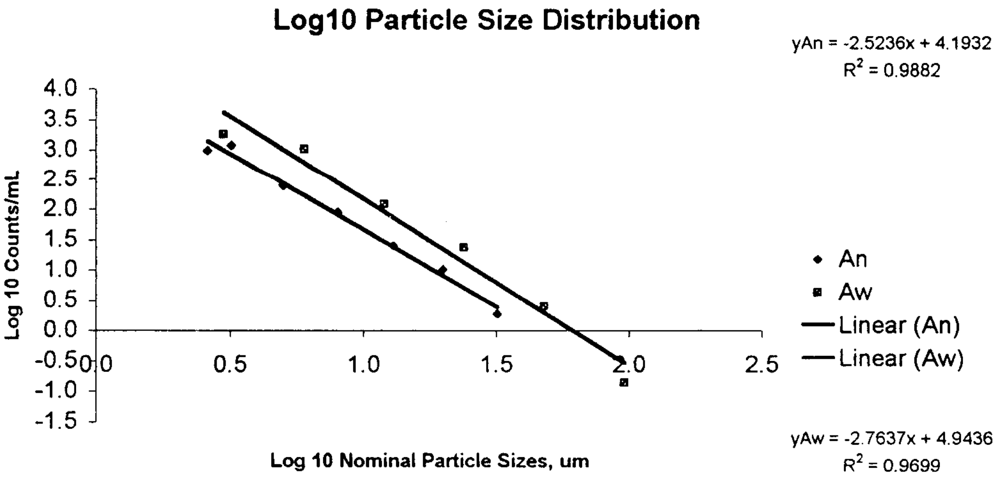
Sampled 2-Apr-01
Tested 3-Apr-01
Flow rate 100 mL
Sample time 2 min

	Class >	2-3.2	3.2-5	5-8	8-13	13-20	20-32	32-51	
	li >	2	3.2	5	8	13	20	32	51
	l* >	2.6	4.1	6.5	10.5	16.5	26	41.5	
	Log10 l* >	0.41497	0.50515	0.69897	0.90309	1.11394	1.30103	1.50515	
	Jar	Particles/mL							
An									
2001/04/03 14:36	D1	957.85	1183.68	244.83	84.75	25.03	11.00	1.80	
2001/04/03 14:38	D1	986.08	1208.45	252.53	91.68	25.80	10.85	2.10	
2001/04/03 14:40	D1	957.08	1153.48	245.33	87.85	24.08	9.58	1.88	
2001/04/03 14:42	D1	979.88	1183.05	245.65	88.80	26.05	10.00	1.83	
Average		970.22	1182.16	247.08	88.27	25.24	10.36	1.90	2577.48
Volume, um^3		8,929	42,661	35,529	53,502	59,360	95,306	71,104	366,391
Log10 PSD		2.98687	3.07268	2.39284	1.94581	1.40205	1.01520	0.27875	
Log10 Volume		3.95079	4.63003	4.55058	4.72837	4.77350	4.97912	4.85190	

	Class >	2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256
	li >	2	4	8	16	32	64	128	256
	l* >	3	6	12	24	48	96	192	
	Log10 l* >	0.47712	0.77815	1.07918	1.38021	1.68124	1.98227	2.28330	
	Jar	Particles/mL							
Aw									
2001/04/03 14:36	D1	1760.98	1006.28	116.70	24.28	2.45	0.18	0.00	0.00
2001/04/03 14:38	D1	1794.90	1032.78	118.65	24.23	2.93	0.10	0.00	0.00
2001/04/03 14:40	D1	1831.58	1033.48	121.40	22.85	2.25	0.08	0.00	0.00
2001/04/03 14:42	D1	1860.83	1047.13	122.38	23.58	2.60	0.20	0.00	0.00
Average		1812.07	1029.91	119.78	23.73	2.56	0.14	0.00	2973.58
Volume, um^3		25,618	116,480	108,376	171,772	148,022	63,696		633,964
Log10 PSD		3.25817	3.01280	2.07839	1.37532	0.40760	-0.86170		
Log10 Volume		4.40854	5.06625	5.03493	5.23495	5.17033	4.80412		





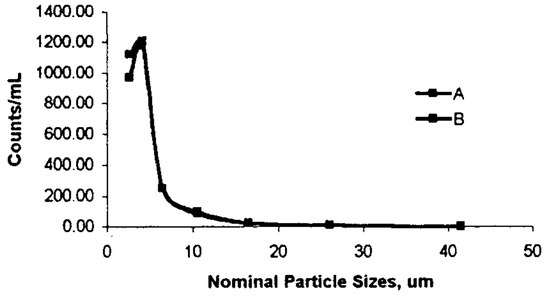


PCX Test of A and B Data, 2-51 Range
Flow rate 100 mL
Sample time 2 min

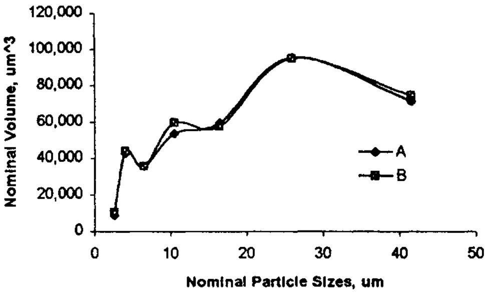
Sampled 2-Apr-01
Tested 3-Apr-01

Class >		2-3.2	3.2-5	5-8	8-13	13-20	20-32	32-51	
li >		2	3.2	5	8	13	20	32	51
l* >		2.6	4.1	6.5	10.5	16.5	26	41.5	
Log10 l* >		0.41497	0.50515	0.69897	0.90309	1.11394	1.30103	1.50515	
	Jar	Particles/mL							
A									
2001/04/03 14:36	D1	957.85	1183.68	244.83	84.75	25.03	11.00	1.80	
2001/04/03 14:38	D1	986.08	1208.45	252.53	91.68	25.80	10.85	2.10	
2001/04/03 14:40	D1	957.08	1153.48	245.33	87.85	24.08	9.58	1.88	
2001/04/03 14:42	D1	979.88	1183.05	245.65	88.80	26.05	10.00	1.83	
Average		970.22	1182.16	247.08	88.27	25.24	10.36	1.90	2577.48
Volume, um^3		8,929	42,661	35,529	53,502	59,360	95,306	71,104	366,391
Log10 PSD		2.98687	3.07268	2.39284	1.94581	1.40205	1.01520	0.27875	
Log10 Volume		3.95079	4.63003	4.55058	4.72837	4.77350	4.97912	4.85190	
									V ol = pi x l*^3 /6 x No. Particles in bin
B									
2001/04/03 14:48	D2	1032.13	1159.95	234.55	93.85	23.38	9.50	1.70	
2001/04/03 14:50	D2	1073.70	1179.93	241.13	96.88	23.95	9.88	1.73	
2001/04/03 14:56	D2	1200.58	1282.83	266.75	105.88	24.53	11.13	2.45	
2001/04/03 14:58	D2	1150.18	1218.18	243.63	97.28	25.25	10.93	1.95	
2001/04/03 15:00	D2	1162.00	1207.58	252.68	96.48	24.43	10.03	2.10	
Average		1123.72	1209.69	247.75	98.07	24.31	10.29	1.99	2894.13
Volume, um^3		10,341	43,654	35,624	59,443	57,167	94,697	74,285	375,212
Log10 PSD		3.05066	3.08267	2.39400	1.99154	1.38570	1.01242	0.29776	
Log10 Volume		4.01457	4.64002	4.55174	4.77410	4.75715	4.97633	4.87090	

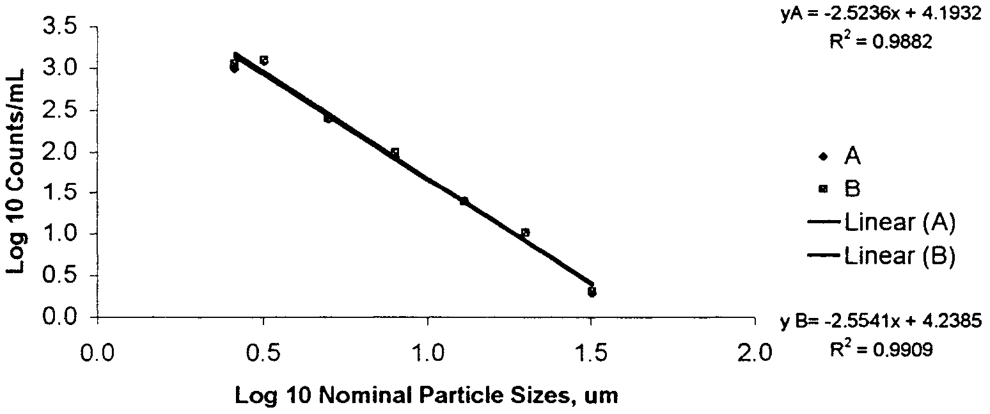
Particle Size Distribution



Volume Distribution



Log10 Particle Size Distribution

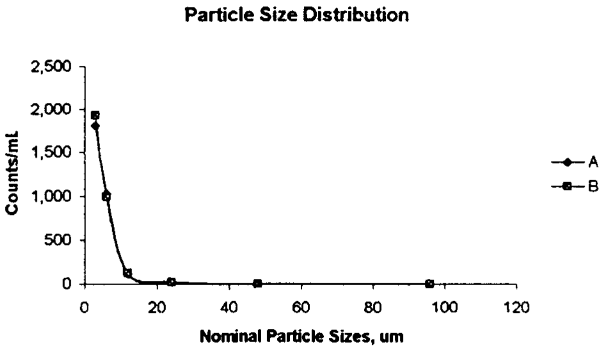


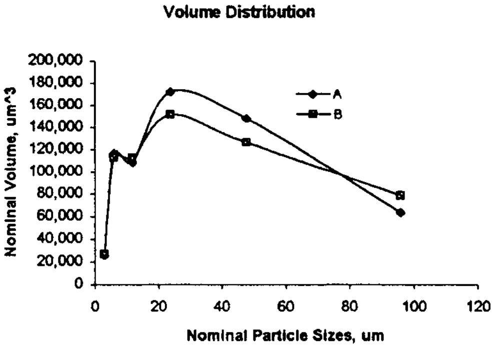
PCX Test of A and B Data, 2-265 Range

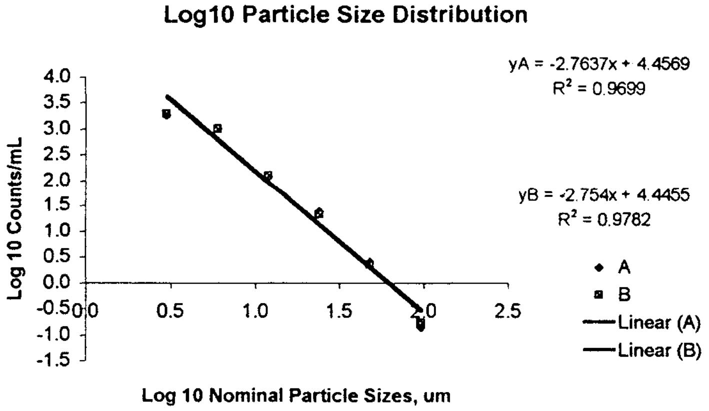
PCX2	Flow rate	100 mL	Sampled	2-Apr-01
	Sample tim	2 min	Tested	3-Apr-01

	Jar	Site										
			Class >	2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256	
			li >	2	4	8	16	32	64	128	256	
			l* >	3	6	12	24	48	96	192		
			Log10 l* >	0.47712	0.77815	1.07918	1.38021	1.68124	1.98227	2.28330		
	Jar	Site		Particles/mL								
A												
2001/04/03 14:36	D1			1760.98	1006.28	116.70	24.28	2.45	0.18	0.00	0.00	
2001/04/03 14:38	D1			1794.90	1032.78	118.65	24.23	2.93	0.10	0.00	0.00	
2001/04/03 14:40	D1			1831.58	1033.48	121.40	22.85	2.25	0.08	0.00	0.00	
2001/04/03 14:42	D1			1860.83	1047.13	122.38	23.58	2.60	0.20	0.00	0.00	
Average				1812.07	1029.91	119.78	23.73	2.56	0.14	0.00	2973.58	
Volume, um^3				25,618	116,480	108,376	171,772	148,022	63,696		633,964	
Log10 PSD				3.25817	3.01280	2.07839	1.37532	0.40760	-0.86170			
Log10 Volume				4.40854	5.06625	5.03493	5.23495	5.17033	4.80412			
B												
2001/04/03 14:48	D2			1876.15	977.38	125.73	21.18	2.43	0.18	0.00	0.00	
2001/04/03 14:50	D2			1892.00	989.78	123.78	21.15	2.08	0.13	0.00	0.00	
2001/04/03 14:56	D2			1901.70	977.25	118.63	20.20	2.53	0.15	0.00	0.00	
2001/04/03 14:58	D2			1965.45	1008.25	126.38	21.28	2.00	0.23	0.00	0.00	
2001/04/03 15:00	D2			1988.28	1001.75	126.53	20.60	1.88	0.18	0.00	0.00	
Average				1924.72	990.88	124.21	20.88	2.18	0.17	0.00		3020.45
Volume, um^3				27,210	112,066	112,378	151,134	126,235	78,752	0		607,775
Log10 PSD				3.28437	2.99602	2.09414	1.31973	0.33846	-0.76955			
Log10 Volume				4.43473	5.04947	5.05068	5.17936	5.10118	4.89626			

V ol = pi x l*^3 /6 x No. Particles in bin







PCX Test of B Data, 2-51 & 2-256 Ranges

Flow rate 100 mL

Sampled 2-Apr-01

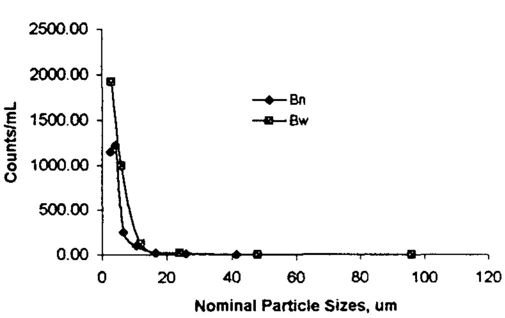
Tested 3-Apr-01

Sample time 2 min

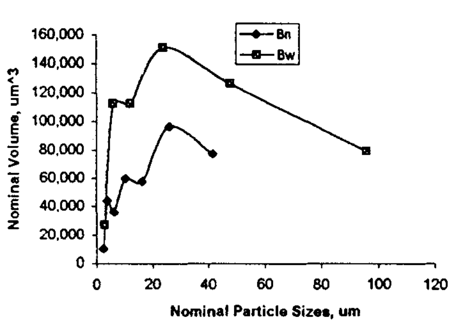
Class >		2-3.2	3.2-5	5-8	8-13	13-20	20-32	32-51	
li >		2	3.2	5	8	13	20	32	51
I* >		2.6	4.1	6.5	10.5	16.5	26	41.5	
Log10 I* >		0.41497	0.50515	0.69897	0.90309	1.11394	1.30103	1.50515	
	Jar	Particles/mL							
Bn									
2001/04/03 14:48	D2	1032.13	1159.95	234.55	93.85	23.38	9.50	1.70	
2001/04/03 14:50	D2	1073.70	1179.93	241.13	96.88	23.95	9.88	1.73	
2001/04/03 14:56	D2	1200.58	1282.83	266.75	105.88	24.53	11.13	2.45	
2001/04/03 14:58	D2	1150.18	1218.18	243.63	97.28	25.25	10.93	1.95	
2001/04/03 15:00	D2	1162.00	1207.58	252.68	96.48	24.43	10.03	2.10	
Average		1146.61	1222.13	251.04	99.13	24.54	10.49	2.06	2894.13
Volume, um^3		10,552	44,103	36,098	60,083	57,714	96,514	76,952	382,016
Log10 PSD		3.05942	3.08712	2.39975	1.99618	1.38983	1.02067	0.31308	
Log10 Volume		4.02334	4.64447	4.55749	4.77875	4.76128	4.98459	4.88622	

Class >		2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256
li >		2	4	8	16	32	64	128	256
I* >		3	6	12	24	48	96	192	
Log10 I* >		0.47712	0.77815	1.07918	1.38021	1.68124	1.98227	2.28330	
	Jar	Particles/mL							
Bw									
2001/04/03 14:48	D2	1876.15	977.38	125.73	21.18	2.43	0.18	0.00	0.00
2001/04/03 14:50	D2	1892.00	989.78	123.78	21.15	2.08	0.13	0.00	0.00
2001/04/03 14:56	D2	1901.70	977.25	118.63	20.20	2.53	0.15	0.00	0.00
2001/04/03 14:58	D2	1965.45	1008.25	126.38	21.28	2.00	0.23	0.00	0.00
2001/04/03 15:00	D2	1988.28	1001.75	126.53	20.60	1.88	0.18	0.00	0.00
Average		1924.72	990.88	124.21	20.88	2.18	0.17	0.00	3020.45
Volume, um^3		27,210	112,066	112,378	151,134	126,235	78,752		607,775
Log10 PSD		3.28437	2.99602	2.09414	1.31973	0.33846	-0.76955		
Log10 Volume		4.43473	5.04947	5.05068	5.17936	5.10118	4.89626		

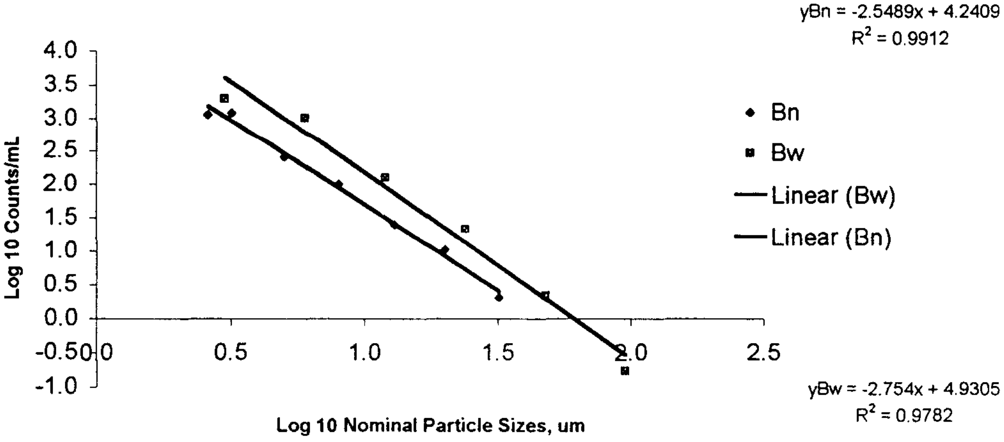
Particle Size Distribution



Volume Distribution



Log10 Particle Size Distribution



PCX Test of BF Data, 2-81 Range Sampled 2-Apr-01

PCXdat3Apra Flow rate 100 mL Tested 3-Apr-01

Sample ti 2 min

Class >	2-3.2	3.2-5	5-8	8-13	13-20	20-32	32-51	51-81	
Ii >	2	3.2	5	8	13	20	32	51	81
I* >	2.6	4.1	6.5	10.5	16.5	26	41.5	66	
Log10 I* >	0.41497	0.61278	0.81291	1.02119	1.21748	1.41497	1.61805	1.81954	

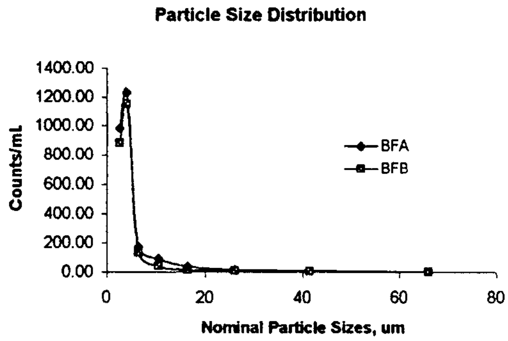
BF_A Biofilter A out

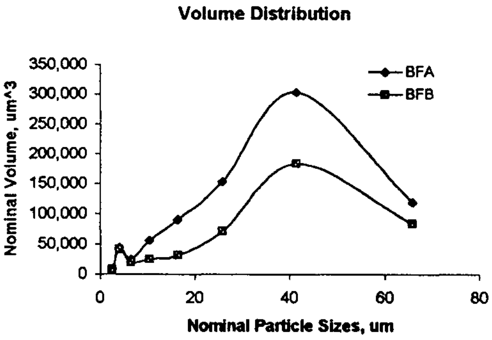
	Jar	Site	Particles/mL							
2001/04/04 09:31	D6	953.63	1199.60	161.50	83.58	32.93	14.98	9.93	0.95	
2001/04/04 09:33	D6	995.25	1256.98	174.20	94.63	39.93	19.60	7.78	0.78	
2001/04/04 09:35	D6	988.15	1249.25	180.03	99.95	42.63	15.93	8.30	0.80	
2001/04/04 09:37	D6	990.55	1218.05	180.15	93.03	38.08	16.13	6.50	0.68	
Average		981.89	1230.97	173.97	92.79	38.39	16.66	8.13	0.80	2580.58
Volume, um^3		9,036	44,422	25,016	56,245	90,290	153,284	304,065	120,426	682,357
Log10 PSD		2.99206	3.09025	2.24047	1.96752	1.58419	1.22158	0.90982	-0.09691	
Log10 Volume		3.95598	4.64760	4.39821	4.75009	4.95564	5.18550	5.48297	5.08072	

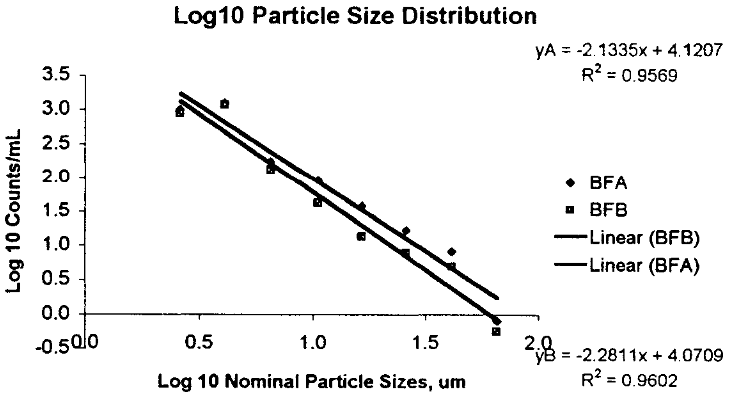
V ol = pi x I*^3 /6 x No. Particles in bin

BF_B Biofilter B out

2001/04/04 09:41	D7	890.38	1162.35	130.30	42.38	14.18	11.73	13.28	1.15	
2001/04/04 09:43	D7	892.03	1166.58	133.98	40.08	12.58	6.48	3.23	0.43	
2001/04/04 09:45	D7	872.88	1153.70	132.58	42.85	13.48	6.48	1.58	0.33	
2001/04/04 09:47	D7	864.85	1121.60	133.60	40.08	12.98	6.33	1.50	0.33	
Average		880.03	1151.06	132.61	41.34	13.30	7.75	4.89	0.56	
Volume, um^3		8,099	41,538	19,069	25,060	31,283	71,321	183,141	83,734	379,510
Log10 PSD		2.94450	3.06110	2.12258	1.61641	1.12385	0.88930	0.68964	-0.25473	
Log10 Volume		3.90842	4.61845	4.28032	4.39898	4.49530	4.85322	5.26278	4.92290	



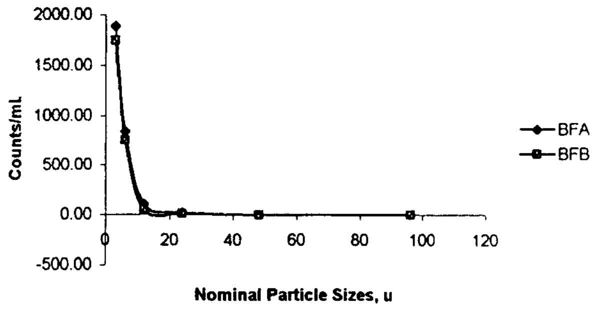




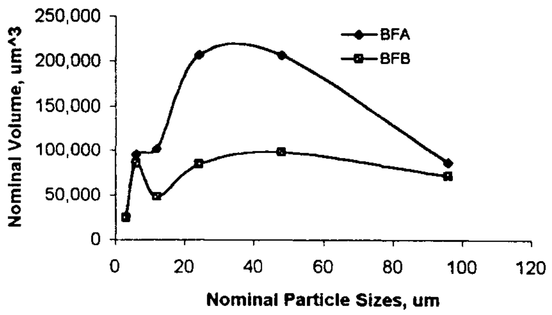
PCX Test of BF_A and BF_B Data, 2-128 Range Sampled 2-Apr-01
PCXdat3Apra Flow rate 100 mL Tested 4-Apr-01
Sampl 2 min

Class		2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256	
li >		2	4	8	16	32	64	128	256	
l* >		3	6	12	24	48	96	192		
Log10 l*		0.47712	0.77815	1.07918	1.38021	1.68124	1.98227	2.28330		
	Jar	Site	Particles/mL							
BF_A	A Line Biofilter exit									
2001/04/04 09:	D6	1851.38	827.93	100.60	26.80	3.48	0.18	0.00	0.00	
2001/04/04 09:	D6	1908.25	843.78	116.45	28.88	3.70	0.23	0.00	0.00	
2001/04/04 09:	D6	1905.80	854.15	117.53	29.83	3.90	0.23	0.00	0.00	
2001/04/04 09:	D6	1899.60	859.20	117.15	29.25	3.28	0.13	0.00	0.00	
Average		1891.26	846.26	112.93	28.69	3.59	0.19	0.00		2901.28
Volume, um^3		26,737	95,710	102,178	207,647	207,737	86,859			726,867
Log10 PSD		3.27675	2.92751	2.05281	1.45769	0.55479	-0.72700			
Log10 Volume		4.42711	4.98096	5.00936	5.31733	5.31751	4.93881			
								V ol = pi x l*^3 /6 x No. Particles in bin		
BF_B	B Line Biofilter exit									
2001/04/04 09:	D7	1760.58	739.48	51.63	11.68	1.70	0.03	0.00	0.00	
2001/04/04 09:	D7	1749.38	755.73	53.15	12.08	1.58	0.03	0.00	0.00	
2001/04/04 09:	D7	1753.58	769.18	54.83	12.03	2.35	0.50	0.00	0.00	
2001/04/04 09:	D7	1742.08	759.55	53.28	11.20	1.18	0.08	0.00	0.00	
Average		1751.40	755.98	53.22	11.74	1.70	0.16	0.00	0.00	
Volume, um^3		24,760	85,499	48,151	85,004	98,440	72,382	0		414,237
Log10 PSD		3.24339	2.87851	1.72606	1.06981	0.23045	-0.80618			
Log10 Volume		4.39375	4.93196	4.68261	4.92944	4.99317	4.85963			

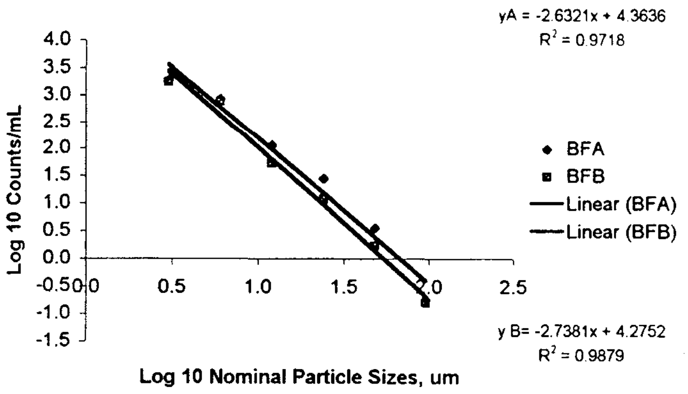
Particle Size Distribution



Volume Distribution

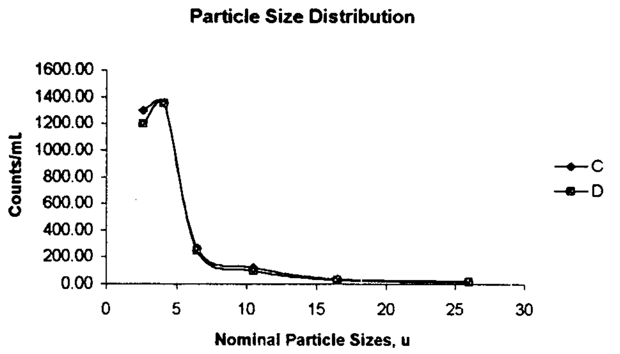


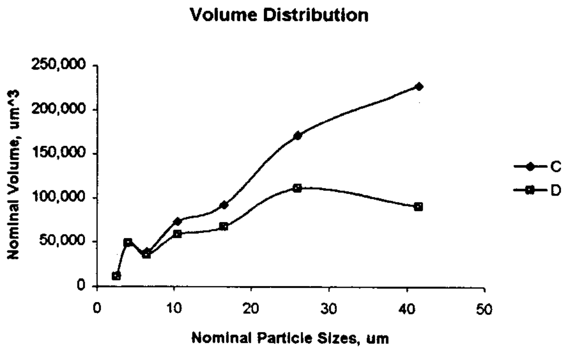
Log10 Particle Size Distribution

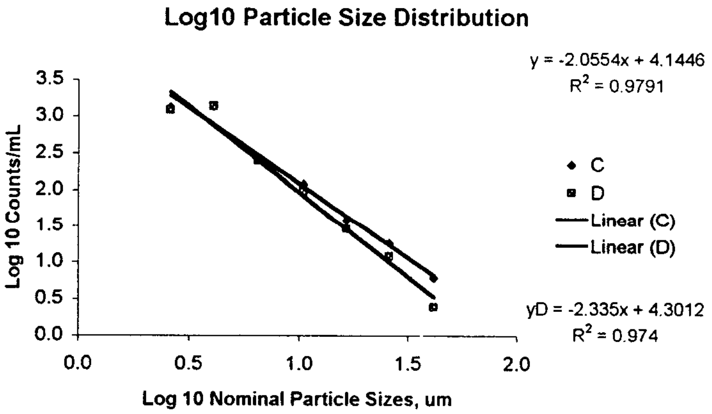


PCX Test of C and D Data, 2-51 Range

		Flow rate		100 mL		Sampled	2-Apr-01		
		Sample time		2 min		Tested	3-Apr-01		
	Class >	2-3.2	3.2-5	5-8	8-13	13-20	20-32	32-51	51
	li >	2	3.2	5	8	13	20	32	51
	l* >	2.6	4.1	6.5	10.5	16.5	26	41.5	
	Log10 l* >	0.41497	0.61278	0.81291	1.02119	1.21748	1.41497	1.61805	
	Jar	Site	Particles/mL						
C	swirl exit								
2001/04/03 15:04	D3	1335.78	1398.50	311.53	168.45	56.25	33.18	16.83	
2001/04/03 15:06	D3	1255.40	1333.93	249.90	104.28	33.80	15.23	3.25	
2001/04/03 15:08	D3	1269.80	1344.53	252.88	108.03	35.18	14.83	3.45	
2001/04/03 15:10	D3	1295.05	1343.23	253.50	109.75	34.93	14.63	3.23	
2001/04/03 15:12	D3	1323.15	1360.18	263.85	109.15	34.68	15.13	3.68	
Average		1295.84	1356.07	266.33	119.93	38.97	18.60	6.09	3028.68
Volume, um^3		11,925	48,936	38,296	72,693	91,648	171,126	227,721	662,347
Log10 PSD		3.11255	3.13228	2.42542	2.07893	1.59067	1.26940	0.78426	
Log10 Volume		4.07647	4.68963	4.58316	4.86149	4.96213	5.23331	5.35740	
									V ol = pi x l*^3 /6 x No. Particles in bin
D	Spipe Out								
2001/04/03 15:18	D4	1174.98	1346.13	241.90	98.35	29.10	12.48	2.35	
2001/04/03 15:20	D4	1172.15	1335.80	241.05	93.28	28.43	11.98	2.70	
2001/04/03 15:22	D4	1195.18	1338.65	243.88	96.40	28.30	12.20	1.98	
2001/04/03 15:24	D4	1235.20	1376.65	256.00	96.98	28.45	11.63	2.63	
Average		1194.38	1349.31	245.71	96.25	28.57	12.07	2.41	2885.38
Volume, um^3		10,992	48,692	35,331	58,340	67,196	111,066	90,284	421,901
Log10 PSD		3.07714	3.13011	2.39042	1.98340	1.45589	1.08166	0.38247	
Log10 Volume		4.04106	4.68746	4.54815	4.76597	4.82734	5.04558	4.95561	

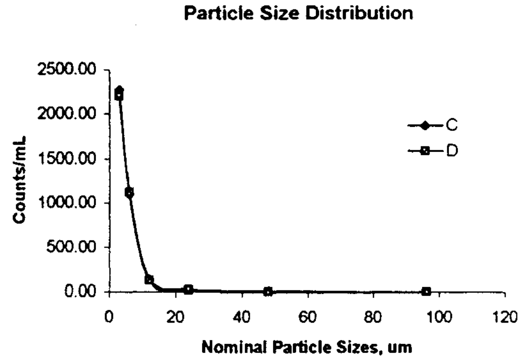


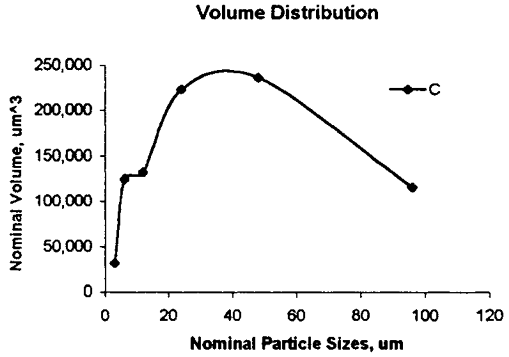


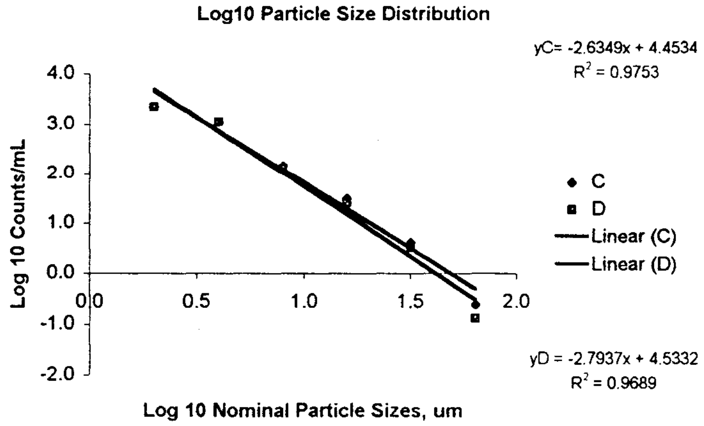


PCX Test of C and D Data, 2-128 Range Sampled 2-Apr-01
PCXdat3Apra Flow rate 100 mL Tested 3-Apr-01
Sampl 2 min

	Class	2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256	
	li >	2	4	8	16	32	64	128	256	
	I* >	3	6	12	24	48	96	192		
	Log10 I*	0.30103	0.60206	0.90309	1.20412	1.50515	1.80618	2.10721		
	Jar	Site	Particles/mL							
C	wirl exit									
2001/04/03 15:	D3	2241.68	1086.80	145.08	30.28	4.45	0.15	0.00	0.00	
2001/04/03 15:	D3	2246.78	1096.48	146.18	28.88	3.95	0.20	0.00	0.00	
2001/04/03 15:	D3	2275.65	1110.55	146.40	31.85	4.25	0.33	0.00	0.00	
2001/04/03 15:	D3	2323.63	1123.63	146.58	32.73	3.70	0.33	0.00	0.00	
Average		2271.93	1104.36	146.06	30.93	4.09	0.25	0.00		3522.45
Volume, um^3		32,119	124,900	132,149	223,887	236,690	115,812			865,557
Log10 PSD		3.35640	3.04311	2.16452	1.49040	0.61146	-0.60206			
Log10 Volume		4.50676	5.09656	5.12106	5.35003	5.37418	5.06375			
								V ol = pi x I*^3 /6 x No. Particles in bin		
D	Spipe Out									
2001/04/03 15:	D4	2159.55	1106.35	128.30	24.58	3.45	0.13	0.00	0.00	
2001/04/03 15:	D4	2182.58	1119.70	127.33	24.80	3.18	0.13	0.00	0.00	
2001/04/03 15:	D4	2209.20	1125.48	127.00	25.23	3.03	0.10	0.00	0.00	
2001/04/03 15:	D4	2260.38	1142.43	132.93	25.65	3.53	0.18	0.00	0.00	
Average		2202.93	1123.49	128.89	25.06	3.29	0.13	0.00	0.00	
Volume, um^3		31,143	127,063	116,615	181,408	190,727	60,801	0		707,758
Log10 PSD		3.34300	3.05057	2.11021	1.39902	0.51769	-0.88190			
Log10 Volume		4.49336	5.10402	5.06675	5.25866	5.28041	4.78391			


Particle Size Distribution


Volume Distribution


Log10 Particle Size Distribution

PCX Test of D and E Data, 2-51 Range

PCXdat3Apra	Flow rate	100 mL			Sampled		2-Apr-01			
	Sample ti	2 min			Tested		3-Apr-01			
	Class >	2-3.2	3.2-5	5-8	8-13	13-20	20-32	32-51		
	li >	2	3.2	5	8	13	20	32	51	
	l* >	2.6	4.1	6.5	10.5	16.5	26	41.5		
	Log10 l* >	0.41497	0.61278	0.81291	1.02119	1.21748	1.41497	1.61805		

D Stand Pipe out

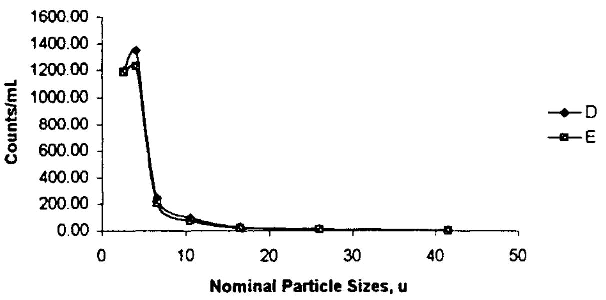
Jar	Site	Particles/mL								
2001/04/03 15:18	D4	1174.98	1346.13	241.90	98.35	29.10	12.48	2.35	0.00	
2001/04/03 15:20	D4	1172.15	1335.80	241.05	93.28	28.43	11.98	2.70	0.00	
2001/04/03 15:22	D4	1195.18	1338.65	243.88	96.40	28.30	12.20	1.98	0.00	
2001/04/03 15:24	D4	1235.20	1376.65	256.00	96.98	28.45	11.63	2.63	0.00	
Average		1194.38	1349.31	245.71	96.25	28.57	12.07	2.41		2882.68
Volume, um^3		10,992	48,692	35,331	58,340	67,196	111,066	90,284		421,901
Log10 PSD		3.07714	3.13011	2.39042	1.98340	1.45589	1.08166	0.38247		
Log10 Volume		4.04106	4.68746	4.54815	4.76597	4.82734	5.04558	4.95561		

V ol = pi x l*^3 /6 x No. Particles in bin

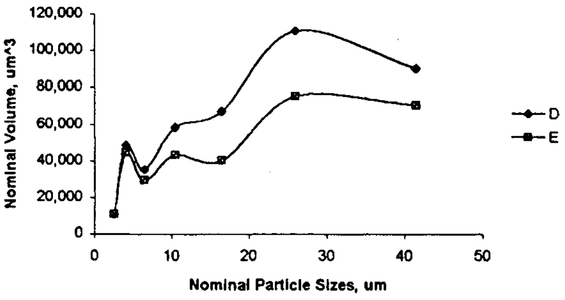
E Drum Filt 1 out

2001/04/03 15:30	D5	1197.93	1260.18	207.18	73.70	17.85	9.18	1.48	0.00	
2001/04/03 15:32	D5	1142.83	1206.20	200.38	71.10	17.58	8.30	2.13	0.00	
2001/04/03 15:34	D5	1155.58	1205.38	203.45	69.95	16.63	7.73	2.53	0.00	
2001/04/03 15:36	D5	1245.68	1255.85	211.15	72.28	16.58	7.48	1.38	0.00	
Average		1185.50	1231.90	205.54	71.76	17.16	8.17	1.88	0.00	
Volume, um^3		10,910	44,456	29,555	43,494	40,353	75,175	70,169		314,111
Log10 PSD		3.07390	3.09058	2.31289	1.85586	1.23442	0.91216	0.27300		
Log10 Volume		4.03782	4.64793	4.47063	4.63843	4.60587	4.87607	4.84614		

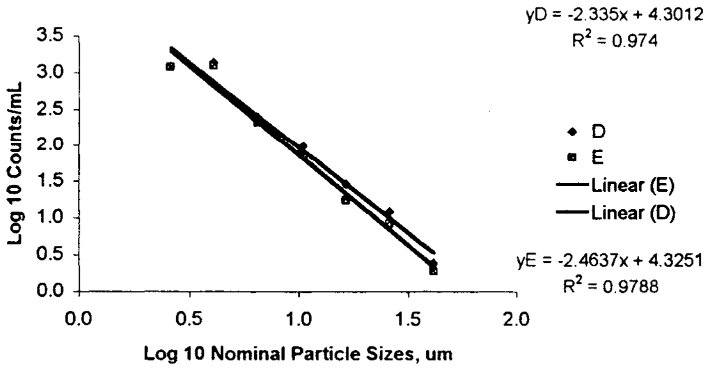
Particle Size Distribution



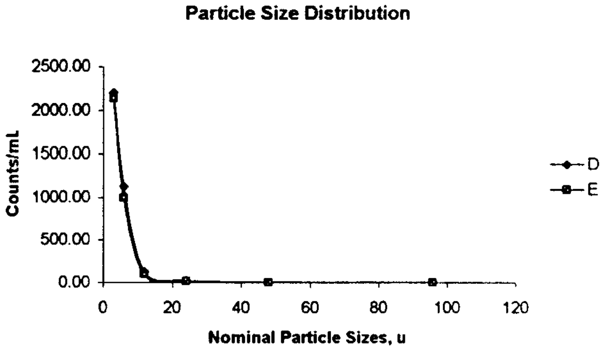
Volume Distribution

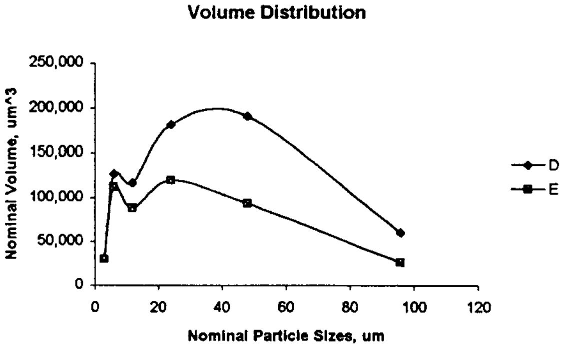


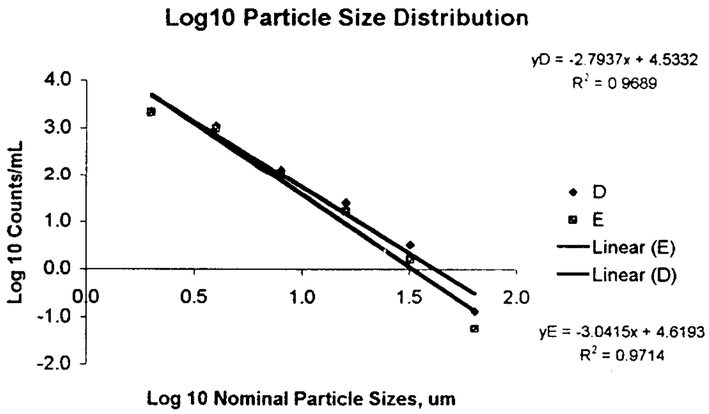
Log10 Particle Size Distribution



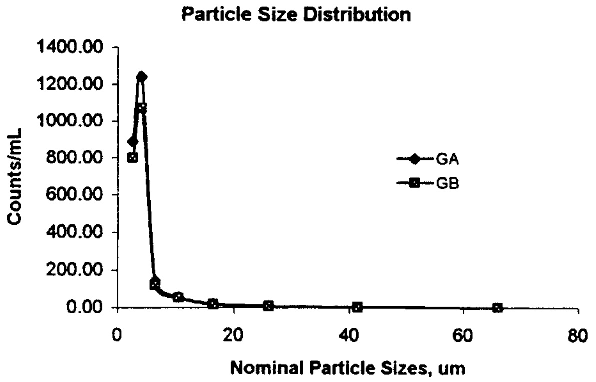
PCX Test of D and E Data, 2-128 Range						Sampled	2-Apr-01			
PCXdat3Apra	Flow rate	100	mL		Tested	3-Apr-01				
	Sample ti	2	min							
	Class >	2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256	
	Ii >	2	4	8	16	32	64	128	256	
	I* >	3	6	12	24	48	96	192		
		Log10 I* >	0.30103	0.60206	0.90309	1.20412	1.50515	1.80618	2.10721	
D	Stand Pipe out									
	Jar	Site	Particles/mL							
2001/04/03 15:	D4	2159.55	1106.35	128.30	24.58	3.45	0.13	0.00	0.00	
2001/04/03 15:	D4	2182.58	1119.70	127.33	24.80	3.18	0.13	0.00	0.00	
2001/04/03 15:	D4	2209.20	1125.48	127.00	25.23	3.03	0.10	0.00	0.00	
2001/04/03 15:	D4	2260.38	1142.43	132.93	25.65	3.53	0.18	0.00	0.00	
Average		2202.93	1123.49	128.89	25.06	3.29	0.13	0.00		3457.70
Volume, um^3		31,143	127,063	116,615	181,408	190,727	60,801			707,758
Log10 PSD		3.34300	3.05057	2.11021	1.39902	0.51769	-0.88190			
Log10 Volume		4.49336	5.10402	5.06675	5.25866	5.28041	4.78391			
								V ol = pi x I*^3 /6 x No. Particles in bin		
E	Drum Filt 1 out									
2001/04/03 15:	D5	2086.65	977.68	94.90	17.08	1.73	0.03	0.00	0.00	
2001/04/03 15:	D5	2089.48	988.35	100.88	15.33	1.65	0.10	0.00	0.00	
2001/04/03 15:	D5	2140.03	991.03	97.25	16.78	1.45	0.03	0.00	0.00	
2001/04/03 15:	D5	2237.00	1011.78	97.60	16.70	1.60	0.08	0.00	0.00	
Average		2138.29	992.21	97.66	16.47	1.61	0.06	0.00	0.00	
Volume, um^3		30,229	112,216	88,357	119,205	93,011	26,058	0		469,076
Log10 PSD		3.33007	2.99660	1.98970	1.21666	0.20581	-1.24988			
Log10 Volume		4.48043	5.05005	4.94624	5.07629	4.96854	4.41593			

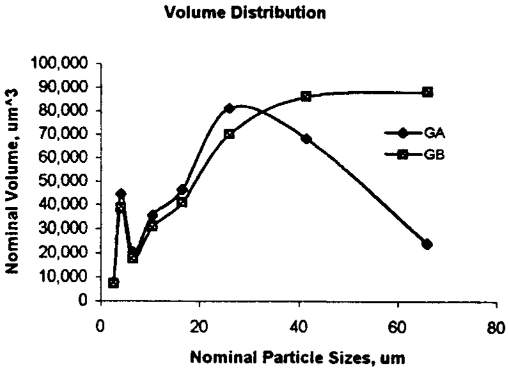


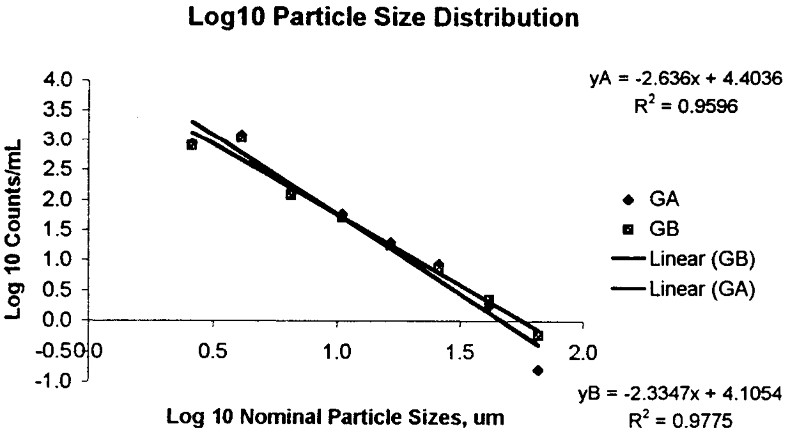




PCX Test of G Data, 2-81 Range						Sampled	2-Apr-01			
PCXdat3Apra	Flow rate	100	mL			Tested	4-Apr-01			
	Sample ti	2	min							
	Class >	2-3.2	3.2-5	5-8	8-13	13-20	20-32	32-51	51-81	
	li >	2	3.2	5	8	13	20	32	51	81
	l* >	2.6	4.1	6.5	10.5	16.5	26	41.5	66	
	Log10 l* >	0.41497	0.61278	0.81291	1.02119	1.21748	1.41497	1.61805	1.81954	
G_A	A Line feed									
	Jar	Site	Particles/mL							
2001/04/04 10:09	D8	886.70	1237.88	143.65	60.03	19.08	9.30	1.90	0.20	
2001/04/04 10:11	D8	885.25	1256.38	144.48	60.50	21.03	9.45	2.08	0.23	
2001/04/04 10:13	D8	893.75	1244.00	145.08	58.40	19.65	8.65	2.00	0.13	
2001/04/04 10:15	D8	888.38	1225.70	140.20	56.80	19.60	7.90	1.33	0.10	
Average		888.52	1240.99	143.35	58.93	19.84	8.83	1.83	0.16	2377.08
Volume, um^3		8,177	44,783	20,613	35,720	46,659	81,214	68,298	24,462	305,464
Log10 PSD		2.94867	3.09377	2.15640	1.77035	1.29749	0.94571	0.26126	-0.78915	
Log10 Volume		3.91259	4.65112	4.31414	4.55291	4.66894	4.90963	4.83441	4.38848	
									V ol = pi x l*^3 /6 x No. Particles in bin	
G_B	B Line feed									
2001/04/04 10:21	D9	787.33	1068.20	115.08	51.80	18.45	7.75	2.78	0.98	
2001/04/04 10:23	D9	816.53	1095.63	122.20	52.68	18.30	7.73	2.43	0.58	
2001/04/04 10:25	D9	799.78	1078.85	125.73	50.18	17.53	7.95	2.50	0.38	
2001/04/04 10:27	D9	796.08	1052.98	123.83	51.40	15.95	7.08	1.53	0.43	
Average		799.93	1073.91	121.71	51.51	17.56	7.63	2.31	0.59	
Volume, um^3		7,362	38,754	17,501	31,223	41,294	70,171	86,308	88,438	292,612
Log10 PSD		2.90305	3.03097	2.08531	1.71191	1.24443	0.88224	0.36291	-0.23099	
Log10 Volume		3.86697	4.58832	4.24305	4.49448	4.61588	4.84616	4.93605	4.94664	







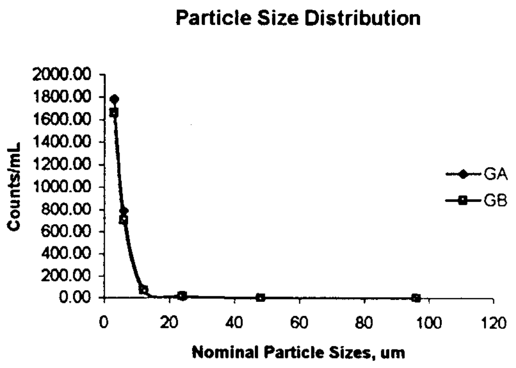
H20

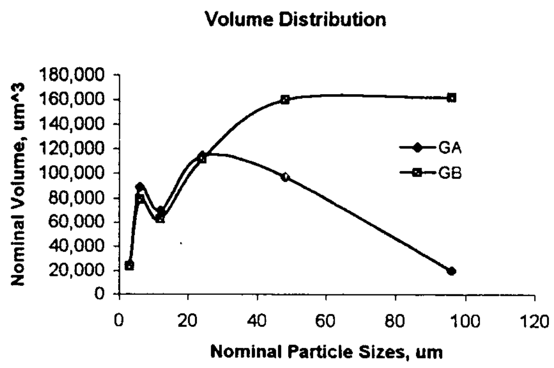
PCX Test of G_A and G_B Data, 2-128 Range Sampled 2-Apr-01
PCXdat3Apra Flow rate 100 mL Tested 4-Apr-01
Sampl 2 min

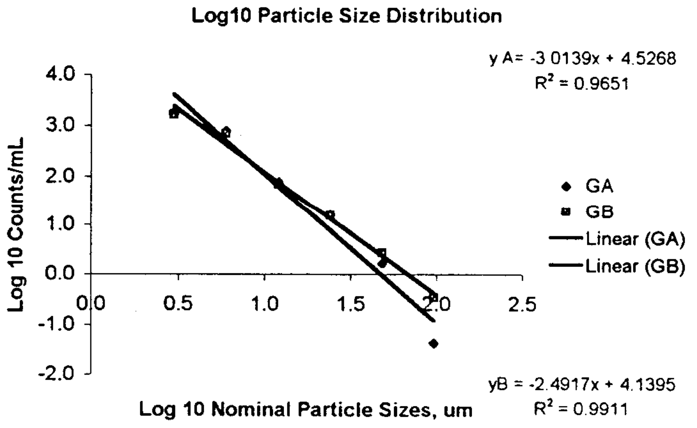
Class		2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256	
li >		2	4	8	16	32	64	128	256	
l* >		3	6	12	24	48	96	192		
Log10 l*		0.47712	0.77815	1.07918	1.38021	1.68124	1.98227	2.28330		
Jar	Site	Particles/mL								
G_A	A line feed									
2001/04/04 10:	D8	1752.73	786.08	78.20	16.80	2.30	0.05	0.00		
2001/04/04 10:	D8	1775.48	792.75	78.13	16.45	1.73	0.03	0.00		
2001/04/04 10:	D8	1790.90	788.70	77.98	15.55	1.45	0.05	0.00		
2001/04/04 10:	D8	1819.28	794.43	76.30	14.65	1.28	0.05	0.00		
Average		1784.59	790.49	77.65	15.86	1.69	0.04	0.00		2664.55
Volume, um^3		25,229	89,402	70,256	114,816	97,716	20,267			417,687
Log10 PSD		3.25154	2.89790	1.89014	1.20037	0.22724	-1.35902			
Log10 Volume		4.40190	4.95135	4.84668	5.06000	4.98997	4.30679			

V ol = pi x l*^3 /6 x No. Particles in bin

G_B	B Line feed									
2001/04/04 10:	D9	1663.40	690.70	65.05	15.35	3.03	0.35	0.00		
2001/04/04 10:	D9	1649.98	698.95	68.00	15.33	2.33	0.48	0.00		
2001/04/04 10:	D9	1653.13	706.58	69.08	13.58	2.03	0.35	0.00		
2001/04/04 10:	D9	1691.93	717.30	75.35	17.55	3.70	0.23	0.00		
Average		1664.61	703.38	69.37	15.45	2.77	0.35	0.00	#DIV/0!	
Volume, um^3		23,533	79,551	62,763	111,831	160,327	162,136	0		600,140
Log10 PSD		3.22131	2.84719	1.84116	1.18893	0.44228	-0.45593			
Log10 Volume		4.37167	4.90064	4.79771	5.04856	5.20501	5.20988			







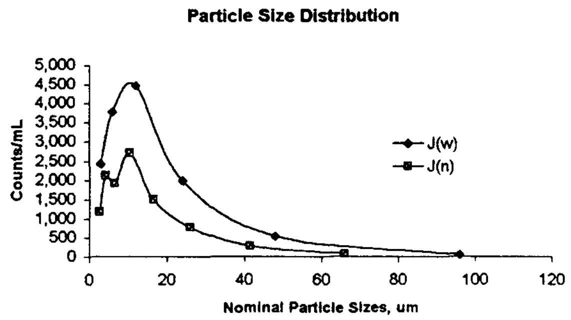
PCX Test of Drum Filter 1 Wash Data, 2-128 & 2-81 Ranges Sampled 2-Apr-01
PCXdat4Apra Flow rate 100 mL Tested 4-Apr-01
Sample tim 2 min

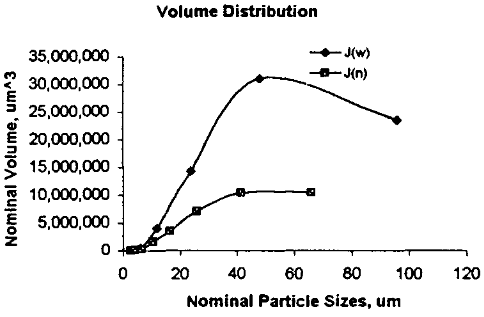
Wide Range

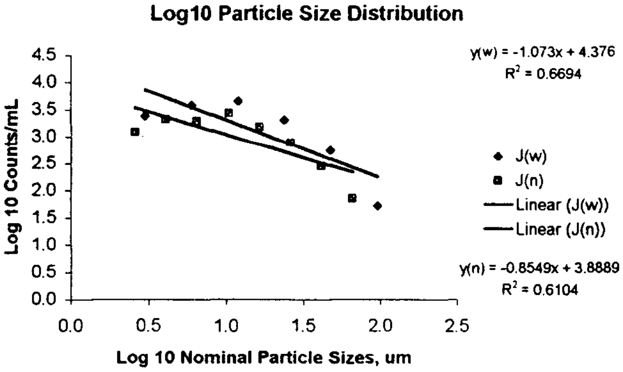
		2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256	
	Class >	2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256	
	li >	2	4	8	16	32	64	128	256	
	l* >	3	6	12	24	48	96	192		
	Log10 l* >	0.47712	0.77815	1.07918	1.38021	1.68124	1.98227	2.28330		
	Jar	Particles/mL								
J(w)										
2001/04/04 11:	D10	3398.65	4767.10	4261.65	1661.10	542.95	56.95	0.00		
2001/04/04 11:	D10	2936.58	4463.30	4584.43	1947.13	598.05	57.95	0.00		
2001/04/04 11:	D10	1796.25	1059.80	855.98	374.20	120.83	18.25	0.00		
2001/04/04 11:	D10	2207.25	3928.20	5098.15	2446.58	698.50	68.03	0.00		
2001/04/04 11:	D10	2161.50	4220.13	5893.13	2641.50	611.60	52.63	0.00		
2001/04/04 11:	D10	2069.30	4145.20	6050.65	2834.55	644.13	48.63	0.00		
Average		2428.25	3763.95	4457.33	1984.18	536.01	50.40	0.00		14446.70
Volume, um^3		34,329	425,693	4,032,896	14,361,914	31,038,011	23,349,563			73,242,406
Log10 PSD		3.38529	3.57564	3.64907	3.29758	2.72917	1.70247			
Log10 Volume		4.53566	5.62910	6.60562	7.15721	7.49189	7.36828			

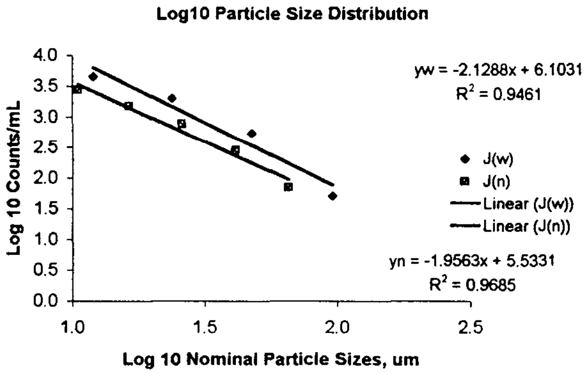
Low Range

J(n)	Class >	2-3.2	3.2-5	5-8	8-13	13-20	20-32	32-51	51-81	
	li >	2	3.2	5	8	13	20	32	51	81
	l* >	2.6	4.1	6.5	10.5	16.5	26	41.5	66	
	Log10 l* >	0.41497	0.61278	0.81291	1.02119	1.21748	1.41497	1.61805	1.81954	
2001/04/04 11:	D10	1555.33	3391.63	2963.53	3605.98	1758.23	887.30	356.53	106.75	
2001/04/04 11:	D10	1305.28	2940.75	2689.25	3556.08	1845.53	958.70	375.50	107.45	
2001/04/04 11:	D10	1126.83	2691.10	2586.15	3664.33	2030.65	1060.53	398.65	103.88	
2001/04/04 11:	D10	1012.58	2144.80	2064.45	2892.48	1525.75	758.60	264.65	64.28	
2001/04/04 11:	D10	997.30	2518.40	2473.98	3730.73	2179.05	1136.58	401.65	97.48	
2001/04/04 11:	D10	1105.38	1129.58	556.65	539.85	271.13	153.28	55.90	14.73	
Average		1183.78	2120.97	1920.31	2706.84	1501.64	777.24	280.21	70.09	10561.09
Volume, um^3		10,894	76,539	276,127	1,640,702	3,531,973	7,152,797	10,486,497	10,550,450	23,175,529
Log10 PSD		3.07327	3.32653	3.28337	3.43246	3.17657	2.89056	2.44749	1.84564	
Log10 Volume		4.03719	4.88388	5.44111	6.21503	6.54802	6.85448	7.02063	7.02327	





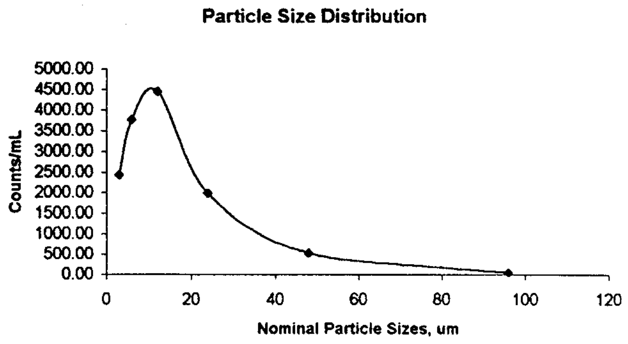


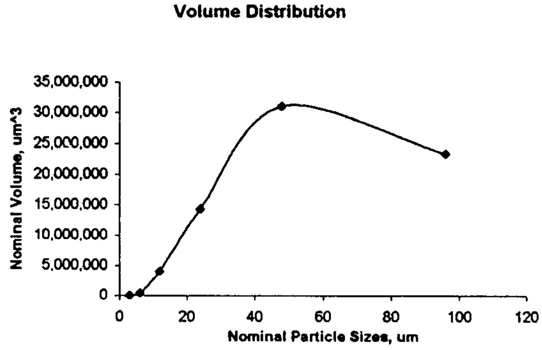


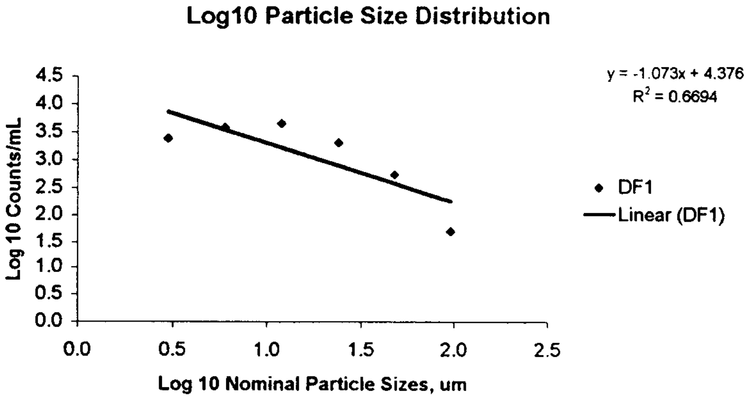
PCX Test of Drum Filter 1 Wash Data, 2-128 Range Sampled 2-Apr-01
PCXdat4Apra Flow rate 100 mL Tested 4-Apr-01

	Sample tim		2 min							
	Class >	2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256	
	li >	2	4	8	16	32	64	128	256	
	I* >	3	6	12	24	48	96	192		
	Log10 I* >	0.47712	0.77815	1.07918	1.38021	1.68124	1.98227	2.28330		
	Jar	Site	Particles/mL							
DF1	DF1									
2001/04/04 11	D10	3398.65	4767.10	4261.65	1661.10	542.95	56.95	0.00		
2001/04/04 11	D10	2936.58	4463.30	4584.43	1947.13	598.05	57.95	0.00		
2001/04/04 11	D10	1796.25	1059.80	855.98	374.20	120.83	18.25	0.00		
2001/04/04 11	D10	2207.25	3928.20	5098.15	2446.58	698.50	68.03	0.00		
2001/04/04 11	D10	2161.50	4220.13	5893.13	2641.50	611.60	52.63	0.00		
2001/04/04 11	D10	2069.30	4145.20	6050.65	2834.55	644.13	48.63	0.00		
Average		2428.25	3763.95	4457.33	1984.18	536.01	50.40	0.00		14446.70
Volume, um^3		34,329	425,693	4,032,896	14,361,914	31,038,011	23,349,563			73,242,406
Log10 PSD		3.38529	3.57564	3.64907	3.29758	2.72917	1.70247			
Log10 Volume		4.53566	5.62910	6.60562	7.15721	7.49189	7.36828			

V ol = pi x I*^3 /6 x No. Particles in bin


Particle Size Distribution


Volume Distribution


Log10 Particle Size Distribution

PCX Test of MUW Data, 2-81 Range

Sampled 2-Apr-01

Tested 4-Apr-01

dpswa1

Flow rate 100 mL

Sample ti 2 min

Class >	2-3.2	3.2-5	5-8	8-13	13-20	20-32	32-51	51-81	
li >	2	3.2	5	8	13	20	32	51	81
l* >	2.6	4.1	6.5	10.5	16.5	26	41.5	66	
Log10 l* >	0.41497	0.61278	0.81291	1.02119	1.21748	1.41497	1.61805	1.81954	

MUW$_A$ Make up water A from Hatchery

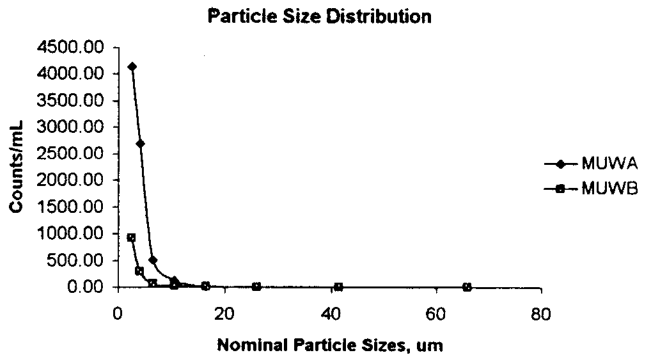
Jar Site Particles/mL

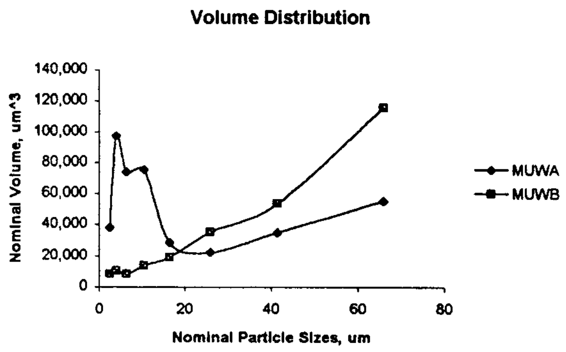
2001/04/04 10:45	D12	4565.50	2972.58	559.73	136.63	14.85	3.60	1.10	0.38	
2001/04/04 10:47	D12	4348.68	2801.00	533.53	128.55	12.43	2.38	0.70	0.33	
2001/04/04 10:49	D12	4125.80	2666.43	504.18	121.95	11.80	1.80	1.05	0.30	
2001/04/04 10:51	D12	4026.03	2622.83	495.03	122.95	13.43	3.08	1.23	0.40	
2001/04/04 10:53	D12	3907.70	2539.63	484.28	117.13	10.33	1.55	0.68	0.45	
2001/04/04 10:55	D12	3871.03	2554.43	491.20	118.80	10.38	2.05	0.83	0.35	
Average		4140.79	2692.81	511.32	124.33	12.20	2.41	0.93	0.37	7283.33
Volume, um^3		38,107	97,175	73,525	75,362	28,695	22,163	34,773	55,195	369,800
Log10 PSD		3.61708	3.43021	2.70869	2.09459	1.08636	0.38172	-0.03191	-0.43573	
Log10 Volume		4.58100	4.98756	4.86643	4.87715	4.45781	4.34564	4.54124	4.74190	

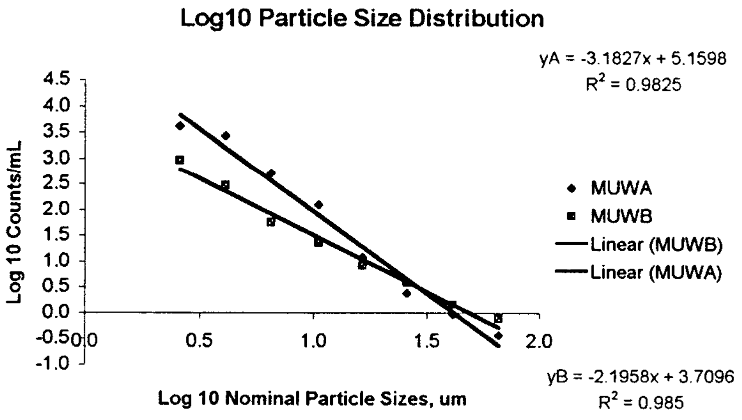
V ol = pi x l*^3 /6 x No. Particles in bin

MUW$_B$ Make up water B, from well direct

2001/04/04 11:11	D13	769.50	344.33	90.18	51.88	18.13	9.33	4.45	2.78	
2001/04/04 11:13	D13	972.15	272.53	46.90	13.20	5.28	2.13	0.65	0.18	
2001/04/04 11:15	D13	958.58	275.95	44.98	12.73	4.10	2.03	0.40	0.10	
2001/04/04 11:17	D13	947.60	271.30	45.05	12.75	4.73	1.85	0.23	0.03	
Average		911.96	291.03	56.78	22.64	8.06	3.83	1.43	0.77	
Volume, um^3		8,393	10,502	8,164	13,721	18,949	35,258	53,562	115,722	148,549
Log10 PSD		2.95997	2.46393	1.75416	1.35483	0.90613	0.58334	0.15572	-0.11421	
Log10 Volume		3.92389	4.02128	3.91190	4.13739	4.27758	4.54726	4.72886	5.06342	







PCX Test of Make-up Waters Data, 2-128 Range Sampled 2-Apr-01
PCXdat4Apra Flow rate 100 mL Tested 4-Apr-01
Sample time 2 min

Class >	2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256
li >	2	4	8	16	32	64	128	256
l* >	3	6	12	24	48	96	192	
Log10 l* >	0.47712	0.77815	1.07918	1.38021	1.68124	1.98227	2.28330	

Jar Site Particles/mL

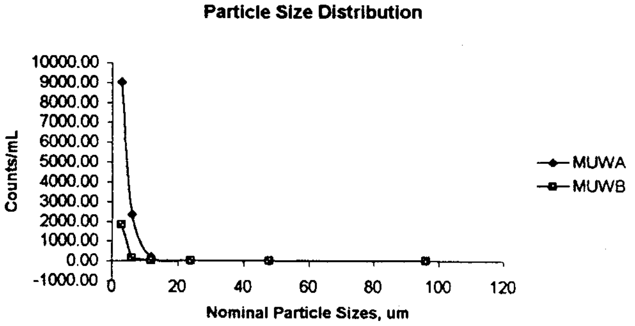
MUW$_A$ DF1

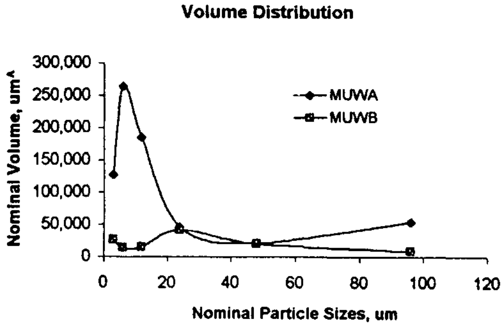
2001/04/04 10 D12?	9062.78	2264.30	194.30	5.88	0.35	0.08	0.00		
2001/04/04 10 D12?	9044.25	2272.68	194.83	6.30	0.38	0.23	0.00		
2001/04/04 10 D12?	8993.15	2303.83	195.78	6.20	0.33	0.05	0.00		
2001/04/04 10 D12?	8990.08	2338.08	202.78	6.15	0.28	0.08	0.00		
2001/04/04 10 D12?	8965.68	2367.60	211.65	6.28	0.48	0.03	0.00		
2001/04/04 10 D12?	9040.50	2433.93	225.63	7.45	0.43	0.25	0.00		
Average	9016.07	2330.07	204.16	6.38	0.37	0.12	0.00		11537.43
Volume, um^3	127,462	263,524	184,718	46,144	21,473	54,045			697,367
Log10 PSD	3.95502	3.36737	2.30997	0.80448	-0.43082	-0.93305			
Log10 Volume	5.10538	5.42082	5.26651	4.66411	4.33190	4.73276			

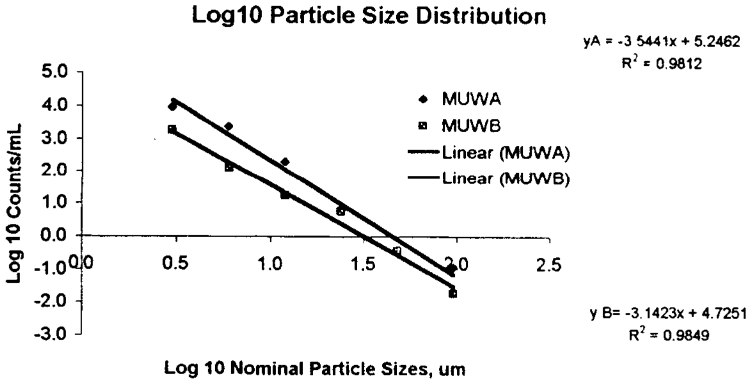
V ol = pi x l*^3 /6 x No. Particles in bin

MUW$_B$

2001/04/04 11 D13	1775.00	126.18	16.98	6.63	0.38	0.03	0.00		
2001/04/04 11 D13	1847.85	128.18	16.08	5.20	0.33	0.00	0.00		
2001/04/04 11 D13	1839.68	127.75	16.08	5.23	0.33	0.03	0.00		
2001/04/04 11 D13	1877.50	128.35	17.90	5.75	0.38	0.03	0.00		
Average	1835.01	127.61	16.76	5.70	0.35	0.02	0.00	#DIV/0!	
Volume, um^3	25,942	14,433	15,161	41,258	20,267	8,686	0		125,746
Log10 PSD	3.26364	2.10589	1.22418	0.75587	-0.45593	-1.72700			
Log10 Volume	4.41400	4.15935	4.18072	4.61551	4.30679	3.93881			







PCX Test of Settle Deck Data, 2-128 & 2-81 Ranges Sampled 2-Apr-01
PCXdat4Apra Flow rate 100 mL Tested 4-Apr-01

High Range

Sampl 2 min

Class	2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256
li >	2	4	8	16	32	64	128	256
I* >	3	6	12	24	48	96	192	
Log10 I*	0.47712	0.77815	1.07918	1.38021	1.68124	1.98227	2.28330	

Jar Site Particles/mL
Sdeck(w) Settle Deck

2001/04/04 10:	D11	2796.48	961.58	80.75	13.75	3.15	0.15	0.00		
2001/04/04 10:	D11	2799.78	954.95	78.18	14.10	3.15	0.08	0.00		
2001/04/04 10:	D11	2814.43	975.30	81.45	13.33	3.18	0.18	0.00		
Average		2803.56	963.94	80.13	13.73	3.16	0.13	0.00		3855.85
Volume, um^3		39,634	109,019	72,495	99,345	182,886	61,766			565,146
Log10 PSD		3.44771	2.98405	1.90377	1.13751	0.49946	-0.87506			
Log10 Volume		4.59807	5.03750	4.86031	4.99714	5.26218	4.79075			

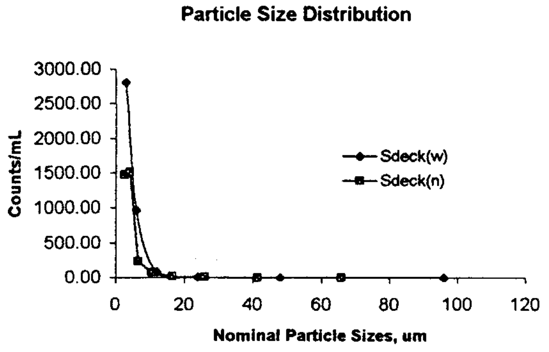
V ol = pi x I*^3 /6 x No. Particles in bin

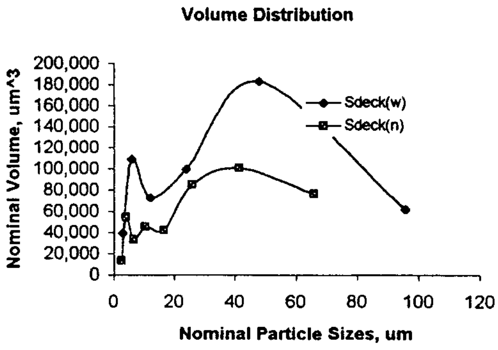
Low Range

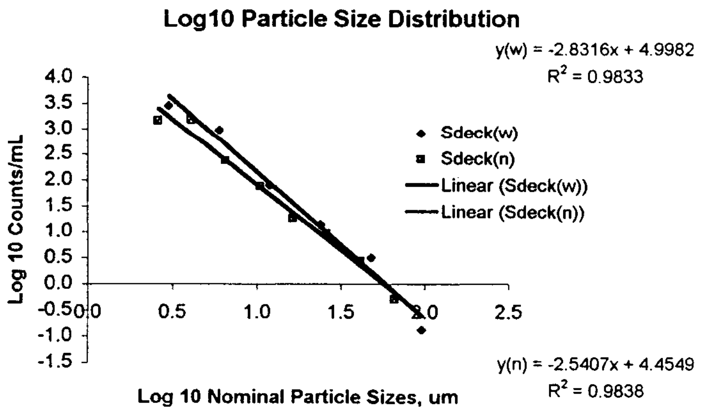
Class	2-3.2	3.2-5	5-8	8-13	13-20	20-32	32-51	51-81	
li >	2	3.2	5	8	13	20	32	51	81
I* >	2.6	4.1	6.5	10.5	16.5	26	41.5	66	
Log10 I*	0.41497	0.61278	0.81291	1.02119	1.21748	1.41497	1.61805	1.81954	

Sdeck(n)

2001/04/04 10:	D11	1511.65	1547.73	234.40	79.78	18.65	9.10	3.00	0.35	
2001/04/04 10:	D11	1433.08	1484.05	231.50	71.90	17.10	8.98	2.70	0.70	
2001/04/04 10:	D11	1482.53	1501.93	234.80	74.08	17.98	9.60	2.35	0.48	
Average		1475.75	1511.23	233.57	75.25	17.91	9.23	2.68	0.51	
Volume, um^3		13,581	54,536	33,585	45,611	42,122	84,896	100,419	76,521	451,271
Log10 PSD		3.16901	3.17933	2.36841	1.87651	1.25306	0.96497	0.42867	-0.29385	
Log10 Volume		4.13293	4.73668	4.52615	4.65907	4.62451	4.92889	5.00182	4.88378	







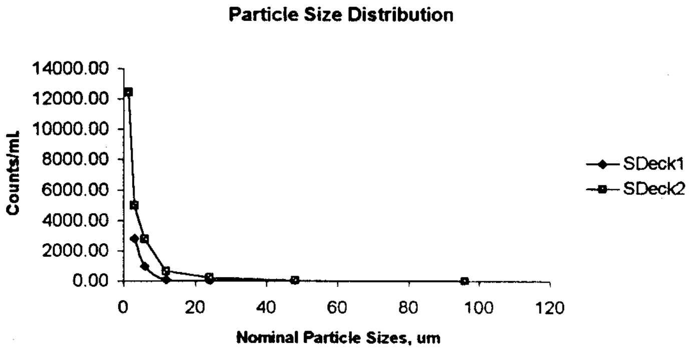
PCX Test of Settle Deck Data, 2-128 and 1-128 Ranges Sampled 2-Apr-01

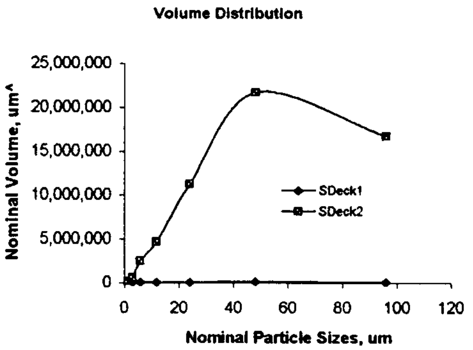
PCXdat4Apra Flow rate 100 mL Tested 4-Apr-01

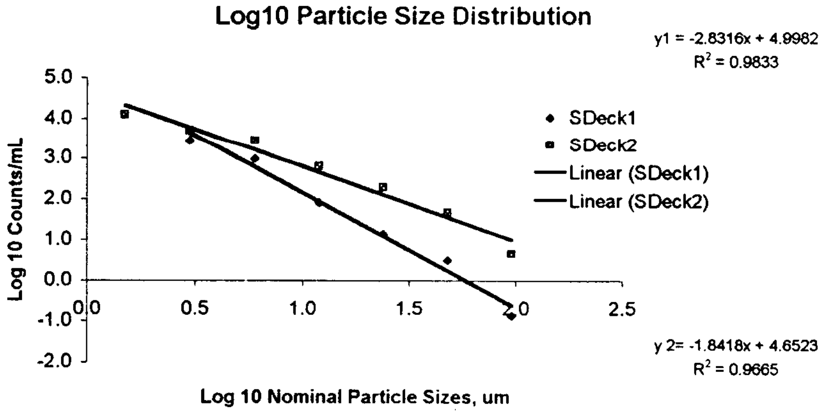
	Sample time	2 min								
	Class >	2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256	
	li >	2	4	8	16	32	64	128	256	
	l* >	3	6	12	24	48	96	192		
	Log10 l* >	0.47712	0.77815	1.07918	1.38021	1.68124	1.98227	2.28330		
	Jar	Site	Particles/mL							
SDeck1	Settle Deck									
2001/04/04 10:35	D11	2796.48	961.58	80.75	13.75	3.15	0.15	0.00		
2001/04/04 10:37	D11	2799.78	954.95	78.18	14.10	3.15	0.08	0.00		
2001/04/04 10:39	D11	2814.43	975.30	81.45	13.33	3.18	0.18	0.00		
Average		2803.56	963.94	80.13	13.73	3.16	0.13	0.00		3855.85
Volume, um^3		39,634	109,019	72,495	99,345	182,886	61,766			565,146
Log10 PSD		3.44771	2.98405	1.90377	1.13751	0.49946	-0.87506			
Log10 Volume		4.59807	5.03750	4.86031	4.99714	5.26218	4.79075			

V ol = pi x l*^3 /6 x No. Particles in bin

	Sample time	2 min								
	Class >	1-2	2-4	4-8	8-16	16-32	32-64	64-128	>128	
	li >	1.00	2.00	4.00	8.00	16.00	32.00	64.00	128.00	
	l* >	1.50	3.00	6.00	12.00	24.00	48.00	96.00		
	Log10 l* >	0.17609	0.47712	0.77815	1.07918	1.38021	1.68124	1.98227		
SDeck2										
2001/04/04 14:32	11b	12417.28	4950.68	2763.98	645.28	194.85	46.75	4.50	0.00	21023.30
Average		12417.28	4950.68	2763.98	645.28	194.85	46.75	4.50	0.00	
Volume, um^3		175,545	559,908	2,500,786	4,670,649	11,282,952	21,656,783	16,676,881		57,523,503
Log10 PSD		4.09403	3.69466	3.44153	2.80974	2.28970	1.66978	0.65321		
Log10 Volume		5.24439	5.74812	6.39808	6.66938	7.05242	7.33559			

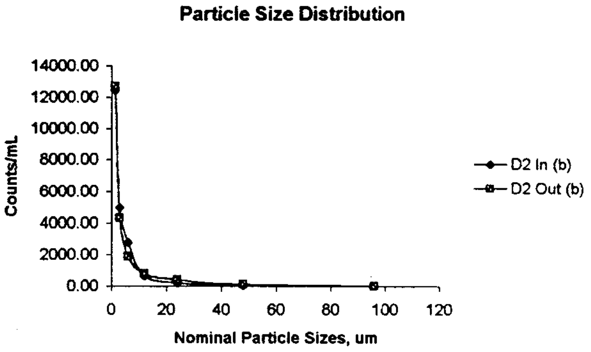


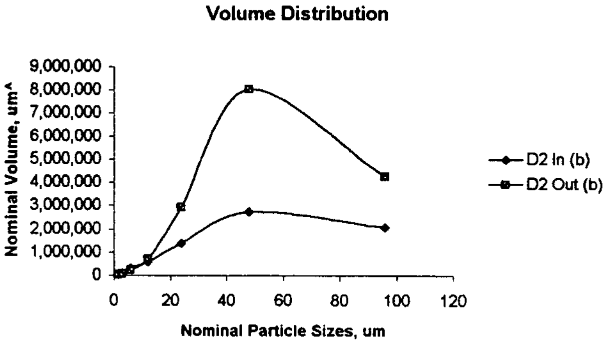


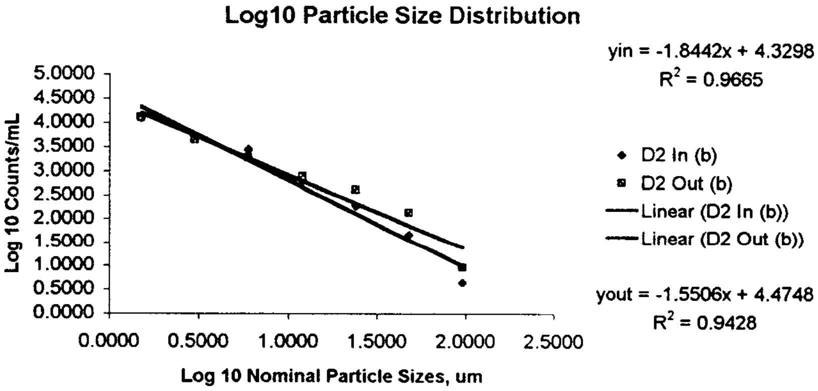


PCX Test of D2 In and Out Data, Wide Range, Data to 1 micron Sampled 2-Apr-01

	Flow rate	100 mL			Tested		4-Apr-01				
PCX2Apr15-16a	Sample tim	2 min									
	Class >	1-2	2-4	4-8	8-16	16-32	32-64	64-128	128-256	>256	
	li >	1	2	4	8	16	32	64	128	256	
	I* >	1.5	3	6	12	24	48	96	192		
	Log10 I* >	0.1761	0.4771	0.7782	1.0792	1.3802	1.6812	1.9823	2.2833		
Jar	Site	Particles/mL									
2001/04/04 14: 15b	D2 in	12393.98	4967.00	2769.73	641.93	189.00	48.43	4.78	0.00		
2001/04/04 14: 15b		12495.33	4971.53	2794.93	646.83	194.43	45.75	4.15	0.00		
Average		12444.65	4969.26	2782.33	644.38	191.71	47.09	4.46	0.00		21083.88
Volume, um^3		21,992	70,251	314,674	583,017	1,387,659	2,726,641	2,067,238	0		7,171,472
Log10 PSD		4.0950	3.6963	3.4444	2.8091	2.2827	1.6729	0.6496			
Log10 Volume		4.3423	4.8467	5.4979	5.7657	6.1423	6.4356	6.3154			
									V ol = pi x I*^3 /6 x No. Particles in bin		
2001/04/04 14: D16b	D2 out	12389.75	4223.90	1841.20	790.23	422.98	149.88	9.78	0.00		
2001/04/04 14: D16b		12791.05	4281.23	1857.60	778.75	416.30	142.50	9.45	0.00		
2001/04/04 14: D16b		12871.88	4446.58	1882.20	753.85	378.45	124.20	8.28	0.00		
Average		12684.23	4317.23	1860.33	774.28	405.91	138.86	9.17			19827.70
Volume, um^3		22,415	61,033	210,399	700,548	2,938,058	8,040,708	4,246,428			16,219,588
Log10 PSD		4.1033	3.6352	3.2696	2.8889	2.6084	2.1426	0.9622			
Log10 Volume		4.3505	4.7856	5.3230	5.8454	6.4681	6.9053	6.6280			



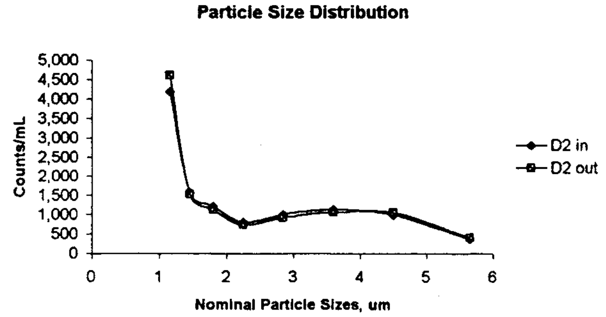


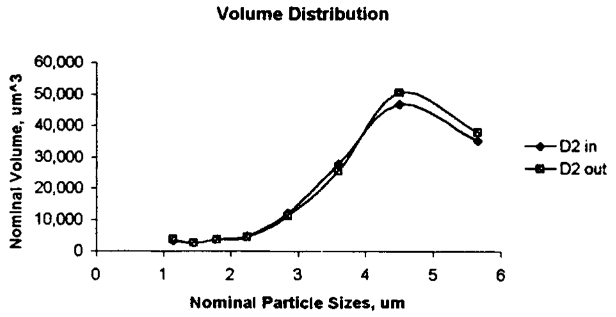


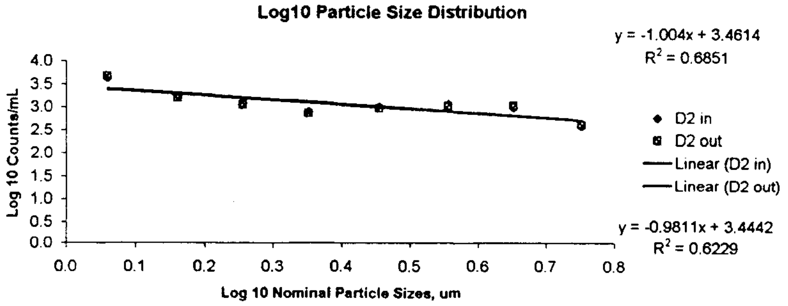
PCX Test of D2 In and Out Data, Low Range, Data 1 - 6.3 micron

Sampled 2-Apr-01
Tested 4-Apr-01
Flow rate 100 mL
Sample tim 2 min
PCX2Apr15-16a

		1-1.3	1.3-1.6	1.6-2	2-2.5	2.5-3.2	3.2-4	4-5	5-6.3	6
	Class >	1-1.3	1.3-1.6	1.6-2	2-2.5	2.5-3.2	3.2-4	4-5	5-6.3	6
	li >	1	1.3	1.6	2	2.5	3.2	4	5	6.3
	l* >	1.15	1.45	1.8	2.25	2.85	3.6	4.5	5.65	
	Log10 l* >	0.0607	0.1614	0.2553	0.3522	0.4548	0.5563	0.6532	0.7520	
D2 in	Jar	Particles/mL								
2001/04/04 14:14	D16b	4077.05	1584.60	1222.45	826.05	1021.33	1176.43	1019.93	391.35	
2001/04/04 14:16	D16b	4175.00	1577.08	1218.80	804.98	1005.28	1140.78	979.83	373.00	
2001/04/04 14:18	D16b	4272.95	1569.55	1215.15	783.90	989.23	1105.13	939.73	354.65	
Average		4175.00	1577.08	1218.80	804.98	1005.28	1140.78	979.83	373.00	
Volume, um^3		3,325	2,517	3,722	4,801	12,185	27,868	46,750	35,225	136,393
Log10 PSD		3.6207	3.1979	3.0859	2.9058	3.0023	3.0572	2.9911	2.5717	
Log10 Volume		3.5217	3.4010	3.5707	3.6813	4.0858	4.4451	4.6698	4.5469	
							V ol = pi x l*^3 /6 x No. Particles in bin			
D2 out										
2001/04/04 14:22	D15b	4316.60	1716.03	1348.20	919.18	1157.85	1343.85	1368.70	518.35	
2001/04/04 14:24	D15b	4873.05	1334.08	882.13	548.15	667.15	751.73	750.50	286.73	
Average		4594.83	1525.05	1115.16	733.66	912.50	1047.79	1059.60	402.54	
Volume, um^3		3,659	2,434	3,405	4,376	11,060	25,596	50,557	38,015	139,102
Log10 PSD		3.6623	3.1833	3.0473	2.8655	2.9602	3.0203	3.0251	2.6048	
Log10 Volume		3.5634	3.3864	3.5322	3.6410	4.0438	4.4082	4.7038	4.5800	


Particle Size Distribution


Volume Distribution

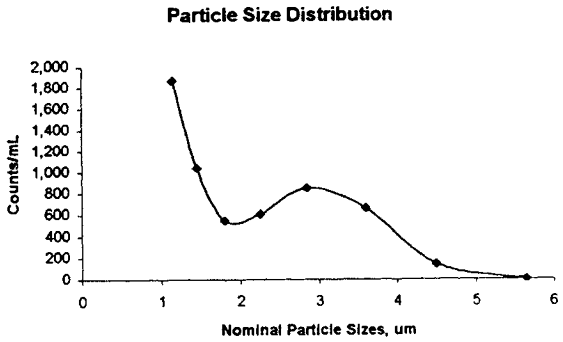

Log10 Particle Size Distribution

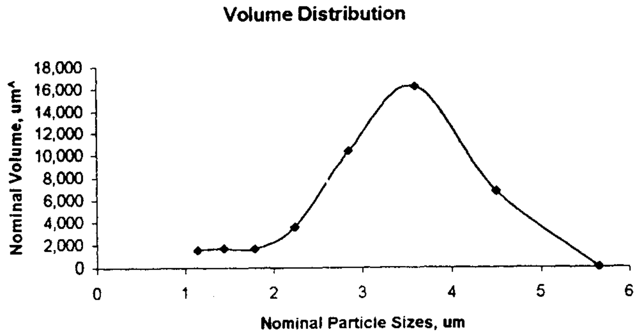
PCX Test of Settle Deck Data, Low Range, Data to 1 micron

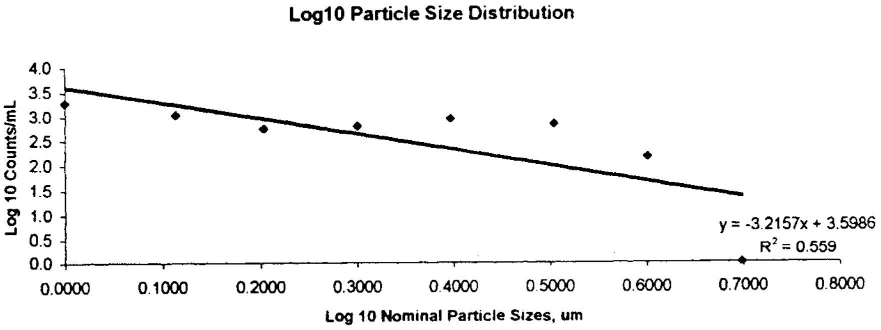
Sampled 2-Apr-01
Tested 4-Apr-01

Flow rate 100 mL
PCX2Apr15-16a
Sample tim 2 min

		Class >	1-1.3	1.3-1.6	1.6-2	2-2.5	2.5-3.2	3.2-4	4-5	5-6.3	6
		li >	1	1.3	1.6	2	2.5	3.2	4	5	6.3
		l* >	1.15	1.45	1.8	2.25	2.85	3.6	4.5	5.65	
		Log10 l* >	0.0000	0.1139	0.2041	0.3010	0.3979	0.5051	0.6021	0.6990	
Sdeck	Jar	Site	Particles/mL								
2001/04/04 14:30	D11b		7697.48	377.78	162.03	90.78	94.65	84.78	61.43	24.95	
2001/04/04 14:52	D11b		7971.85	2081.75	1161.55	614.78	679.28	958.75	745.65	159.73	
2001/04/04 14:54	D11b		7858.60	1658.95	918.08	476.10	532.93	745.38	580.15	123.15	
Average			1870.35	1039.81	545.44	606.10	852.06	662.90	141.44	#REF!	
Volume, um^3			1,489	1,660	1,666	3,615	10,328	16,194	6,748	#REF!	#REF!
Log10 PSD			3.2719	3.0170	2.7367	2.7825	2.9305	2.8214	2.1506	#REF!	
Log10 Volume			3.1730	3.2201	3.2216	3.5581	4.0140	4.2094	3.8292	#REF!	
								V ol = pi x l*^3 /6 x No. Particles in bin			
D2 out											
2001/04/04 14:22	D15b		4316.60	1716.03	1348.20	919.18	1157.85	1343.85	1368.70	518.35	
2001/04/04 14:24	D15b		4873.05	1334.08	882.13	548.15	667.15	751.73	750.50	286.73	
Average			4594.83	1525.05	1115.16	733.66	912.50	1047.79	1059.60	402.54	
Volume, um^3			3,659	2,434	3,405	4,376	11,060	25,596	50,557	38,015	139,102
Log10 PSD			3.6623	3.1833	3.0473	2.8655	2.9602	3.0203	3.0251	2.6048	
Log10 Volume			3.5634	3.3864	3.5322	3.6410	4.0438	4.4082	4.7038	4.5800	







Particle Size Analysis

PCX Results for samples taken 16 April 01.

The PCX particle counters were set up in tandem in two x eight channels spans:

Lower span: 2-2.5, 2.5-3.2, 3.2-4, 4-5, 5-6.3, 6.3-8,8-10, 10-13 µm

and

Upper span: 13-16, 16-20, 20-25, 25-32, 32-40, 40-51, 51-81, >81 µm

There was adjustment for variation in flow rates but no adjustment for cell noise.

Results log:

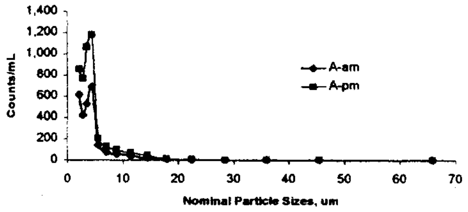
Site>	**A**	**B**	**C**	**D**	**E**	**SD**	**BF$_A$**	**BF$_B$**	**G$_A$**	**G$_B$**	**MW$_A$ 1**	**MW$_A$ 2**	**MW B**	**I/J**	**D2**
Data	√	√	√	√	√	√	√	√	√	√	√	√			

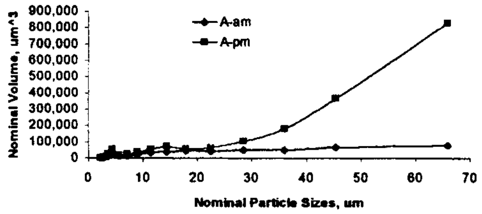
PCX Test of A Data, Combined Ranges

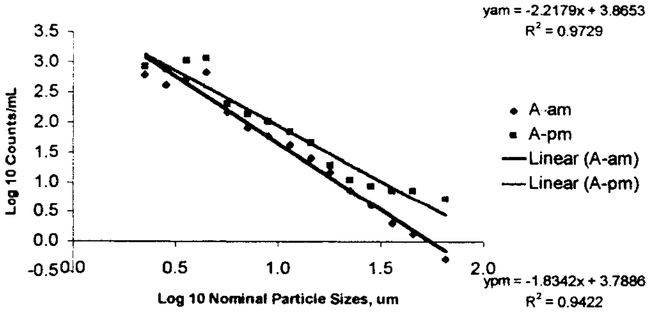
Full data set

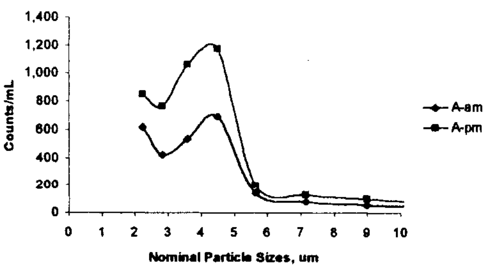
		Nominal	PCX1	PCX2			
					Sampled	16-Apr-01	
					Tested	17-Apr-01	
	Flow rate	100	99.3	100.5			
	mL		101.93	100.96		Sample tim	2 min
			97.24			Particles/mL	
	Mean		99.49	100.73			

	Jar	<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1							>>>>>>>>>>>>>>>>>>>>>>>>>>>>	<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2							>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>	
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-81'	>81'	est
l >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	81	256
l* >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	66	168.5	
Log10 l* :		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.81954		
A-am																		
2001/04/17 10:	1	622.48	431.28	547.55	688.38	144.30	84.18	61.00	44.53	26.10	14.05	6.85	3.78	2.10	1.23	0.55	0.13	
2001/04/17 10:	1	617.88	426.30	535.90	703.95	146.48	82.98	59.83	43.93	25.98	13.95	8.15	4.33	1.93	1.28	0.43	0.20	
2001/04/17 10:	1	611.30	427.15	535.13	690.80	148.38	80.75	58.43	40.93	25.55	15.90	7.38	3.98	2.28	1.30	0.35	0.03	
2001/04/17 10:	1	610.88	412.28	513.10	680.93	148.38	77.28	56.60	44.93	26.78	16.05	7.03	4.30	2.23	1.58	0.78	0.13	
2001/04/17 10:	1	624.40	422.00	527.13	704.13	146.78	81.75	56.50	41.40	26.15	15.58	8.15	4.25	1.70	1.45	0.60	0.10	
Average		617.39	423.80	531.76	693.64	146.86	81.39	58.47	43.14	26.11	15.11	7.51	4.13	2.05	1.37	0.54	0.12	
Flow Ajusted		620.55	425.97	534.49	697.19	147.61	81.80	58.77	43.36	25.92	15.00	7.46	4.10	2.03	1.36	0.54	0.11	2,666
Volume, um^3		3,701	5,163	13,057	33,265	13,940	15,656	22,433	34,530	41,376	45,791	44,466	49,636	49,595	66,835	80,698	285,981	806,124
Log10 PSD		2.79278	2.62938	2.72794	2.84335	2.16912	1.91276	1.76915	1.63710	1.41365	1.17596	0.87248	0.61227	0.30753	0.13197	-0.27077		
A-pm																		
2001/04/17 14:	10	853.85	759.30	1068.40	1152.90	198.80	134.53	103.60	69.28	47.88	20.70	12.55	10.53	10.45	13.50	9.33	0.83	256
2001/04/17 14:	10	862.78	778.88	1096.80	1201.45	204.58	136.63	100.53	72.98	47.20	19.03	12.40	8.38	7.55	6.33	4.48	0.58	
2001/04/17 14:	10	852.63	763.00	1042.10	1172.25	203.55	133.23	103.88	67.95	44.95	19.40	10.85	8.30	5.55	5.63	3.85	0.68	
2001/04/17 14:	10	844.48	755.95	1036.35	1176.40	206.13	131.98	99.95	69.63	47.18	19.38	10.58	8.68	6.33	4.50	4.55	0.80	
Average		853.43	764.28	1060.91	1175.75	203.26	134.09	103.49	69.96	46.80	19.63	11.59	8.97	7.47	7.49	5.55	0.72	
Flow Ajusted		857.81	768.20	1066.35	1181.78	204.30	134.77	104.02	70.31	46.46	19.48	11.51	8.90	7.41	7.43	5.51	0.71	4,495
Volume, um^3		5,116	9,311	26,050	56,386	19,294	25,794	39,704	55,994	74,163	59,493	68,645	107,921	181,132	366,615	829,401	1,787,382	3,712,403
Log10 PSD		2.93339	2.88547	3.02790	3.07254	2.31028	2.12961	2.01711	1.84705	1.66709	1.28965	1.06107	0.94957	0.87009	0.87118	0.74113		


Particle Size Distribution


Volume Distribution

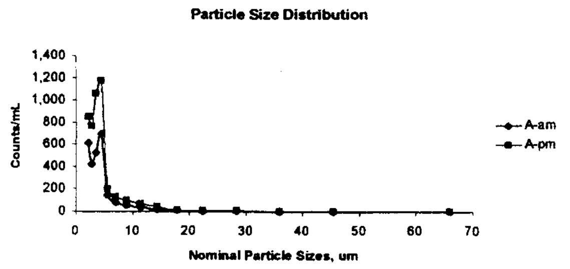

Log10 Particle Size Distribution

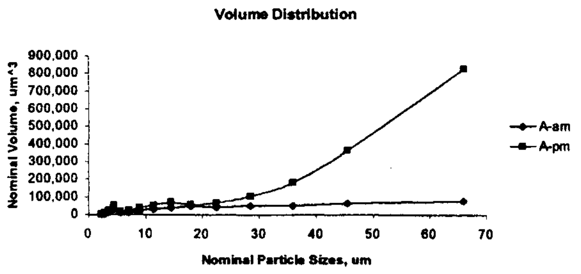

Particle Size Distribution

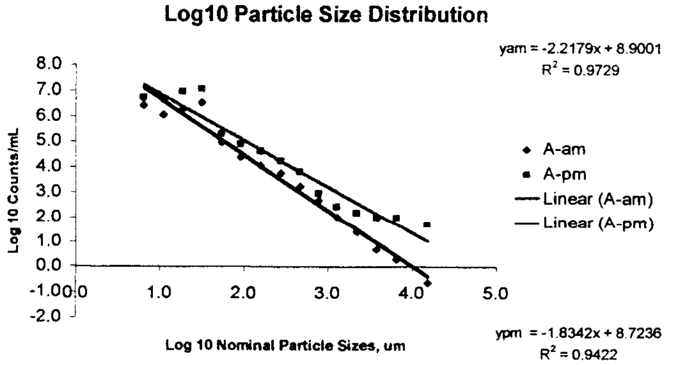
PCX Test of A Data, Combined Ranges

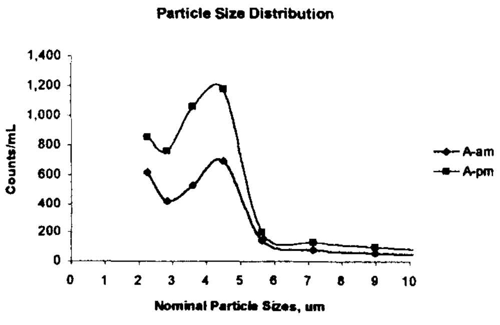
					Sampled	16-Apr-01		
Full data set		Nominal	PCX1	PCX2	Tested	17-Apr-01		
	Flow rate	100	99.3	100.5				
Log base e	mL		101.93	100.96		Sample tim	2	min
			97.24			Particles/mL		
	Mean		99.49	100.73				

	Jar	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-81'	>81'	est
		<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-81'	>81'	est
li >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	81	256
r >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	66	168.5	
Logn r >		0.81093	1.04732	1.28093	1.50408	1.73166	1.96711	2.19722	2.44235	2.67415	2.89037	3.11352	3.34990	3.58352	3.81771	4.18965		
A-am																		
2001/04/17 10:!	1	622.48	431.28	547.55	688.38	144.30	84.18	61.00	44.53	26.10	14.05	6.85	3.78	2.10	1.23	0.55	0.13	
2001/04/17 10:!	1	617.88	426.30	535.90	703.95	146.48	82.98	59.83	43.93	25.98	13.95	8.15	4.33	1.93	1.28	0.43	0.20	
2001/04/17 10:!	1	611.30	427.15	535.13	690.80	148.38	80.75	58.43	40.93	25.55	15.90	7.38	3.98	2.28	1.30	0.35	0.03	
2001/04/17 10:!	1	610.88	412.28	513.10	680.93	148.38	77.28	56.60	44.93	26.78	16.05	7.03	4.30	2.23	1.58	0.78	0.13	
2001/04/17 10:!	1	624.40	422.00	527.13	704.13	146.78	81.75	56.50	41.40	26.15	15.58	8.15	4.25	1.70	1.45	0.60	0.10	
Average		617.39	423.80	531.76	693.64	146.86	81.39	58.47	43.14	26.11	15.11	7.51	4.13	2.05	1.37	0.54	0.12	
Flow Ajusted		620.55	425.97	534.49	697.19	147.61	81.80	58.77	43.36	25.92	15.00	7.46	4.10	2.03	1.36	0.54	0.11	2,666
Volume, um^3		3,701	5,163	13,057	33,265	13,940	15,656	22,433	34,530	41,376	45,791	44,466	49,636	49,595	66,835	80,698	285,981	806,124
Logn PSD		6.43061	6.05437	6.28131	6.54706	4.99459	4.40430	4.07363	3.76956	3.25504	2.70775	2.00896	1.40979	0.70812	0.30388	-0.62346		
A-pm																		
2001/04/17 14:(	10	853.85	759.30	1068.40	1152.90	198.80	134.53	103.60	69.28	47.88	20.70	12.55	10.53	10.45	13.50	9.33	0.83	256
2001/04/17 14:(	10	862.78	778.88	1096.80	1201.45	204.58	136.63	106.53	72.98	47.20	19.03	12.40	8.38	7.55	6.33	4.48	0.58	
2001/04/17 14:(	10	852.63	763.00	1042.10	1172.25	203.55	133.23	103.88	67.95	44.95	19.40	10.85	8.30	5.55	5.63	3.85	0.68	
2001/04/17 14:'	10	844.48	755.95	1036.35	1176.40	206.13	131.98	99.95	69.63	47.18	19.38	10.58	8.68	6.33	4.50	4.55	0.80	
Average		853.43	764.28	1060.91	1175.75	203.26	134.09	103.49	69.96	46.80	19.63	11.59	8.97	7.47	7.49	5.55	0.72	
Flow Ajusted		857.81	768.20	1066.35	1181.78	204.30	134.77	104.02	70.31	46.46	19.48	11.51	8.90	7.41	7.43	5.51	0.71	4,495
Volume, um^3		5,116	9,311	26,050	56,386	19,294	25,794	39,704	55,994	74,163	59,493	68,645	107,921	181,132	366,615	829,401	1,787,382	3,712,403
Logn PSD		6.75438	6.64405	6.97200	7.07477	5.31961	4.90361	4.64456	4.25298	3.83861	2.96953	2.44319	2.18647	2.00345	2.00596	1.70652		


Particle Size Distribution


Volume Distribution


Log10 Particle Size Distribution


Particle Size Distribution

PCX Test of B Data, Combined Ranges

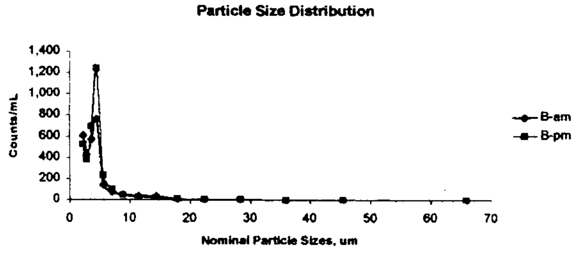
Full data set

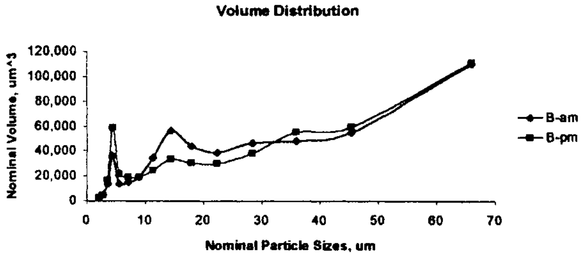
Sampled 16-Apr-01
Tested 17-Apr-01

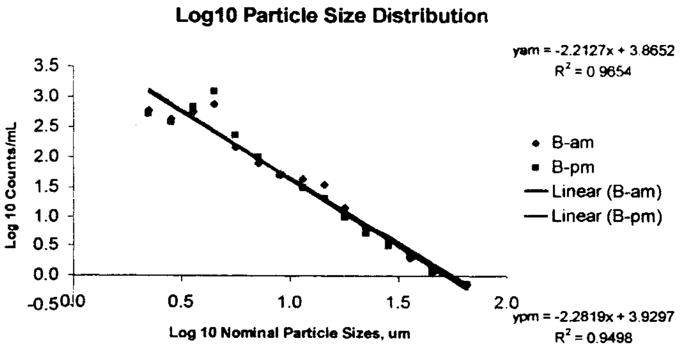
	Nominal	PCX1	PCX2
Flow rate	100	99.3	100.5
mL		101.93	100.96
		97.24	
Mean		99.49	100.73

Sample time 2 min
Particles/mL

	Jar	<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-81'	>81'	est
l >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	81	256
l' >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	66	168.5	
Log10 l' :		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.81954		
B-am																		
2001/04/17 11:02	2	609.70	427.90	545.28	705.83	147.00	83.90	61.75	49.80	25.73	14.05	8.03	4.98	2.63	1.83	1.70	1.40	
2001/04/17 11:04	2	599.83	427.00	580.78	758.55	142.65	80.65	49.48	42.48	36.48	14.00	6.03	3.53	1.88	1.03	0.65	0.10	
2001/04/17 11:06	2	601.95	436.45	595.43	782.95	147.30	79.00	50.38	43.65	37.88	14.03	6.18	3.75	1.60	0.83	0.48	0.05	
2001/04/17 11:08	2	598.05	419.73	546.38	764.93	146.20	75.83	47.83	40.23	37.08	14.23	6.45	3.68	2.03	0.78	0.63	0.35	
2001/04/17 11:10	2	605.30	421.18	569.53	772.78	148.58	78.80	47.90	41.63	36.38	15.43	6.08	3.40	1.73	1.05	0.43	0.05	
2001/04/17 11:12	2	615.53	434.40	567.23	778.25	149.40	76.73	50.75	43.00	37.90	15.20	6.38	3.80	1.93	1.20	0.50	0.10	
Average		605.06	427.78	567.43	760.55	146.85	79.15	51.35	43.46	35.24	14.49	6.52	3.85	1.96	1.12	0.73	0.34	
Flow Ajusted		608.16	429.97	570.34	764.44	147.61	79.56	51.61	43.69	35.42	14.56	6.55	3.87	1.97	1.12	0.73	0.34	2,760
Volume, um^3		3,627	5,212	13,933	36,474	13,940	15,226	19,699	34,768	56,536	44,466	39,090	46,955	48,188	55,358	110,326	860,244	1,404,062
Log10 PSD		2.78402	2.63344	2.75614	2.88335	2.16911	1.90067	1.71273	1.64034	1.54923	1.16321	0.81652	0.58815	0.29503	0.05014	-0.13495		
B-pm																		
2001/04/17 14:54	15	522.23	372.20	692.16	1239.13	231.60	101.23	51.58	31.48	21.43	9.85	5.50	2.98	1.93	1.13	0.95	0.10	
2001/04/17 14:56	15	517.80	381.40	691.23	1216.78	230.03	101.78	50.75	31.20	21.53	10.88	4.58	3.23	2.00	1.03	0.90	0.15	256
2001/04/17 14:58	15	532.90	381.25	703.50	1256.75	237.38	102.23	51.18	32.33	21.55	10.08	5.38	3.33	2.48	1.30	0.63	0.20	
2001/04/17 15:00	15	517.00	379.30	675.15	1221.28	237.03	101.25	49.78	29.40	20.58	10.03	5.00	3.10	2.38	1.40	0.60	0.20	
2001/04/17 15:02	15	526.98	382.43	680.80	1245.45	238.48	101.13	49.20	30.88	20.98	9.73	4.78	3.30	2.55	1.18	0.60	0.10	
Average		523.38	379.32	688.57	1235.88	234.90	101.52	50.50	31.06	21.21	10.11	5.05	3.19	2.27	1.21	0.74	0.15	
Flow Ajusted		526.06	381.26	692.10	1242.21	236.10	102.04	50.75	31.21	21.32	10.16	5.07	3.20	2.28	1.21	0.74	0.15	3,306
Volume, um^3		3,138	4,621	16,907	59,270	22,297	19,529	19,373	24,857	34,030	31,030	30,243	38,803	55,615	59,737	111,209	377,668	908,327
Log10 PSD		2.72104	2.58122	2.84017	3.09420	2.37310	2.00877	1.70547	1.49435	1.32876	1.00697	0.70508	0.50533	0.35729	0.08321	-0.13149		







PCX Test of C Data, Combined Ranges

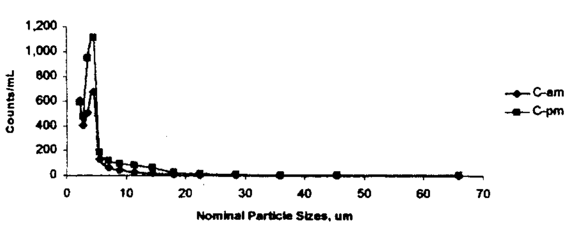
Full data set

	Nominal	PCX1	PCX2		
Flow rate	100	99.3	100.5		
mL		101.93	100.96	Sample time	2 min
		97.24		Particles/mL	
Mean		99.49	100.73		

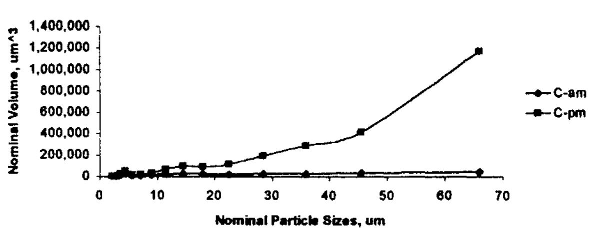
Sampled 16-Apr-01
Tested 17-Apr-01

	Jar	<<<<<<<<<<<<	<<<<<<<<<<<<	<<<<< PCX 1	>>>>>	>>>>>>>>>>>>	>>>>>>>>>>>>	>>>>>>>>>>>>	>>>>>>>>>>>>	<<<<<<<<<<<<	<<<<<<<<<<<<	<<<<< PCX 2	>>>>>>>>>>>>	>>>>>>>>>>>>	>>>>>>>>>>>>	>>>>>>>>>>>>	>>>>>>>>>>>>	
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-81'	>81'	est
li >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	81	256
r >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	66	168.5	
Log10 r :		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.81954		
C-am																		
2001/04/17 11:16	3	601.63	403.78	506.25	666.93	131.30	67.65	47.48	31.43	18.10	8.70	4.23	2.78	1.08	0.75	0.53	0.08	
2001/04/17 11:18	3	598.73	400.15	500.03	672.13	132.65	67.08	45.78	31.45	17.08	8.23	4.60	2.50	1.23	0.83	0.18	0.03	
2001/04/17 11:20	3	613.33	410.23	522.08	687.53	134.98	72.63	45.73	33.93	17.98	9.40	4.05	2.23	1.50	0.93	0.33	0.03	
2001/04/17 11:22	3	604.20	404.60	498.03	676.55	131.03	69.00	47.00	32.58	18.30	8.55	4.93	2.75	1.15	0.60	0.25	0.00	
2001/04/17 11:24	3	622.68	417.48	514.88	696.75	137.03	67.48	47.90	32.58	18.95	9.40	3.90	2.90	1.48	0.60	0.28	0.03	
Average		608.11	407.25	508.25	679.98	133.40	68.77	46.78	32.39	18.08	8.86	4.38	2.63	1.29	0.74	0.31	0.03	
Flow Ajusted		611.23	409.33	510.86	683.46	134.08	69.12	47.01	32.56	18.17	8.90	4.40	2.64	1.29	0.74	0.31	0.03	2,534
Volume, um^3		3,645	4,961	12,480	32,610	12,662	13,228	17,946	25,925	29,008	27,178	26,257	32,041	31,552	36,685	46,904	75,534	428,617
Log10 PSD		2.78620	2.61208	2.70830	2.83471	2.12736	1.83959	1.67223	1.51263	1.25942	0.94941	0.64369	0.42218	0.11112	-0.12855	-0.50642		
C-pm																		
2001/04/17 15:06	16	597.75	500.48	993.13	1130.85	188.90	124.96	101.05	91.48	65.55	32.23	19.83	18.33	13.38	10.65	8.78	3.48	
2001/04/17 15:08	16	611.28	490.08	993.95	1146.18	194.10	128.35	98.13	90.48	66.75	29.90	18.40	16.10	11.73	7.03	7.05	2.80	256
2001/04/17 15:10	16	579.00	463.15	921.70	1098.10	184.63	119.80	89.93	85.30	67.10	32.98	20.75	17.40	12.93	9.10	8.23	2.60	
2001/04/17 15:12	16	586.58	471.25	910.45	1092.90	187.93	122.58	94.38	84.45	60.63	30.95	18.93	15.60	10.75	7.85	7.73	2.73	
2001/04/17 15:14	16	577.78	473.20	909.35	1091.08	185.68	124.38	93.28	87.00	65.43	29.65	20.05	14.43	11.18	7.68	7.13	2.48	
Average		590.48	479.63	945.72	1112.22	188.25	124.02	95.35	87.74	65.09	31.14	19.59	16.41	11.99	8.46	7.78	2.82	
Flow Ajusted		593.50	482.09	950.56	1117.92	189.21	124.65	95.84	88.19	65.42	31.30	19.69	16.49	12.05	8.50	7.82	2.83	3,806
Volume, um^3		3,540	5,843	23,221	53,339	17,868	23,857	36,582	70,228	104,433	95,577	117,436	199,923	294,405	419,395	1,177,147	7,087,569	9,730,365
Log10 PSD		2.77342	2.68313	2.97798	3.04841	2.27694	2.09569	1.98154	1.94542	1.81573	1.49554	1.29426	1.21733	1.08104	0.92959	0.89320		

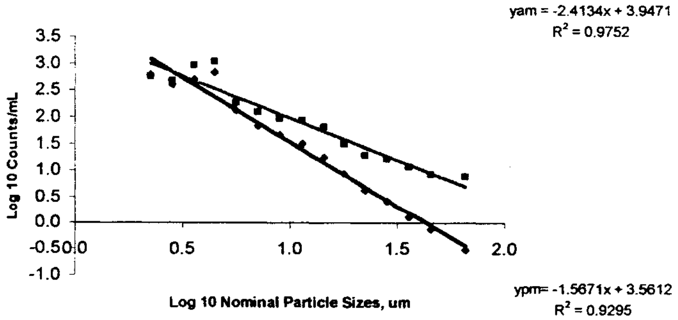
Particle Size Distribution



Volume Distribution



Log10 Particle Size Distribution



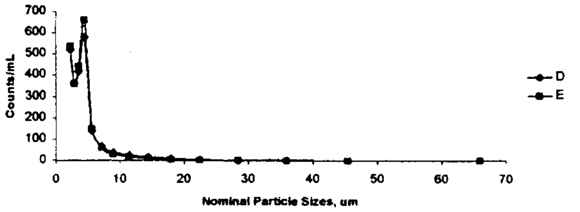
PCX Test of D & E Data, Combined Ranges

Full data set

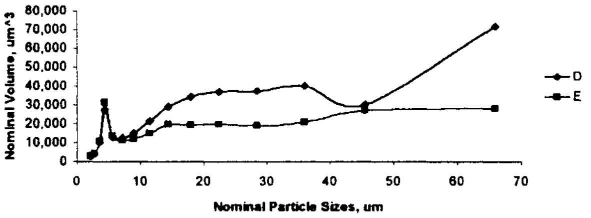
	Nominal	PCX1	PCX2			
				Sampled	16-Apr-01	
				Tested	17-Apr-01	
Flow rate	100	99.3	100.5			
mL		101.93	100.96	Sample time	2	min
		97.24		Particles/mL		
Mean		99.49	100.73			

		<<<<<<<<<<<<<<<<<<<<<<<<<<<		PCX 1		>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>		<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<			PCX 2			>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>				
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-81'	>81'	est	
i >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	81		256
r >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	66	168.5		
Log10 r :		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.81954			
	Jar																		
D																			
2001/04/17 12:10	4	517.68	364.35	422.98	586.93	137.68	68.23	39.83	26.10	16.50	10.75	5.63	2.73	1.68	0.63	0.48	0.05		
2001/04/17 12:12	4	520.16	355.65	418.65	576.00	139.88	64.40	40.33	26.10	18.48	11.33	5.93	3.35	1.83	0.48	0.43	0.08		
2001/04/17 12:14	4	517.90	362.98	412.68	571.60	140.45	65.75	39.50	27.50	18.40	10.48	6.75	3.10	1.70	0.70	0.50	0.10		
2001/04/17 12:16	4	526.30	358.05	413.38	566.93	136.93	65.55	37.45	27.65	17.45	12.20	6.50	3.15	1.33	0.65	0.50	0.03		
Average		520.51	360.26	416.92	575.36	138.73	65.98	39.28	26.84	18.21	11.19	6.20	3.08	1.63	0.61	0.48	0.06		
Flow Ajusted		523.18	362.10	419.06	578.31	139.44	66.32	39.48	26.98	18.30	11.24	6.23	3.10	1.64	0.62	0.48	0.06		2,197
Volume, um^3		3,120	4,389	10,237	27,593	13,169	12,693	15,068	21,481	29,211	34,338	37,167	37,539	40,054	30,364	71,869	157,362		545,654
Log10 PSD		2.71865	2.55883	2.62227	2.76216	2.14439	1.82164	1.59634	1.43096	1.26244	1.05095	0.79461	0.49095	0.21474	-0.21067	-0.32109			
E																			
2001/04/17 12:22	5	519.35	349.60	437.63	655.83	143.50	58.58	30.55	18.98	12.38	6.25	2.83	1.40	1.28	0.88	0.38	0.03		
2001/04/17 12:24	5	531.43	360.43	446.80	658.38	144.35	59.25	30.83	20.33	11.93	6.05	3.40	1.65	0.98	0.65	0.18	0.03		256
2001/04/17 12:26	5	537.65	361.80	448.68	660.05	147.98	59.43	32.83	18.18	13.35	6.43	3.75	1.58	0.65	0.45	0.10	0.03		
2001/04/17 12:28	5	539.53	357.58	445.50	659.80	148.35	58.23	30.43	18.93	12.85	6.10	3.10	1.58	0.60	0.40	0.15	0.03		
2001/04/17 12:30	5	536.68	356.83	432.10	651.13	145.30	61.23	29.78	18.45	12.03	6.90	3.43	1.75	0.78	0.38	0.13	0.00		
Average		532.93	357.25	442.14	657.04	145.90	59.34	30.88	18.97	12.51	6.35	3.30	1.59	0.86	0.55	0.19	0.02		
Flow Ajusted		535.66	359.08	444.41	660.40	146.64	59.64	31.04	19.07	12.57	6.38	3.32	1.60	0.86	0.55	0.19	0.02		2,281
Volume, um^3		3,195	4,352	10,856	31,510	13,849	11,415	11,847	15,184	20,064	19,475	19,782	19,371	20,994	27,266	27,991	50,356		307,506
Log10 PSD		2.72889	2.55519	2.64778	2.81981	2.16626	1.77557	1.49190	1.28029	1.09930	0.80465	0.52073	0.20362	-0.06561	-0.25742	-0.73061			

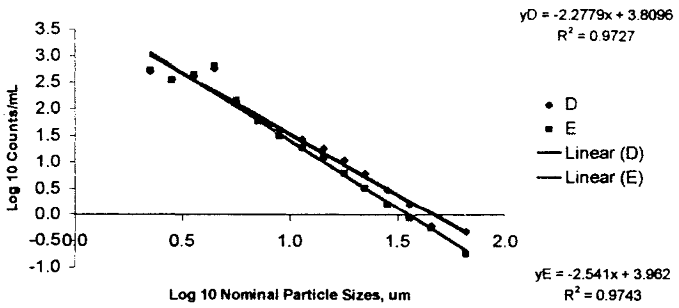
Particle Size Distribution



Volume Distribution



Log10 Particle Size Distribution



PCX Test of Biofilter Outlet Data, Combined Ranges

Full data set

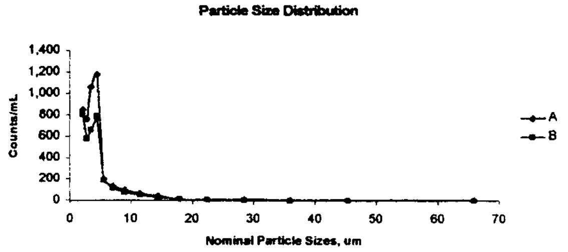
	Nominal	PCX1	PCX2
Flow rate	100	99.3	100.5
mL		101.93	100.96
		97.24	
Mean		99.49	100.73

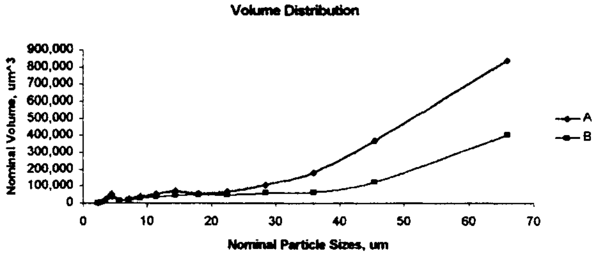
Sampled 16-Apr-01
Tested 17-Apr-01

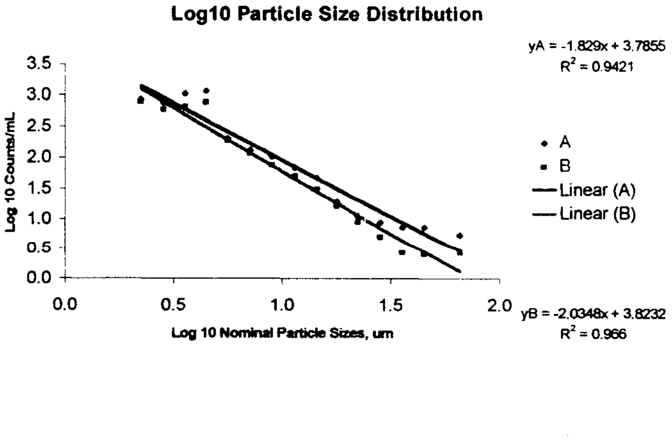
Sample time 2 min
Particles/mL

<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>> <<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-61'	>81'	est
li >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	81	256
l* >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	66	168.5	
Log10 l* =		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.81954		
	Jar																	
A																		
2001/04/17 14:04	10	853.85	759.30	1068.40	1152.90	198.80	134.53	103.60	69.28	47.88	20.70	12.55	10.53	10.45	13.50	9.33	0.83	
2001/04/17 14:06	10	862.78	778.88	1096.80	1201.45	204.58	136.63	106.53	72.98	47.20	19.03	12.40	8.38	7.55	6.33	4.48	0.58	
2001/04/17 14:08	10	852.63	763.00	1042.10	1172.25	203.55	133.23	103.88	67.95	44.95	19.40	10.85	8.30	5.55	5.63	3.85	0.68	
2001/04/17 14:10	10	844.48	755.95	1036.35	1176.40	206.13	131.98	99.95	69.63	47.18	19.38	10.58	8.68	6.33	4.50	4.55	0.80	
Average		853.43	764.28	1060.91	1175.75	203.26	134.09	103.49	69.96	46.80	19.63	11.59	8.97	7.47	7.49	5.55	0.72	
Flow Ajusted		857.81	768.20	1066.35	1181.78	204.30	134.77	104.02	70.31	47.04	19.73	11.65	9.01	7.51	7.53	5.58	0.72	4,496
Volume, um^3		5,116	9,311	26,050	56,386	19,294	25,794	39,704	55,994	75,088	60,235	69,501	109,266	183,390	371,185	839,738	1,809,659	3,755,711
Log10 PSD		2.93339	2.88547	3.02790	3.07254	2.31028	2.12961	2.01711	1.84705	1.67247	1.29503	1.06644	0.95495	0.87547	0.87656	0.74651		
B																		
2001/04/17 14:16	11	783.13	558.50	628.55	757.45	184.68	111.30	74.00	47.75	31.85	19.73	10.38	7.30	4.55	8.28	11.20	1.20	
2001/04/17 14:18	11	797.78	567.40	644.65	779.73	188.70	116.65	72.75	46.65	26.93	13.73	7.80	4.25	1.93	0.93	0.50	0.83	256
2001/04/17 14:20	11	824.35	598.95	687.63	812.03	195.03	121.15	79.25	52.25	33.10	16.93	8.60	5.00	2.50	1.20	1.10	0.30	
2001/04/17 14:22	11	819.18	590.58	687.70	813.83	195.73	121.00	78.18	53.93	30.03	16.85	8.98	5.10	2.23	1.15	0.28	0.13	
2001/04/17 14:24	11	808.83	584.50	658.95	791.23	191.13	117.08	75.18	51.70	31.85	15.35	9.03	4.50	2.48	1.18	0.35	0.05	
Average		806.65	579.99	661.50	790.85	191.05	117.44	75.87	50.46	30.75	16.52	8.96	5.23	2.74	2.55	2.69	0.50	
Flow Ajusted		810.79	582.96	664.89	794.90	192.03	118.04	76.26	50.71	30.91	16.60	9.00	5.26	2.75	2.56	2.70	0.50	3,361
Volume, um^3		4,836	7,066	16,243	37,927	18,135	22,591	29,108	40,385	49,336	50,689	53,682	63,717	67,156	126,166	406,252	1,258,893	2,252,182
Log10 PSD		2.90891	2.76564	2.82275	2.90031	2.28337	2.07202	1.88229	1.70512	1.49007	1.22010	0.95429	0.72072	0.43918	0.40791	0.43116		


Particle Size Distribution


Volume Distribution


Log10 Particle Size Distribution

PCX Test of G; Inflow Culture Water Data, Combined Ranges

Full data set

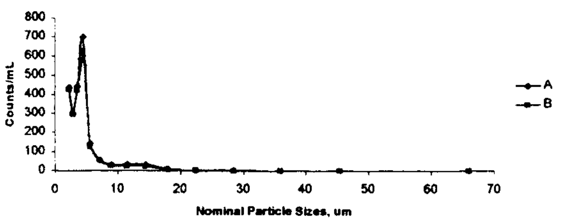
Sampled 16-Apr-01
Tested 17-Apr-01

	Nominal	PCX1	PCX2
Flow rate	100	99.3	100.5
mL		101.93	100.96
		97.24	
Mean		99.49	100.73
		*	*

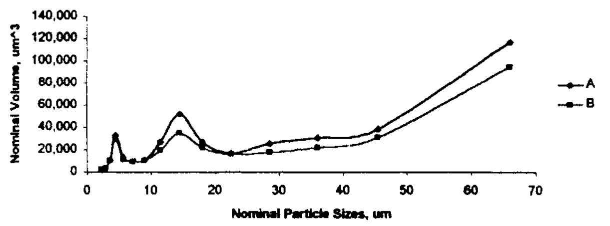
Sample time 2 min
Particles/mL

		<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>									<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>							
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-81'	>81'	est
I >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	81	256
I* >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	66	168.5	
Log10 I* >		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.81954		
	Jar																	
A																		
2001/04/17 13:36	8	420.38	286.30	429.35	688.20	142.80	51.93	29.33	33.90	32.05	9.23	2.83	2.10	1.40	0.93	2.03	0.08	
2001/04/17 13:38	8	428.35	292.98	436.83	698.33	138.33	52.73	28.65	33.63	33.43	9.65	3.00	1.95	1.33	0.80	0.45	0.48	
2001/04/17 13:40	8	430.28	299.00	436.95	698.33	139.65	52.75	28.30	32.95	33.13	8.23	2.95	2.38	1.18	0.53	0.45	0.48	
2001/04/17 13:42	8	440.90	306.40	447.08	704.03	145.83	52.03	29.85	34.83	31.98	9.18	2.65	2.08	1.08	0.70	0.40	0.18	
2001/04/17 13:44	8	439.60	300.65	443.85	704.70	145.55	54.25	29.53	35.60	33.18	8.50	2.75	1.95	1.28	1.00	0.53	0.18	
Average		431.90	297.07	438.81	698.72	142.43	52.74	29.13	34.18	32.75	8.96	2.84	2.09	1.25	0.79	0.77	0.28	
Flow Ajusted		434.11	298.59	441.06	702.30	143.16	53.01	29.28	34.36	32.92	9.00	2.85	2.10	1.26	0.79	0.77	0.28	2,186
Volume, um^3		2,589	3,619	10,775	33,509	13,520	10,145	11,176	27,358	52,545	27,485	16,995	25,462	30,693	39,163	116,504	692,391	1,113,930
Log10 PSD		2.63760	2.47507	2.64450	2.84652	2.15582	1.72432	1.46656	1.53599	1.51743	0.95429	0.45477	0.32237	0.09913	-0.10015	-0.11129		
B																		
2001/04/17 13:48	9	387.10	285.08	376.28	508.13	105.80	49.30	27.15	21.10	13.93	4.40	1.75	1.03	0.63	1.08	1.83	0.05	
2001/04/17 13:50	9	424.53	296.85	433.08	652.08	130.20	53.33	28.63	26.40	23.85	7.78	2.88	1.58	0.88	0.43	0.28	0.23	256
2001/04/17 13:52	9	431.85	297.75	437.85	660.70	132.83	53.20	28.28	26.78	24.45	7.80	2.88	1.80	1.05	0.50	0.20	0.10	
2001/04/17 13:54	9	422.78	286.88	411.48	635.73	127.53	53.78	27.38	23.95	24.38	8.03	3.13	1.45	1.10	0.53	0.40	0.10	
2001/04/17 13:56	9	442.53	306.18	435.18	667.03	132.38	55.43	29.15	26.93	24.10	8.10	2.83	1.63	0.88	0.65	0.40	0.08	
Average		421.76	294.55	418.77	624.73	125.75	53.01	28.12	25.03	22.14	7.22	2.69	1.50	0.91	0.64	0.62	0.11	
Flow Ajusted		423.92	296.05	420.92	627.93	126.39	53.28	28.26	25.16	22.25	7.26	2.70	1.50	0.91	0.64	0.62	0.11	2,038
Volume, um^3		2,528	3,588	10,283	29,961	11,936	10,197	10,787	20,034	35,522	22,160	16,126	18,214	22,222	31,479	93,809	276,957	615,801
Log10 PSD		2.62728	2.47137	2.62420	2.79791	2.10171	1.72654	1.45116	1.40068	1.34740	0.86076	0.43197	0.17686	-0.04113	-0.19501	-0.20539		

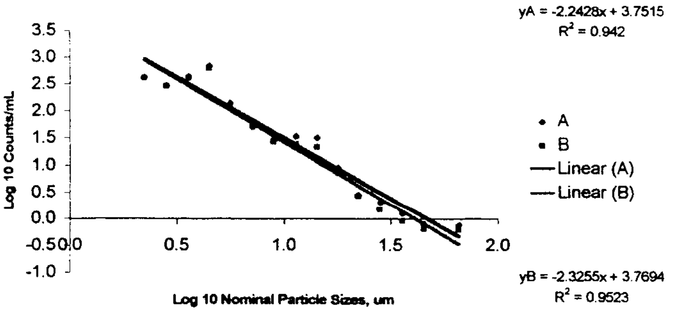
Particle Size Distribution



Volume Distribution



Log10 Particle Size Distribution



PCX Test of Make-up Water Data, Combined Ranges

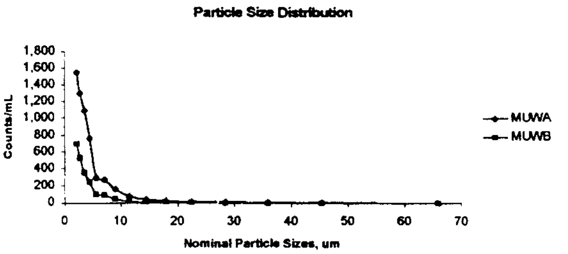
Full data set

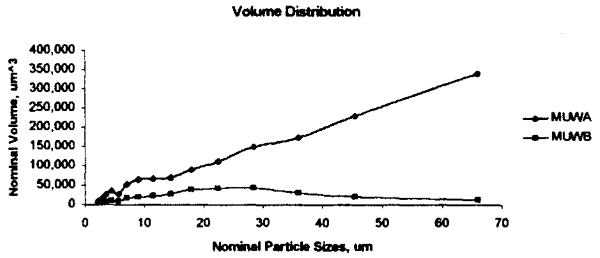
Sampled 16-Apr-01
Tested 17-Apr-01

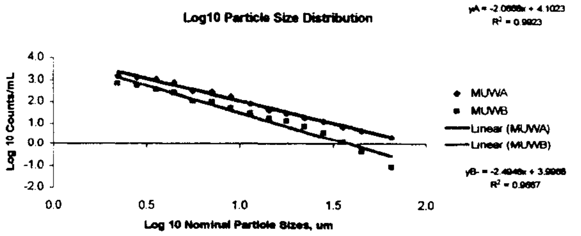
	Nominal	PCX1	PCX2
Flow rate	100	99.3	100.5
mL		101.93	100.96
		97.24	
Mean		99.49	100.73

Sample time 2 min
Particles/mL

		<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-81'	>81'	est
li >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	81	256
l* >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	66	168.5	
Log10 l* :		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.81954		
	Jar																	
MUW_A																		
2001/04/17 14:30	12	1466.63	1224.03	1035.38	724.95	286.23	265.13	163.75	82.58	38.43	26.43	18.00	11.98	8.65	6.03	3.63	0.93	
2001/04/17 14:32	12	1579.38	1315.30	1115.40	783.93	305.95	281.28	172.15	85.30	45.20	31.55	17.88	11.88	7.65	5.98	2.80	0.10	
2001/04/17 14:34	12	1586.70	1330.63	1126.08	795.15	311.23	284.35	171.43	83.45	44.00	29.78	17.98	13.30	6.25	4.00	2.03	0.18	
2001/04/17 14:36	12	1564.93	1312.08	1094.43	769.55	299.53	282.33	166.73	83.23	45.50	29.25	19.85	12.30	6.30	4.03	1.50	0.15	
2001/04/17 14:38	12	1594.23	1343.43	1122.65	790.00	317.05	287.55	169.70	85.43	42.43	30.28	19.05	12.25	6.43	3.18	1.28	0.20	
Average		1558.37	1305.09	1098.79	772.72	304.00	280.13	168.75	84.00	43.11	29.46	18.55	12.34	7.06	4.64	2.25	0.31	
Flow Ajusted		1566.36	1311.78	1104.42	776.68	305.55	281.56	169.62	84.43	43.33	29.61	18.65	12.40	7.09	4.66	2.26	0.31	5,719
Volume, um^3		9,342	15,900	26,980	37,057	28,856	53,888	64,743	67,230	69,167	90,406	111,202	150,338	173,230	230,023	339,678	780,514	2,248,553
Log10 PSD		3.19489	3.11786	3.04313	2.89024	2.48509	2.44957	2.22946	1.92647	1.63680	1.47138	1.27056	1.09354	0.85072	0.66874	0.35344		
MUW_B																		
2001/04/17 14:46	13	704.78	530.00	364.88	259.43	102.48	98.68	52.50	31.08	17.58	13.00	7.78	3.75	1.10	0.50	0.05	0.15	
2001/04/17 14:48	13	699.20	529.53	362.85	253.18	106.73	99.70	49.48	29.98	18.25	13.45	6.70	3.68	1.55	0.35	0.13	0.23	
2001/04/17 14:50	13	698.48	532.18	356.78	247.93	103.10	98.45	48.33	29.10	18.15	12.88	7.48	3.75	1.28	0.50	0.10	0.15	
Average		700.82	530.57	361.50	253.51	104.10	98.94	50.10	30.05	17.99	13.11	7.32	3.73	1.31	0.45	0.09	0.18	
Flow Ajusted		704.41	533.29	363.35	254.81	104.63	99.45	50.36	30.20	18.08	13.18	7.35	3.74	1.32	0.45	0.09	0.18	2,185
Volume, um^3		4,201	6,464	8,876	12,158	9,881	19,033	19,221	24,052	28,867	40,233	43,861	45,382	32,125	22,308	13,870	440,613	771,146
Log10 PSD		2.84782	2.72696	2.56033	2.40621	2.01967	1.99760	1.70206	1.48007	1.25729	1.11977	0.86653	0.57335	0.11894	-0.34457	-1.03557		


Particle Size Distribution


Volume Distribution


Log10 Particle Size Distribution

PCX Test of Settle Deck Data, Combined Ranges

Full data set

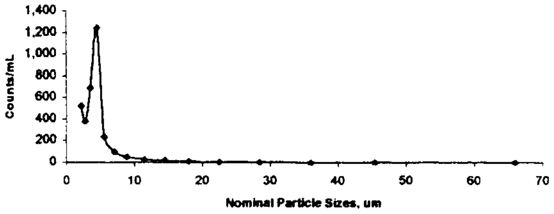
Sampled 16-Apr-01
Tested 17-Apr-01

	Nominal	PCX1	PCX2
Flow rate	100	99.3	100.5
mL		101.93	100.96
		97.24	
Mean		99.49	100.73

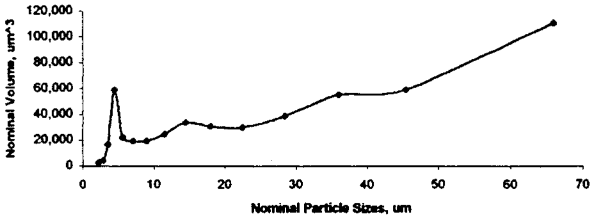
Sample time 2 min
Particles/mL

		<<<<<<<<<<<<<<<<<<<<<<<<<<<			PCX 1	>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>				<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<				PCX 2	>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>				
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-81'	>81'	est	
li >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	81		256
f* >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	66	168.5		
Log10 f* >		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.81954			
	Jar																		
S Deck																			
2001/04/17 14:54	15	522.23	372.20	692.18	1239.13	231.60	101.23	51.58	31.48	21.43	9.85	5.50	2.98	1.93	1.13	0.95	0.10		
2001/04/17 14:56	15	517.80	381.40	691.23	1216.78	230.03	101.78	50.75	31.20	21.53	10.88	4.58	3.23	2.00	1.03	0.90	0.15		
2001/04/17 14:58	15	532.90	381.25	703.50	1256.75	237.38	102.23	51.18	32.33	21.55	10.08	5.38	3.33	2.48	1.30	0.63	0.20		
2001/04/17 15:00	15	517.00	379.30	675.15	1221.28	237.03	101.25	49.78	29.40	20.58	10.03	5.00	3.10	2.38	1.40	0.60	0.20		
2001/04/17 15:02	15	526.98	382.43	680.80	1245.45	238.48	101.13	49.20	30.88	20.98	9.73	4.78	3.30	2.55	1.18	0.60	0.10		
Average		523.38	379.32	688.57	1235.88	234.90	101.52	50.50	31.06	21.21	10.11	5.05	3.19	2.27	1.21	0.74	0.15		
Flow Ajusted		526.06	381.26	692.10	1242.21	236.10	102.04	50.75	31.21	21.32	10.16	5.07	3.20	2.28	1.21	0.74	0.15		3,306
Volume, um^3		3,138	4,621	16,907	59,270	22,297	19,529	19,373	24,857	34,030	31,030	30,243	38,803	55,615	59,737	111,209	377,668		908,327
Log10 PSD		2.72104	2.58122	2.84017	3.09420	2.37310	2.00877	1.70547	1.49435	1.32876	1.00697	0.70508	0.50533	0.35729	0.08321	-0.13149			

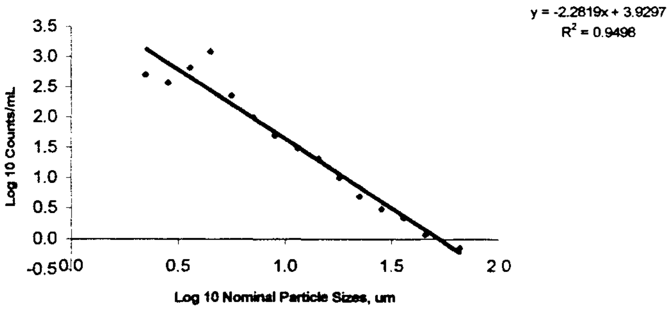
Particle Size Distribution



Volume Distribution



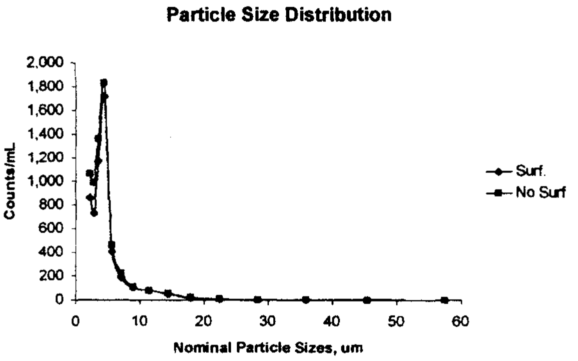
Log10 Particle Size Distribution

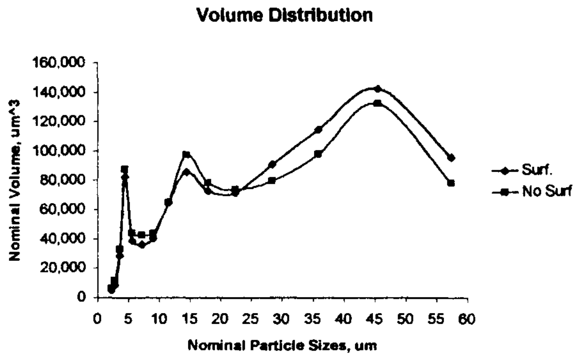


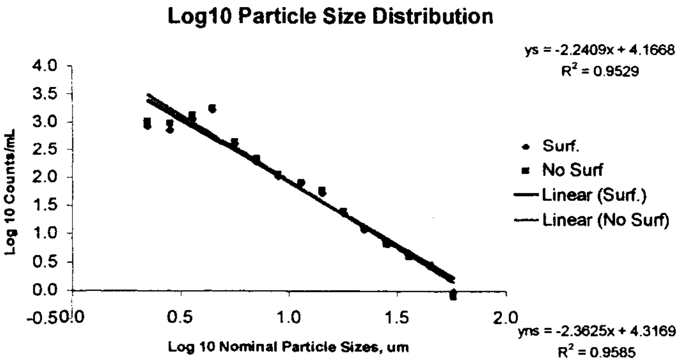
PCX Test of A Data, with/without surfactant

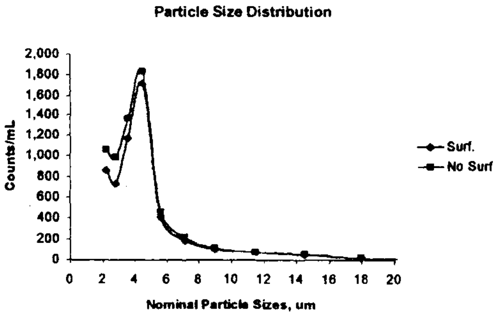
	Nominal	PCX1	PCX2			
				Sampled	30-Apr-01	
				Tested	1-May-01	
Flow rate	100	99.875	100.167			
mL		90.03	100.62	Sample tim	2	min
		99.88	99.63	Particles/mL		
Mean		96.595	100.139			

		<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
	l >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	128
	f' >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	96	
	Log10 f' >	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
FDDW		149.55	123.60	109.70	73.65	30.28	29.85	23.98	16.13	15.63	10.25	4.78	1.68	0.68	0.30	0.08	0.10	
		140.45	120.15	93.55	54.43	19.18	16.60	9.73	3.58	1.30	0.90	0.33	0.18	0.15	0.05	0.00	0.03	
		145.00	121.88	101.63	64.04	24.73	23.23	16.85	9.85	8.46	5.58	2.55	0.93	0.41	0.18	0.04	0.06	
	Jar																	
Surf.																		
2001/05/01 12:47	D1	835.47	715.95	1145.58	1657.03	391.73	180.85	105.93	78.48	51.83	24.73	11.60	7.50	4.70	3.30	1.08	0.40	
2001/05/01 12:49	D1	815.80	694.38	1099.18	1627.98	393.45	179.13	98.65	76.18	55.53	23.13	12.23	7.28	5.00	2.83	1.03	0.40	
2001/05/01 12:51	D1	834.03	704.50	1149.73	1676.43	403.63	184.93	103.60	81.15	54.48	23.45	12.70	7.73	4.55	3.05	0.88	0.35	
2001/05/01 12:53	D1	829.93	708.50	1110.95	1641.03	397.05	184.75	99.53	77.58	53.60	24.03	11.93	7.75	4.70	2.60	0.70	0.43	
2001/05/01 12:55	D1	866.13	734.65	1181.00	1720.20	410.75	191.68	106.23	83.05	53.43	24.68	12.08	7.50	4.55	2.75	1.15	0.45	
Average		836.27	711.60	1137.29	1664.53	399.32	184.27	102.79	79.29	53.77	24.00	12.11	7.55	4.70	2.91	0.97	0.41	
Flow Ajusted		865.75	736.68	1177.37	1723.21	413.40	190.76	106.41	82.08	53.70	23.97	12.09	7.54	4.69	2.90	0.96	0.40	5,402
Volume, um^3		5,163	8,929	28,762	82,219	39,040	36,509	40,616	65,362	85,712	73,185	72,095	91,385	114,657	143,079	95,924	187,354	1,169,994
Log10 PSD		2.93739	2.86728	3.07091	3.23634	2.61637	2.28049	2.02698	1.91424	1.72994	1.37961	1.08236	0.87734	0.67149	0.46254	-0.01608		
No Surf																		
2001/05/01 12:37	D14	1003.83	943.93	1304.80	1757.05	440.35	213.43	107.88	76.18	59.95	24.40	11.60	6.85	4.00	2.85	0.68	0.18	
2001/05/01 12:39	D14	1016.75	941.70	1292.90	1741.65	450.30	215.60	110.40	78.65	60.20	25.55	12.38	6.90	3.80	2.78	0.73	0.23	
2001/05/01 12:41	D14	1036.10	957.13	1327.68	1776.20	452.88	217.55	113.88	79.68	62.60	26.70	11.80	5.85	3.83	2.40	0.60	0.15	
2001/05/01 12:43	D14	1067.35	981.15	1355.10	1823.00	461.80	224.15	115.25	82.85	62.45	26.38	13.73	6.70	4.50	2.75	1.15	0.25	
Average		1031.01	955.98	1320.12	1774.48	451.33	217.68	111.85	79.34	61.30	25.76	12.43	6.58	4.03	2.69	0.79	0.20	
Flow Ajusted		1067.35	989.67	1366.65	1837.03	467.24	225.35	115.79	82.13	61.21	25.72	12.41	6.57	4.03	2.69	0.79	0.20	6,265
Volume, um^3		6,366	11,996	33,386	87,650	44,125	43,130	44,198	65,406	97,715	78,541	74,001	79,584	98,343	132,674	78,280	92,521	1,067,915
Log10 PSD		3.02831	2.99549	3.13566	3.26412	2.66954	2.35287	2.06368	1.91452	1.78686	1.41028	1.09369	0.81729	0.60484	0.42975	-0.10435		









Particle Size Analysis

PCX Results for samples taken 30 April 01.

The PCX particle counters were set up in tandem in two x eight channels spans:

Lower span (A): 2-2.5, 2.5-3.2, 3.2-4, 4-5, 5-6.3, 6.3-8,8-10, 10-13 µm
and
Upper span(A): 13-16, 16-20, 20-25, 25-32, 32-40, 40-51, 51-81, >81 µm

and sites A and B using the filtration screen classes of:
(B):1-5, 5-10, 10-20, 20-30, 30-41 µm

There was adjustment for variation in flow rates but no adjustment for cell noise except in the screen classes, although the noise was recorded against filtered (0.45 µm) de-ionized, distilled water. The effect of surfactant (Nonidet P-40 and later it's replacement IGEPAL CA-630) was trialed.

Results log:

Site>	**A**	**B**	**C**	**D**	**E**	**SD**	**BF_A**	**BF_B**	**G_A**	**G_B**	**MW_A 1**	**MW_A 2**	**MW B**	**I/J**	**OF**
A	√	√	√	√	√	√	√	√	√	√	√		√	√	√
B	√	√													

PCX Test of A Data; with/wthout Filt Water Removed

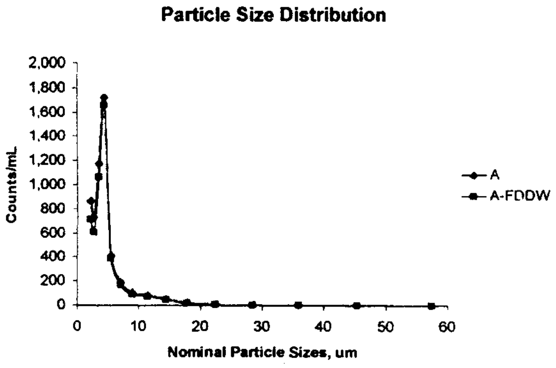
Sampled 30-Apr-01
Tested 1-May-01

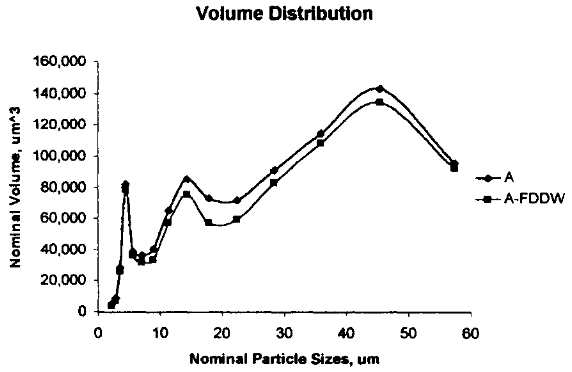
	Nominal	PCX1	PCX2
Flow rate	100	99.875	100.167
mL		90.03	100.62
		99.88	99.63
Mean		96.595	100.139

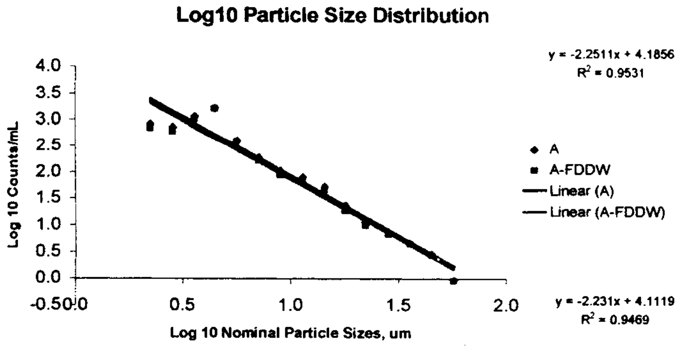
Sample tim 2 min
Particles/mL

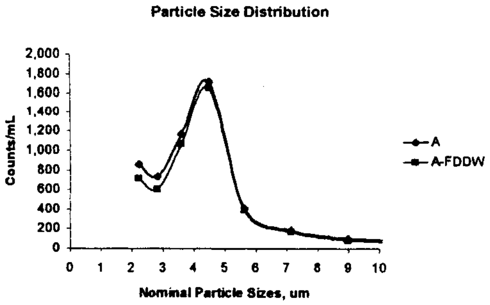
	<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
ll >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	128
r >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	96	
Log10 r :	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
FDDW	149.55	123.60	109.70	73.65	30.28	29.85	23.98	16.13	15.63	10.25	4.78	1.68	0.68	0.30	0.08	0.10	
	140.45	120.15	93.55	54.43	19.18	16.60	9.73	3.58	1.30	0.90	0.33	0.18	0.15	0.05	0.00	0.03	
	145.00	121.88	101.63	64.04	24.73	23.23	16.85	9.85	8.46	5.58	2.55	0.93	0.41	0.18	0.04	0.06	
Jar																	
A																	
2001/05/01 12:47 D1	835.47	715.95	1145.58	1657.03	391.73	180.85	105.93	78.48	51.83	24.73	11.60	7.50	4.70	3.30	1.08	0.40	
2001/05/01 12:49 D1	815.80	694.38	1099.18	1627.98	393.45	179.13	98.65	76.18	55.53	23.13	12.23	7.28	5.00	2.83	1.03	0.40	
2001/05/01 12:51 D1	834.03	704.50	1149.73	1676.43	403.63	184.93	103.60	81.15	54.48	23.45	12.70	7.73	4.55	3.05	0.88	0.35	
2001/05/01 12:53 D1	829.93	708.50	1110.95	1641.03	397.05	184.75	99.53	77.58	53.60	24.03	11.93	7.75	4.70	2.60	0.70	0.43	
2001/05/01 12:55 D1	866.13	734.65	1181.00	1720.20	410.75	191.68	106.23	83.05	53.43	24.68	12.08	7.50	4.55	2.75	1.15	0.45	
Average	836.27	711.60	1137.29	1664.53	399.32	184.27	102.79	79.29	53.77	24.00	12.11	7.55	4.70	2.91	0.97	0.41	
Flow Ajusted	865.75	736.68	1177.37	1723.21	413.40	190.76	106.41	82.08	53.70	23.97	12.09	7.54	4.69	2.90	0.96	0.40	5,402
Volume, um^3	5,163	8,929	28,762	82,219	39,040	36,509	40,616	65,362	85,712	73,185	72,095	91,385	114,657	143,079	95,924	167,354	1,169,994
Log10 PSD	2.93739	2.86728	3.07091	3.23634	2.61637	2.28049	2.02698	1.91424	1.72994	1.37961	1.08236	0.87734	0.67149	0.46254	-0.01608		

A-FDDW																	
2001/05/01 12:47 D1	835.47	715.95	1145.58	1657.03	391.73	180.85	105 93	78.48	51.83	24.73	11.60	7.50	4.70	3.30	1.08	0.40	
2001/05/01 12:49 D1	815.80	694.38	1099.18	1627.98	393.45	179.13	98.65	76.18	55.53	23.13	12.23	7.28	5.00	2.83	1.03	0.40	256
2001/05/01 12:51 D1	834.03	704.50	1149.73	1676.43	403.63	184.93	103.60	81.15	54.48	23.45	12.70	7.73	4.55	3.05	0.88	0.35	
2001/05/01 12:53 D1	829.93	708.50	1110.95	1641.03	397.05	184.75	99.53	77.58	53.60	24.03	11.93	7.75	4.70	2.60	0.70	0.43	
2001/05/01 12:55 D1	866.13	734.65	1181.00	1720.20	410.75	191.68	106.23	83.05	53.43	24.68	12.08	7.50	4.55	2.75	1.15	0.45	
Average	836.47	710.51	1135.21	1666.41	401.22	185.12	102.00	79.49	54.26	23.82	12.23	7.56	4.70	2.81	0.94	0.41	
less FDDW	691.47	588.63	1033.59	1602.37	376.49	161.89	85.15	69.64	45.79	18.24	9.68	6.64	4.29	2.63	0.90	0.34	
Flow Ajusted	715.64	609.38	1070.02	1658.85	386.77	167.60	88.15	72.09	47.41	18.89	10.02	6.87	4.44	2.72	0.93	0.36	4,863
Volume, um^3	4,269	7,386	26,140	79,149	36,808	32,077	33,648	57,409	75,675	57,673	59,775	83,288	108,432	134,351	92,745	164,854	1,053,680
Log10 PSD	2.85482	2.78489	3.02939	3.21981	2.59080	2.22428	1.94523	1.85789	1.67585	1.27616	1.00098	0.83705	0.64725	0.43521	-0.03071		









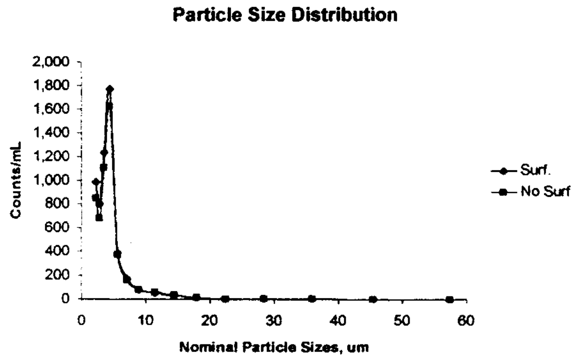
PCX Test of B Data, with/without surfactant

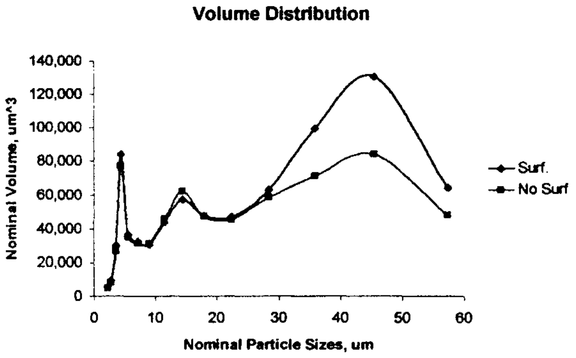
Sampled 30-Apr-01
Tested 1-May-01

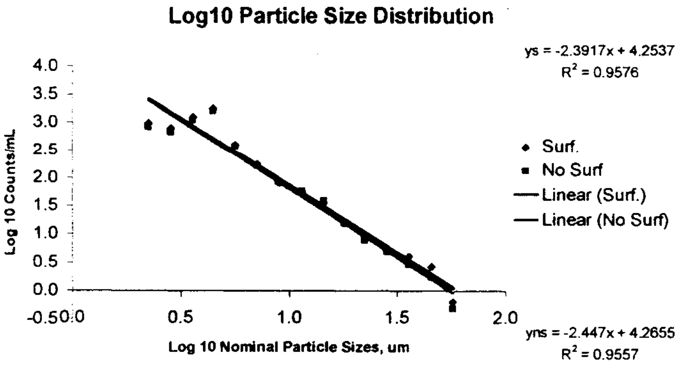
	Nominal	PCX1	PCX2
Flow rate	100	99.875	100.167
mL		90.03	100.62
		99.88	99.63
Mean		96.595	100.139

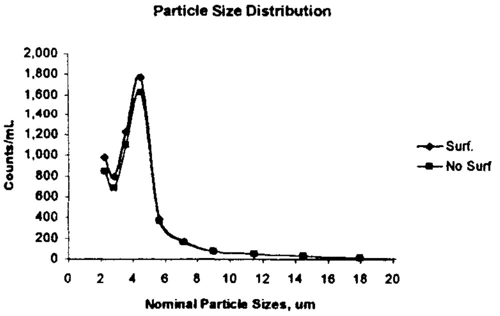
Sample tim 2 min
Particles/mL

	<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>									
Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
l >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	128
r >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	96	
Log10 r >	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
FDDW	149.55	123.60	109.70	73.65	30.28	29.85	23.98	16.13	15.63	10.25	4.78	1.68	0.68	0.30	0.08	0.10	
	140.45	120.15	93.55	54.43	19.18	16.60	9.73	3.58	1.30	0.90	0.33	0.18	0.15	0.05	0.00	0.03	
	145.00	121.88	101.63	64.04	24.73	23.23	16.85	9.85	8.46	5.58	2.55	0.93	0.41	0.18	0.04	0.06	
Jar																	
Surf.																	
2001/05/01 13:09 D2	940.40	761.10	1193.73	1696.25	368.23	163.53	77.73	54.15	35.65	16.03	8.53	5.45	4.20	2.90	0.63	0.23	
2001/05/01 13:11 D2	961.75	787.30	1222.45	1734.10	374.03	165.65	78.73	54.78	35.80	16.18	7.68	5.70	4.25	2.90	0.58	0.15	
2001/05/01 13:13 D2	960.88	782.75	1214.10	1731.08	382.83	165.60	77.18	53.63	36.10	15.40	7.00	5.48	4.13	2.25	0.70	0.23	
2001/05/01 13:15 D2	949.23	761.40	1142.60	1686.23	388.40	166.63	77.50	52.28	37.25	15.13	8.40	4.35	3.80	2.58	0.70	0.30	
Average	953.06	773.14	1193.22	1711.91	378.37	165.35	77.78	53.71	36.20	15.68	7.90	5.24	4.09	2.66	0.65	0.23	
Flow Ajusted	986.66	800.39	1235.28	1772.26	391.71	171.18	80.52	55.60	36.15	15.66	7.89	5.24	4.09	2.65	0.65	0.22	5,566
Volume, um^3	5,885	9,701	30,177	84,560	36,992	32,762	30,736	44,275	57,704	47,818	47,051	63,471	99,868	130,827	64,612	104,086	890,524
Log10 PSD	2.99417	2.90330	3.09177	3.24853	2.59296	2.23345	1.90592	1.74507	1.55811	1.19478	0.89702	0.71904	0.61152	0.42367	-0.18769		
No Surf																	
2001/05/01 12:59 D15	822.20	663.95	1083.88	1585.40	365.00	162.35	81.85	58.30	39.90	15.53	7.33	4.65	2.85	1.55	0.58	0.20	
2001/05/01 13:01 D15	804.93	647.40	1044.30	1553.48	353.35	156.48	78.23	54.08	39.43	15.60	7.73	4.73	3.00	1.48	0.45	0.13	
2001/05/01 13:03 D15	849.28	687.40	1110.85	1609.33	369.63	164.90	80.08	58.23	39.40	15.45	7.75	5.13	2.60	1.85	0.55	0.33	
2001/05/01 13:05 D15	812.98	650.38	1029.55	1540.98	355.05	152.40	79.70	52.75	38.50	15.78	7.95	4.95	3.28	1.98	0.38	0.53	
Average	822.34	662.28	1067.14	1572.29	360.76	159.03	79.96	55.84	39.31	15.59	7.69	4.86	2.93	1.71	0.49	0.29	
Flow Ajusted	851.33	685.63	1104.76	1627.72	373.47	164.64	82.78	57.81	39.25	15.57	7.68	4.86	2.93	1.71	0.49	0.29	5,021
Volume, um^3	5,077	8,310	26,988	77,663	35,270	31,510	31,598	46,032	62,656	47,532	45,786	58,856	71,508	84,345	48,459	135,890	817,481
Log10 PSD	2.93010	2.83609	3.04327	3.21158	2.57226	2.21653	1.91793	1.76197	1.59386	1.19217	0.88518	0.68626	0.46645	0.23303	-0.31263		









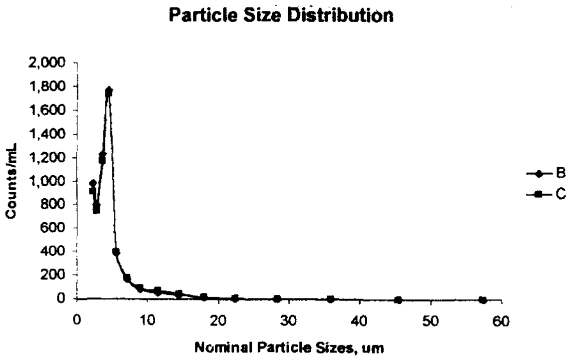
PCX Test of B-C Data, with surfactant

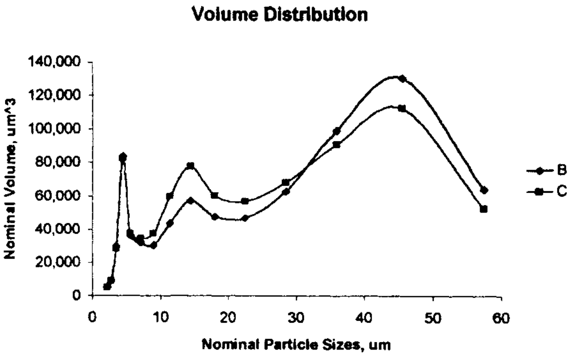
Sampled 30-Apr-01
Tested 1-May-01

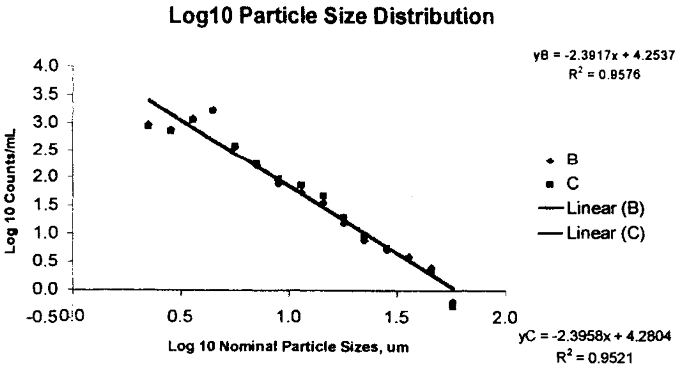
	Nominal	PCX1	PCX2
Flow rate	100	99.875	100.167
mL		90.03	100.62
		99.88	99.63
Mean		96.595	100.139

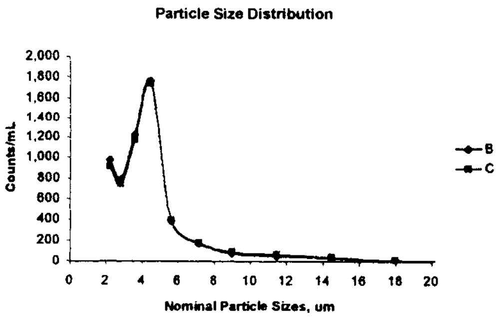
Sample tim 2 min
Particles/mL

	Jar	<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
i >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	128
r >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	96	
Log10 r :		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
FDDW		149.55	123.60	109.70	73.65	30.28	29.85	23.98	16.13	15.63	10.25	4.78	1.68	0.68	0.30	0.08	0.10	
		140.45	120.15	93.55	54.43	19.18	16.60	9.73	3.58	1.30	0.90	0.33	0.18	0.15	0.05	0.00	0.03	
		145.00	121.88	101.63	64.04	24.73	23.23	16.85	9.85	8.46	5.58	2.55	0.93	0.41	0.18	0.04	0.06	
	Jar																	
B																		
2001/05/01 13:09	D2	940.40	761.10	1193.73	1696.25	368.23	163.53	77.73	54.15	35.65	16.03	8.53	5.45	4.20	2.90	0.63	0.23	
2001/05/01 13:11	D2	961.75	787.30	1222.45	1734.10	374.03	165.65	78.73	54.78	35.80	16.18	7.68	5.70	4.25	2.90	0.58	0.15	
2001/05/01 13:13	D2	960.88	782.75	1214.10	1731.08	382.83	165.60	77.18	53.63	36.10	15.40	7.00	5.48	4.13	2.25	0.70	0.23	
2001/05/01 13:15	D2	949.23	761.40	1142.60	1686.23	388.40	166.63	77.50	52.28	37.25	15.13	8.40	4.35	3.80	2.58	0.70	0.30	
Average		953.06	773.14	1193.22	1711.91	378.37	165.35	77.78	53.71	36.20	15.68	7.90	5.24	4.09	2.66	0.65	0.23	
Flow Ajusted		986.66	800.39	1235.28	1772.26	391.71	171.18	80.52	55.60	36.15	15.66	7.89	5.24	4.09	2.65	0.65	0.22	5,566
Volume, um^3		5,885	9,701	30,177	84,560	36,992	32,762	30,736	44,275	57,704	47,818	47,051	63,471	99,868	130,827	64,612	104,086	890,524
Log10 PSD		2.99417	2.90330	3.09177	3.24853	2.59296	2.23345	1.90592	1.74507	1.55811	1.19478	0.89702	0.71904	0.61152	0.42367	-0.18769		
C																		
2001/05/01 13:21	D3	887.28	724.22	1134.03	1680.45	388.45	178.18	96.23	73.93	49.00	19.83	9.83	5.68	4.00	2.00	0.60	0.10	
2001/05/01 13:23	D3	875.13	709.83	1123.93	1663.90	383.00	173.48	94.98	71.58	49.70	19.63	9.55	5.45	4.03	2.43	0.40	0.08	
2001/05/01 13:25	D3	889.58	722.00	1142.83	1699.78	388.45	175.40	97.53	72.65	47.95	19.88	9.93	5.68	3.75	2.30	0.50	0.18	
2001/05/01 13:27	D3	890.75	733.95	1148.65	1693.30	390.45	178.83	95.13	73.93	49.80	20.13	9.03	5.93	3.18	2.43	0.63	0.10	
Average		885.68	722.50	1137.36	1684.36	387.59	176.47	95.96	73.02	49.11	19.86	9.58	5.68	3.74	2.29	0.53	0.11	
Flow Ajusted		916.90	747.97	1177.45	1743.73	401.25	182.69	99.35	75.59	49.04	19.83	9.57	5.67	3.73	2.28	0.53	0.11	5,436
Volume, um^3		5,469	9,066	28,764	83,198	37,893	34,965	37,920	60,197	78,287	60,568	57,064	68,766	91,177	112,665	52,808	52,043	870,851
Log10 PSD		2.96232	2.87388	3.07094	3.24148	2.60342	2.26171	1.99715	1.87848	1.69059	1.29743	0.98082	0.75384	0.57198	0.35876	-0.27530		


Particle Size Distribution


Volume Distribution


Log10 Particle Size Distribution

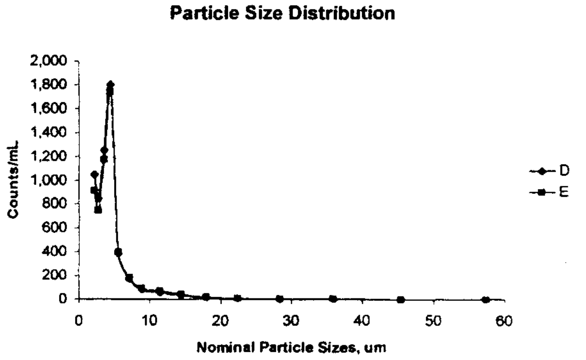

Particle Size Distribution

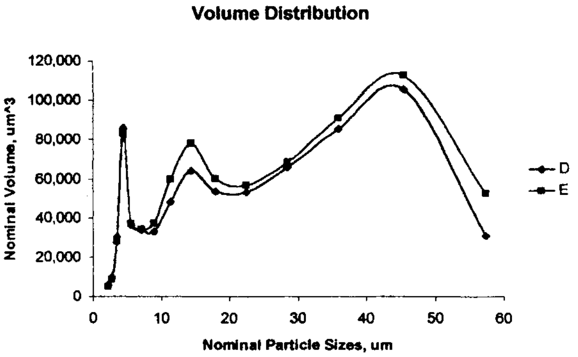
PCX Test of D-E Data, with surfactant

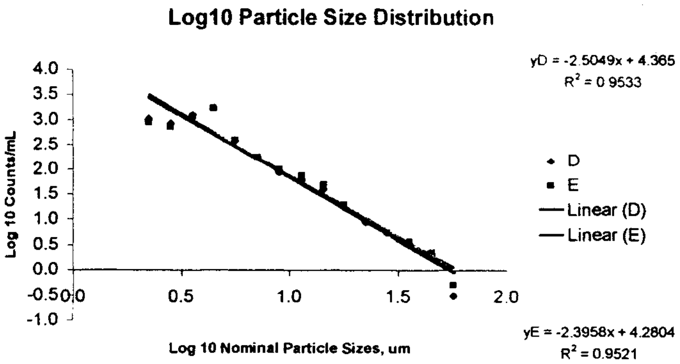
Sampled 30-Apr-01

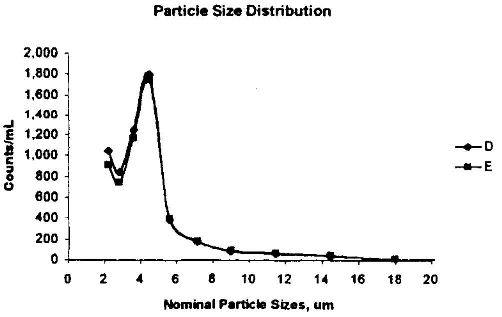
	Nominal	PCX1	PCX2	Tested	1-May-01
Flow rate	100	99.875	100.167		
mL		90.03	100.62	Sample tim	2 min
		99.88	99.63	Particles/mL	
Mean		96.595	100.139		

		<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
li >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	128
ri >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	96	
Log10 ri :		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
FDDW		149.55	123.60	109.70	73.65	30.28	29.85	23.98	16.13	15.63	10.25	4.78	1.68	0.68	0.30	0.08	0.10	
		140.45	120.15	93.55	54.43	19.18	16.60	9.73	3.58	1.30	0.90	0.33	0.18	0.15	0.05	0.00	0.03	
		145.00	121.88	101.63	64.04	24.73	23.23	16.85	9.85	8.46	5.58	2.55	0.93	0.41	0.18	0.04	0.06	
	Jar																	
D																		
2001/05/01 13:33	D5	1012.65	831.55	1242.10	1746.45	375.23	175.78	85.18	59.95	41.18	16.73	8.23	5.45	3.13	2.33	0.33	0.00	
2001/05/01 13:35	D5	1030.88	831.98	1251.30	1775.50	381.53	174.83	86.15	61.53	38.50	18.63	9.80	5.33	3.78	2.05	0.40	0.03	
2001/05/01 13:37	D5	1003.13	803.25	1176.00	1704.93	378.58	171.70	82.13	57.10	40.53	18.10	9.00	5.25	3.55	2.15	0.20	0.05	
2001/05/01 13:39	D5	1019.68	816.58	1196.23	1743.08	381.88	174.90	85.18	57.25	41.50	17.43	9.00	5.85	3.58	2.05	0.35	0.03	
Average		1016.58	820.84	1216.41	1742.49	379.30	174.30	84.66	58.96	40.43	17.72	9.01	5.47	3.51	2.14	0.32	0.03	
Flow Ajusted		1052.42	849.77	1259.28	1803.91	392.67	180.44	87.64	61.03	40.37	17.69	8.99	5.46	3.50	2.14	0.32	0.02	5,766
Volume, um^3		6,277	10,300	30,763	86,070	37,083	34,535	33,453	48,603	64,439	54,031	53,640	66,194	85,535	105,585	31,685	11,565	759,758
Log10 PSD		3.02219	2.92930	3.10012	3.25622	2.59403	2.25634	1.94270	1.78556	1.60605	1.24783	0.95394	0.73728	0.54424	0.33057	-0.49715		
E																		
2001/05/01 13:21	D3	887.28	724.22	1134.03	1680.45	388.45	178.18	96.23	73.93	49.00	19.83	9.83	5.68	4.00	2.00	0.60	0.10	
2001/05/01 13:23	D3	875.13	709.83	1123.93	1663.90	383.00	173.48	94.98	71.58	49.70	19.63	9.55	5.45	4.03	2.43	0.40	0.08	
2001/05/01 13:25	D3	889.58	722.00	1142.83	1699.78	388.45	175.40	97.53	72.65	47.95	19.88	9.93	5.68	3.75	2.30	0.50	0.18	
2001/05/01 13:27	D3	890.75	733.95	1148.65	1693.30	390.45	178.83	95.13	73.93	49.80	20.13	9.03	5.93	3.18	2.43	0.63	0.10	
Average		885.68	722.50	1137.36	1684.36	387.59	176.47	95.96	73.02	49.11	19.86	9.58	5.68	3.74	2.29	0.53	0.11	
Flow Ajusted		916.90	747.97	1177.45	1743.73	401.25	182.69	99.35	75.59	49.04	19.83	9.57	5.67	3.73	2.28	0.53	0.11	5,436
Volume, um^3		5,469	9,066	28,764	83,198	37,893	34,965	37,920	60,197	78,287	60,568	57,064	68,766	91,177	112,665	52,808	52,043	870,851
Log10 PSD		2.96232	2.87388	3.07094	3.24148	2.60342	2.26171	1.99715	1.87848	1.69059	1.29743	0.98082	0.75384	0.57198	0.35876	-0.27530		









PCX Test of BFa-BFb Data, with surfactant

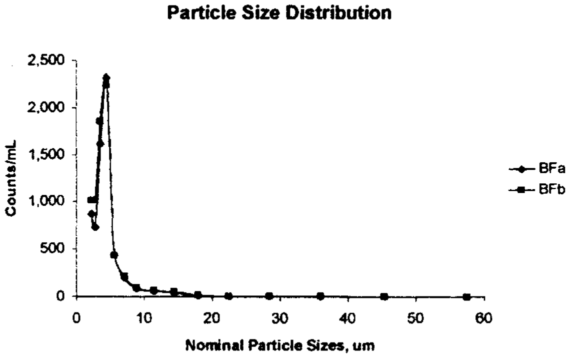
Sampled 30-Apr-01
Tested 1-May-01

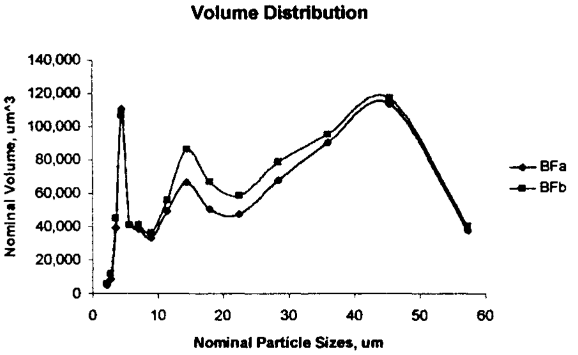
	Nominal	PCX1	PCX2
Flow rate	100	99.875	100.167
mL		90.03	100.62
		99.88	99.63
Mean		96.595	100.139

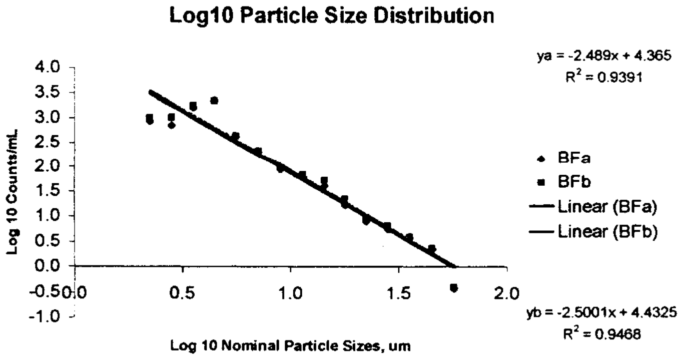
Sample tim 2 min
Particles/mL

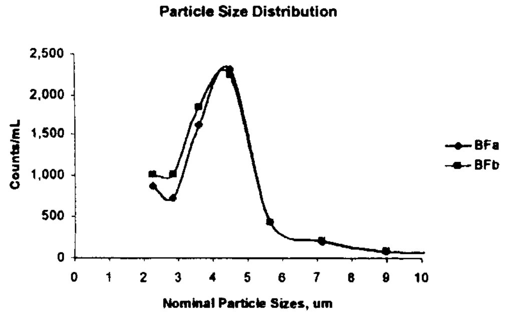
<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>> <<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
i >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	128
r >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	96	
Log10 r :	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
FDDW	149.55	123.60	109.70	73.65	30.28	29.85	23.98	16.13	15.63	10.25	4.78	1.68	0.66	0.30	0.08	0.10	
	140.45	120.15	93.55	54.43	19.16	16.60	9.73	3.58	1.30	0.90	0.33	0.18	0.15	0.05	0.00	0.03	
	145.00	121.88	101.63	64.04	24.73	23.23	16.85	9.85	8.46	5.58	2.55	0.93	0.41	0.16	0.04	0.06	
Jar																	
BFa																	
2001/05/01 13:45 D6	844.30	721.70	1622.70	2271.23	422.95	197.38	86.88	62.70	40.53	16.68	8.50	5.93	3.53	2.08	0.40	0.10	
2001/05/01 13:47 D6	831.88	690.63	1534.93	2203.63	416.95	194.13	81.25	57.95	41.75	16.85	8.05	5.95	4.28	2.50	0.38	0.05	
2001/05/01 13:49 D6	852.75	705.03	1575.03	2254.80	426.93	193.70	84.10	60.35	41.90	16.83	7.80	5.23	3.38	2.25	0.38	0.05	
2001/05/01 13:51 D6	840.08	704.83	1520.80	2232.58	433.00	196.70	84.05	58.25	42.90	15.85	7.53	5.30	3.68	2.43	0.38	0.08	
Average	842.25	705.54	1563.36	2240.56	425.40	195.48	84.07	59.81	41.77	16.55	7.97	5.60	3.71	2.31	0.38	0.07	
Flow Ajusted	871.94	730.41	1618.47	2319.54	440.45	202.37	87.03	61.92	41.71	16.53	7.96	5.59	3.71	2.31	0.38	0.07	6,410
Volume, um^3	5,200	8,853	39,538	110,672	41,595	38,731	33,220	49,309	66,581	50,467	47,461	67,783	90,567	113,897	37,897	31,804	833,575
Log10 PSD	2.94049	2.86357	3.20911	3.36540	2.64390	2.30614	1.93968	1.79184	1.62025	1.21819	0.90079	0.74758	0.56906	0.36348	-0.41939		
BFb																	
2001/05/01 13:55 D7	978.83	993.13	1866.08	2156.00	408.83	205.80	94.63	70.95	54.03	22.43	10.53	6.90	3.63	2.50	0.58	0.03	
2001/05/01 13:57 D7	987.85	986.60	1813.68	2159.38	417.75	208.75	91.98	67.95	53.78	21.83	9.75	6.05	4.25	2.35	0.15	0.03	
2001/05/01 13:59 D7	963.85	960.00	1759.28	2140.80	418.73	206.70	88.63	66.15	54.73	21.40	9.58	6.55	3.60	2.53	0.43	0.13	
2001/05/01 14:01 D7	1007.38	1000.80	1815.23	2218.43	427.58	210.68	93.80	68.63	53.38	21.45	9.50	6.33	3.75	1.93	0.28	0.03	
2001/05/01 14:03 D7	975.93	952.90	1719.60	2163.40	427.03	209.20	91.50	65.03	55.55	22.90	9.95	6.85	4.18	2.63	0.63	0.05	
Average	982.77	978.69	1794.77	2167.60	419.98	208.23	92.15	67.74	54.29	22.00	9.86	6.54	3.92	2.39	0.41	0.05	
Flow Ajusted	1017.41	1013.18	1858.04	2244.01	434.78	215.56	95.39	70.13	54.21	21.97	9.85	6.53	3.91	2.38	0.41	0.05	7,048
Volume, um^3	6,068	12,281	45,390	107,068	41,060	41,257	36,412	55,845	86,540	67,087	58,725	79,100	95,629	117,468	40,755	23,130	913,813
Log10 PSD	3.00750	3.00569	3.26905	3.35102	2.63827	2.33358	1.97952	1.84589	1.73412	1.34182	0.99327	0.81464	0.59268	0.37689	-0.38782		


Particle Size Distribution


Volume Distribution


Log10 Particle Size Distribution


Particle Size Distribution

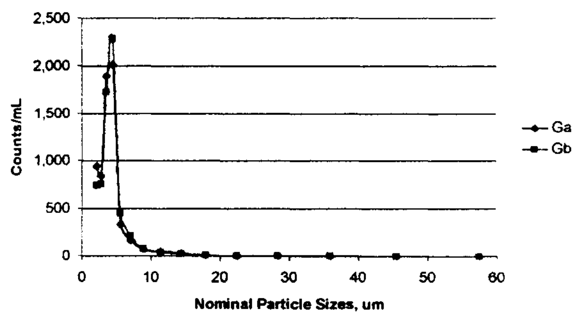
PCX Test of Ga-Gb Data, with surfactant

Sampled 30-Apr-01
Tested 1-May-01

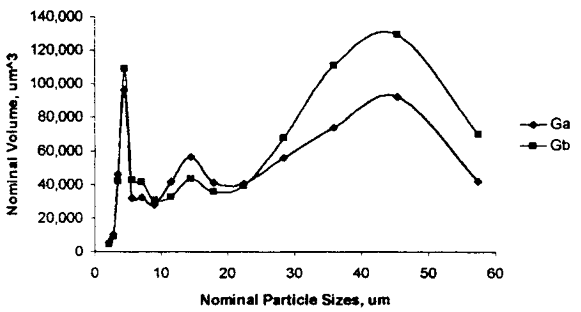
	Nominal	PCX1	PCX2		
Flow rate	100	99.875	100.167		
mL		90.03	100.62	Sample tim	2 min
		99.88	99.63	Particles/mL	
Mean		96.595	100.139		

		<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
li >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	128
r >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	96	
Log10 r :		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
FDDW		149.55	123.60	109.70	73.65	30.28	29.85	23.98	16.13	15.63	10.25	4.78	1.68	0.68	0.30	0.08	0.10	
		140.45	120.15	93.55	54.43	19.18	16.60	9.73	3.58	1.30	0.90	0.33	0.18	0.15	0.05	0.00	0.03	
		145.00	121.88	101.63	64.04	24.73	23.23	16.85	9.85	8.46	5.58	2.55	0.93	0.41	0.18	0.04	0.06	
	Jar																	
Ga																		
2001/05/01 14:07	D8	922.43	831.72	1862.70	1944.38	321.73	164.30	71.18	51.80	37.23	13.90	6.88	4.98	3.00	1.58	0.50	0.08	
2001/05/01 14:09	D8	892.40	785.75	1782.23	1909.13	320.45	161.33	71.75	48.03	34.45	13.88	7.70	4.75	3.13	1.98	0.43	0.10	
2001/05/01 14:11	D8	928.00	817.55	1834.48	1983.90	335.83	167.23	73.83	49.63	34.75	12.83	6.65	4.43	2.88	1.85	0.35	0.10	
2001/05/01 14:13	D8	933.70	824.68	1844.30	1974.70	332.60	166.68	71.88	52.88	35.95	13.68	6.15	4.38	3.15	2.10	0.43	0.13	
Average		919.13	814.93	1830.93	1953.03	327.65	164.88	72.16	50.58	35.59	13.57	6.84	4.63	3.04	1.88	0.43	0.10	
Flow Ajusted		951.53	843.65	1895.47	2021.87	339.20	170.69	74.70	52.36	35.54	13.55	6.83	4.62	3.03	1.87	0.42	0.10	6,415
Volume, um^3		5,675	10,226	46,304	96,469	32,033	32,669	28,513	41,699	56,738	41,376	40,760	56,057	74,100	92,349	42,246	46,260	743,476
Log10 PSD		2.97842	2.92616	3.27772	3.30575	2.53046	2.23222	1.87332	1.71903	1.55077	1.13194	0.83469	0.66509	0.48191	0.27240	-0.37221		
Gb																		
2001/05/01 14:17	D9	717.75	741.63	1713.45	2224.05	444.13	214.40	79.15	38.73	27.75	11.73	6.55	5.90	4.48	2.83	0.88	0.23	
2001/05/01 14:19	D9	732.33	746.72	1720.85	2256.05	444.35	213.48	78.85	40.10	27.33	11.23	6.18	4.90	4.65	2.23	0.50	0.18	
2001/05/01 14:21	D9	717.00	725.63	1670.68	2199.10	438.00	210.28	79.23	40.13	26.38	12.58	6.88	4.90	4.23	2.60	0.58	0.08	
2001/05/01 14:23	D9	702.45	700.67	1577.85	2130.80	425.13	205.80	75.65	38.05	27.50	11.85	6.15	5.33	4.08	1.98	0.68	0.10	
2001/05/01 14:25	D9	733.47	749.55	1655.45	2260.70	444.43	215.90	78.25	42.08	27.63	11.55	7.53	7.05	5.35	3.55	0.90	0.20	
Average		720.60	733.24	1667.66	2214.14	439.21	211.97	78.23	39.82	27.32	11.79	6.66	5.62	4.56	2.64	0.71	0.16	
Flow Ajusted		746.00	759.09	1726.44	2292.19	454.69	219.44	80.98	41.22	27.28	11.77	6.65	5.61	4.55	2.63	0.70	0.15	6,379
Volume, um^3		4,449	9,201	42,175	109,367	42,939	41,999	30,911	32,823	43,541	35,937	39,636	67,964	111,120	129,781	70,079	71,704	863,627
Log10 PSD		2.87274	2.88029	3.23715	3.36025	2.65771	2.34132	1.90839	1.61509	1.43580	1.07073	0.82254	0.74875	0.65789	0.42018	-0.15241		

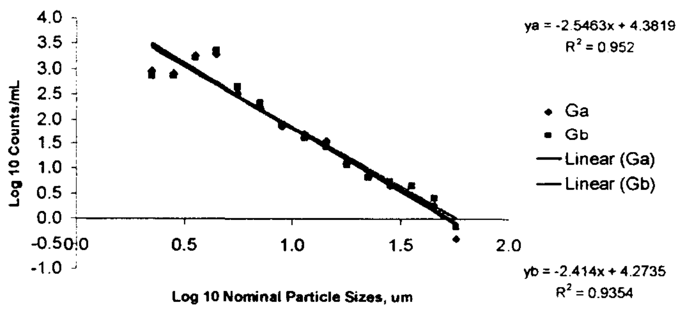
Particle Size Distribution



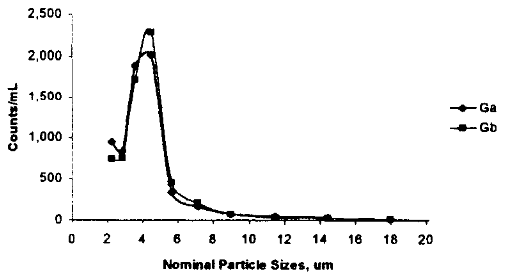
Volume Distribution



Log10 Particle Size Distribution



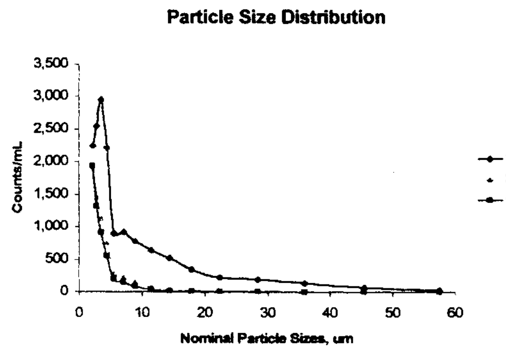
Particle Size Distribution

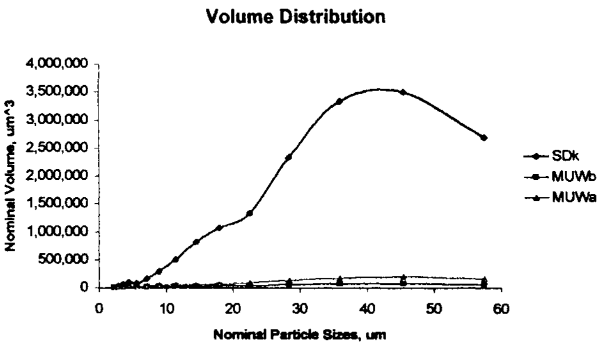


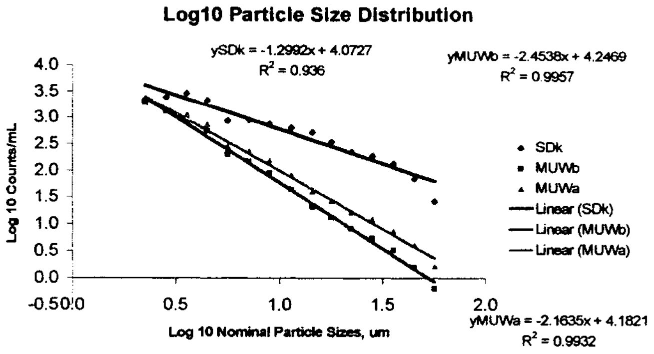
PCX Test of Settle Deck and make-up Waters

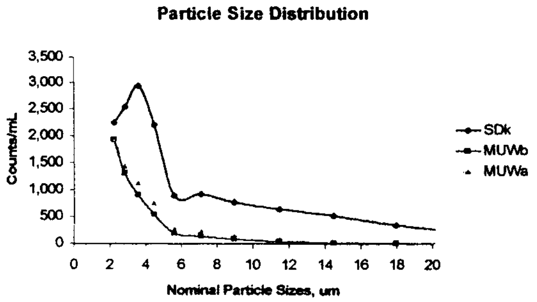
	Nominal	PCX1	PCX2		
				Sampled	30-Apr-01
				Tested	1-May-01
Flow rate	100	99.875	100.167		
mL		90.03	100.62	Sample tim	2 min
		99.88	99.63	Particles/mL	
Mean		96.595	100.139		

		<<<<<<<<<<<<<<<<<<<<<<<<<				PCX 1				>>>>>>>>>>>>>>>>>>>>>>>>>	<<<<<<<<<<<<<<<<<<<<<<<<<<<			PCX 2			>>>>>>>>>>>>>>>>>>>>>>>>>>>>	
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
	li >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	128
	l* >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	96	
	Log10 l* >	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
FDDW		149.55	123.60	109.70	73.65	30.28	29.85	23.98	16.13	15.63	10.25	4.78	1.68	0.68	0.30	0.08	0.10	
		140.45	120.15	93.55	54.43	19.18	16.60	9.73	3.58	1.30	0.90	0.33	0.18	0.15	0.05	0.00	0.03	
		145.00	121.88	101.63	64.04	24.73	23.23	16.85	9.85	8.46	5.58	2.55	0.93	0.41	0.18	0.04	0.06	
	Jar																	
SDk																		
2001/05/01 14:29	D11	2184.63	2490.48	2874.88	2162.85	891.13	897.08	772.48	635.28	515.38	344.55	224.50	194.05	139.15	74.58	28.63	11.98	
2001/05/01 14:31	D11	2183.15	2486.38	2863.65	2153.15	866.78	891.20	750.95	624.03	514.93	349.90	221.60	190.43	136.15	70.30	26.08	11.18	
2001/05/01 14:33	D11	2185.45	2472.75	2887.28	2159.28	882.15	897.75	765.25	629.05	531.85	356.95	233.23	196.03	135.85	69.93	26.85	12.10	
2001/05/01 14:35	D11	2139.13	2411.40	2787.50	2107.58	841.58	859.98	729.03	604.83	535.53	351.78	218.65	194.98	137.38	69.90	26.85	11.93	
Average		2173.09	2465.25	2853.33	2145.71	870.41	886.50	754.43	623.29	524.42	350.79	224.49	193.87	137.13	71.18	27.10	11.79	
Flow Ajusted		2249.69	2552.15	2953.91	2221.35	901.09	917.75	781.02	645.27	523.69	350.31	224.18	193.60	136.94	71.08	27.06	11.78	14,761
Volume, um^3		13,417	30,934	72,161	105,987	85,096	175,647	298,118	513,843	835,945	1,069,707	1,337,049	2,346,593	3,345,333	3,505,557	2,693,818	5,455,832	21,885,036
Log10 PSD		3.35212	3.40691	3.47040	3.34662	2.95477	2.96272	2.89266	2.80974	2.71907	2.54445	2.35060	2.28690	2.13653	1.85172	1.43237		
MUWa																		
2001/05/01 14:39	D12	1363.05	1045.30	848.80	589.80	231.78	199.20	151.23	93.73	56.85	40.10	28.43	19.73	12.83	7.88	3.58	2.73	
2001/05/01 14:41	D12	1998.95	1495.55	1160.90	777.98	298.63	235.43	157.70	76.48	38.95	24.38	14.98	11.68	6.38	3.15	1.13	0.68	
2001/05/01 14:43	D12	1934.70	1458.05	1128.83	756.08	288.60	231.50	151.25	76.23	37.80	23.23	15.18	11.40	6.23	3.10	1.25	0.30	
2001/05/01 14:45	D12	1976.53	1494.15	1150.65	772.55	291.13	235.13	154.20	76.25	38.25	24.48	14.28	11.43	5.98	3.30	1.35	0.30	
2001/05/01 14:47	D12	2040.65	1525.38	1189.00	797.85	300.65	243.20	154.23	76.98	36.23	23.75	15.35	9.58	6.53	3.53	1.23	0.65	
Average		1862.78	1403.69	1095.24	738.85	282.16	228.89	153.72	79.93	41.62	27.19	17.24	12.76	7.59	4.19	1.71	0.93	
Flow Ajusted		1928.44	1453.17	1133.84	764.89	292.10	236.96	159.14	82.75	41.56	27.15	17.22	12.74	7.57	4.18	1.70	0.93	6,164
Volume, um^3		11,501	17,614	27,699	36,495	27,585	45,351	60,744	65,894	66,336	82,898	102,679	154,447	185,037	206,369	169,482	430,221	1,690,352
Log10 PSD		3.28521	3.16232	3.05455	2.88360	2.46553	2.37467	2.20178	1.91776	1.61865	1.43373	1.23593	1.10525	0.87935	0.62161	0.23112		
MUWb																		
2001/05/01 14:51	D19	1912.13	1298.55	886.53	538.30	193.03	142.50	85.95	39.70	19.40	12.10	7.83	4.48	2.80	1.53	0.73	0.15	
2001/05/01 14:53	D19	1929.18	1305.33	884.85	539.55	194.70	144.30	84.05	41.35	19.58	12.73	7.35	4.68	2.38	0.85	0.18	0.25	
2001/05/01 14:55	D19	1921.18	1303.25	889.83	537.38	194.13	141.70	85.65	39.53	19.35	12.15	6.98	4.38	2.53	1.00	0.05	0.25	
2001/05/01 14:57	D19	1762.85	1207.20	848.93	530.28	194.43	148.23	95.30	51.33	25.53	16.78	11.18	8.58	5.65	3.10	1.63	5.23	
Average		1881.33	1278.58	877.53	536.38	194.07	144.18	87.74	42.98	20.96	13.44	8.33	5.53	3.34	1.62	0.64	1.47	
Flow Ajusted		1947.65	1323.65	908.46	555.28	200.91	149.26	90.83	44.49	20.93	13.42	8.32	5.52	3.33	1.62	0.64	1.47	5,276
Volume, um^3		11,616	16,044	22,193	26,494	18,973	28,567	34,670	35,429	33,415	40,976	49,620	66,875	81,419	79,728	63,991	679,449	1,289,458
Log10 PSD		3.28951	3.12177	2.95831	2.74451	2.30300	2.17395	1.95823	1.64826	1.32084	1.12772	0.92011	0.74173	0.52282	0.20858	-0.19189		









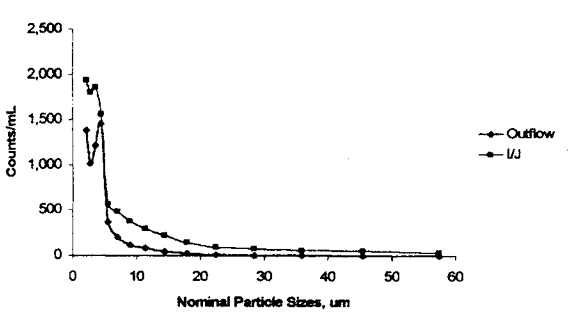
PCX Test of Outflow (& I/J) Data, with surfactant

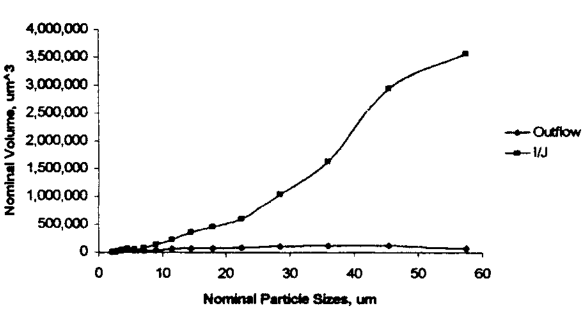
	Nominal	PCX1	PCX2
Flow rate	100	99.875	100.167
mL		90.03	100.62
		99.88	99.63
Mean		96.595	100.139

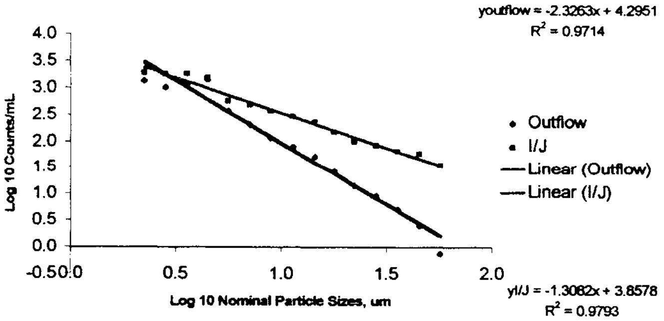
Sampled 30-Apr-01
Tested 1-May-01

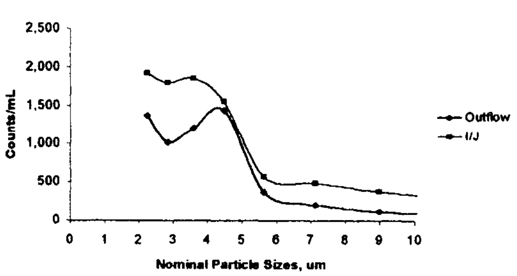
Sample tim 2 min
Particles/mL

		<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
	li >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	128
	l* >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	96	
	Log10 l* >	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
FDDW		149.55	123.60	109.70	73.65	30.28	29.85	23.98	16.13	15.63	10.25	4.78	1.68	0.68	0.30	0.08	0.10	
		140.45	120.15	93.55	54.43	19.18	16.60	9.73	3.58	1.30	0.90	0.33	0.18	0.15	0.05	0.00	0.03	
		145.00	121.88	101.63	64.04	24.73	23.23	16.85	9.85	8.46	5.58	2.55	0.93	0.41	0.18	0.04	0.06	
	Jar																	
Outflow																		
2001/05/01 15:01	D13	1345.23	963.65	1200.35	1427.68	361.35	198.20	116.10	79.40	54.48	28.58	15.08	9.03	5.68	3.73	1.60	0.20	
2001/05/01 15:03	D13	1355.63	1007.05	1223.00	1435.55	366.05	202.30	120.35	80.48	53.13	26.95	14.75	9.85	4.78	2.23	0.75	0.25	
2001/05/01 15:05	D13	1339.70	984.18	1155.38	1396.93	360.93	196.93	117.78	77.90	52.85	25.25	13.50	8.95	5.23	2.13	0.25	0.20	
2001/05/01 15:07	D13	1324.05	968.78	1137.53	1369.43	368.33	193.53	113.20	78.38	52.30	27.28	14.88	9.45	5.05	2.15	0.55	0.15	
Average		1341.15	965.91	1179.06	1407.39	364.16	197.74	116.86	79.04	53.19	27.01	14.55	9.32	5.18	2.56	0.79	0.20	
Flow Ajusted		1388.43	1020.67	1220.62	1457.00	377.00	204.71	120.98	81.82	53.11	26.98	14.53	9.31	5.17	2.55	0.79	0.20	5,984
Volume, um^3		8,281	12,371	29,819	69,518	35,603	39,179	46,177	65,158	84,783	82,372	86,657	112,794	126,397	125,902	78,280	92,521	1,095,812
Log10 PSD		3.14252	3.00888	3.08658	3.16346	2.57634	2.31113	2.08270	1.91288	1.72521	1.43096	1.16226	0.96875	0.71383	0.40700	-0.10435		
I/J																		
2001/05/01 15:11	D10	1865.78	1753.00	1806.05	1509.58	553.28	479.18	370.30	283.78	228.55	152.43	102.93	85.33	63.88	60.18	35.80	15.93	
2001/05/01 15:13	D10	1864.35	1725.65	1780.45	1494.98	543.58	467.48	360.15	280.95	234.20	152.90	103.63	89.53	68.98	58.58	36.50	16.03	
2001/05/01 15:15	D10	1909.15	1798.40	1853.83	1579.68	565.30	489.03	384.58	299.38	229.45	151.63	101.13	85.70	67.73	61.48	37.05	15.40	
2001/05/01 15:17	D10	1848.50	1713.30	1764.50	1475.43	542.28	458.08	355.83	274.40	227.88	149.33	101.90	86.18	67.00	59.20	34.35	15.05	
Average		1871.94	1747.59	1801.21	1514.91	551.11	473.44	367.71	284.63	230.02	151.57	102.44	86.68	66.89	59.86	35.93	15.60	
Flow Ajusted		1937.93	1809.19	1864.70	1568.31	570.53	490.13	380.67	294.66	229.70	151.36	102.30	86.56	66.80	59.77	35.88	15.58	9,664
Volume, um^3		11,558	21,929	45,553	74,829	53,880	93,805	145,305	234,645	366,659	462,192	610,138	1,049,192	1,631,881	2,948,079	3,571,048	7,216,617	18,537,309
Log10 PSD		3.28734	3.25748	3.27061	3.19543	2.75628	2.69031	2.58055	2.46932	2.36116	2.18001	2.00988	1.93732	1.82478	1.77651	1.55479		


Particle Size Distribution


Volume Distribution


Log10 Particle Size Distribution


Particle Size Distribution

PCX Test of Gravimetric Channels for A & B

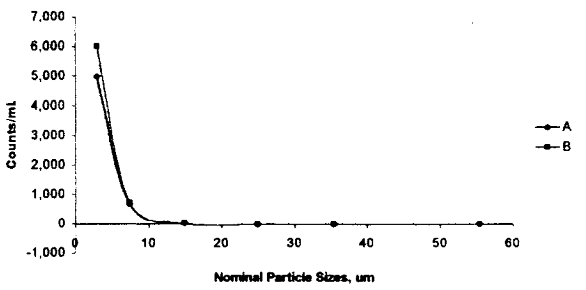
	Nominal	PCX1	PCX2
Flow rate	100	97.102	
mL		95.75	
		92.86	
Mean		95.2373	

Sampled 30-Apr-01
Tested 1-May-01

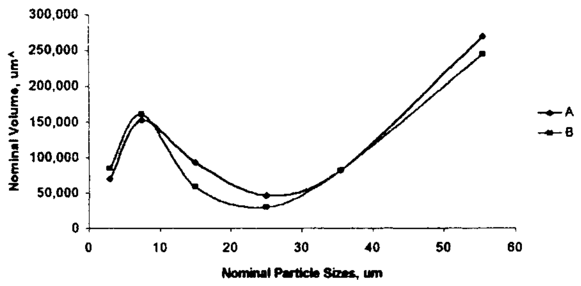
Sample time 2 min
Particles/mL

	Jar	1-5	5-10	10-20	20-30	30-41	41-70	:>70	
Class >		1-5	5-10	10-20	20-30	30-41	41-70	:>70	
i >		1	5	10	20	30	41	70	
r' >		3	7.5	15	25	35.5	55.5	35	
Log10 r' :		0.47712	0.87506	1.17609	1.39794	1.55023	1.74429	1.54407	
FDDW		8214.13	58.23	37.43	5.90	1.00	0.50	0.15	
		8290.00	51.78	33.80	4.88	1.18	0.23	0.00	
		7778.65	54.25	34.30	4.88	1.10	0.30	0.03	
		7414.33	55.23	37.60	5.08	1.00	0.43	0.00	
		7924.28	54.87	35.78	5.18	1.07	0.36	0.04	
A									
2001/05/01 16:04	A	11760.98	705.70	85.55	11.40	4.43	3.40	0.43	
2001/05/01 16:06	A	11676.83	685.90	80.65	10.83	4.28	2.68	0.20	
2001/05/01 16:08	A	12309.10	719.33	87.58	10.40	4.65	3.70	0.10	
2001/05/01 16:10	A	12225.83	698.68	84.13	9.23	4.08	3.10	0.35	
2001/05/01 16:12	A	12442.63	725.90	86.58	10.43	4.20	3.25	0.25	
2001/05/01 16:14	A	12415.43	701.65	82.88	9.93	4.23	3.03	0.25	
2001/05/01 16:16	A	12812.38	723.03	83.98	10.13	4.48	3.50	0.43	
2001/05/01 16:18	A	13015.13	745.73	85.78	10.90	4.50	3.05	0.35	
Average		12307.28	713.24	84.64	10.40	4.35	3.21	0.29	
Flow Ajusted		12922.75	748.91	88.87	10.92	4.57	3.37	0.31	
less FDDW		4998.48	694.04	53.09	5.74	3.50	3.01	0.26	
Volume, um^3		70,664	153,308	93,816	46,978	82,037	269,487	5,942	
Log10 PSD		3.69884	2.84138	1.72500	0.75907	0.54432	0.47866	-0.57726	
B									Total PCX
2001/05/01 16:24	B	13127.20	751.50	66.20	7.80	4.40	2.78	0.18	5931.00
2001/05/01 16:26	B	13045.08	729.78	65.63	8.55	4.50	3.30	0.38	
2001/05/01 16:28	B	13107.53	738.30	66.75	8.83	4.93	3.18	0.30	
2001/05/01 16:30	B	13177.03	731.08	65.70	7.85	4.35	2.73	0.18	
2001/05/01 16:32	B	13588.00	767.53	68.40	8.63	4.60	2.65	0.20	
2001/05/01 16:34	B	13505.08	762.30	68.15	8.68	4.53	2.78	0.18	
2001/05/01 16:36	B	13267.88	749.25	65.53	9.20	3.95	2.68	0.33	
2001/05/01 16:38	B	13450.85	764.05	64.60	8.60	3.68	3.53	0.33	
Average		13283.58	749.22	66.37	8.52	4.37	2.95	0.26	
Flow Ajusted		13947.87	786.69	69.69	8.94	4.58	3.10	0.27	
less FDDW		6023.59	731.82	33.91	3.76	3.52	2.74	0.23	
Volume, um^3		85,157	161,654	59,918	30,763	82,344	244,815	5,058	
Log10 PSD		3.77986	2.86440	1.53028	0.57521	0.54595	0.43696	-0.64721	
1st B sample count		13127.20	751.50	66.20	7.80	4.40	2.78	0.18	Sum
Less FDDW		5202.93	696.63	30.42	2.62	3.33	2.41	0.13	5938.47

Particle Size Distribution

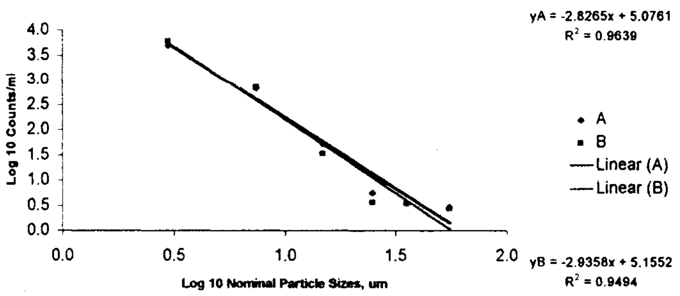


Volume Distribution

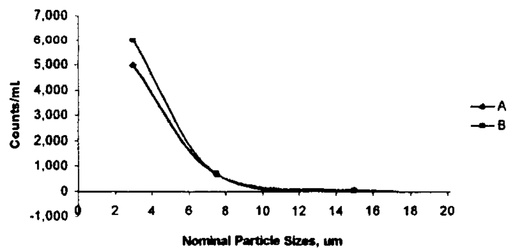


Ra = 0.9818 Rb = 0.9744

Log10 Particle Size Distribution



Particle Size Distribution



Particle Size Analysis

PCX Results for samples taken 7 May 01.

The PCX particle counters were set up in tandem in two x eight channel spans:

Lower span: 2-2.5, 2.5-3.2, 3.2-4, 4-5, 5-6.3, 6.3-8,8-10 µm

and

Upper span: 13-16, 16-20, 20-25, 25-32, 32-40, 40-51, 51-64, >64 µm (A)

and sites A and B using the filtration screen classes of:
1-5, 5-10, 10-20, 20-30, 30-41 µm (B)

There was adjustment for variation in flow rates and for cell noise. The use of surfactant was trialled.

Results log:

Site>	A	B	C	D	E	SD	BF_A	BF_B	G_A	G_B	MW_{A1}	MW_{A2}	MW_B	I/J	D2
A	√	√													
B	√	√													

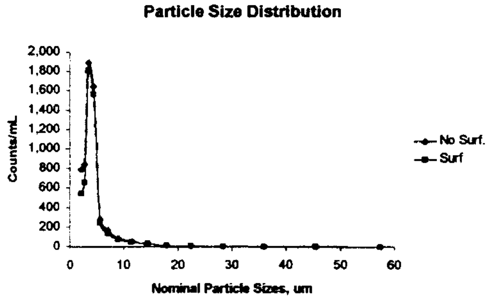
PCX Test of A Data, with/without surfactant

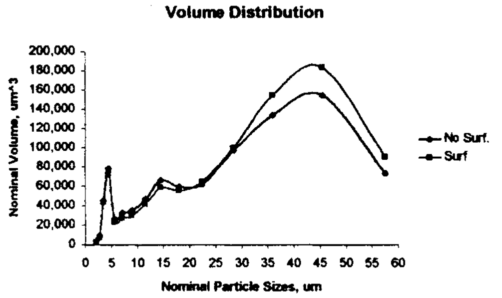
Sampled 7-May-01
Tested 8-May-01

	Nominal	PCX1	PCX2
Flow rate	100	100.34	98.67
mL		92.04	104.77
		92.17	105.18
Mean		94.85	102.873

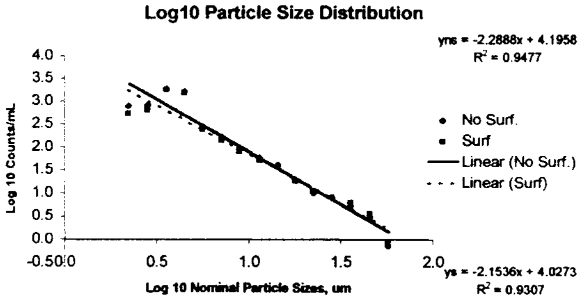
Sample tim 2 min
Particles/mL

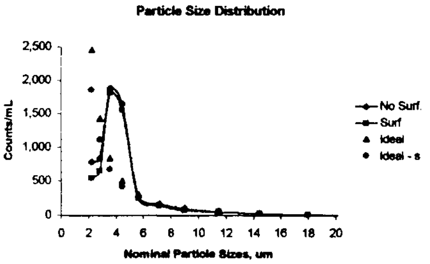
	<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>											
Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est			
i >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	128			
r* >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	96				
Log10 r* :	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967					
2001/05/08 12:42 FDDW	81.98	65.90	56.53	34.53	14.40	12.45	9.58	5.13	2.45	1.28	0.38	0.13	0.05	0.00	0.03	0.03				
No Surf.																				
2001/05/08 12:48 D1	850.53	901.45	1943.70	1645.85	290.90	179.50	102.65	63.48	48.30	23.75	12.95	11.88	8.83	5.23	1.03	0.20	5978	5670	112.15	9569
2001/05/08 12:50 D1	809.03	848.95	1801.73	1551.75	278.70	167.95	94.38	59.73	46.18	22.08	10.33	8.05	6.05	3.15	0.73	0.28	5612	5829	96.83	9553
2001/05/08 12:52 D1	812.10	833.43	1791.88	1555.56	277.85	168.48	96.58	58.45	44.55	20.83	10.33	8.10	4.80	2.43	0.95	0.10	5594	5981	92.08	
2001/05/08 12:54 D1	851.60	889.23	1897.13	1633.48	292.95	176.30	102.13	64.18	44.85	21.03	11.20	7.08	4.18	2.48	0.53	0.13	5907		91.45	
2001/05/08 12:56 D1	847.90	861.85	1841.03	1615.00	290.03	177.03	96.03	61.00	42.95	20.25	10.55	6.60	4.63	2.85	0.70	0.25	5790		88.78	
Average	834.23	866.98	1855.09	1600.33	286.09	173.85	98.35	61.37	45.37	21.59	11.07	8.34	5.70	3.23	0.79	0.19				
less FDDW	752.26	801.08	1798.57	1565.80	271.69	161.40	88.78	56.24	42.92	20.31	10.70	8.22	5.65	3.23	0.76	0.17				
Flow Ajusted	793.10	844.58	1896.22	1650.82	286.44	170.16	93.60	59.29	41.72	19.74	10.40	7.99	5.49	3.13	0.74	0.16	5,884			
Volume, um^3	4,730	10,237	46,323	78,765	27,050	32,567	35,726	47,217	66,590	60,267	62,005	96,792	134,050	154,618	73,538	74,301	1,004,796			
Log10 PSD	2.89933	2.92664	3.27789	3.21770	2.45703	2.23067	1.97125	1.77301	1.62031	1.29541	1.01688	0.90230	0.73936	0.49623	-0.13149					
Surf																				
2001/05/08 13:12 D3	589.78	681.35	1749.83	1481.03	243.10	143.70	82.90	53.80	41.38	21.38	13.20	12.25	10.03	6.25	1.38	0.28	5025		106.13	
2001/05/08 13:14 D3	620.60	733.53	1893.55	1563.10	253.63	151.60	88.28	58.93	41.68	19.75	11.13	7.93	5.83	3.88	1.08	0.18	5363		91.43	
2001/05/08 13:16 D3	613.48	707.72	1811.63	1526.68	254.48	154.78	85.65	56.45	39.65	19.90	11.15	8.25	6.10	3.20	0.70	0.25	5211		89.20	
2001/05/08 13:18 D3	600.92	693.13	1772.88	1529.38	250.75	146.15	85.95	55.38	41.38	19.93	11.43	7.38	5.13	3.33	0.95	0.15	5135		89.65	
2001/05/08 13:20 D3	583.40	642.85	1667.83	1469.05	239.25	140.00	79.68	53.25	40.70	20.58	11.50	7.43	5.78	2.56	0.68	0.30	4875		89.50	
Average	601.64	691.72	1779.18	1513.89	248.24	147.25	84.49	55.56	40.98	20.31	11.68	8.65	6.57	3.84	0.96	0.23				
less FDDW	519.66	625.82	1722.66	1479.36	233.84	134.80	74.92	50.44	38.51	19.03	11.31	8.52	6.52	3.84	0.93	0.21				
Flow Ajusted	547.86	659.79	1816.19	1559.68	246.54	142.11	78.98	53.17	37.43	18.50	10.99	8.28	6.34	3.73	0.90	0.20	5,191			
Volume, um^3	3,268	7,997	44,368	74,417	23,282	27,199	30,148	42,344	59,747	56,487	65,541	100,385	154,829	184,103	89,988	92,313	1,056,416			
Log10 PSD	2.73868	2.81941	3.25916	3.19304	2.39188	2.15264	1.89753	1.72569	1.57321	1.26714	1.04097	0.91814	0.80194	0.57203	-0.04382					





R = 0.9734986





R = 0.9647279

PS	Log PS	yns Log Cnt	Cnt	ys Log Cnt	Cnt
2.25	0.35218	3.3897247	2453.15	3.26884	1857.11898
2.85	0.45484	3.1547511	1428.08	3.047746	1116.21052
3.6	0.5563	2.9225348	836.633	2.829247	674.911885
4.5	0.65321	2.7007272	502.027	2.620542	417.38951
5.65	0.75205	2.4745115	298.203	2.407688	255.675117
7.15	0.85431	2.2404643	173.986	2.187467	153.980778
9	0.95424	2.0117297	102.738	1.972243	93.8087462
11.5	1.0607	1.7680748	58.6239	1.742981	55.3326088

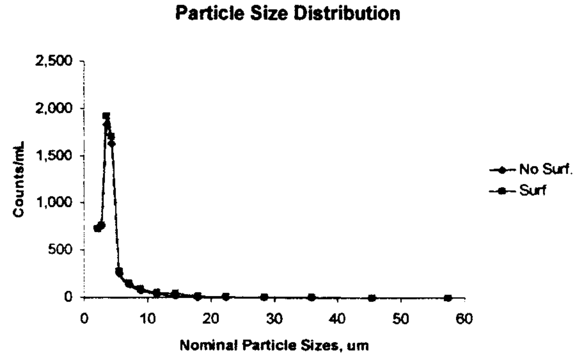
PCX Test of B Data, with/without surfactant

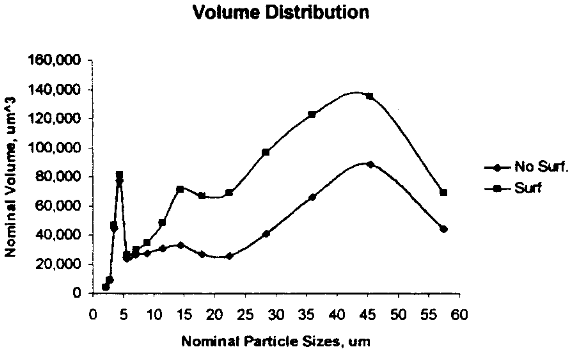
Sampled 7-May-01
Tested 8-May-01

	Nominal	PCX1	PCX2
Flow rate	100	100.34	98.67
mL		92.04	104.77
		92.17	105.18
Mean		94.85	102.873

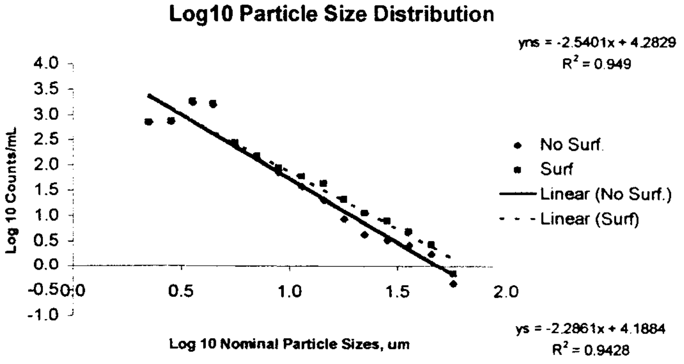
Sample tim 2 min
Particles/mL

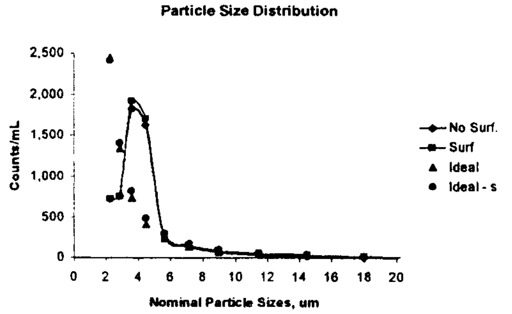
		<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
fi >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	128
f' >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	96	
Log10 f' >		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
2001/05/08 12:42	FDDW	81.98	65.90	56.53	34.53	14.40	12.45	9.58	5.13	2.45	1.28	0.38	0.13	0.05	0.00	0.03	0.03	
No Surf.																		
2001/05/08 13:00	D2	760.53	781.50	1771.83	1575.30	255.63	143.05	77.58	42.43	23.28	10.65	5.13	3.83	3.20	2.00	0.48	0.18	5408
2001/05/08 13:02	D2	781.63	807.78	1848.93	1615.63	264.45	144.53	77.65	42.05	23.60	9.83	4.68	3.60	2.75	1.83	0.63	0.28	5583
2001/05/08 13:04	D2	797.72	808.35	1850.25	1600.88	260.78	149.95	82.98	42.35	24.78	10.45	4.40	3.40	2.73	1.73	0.33	0.25	5593
2001/05/08 13:06	D2	770.60	791.55	1777.33	1581.50	257.85	144.18	78.73	43.25	23.58	11.28	5.08	3.43	2.73	1.90	0.55	0.18	5445
2001/05/08 13:08	D2	768.90	759.60	1730.13	1550.45	253.68	141.80	74.50	41.50	24.98	10.33	5.03	3.95	2.85	1.80	0.45	0.13	5321
Average		775.88	789.76	1795.69	1584.75	258.48	144.70	78.29	42.32	24.04	10.51	4.86	3.64	2.85	1.85	0.49	0.20	
less FDDW		693.90	723.86	1739.17	1550.23	244.08	132.25	68.71	37.19	21.59	9.23	4.49	3.52	2.80	1.85	0.46	0.18	
Flow Ajusted		731.58	763.16	1833.60	1634.40	257.33	139.43	72.44	39.21	20.99	8.97	4.36	3.42	2.72	1.80	0.45	0.17	5,514
Volume, um^3		4,363	9,250	44,793	77,982	24,301	26,685	27,651	31,223	33,501	27,398	26,002	41,415	66,491	68,696	44,510	78,804	653,064
Log10 PSD		2.86426	2.88261	3.26330	3.21336	2.41049	2.14436	1.85998	1.59339	1.32195	0.95290	0.63946	0.53362	0.43486	0.25487	-0.34954		
Surf																		
2001/05/08 13:26	D4	783.48	806.40	1924.60	1684.80	286.03	165.98	98.05	62.83	47.40	22.25	12.23	8.73	5.55	2.98	0.63	0.40	5814
2001/05/08 13:28	D4	773.80	809.70	1939.03	1679.53	287.30	169.50	100.88	66.38	49.45	25.10	12.98	8.85	5.68	2.60	0.78	0.25	5826
2001/05/08 13:30	D4	769.13	781.63	1853.50	1636.75	279.25	157.25	93.15	62.45	48.50	23.43	11.38	8.10	4.90	2.55	0.83	0.38	5633
2001/05/08 13:32	D4	778.70	774.85	1809.85	1621.33	281.13	160.40	95.30	61.23	48.80	24.88	12.95	7.80	4.83	3.23	0.75	0.48	5583
Average		776.28	793.14	1881.74	1655.60	283.93	163.28	96.84	63.22	48.54	23.91	12.38	8.37	5.24	2.84	0.74	0.38	
less FDDW		694.30	727.24	1825.22	1621.08	269.53	150.83	87.27	58.09	46.09	22.64	12.01	8.24	5.19	2.84	0.72	0.35	
Flow Ajusted		732.00	766.73	1924.32	1709.09	284.16	159.02	92.01	61.25	44.80	22.01	11.67	8.01	5.04	2.76	0.70	0.34	5,824
Volume, um^3		4,366	9,293	47,009	81,546	26,835	30,435	35,119	48,774	71,513	67,196	69,607	97,130	123,186	136,040	69,547	157,608	1,075,203
Log10 PSD		2.86451	2.88464	3.28428	3.23277	2.45356	2.20145	1.96382	1.78709	1.65128	1.34253	1.06710	0.90382	0.70266	0.44063	-0.15572		


Particle Size Distribution


Volume Distribution

R = 0.9741663


Log10 Particle Size Distribution


Particle Size Distribution

R = 0.9709789

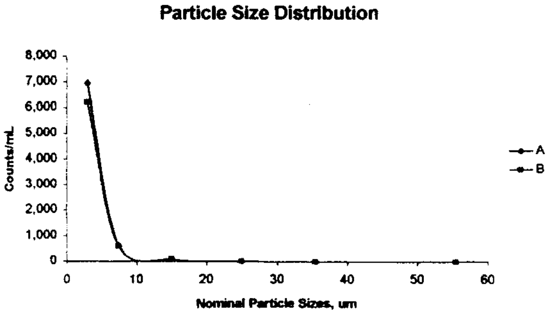
		yns		ys	
PS	Log PS	Log Cnt	Cnt	Log Cnt	Cnt
2.25	0.35218	3.3883	2445	3.3833	2417
2.85	0.45484	3.1275	1341	3.1486	1408
3.6	0.5563	2.8698	741	2.9166	825
4.5	0.65321	2.6237	420	2.6951	496
5.65	0.75205	2.3726	236	2.4691	295
7.15	0.85431	2.1129	130	2.2354	172
9	0.95424	1.8590	72	2.0069	102
11.5	1.0607	1.5886	39	1.7635	58

PCX Test of Gravimetric Channels for A & B

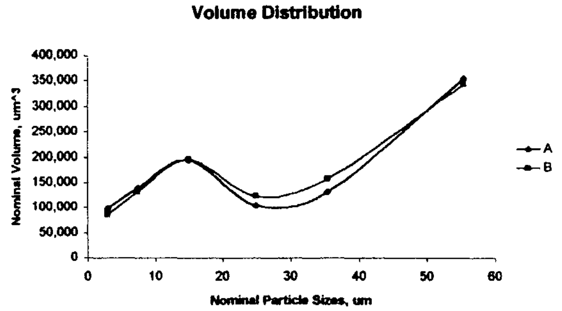
	Nominal	PCX1	PCX2			
				Sampled	7-May-01	
				Tested	8-May-01	
Flow rate	100	98.43				
mL		87.54		Sample time	2	min
		89.04		Particles/mL		
Mean		91.67				

Class >		1-5	5-10	10-20	20-30	30-41	41-70	:>70				
l >		1	5	10	20	30	41	70				
l* >		3	7.5	15	25	35.5	55.5	35				
Log10 l* :		0.47712	0.87506	1.17609	1.39794	1.55023	1.74429	1.54407				
FDDW		5737.45	32.20	8.35	1.08	0.38	0.20	0.03				
		5762.58	27.70	5.60	0.60	0.43	0.13	0.00				
		5670.65	27.95	5.68	0.68	0.33	0.03	0.00				
		5669.48	18.53	4.10	0.80	0.25	0.08	0.00				
		5888.83	17.05	4.08	0.43	0.25	0.13	0.00				
		5528.10	15.48	3.30	0.43	0.20	0.03	0.03				
Avg		5709.51	23.15	5.18	0.67	0.30	0.10	0.01				
	Jar											
A												
2001/05/08 14:09	D5	11648.30	614.80	109.53	13.15	5.45	4.05	0.33		5649		
2001/05/08 14:11	D5	11688.50	613.85	108.55	13.00	5.45	4.25	0.28	12433.88	11689	5781	6653
2001/05/08 14:13	D5	11722.88	606.50	106.05	13.28	6.85	3.70	0.30	12459.55	11722	5705	6755
2001/05/08 14:15	D5	11436.53	591.43	103.83	13.58	5.98	4.03	0.18	12155.53	11436	5504	6652
2001/05/08 14:17	D5	11632.35	612.10	108.45	14.05	6.25	3.85	0.28	12377.33			
2001/05/08 14:19	D5	11623.48	600.55	106.30	12.43	5.43	3.73	0.38	12352.28		5631	6721
Flow Ajusted		12679.69	655.12	115.96	13.55	5.92	4.06	0.41			5655.25	
less FDDW		6970.18	631.97	110.78	12.89	5.61	3.97	0.40				
Volume, um^3		98,539	139,598	195,758	105,435	131,504	355,150	8,996				
Log10 PSD		3.84324	2.80070	2.04445	1.11016	0.74926	0.59853	-0.39713				
B										Total PCX		
2001/05/08 14:27	D6	10822.65	564.10	105.88	14.05	6.33	3.70	0.33		11275	5473	5802
2001/05/08 14:29	D6	10974.95	584.30	110.30	14.93	6.38	3.73	0.30				
2001/05/08 14:31	D6	11062.05	574.38	109.53	14.73	7.18	3.63	0.30				
2001/05/08 14:33	D6	11061.70	569.80	109.48	15.15	6.23	3.48	0.20		10612	5168	5444
2001/05/08 14:35	D6	10741.40	542.00	100.30	14.03	6.38	3.53	0.30		10880	4956	5924
Average		10932.55	566.92	107.10	14.58	6.50	3.61	0.29				
Flow Ajusted		11925.98	618.43	116.83	15.90	7.09	3.94	0.31				
less FDDW		6216.47	595.28	111.64	15.23	6.78	3.84	0.30				
Volume, um^3		87,683	131,493	197,290	124,623	158,847	343,921	6,792				
Log10 PSD		3.79354	2.77472	2.04783	1.18278	0.83130	0.58458	-0.51918				
1st B sample count		13127.20	751.50	66.20	7.80	4.40	2.78	0.18		Sum		
Less FDDW		7417.69	728.35	61.02	7.13	4.10	2.68	0.17		8221.13		

Particle Size Distribution

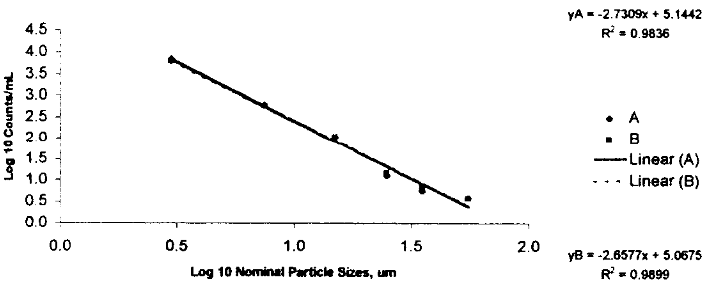


Volume Distribution

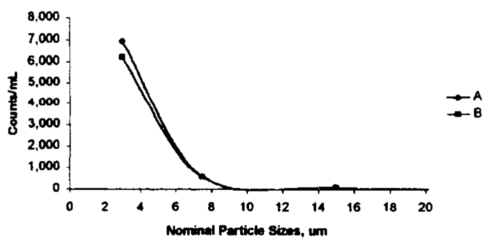


Ra = 0.9916 Rb = 0.9949

Log10 Particle Size Distribution



Particle Size Distribution



Particle Size Analysis

PCX Results for samples taken 14 May 01.

The PCX particle counters were set up in tandem in two x eight channel spans:

Lower span: 2-2.5, 2.5-3.2, 3.2-4, 4-5, 5-6.3, 6.3-8,8-10 µm

and

Upper span: 13-16, 16-20, 20-25, 25-32, 32-40, 40-51, 51-64, >64 µm

There was adjustment for variation in flow rates and for cell noise.

Results log:

Site>	**A**	**B**	**C**	**D**	**E**	**SD**	**BF$_A$**	**BF$_B$**	**G$_A$**	**G$_B$**	**MW$_A$ 1**	**MW$_A$ 2**	**MW B**	**I/J**	**D2**
Data	√	√	√	√	√	√	√	√	√	√	√	√	√	√	

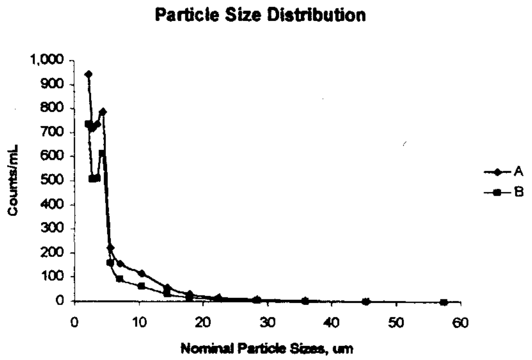
PCX Test of A, B Data +

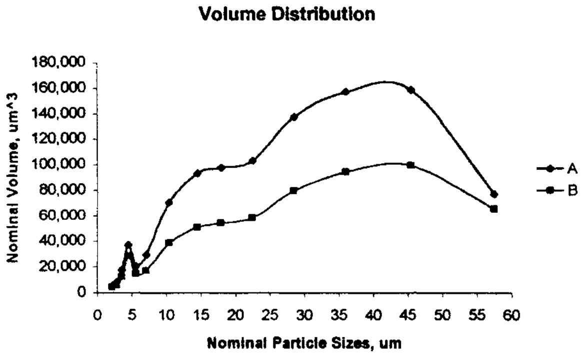
Sampled 14-May-01
Tested 15-May-01

	Nominal	PCX1	PCX2
Flow rate	100	99.62	100.55
mL		96.82	98.38
		98.62	99.14
Mean		98.35	99.36

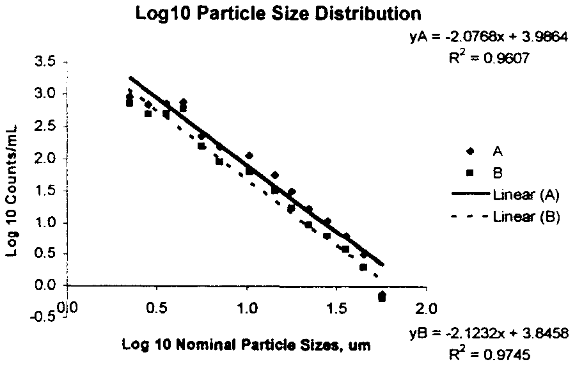
Sample time 2

Particles/mL		<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>						<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>									
		2-2.5	2.5-3.2	3.2-4	4-5	5-6.3	6.3-8	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
	l >	2	2.5	3.2	4	5	6	8	13	16	20	25	32	40	51	64	128
	r >	2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5		
	Log10 r >	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
2001/05/08 12:42	FDDW	70.44	57.31	48.34	31.28	12.61	12.98	8.03	2.74	1.51	0.65	0.30	0.11	0.06	0.00	0.03	
A																	
2001/05/15 12:31	D1	1048.98	810.40	838.65	859.78	248.00	181.65	133.03	60.28	33.88	18.35	11.45	6.53	3.08	0.80	0.33	
2001/05/15 12:33	D1	1048.78	803.43	824.58	858.60	245.78	179.53	130.25	63.53	32.93	17.00	11.00	6.48	3.48	0.85	0.28	
2001/05/15 12:35	D1	943.10	714.98	716.73	751.10	221.43	152.88	119.10	61.88	32.98	18.38	12.40	6.40	3.13	0.75	0.28	
2001/05/15 12:37	D1	951.53	722.18	713.58	748.83	218.68	153.98	113.80	57.65	34.15	17.93	11.58	6.68	3.38	0.70	0.30	
Average		998.09	762.74	773.38	804.58	233.47	167.01	124.04	60.83	33.48	17.91	11.61	6.52	3.26	0.78	0.29	
less FDDW		927.66	705.43	725.04	773.30	220.86	154.03	116.02	58.09	31.97	17.26	11.31	6.41	3.20	0.78		
Flow Ajusted		943.19	717.24	737.18	786.25	224.55	156.61	116.77	58.47	32.18	17.37	11.38	6.45	3.22	0.78	3,812	
Volume, um^3		5,625	8,694	18,009	37,514	21,206	29,973	70,778	93,333	98,253	103,622	137,929	157,512	158,849	77,644	1,018,941	
Log10 PSD		2.97460	2.85567	2.86758	2.89556	2.35132	2.19482	2.06733	1.76693	1.50753	1.23991	1.05612	0.80941	0.50795	-0.10790		
B																	
2001/05/15 12:41	D2	793.45	555.85	559.13	645.00	168.75	104.80	74.10	34.80	18.80	10.13	6.68	4.18	2.10	0.83	0.33	
2001/05/15 12:43	D2	807.68	569.80	566.28	652.65	174.53	107.65	74.55	33.45	19.58	10.30	6.70	4.40	1.85	0.68	0.13	
2001/05/15 12:45	D2	802.93	567.88	556.25	635.60	168.53	105.70	75.20	35.13	19.15	9.90	7.43	3.75	1.98	0.68	0.25	
2001/05/15 12:47	D2	789.05	549.08	544.55	631.25	170.10	101.10	70.18	34.90	20.53	10.93	6.70	3.58	2.33	0.53	0.25	
2001/05/15 12:49	D2	775.43	542.75	523.30	609.55	164.83	98.15	69.38	35.13	18.40	10.90	6.68	3.85	2.08	0.58	0.53	
Average		793.71	557.07	549.90	634.81	169.35	103.48	72.68	34.68	19.29	10.43	6.84	3.95	2.07	0.66		
less FDDW		723.27	499.76	501.56	603.54	156.73	90.51	64.66	31.94	17.78	9.78	6.54	3.84	2.00	0.66		
Flow Ajusted		735.38	508.12	509.96	613.64	159.36	92.02	65.07	32.15	17.89	9.84	6.58	3.86	2.02	0.66	2,757	
Volume, um^3		4,386	6,159	12,458	29,279	15,049	17,612	39,443	51,319	54,637	58,707	79,723	94,353	99,405	65,622	628,150	
Log10 PSD		2.86651	2.70597	2.70754	2.78791	2.20237	1.96388	1.81341	1.50717	1.25267	0.99314	0.81805	0.58685	0.30438	-0.18096		

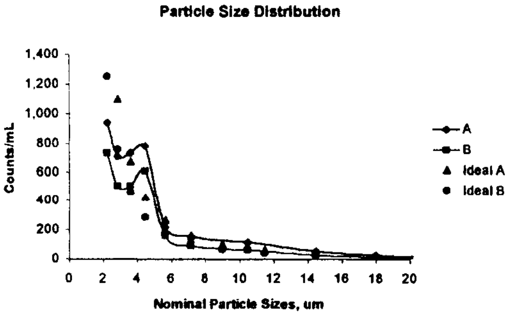




R = 0.98015



R = 0.98717



		A		B	
PS	Log PS	Log Cnt	Cnt	Log Cnt	Cnt
2.25	0.35218	3.2549873	1798.82	3.098046	1253.27414
2.85	0.45484	3.0417782	1100.98	2.880073	758.705781
3.6	0.5563	2.831071	677.752	2.664659	462.017611
4.5	0.65321	2.6298083	426.391	2.458899	287.673059
5.65	0.75205	2.4245458	265.794	2.249051	177.439676
7.15	0.85431	2.2121772	162.996	2.031937	107.631009
9	0.95424	2.0046292	101.072	1.819752	66.0316735
11.5	1.0607	1.7835427	60.7495	1.593726	39.2397603

PCX Test of A, C Data +

Sampled 14-May-01
Tested 15-May-01

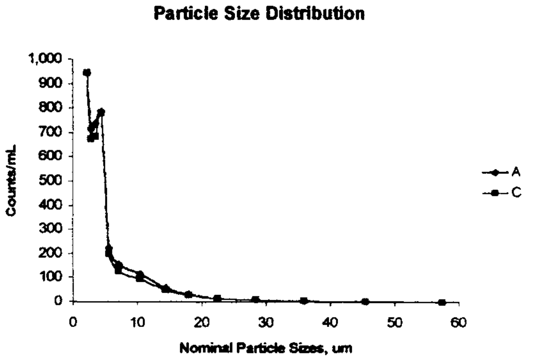
	Nominal	PCX1	PCX2
Flow rate	100	99.62	100.55
mL		98.62	99.14
		95.97	100.55
Mean		98.07	100.08

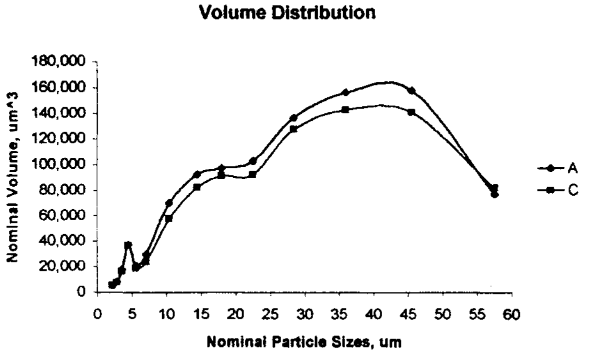
Bin 10-13 out

Sample time 2

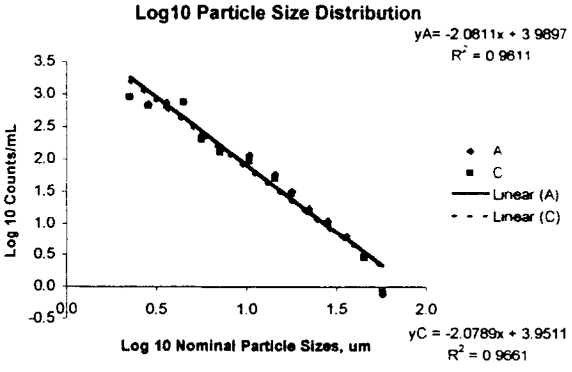
Particles/mL <<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>> <<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

		2-2.5	2.5-3.2	3.2-4	4-5	5-6.3	6.3-8	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
	l >	2	2.5	3.2	4	5	6	8	13	16	20	25	32	40	51	64	128
	r >	2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5		
	Log10 r >	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
2001/05/08 12:42	FDDW	70.44	57.31	48.34	31.28	12.61	12.98	8.03	2.74	1.51	0.65	0.30	0.11	0.06	0.00	0.03	
A																	
2001/05/15 12:31	D1	1048.98	810.40	838.65	859.78	248.00	181.65	133.03	60.28	33.88	18.35	11.45	6.53	3.08	0.80	0.33	
2001/05/15 12:33	D1	1048.78	803.43	824.58	858.60	245.78	179.53	130.25	63.53	32.93	17.00	11.00	6.48	3.48	0.85	0.28	
2001/05/15 12:35	D1	943.10	714.98	716.73	751.10	221.43	152.88	119.10	61.88	32.98	18.38	12.40	6.40	3.13	0.75	0.28	
2001/05/15 12:37	D1	951.53	722.18	713.58	748.83	218.68	153.98	113.80	57.65	34.15	17.93	11.58	6.68	3.38	0.70	0.30	
Average		998.09	762.74	773.38	804.58	233.47	167.01	124.04	60.83	33.48	17.91	11.61	6.52	3.26	0.78	0.29	
less FDDW		927.66	705.43	725.04	773.30	220.86	154.03	116.02	58.09	31.97	17.26	11.31	6.41	3.20	0.78		
Flow Ajusted		945.91	719.31	739.31	788.52	225.20	157.06	115.93	58.05	31.94	17.25	11.30	6.40	3.20	0.77	3,820	
Volume, um^3		5,642	8,719	18,061	37,623	21,268	30,060	70,266	92,658	97,543	102,873	136,932	156,373	157,701	77,083	1,012,801	
Log10 PSD		2.97585	2.85692	2.86883	2.89681	2.35257	2.19607	2.06418	1.76378	1.50438	1.23676	1.05297	0.80626	0.50480	-0.11105		
C																	
2001/05/15 13:03	D3	982.83	711.50	715.18	798.15	212.88	136.55	103.38	53.50	31.18	16.23	11.98	5.53	3.23	0.85	0.45	
2001/05/15 13:05	D3	982.05	708.80	703.38	786.45	204.10	135.88	100.93	57.00	30.73	17.10	11.15	6.18	2.95	0.73	0.33	
2001/05/15 13:07	D3	1010.38	731.55	740.23	801.55	210.38	141.45	105.00	55.55	32.48	16.15	11.25	6.43	3.00	1.05	0.35	
2001/05/15 13:09	D3	1013.35	725.95	728.85	807.73	210.18	140.95	106.95	56.05	31.63	15.98	10.35	6.00	2.80	0.63	0.58	
2001/05/15 13:11	D3	1001.88	719.50	722.18	795.85	207.23	132.88	100.13	50.43	31.33	15.48	9.48	5.70	2.60	0.88	0.45	
Average		998.10	719.46	721.96	797.95	208.95	137.54	103.28	54.52	31.47	16.19	10.84	5.97	2.92	0.83		
less FDDW		927.66	662.15	673.62	766.67	196.34	124.57	95.25	51.78	29.95	15.54	10.54	5.85	2.85	0.83		
Flow Ajusted		945.91	675.18	686.88	781.76	200.20	127.02	95.17	51.74	29.93	15.52	10.53	5.85	2.85	0.82	3,629	
Volume, um^3		5,642	8,184	16,780	37,300	18,906	24,310	57,688	82,584	91,391	92,578	127,652	142,857	140,576	82,056	928,502	
Log10 PSD		2.97585	2.82942	2.83688	2.89307	2.30147	2.10386	1.97852	1.71379	1.47609	1.19096	1.02249	0.76699	0.45488	-0.08389		

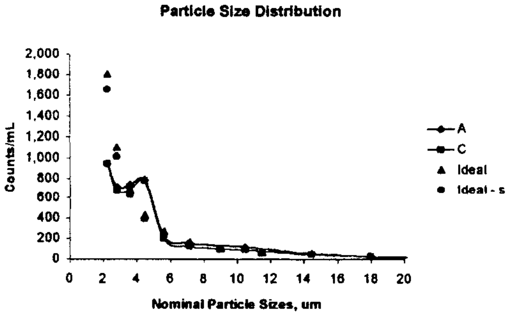

Particle Size Distribution


Volume Distribution

R = 0 98036


Log10 Particle Size Distribution

R = 0 98290


Particle Size Distribution

		A		B	
PS	Log PS	Log Cnt	Cnt	Log Cnt	Cnt
2.25	0.35218	3.256773	1806.23	3.218948	1655.57082
2.85	0.45484	3.0431224	1104.39	3.005523	1012.79843
3.6	0.5563	2.8319789	679.171	2.794603	623.164538
4.5	0.65321	2.6302994	426.874	2.593137	391.865027
5.65	0.75205	2.424612	265.835	2.387666	244.155483
7.15	0.85431	2.2118037	162.856	2.175083	149.652222
9	0.95424	2.0038259	100.885	1.967325	92.7524195
11.5	1.0607	1.7822817	60.5734	1.746015	55.7205327

PCX Test of D, E Data +

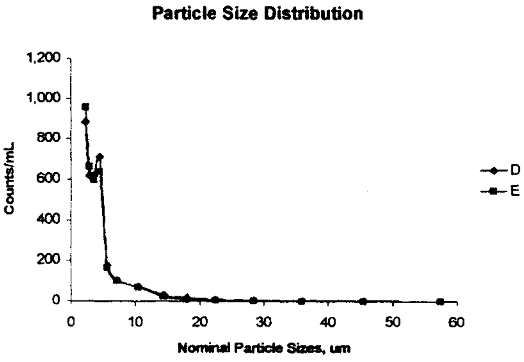
Sampled 14-May-01
Tested 15-May-01

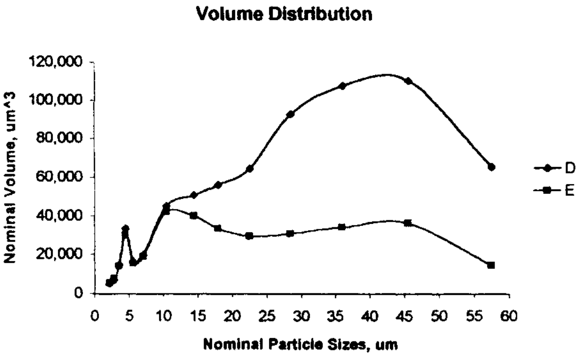
	Nominal	PCX1	PCX2
Flow rate	100	95.97	100.55
mL		101.24	101.59
		93.4	101.43
Mean		96.87	101.19

Bin 10-13 out

Sample time 2

Particles/mL		<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>						<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>									
		2-2.5	2.5-3.2	3.2-4	4-5	5-6.3	6.3-8	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
	ll >	2	2.5	3.2	4	5	6	8	13	16	20	25	32	40	51	64	128
	f' >	2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5		
	Log10 f' >	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
2001/05/08 12:42	FDDW	70.44	57.31	48.34	31.28	12.61	12.98	8.03	2.74	1.51	0.65	0.30	0.11	0.06	0.00	0.03	
D																	
2001/05/15 13:15	D4	915.50	646.60	637.33	710.03	184.55	116.83	82.23	35.35	21.38	12.35	7.95	4.40	2.58	0.88	0.35	
2001/05/15 13:17	D4	943.55	671.70	659.90	740.93	188.63	116.58	87.23	35.20	21.18	11.73	8.25	4.98	2.33	0.63	0.25	
2001/05/15 13:19	D4	921.90	664.08	658.33	721.93	188.73	113.83	85.30	35.78	21.00	12.28	8.33	5.05	2.68	0.58	0.35	
2001/05/15 13:21	D4	947.63	667.38	660.43	732.73	184.93	114.45	85.83	37.73	21.40	12.13	8.73	4.33	2.15	0.75	0.35	
2001/05/15 13:23	D4	898.00	639.95	619.55	693.45	181.95	109.05	78.20	31.43	15.93	9.63	7.08	4.10	1.90	0.50	0.35	
Average		925.32	657.94	647.11	719.81	185.76	114.15	83.76	35.10	20.18	11.62	8.07	4.57	2.33	0.67	0.33	
less FDDW		854.88	600.63	598.77	688.54	173.14	101.17	75.73	32.36	18.66	10.97	7.77	4.46	2.28	0.67		
Flow Ajusted		882.50	620.03	618.11	710.78	178.74	104.44	74.84	31.98	18.44	10.84	7.67	4.41	2.24	0.66	3,266	
Volume, um^3		5,263	7,515	15,100	33,914	16,879	19,988	45,362	51,043	56,318	64,657	93,012	107,612	110,277	65,416	692,358	
Log10 PSD		2.94571	2.79242	2.79107	2.85174	2.25221	2.01886	1.87413	1.50484	1.26583	1.03507	0.88500	0.64395	0.34945	-0.18232		
E																	
2001/05/15 13:27	D5	1011.70	705.10	628.63	658.10	174.30	114.20	80.23	29.40	13.20	5.23	3.03	1.75	0.70	0.05	0.03	
2001/05/15 13:29	D5	993.40	702.18	622.63	653.15	172.88	109.80	78.48	27.43	12.65	6.28	3.40	1.53	0.93	0.20	0.03	
2001/05/15 13:31	D5	994.35	699.73	622.23	641.55	171.98	110.85	78.45	27.90	12.75	4.98	2.70	1.40	0.73	0.13	0.03	
2001/05/15 13:33	D5	991.23	700.60	638.38	651.25	173.88	112.45	78.33	28.85	12.33	5.93	2.48	1.63	0.93	0.23	0.05	
2001/05/15 13:35	D5	995.20	697.15	618.25	640.43	169.48	108.68	77.78	28.05	12.50	6.13	2.88	1.40	0.78	0.15	0.08	
Average		997.18	700.95	626.02	648.90	172.50	111.20	78.65	28.33	12.69	5.71	2.90	1.54	0.81	0.15		
less FDDW		926.74	643.64	577.68	617.62	159.89	98.22	70.63	25.59	11.17	5.06	2.60	1.43	0.75	0.15		
Flow Ajusted		956.68	664.43	596.35	637.58	165.05	101.39	69.79	25.29	11.04	5.00	2.56	1.41	0.74	0.15	3,237	
Volume, um^3		5,706	8,054	14,568	30,421	15,587	19,406	42,305	40,364	33,715	29,794	31,084	34,462	36,434	14,756	356,655	
Log10 PSD		2.98077	2.82245	2.77550	2.80453	2.21763	2.00601	1.84382	1.40289	1.04301	0.69858	0.40900	0.14944	-0.13153	-0.82905		





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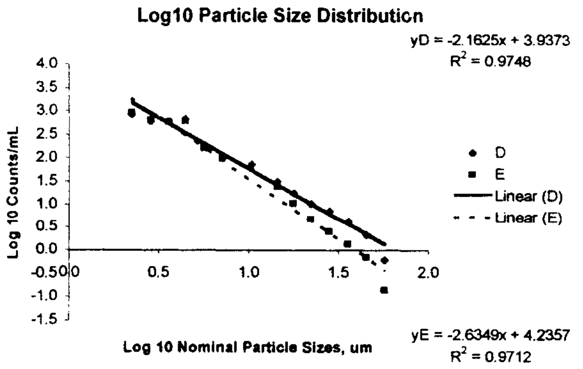

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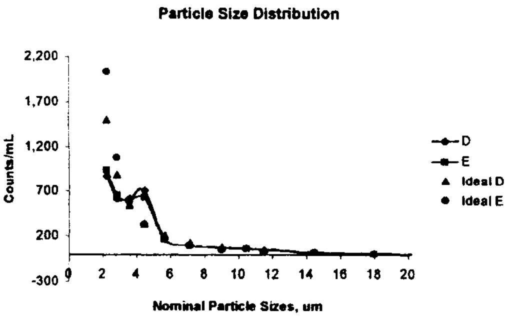


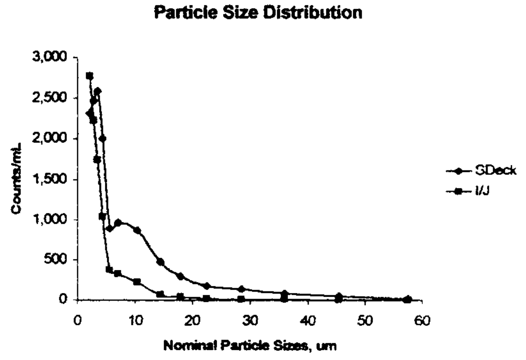
		A		B	
PS	Log PS	Log Cnt	Cnt	Log Cnt	Cnt
2.25	0.35218	3.1757053	1498.67	3.307734	2031.11392
2.85	0.45484	2.953698	898.872	3.037229	1089.50513
3.6	0.5563	2.7342958	542.37	2.769899	588.706107
4.5	0.65321	2.5247279	334.756	2.51455	327.001954
5.65	0.75205	2.3109952	204.642	2.254128	179.526079
7.15	0.85431	2.0898632	122.988	1.984689	96.5359357
9	0.95424	1.8737506	74.774	1.721366	52.6461252
11.5	1.0607	1.6435409	44.0089	1.440867	27.5973423

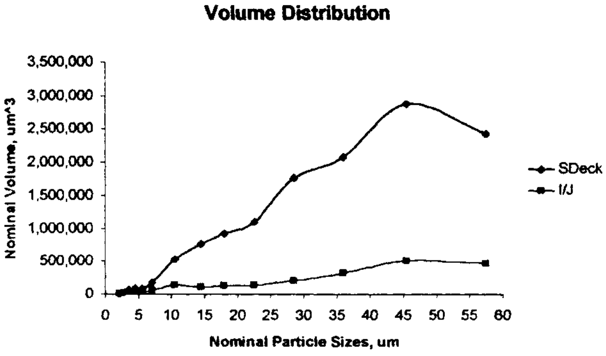
PCX Test of Settle Deck & I/J Data +

	Nominal	PCX1	PCX2		
				Sampled	14-May-01
				Tested	15-May-01
Flow rate	100	102.15	100.7		
mL		98.32	101.76		
		99.5	101.75		
Mean		99.99	101.40		

Sample time 2

Particles/mL		<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>							<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
		2-2.5	2.5-3.2	3.2-4	4-5	5-6.3	6.3-8	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
I >		2	2.5	3.2	4	5	6	8	13	16	20	25	32	40	51	64	128
f >		2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5		
Log10 f >		0.35218	0.45464	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
2001/05/08 12:42	FDDW	70.44	57.31	48.34	31.28	12.61	12.98	8.03	2.74	1.51	0.65	0.30	0.11	0.06	0.00	0.03	
SDeck																	
2001/05/15 15:27	D6	2395.90	2589.00	2701.85	2102.48	937.16	1024.05	933.40	489.78	306.10	190.50	151.38	85.10	60.28	23.80	10.43	
2001/05/15 15:29	D6	2377.58	2506.63	2601.88	2004.55	891.48	971.40	884.48	494.45	312.98	190.83	150.53	88.45	58.83	24.40	11.23	
2001/05/15 15:31	D6	2376.80	2518.10	2622.25	2025.93	905.43	981.95	894.00	490.13	309.65	189.63	148.63	86.18	60.73	26.25	10.95	
2001/05/15 15:33	D6	2391.78	2539.63	2642.65	2024.38	911.10	971.43	880.35	489.73	304.73	183.08	143.00	86.50	57.58	24.30	9.78	
Average		2385.51	2538.34	2642.16	2039.33	911.29	987.21	898.06	491.02	308.36	188.51	148.38	86.56	59.35	24.69	10.59	
less FDDW		2315.08	2481.03	2593.82	2008.06	898.68	974.23	890.03	488.28	306.85	187.86	148.08	86.44	59.29	24.69		
Flow Ajusted		2315.31	2481.27	2594.08	2008.26	898.77	974.33	877.71	481.52	302.60	185.26	146.03	85.25	58.47	24.35	13,433	
Volume, um^3		13,809	30,075	63,371	95,820	84,878	186,476	532,010	768,636	924,038	1,104,891	1,770,032	2,082,512	2,883,658	2,423,411	12,963,615	
Log10 PSD		3.36461	3.39467	3.41398	3.30282	2.95365	2.98871	2.94335	2.68262	2.48087	2.26777	2.16445	1.93068	1.76691	1.38642		
I/J																	
2001/05/15 15:37	D13	2891.60	2318.15	1832.70	1094.93	397.28	350.20	251.13	78.95	46.63	26.70	18.23	12.80	10.70	5.38	2.48	
2001/05/15 15:39	D13	2864.13	2303.80	1792.08	1075.35	391.75	343.53	244.23	80.18	46.35	25.18	19.58	14.53	10.80	4.78	2.73	
2001/05/15 15:41	D13	2827.03	2277.93	1775.85	1070.75	387.38	347.10	240.78	78.75	46.45	26.20	17.28	13.80	10.20	4.63	2.08	
2001/05/15 15:43	D13	2847.68	2288.60	1794.65	1078.85	392.25	347.88	242.68	78.73	45.15	26.55	18.55	13.55	10.93	4.60	2.45	
2001/05/15 15:45	D13	2817.75	2270.20	1778.83	1056.28	384.40	340.98	237.00	77.28	45.80	25.28	18.73	13.45	10.25	4.85	2.43	
Average		2849.64	2291.74	1794.82	1075.23	390.61	345.94	243.16	78.78	46.08	25.98	18.47	13.63	10.58	4.85		
less FDDW		2779.20	2234.42	1746.48	1043.96	378.00	332.96	235.14	76.04	44.56	25.33	18.17	13.51	10.51	4.85		
Flow Ajusted		2779.48	2234.65	1746.66	1044.06	378.04	332.99	231.88	74.99	43.95	24.98	17.92	13.33	10.37	4.78	8,938	
Volume, um^3		16,577	27,086	42,669	49,815	35,701	63,731	140,550	119,696	134,194	148,980	217,186	325,529	511,313	475,602	2,308,631	
Log10 PSD		3.44396	3.34921	3.24221	3.01873	2.57753	2.52244	2.36527	1.87498	1.64292	1.39758	1.25330	1.12468	1.01565	0.67924		





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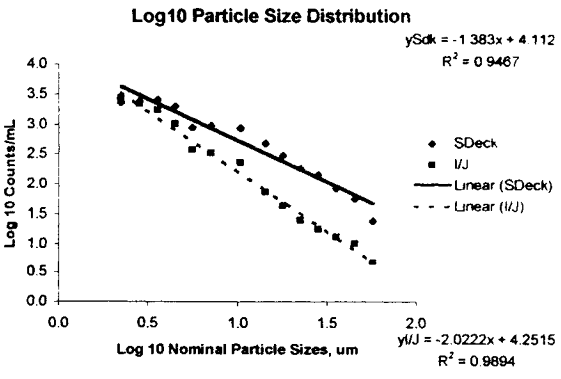

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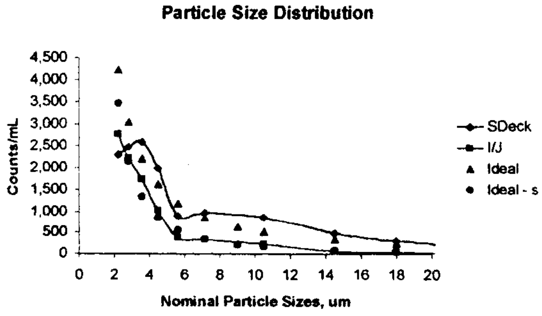


		A		B	
PS	Log PS	Log Cnt	Cnt	Log Cnt	Cnt
2.25	0.3521825	3.6249316	4216.3007	3.53931651	3461.91589
2.85	0.4548449	3.4829496	3040.5319	3.33171272	2146.4102
3.6	0.5563025	3.3426336	2201.0689	3.12654508	1338.27413
4.5	0.6532125	3.2086071	1616.6168	2.93057365	852.26304
5.65	0.7520484	3.071917	1180.0951	2.73070763	537.907536
7.15	0.854306	2.9304947	852.1082	2.52392232	334.135271
9	0.9542425	2.7922826	619.8443	2.3218308	209.812229
10.5	1.0211893	2.6996952	500.83561	2.186451	153.621146
14.5	1.161368	2.5058281	320.50001	1.90298163	79.9800416
18	1.2552725	2.3759581	237.66111	1.71308794	51.6520949

H60

PCX Test of BF Data +

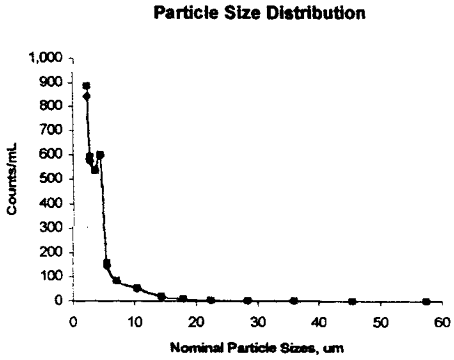
	Nominal	PCX1	PCX2		
				Sampled	14-May-01
				Tested	15-May-01
Flow rate	100	93.4	101.43		
mL		91.15	101.66		
		92.76	101.76		
Mean		92.44	101.62		

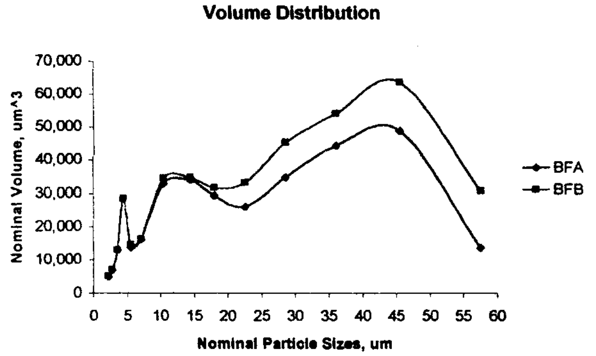
Sample time 2

Particles/mL

<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>> <<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

		2-2.5	2.5-3.2	3.2-4	4-5	5-6.3	6.3-8	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
	fi >	2	2.5	3.2	4	5	6	8	13	16	20	25	32	40	51	64	128
	f' >	2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5		
	Log10 f' >	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
2001/05/08 12:42	FDDW	70.44	57.31	48.34	31.28	12.61	12.98	8.03	2.74	1.51	0.65	0.30	0.11	0.06	0.00	0.03	
BF$_A$																	
2001/05/15 13:43	D7 - BFA	855.88	591.95	555.25	599.55	151.43	92.08	65.23	24.93	11.95	5.25	2.93	2.18	1.20	0.18	0.08	
2001/05/15 13:45	D7	828.53	568.86	529.86	570.43	146.36	88.66	61.73	24.88	10.58	5.03	3.30	2.00	1.20	0.15	0.05	
2001/05/15 13:47	D7	846.50	584.93	545.43	581.00	145.23	93.05	62.85	24.03	11.33	5.23	3.60	1.78	1.23	0.13	0.08	
2001/05/15 13:49	D7	861.15	595.98	549.88	591.48	150.28	92.63	62.58	23.70	10.83	4.90	2.80	2.05	0.75	0.18	0.05	
2001/05/15 13:51	D7	855.13	594.28	539.88	581.25	150.30	92.38	63.30	24.30	11.60	5.00	3.45	1.78	0.98	0.08	0.03	
Average		849.44	587.20	544.06	584.74	148.72	91.76	63.14	24.37	11.26	5.08	3.22	1.96	1.07	0.14	0.06	
less FDDW		779.00	529.89	495.72	553.47	136.11	78.79	55.11	21.63	9.74	4.43	2.92	1.84	1.01	0.14		
Flow Ajusted		842.74	573.24	536.26	598.75	147.24	85.23	54.23	21.28	9.59	4.36	2.87	1.81	0.99	0.14	2,879	
Volume, um^3		5,026	6,948	13,101	28,568	13,905	16,312	32,872	33,974	29,277	26,001	34,770	44,294	48,900	13,714	347,664	
Log10 PSD		2.92569	2.75834	2.72939	2.77725	2.16804	1.93060	1.73427	1.32804	0.98171	0.63944	0.45787	0.25844	-0.00372	-0.86084		
BF$_B$																	
2001/05/15 13:55	D8 - BFB	887.15	604.85	548.63	581.43	156.38	91.78	67.50	24.48	11.98	7.03	4.53	2.90	1.65	0.25	0.15	
2001/05/15 13:57	D8	900.70	617.68	549.18	599.03	158.95	92.58	66.20	25.43	12.63	6.60	3.73	2.18	1.35	0.30	0.08	
2001/05/15 13:59	D8	901.38	605.53	540.33	590.10	159.30	93.00	67.48	25.20	11.63	6.18	3.63	2.20	1.35	0.33	0.03	
2001/05/15 14:01	D8	871.48	597.85	534.70	572.78	151.80	90.23	62.65	24.58	12.10	5.48	4.55	2.18	1.15	0.36	0.03	
Average		890.18	606.46	543.21	585.83	156.61	91.89	65.96	24.92	12.08	6.32	4.11	2.36	1.38	0.31		
less FDDW		819.74	549.16	494.87	554.56	143.99	78.92	57.93	22.18	10.57	5.67	3.81	2.25	1.31	0.31		
Flow Ajusted		886.81	594.10	535.36	599.93	155.78	85.38	57.01	21.83	10.40	5.58	3.75	2.21	1.29	0.31	2,960	
Volume, um^3		5,289	7,201	13,078	28,624	14,711	16,340	34,555	34,844	31,760	33,271	45,401	54,091	63,704	30,612	413,481	
Log10 PSD		2.94783	2.77386	2.72865	2.77810	2.19250	1.93134	1.75595	1.33902	1.01706	0.74652	0.57353	0.34522	0.11113	-0.51211		





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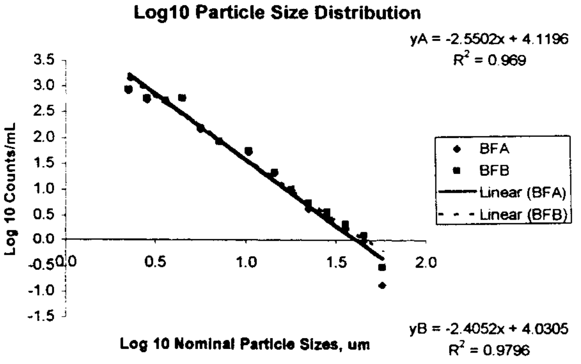

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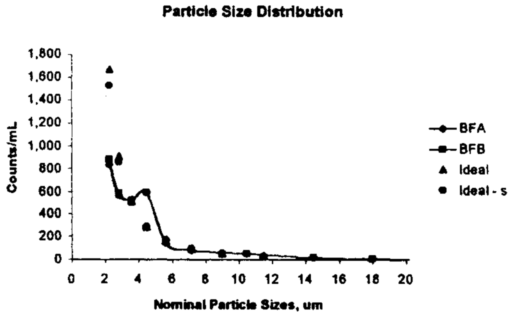


		A		B	
PS	Log PS	Log Cnt	Cnt	Log Cnt	Cnt
2.25	0.35218	3.22146	1665	3.18343	1526
2.85	0.45484	2.95965	911	2.93651	864
3.6	0.5563	2.70092	502	2.69248	493
4.5	0.65321	2.45378	284	2.45939	288
5.65	0.75205	2.20173	159	2.22167	167
7.15	0.85431	1.94095	87	1.97572	95
9	0.95424	1.68609	49	1.73536	54
11.5	1.0607	1.41461	26	1.47931	30

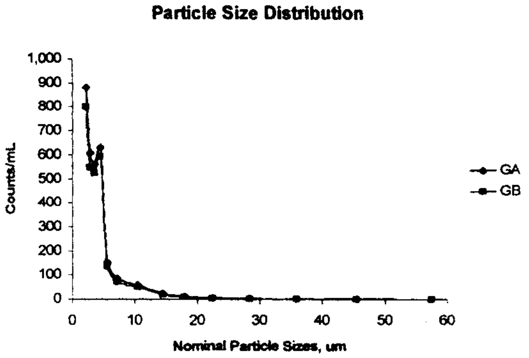
PCX Test of G Data

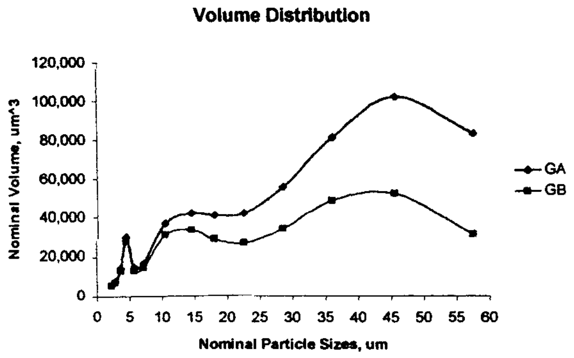
Sampled 14-May-01
Tested 15-May-01

	Nominal	PCX1	PCX2
Flow rate	100	94.52	101.76
mL		98.52	101.42
		95.79	101.75
Mean		96.28	101.64

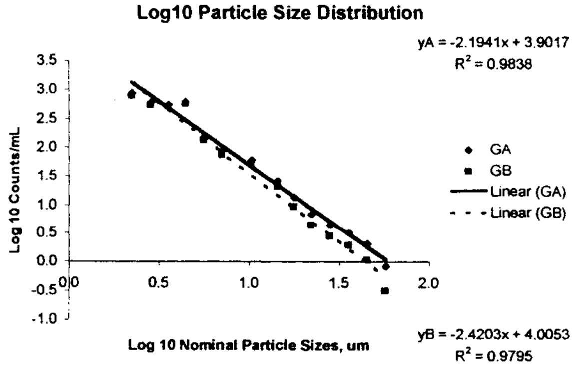
Sample time 2

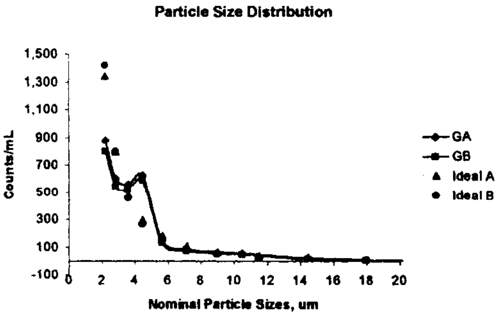
Particles/mL		2-2.5	2.5-3.2	3.2-4	4-5	5-6.3	6.3-8	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
		<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>						<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>									
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
ll >		2	2.5	3.2	4	5	6	8	13	16	20	25	32	40	51	64	128
r >		2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5		
Log10 r >		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
2001/05/08 12:42	FDDW	70.44	57.31	48.34	31.28	12.61	12.98	8.03	2.74	1.51	0.65	0.30	0.11	0.06	0.00	0.03	
G_A																	
2001/05/15 14:05	D9 - GA	931.68	656.73	607.40	658.18	163.80	99.80	72.50	30.13	15.68	7.65	5.08	3.95	2.48	0.75	0.50	
2001/05/15 14:07	D9	906.65	634.25	585.08	629.75	159.20	97.60	70.38	29.00	15.55	7.93	4.90	3.68	2.33	1.13	0.33	
2001/05/15 14:09	D9	936.40	645.98	598.78	650.53	162.20	98.23	71.83	30.20	15.60	8.23	4.30	3.20	2.33	0.73	0.30	
2001/05/15 14:11	D9	946.55	656.98	603.03	644.55	160.58	98.75	71.03	30.83	15.05	8.05	5.25	3.15	2.15	0.83	0.60	
2001/05/15 14:13	D9	883.53	626.58	560.60	609.40	157.10	91.65	69.13	30.05	15.18	7.90	5.53	3.65	1.63	0.85	0.40	
Average		920.96	644.10	590.98	638.48	160.58	97.21	70.97	30.04	15.41	7.95	5.01	3.53	2.18	0.86	0.43	
less FDDW		850.52	586.79	542.64	607.21	147.96	84.23	62.95	27.30	13.90	7.30	4.71	3.41	2.12	0.86		
Flow Ajusted		883.41	609.48	563.62	630.69	153.68	87.49	61.93	26.86	13.67	7.18	4.63	3.36	2.08	0.84	3,049	
Volume, um^3		5,269	7,387	13,769	30,092	14,514	16,744	37,536	42,877	41,752	42,834	56,166	82,016	102,749	83,732	577,437	
Log10 PSD		2.94616	2.78496	2.75099	2.79981	2.18663	1.94195	1.79188	1.42912	1.13586	0.85624	0.66594	0.52599	0.31874	-0.07511		
G_B																	
2001/05/15 14:17	D10 - GB	836.80	579.45	554.95	593.40	144.70	84.90	60.40	24.25	10.55	6.03	3.33	2.10	0.85	0.35	0.13	
2001/05/15 14:19	D10	839.48	583.05	554.28	611.23	142.80	87.93	60.65	23.40	10.75	5.35	3.45	2.30	0.98	0.40	0.10	
2001/05/15 14:21	D10	854.90	599.18	563.15	611.25	144.38	86.93	63.85	25.08	13.08	4.93	3.50	2.23	1.35	0.33	0.18	
2001/05/15 14:23	D10	839.78	586.18	556.08	606.90	144.30	84.45	60.30	25.30	11.25	5.03	3.08	2.15	1.10	0.23	0.18	
2001/05/15 14:25	D10	832.70	575.70	546.25	587.93	144.63	84.33	60.78	24.78	11.13	5.35	2.83	2.08	1.50	0.33	0.18	
Average		841.13	584.71	554.94	602.14	144.16	85.71	61.20	24.56	11.35	5.34	3.24	2.17	1.16	0.33		
less FDDW		770.69	527.40	506.60	570.87	131.55	72.73	53.17	21.82	9.84	4.69	2.94	2.06	1.09	0.33		
Flow Ajusted		800.50	547.79	526.19	592.94	136.63	75.54	52.31	21.47	9.68	4.61	2.89	2.02	1.07	0.32	2,774	
Volume, um^3		4,774	6,640	12,854	28,291	12,903	14,458	31,707	34,271	29,554	27,490	35,000	49,450	53,012	31,828	372,233	
Log10 PSD		2.90336	2.73862	2.72115	2.77301	2.13556	1.87819	1.71859	1.33183	0.98581	0.66363	0.46053	0.30626	0.03134	-0.49520		





R = 0.9919





R = 0.9897

PS	Log PS	A Log Cnt	Cnt	B Log Cnt	Cnt
2.25	0.35218	3.12898	1346	3.15291	1422
2.85	0.45484	2.90372	801	2.90444	802
3.6	0.5563	2.68112	480	2.65888	456
4.5	0.65321	2.46849	294	2.42433	266
5.65	0.75205	2.25163	178	2.18512	153
7.15	0.85431	2.02727	106	1.93762	87
9	0.95424	1.80800	64	1.69575	50
11.5	1.0607	1.57442	38	1.43809	27

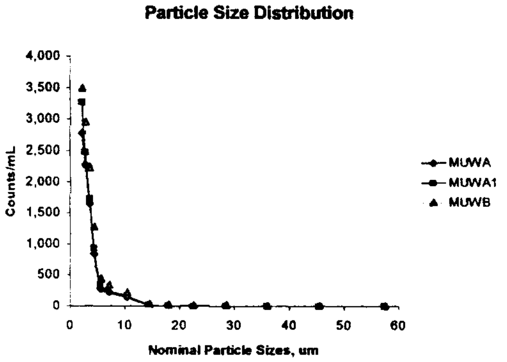
H62

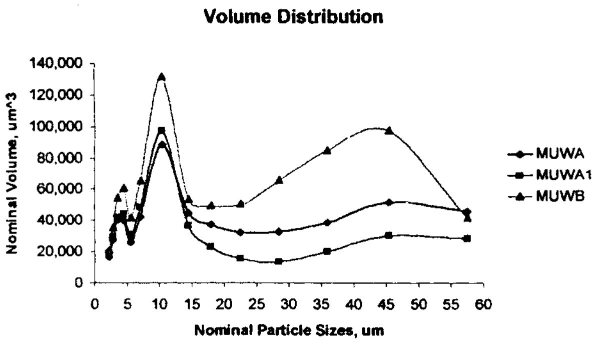
PCX Test of Make Up Waters +

	Nominal	PCX1	PCX2		
				Sampled	14-May-01
				Tested	15-May-01
Flow rate	100	102.15	100.7		
mL		98.32	101.76		
		99.5	101.75		
Mean		99.99	101.40		

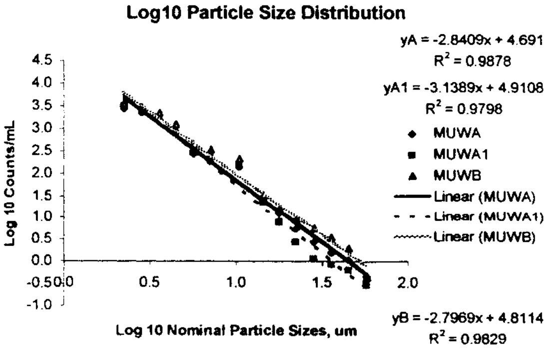
Sample time 2

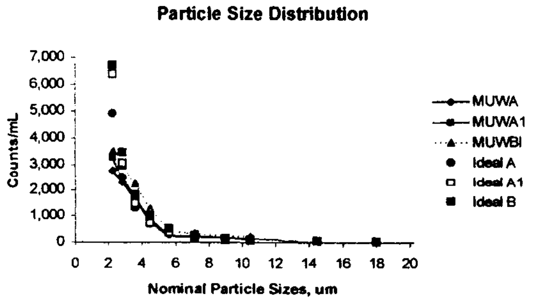
Particles/mL	<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>					<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>									
	2-2.5	2.5-3.2	3.2-4	4-5	5-6.3	6.3-8	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
f >	2	2.5	3.2	4	5	6	8	13	16	20	25	32	40	51	64	128
f' >	2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5		
Log10 f' :	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
2001/05/08 12:42 FDDW	70.44	57.31	48.34	31.28	12.61	12.98	8.03	2.74	1.51	0.65	0.30	0.11	0.06	0.00	0.03	
MUW$_{A}$																
2001/05/15 14:29 D11-MU\	2820.80	2306.48	1663.98	852.75	285.50	228.20	157.83	31.18	13.88	5.83	3.28	2.25	1.53	0.50	0.20	
2001/05/15 14:31 D11	2908.58	2379.05	1729.20	881.58	296.73	241.00	161.28	32.53	14.83	5.95	3.13	1.55	1.13	0.28	0.23	
2001/05/15 14:33 D11	2865.75	2362.70	1713.73	877.85	294.98	235.35	158.30	29.63	14.40	6.35	3.23	1.48	1.30	0.68	0.35	
2001/05/15 14:35 D11	2831.18	2294.95	1692.68	865.78	289.28	229.70	149.83	31.93	13.70	6.50	2.70	1.80	0.90	0.50	0.40	
2001/05/15 14:37 D11	2860.73	2341.05	1720.78	883.50	291.50	238.23	155.55	31.70	13.63	6.45	2.98	1.58	0.83	0.38	0.25	
Average	2857.41	2336.85	1704.07	872.29	291.60	234.50	156.56	31.39	14.09	6.22	3.06	1.73	1.14	0.47	0.29	
less FDDW	2786.97	2279.53	1655.73	841.02	278.98	221.52	148.53	28.65	12.57	5.57	2.76	1.62	1.07	0.47		
Flow Ajusted	2787.25	2279.76	1655.90	841.10	279.01	221.54	146.47	28.26	12.40	5.49	2.72	1.60	1.06	0.46	8,263	
Volume, um^3	16,623	27,633	40,452	40,131	26,349	42,401	88,783	45,104	37,860	32,731	32,991	38,967	52,165	45,646	567,836	
Log10 PSD	3.44516	3.35789	3.21903	2.92485	2.44562	2.34546	2.16576	1.45111	1.09337	0.73941	0.43486	0.20279	0.02435	-0.33860		
MUW$_{A1}$																
2001/05/15 14:53 D14	3344.13	2542.90	1773.18	958.43	341.05	268.95	173.60	24.93	8.88	3.70	1.90	1.55	1.85	0.93	0.18	
2001/05/15 14:55 D14	3340.38	2522.65	1774.18	966.83	338.20	265.75	172.38	25.70	9.35	3.10	1.38	0.75	0.40	0.18	0.05	
2001/05/15 14:57 D14	3330.70	2552.45	1784.58	971.90	344.40	268.00	169.18	28.08	10.10	3.43	1.18	0.78	0.33	0.05	0.08	
2001/05/15 14:59 D14	3330.75	2532.25	1779.58	952.13	338.83	266.20	168.65	26.23	8.95	3.35	1.40	0.78	0.20	0.03	0.03	
Average	3336.49	2537.56	1777.88	962.32	340.62	267.23	171.00	26.23	9.32	3.39	1.46	0.96	0.69	0.29		
less FDDW	3266.05	2480.25	1729.54	931.04	328.01	254.25	162.98	23.49	7.81	2.74	1.16	0.85	0.63	0.29		
Flow Ajusted	3266.38	2480.50	1729.71	931.14	328.04	254.28	160.72	23.17	7.70	2.71	1.15	0.84	0.62	0.29	9,187	
Volume, um^3	19,481	30,066	42,255	44,427	30,979	48,665	97,417	36,983	23,507	16,138	13,895	20,477	30,703	28,636	483,831	
Log10 PSD	3.51407	3.39454	3.23797	2.96901	2.51593	2.40530	2.20607	1.36490	0.88639	0.43229	0.05934	-0.07663	-0.20585	-0.53807		
MUW$_{B}$																
2001/05/15 14:41 D12	3451.23	2895.43	2184.08	1245.35	439.80	340.55	221.23	36.25	18.50	9.98	6.30	4.20	2.25	0.58	0.08	
2001/05/15 14:43 D12	3514.68	2917.03	2201.83	1264.50	443.88	341.63	222.13	37.48	17.43	9.78	5.95	3.00	2.55	0.23	0.10	
2001/05/15 14:45 D12	3688.48	3123.13	2386.25	1374.35	472.23	368.63	236.03	36.80	17.70	8.85	6.03	4.10	2.18	0.50	0.13	
2001/05/15 14:47 D12	3626.30	3086.88	2351.73	1348.50	471.15	366.10	233.45	36.55	18.15	8.60	5.10	3.23	1.28	0.40	0.03	
Average	3570.22	3005.61	2280.97	1308.18	456.76	354.23	228.21	36.77	17.94	9.30	5.84	3.63	2.06	0.43		
less FDDW	3499.78	2948.30	2232.63	1276.90	444.15	341.25	220.18	34.03	16.43	8.65	5.54	3.52	2.00	0.43	-0.03	
Flow Ajusted	3500.13	2948.59	2232.85	1277.03	444.19	341.28	217.13	33.56	16.20	8.53	5.47	3.47	1.97	0.42	11,031	
Volume, um^3	20,875	35,739	54,546	60,931	41,949	65,318	131,612	53,571	49,481	50,876	66,265	84,770	97,277	41,719	854,929	
Log10 PSD	3.54408	3.46962	3.34886	3.10620	2.64757	2.53312	2.33673	1.52583	1.20962	0.93096	0.73775	0.54034	0.29498	-0.37766		


Particle Size Distribution


Volume Distribution

RA= 0.9939


Log10 Particle Size Distribution


Particle Size Distribution

RA1 = 0.9898
RB = 0.9914

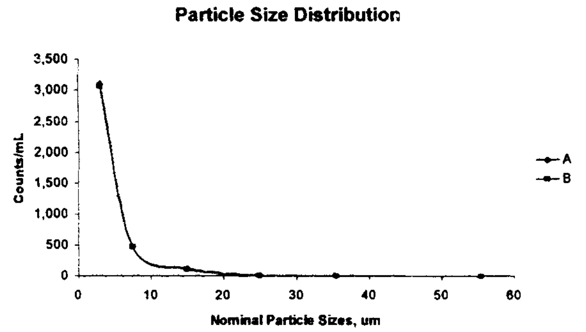
			A		A1		B
PS	Log PS	Log Cnt	Cnt	Log Cnt	Cnt	Log Cnt	Cnt
2.25	0.35218	3.69048	4903	3.80533	6388	3.82638	6705
2.85	0.45484	3.39883	2505	3.48309	3041	3.53924	3461
3.6	0.55630	3.11060	1290	3.16462	1461	3.25548	1801
4.5	0.65321	2.83529	684	2.86043	725	2.98443	965
5.65	0.75205	2.55451	359	2.55020	355	2.70800	510
7.15	0.85431	2.26400	184	2.22922	170	2.42199	264
9	0.95424	1.98009	96	1.91553	82	2.14248	139
10.5	1.02119	1.78990	62	1.70539	51	1.95524	90
14.5	1.16137	1.39167	25	1.26538	18	1.56317	37
18	1.25527	1.12490	13	0.97063	9	1.30053	20

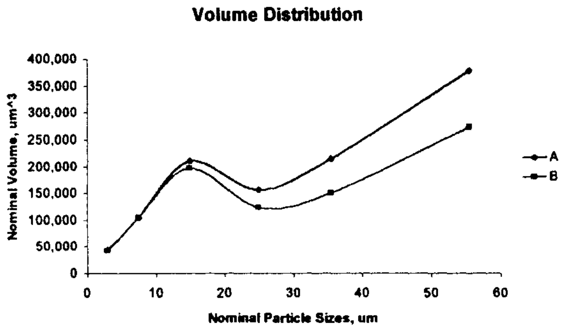
PCX Test of Gravimetric Channels for A & B

Sampled 14-May-01
Tested 15-May-01
Sample time 2 min
Particles/mL

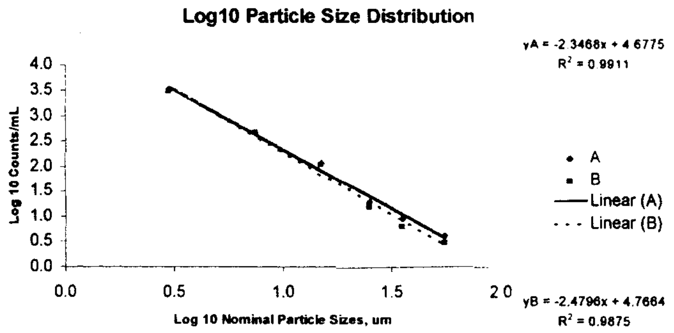
	Nominal	PCX1	PCX2
Flow rate	100	99.25	
mL		100.24	
		96.79	
		100.73	
Mean		99.2525	

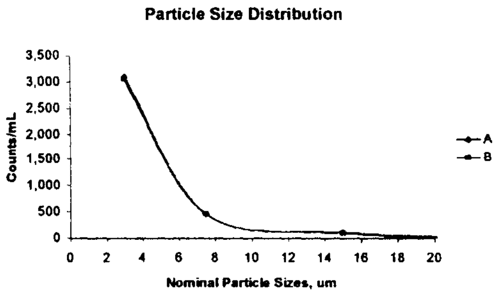
Class >		1-5	5-10	10-20	20-30	30-41	41-70	:>70
ri >		1	5	10	20	30	41	70
r* >		3	7.5	15	25	35.5	55.5	35
Log10 r* :		0.47712	0.87506	1.17609	1.39794	1.55023	1.74429	1.54407
FDDW		392.25	34.35	6.98	1.20	0.18	0.05	0.00
		342.00	30.75	6.35	0.68	0.10	0.10	0.03
Avg		367.13	32.55	6.66	0.94	0.14	0.08	0.01
	Jar							
A								
2001/05/15 10:46	D19	3402.72	508.10	125.80	20.38	9.15	4.13	0.30
2001/05/15 10:48	D19	3484.48	510.88	127.18	20.80	8.65	4.60	0.43
2001/05/15 10:50	D19	3439.23	508.85	126.38	20.58	9.35	4.25	0.38
2001/05/15 10:52	D19	3387.45	505.88	123.35	18.95	8.20	3.85	0.33
2001/05/15 10:54	D19	3359.33	496.08	126.90	19.95	8.93	4.38	0.45
2001/05/15 10:56	D19	3443.90	504.70	125.48	20.00	9.23	4.28	0.43
Flow Ajusted		3469.84	508.50	126.42	20.15	9.29	4.31	0.43
less FDDW		3102.71	475.95	119.76	19.21	9.16	4.23	0.42
Volume, um^3		43,864	105,134	211,629	157,187	214,504	378,829	9,332
Log10 PSD		3.49174	2.67756	2.07830	1.28360	0.96175	0.62657	-0.38122
B								
2001/05/15 11:00	D20	3429.85	500.15	115.55	15.60	6.03	2.93	0.48
2001/05/15 11:02	D20	3328.28	496.48	113.78	15.13	6.33	2.75	0.28
2001/05/15 11:04	D20	3420.65	507.63	115.30	16.90	6.33	3.38	0.20
2001/05/15 11:06	D20	3432.75	511.00	121.58	17.08	7.30	3.03	0.28
2001/05/15 11:08	D20	3417.15	507.50	120.95	15.25	6.33	3.08	0.33
2001/05/15 11:10	D20	3409.00	512.48	121.80	16.58	6.85	3.53	0.35
Average		3406.31	505.87	118.16	16.09	6.53	3.11	0.32
Flow Ajusted		3431.96	509.68	119.05	16.21	6.57	3.14	0.32
less FDDW		3064.84	477.13	112.39	15.27	6.44	3.06	0.31
Volume, um^3		43,328	105,395	198,602	124,937	150,780	273,989	6,882
Log10 PSD		3.48641	2.67864	2.05071	1.18387	0.80866	0.48585	-0.51350





Ra = 0.9918 Rb = 0.9949





Particle Size Analysis

PCX Results for samples taken 21 May 01

The PCX particle counters were set up in tandem in two x eight channel spans:

Lower span: 2-2.5, 2.5-3.2, 3.2-4, 4-5, 5-6.3, 6.3-8,8-10 µm

and

Upper span: 13-16, 16-20, 20-25, 25-32, 32-40, 40-51, 51-64, >64 µm (A)

There was adjustment for variation in flow rates and for cell noise.

Results log:

Site>	**A**	**B**	**C**	**D**	**E**	**SD**	**BF$_A$**	**BF$_B$**	**G$_A$**	**G$_B$**	**MW$_A$ 1**	**MW$_A$ 2**	**MW B**	**I/J**	**D2**
Data	√	√													

PCX Test of A & B Data (lessFDDW)

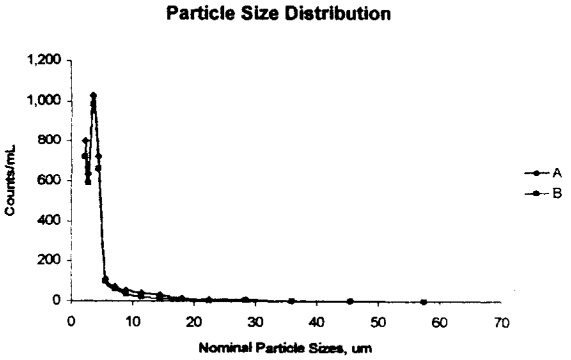
Full data set

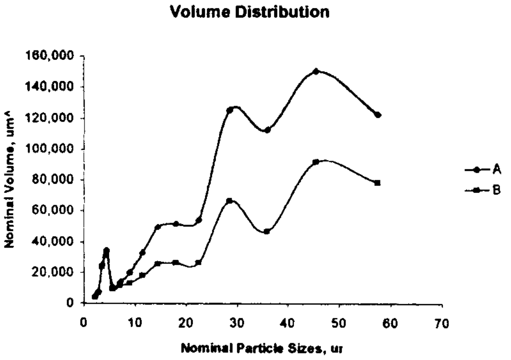
	Nominal	PCX1	PCX2
Flow rate	100	103.53	100.71
mL		100.79	100.65
		101.47	101.7
Mean		101.93	101.02

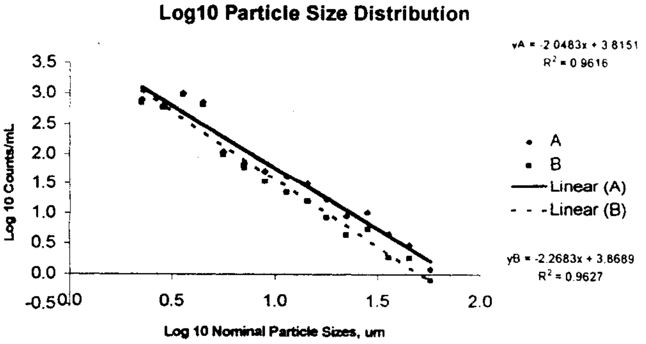
Sampled 21-May-01
Tested 23-May-01
Sample time 2 min
Particles/mL

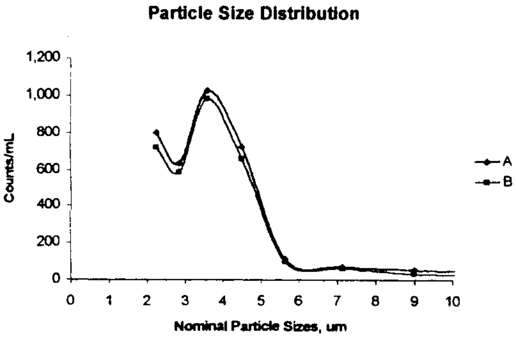
<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>> <<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
	ll >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	256
	l* >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	160	
	Log10 l* :	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
FDDW																		
2001/05/23 09:52	FDDW	210.28	175.18	145.90	93.20	38.30	38.83	37.63	25.03	12.93	6.80	5.90	4.50	2.05	0.78	0.13	0.93	800
A	Jar																	
2001/05/23 09:58	D1 (Scr)	1016.60	832.28	1211.78	829.73	155.75	114.93	93.90	68.05	45.05	26.15	14.68	14.63	6.98	3.65	1.53	0.50	4436
2001/05/23 10:00	D1	1027.05	831.30	1203.80	840.15	154.05	116.18	91.18	69.95	43.68	25.53	14.85	15.70	6.80	3.98	1.43	0.78	
2001/05/23 10:02	D1	1047.78	833.03	1207.73	842.78	154.65	113.60	94.48	66.03	44.03	25.60	15.75	14.23	6.60	3.80	1.18	0.43	
2001/05/23 10:04	D1	1028.13	811.50	1149.15	825.20	148.43	111.10	89.93	65.40	44.80	26.40	15.23	15.30	6.48	4.00	1.35	0.58	4343
Average		1029.89	827.03	1193.11	834.46	153.22	113.95	92.37	67.36	44.39	25.92	15.13	14.96	6.71	3.86	1.37	0.57	
Less FDDW		819.61	651.85	1047.21	741.26	114.92	75.13	54.74	42.33	31.46	17.12	9.23	10.46	4.66	3.08	1.24	-0.36	
Flow Ajusted		804.09	639.51	1027.38	727.23	112.74	73.70	53.71	41.53	31.14	16.95	9.13	10.36	4.62	3.05	1.23	0.56	3,557
Volume, um^3		4,796	7,751	25,098	34,698	10,647	14,106	20,500	33,071	49,715	51,746	54,463	125,534	112,750	150,436	122,554	1,207,460	2,025,327
Log10 PSD		2.90531	2.80585	3.01173	2.86167	2.05209	1.86748	1.73003	1.61836	1.49339	1.22906	0.96056	1.01523	0.66421	0.48432	0.09033		
B																		
2001/05/23 10:10	D2 (Scr)	949.43	772.08	1136.55	760.98	139.15	101.73	71.53	46.63	29.00	18.50	12.30	11.45	4.38	3.18	1.05	0.13	4058
2001/05/23 10:12	D2	942.13	786.56	1148.80	773.88	142.50	101.80	72.00	47.83	28.88	18.20	10.30	9.13	3.80	2.40	0.98	0.53	
2001/05/23 10:14	D2	947.30	771.30	1152.05	765.58	140.23	102.33	73.05	48.55	29.75	17.35	9.43	9.78	4.25	2.25	0.95	0.30	
2001/05/23 10:16	D2	950.65	785.78	1153.40	774.30	143.30	99.93	72.78	50.58	29.55	17.18	10.50	9.95	4.15	2.63	0.75	0.35	
2001/05/23 10:18	D2	957.50	763.48	1156.65	773.75	137.68	100.63	73.93	48.35	29.20	16.73	9.35	9.93	3.38	2.83	0.88	0.48	
Average		949.40	775.84	1149.49	769.70	140.57	101.28	72.66	48.39	29.28	17.59	10.38	10.05	3.99	2.66	0.92	0.36	
Less Fddw		739.13	600.67	1003.59	676.50	102.27	62.46	35.03	23.36	16.35	8.79	4.48	5.55	1.94	1.88	0.80	-0.57	
Flow Ajusted		725.13	589.29	984.59	663.69	100.33	61.27	34.37	22.92	16.18	8.70	4.43	5.49	1.92	1.86	0.79	0.35	3,221
Volume, um^3		4,325	7,143	24,053	31,666	9,475	11,727	13,118	18,250	25,835	26,570	26,420	66,532	46,914	91,787	78,336	753,667	1,235,818
Log10 PSD		2.86042	2.77033	2.99325	2.82196	2.00145	1.78727	1.53614	1.36017	1.20911	0.93958	0.64639	0.73949	0.28339	0.26975	-0.10404		


Particle Size Distribution


Volume Distribution


Log10 Particle Size Distribution


Particle Size Distribution

Particle Size Analysis

PCX Results for samples taken 4 Jun 01

(For comparison to earlier sampling)

The PCX particle counters were set up in tandem in two x eight channel spans:

Lower span: 2-2.5, 2.5-3.2, 3.2-4, 4-5, 5-6.3, 6.3-8,8-10 μm

and

Upper span: 13-16, 16-20, 20-25, 25-32, 32-40, 40-51, 51-64, >64 μm (A)

and sites A and B using the filtration screen classes of:

1-5, 5-10, 10-20, 20-30, 30-41 μm (B)

There was adjustment for variation in flow rates and for cell noise.

Results log:

Site>	**A**	**B**	**C**	**D**	**E**	**SD**	**BF$_A$**	**BF$_B$**	**G$_A$**	**G$_B$**	**MW$_A$ 1**	**MW$_A$ 2**	**MW B**	**I/J**	**D2**
A		√						√		√					
B														√	

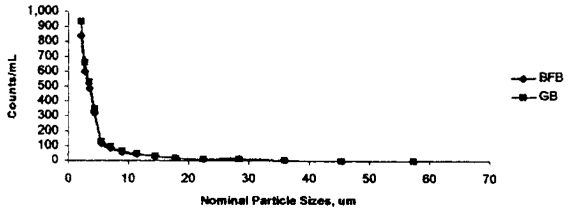
PCX Test of BFB & GB Data

Sampled 4-Jun-01 Tested 5-Jun-01 Full data set

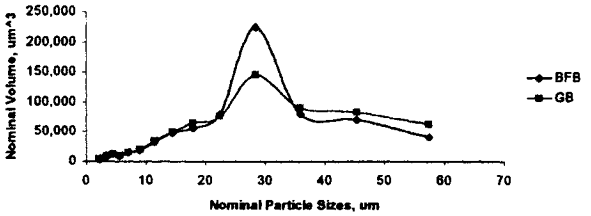
Particles/mL				FDDW		BFB		GB		Sample time
Flow rate	mL	Nominal	100	PCX1	PCX2	PCX1	PCX2	PCX1	PCX2	2 min
		Mean		97.41	102.23	97.67	102.54	97.36	101.85	

		<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>							
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	>64'	est
	l >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	
	r >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	32	
	Log10 r :	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967		
FDDW	Avg	124.08	109.68	90.40	56.45	20.79	16.19	10.70	5.67	2.59	1.73	0.96	0.42	0.25	0.13	0.01	0.03	
Flow Adjusted		127.39	112.59	92.81	57.95	21.34	16.62	10.98	5.82	2.54	1.70	0.94	0.41	0.24	0.13	0.01	0.02	
BF_B																		
Average		824.59	587.62	478.81	319.06	119.02	90.35	61.00	46.32	33.92	20.72	14.57	19.52	3.61	1.61	0.44	0.19	
Flow Ajusted		844.30	601.66	490.26	326.70	121.86	92.51	62.46	47.42	33.08	20.21	14.21	19.03	3.52	1.57	0.42	0.19	
Less FDDW		716.92	489.07	397.45	268.75	100.52	75.89	51.47	41.60	30.55	18.51	13.27	18.62	3.28	1.44	0.42	0.16	
Volume, um^3		4,276	5,928	9,709	12,623	9,492	14,524	19,648	33,131	48,758	56,528	79,156	225,744	80,032	71,009	41,417	2,760	714,934
Log10 PSD		2.85547	2.68937	2.59928	2.42935	2.00223	1.88017	1.71158	1.61914	1.48494	1.26745	1.12294	1.27008	0.51536	0.15828	-0.38082		
G_B																		
Average		916.03	646.61	521.34	343.91	128.64	97.79	66.43	48.95	35.07	23.69	13.98	12.72	4.07	1.87	0.66	0.30	
Flow Ajusted		940.40	663.81	535.21	353.06	132.06	100.39	68.19	50.25	34.30	23.17	13.68	12.44	3.98	1.83	0.64	0.29	
Less Fddw		813.02	551.22	442.41	295.10	110.72	83.76	57.21	44.44	31.77	21.47	12.74	12.04	3.74	1.70	0.63	0.27	
Volume, um^3		4,849	6,681	10,808	14,080	10,456	16,032	21,836	35,385	50,706	65,572	75,970	145,877	91,285	83,788	62,967	4,615	700,908
Log10 PSD		2.91010	2.74132	2.64582	2.46998	2.04422	1.92306	1.75746	1.64773	1.50196	1.33190	1.10510	1.08045	0.57250	0.23015	-0.19889		

Particle Size Distribution

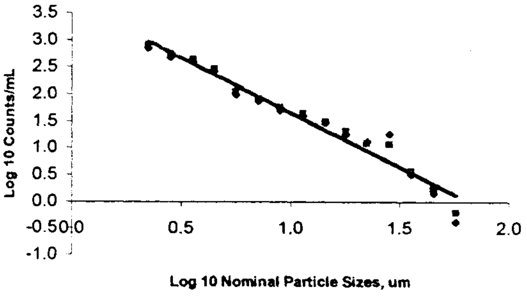


Volume Distribution



R = 0.98336

Log10 Particle Size Distribution

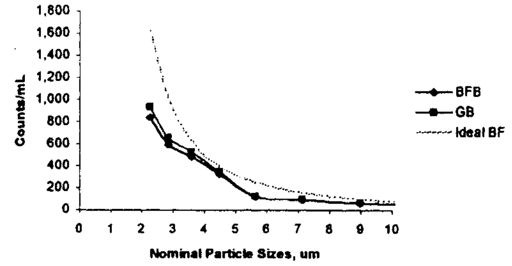


yA = -2.0244x + 3.926
$R^2 = 0.967$

yB = -2.169x + 3.9654
$R^2 = 0.9717$

R = 0.98575

Particle Size Distribution



r	log r*	Log BF	Alog BF
2.25	0.352183	3.21304	1633.21
2.85	0.454845	3.00521	1012.07
3.6	0.556303	2.79982	630.70
4.5	0.653213	2.60364	401.45
5.65	0.752048	2.40355	253.25
7.15	0.854306	2.19654	157.23
9	0.954243	1.99423	98.68
11.5	1.060698	1.77872	60.08
14.5	1.161368	1.57493	37.58
18	1.255273	1.38483	24.26

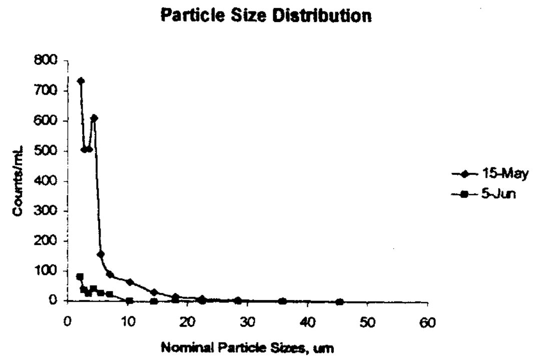
PCX Test of B Data Sampled 14 May, Tested 15 May and 5 Jun

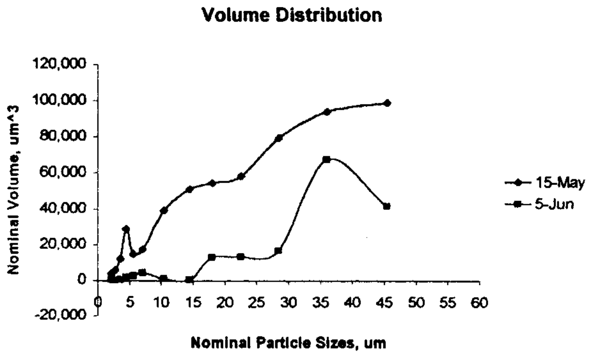
	Nominal	14-May PCX1	14-May PCX2	5-Jun PCX1	5-Jun PCX2
Flow rate mL	100	99.62	100.55		
		96.82	98.38		
		98.62	99.14		
Mean		98.35	99.36	97.36	101.85

Sample time 2

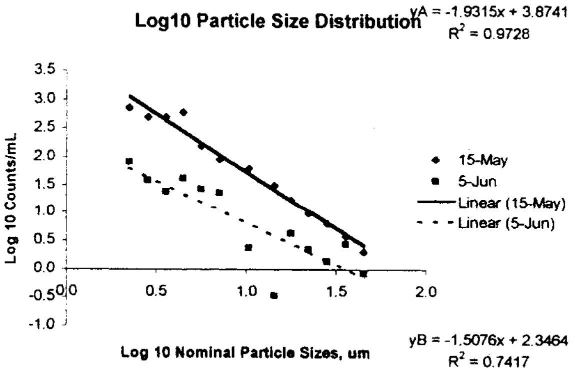
Particles/mL <<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>> <<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

		2-2.5	2.5-3.2	3.2-4	4-5	5-6.3	6.3-8	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10	13-16	16-20	20-25	25-32	32-40	40-51	51-64	>64	
	l >	2	2.5	3.2	4	5	6	8	13	16	20	25	32	40	51	64	128
	l' >	2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5		
	Log10 l' >	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	1.02119	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801			
FDDW	15-May	70.44	57.31	48.34	31.28	12.61	12.98	8.03	2.74	1.51	0.65	0.30	0.11	0.06	0.00	0.03	
FDDW	5-Jun	127.45	112.85	92.85	57.98	21.36	16.63	10.99	5.82	2.54	1.70	0.94	0.41	0.25	0.13	0.008182252	0.024547
15-May																	
2001/05/15 12:41	D2	793.45	555.85	559.13	645.00	168.75	104.80	74.10	34.80	18.80	10.13	6.68	4.18	2.10	0.83	0.33	
2001/05/15 12:43	D2	807.68	569.80	566.28	652.65	174.53	107.65	74.55	33.45	19.58	10.30	6.70	4.40	1.85	0.68	0.13	
2001/05/15 12:45	D2	802.93	567.88	556.25	635.60	168.53	105.70	75.20	35.13	19.15	9.90	7.43	3.75	1.98	0.68	0.25	
2001/05/15 12:47	D2	789.05	549.08	544.55	631.25	170.10	101.10	70.18	34.90	20.53	10.93	6.70	3.58	2.33	0.53	0.25	
2001/05/15 12:49	D2	775.43	542.75	523.30	609.55	164.83	98.15	69.38	35.13	18.40	10.90	6.68	3.85	2.08	0.58	0.53	
Average		793.71	557.07	549.90	634.81	169.35	103.48	72.68	34.68	19.29	10.43	6.84	3.95	2.07	0.66	0.30	
less FDDW		723.27	499.76	501.56	603.54	156.73	90.51	64.66	31.94	17.78	9.78	6.54	3.84	2.00	0.66		
Flow Ajusted		735.38	508.12	509.96	613.64	159.36	92.02	65.07	32.15	17.89	9.84	6.58	3.86	2.02	0.66	2,757	
Volume, um^3		4,386	6,159	12,458	29,279	15,049	17,612	39,443	51,319	54,637	58,707	79,723	94,353	99,405	65,622	628,150	
Log10 PSD		2.86651	2.70597	2.70754	2.78791	2.20237	1.96388	1.81341	1.50717	1.25267	0.99314	0.81805	0.58685	0.30438			
5-Jun																	
Average		208.13	150.76	117.31	99.60	48.51	39.79	13.31	6.17	6.93	3.99	2.36	3.24	1.11	0.46	0	0.19375
less FDDW		80.69	38.11	24.46	41.68	27.15	23.16	2.32	0.35	4.38	2.29	1.42	2.83	0.87	0.33		
Flow Ajusted		82.87	39.14	25.12	42.81	27.89	23.78	2.38	0.34	4.30	2.25	1.40	2.78	0.85	0.33	0.00	
Volume, um^3		494	474	614	2,042	2,634	4,552	1,442	546	13,133	13,421	16,916	67,992	41,988	32,408	198,656	
Log10 PSD		1.91841	1.59264	1.40000	1.63150	1.44540	1.37630	0.37640	-0.46574	0.63356	0.35224	0.14481	0.44455	-0.06991			





R = 0.98631



R = 0.98848

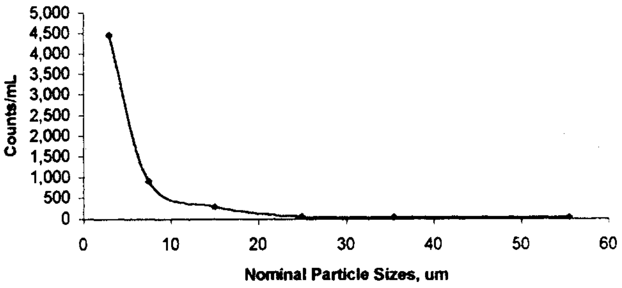
PCX Test of Gravimetric Channels for I/J

Sampled 4-Jun-01
Tested 5-Jun-01

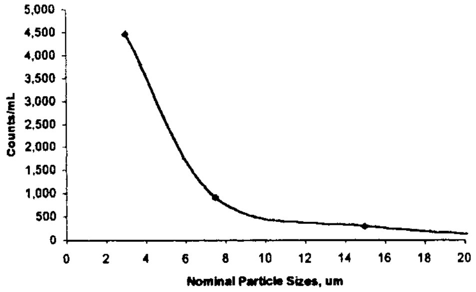
	Nominal	FDDW	
Flow rate	100		
mL			
Mean		99.62	99.29

From: PCXGrav4Jun_I.xls
Sample ti 2 min

		1-5	5-10	10-20	20-30	30-41	41-70	:>70
	Class >	1-5	5-10	10-20	20-30	30-41	41-70	:>70
	li >	1	5	10	20	30	41	70
	l* >	3	7.5	15	25	35.5	55.5	35
	Log10 l* >	0.47712	0.87506	1.17609	1.39794	1.55023	1.74429	1.54407
Particles/mL								
	FDDW							
	Avg	158.55	21.20	5.69	0.73	0.29	0.04	0.01
	Flow adjust	159.15	21.28	5.71	0.73	0.29	0.04	0.01
I/J								
Avg	D11 (I)	4600.64	927.96	300.29	68.04	50.20	46.41	4.09
Flow Ajusted		4633.34	934.56	302.43	68.53	50.55	46.74	4.12
less FDDW		4474.19	913.28	296.72	67.80	50.27	46.70	4.10
Volume, um^3		63,252	201,736	524,341	554,685	1,177,472	4,180,323	92,132
Log10 PSD		3.65071	2.96060	2.47234	1.83123	1.70127	1.66933	0.61321

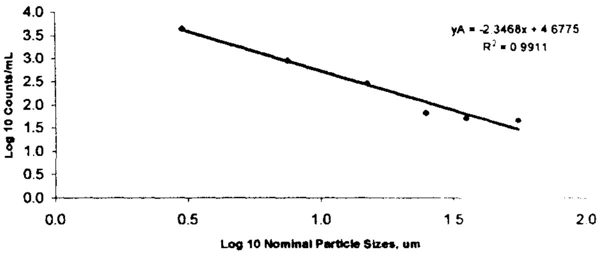


Particle Size Distribution

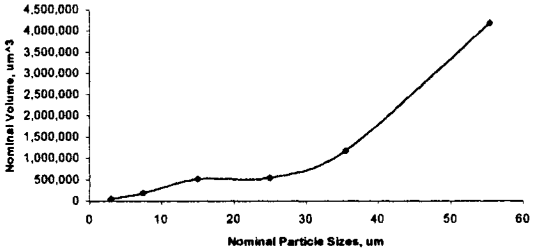


Particle Size Distribution

Rs = 0.9955



Log10 Particle Size Distribution



Volume Distribution

Particle Size Analysis

PCX Results for Feed Samples taken 12 Apr, 19 Apr and 6 Jun 01

The PCX particle counters were set up in <u>tandem</u> in two x eight channel spans:

Lower span: 2-2.5, 2.5-3.2, 3.2-4, 4-5, 5-6.3, 6.3-8,8-10 µm

and

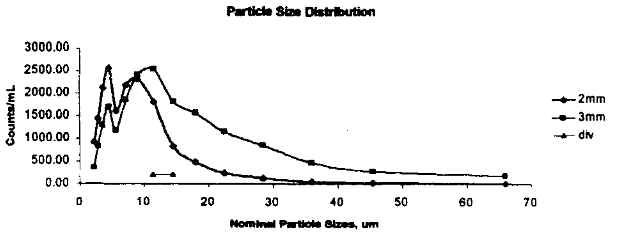
Upper span: 13-16, 16-20, 20-25, 25-32, 32-40, 40-51, 51-81, >81 µm

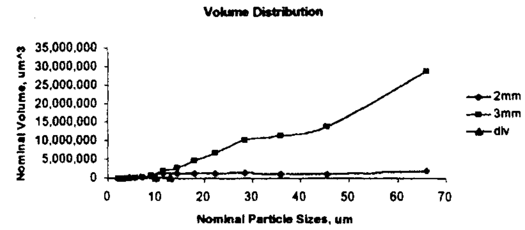
(Last channels 51-64 and >64 for 6 Jun 01)

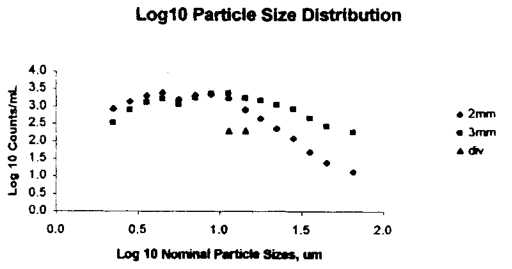
There was adjustment for variation in flow rates in all test but only in the 7 Jun 01 samples for cell noise.

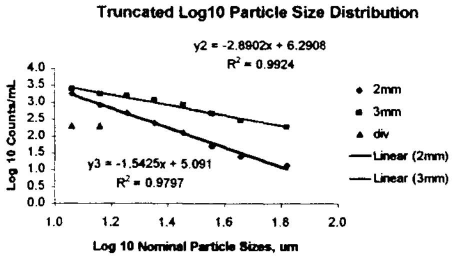
PCX Test of Feeds, Joint   Sampled 12-Apr-01
Flow rate 100 mL   Tested 12-Apr-01
Sample tim 2 min

	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-81'	:>81'	
	l >	2	2.5	3.2	4	5	6.3	8	10	13	16	20	25	32	40	51	81	128
	l* >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	66	104.5	
	Log10 l* >	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.81954		
		|—			Low range				—|	|—			High range				—|	
Flow rate	99.25	mL/min																
2001/04/12 14:	2mm	894.75	1195.25	1624.68	1868.33	1111.58	1377.20	1394.33	1061.53	409.65	236.68	127.00	66.33	27.98	12.95	7.88	1.85	
2001/04/12 14:	2mm	954.70	1700.28	2640.95	3265.35	2112.43	2997.73	3248.50	2565.20	1238.75	727.63	366.78	188.20	75.35	37.83	19.85	2.43	
Average		924.73	1447.76	2132.81	2566.84	1612.00	2187.46	2321.41	1813.36	824.20	482.15	246.89	127.26	51.66	25.39	13.86	2.14	16,780
Volume, um^3		5,515	17,548	52,103	122,471	152,233	418,656	886,091	1,444,032	1,315,634	1,472,307	1,472,466	1,542,530	1,262,064	1,252,140	2,086,758	1,277,164	14,779,733
Log10 PSD		2.96601	3.16070	3.32895	3.40940	3.20737	3.33994	3.36575	3.25848	2.91603	2.68318	2.39250	2.10470	1.71318	1.40462	1.14184	0.32991	
Log10 Volume		3.74156	4.24423	4.71686	5.08803	5.18251	5.62186	5.94748	6.15958	6.11914	6.16800	6.16805	6.18823	6.10108	6.09765	6.31947	6.10625	
									V ol = pl x l**3 /6 x No. Particles in bin									
Flow rate	99.31	mL/min																
2001/04/12 14:	3mm	357.02	834.65	1306.63	1707.80	1184.75	1857.00	2411.20	2529.85	1807.08	1566.05	1153.80	853.95	475.35	287.08	192.88	49.98	
2001/04/12 14:	3mm	360.70	832.00	1304.35	1702.53	1194.05	1843.43	2409.68	2548.65	1823.68	1570.48	1154.98	861.00	474.48	283.68	191.00	47.53	
Average		358.86	833.33	1305.49	1705.16	1189.40	1850.21	2410.44	2539.25	1815.38	1568.26	1154.39	857.48	474.91	285.38	191.94	48.75	18,589
Volume, um^3		2,140	10,101	31,892	81,358	112,324	354,110	920,072	2,022,077	2,897,804	4,788,890	6,884,902	10,393,329	11,601,649	14,075,011	28,892,842	29,128,768	112,197,269
Log10 PSD		2.55493	2.92081	3.11577	3.23177	3.07533	3.26722	3.38210	3.40471	3.25897	3.19542	3.06235	2.93322	2.67661	2.45542	2.28316	1.68797	
Log10 Volume		3.33047	4.00435	4.50368	4.91040	5.05047	5.54914	5.96382	6.30580	6.46207	6.68023	6.83790	7.01675	7.06452	7.14845	7.46079	7.46432	
									200	200								
									2.30103	2.30103								









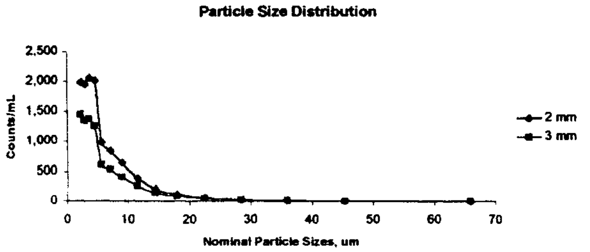
PCX Test of 2 and 3 mm feed

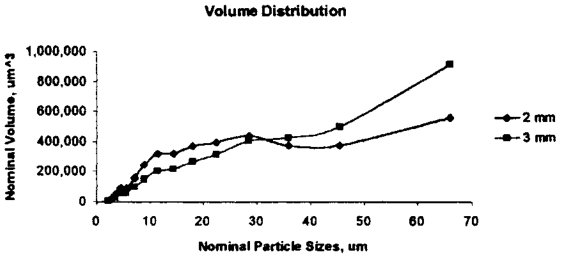
Full data set

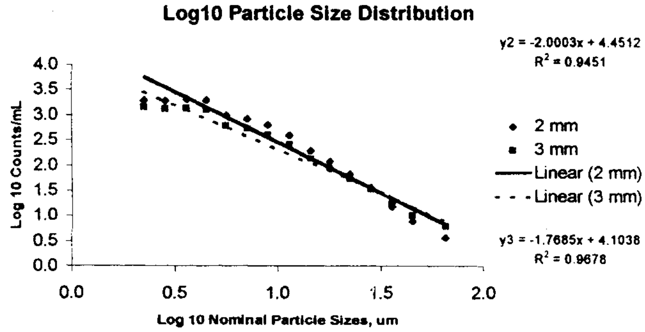
	Nominal	PCX1	PCX2			
				Sampled	19-Apr-01	
				Tested	19-Apr-01	
Flow rate	100	101.38	96.29			
mL		101.38	100.42	Sample time	2	min
Mean		101.38	98.355	Particles/mL		

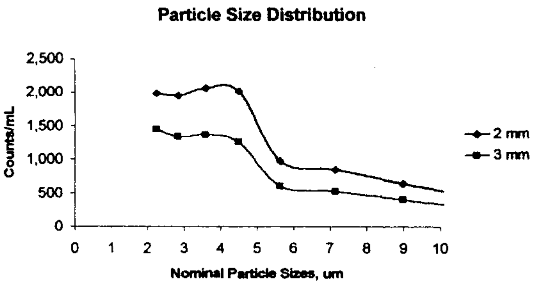
Samples strained at 179 um

		<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>								<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2 >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>								
Class >		2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-61'	>61'	est
ll >		2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	61	256
r' >		2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	66	168.5	
Log10 r' :		0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.81954		
	Jar																	
2 mm																		
2001/04/19 14:36	2mm	2004.08	1980.50	2068.48	2027.55	986.48	862.68	648.38	398.98	198.83	120.48	66.70	35.73	15.98	7.40	3.38	0.55	
2001/04/19 14:38	2mm	2040.15	1995.18	2115.48	2076.95	1015.78	869.65	663.23	415.50	196.40	119.90	64.38	35.85	14.28	7.70	3.95	0.48	
Average		2022.11	1987.84	2101.98	2052.25	1001.13	866.16	655.80	407.24	197.61	120.19	65.54	35.79	15.13	7.55	3.66	0.51	
Flow Ajusted		1994.59	1960.78	2073.36	2024.31	987.50	854.37	646.87	401.69	200.92	122.20	66.63	36.39	15.38	7.68	3.72	0.52	11,397
Volume, um^3		11,896	23,766	50,650	96,586	93,257	163,517	246,914	319,860	320,716	373,146	397,411	441,030	375,669	378,602	560,546	1,305,256	5,158,843
Log10 PSD		3.29985	3.29243	3.31668	3.30628	2.99454	2.93165	2.81082	2.60390	2.30302	2.08706	1.82369	1.56093	1.18690	0.88515	0.57098		
3 mm																		
2001/04/19 14:44	3mm	1473.38	1369.58	1395.20	1275.70	624.90	537.98	411.50	257.25	132.88	86.45	53.53	33.28	16.78	9.98	5.75	0.45	
2001/04/19 14:46	3mm	1477.55	1364.08	1398.98	1291.35	621.90	545.75	411.60	263.73	135.95	87.93	51.23	33.03	17.75	10.05	6.28	0.58	
Average		1475.46	1366.83	1397.09	1283.53	623.40	541.86	411.55	260.49	134.41	87.19	52.38	33.15	17.26	10.01	6.01	0.51	
Flow Ajusted		1455.38	1348.22	1378.07	1266.05	614.91	534.49	405.95	256.94	136.66	88.65	53.25	33.70	17.55	10.18	6.11	0.52	7,607
Volume, um^3		8,680	16,342	33,665	60,407	58,071	102,295	154,952	204,610	218,145	270,691	317,595	408,527	428,759	502,087	920,215	1,305,256	5,010,296
Log10 PSD		3.16298	3.12976	3.13927	3.10245	2.78881	2.72794	2.60847	2.40983	2.13564	1.94766	1.72633	1.52769	1.24431	1.00775	0.78626		









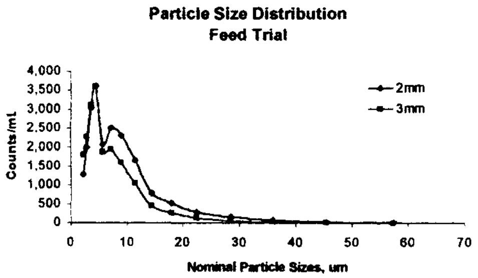
R^2	R
0.9451	0.9722
0.9678	0.9838

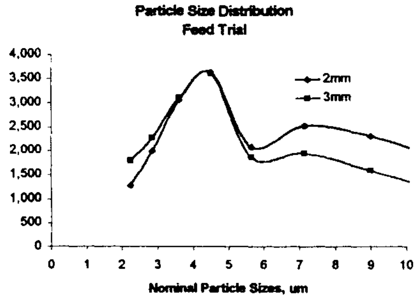
PCX Test of 2 & 3 mm Feed Data

Full data set

	Nominal	PCX1	PCX2			
				Sampled	6-Jun-01	
				Tested	6-Jun-01	
Flow rate	100	98.96	101.4			
mL		94.05	104.44	Sample time	2	min
		98.86	105.13	Particles/mL		
Mean		97.29	103.657			

		<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 1							>>>>>>>>>>>>>>>>>>>>>>>>>>>>	<<<<<<<<<<<<<<<<<<<<<<<<<<<< PCX 2							>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>	
	Class >	2-2.5'	2.5-3.2'	3.2-4'	4-5'	5-6.3'	6.3-8'	8-10'	10-13'	13-16'	16-20'	20-25'	25-32'	32-40'	40-51'	51-64'	64-179'	
	li >	2	2.5	3.2	4	5	6	8	10	13	16	20	25	32	40	51	64	
	l* >	2.25	2.85	3.6	4.5	5.65	7.15	9	11.5	14.5	18	22.5	28.5	36	45.5	57.5	32	
	Log10 l* >	0.35218	0.45484	0.55630	0.65321	0.75205	0.85431	0.95424	1.06070	1.16137	1.25527	1.35218	1.45484	1.55630	1.65801	1.75967	1.50515	
FDDW																		
2001/06/06 12:57	FDDW	76.35	64.13	59.70	42.15	19.98	21.90	20.63	16.40	14.30	10.10	6.95	3.80	1.56	0.38	0.08	0.03	
2001/06/06 12:59	FDDW	72.43	62.53	56.60	39.43	18.88	21.03	18.85	15.70	11.38	7.38	3.23	1.73	0.45	0.10	0.00	0.00	
2001/06/06 13:01	FDDW	68.33	59.88	55.63	38.40	16.95	17.55	18.10	13.90	8.10	5.28	2.73	1.08	0.20	0.10	0.03	0.03	
		72.37	62.18	57.31	39.99	18.60	20.16	19.19	15.33	11.26	7.58	4.30	2.20	0.74	0.19	0.03	0.02	
2mm	Jar																	
2001/06/06 13:07	D1	1325.83	2006.48	3031.08	3562.53	2040.70	2473.08	2260.35	1648.43	842.98	552.00	318.83	189.85	85.60	42.90	16.43	7.68	
2001/06/06 13:09	D1	1324.15	1983.80	3019.40	3567.25	2032.05	2460.98	2264.95	1632.83	849.68	548.73	309.55	181.95	81.73	40.03	14.53	7.08	
2001/06/06 13:11	D1	1324.70	2007.78	3025.18	3579.73	2033.60	2484.58	2261.08	1644.98	841.65	546.53	307.65	182.55	83.75	38.18	13.88	6.30	
2001/06/06 13:13	D1	1320.60	2011.38	3043.13	3582.70	2042.10	2472.88	2269.80	1640.08	840.63	540.75	302.60	180.80	79.13	38.15	14.28	6.80	
Average		1323.82	2002.36	3029.69	3573.05	2037.11	2472.88	2264.04	1641.58	843.73	547.00	309.66	183.79	82.55	39.81	14.78	6.96	
Less FDDW		1251.45	1940.18	2972.39	3533.06	2018.51	2452.72	2244.85	1626.24	832.47	539.42	305.36	181.59	81.81	39.62	14.74	6.95	
Flow Ajusted		1286.31	1994.22	3055.18	3631.47	2074.74	2521.04	2307.38	1671.54	803.11	520.39	294.58	175.18	78.92	38.22	14.22	6.72	
Volume, um^3		7,672	24,172	74,635	173,268	195,933	482,498	880,736	1,331,095	1,281,963	1,589,071	1,756,935	2,123,352	1,927,997	1,885,208	1,415,636	115,244	15,265,414
Log10 PSD		3.10935	3.29977	3.48504	3.56008	3.31696	3.40158	3.36312	3.22312	2.90477	2.71633	2.46921	2.24349	1.89720	1.58233	1.15295	0.82717	
3mm																		
2001/06/06 13:19	D5	1804.53	2258.70	3052.28	3500.60	1812.98	1897.75	1565.98	1035.93	485.58	290.58	152.88	85.10	35.45	16.73	6.00	2.33	
2001/06/06 13:21	D5	1828.88	2287.80	3104.95	3563.00	1833.78	1924.50	1589.40	1048.18	490.20	283.98	150.35	80.25	35.13	15.70	4.90	2.00	
2001/06/06 13:23	D5	1815.10	2278.53	3062.03	3545.75	1830.63	1904.10	1563.40	1028.23	486.48	284.45	149.78	81.15	30.50	14.60	4.28	1.73	
2001/06/06 13:25	D5	1855.78	2323.08	3112.18	3590.53	1852.33	1931.30	1582.88	1040.88	478.78	280.30	142.63	77.78	30.13	11.78	3.60	1.33	
Average		1826.07	2287.03	3082.86	3549.97	1832.43	1914.41	1575.41	1038.30	485.26	284.83	148.91	81.07	32.80	14.70	4.69	1.84	
Less Fddw		1753.70	2224.85	3025.55	3509.98	1813.83	1894.25	1556.22	1022.97	474.00	277.24	144.61	78.87	32.06	14.51	4.66	1.83	
Flow Ajusted		1802.55	2286.82	3109.82	3607.75	1864.35	1947.02	1599.57	1051.46	457.28	267.46	139.51	76.09	30.93	14.00	4.50	1.78	
Volume, um^3		10,751	27,718	75,970	172,136	176,064	372,638	610,561	837,308	729,931	816,728	832,024	922,234	755,527	690,324	447,538	30,518	7,507,970
Log10 PSD		3.25589	3.35923	3.49274	3.55724	3.27053	3.28937	3.20400	3.02179	2.66018	2.42726	2.14459	1.88131	1.49034	1.14602	0.65283	0.25010	


Particle Size Distribution
Feed Trial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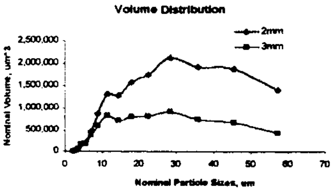
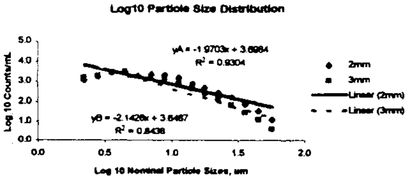
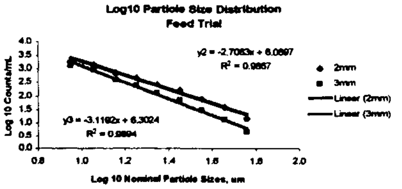
Feed Trial

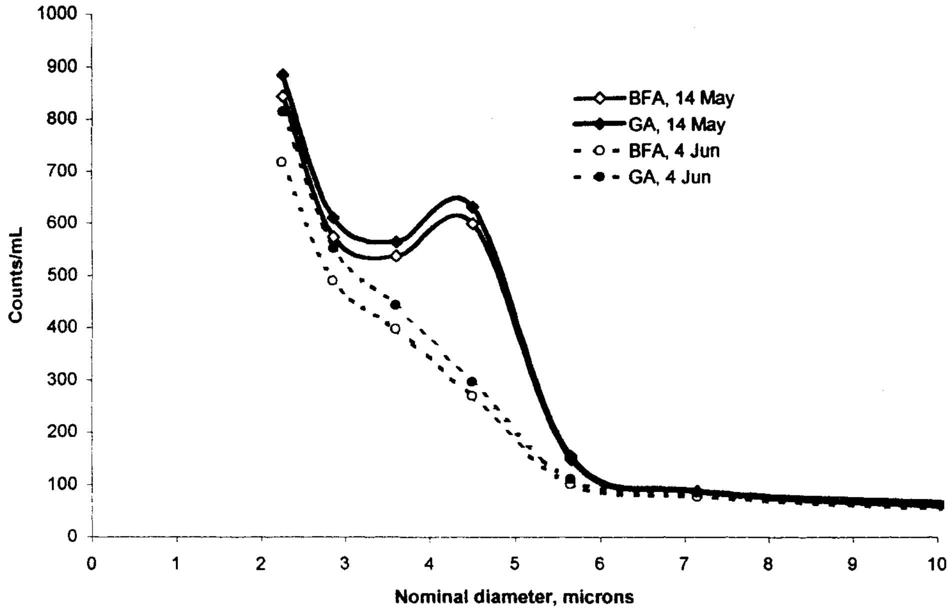

Volume Distribution


Log10 Particle Size Distribution


Log10 Particle Size Distribution
Feed Trial

PCX Data Comparison, BF and G sites, 14 May 01 - 4 Jun 01

I*	2.25	2.85	3.6	4.5	5.65	7.15	10.5	14.5	18	22.5	28.5	36	45.5	57.5
BF$_A$, 14 May	842.7365	573.2438	536.2834	598.7505	147.2441	85.23133	54.23323	21.28342	9.587502	4.359521	2.868624	1.813187	0.991471	0.137773
G$_A$, 14 May	883.415	609.4805	563.6231	630.6876	153.6847	87.48745	61.92733	26.86108	13.67281	7.181976	4.63385	3.357328	2.083265	0.841177
BF$_A$, 4 Jun	716.916	489.0681	397.4501	268.7501	100.515	75.88722	51.47343	41.60467	30.54534	18.51165	13.27196	18.62444	3.276105	1.439727
G$_A$, 4 Jun	813.02	551.22	442.41	295.10	110.72	83.76	57.21	44.44	31.77	21.47	12.74	12.04	3.74	1.70



Beta Values

SITE		2-Apr-01		16-Apr-01		30-Apr-01			7-May-01		14-May-01	21-May-01
		Wide Rge	Low Rge	am	pm	Surf.	No Surf.	(-) FDDW	Surf.	No Surf.	(-)FDDW	(-)FDDW
		a	b	c	d	e	f	g	h	I	j	k
A	Beta	2.764	2.524	2.213	1.829	2.241	2.363	2.231	2.154	2.289	2.077	2.048
	R	0.9848	0.9941	0.9864	0.9706	0.9762	0.9790	0.9731	0.9647	0.9735	0.9802	0.9806
B	Beta	2.754	2.554	2.218	1.834	2.392	2.447		2.286	2.540	2.123	2.268
	R	0.9890	0.9954	0.9864	0.9707	0.9786	0.9776		0.9710	0.9742	0.9872	0.9812
C	Beta	2.635	2.055	2.413	1.567	2.396					2.079	
	R	0.9876	0.9895	0.9875	0.9641	0.9758					0.9829	
D	Beta	2.794	2.335	2.278		2.505					2.163	
	R	0.9843	0.9869	0.9863		0.9764					0.9873	
E	Beta	3.042	2.464	2.541		2.396					2.635	
	R	0.9856	0.9893	0.9871		0.9758					0.9855	
Settle Deck	Beta	2.832	2.541	2.282		1.299					1.383	
	R	0.9916	0.9919	0.9746		0.9675					0.9730	
BFA	Beta	2.632	2.134	1.829		2.489					2.550	
	R	0.9858	0.9782	0.9706		0.9691					0.9844	
GA	Beta	3.014	2.636	2.243		2.546					2.194	
	R	0.9824	0.9796	0.9706		0.9757					0.9919	
BFB	Beta	2.738	2.281	2.035		2.500					2.404	
	R	0.9939	0.9799	0.9829		0.9730					0.9897	
GB	Beta	2.492	2.335	2.326		2.414					2.420	
	R	0.9955	0.9887	0.9759		0.9672					0.9897	
I/J	Beta	2.129	1.956			1.308					2.022	
	R	0.9727	0.9841			0.9896					0.9947	
MUWA	Beta	3.544	3.183	2.067		2.164					2.841	
	R	0.9906	0.9912	0.9961		0.9966					0.9939	
MUWA1	Beta										3.139	
	R										0.9898	
MUWB	Beta	3.142	2.196	2.495		2.454					2.797	
	R	0.9924	0.9925	0.9667		0.9978					0.9914	
Over Flow	Beta					2.326						
	R					0.9856						

Notes:

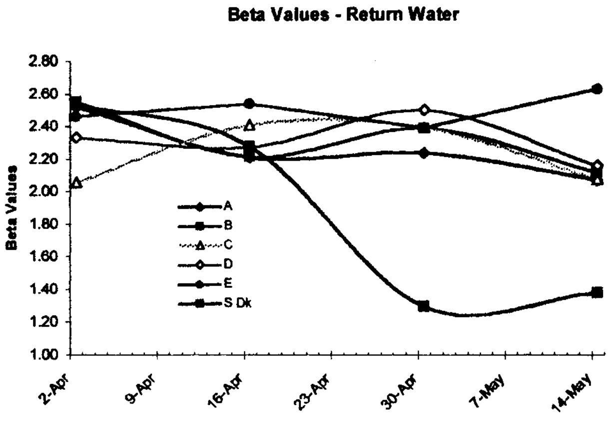
1 Rge = range

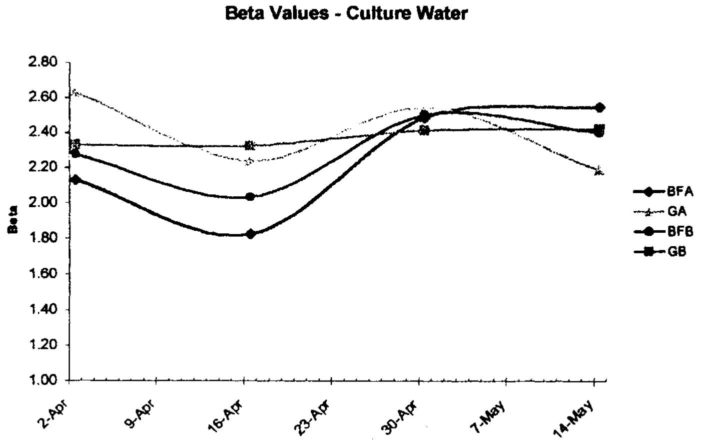
2 Surf = surfactant (see text)

3 (-) FDDW: a base rune of filtered, de-ionozed, distilled water was run on the PXC and then subtracted from the counts
This was also applied to the 7 Mar trials, though not noted above.

Collective Data on Beta Values - 2 Apr to 14 May

SITE		2-Apr-01	16-Apr-01	30-Apr-01	14-May-01
		Low Rge	am	Surf.	(-)FDDW
		b	c	e	j
A	Beta	2.524	2.213	2.241	2.077
	R	0.9941	0.9864	0.9762	0.9802
B	Beta	2.554	2.218	2.392	2.123
	R	0.9954	0.9864	0.9786	0.9872
C	Beta	2.055	2.413	2.396	2.079
	R	0.9895	0.9875	0.9758	0.9829
D	Beta	2.335	2.278	2.505	2.163
	R	0.9869	0.9863	0.9764	0.9873
E	Beta	2.464	2.541	2.396	2.635
	R	0.9893	0.9871	0.9758	0.9855
S Dk	Beta	2.541	2.282	1.299	1.383
	R	0.9919	0.9746	0.9675	0.9730
BFA	Beta	2.134	1.829	2.489	2.550
	R	0.9782	0.9706	0.9691	0.9844
GA	Beta	2.636	2.243	2.546	2.194
	R	0.9796	0.9706	0.9757	0.9919
BFB	Beta	2.281	2.035	2.500	2.404
	R	0.9799	0.9829	0.9730	0.9897
GB	Beta	2.335	2.326	2.414	2.420
	R	0.9887	0.9759	0.9672	0.9897
I/J	Beta	1.956		1.308	2.022
	R	0.9841		0.9896	0.9947
MUWA	Beta	3.183	2.067	2.164	2.841
	R	0.9912	0.9961	0.9966	0.9939
MUWB	Beta	2.196	1.052	2.454	2.797
	R	0.9925	0.8261	0.9978	0.9914
Over Flow	Beta			2.326	
	R			0.9856	





t-test of Variance: Samples with Surfactant vs Those Without

Test of the hypothesis that u1 = u2: there is no statistical difference between the two means

Date	**Surf.**	**No Surf**
1	2.2409	2.3625
	2.3917	2.447
2	2.1536	2.2888
	2.2861	2.5401

t-Test Two Sample Assuming Equal Varianc	Ybar ***Variable 1***	Zbar ***Variable 2***	
Mean	2.268075	2.4096	
Variance	0.00981702	0.01174669	
Observations	4	4	
Pooled Variance	0.01078185		
Hypothesized Mean Difference	0		
df	6		
t	-1.9275315	t*	
P(T<=t) one-tail	0.05109668		
t Critical one-tail	1.94318028		
P(T<=t) two-tail	0.10219337		
t Critical two-tail	2.44691185	t	

Test 1

Ho:u1 = u2		If |t*| =< |t(1-a/2; n1+n2-2)|		
Ha:u1 ≠ u2		If |t*| > |t(1-a/2; n1+n2-2)|		
a =	0.05			
1-a =	0.95	n1+n2-2	6	
1-a/2	0.975	Table A2	2.447	t (0.975, 6)

Test 2

P-value: probability that the sample outcome could have been more extreme than the observed one when u=uo.
Large P-values support u = uo.
If P-value = or > than a, Ho is concluded

Conclusion |t*| < |t (cr, 2-tail)|, therefore the means are statistically the same
P = 0.102, > a (0.05), therefoe the means are statistically the same.

Calculations from text.

Ybar-Zbar -0.141525

	(Yi-Ybar)^2	(Zi-Zbar)^2
	0.0007385	0.002218
	0.0152831	0.001399
	0.0131045	0.014593
	0.0003249	0.01703
Sum	0.029451	0.03524

s^2	s^2(y-z)	s (y-z)
0.0107819	0.005391	0.0734

t* =(Ybar-Zbar)/s(y-z)
t* = -1.927532

t-test of Variance Between Beta values for A and B Sites

Alpha = 5%

A	B
Beta	Beta
2.5236	2.5541
2.2126	2.2179
2.2409	2.3917
2.1536	2.2861
2.0768	2.1232
2.0483	2.2683

t-Test Two Sample Assuming Equal Variance

	2.5236	***2.5541***
Mean	2.14644	2.25744
Variance	0.006958	0.009637
Observations	5	5
Pooled Variance	0.008298	
Hypothesized Mean Difference	0	
df	8	
t	-1.92671	
P(T<=t) one-tail	0.045089	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.090178	
t Critical two-tail	2.306004	

Vista Channel Selection ans Setup Routine:

Power up the PCXs. Load **Senor Set-up Utility** Password: **Met One**

For each sensor ensure that it is functioning, the calibration curve is OK and the size channels are correct. (**COM1, Verify Hardware, Identify Sensors**)

Calibration:

Click **'Setup PCX'**.
Highlight a PCX and go to **Calibration**:
The original calibration is different for each PCX. The calibration box will take only 14 values. Check to see, or enter the following values for each PCX.

Value, μm	PCX 1, mV	PCX 2, mV
2	29	29
3	46	48
4	78	82
5	120	128
6	147	159
7	174	189
8	217	239
9	270	301
10	324	367
12	432	500
15	606	723
30	1657	2059
50	3563	5617
80	7208	9704

The associated regression lines from original calibration data are:

$$PCX1:\ y = 1.499x + 1.0051,\quad R^2 = 0.9935$$

and

$$PCX2:\ y = 1.5805x + 0.9791,\quad R^2 = 0.9941$$

In the **Channel Set-up** enter the following values for each PCX:
(From Sheldon and Parsons, 1967)

PCX 1	PCX 2
2.00	12.7
2.52	16.0
3.18	20.2
4.00	25.4
5.04	32.0
6.34	40.3
8.00	50.8
10.1	64.0
12.7	

Close:

Open **Vista**. program will start running with prior setup.

File, **Sign on**. Password is **<Enter>**. **Set-up** will appear.

Set-up, **Locations**, **Location List** window.
Highlight **Location 1,** double click to bring up window **Set-up Location**.
Turn Location on (Right Hand box.)
Double click each channel and enter as per table:

Ch	PCX 1	PCX 2
1	2.00-2.52	12.7-16.0
2	2.52-3.18	16.0-20.2
3	3.18-4.00	20.2-25.4
4	4.00-5.04	25.4-32.0
5	5.04-6.34	32.0-40.3
6	6.34-8.00	40.3-50.6
7	8.00-10.1	50.8-64.0
8	10.1-12.7	>64.0

Name the channel as noted, with a ‘ or some other mark, to distinguish it in report set-up.

Charting:

Go **Setup**, **Graph**, **Graph List** window, **Setup Graph** window. For each location (PCX) double click the location and enter the channels that you wish to monitor.

Reports:

Report Setup
If not already entered a **Report Group** setup is required..
Go **Setup**, **Reports**, **Setup Groups**.
In this window, define a report group. Enter a name for your group and click **Add Definition.**
In **Report Name** scroll down to **Raw Data to Spreadsheet**. Click on **Add Report**.
In **Location Measurement**, highlight all those for **Location1** (PCX 1) by holding down the Ctl key (channels noted by your special tick), then click **Add Measurement**.
Repeat for **Location 2** (PCX 2).

Report Generation.
Go **Reports**, select your defined report group, check dates and times, click **View/Export**
In the window **Raw Data to Spreadsheet Export**, check the time range of the report. If OK, click the envelop at the top.
The next window will show a directory and **Raw Data to Spreadsheet Export** as a file name. Change file name, click **OK**.
A window will come up saying that the download is happening.

In **Explorer**, you will find the report in **Program Files**, **Pacific Science**, **WQS Vista**, **Reports**.

APPENDIX I

DENSITY GRADIENT CENTRIFUGING DATA

SPREADSHEET CHECK ON VARIANCE BETWEEN REFRACTIVE INDEX AND MARKER BEADS

Estimate of Percoll Solutions: % Dilution vs RI, Rho

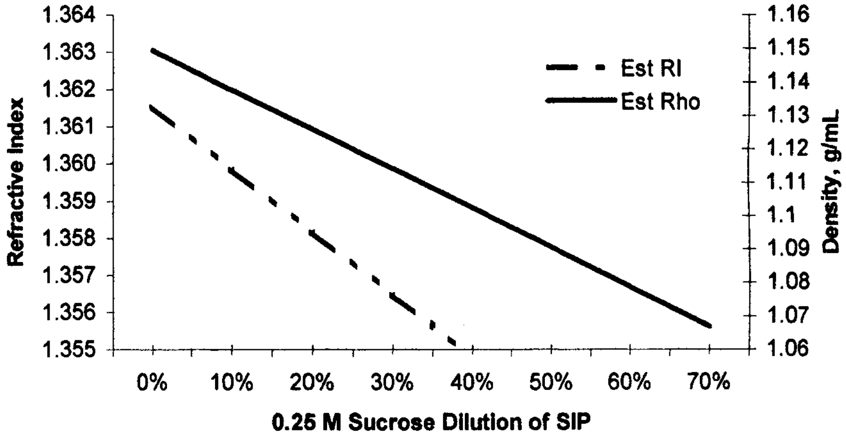
	Rho	Parts
SIP	1.1495	
Water	1	9
2.5 M S	1.316	1
0.25 M S	1.0316	10

Regression:

a	b
7.0002	8.3815

rho = aRI-b

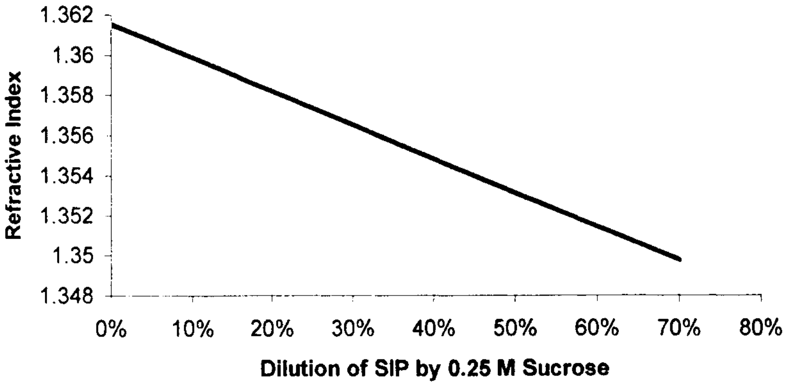
SIP	0.25 M S	% Dilute	MIX Rho	RI
10	0	0%	1.1495	1.361533
9	1	10%	1.13771	1.359848
8	2	20%	1.12592	1.358164
7	3	30%	1.11413	1.35648
6	4	40%	1.10234	1.354796
5	5	50%	1.09055	1.353111
4	6	60%	1.07876	1.351427
3	7	70%	1.06697	1.349743
			1.05	1.347319
			1.04	1.34589
			1.02	1.343033
			1	1.340176



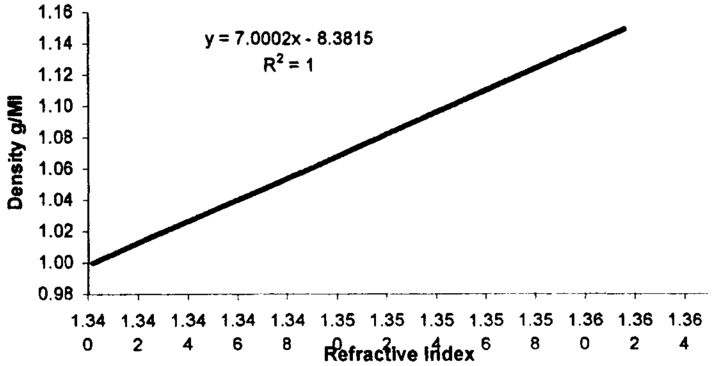
Try >	RI	Density
	1.364	1.166773

< interactive: enter RI to get density

Refractive Index Estimate vs SIP Dilutions



0.25 M Sucrose in Percoll



Distances from the Meniscus (dfm), Densities by Refractometry and Descriptions
Of the 30 Jul 01 Feed Samples Samples centrifuged for 60 min @ 30,000 x g

40 % 0.25 Sucrose dilution of SIP

	<5 um			5-10 um			10-20 um		
	dfm	Rho	Description	dfm	Rho	Description	dfm	Rho	Description
Loc	mm	g/mL		mm	g/mL		mm	g/mL	
A	0.5	1.060	light haze	1.5	1.077	haze	1.5	1.076	band white haze
B	17.5	1.062	scattered particles	4.5	1.114	haze line	11.5	1.088	thin white line
C	42.5	1.070							
D	52.5	1.076							
E							59.5	1.149	brown flecks
F	65.0	1.160		64.5	1.153				

	20-30 um			30-41 um			41-179 um		
	dfm	Rho	Description	dfm	Rho	Description	dfm	Rho	
Loc	mm	g/mL		mm	g/mL		mm	g/mL	
A	2.5	1.076	haze	2.0	1.084	light haze band	0.5	1.076	light haze band
B	11.5		few flecks	7.5		light floc	17.5	1.097	scattered particles
C	15.5	1.090	haze	13.0	1.095	specks	42.5	1.110	light particles
D				43.0	1.110	specks, generally	52.5	1.123	more brown particles
E	59.5	1.146	few brown flecks	60.0	1.135	band brown flecks	59.5	1.139	brown layer
F	64.5	1.160		65.5	1.149		64.0	1.139	clearer, particles

20 % 0.25 Sucrose dilution of SIP

	<5 um			5-10 um			30-41 um			41-179 um		
	dfm	Rho	Description	dfm	Rho	Description	dfm	Rho	Description	dfm	Rho	Description
Loc	mm	g/mL		mm	g/mL		mm	g/mL		mm	g/mL	
A	0.5	1.077	surface	1.5	1.098	haze	1.0	1.097	light haze band	1.0	1.102	haze
B	2.5	1.090	haze	5.0	1.114	haze line	6.0		floc	4.0	1.103	clearer band
C	7.0	1.097	thin line of specks				8.5	1.107	haze	9.0	1.118	light floc
D	10.5	1.112					41.0	1.114		43.0	1.131	some particles
E							58.0	1.160	brown flecks	56.0	1.159	heavy brown flecks
F	65.5	1.191		65.0	1.167		65.0	1.174		66.0	1.201	Some particles

Feed, 30 Jul - RI to Density

Feed Trial, 30, 31 Jul: Screened to 179 um, Centrifuge: 18,400 RPM (30,000 x g), 60 min

Using rho = 7.0002 x RI - 8.3815

Coefficients >	**a**	**b**
	7.000	8.3815

Cell>	3: 41 um, 40%		4: 41 um, 20%		5: 30 um, 40%		6: 30 um, 20%		7: 20 um, 40%		8: 10 um, 40%		9: 5 um, 40%		10: 5 um, 20%		11: >5 um, 40%		12: >5 um, 20%	
Loc	RI	Rho	RI	Rho	RI	Rho	RI	Rho	RI	Rho	RI	Rho	RI	Rho	RI	Rho	RI	Rho	RI	Rho
A	1.3511	1.076	1.3548	1.102	1.3522	1.084	1.3541	1.097	1.3511	1.076	1.3511	1.076	1.3512	1.077	1.3542	1.098	1.3487	1.060	1.3512	1.077
B	1.3541	1.097	1.3549	1.103	1.3538	1.095	1.3555	1.107	1.3531	1.090	1.3528	1.088	1.3564	1.114	1.3564	1.114	1.3490	1.062	1.3530	1.090
C	1.3559	1.110	1.3571	1.118													1.3502	1.070	1.3540	1.097
D	1.3578	1.123	1.3589	1.131	1.3559	1.110	1.3565	1.114									1.3511	1.076	1.3562	1.112
E	1.3600	1.139	1.3629	1.159	1.3595	1.135	1.3630	1.160	1.3611	1.146										
F	1.3600	1.139	1.3689	1.201	1.3615	1.149	1.3651	1.174	1.3630	1.160	1.3615	1.149	1.3620	1.153	1.3641	1.167	1.3630	1.160	1.3675	1.191

Centrifuge Loading Plan for 12 Aug Samples.

Spin:	30,000 x g for 60 min	Samples from Merlin juvenile tank C1
Rho SIP	1.1495 g/mL	
Rho 0.25 M Sucrose	1.0316 g/mL	
25 mm from top of cell = 23 mL		
Sample	2 mL	
DGM	21 mL	

Cell >	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total mL**	**Total mL**		
Sample	**S70**	**S41**	**S30**	**S20**	**S10**	**S5**	**S<5**	**S>179**	**S41**	**S<5**	**F<5**	**Beads**	**SIP**	**0.25 M S**	**Sum**	**sum/n**
% S	30%	30%	30%	30%	30%	30%	30%	0%	0%	40%	40%	30%				
SIP, mL	14.7	14.7	14.7	14.7	14.7	14.7	14.7	21	21	12.6	12.6	14.7	184.8			
40 % S, mL										12.6	12.6		25.2	16.8	42	21
30 % S, mL	14.7	14.7	14.7	14.7	14.7	14.7	14.7					14.7	117.6	50.4	168	21
0 % S, mL								21	21				42	0	42	21
Weights, g											**Totals >**		184.8	67.2		
SIP	16.90	16.90	16.90	16.90	16.90	16.90	16.90	24.14	24.14	14.48	14.48	16.90				
0.25 M S	6.50	6.50	6.50	6.50	6.50	6.50	6.50	0.00	0.00	8.67	8.67	6.50				
Est. DGM Wt, g	23.40	23.40	23.40	23.40	23.40	23.40	23.40	24.14	24.14	23.15	23.15	23.40				
Sample wt	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20				
Total, g	25.60	25.60	25.60	25.60	25.60	25.60	25.60	26.34	26.34	25.35	25.35	25.60				
Actual Wts, g	37.94	37.94	37.93	37.94	37.95	37.96	37.96	37.95	37.94	37.94	37.96	37.94	Includes centrif. cell			
Rho	1.1141							1.1495		1.1023						
RI	1.3565							1.3615		1.3548						

Rho to RI regression coefficients.

RI = (Rho - b)/a

a	7.0002
b	-8.3815

Make up, mL

%	**SIP**	**0.25M**	**Total mL**	**RI**	**Rdg**	**Rho**
40%	30	20	50	1.3548	1.3548	1.1024
30%	128	54.9	182.9	1.3565	1.3563	1.1129
0%	42	0	42	1.3615	1.3615	1.1493
	200					

Site Sample, 12 Aug 01 - RI to Density

Sample Trial, 12, 13 Aug: Screened to 179 um, Centrifuge: 18,400 RPM (30,000 x g), 60 min (+ machine over-run)

Using rho = 7.0002 x RI - 8.3815

Coefficients >	**a**	**b**
	7.000	8.3815

Cell>	**1: S70 um, 30%**		**2: S41 um, 30%**		**3: S30 um, 30%**		**4: S20 um, 20%**		**5: S10 um, 30%**	
Loc	**RI**	**Rho**	**RI**	**Rho**	**RI**	**Rho**	**RI**	**Rho**	**RI**	**Rho**
A	1.3459	1.040	1.3456	1.038	1.3456	1.038	1.3460	1.041	1.3452	1.035
B	1.3470	1.048	1.3488	1.060	1.347	1.048	1.3465	1.044	1.3470	1.048
C	1.3520	1.083	1.3514	1.079	1.352	1.083	1.3491	1.062	1.3500	1.069
D										
E	1.3602	1.140	1.3605	1.142	1.3635	1.163	1.3626	1.157	1.3625	1.156
F	1.3640	1.167	1.3644	1.170						

Cell>	**6: S5 um, 30%**		**7: S<5 um, 30%**		**8: >179 um, 0%**		**9: S41 um, 0%**		**10: <5 um, 40%**		**11: F<5 um, 40%**	
Loc	**RI**	**Rho**	**RI**	**Rho**	**RI**	**Rho**	**RI**	**Rho**	**RI**	**Rho**	**RI**	**Rho**
A	1.3452	1.035	1.3452	1.035	1.3472	1.049	1.3444	1.030	1.3459	1.040	1.3451	1.034
B	1.3478	1.053	1.3473	1.050	1.3485	1.058	1.3497	1.067	1.3469	1.047	1.3465	1.044
C	1.3499	1.068	1.3499	1.068	1.3550	1.104	1.3522	1.084	1.3491	1.062	1.3494	1.065
D					1.3600	1.139						
E	1.3632	1.161	1.3622	1.154	1.3663	1.183	1.3630	1.160			1.3550	1.104
F					1.3666	1.185	1.3702	1.210	1.3640	1.167	1.3590	1.132
					1.3686	1.199						

Distances from the Meniscus (dfm), Densities by Refractometry and Descriptions
Of the 12 Aug 01 Site C1 Samples Samples centrifuged for 60 min @ 30,000 x g

30 % 0.25 Sucrose dilution of SIP

	<5 um			5-10 um			10-20 um		
	dfm	Rho	Description	dfm	Rho	Description	dfm	Rho	Description
Loc	mm	g/mL		mm	g/mL		mm	g/mL	
A	3.1	1.035	haze	3.5	1.035	haze	3.0	1.035	
B	9.0	1.050	light floc	8.0	1.053	floc, lt tan	8.5	1.048	yellow floc
C	11.0	1.068		11.5	1.068		10.5	1.069	scattered particles
D									
E	55.5	1.154	v lt red-brown	56.0	1.161	v lt red-brown	56.0	1.156	lt red-brown
F									

	20-30 um			30-41 um			41-179 um			70-179 um		
	dfm	Rho	Description	dfm	Rho	Description	dfm	Rho		dfm	Rho	
Loc	mm	g/mL		mm	g/mL		mm	g/mL		mm	g/mL	
A	3.0	1.041		2.7	1.038		3.0	1.038	hy yellow-brown floc	3.0	1.040	hy green-brown floc
B	7.6	1.044	floc line	7.5	1.048	floc line	7.5	1.060	large flocs	8.0	1.048	large flocs
C	12.5	1.062	fewer flocs	12.5	1.083	fewer flocs	13.0	1.079	scatttered sm flocs	13.5	1.083	scatttered sm flocs
D												
E	55.5	1.157	brown floc	55.5	1.163	brown floc	56.0	1.142	red-brown floc	56.0	1.140	red-brown floc
F							60.5	1.170		60.0	1.167	

Mean Densities

Zone	B	E
	1.050	1.154
	1.053	1.161
	1.048	1.156
	1.044	1.157
	1.048	1.163
	1.060	1.142
	1.048	1.140
Avg	1.050	1.153
SD	0.005	0.009

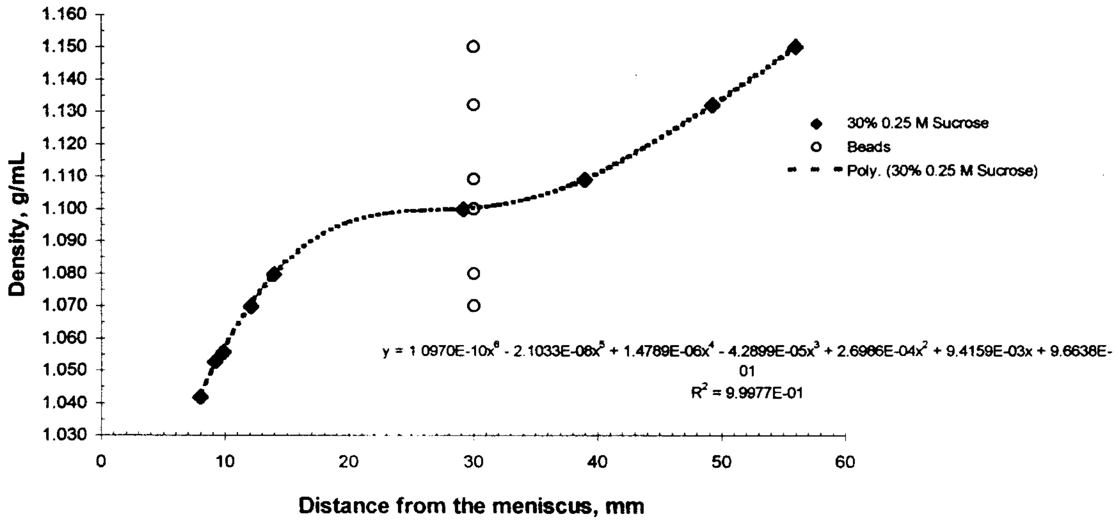
Bead Test - 12 Aug 01

Centrifuge; 18,400RPM (30,000 x g) for 60 min

Part of Site Sample C1 test

Adjusted for meniscus and decimal places in regression

	Cell >	30% 0.25 M Sucrose	Adjusted	Beads
Bead	Meniscus >	24	(dfm)	
Colour	Rho, mg/L		(mm)	
Blue	1.042	32	8	30
Orange	1.053	33.2	9.2	30
Green	1.056	33.9	9.9	30
Red	1.070	36.1	12.1	30
Blue	1.080	38	14	30
Orange	1.100	53.2	29.2	30
Green	1.109	63	39	30
Red	1.132	73.3	49.3	30
Violet	1.150	80	56	30



Comparison: Regression Values versus Refractometry Results

Sites Samples C1, 12 Aug 01

Regression	dfm	Rho, eqn	Rho, refract.	Variation	
<5 um	3.1	0.997	1.035	-3.67%	*
	9.0	1.050	1.050	0.02%	*
	11.0	1.064	1.068	-0.38%	*
	55.0	1.147	1.154	-0.60%	*

Regression	dfm	Rho, eqn	Rho, refract.	Variation	
5-10 um	3.5	1.001	1.035	-3.28%	*
	8.0	1.042	1.053	-1.01%	*
	11.5	1.067	1.068	-0.09%	*
	56.0	1.150	1.161	-0.93%	*

Regression	dfm	Rho, eqn	Rho, refract.	Variation	
10-20 um	3.0	0.996	1.035	-3.77%	*
	8.5	1.046	1.048	-0.15%	*
	10.5	1.061	1.069	-0.77%	*
	56.0	1.150	1.156	-0.51%	*

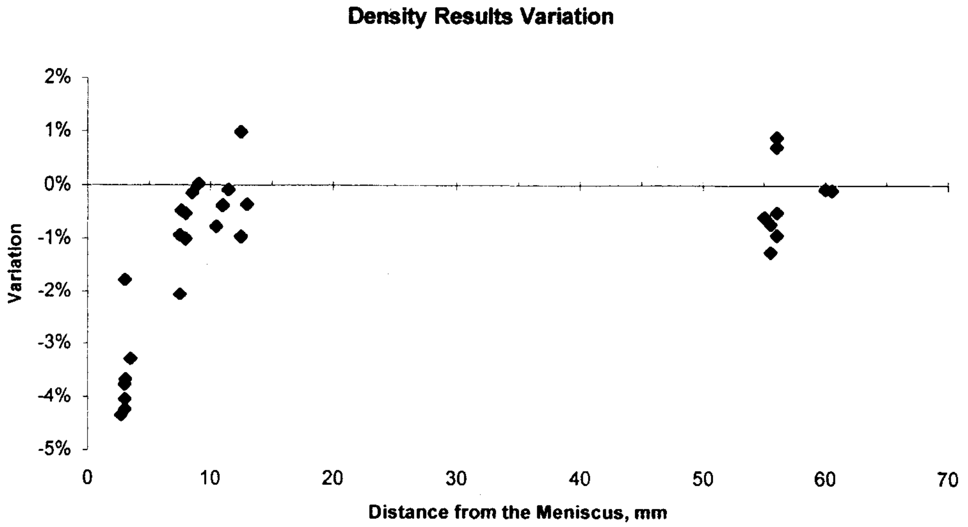
Regression	dfm	Rho, eqn	Rho, refract.	Variation	
20-30 um	3.0	0.996	1.014	-1.77%	*
	7.6	1.039	1.044	-0.47%	*
	12.5	1.073	1.062	0.99%	*
	55.5	1.149	1.157	-0.73%	*

Regression	dfm	Rho, eqn	Rho, refract.	Variation	
30-41 um	2.7	0.993	1.038	-4.34%	*
	7.5	1.038	1.048	-0.93%	*
	12.5	1.073	1.083	-0.96%	*
	55.5	1.149	1.163	-1.24%	*

Regression	dfm	Rho, eqn	Rho, refract.	Variation	
41-179 um	3.0	0.996	1.038	-4.04%	*
	7.5	1.038	1.060	-2.05%	*
	13.0	1.075	1.079	-0.36%	*
	56.0	1.150	1.142	0.71%	*
	60.5	1.169	1.170	-0.11%	*

Regression	dfm	Rho, eqn	Rho, refract.	Variation	
70-179 um	3.0	0.996	1.040	-4.23%	*
	8.0	1.042	1.048	-0.53%	*
	11.0	1.064	1.068	-0.38%	*
	56.0	1.150	1.140	0.89%	*
	60.0	1.166	1.167	-0.08%	*

Variation Plot		
	dfm	%
1	2.7	-0.043351
2	3.0	-0.017739
3	3.0	-0.037669
4	3.0	-0.04045
5	3.0	-0.042295
6	3.1	-0.0367
7	3.5	-0.032837
8	7.5	-0.009274
9	7.5	-0.02049
10	7.6	-0.004676
11	8.0	-0.005333
12	8.0	-1.01%
13	8.5	-0.001531
14	9.0	0.000217
15	10.5	-0.007692
16	11.0	-0.003774
17	11.0	-0.00384
18	11.5	-0.000939
19	12.5	0.009946
20	12.5	-0.009637
21	13.0	-0.003612
22	55.0	-0.005975
23	55.5	-0.007261
24	55.5	-0.012383
25	56.0	-0.009345
26	56.0	-0.00506
27	56.0	0.007137
28	56.0	0.008904
29	60.0	-0.000778
30	60.5	-0.001059

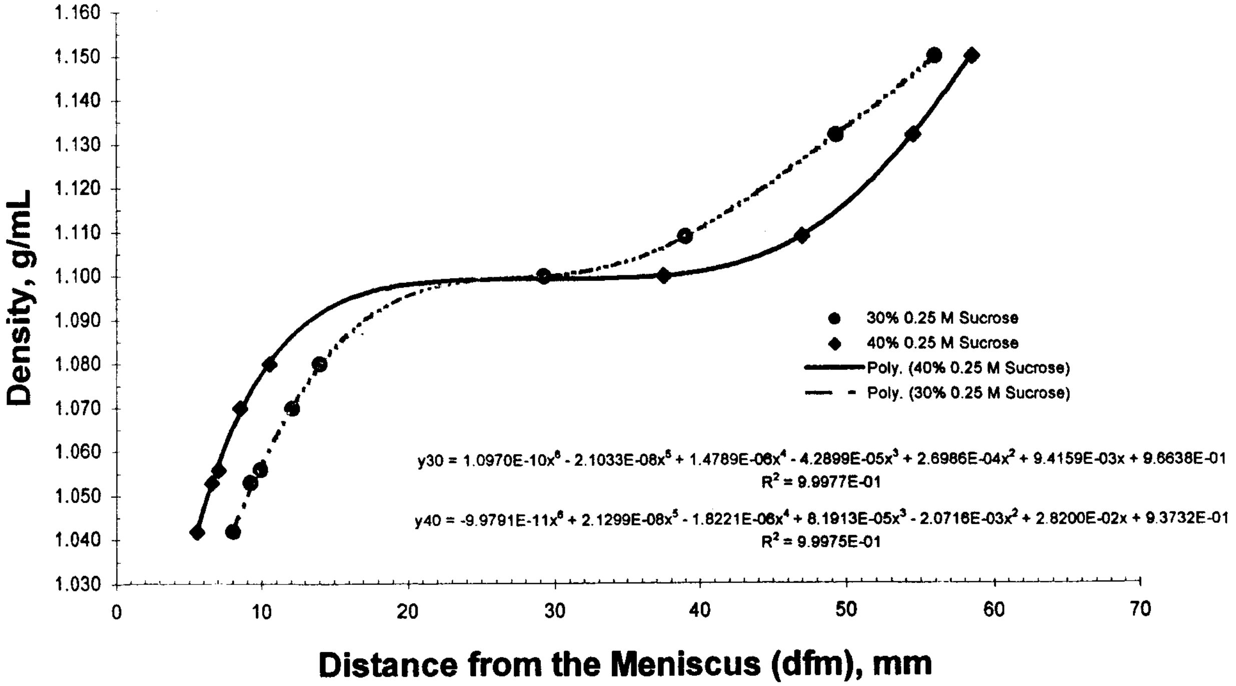

Density Results Variation

Bead Tests - 30 Jul 01 and 1 Aug 01 Adjusted for meniscus and decimal places in regression

Centrifuge; 18,400RPM (30,000 x g) for 60 min

Part of Feed (30 Jul 01) and Site Sample (12 Aug 01) test runs

		30 Jul 01 Feed		**12 Aug 01 Sample**	
		40% 0.25 M Sucrose	**Adjusted**	**30% 0.25 M Sucrose**	**Adjusted**
	Meniscus >	**22.5**	**(dfm)**	**24**	**(dfm)**
Col.	**Rho**		(mm)		(mm)
Blue	1.042	28	5.5	32	8
Orange	1.053	29	6.5	33.2	9.2
Green	1.056	29.5	7	33.9	9.9
Red	1.070	31	8.5	36.1	12.1
Blue	1.080	33	10.5	38	14
Orange	1.100	60	37.5	53.2	29.2
Green	1.109	69.5	47	63	39
Red	1.132	77	54.5	73.3	49.3
Violet	1.150	81	58.5	80	56



SPREADSHEET OF CHECK ON THE VARIATION BETWEEN DENSITY DETERMINATIONS FROM REFRACTIVE INDEX VERSUS DENSITY MARKER BEADS

On each density gradient test, at least one cell was run using density market beads. In the feed trial, bead cells were included for mixtures of 20% and 40% dilutions of Standard Isotonic Percoll (SIP). Samples were extracted using a thin glass pipette from the lower Blue bead line down to Violet ring regions. The refractive indices of these extractions were read on an ABBE Refractometer, Type 4A and translated to densities using four digitizations of published lines of 0.25 M sucrose in Percoll.

These results were compared to the known values for the beads and are displayed in the spreadsheet as shown on page I13.

It was concluded that the first digitization:

$$\rho \equiv 7.0002\ n - 8.3815, \quad R^2 = 0.9969 \tag{I1}$$

where ρ = the band density, g/mL and n = the refractive index.

is the best line to use. The variations are shown below. The difficulties include a tendency to drag in fluid below the level one wishes to sample and the less dense beads being too close together. Considering the difficulties in extracting only the level of interest using the glass pipette, the results are remarkably accurate.

Bead Colour	Density by Beads mg/L	Density by Refraction mg/L	Variation %
Blue	1.080	1.093271	-1.23%
Orange	1.100	1.097471	0.23%
Green	1.109	1.107271	0.16%
Red	1.132	1.132472	-0.04%
Violet	1.150	1.145072	0.43%

Check on Density Determination vs Beads

Four line coefficients of digitizations of published plots of 0.25 M sucrose in Percoll

40% Dilution of SIP by 0.25 M sucrose

Blue 1.080 g/mL

	a	b	R^2	RI	Rho	Variation	Ref.
	7.0002	8.3815	0.9969	1.3535	mm	#VALUE!	1
	6.9351	8.2947	0.9988	1.3535	1.092	1.11%	2
	6.6311	7.8849	1	1.3535	1.090	0.95%	3
	6.2728	7.4014	0.9988	1.3535	1.089	0.82%	4
Avg	6.7098	7.9906	0.9986	1.3535	1.091	1.03%	

Orange 1.100 g/mL

	a	b	R^2	RI	Rho	Variation
	7.0002	8.3815	0.9969	1.3541	1.097	-0.23% *
	6.9350	8.2947	0.9988	1.3541	1.096	-0.37%
	6.6311	7.8849	1	1.3541	1.094	-0.52%
	6.2728	7.4014	0.9988	1.3541	1.093	-0.67%
Avg	6.7098	7.9906	0.9986	1.3541	1.095	-0.45%

Green 1 109 g/mL

	a	b	R^2	RI	Rho	Variation
	7.0002	8.3815	0.9969	1.3555	1.107	-0.16%
	6.9350	8.2947	0.9988	1.3555	1.106	-0.30%
	6.6311	7.8849	1	1.3555	1.104	-0.49%
	6.2728	7.4014	0.9988	1.3555	1.101	-0.69%
Avg	6.7098	7.9906	0.9986	1.3555	1.104	-0.41%

Red 1.132 g/mL

	a	b	R^2	RI	Rho	Variation
	7.0002	8.3815	0.9969	1.3591	1.132	0.04%
	6.9350	8.2947	0.9988	1.3591	1.131	-0.12%
	6.6311	7.8849	1	1.3591	1.127	-0.40%
	6.2728	7.4014	0.9988	1.3591	1.124	-0.71%
Avg	6.7098	7.9906	0.9986	1.3591	1.129	-0.30%

Violet 1.150 g/mL

	a	b	R^2	RI	Rho	Variation
	7.0002	8.3815	0.9969	1.3609	1.145	-0.43%
	6.9350	8.2947	0.9988	1.3609	1.143	-0.60%
	6.6311	7.8849	1	1.3609	1.139	-0.92%
	6.2728	7.4014	0.9988	1.3609	1.135	-1.28%
Avg	6.7098	7.9906	0.9986	1.3609	1.141	-0.81%

References:

1 Anon. (1978) Figure 2A, points digitized
2 Anon. (1978) Figure 2A, line digitized
3 Anon. (1995) Figure 16, blow-up, line digitized
4 Anon. (1995) Figure 16, line digitized

Notes:

Lower density bead layers too close together to extract separately
**Difficult to prevent the dragging in of a lower layer on extraction
Probably best to use the 1st equation.

20% Dilution of SIP by 0.25 M sucrose

Orange 1.100 g/mL (dragged in some Green layer)

	a	b	R^2	RI	Rho	Variation
	7.0002	8.3815	0.9969	1.3555	1.1073	0.66% **
	6.9350	8.2947	0.9988	1.3555	1.1057	0.52%
	6.6311	7.8849	1	1.3555	1.1036	0.32%
	6.2728	7.4014	0.9988	1.3555	1.1014	0.13%
Avg	6.7098	7.9906	0.9986	1.3555	1.1045	0.41%

Green 1.109 g/mL

	a	b	R^2	RI	Rho	Variation
	7.0002	8.3815	0.9969	1.3555	1.1073	-0.16%
	6.9350	8.2947	0.9988	1.3555	1.1057	-0.30%
	6.6311	7.8849	1	1.3555	1.1036	-0.49%
	6.2728	7.4014	0.9988	1.3555	1.1014	-0.69%
Avg	6.7098	7.9906	0.9986	1.3555	1.1045	-0.41%

Red 1.132 g/mL

	a	b	R^2	RI	Rho	Variation
	7.0002	8.3815	0.9969	1.358	1.1248	-0.64%
	6.9350	8.2947	0.9988	1.358	1.1230	-0.79%
	6.6311	7.8849	1	1.358	1.1201	-1.05%
	6.2728	7.4014	0.9988	1.358	1.1171	-1.32%
Avg	6.7098	7.9906	0.9986	1.358	1.1212	-0.95%

Violet 1.150 g/mL

	a	b	R^2	RI	Rho	Variation
	7.0002	8.3815	0.9969	1.3616	1.1500	0.00%
	6.9350	8.2947	0.9988	1.3616	1.1480	-0.17%
	6.6311	7.8849	1	1.3616	1.1440	-0.52%
	6.2728	7.4014	0.9988	1.3616	1.1396	-0.90%
Avg	6.7098	7.9906	0.9986	1.3616	1.1454	-0.40%

APPENDIX J

PAPER:

THE POWER LAW IN PARTICLE SIZE ANALYSIS FOR AQUACULTURE FACILITIES

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The power law in particle size analysis for aquacultural facilities

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Abstract

Fine particles tend to accumulate in recirculating aquacultural facilities, which can lead to serious fish health problems. The literature indicated that in many particle systems, the particle size distribution may be accurately represented by a two-parameter, hyperbolic power-law function, $dN/dl = Al^{-\beta}$.

The purpose of this paper is to investigate whether this observation holds for aquacultural facilities. Particle size distribution data from four research establishments were examined, using 14 data sets, comprising 11 aquacultural systems, and covering three species of salmonids and one of striped bass. In the data examined, the exponent, β, varied from 2.9 to 4.6, with one sample reaching as high as 6.3. Correlation coefficients varied from 0.998 to 0.975. Larger exponents, indicating a greater number of fine particles, appear to dominate recirculating aquaculture systems.

The results strongly suggest that a hyperbolic distribution is valid for aquaculture systems. The usefulness in this technique is that once a worker has established the exponent from the distribution of particle sizes at any given point in his facility, an estimate of particulate contributions by size to the total particle number, surface area and volume/mass concentration can be obtained. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Recirculating aquaculture; Particle size distribution; Suspended solids; Power law

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1. Introduction

1.1. Background

With the maturing of the finfish aquaculture industry, water recirculation facilities are coming increasingly into use. A typical cold water version of such a facility is blocked out in Fig. 1.

The degree of recirculation varies: the greater the degree of recirculation, the greater is the requirement for water reprocessing. In current practice, a practical range appears to be replacement of 5–10% of total system water per day. However, the Achilles heel of these systems is in the area of solids removal.

Several authors (for example, Alabaster and Lloyd, 1962; Chapman et al., 1987; Chen and Malone, 1991) have pointed out the negative effects of solid particles from uneaten food and fish faeces in recirculating aquacultural systems. Some effects are: (1) the clogging of biofilters; (2) the secondary production of ammonia, thus increasing the biofilter load and reducing available oxygen; (3) the production of sites for pathogens to thrive; and (4) the direct, physical production of fish disease. It is now universally accepted that suspended solids removal is of critical

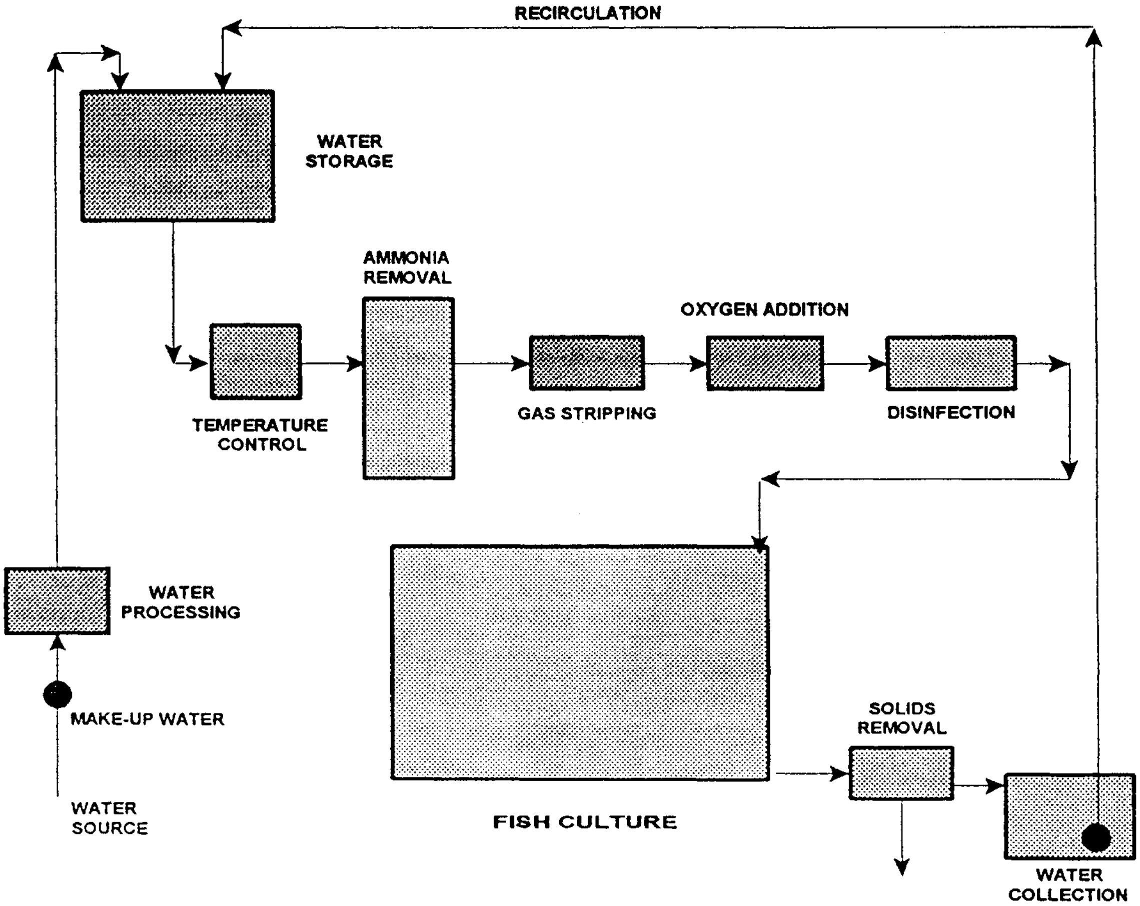

Fig. 1. Typical water recirculation system for intensive culture of finfish.

importance to the long-term health of a recirculation system. Unfortunately, in present commercial systems, particle removal below about 50 μm appears to be economically difficult, if not impractical. As the system is used, fines build up and, through pump shearing, can be expected to get finer with time. Currently, such systems are flushed in an idle period to remove all unwanted residues. However, as more continuous plant use becomes standard, this expedient will no longer be available to the operator.

In the study of suspended solids in recirculating systems, some data are now available on particle size distributions using such equipment as the resistance pulse counters (Elzone, Coulter Counter) and the laser diffraction analyzer (e.g. Malvern, Coulter LS series) (McCave and Syvitski, 1991; Ebeling et al., 1997). The information currently available shows a large number of fine particles in these systems, but further analysis has been limited. This paper will demonstrate a systematic method of analysis of these data, and will apply the method to the results of four workers.

1.2. The nature of the distribution

The analysis of suspended solids in aqueous solutions has been pioneered in other fields such as geology (sediments in seawater) (Sheldon and Parsons, 1967; Milligan and Krank, 1991), cosmic and terrestrial dust (Bader, 1970), and wastewater processing (Kavanaugh et al., 1980). Bader (1970) noted, from the work of several earlier authors, that the size distributions appeared to consistently follow a near-hyperbolic pattern and that a very good approximation could be obtained by the relationship:

$$N = K(x/x_o)^{-c} \tag{1}$$

where N is the number of particles larger than a given particle size, x is the particle size parameter (e.g. volume, diameter, surface area), x_o is the base parameter (often set to 1 for simplicity), and K and c are positive constants.

Kavanaugh et al. (1980) adjusted this power-law formula to:

$$\mathrm{d}N/\mathrm{d}l \;=\; A\ l^{-\beta} \tag{2}$$

where N is the particle number density, l is the particle size parameter, and A and β are empirical constants.

In the log form, the equation is:

$$\log(\mathrm{d}N/\mathrm{d}l) \;= \log A - \beta\ \log l \tag{3}$$

which is a straight line with slope $-\beta$. Once β is determined for a particular system, a rapid estimate can be made of the particle size distribution, surface area and volume contributions of the various size classes, as will be shown. Practically, for any class i, the parameters are defined by:

$$\Delta N_i \;=\; A\ l_i^{*\,-\beta} \Delta l_i \tag{4}$$

where ΔN_i is the number of counts in class I, l_i^* is the particle size parameter (median of class i, i.e. $(l_i + l_{i+1})/2$) (normally the diameter of a sphere of volume equal to the volume of the particle), and Δl_i is the range of class i, i.e. $(l_{i+1} - l_i)$

Table 1
Particle size class boundaries (l_i, l_{i+1}), size (Δl_i), volume equivalent diameter (l_i^*) and ratio, $\Delta l_i/l_i^*$

Class	l_i	l_{i+1}	Δl_i	l_i^*	$\Delta l_i/l_i^*$
1	1.00	1.26	0.26	1.13	0.23
2	1.26	1.58	0.32	1.42	0.23
3	1.58	2.00	0.42	1.79	0.23
4	2.00	2.52	0.52	2.26	0.23
5	2.52	3.18	0.66	2.85	0.23
6	3.18	4.00	0.82	3.59	0.23
7	4.00	5.04	1.04	4.52	0.23
8	5.04	6.34	1.30	5.69	0.23
9	6.34	8.00	1.66	7.17	0.23
10	8.00	10.10	2.10	9.05	0.23
11	10.10	12.70	2.60	11.40	0.23
12	12.70	16.00	3.30	14.35	0.23
13	16.00	20.20	4.20	18.10	0.23
14	20.20	25.40	5.20	22.80	0.23
15	25.40	32.00	6.60	28.70	0.23
16	32.00	40.30	8.30	36.15	0.23
17	40.30	50.80	10.50	45.55	0.23
18	50.80	64.00	13.20	57.40	0.23
19	64.00	80.60	16.60	72.30	0.23
20	80.60	102.00	21.40	91.30	0.23
21	102.00	128.00	26.00	115.00	0.23

When $\Delta N/\Delta l$ versus l^* is plotted on a log–log basis, the data can be linearly regressed. If the function is near hyperbolic, which the regression coefficient, R, will indicate, the absolute value of the slope yields the characteristic distribution parameter, β. The interpretation of this parameter will be shown in the following section.

Both Sheldon and Parsons (1967) and Kavanaugh et al. (1980) point out the necessity of arranging the class boundaries in ascending geometric progression, such that the ratio of $\Delta l_i/l_i^*$ is a constant, to ensure statistical reliability in a particle size distribution that is hyperbolic in nature. Sheldon and Parsons (1967) recommended a progression based on volume, such that $V_{i+1} = 2V_i$. This is back-converted by the equation $V = (\pi d^3)/6$ to an artificial dimension, l^*, the volume equivalent diameter; i.e. the diameter of a sphere whose volume is equal to the volume of the particle. In this form, the class boundaries are defined by $l_{i+1} = 1.26 l_i$, which satisfies the ratio condition. These recommended class ranges were used in this study as shown in Table 1.

1.3. *The power law in number, area and volume distributions*

As noted earlier, physical toxicity in fish has been connected to fine suspended solid particles (about 5 μm; Chapman et al., 1987) and solids loading, which is a function of total particle volume (Muir, 1982). Particle surface area provides the substrate for chemical and microbial contaminants. Thus, the particle number, surface area and volume contributions are all important.

Kavanaugh et al. (1980) showed that when a particle distribution can be described by the power-law model (Eq. (2)), a rapid estimate of the particle number, area and volume distributions can be made using the frequency distribution slope β, as given for the ith size fraction of interval (class) Δl by the expressions:

$$\begin{aligned} \Delta N_i &= C l_i^{*-\beta} \Delta l_i \\ \Delta A_i &= C_2 l_i^{*2} \Delta N_i \\ \Delta V_i &= C_3 l_i^{*3} \Delta N_i \end{aligned} \tag{5}$$

where A and V are surface area and volume, C is a proportional constant, and C_2 and C_3 are shape factors.

Kavanaugh et al. (1980) went on to normalize the equations into the following forms:

$$\begin{aligned} \Delta N_i/N_T &= l_i^{*(1-\beta)} / \sum_i l_i^{*(1-\beta)} \\ \Delta A_i/A_T &= l_i^{*(3-\beta)} / \sum_i l_i^{*(3-\beta)} \\ \Delta V_i/V_T &= l_i^{*(4-\beta)} / \sum_i l_i^{*(4-\beta)} \end{aligned} \tag{6}$$

Through the constant ratio of $\Delta l_i / l_i^*$, the constants C, C_2, and C_3 are normalized out of these expressions. Thus, this form of the equations has the advantage of removing shape factors, assuming particle shape is the same throughout the size range.

For a hypothetical suspension with particle sizes from about 1 to 700 µm, Figs. 2–4 indicate the types of distribution that can be expected for three representative β values, 2, 3 and 4, using the three parts of Eq. (6). Kavanaugh et al. (1980) reviewed data from several natural waters (lakes and rivers) and wastewater sources. β varied from 1.7 to 4.2, with correlation coefficients from 0.88 to 0.99 (seven out of nine had $R = 0.95$ or greater). $\beta = 3$ appears to be a median value for wastewater systems.

For $\beta = 2$ (Fig. 2), larger particles dominate surface area and volume distributions, and the effect of fine particles on the number contributions is weak. For $\beta = 3$ (Fig. 3), the plots indicate a large number of small particles, but the larger particles dominate the volume distribution. Surface area contributions are equally shared by all classes. For $\beta = 4$ (Fig. 4), fine particles dominate particle size and area distributions. The particles' contribution to total volume is equally distributed across the classes.

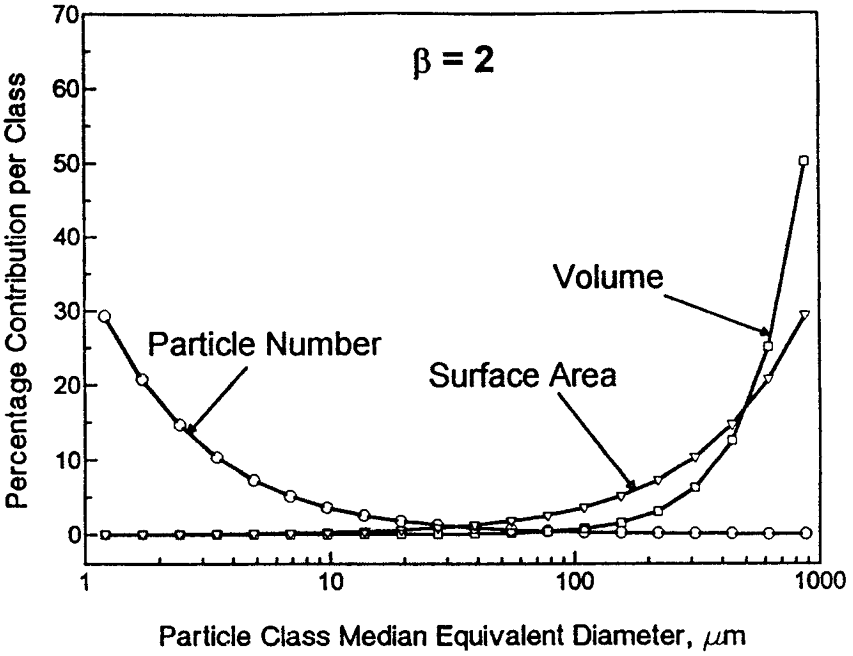

Fig. 2. Hypothetical contribution/distribution curves for $\beta = 2$.

1.4. Hypothesis

The hypothesis for this paper is that water in finfish aquaculture systems have an inherent particle distribution that is nearly hyperbolic. Thus, the power law and its predictors can be used when analyzing particle number, area and volume (hence,

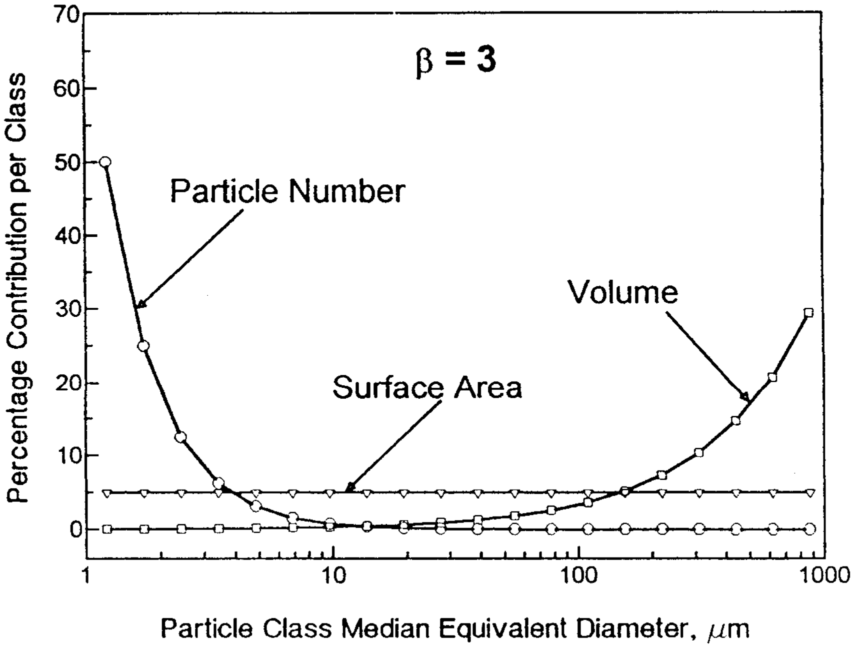

Fig. 3. Hypothetical contribution/distribution curves for $\beta = 3$.

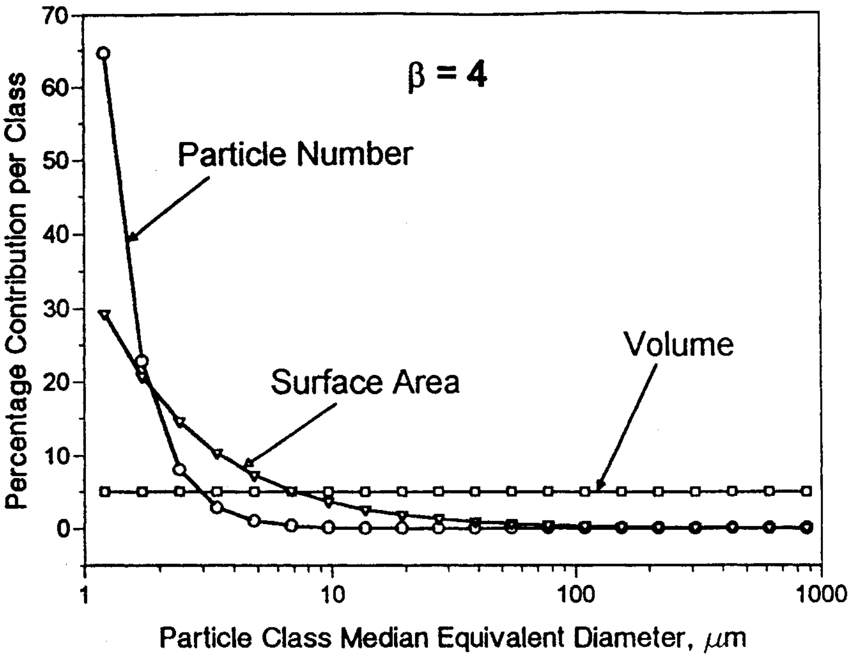

Fig. 4. Hypothetical contribution/distribution curves for $\beta = 4$.

with density, mass) with respect to particle size in such systems, regardless of the nature of the system or the fish reared. The indications are that this may be a universal rule of which this is but the first test.

2. Method

2.1. Data sources

Data on extant particle size distributions from aquaculture related systems, with an emphasis on recirculating water systems, were solicited from several sources, seeking as wide a range as possible of species, feeding regimes and aquaculture system sampling points. Contributions were received from the following contributors.

Dr Simon Cripps, RF-Rogaland Research, Stavanger, Norway: one sample of effluent from a land-based, flow-through Atlantic salmon (*Salmo salar*) rearing facility; particle size distribution information was obtained using a Coulter Particle Counter (model and aperture unknown). Designated 'Cripps' data set' for purposes of this paper.

Dr Michael B. Timmons, Department of Agricultural and Biological Engineering, Cornell University, Ithaca, NY, USA: multiple samples from a study of fish physiology with respect to suspended solids (SS) level in water recirculation rearing of rainbow trout (*Oncorhynchus mykiss*); particle size distribution information was obtained using an Elzone Model 180XY and a 120 μm aperture tube (designated 'Timmons' data sets'). Four tanks, each divided into three sections were used (Krise et al., 1994). In each section, the concentration of suspended solids was controlled by the recirculation of a portion of the sludge output from clarifiers to maintain test levels; 7.0, 10.6 and 11.8 mg/l. The data chosen for examination were:

tank 1, section 1 (SS load 7 mg/l), day 1;
tank 1, section 3 (SS load 11.8 mg/l), day 1;
tank 1, section 3 (SS load 11.8 mg/l), day 15;
tank 3, section 3 (SS load 11.8 mg/l), day 1.

Dr Fred Wheaton, Dr Sahdev Singh, and James Ebeling, Biological Resources Engineering Department, University of Maryland: several data sets from various sample points on four recirculating test systems rearing fingerling hybrid striped bass, each with different combinations of particulate and biological filters; particle size distribution information was obtained using a Coulter LS100 laser light-scattering particle sizer and the Fraunhofer algorithms (Ebeling et al., 1997) (designated 'Singh's data sets'). The systems were as follows:

system 1: 20 m^3 tank, 60 μm drum filter, half of flow to a bubble wash bead filter, half to tank;
system 2: 20 m^3 tank, settling tank, trickling filter (Bio Barrels);
system 3: 20 m^3 tank, 60 μm drum filter, trickling filter (Bio Barrels);
system 4: 20 m^3 tank, settling tank, half of flow to a bubble wash bead filter, half to tank.

All systems were initially stocked with 320 × 100 g hybrid striped bass. The data sets examined are shown in Table 2.

In addition, one data set was taken from Chen et al. (1993), (Fig. 1 a–c, particle number and volume distribution plots), by digitizing (designated 'Chen's data sets'). Three tank-based recirculation trials with different suspended solids removal strategies were reported.

System 1: 5.8 m^3 tank, trough with 12 screens (mesh numbers not reported).
System 2: 30 m^3 tank, clarifier (9 m^2) with a rotating biological contactor (RBC).
System 3: 6.4 m^3 tank, sand filter, biological filter, ozonation.

Systems 1 and 3 held rainbow trout (*Oncorhynchus mykiss*) and system 2 held brook trout (*Salvelinus fontinalis*). An Elzone Model 180XY and a 190 μm aperture tube were used for particle counting The sampling point was not identified, but is presumed to be the fish rearing tanks.

2.2. Equipment

Both the Elzone and Coulter particle counters are of the resistance pulse type and operate by passing the sample, in an electrolyte, through an aperture across which there is an electric field. The particle interrupts the field, changing the resistance across the aperture. The interruption pulse gives the count and the amplitude of the pulse, the volume of the particle, which is calculated back to a volume equivalent diameter as already described. Note that the reliability of the output is theoretically limited to between about 4 and 20% of the aperture size, with the lower end sometimes being affected by electronic noise. (McCave and Syvitski, 1991).

The LS100 is based on the scattering of a light beam by the particles in a solution, the scatter pattern being detected on an array of sensors. The detection flux is then processed through theoretical algorithms into a particle distribution based on the percentage of a size class detected. The Fraunhofer algorithm set is generally valid down to particles whose size is 10 times the wavelength of the light used. Below that, the Mie set is used, but requires that the refractive index of the particles in question be known (McCave and Syvitski, 1991). The LS100 laser has a wavelength of 495 nm, and so sizing below about 5 μm using Fraunhofer is spurious. Note that this instrument also reads volume and converts this data to a volume equivalent diameter in its software.

2.3. Data Formatting and Power Derivation

The data sets in the study had large numbers of small class sizes which were first reprocessed into the Sheldon and Parsons (1967) classes as described in Table 1. Next, the data stream for plotting was started at the first complete class. Partial classes below this class were rejected as under-represented. The count per sample (or the percent per sample) was plotted against the median class particle size, l^* (the volume equivalent diameter; see earlier) on a log–log basis, and the absolute value of the slope of a linear regression of the points was recorded as β, along with the regression coefficient, R.

Careful consideration had to be taken on data set selection. The sampling methods used in these trials will give data that is outside the reliable range of the instrument concerned, under-represented, or merely noise, especially in the low size ranges. That data must be judiciously pared from the final data set.

3. Results and discussion

The resultant β values, with correlation coefficients, are summarized in Table 2, and a selection of the resultant and derived normalized curves will be illustrated in the following figures. For the purposes of this paper, the absolute values of the particle size counts ($\Delta N/\Delta l$) should be ignored. They depend on the sample size, which varies. It is the relative contribution of the particle class to the total load, as shown in the curves derived from the normalized equations (Eq. (6)) that is important in this context. The derived (percentage contribution) curves are based on the range of l_i^* shown in Table 1.

The β power factors in all data sets except one were within the ranges expected in wastewater. All correlation coefficients indicate very good adherence to the power law.

Cripps' 'flow-through' data, although only one set, gave a β value near the normal, at 2.94 (similar to Fig. 3), indicating a predominance of fines in numbers and an even distribution in surface area. However, the predominance of volume contribution, hence mass, is to be found in the larger particles.

Table 2
Summary of β values obtained, with correlation coefficients, from the data sets selected

Source	Set	β	R	Comment
Cripps	1	2.94	0.994	Atlantic Salmon: flow-through system
Timmons	1	4.24	0.996	Trout: recirc.[a]; tank 1, section 1;
	2	4.64	0.997	Trout: recirc.; tank 1, section 3
	3	4.53	0.996	Trout: recirc.; tank 1, section 3; 21 days after set 2
	4	4.39	0.997	Trout: recirc.; tank 3, section 3
Singh	1	4.31	0.998	Striped Bass: recirc.; tank 1, grab sample @ 11:00
	2	3.52	0.998	Striped Bass: recirc.; tank 1, grab sample @ 15:00
	3	3.84	0.998	Striped Bass: recirc.; tank 2, grab sample 2 h after feeding
	4	3.94	0.993	Striped Bass: recirc.; tank 2, inflow to filter from central standpipe
	5	4.47	0.995	Striped Bass: recirc.; tank 2, outflow from settling basin
	6	3.86	0.996	Striped Bass: recirc.; tank 3: grab sample @ 15:00
	7	3.86	0.995	Striped Bass: recirc.; tank 4: grab sample 3 h after feeding
Chen	1	3.16	0.975	Trout: recirc.; screens, foam fractionator in tank
	2	6.29	0.998	Trout: recirc.; clarifier w/RBC
	3	3.04	0.977	Trout: recirc.; settling zone, sand and biofilter, O_3

[a] Recirc., recirculation system.

For Timmons' data sets, typical arithmetic and logarithmic curves and derived distribution curves are shown in Figs. 5 and 6, respectively. In these trials, the main thrust was on testing the reaction of fish to different concentrations of suspended

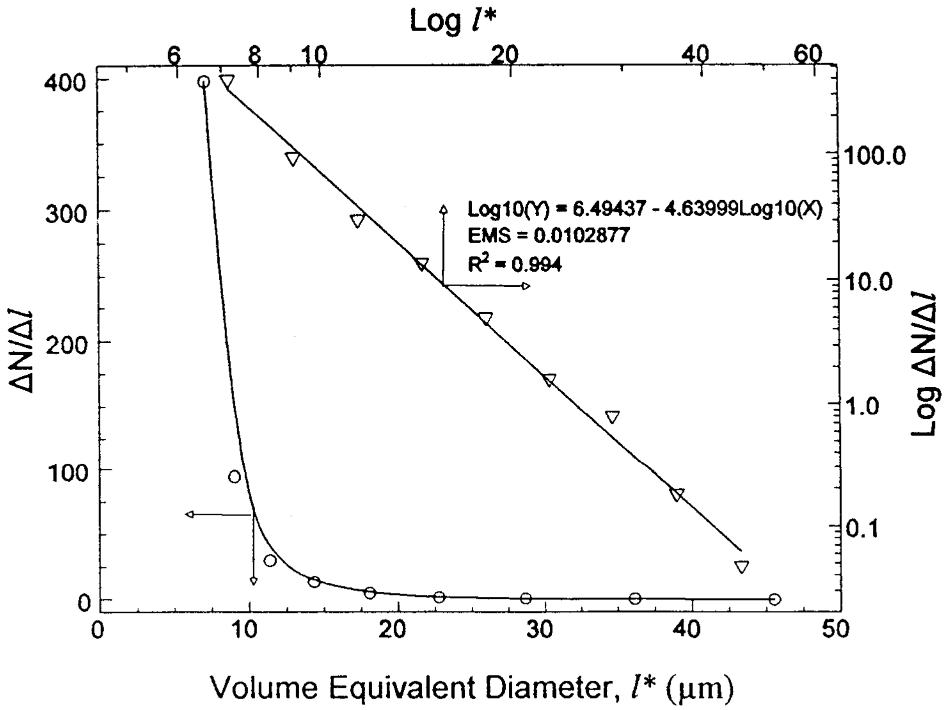

Fig. 5. Particle size distribution versus volume equivalent particle diameter, l^*, (left, bottom, B-splined) and its log-linear regression (top, right) for Timmons' set 2.

solids in the culture water. The method used to concentrate the solids was to recycle portions of the wastewater. Thus, all systems show a preponderance of fine particles and this is reflected in the consistent β number over 4, and in the derived distribution curves, which show dominance of fine particles in all three: particle number, surface area, and even volume contribution.

Singh's data set is particularly interesting as the data come in the form of a differential percentage of particles of a given nominal size ('particle sizing' versus particle counts). The results indicate that this form is equally valid for the determination of β. Similar to Timmons' recirculation system sets, there is a fine particle domination, with β powers around 4. A typical set is shown in Figs. 7 and 8.

Also of interest in Table 2 is the comparison of set 4 with set 5, which were taken on the same day at approximately the same time. Set 5, from the outflow of the RBC/clarifier, has a power of 4.47 versus the inflow power of 3.94, suggesting the removal of larger particles from the flow, as would be expected.

The correlation coefficients for Chen's data sets 1 and 3 are slightly weaker than that for the other set. This can be explained by the digitizing technique. The particle size distribution plot was partially obscured by a darker volume plot, especially around 10 μm, and this value was under represented.

Chen's systems 1 and 3 (sets 1 and 3) appear to be in the centre of the range for wastewater systems, but set 2 (Figs. 9 and 10) shows a very strong skewing to the fine particle end of the spectrum, with a very large power of 6.29. This is most probably due to the fact that this was a new system, with juvenile fish (50 versus 500 g fish in the other two systems) and hence the feed would be small crumbles, and the faeces also small, and perhaps less stable.

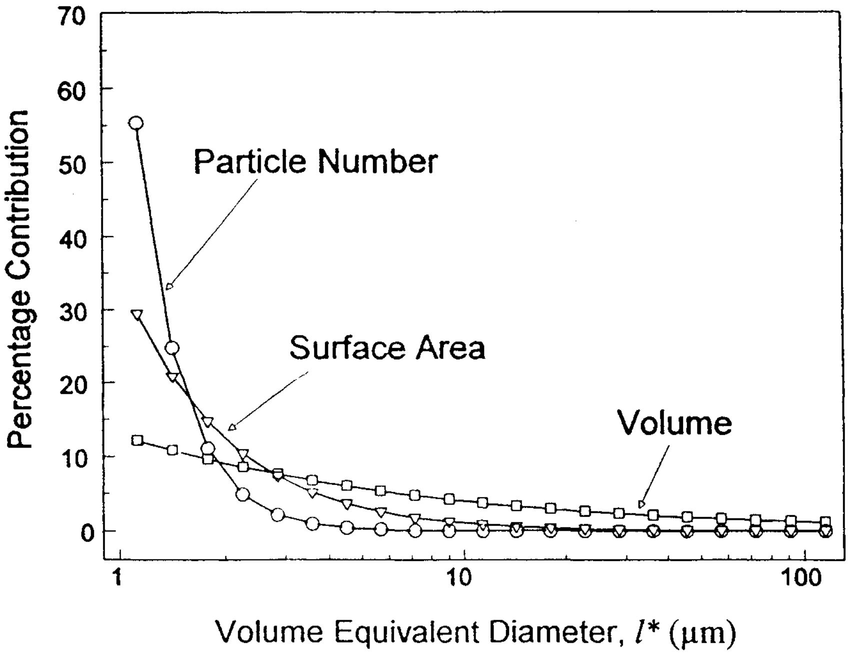

Fig. 6. Derived distribution curves for Timmons' data set 2, $\beta = 4.64$.

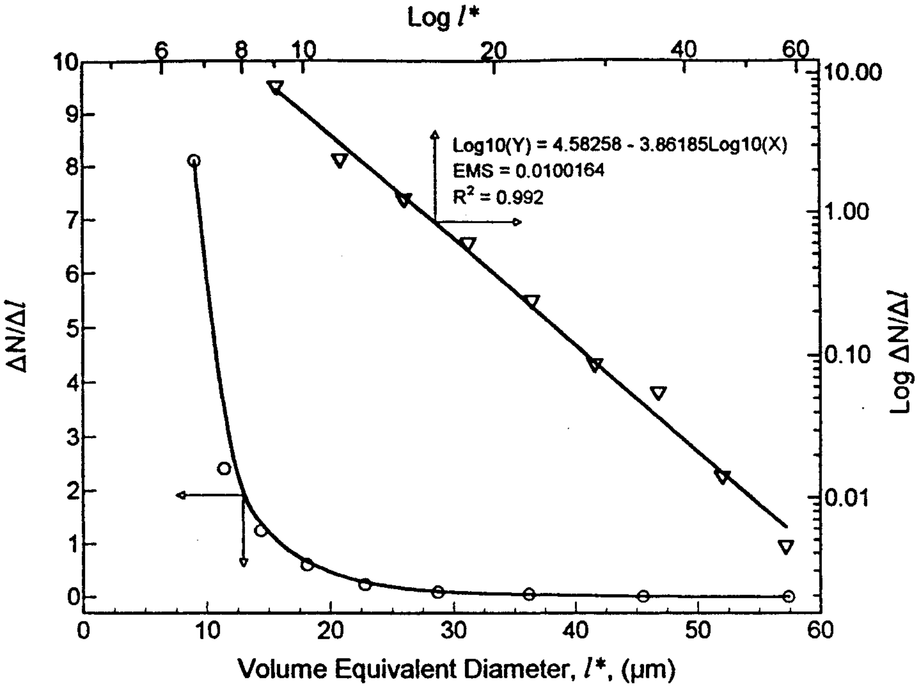

Fig. 7. Particle size distribution versus volume equivalent particle diameter, l^*, (left, bottom, B-splined) and its log-linear regression (top, right) for Singh's set 6.

Fig. 10 suggests by extrapolation that there was a predominance of fines under 5 μm in this system, which not only carry the greatest number of particles, but the major portion of both the weight of suspended solids and the surface area contributions. This range was not detected by the particle counter, which had a lower limit of 6.5 μm.

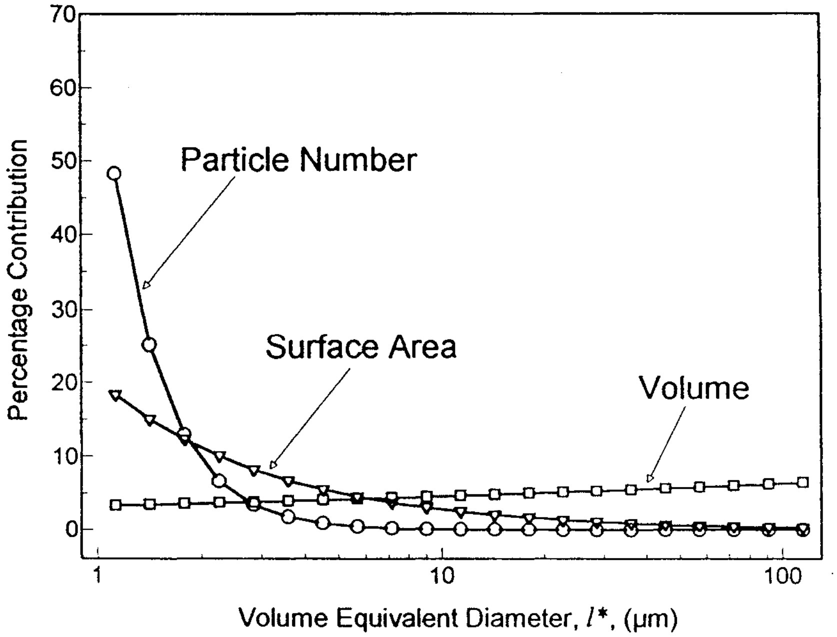

Fig. 8. Derived distribution curves for Singh's data set 6, $\beta = 3.86$.

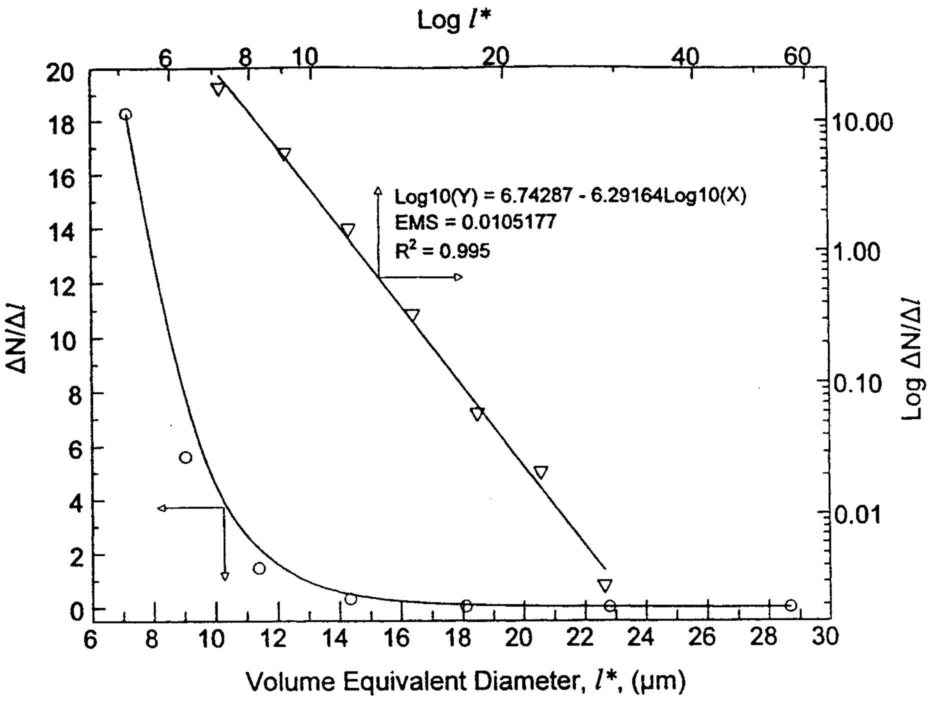

Fig. 9. Particle size distribution versus volume equivalent particle diameter, *l**, (left, bottom, B-splined) and its log-linear regression (top, right) for Chen's set 2.

In all cases, the consistency of results is remarkable, given the size of the samples used in present counting (resistance pulse) and sizing (light scattering) machines. For example, Timmons' data sets sample size involves 10 ml of raw water combined with 190 ml of electrolyte, of which 2 ml are sampled. Hence, the raw water sampled is one-tenth of a milliliter.

4. Conclusions

This review of data from 11 aquaculture systems (one flow-through and the remainder recirculation systems), covering three species of salmonids and one of bass, for a total of 15 data sets, strongly suggests that the power law is valid for aquacultural systems. The value of the power, β, is easily obtained from either particle counting or particle sizing equipment outputs, and, through the Kavanaugh et al. (1980) normalized contribution/distribution equations, it can offer the worker an expedient method of examining the particle number, surface area and volume contributions of any compliant particle size distribution. Whether this distribution pattern is universal for all species and aquaculture systems remains to be confirmed as more data sets become available. In the meantime, it is suggested that workers should expect to see hyperbolic particle size distributions, which the correlation coefficient of a log–log plot will confirm, in any aquacultural system, and to re-examine their data when they do not.

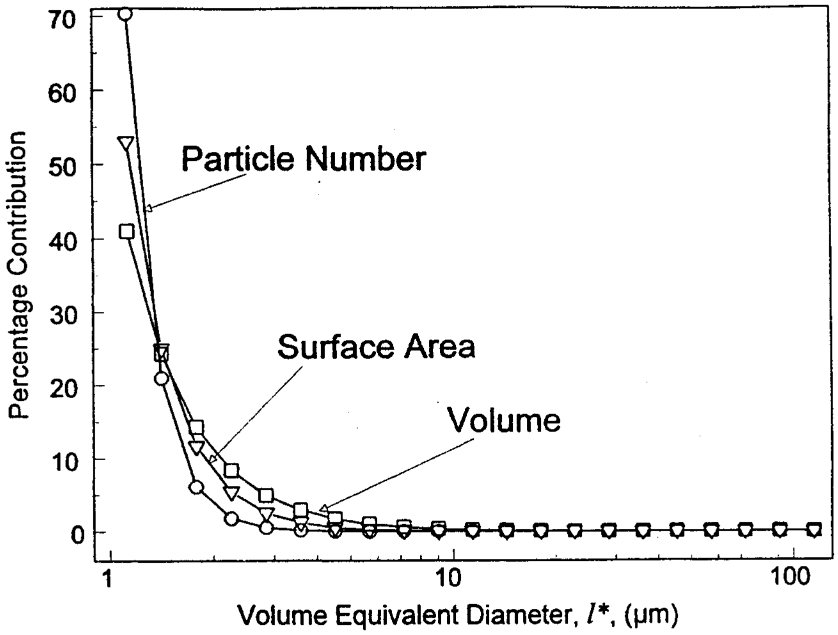

Fig. 10. Derived distribution curves for Chen's data set 2, $\beta = 6.29$.

The β factor allows simple comparison of particle distributions between systems and between sectors within systems. One can develop a reasonable estimate of the complete distribution, and the contribution of that distribution to the surface area and volume/mass spectra from a limited data set, as shown in several of the cases given.

Extrapolation beyond the range limits of present particle counters using the normalized equations of Kavanaugh et al. (1980) appears feasible and can give insight, especially in the lower ranges. From an aquaculture design point of view, the results give a strong indication that, not only are recirculating water systems inherently rich in fine particles (below 30 μm) which are not easily removed by mechanical means, a fact already established, but there is a range of particles below the detection thresholds of current counters that can dominate all aspects of some systems. For example, Fig. 10 strongly suggests that there is a range of particles from 1 to 6.5 μm (the lower limit of the apparatus used) that provided the controlling share of particle numbers, surface area and mass contributions of the particle spectrum in that system. Further work in this area to seek confirmation is planned.

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