Testing the Hydraulic Efficiency of Pressure Difference Samplers While Varying Mesh Size and Type

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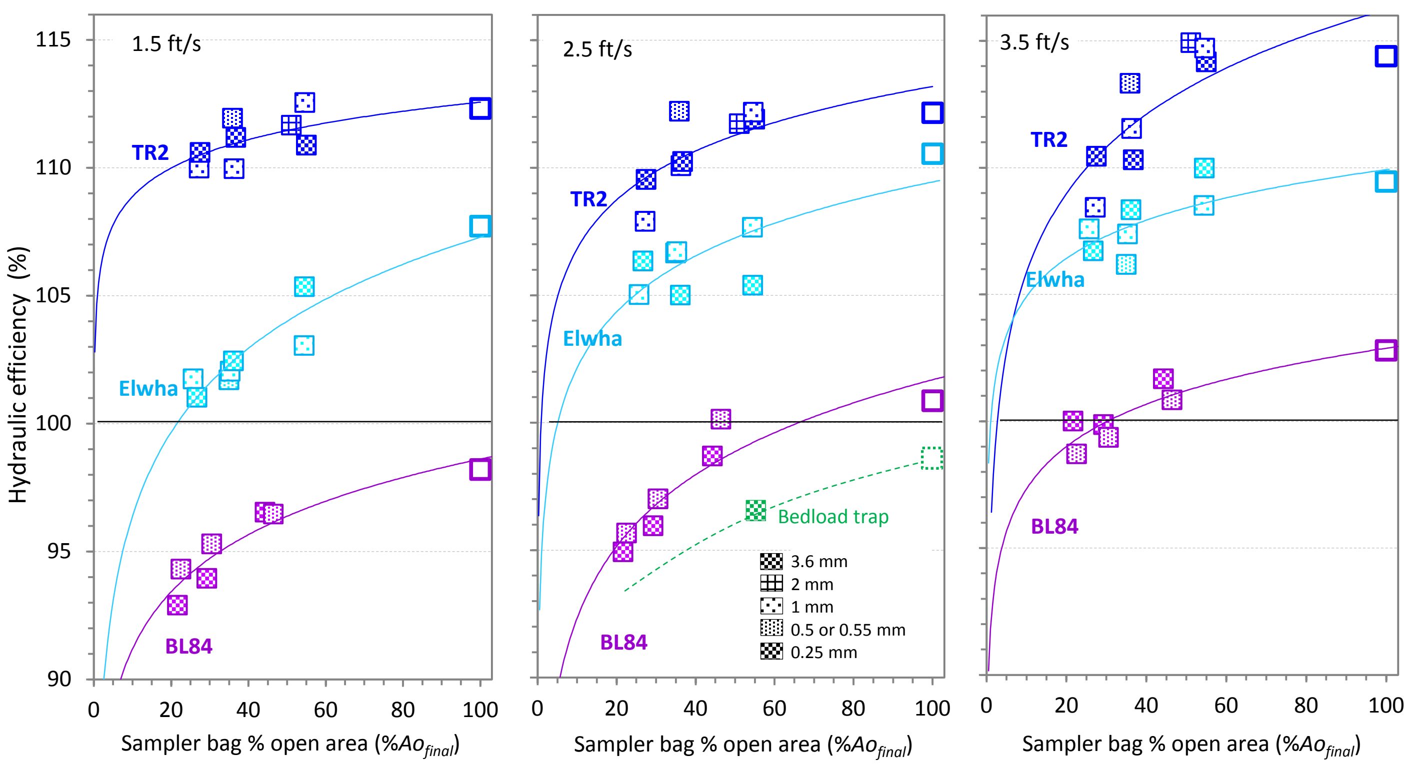
By

Kristin Bunte, Matthew Klema, Taylor Hogan and Christopher Thornton



Colorado State University, Engineering Research Center, Fort Collins, CO 80523

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Flume experiments

This study conducted flume experiments to test how the hydraulic efficiency of three pressure-difference bedload samplers is affected by different collection bag fabrics and the degree to which the sample bag was filled with gravel. Hydraulic efficiency determines whether the flow velocity passing through the sampler is faster or slower than the ambient velocity which might cause over- or under-sampling of bedload depending on sampler, the kind of net attached to it, and its fill level. A hydraulic efficiency of 100% over all flows and for different nets and their fill levels is considered an ideal (though probably unattainable) goal.

The experiments were conducted in a large flume at the Engineering Research Center at Colorado State University. The flow was 6 ft wide and 2.2 ft deep for all runs, ensuring that all samplers were well submerged and wall effects were minimized. Three pressure-difference samplers with 1.4 expansion ratios were tested: The Toutle River 2 (TR2) sampler with a 12” by 6” opening, its smaller cousin, the 8” by 4” opening Elwha sampler, and the 3” by 3” BL-84 sampler. Bags with four different mesh widths were tested for the TR2: 0.55, 1, 2, and 3.6 mm. Three bags with 0.55, 1, and 3.6 mm were tested for the Elwha sampler and two bags with 0.25 and a 0.5 mm bag for the BL-84. The custom-sewn bags available for the study differed in size and shape; their bag surface areas were equalized by adjusting the clamping location at the bag ends. Each bag was tested empty as well as filled to 30 and 50% of its volumetric capacity with gravel.

Testing each sampler and each net with three fill levels and three target velocities of 1.5, 2.5, and 3.5 ft/s, as well as each sampler with no net attached and the velocity in the absence of a sampler in the flume amounted to 77 runs. Flow velocities were measured using an ADV at 7-9 locations (=verticals) spaced at specified intervals along a line about 1 inch in front of each sampler. Fume experiments started out with sampling full velocity profiles with 4-5 points at each vertical per runs.

The flume pump system started to fail 2/3 of the way through the experiments, producing unreliable results. After repairs, a second series of flume runs was conducted with improvements in the flume set-up, instrumentation, and sampling scheme. Due to time constraints and because velocity profiles—compared to one-point measurements—did not seem to provide much more information for evaluating hydraulic efficiency, velocity measurements on each vertical were limited to a constant height of 2” above ground ($v_{x,2}$) for all runs.

Simulation of sampler bag fill levels using different materials

To assess the effects of sampler bag fill levels on hydraulic efficiency, 30 and 50% of the bags’ volume were blocked with a plastic liner sewn into the bags’ ends to mimic clogging by suspended organic debris and sand in the first set of flume experiments. Bags were filled to the same volumes with gravel in the second set of flume experiments.

Data analyses

Condensing the matrix of velocity measurements to single parameters to relate to net openness

Flow velocities measured in front of the samplers during the various runs were condensed into single hydraulic parameters that could subsequently be related to the combined parameter for net openness $\%Ao_{final}$. Velocities measured at 2 inches above ground ($v_{x,2}$) in the second series of runs were analyzed as lateral averages over all verticals measured within the sampler width ($v_{xin,2}$), within the central part of the sampler width ($v_{xctr,2}$), as well as the ratio of inside to outside of the sampler ($x_{xin,2}/v_{xout,2}$). For comparison with the first series of experiments, $v_{x,2}$ was interpolated from the velocity profiles. Discharge passing through the sampler (Q_{in}) was computed from the velocity profiles measured in the first series of flume experiments. Hydraulic efficiency was computed from the $v_{xin,2}$ divided by the $v_{xin,2}$ measured when no sampler was in the flume and was accordingly termed $HE_{in,2}$. Detailed plots were prepared to show the relations of the hydraulic variables with the $\%Ao_{final}$, indicating the individual net mesh sizes.

Study results

Relation between mesh width and the density of the netting weave

The study examined the relation between mesh width and the density of the netting weave that may be characterized by the percent open area ($\%Ao$) and found only a loose relation between mesh width and netting density. The effects of weave density as well as bag surface area blocked by seams and gravel fill (or clad with a sewn-in liner) were mathematically combined into a single parameter of net openness ($\%Ao_{final}$) to which measured flow velocities and other hydraulic parameters could then be related.

Relations of flow velocity and discharge to $\%Ao_{final}$

For each sampler and each target velocity, flow velocity and the other hydraulic parameters formed positive relations with the combined percent bag open area ($\%Ao_{final}$). Logarithmic functions best described those relations with their initial steep rise from low to moderate values of $\%Ao_{final}$ (basically from clogged to empty bags) and flattening from moderate to high values of $\%Ao_{final}$ (basically from empty nets to no net attached to the sampler).

The relative magnitude with which the three parameters sampler entrance area, target velocity and the $\%Ao_{final}$, affected $v_{xin,2}$ as well as the other hydraulic parameter was analyzed by comparing results obtained at a specified percentage of net openness, 50% Ao_{final}. Discharge passing through the samplers was controlled by sampler entrance area and ambient (=target) velocity. $v_{xin,2}$ was mostly controlled by target velocity, while sampler entrance area and net openness had minor influences.

An unexpected discovery was the effect of sampler width on $v_{xin,2}$. The BL-84 and the Elwha samplers differ by just one inch in height, but the notably larger $v_{xin,2}$ for the Elwha suggested that not only protrusion into fast flow but sampler width likewise exerted an influence on $v_{xin,2}$.

Hydraulic efficiency

Similar to the results obtained for flow velocity $v_{xin,2}$, hydraulic efficiency based on the flow velocity at 2" above ground ($HE_{in,2}$) increased with sampler entrance area, with target velocity, and with the % bag open area $\%Ao_{final}$. However, because hydraulic efficiency is calculated as a velocity ratio, the dominating influence of the target velocity parameter dropped out. Instead, all three parameters: sampler entrance area, target velocity, and the % bag open area - each exerted relatively equal control on hydraulic efficiency and showed a complex interplay among the parameters.

Absolute values of hydraulic efficiency for the TR2 and Elwha samplers were within 101 to 115%, showing that flow was sucked into those two pressure-difference samplers for all target velocities and net configurations, even for clogged nets. $HE_{in,2}$ for the BL-84 was near 100%. A TR2 sampler half filled with gravel had a higher hydraulic efficiency than an Elwha with empty bags, and an Elwha with half-clogged nets has a higher efficiency than an empty BL-84 sampler. On average, sampler entrance size affected hydraulic efficiency slightly more than target velocity, while bag openness ($\%Ao_{final}$) ranked third. A single test run with an unflared bedload trap yielded a hydraulic efficiency of just below 100%, showing that expansion ratios affected hydraulic efficiency much more than either target velocity, sampler entrance area, or bag opening.

The effects of bag openness on hydraulic efficiency were complex and differed among samplers, among bags, and among target velocities. Empty coarse-meshed nets (with Ao_{final} >50%) did not reduce hydraulic efficiency for the TR2 sampler, but net clogging did, indicating that bag choice mattered little for the TR2 sampler but the bag should not be filled to 50%, especially not in faster flow and not for the shape-retaining 1-mm bag. For the BL-84 sampler, the choice among coarse nets was likewise less important for hydraulic efficiency than avoiding filling the bag to 50%, especially in slower flow. By contrast for the Elwha sampler, gravel fill and the sheer presence of a coarse net equally reduced $HE_{in,2}$, particularly at slower flow.

Comparison between the two sets of flume experiments showed that symmetrically blocking the sampler bag ends with a plastic liner (simulating clogging by suspended organic debris and sand) reduced hydraulic efficiency notably more than similarly sized gravel fills, because water could easily exit the bags above the gravel wedges. Investigating the effects of net shape had not been an explicit study aim, but in several cases net shape was found to exert a notable influence on how net openness affected hydraulic efficiency.

Relation of hydraulic efficiency to sampling efficiency

In order to use multiple bedload samplers interchangeably, all samplers should have the same hydraulic efficiency, and ideally, that value should be near 100% for a wide range of sampler bag configurations. However, hydraulic efficiency is not a straightforward measure of sampling efficiency, but the relation between flow hydraulics and bedload transport is highly complex, and even estimating a possible relation requires several assumptions. Rather than a direct transfer of hydraulic efficiency into sampling efficiency, a high hydraulic efficiency more likely causes pronounced oversampling under specific conditions: 1) When suspended sand is sucked into the sampler, 2) When sandy bed material is scoured at the sampler entrance and then sucked into the sampler, 3) When gravel particles are dislodged during sampler placement on the bed and then sucked into sampler.

Recommendations

Improvements for future studies

Flume experiments with flows 6 ft wide and 2.2 ft deep and near-bottom velocities of more than 2 ft/s require large discharges. Turbulence created as pipes empty into a head box takes a long downstream distance to dissipate, making a longer flume desirable. Scheduling multiple repetitions for most runs would improve the ability to better differentiate between variability and complexity in observed effects.

Net shape—though not specifically tested—was found to affect hydraulic efficiency about as much as the degree of net openness. To isolate the effects of net shape on hydraulic efficiency, tested nets should have identical shapes, and a set of different net shapes should be tested for each mesh size. The effects of net shape exposed in this study strongly suggested that standardized patterns be developed and used when sewing sampler bags.

Future study points

A sampler body expansion ratio seemed to control hydraulic efficiency more than sampler size, target velocity, and the nets' $\%Ao_{final}$. This study estimated that hydraulic efficiencies of near 100% may be obtained by an TR2-sized sampler with an expansion ratio of about 1.1, an Elwha-sized sampler with an expansion ratio of 1.2, and by a down-scaled version of an Elwha sampler with a 3" by 6" opening size.

1. Introduction

1.1 Wide range of bedload samplers and bags

Bedload samplers differ in the size of their entrance area, bag size and mesh width. One of the reasons for this variability is that bedload transport in mountain streams extends over a wide range of particle sizes from medium sand to cobbles (0.2 – 256 mm). Gravel transport rates per unit width span an even wider range and may be as small as one pea-sized particle collected per hour (1E-6 g/m·s) or a 5-gal bucket filled in 1-2 seconds (1-E4 g/m·s). Sampling the entire range of particle sizes and transport rates that can move within a normal high flow event in mountain streams would require using a bedload sampler with an opening large enough for cobbles to enter, a bag large enough to hold 5 gallons of sediment and a mesh width fine enough to retain medium sand. No single configuration of sampler entrance size, bag size and mesh width can cope with all situations because each combination is suitable for only a part of the wide spectrum of bedload transport conditions encountered in gravel-bed streams. These factors must be taken into consideration when designing a bedload sampling program and selecting a sampler appropriate for the expected conditions.

Manageability of the bedload sampler also comes into play when selecting a device for a project. While the large-bodied Toutle River 2 (TR2) pressure-difference sampler with a 12" by 6"opening with a long 0.5 mm mesh width bag attached would be suited to collect a wide range of particle sizes and transport rates, the TR2 sampler is difficult to place and hold on a streambed even in wadeable flow. The Elwha sampler with its 8" by 4" opening (a 2/3 scaled down version of the TR2 sampler), and especially the BL-84 sampler with its 3" by 3" opening, are more manageable, but their smaller opening sizes and bag volumes restrict the largest collectable bedload particle sizes and total bedload mass.

Availability plays a role in why samplers and bag configurations differ among projects. Some studies can chose from a wide assortment of samplers and bags to meet expected bedload transport rates, grain sizes, and flow conditions, while limited resources may tie other studies to the one sampler and bag on hand. All of those reasons contribute to a wide range of samplers with different-sized openings, bag sizes and mesh widths being deployed for different field projects, and sometimes multiple samplers might be deployed as conditions change within one project. This equipment variability presents a problem for the bedload researcher because different samplers and their accompanying nets do not provide the same transport rates and particle sizes.

1.2 Intersampler differences in hydraulic and sampling efficiency

1.2.1 Effects of sampler size and shape

The use of different samplers and bag combinations within and among projects requires that sampled transport rates are nevertheless equivalent in order to compare or combine sampling results. However, sampling results are known to differ among samplers. Hubbell et al. (1987), Pitlick (1988) Gray et al. (1991), Ryan and Porth (1999), Childers (1991, 1999), Ryan (2005), and Vericat et al. (2006) have shown that sampling and hydraulic efficiency differ among pressure- difference samplers. O'Leary and Beschta

(1981) and Sterling and Church (2002) showed that transport rates differ between a pressure-difference Helley-Smith sampler and vortex sampler and between a Helley-Smith and a pit sampler, respectively. Bunte and Abt (2005) and Bunte et al. (2008) showed that sampling efficiency differs between a Helley-Smith sampler and non-flared bedload traps. Inter-sampler differences are typically attributed to different sizes and shapes of the sampler body, while little attention has focused on the possible effects of the samplers' bags.

1.2.2 Netting properties

Sampler bags differ not only in mesh width and bag length. Researchers involved in bedload studies often have an assortment of bags for their bedload samplers. The bags, often home sewn from netting material of a known or estimated mesh width, differ in netting properties such as thread diameter and material stiffness, as well as in bag shape, and sewing style. Nevertheless, sampler bags are typically used interchangeably, but apart from the clogging response, few studies have examined the effects of bag properties on hydraulic or sampling efficiency.

Bunte and Swingle (2009) turned their attention to the effects of a mesh's thread diameter in relation to the mesh width, i.e., the density of the weave. The ratio of mesh width to thread diameter is expressed by the percentage of mesh open area (Figure 1), a parameter used by industry to describe netting permeability (Sefar 2006). The percent mesh open area (%*Ao*) is defined as

$$\%Ao = w^2 \cdot 100/(w+d)^2 \qquad \text{(Eq. 1)}$$

where w = mesh width and d = thread diameter. Bunte and Swingle (2009) sewed nets of similar size

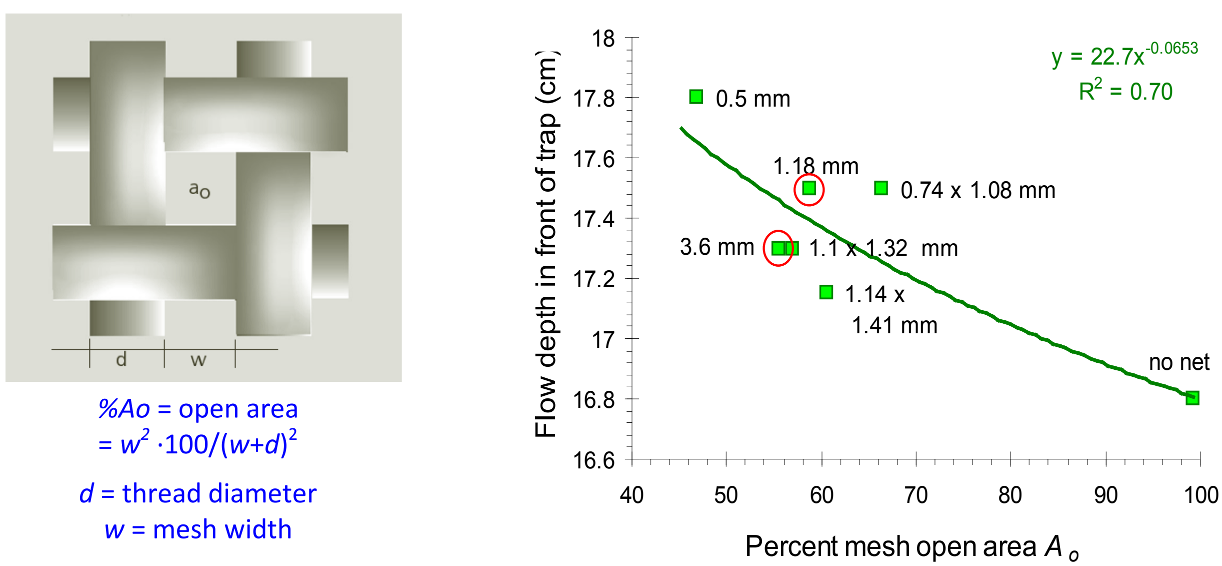


Figure 1: Definition diagram of percentage mesh open area (%*Ao*) (copied from the Sefar (2006) product brochure) (left). Decrease in backwater height measured in front of a bedload trap with nets of different %*Ao* attached (the respective mesh opening sizes are indicated by figure labels) (copied from Bunte and Swingle 2009) (right).

and shape from different netting materials, attached them to unflared bedload traps and found that the height of backwater (a measure of hydraulic efficiency) measured in front of a bedload trap decreased with increasing percent mesh open area.

1.2.3 Clogging effects of sampler bags

Some effects of net clogging on hydraulic and sampler efficiency have been recognized. Druffel et al. (1976) noted that organic debris trapped inside the net as well as sediment particles stuck in the mesh openings clogged the nets and decreased sampling efficiency, a phenomenon also noted by Johnson et al. (1977). Edwards (1980), O'Leary and Beschta (1981) and Beschta (1981a) showed that sampling efficiency increased as bag size attached to a 3" Helley-Smith sampler was tripled from 1,950 cm^2 to 6,000 cm^2 because the larger net delayed the clogging process. Bunte and Swingle (2009) and Bunte et al. (2015, 2016) showed that clogging by organic debris compromised hydraulic and sampling efficiency more in 1.18 mm mesh-width, stiff, precision nets than in a knitted 3.6 mm mesh bag that flow stretches to a funnel shape.

1.3 Aim of this study

Effects of netting properties on hydraulic and sampling efficiency have been approached in a few case studies, but systematic investigations of this topic are lacking. It is the aim of this study to conduct flume experiments to systematically investigate the effects of mesh width, the percentage of mesh opening area, and the degree of bag clogging on hydraulic efficiency of three pressure difference samplers (Figure 2):

- 6" x 12" Toutle River 2
- 4" x 8" Elwha
- 3" x 3" BL-84

The flume experiments are to be conducted in hydraulic conditions that deeply submerge each sampler in flow and minimize wall effects. Such conditions may reflect a mid-sized gravel-bed stream that has exceeded wadeability at high flow.

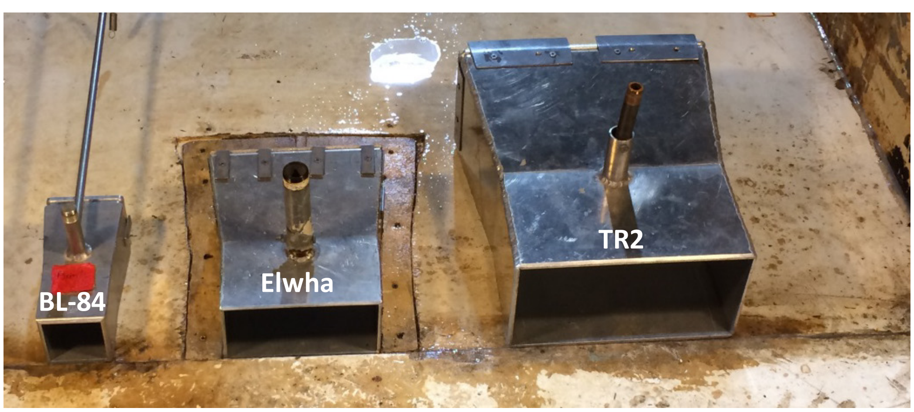


Figure 2: The three pressure-difference samplers used for testing (shown here with no bags attached).

2. Nets used for testing

The FISP Technical Committee funding this study decided that rather than making new nets for the flume experiments, testing should be performed on nets that are in use by various agencies and universities because testing nets already available reflects actual conditions, while saving labor and cost. Bags unavailable in the mesh sizes to be tested were sewn in this study.

2.1 Mesh width and percent open area

Mesh width, a widely known netting parameter, refers to the opening between the threads of a net and determines the smallest particle size that can be collected in the net. Nets attached to bedload samplers typically have mesh widths that coincide with particle-size class borders as defined by the Wentworth scale in which sizes progress as multiples of $\sqrt{2}$. Typical mesh widths used for bags attached to pressure-difference samples are 0.25 and 0.5 mm for the BL-84, 0.5 and 1 mm for the Elwha, and 0.5, 1, and 2 mm for the TR2 sampler (Childers, 1999, 2000), while a 3.6 mm net has been found suitable for unflared bedload traps (Bunte et al., 2004, 2007). Coarser mesh sizes have also been used, such as a 6 mm net ($d \cong 0.8$ mm, $\%Ao \cong 73$) for bedload traps (Turowski et al., 2013), as well as nets of 10 mm mesh width ($d \cong 1.2$ mm, $\%Ao \cong 78$) (Bunte, 1996) and 25 mm mesh width ($d \cong 2.5$ mm, $\%Ao \cong 83$) (Whitacker and Potts, 2007a and b) for large, likewise unflared net-frame samplers.

Net sturdiness requires that fine meshes (e.g., 0.2 mm) be woven from relatively thick thread with a diameter half the mesh widths. As a result, mesh width is only moderately well related (r^2=0.48) to the % mesh open area (Figure 3). Thread diameters $^1/_3$ of the mesh width provide sufficient sturdiness for coarser nets up to about 2 mm, while thread diameters in fishing nets knotted with twilled yarn is about $^1/_6$ to $^1/_{10}$ of the mesh width. Consequently, there is a generally positive trend between *%Ao* and mesh width. The trend is poorly defined for fine mesh widths <300 micron but becomes better defined for coarser nets. Bedload sampler nets with 0.25 to 3.6 mm mesh widths used in this study had open areas of 38 to 58 *%Ao*.

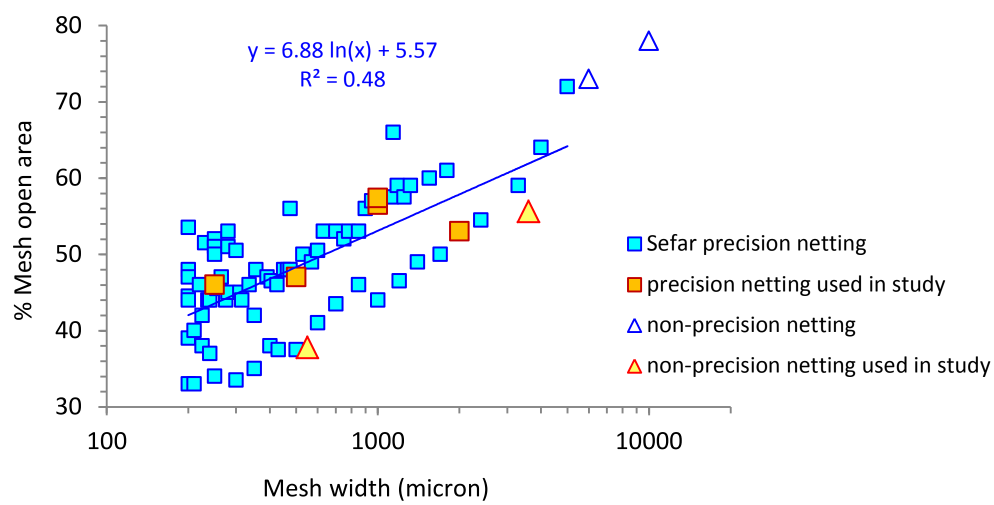


Figure 3: Relation of % mesh open area to mesh width for Sefar precision netting. Data from the Sefar (2006) product catalogue. Data for other netting materials are included in the plot.

2.2 Mesh widths tested for the three samplers

2.2.1 TR2 sampler

Custom, contractor-sewn bags with mesh widths of 0.55, 1, 2, and 3.6 mm (Figure 4) were available for testing with the TR2 sampler. The netting material for the 1 and 2 mm mesh widths nets was fabricated by the Swiss company Sefar from woven monofilament precision threads 320 and 750 microns thick and with resulting open areas of 57.4 and 52.9%, respectively (Table 1). The 0.55 mm net, that had been assumed to be 0.5 mm precision netting, turned out to be woven from non-precision monofilament thread, which meant that mesh widths differed among holes. Thread diameter was measured as 340 micron, while mesh width was 600 microns in one direction and 500 micron in the other direction. Averaged over both directions, the percent open area of this netting material was computed as $(\%Ao_1+\%Ao_2)/2$ = (40.4 + 35.3)/2 = 37.8%, a value considerably lower than any of the other tested nets and showing that the 0.55 mm net was a much denser weave (Figure 3).

Figure 4: Bags with four different mesh widths were used for testing with the TR2 sampler. The 0.55 mm net is shown attached to the TR2 sampler and with a clamp at the end.

The contractor-made 2 mm mesh-width net used with the TR2 had a 53% open area, a value similar to the other nets. However, the thread width of 0.75 mm makes the netting so stiff such that a cylinder one foot in diameter and 4 ft tall stands like a tower, i.e., the bag is more like a basket than a net. The seam along the bag cannot be sewn overlapping onto the material to make a smooth cylinder. Instead, the two ends are sewn together like the bows of an old-fashioned snow-shoe, which makes the seam stand up like a fish's back fin. A flexible cordura sleeve at the upper portion of the net about 2 inches wide is necessary to provide a connection between the stiff basket-like bag and the corners of the TR2 exit.

Table 1: Netting material used for flume experiments.

Used with sampler	Kind of netting	Netting code no.	Mesh opening (μ)	Thread diameter (μ)	Mesh count (n/cm)	Nominal % mesh open area*	Actual % mesh open area (%*Ao*)
BL-84	Sefar precision, monofilament	07-250/46	250	122	27	46	45.2
		06-500/47	500	230	14	47	46.9
Elwha	non-precision, monofilament	unknown	500 by 600	340	11 x 12	-	37.8
	Sefar, precision monofilament	06-1000/57	1000	330	7.5	57	56.5
	Raschel, knitted non-precision, lightly twilled tread	210d/9	3600	1230	2.1	-	55.6
TR2	Sefar, precision, monofilament	07-1000/57	1000	320	7.6	58	57.4
		06-2000/53	2000	750	3.6	53	52.9
	non-precision, monofilament	unknown	500 by 600	340	11 x 12	-	37.8
	Raschel, knitted non-precision, lightly twilled tread	210d/9	3600	1230	2.1	-	55.6

* as listed in the Sefar (2006) catalog

Nets with a 3.6 mm mesh width were sewn by the author of this study for both the TR2 and the Elwha samplers from the flexible netting material typically used for bedload traps. The non-precision netting is knitted from a lightly twilled thread of fine nylon fibers. The netting is flexible, drapes like cloth, and has 55.6% *Ao*, similar to that of the 1-mm and the 2-mm precision netting. The knitted netting is typically used for catfish farming, is inexpensive, and readily available (e.g., from Delta Net & Twine in Greenville, MS). The netting material can be sewn without difficulty by hand or machine, and handles much more easily than the stiff 2-mm precision netting. An important difference is that flexible netting stretches in fast flow and especially as sediment and organics accumulate in the end of the bag. Precision netting retains the overall shape of the bag much better. This difference affects the water flow-through of partially filled or clogged bags (Section 6.3 and 6.4).

2.2.2 Elwha

Bags with three mesh widths were tested with the Elwha sampler: 0.55 mm, 1 mm, and 3.6 mm. The netting materials are the same as those used for the TR2 sampler (see above). A 2-mm bag was not available for the Elwha. Netting material identical to that used to make the 2 mm bag for the TR2 sampler was too stiff to sew on a home sewing machine. Even if a stiff bag could have been sewn by hand, the bag's cross-sectional shape would not have been circular or ellipsoid but rather teardrop-shaped with a stiff stand-up seam along the outside of the sampler. Also, a long flexible sleeve would have been needed to connect the stiff bag to the corners of Elwha's exit. Considering that other users would encounter similar difficulties in fabricating a 2-mm precision net for the Elwha sampler and that the stiff bag would handle like a basket rather than a net, a widespread adoption of this net with an Elwha sampler is unlikely.

2.2.3 BL-84

A 0.25 mm and a 0.5 mm net were tested for the BL-84 sampler. The 0.25 mm net had originally been made by an unknown manufacturer and from unlabeled precision netting. Among the possibilities of 0.25 mm netting material listed in the Sefar (2006) catalog, the netting coded 07-250/46 with a 45.2 *%Ao* seemed the most likely candidate because it is polyester (PET) rather than polyamide (PA), and at least one manufacturer is known to fabricate bags from this material for the Helley-Smith sampler.

Commercially available bags for the BL-84 sampler are wider at the upper end than the sampler exit. As a result, the bags are bunched together and held on the sampler with a tight-fitting rubber O-ring, a design different from the bags used with the TR2 and the Elwha samplers. To test bags with a more similar design, the connection between net and sampler was made more slender. The upper end of the existing bag was pleated, and the rubber O-ring was replaced by cotton cloth line that just fit around the sampler body. The cloth line was sewn into a sleeve of nylon webbing which was then connected to the pleated netting. This alteration extended the net length by about two inches.

No bag was available for the BL-84 with a 0.5 mm mesh width among the borrowed nets; hence, one was sewn from 0.5 mm precision netting Sefar (06-500/47). Copying the design of the altered standard 0.25 mm bag, gores were cut out of the 0.5 mm netting and sewn into the bag on a home sewing machine. Compared to the altered 0.25 mm net, the 0.5 mm mesh-width net was about 1 inch shorter.

2.3 Equalizing bag sizes

The bags for each sampler on loan from various sources differed in length and width, and some net shapes were not rectangular but tapered towards the downstream end (Figure 4). The difference among nets for a specified sampler typically amounted to 1-2 inches in width at the front (note: bag widths = 2 x circumference), up to 5 inches in width at the rear end, up to 6 inch in maximum length. Net surface area is known to affect hydraulic efficiency (O'Leary and Beschta, 1981), hence bags tested for a sampler needed to have at least similar surface areas. The maximum bag surface area attainable for a specified sampler was set by the smallest available net. Larger bags were adjusted in length by clamping off the net's rear end at the appropriate length to approach the surface area of the smallest bag.

Several of the nets seemed to have had no prior use and stretched during the flume experiments. Net width typically became slimmer, while net length expanded. Overall, net surface areas increased, although not evenly for all nets, such that bag areas differed by up to ±16% from the mean bag area for a specified sampler. Assuming that the stretching occurred early in the flume experiments, the net dimensions measured after the experiments were assigned to the experiments (Table 2).

Table 2: Bag dimensions for second series of flume experiments

Sampler					Bag					Ratio sampler exit area to bag area
Entrance inside area	Exit inside area	Expan-sion ratio	Exit outside area	Exit outside circum.	Mesh width	Top width*	Bottom width*	Close-off length for equal area	Resulting surface area	
($inch^2$)	($inch^2$)	(-)	($inch^2$)	(inch)	(mm)	(inch)	(inch)	(inch)	($inch^2$)	(-)
TR2 sampler 6" by 12"										
72	101.1	1.40	110.1	44.1	0.55	21	16.25	36	1341	13.3
					1	21.5	17.5	34.5	1346	13.3
					2	21.25	17.5	34.75	1347	13.3
					3.6	20	16.5	37	1351	13.4
Elwha sampler 4" by 8"										
32	46.3	1.45	51.4	30.1	0.55	15	15	26.5	795	17.2
					1	14.5	10	32.5	796	17.2
					3.6	12.5	12.5	32	800	17.3
BL-84 sampler 3" by 3"										
9	12.6	1.39	16.1	16.1	0.25	12.25	6	15.75	287	22.9
					0.5	11	5	15	240	19.1

*Width refers to the bag top side as measured about 1 inch past the sampler exit. Total material width is twice the reported width.

2.4 Bag clogging

Sampler bags can become clogged while deployed in streams. Clogging results not only from fine sediment particles that stick in the mesh openings but also by bedload and organic debris that accumulate towards the bag's rear. The by-catch of organic material in bedload samplers may reach copious amounts on the first rising limb of a snowmelt high flow season (Beschta 1981a; 1983a; Bunte et al., 2016b) with organic volumes far exceeding those of bedload gravel. This study examined the effect of bag clogging by organic debris, i.e., complete clogging of the portion of the net end, and by gravel bedload, i.e., a gravel wedge in the back end of the net (Sections 2.4.2 and 2.4.3).

2.4.1 Bag shape and computation of fill levels

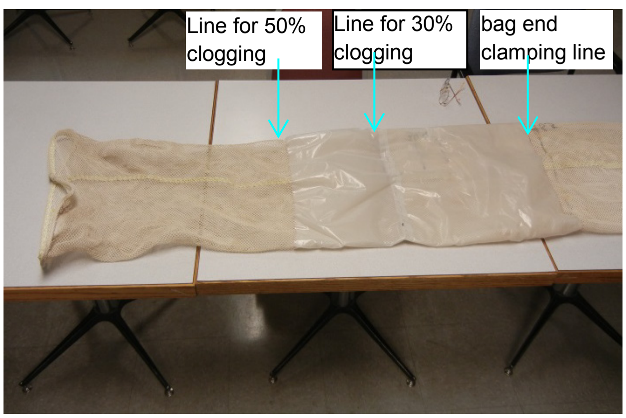
Cross-sectional shapes varied along the length of the sampler bags. For nets made from precision netting, shapes morphed from an ellipsoidal cylinder close to the sampler exit to a wedge shape just above the clamp at the rear end. The flexible 3.6 mm netting quickly necked down to the shape of an ellipsoidal cylinder after the sampler exit and then tapered more slowly towards the bag's rear end.

When partially filled with gravel, the precision bags bulked up at the rear ends, while the flexible 3.6 mm net became narrower at mid length and bulged at the rear end.

Details in the lengthwise variations of the bags' cross-sectional shape were not taken into account when computing the surface bag area associated with various fill levels. However, downstream tapering of the bag cross-sectional area was accounted for by fitting a linear function between bag width at the front end (w_{bf}) and rear end (w_{br}) and bag length (l_b). With the bag surface area known, the function $w_b = f(l_b)$ was solved to determine the distance from the net end and the associated bag width at which the bag surface area is reduced to 30 and 50%. A small allowance was made to account for the small volume occupied near the clamped rear end.

2.4.2 Simulating bag clogging using a plastic liner

Clogging of the rear end of a net was simulated in two different ways. The first approach was to sew a plastic liner into the back end of the nets. The liner extended forward to a fill level that corresponded to 30% and 50% of the bag surface area (starting from the rear end) (Figure 5). This approach mimicked particle blockage of the mesh pores at the net's rear end. Those particles comprise sand travelling in near-bed suspension during high flow as well as particulate organic material (POM) about 0.25 to 4 mm in diameter.



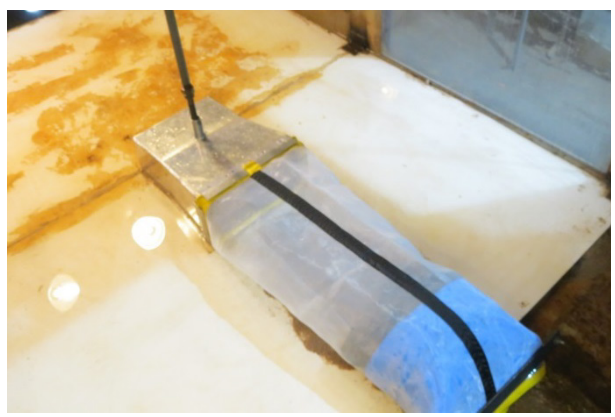


Figure 5: A clear plastic liner sewn into the back part of the 3.6 mm net for the TR2 sampler, blocking 50 and 30% of the net surface area (left). 30% of the bag area of the 1 mm net is clogged by lining the bag with blue adhesive tape, a measure less time consuming than sewing but abandoned because not holding up to use (right).

Adding sawdust and wood shavings to the bags may have mimicked clogging from organic debris more realistically. However, where exactly his material would clog the net and how much of the bag area would be affected is not exactly controllable and might have varied among samplers, mesh widths, and flow velocities. To ensure that similar degrees of clogging can be compared among samplers, mesh widths, and flow velocity, clogging was extended symmetrically around the bag's rear end. To avoid the development of a large eddy in the bag end, a crumpled piece of semi-permeable plastic (landscaping cloth) was stuffed into the blocked bag space.

2.4.3 Simulating bag filling with gravel

In a second series of flume runs (see Sections 4.3 and 4.4), clogging was mimicked by filling the bags' rear ends to the levels specified for 30 and 50% clogging with fine gravel and then placing the sampler-bag assembly flat onto the flume bottom. To ensure the bags had the same amount of gravel for each run, gravel for each bag and fill level was stored in separate buckets.

The relation between the bag surface area below the 30 and 50% fill lines and the mass of gravel fill had some scatter among samplers and among fill levels that was attributed to uneven cross-sectional shapes and stretching net length (Figure 6). Once laid flat, the gravel in the bags assumed a wedge shape, covering more area where the bag contacts the flume bottom, while leaving much of the net top side open and exposed to flow. The shape of the gravel wedges differed between the stiff 1 mm precision netting and the 3.6 mm flexible netting. In the 1 mm net, increasing the gravel fill extended the wedge further towards the front end of the net without creating a large hump. In the 3.6 mm net, , increasing the gravel fill extended the height of the hump rather than extending the hump towards the front of the net (Figure 7, Figure 8).

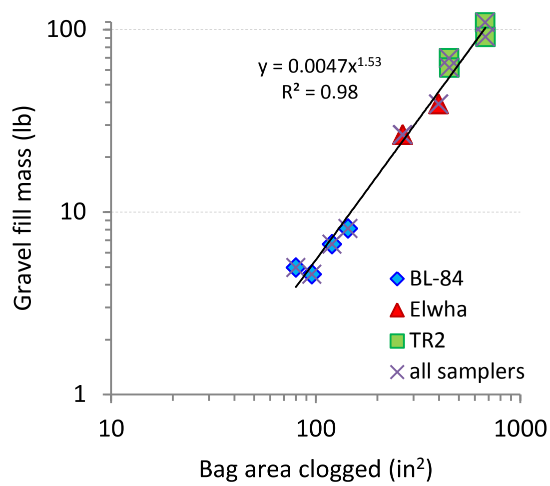


Figure 6: Relation between gravel fill mass and the surface area of the clogged portion of the bags.

Figure 7: Elwha sampler bags: Post-run side view of gravel wedge in the stiff 1-mm and the flexible 3.6 mm bags filled to 30% and 50% with gravel. In the 1 mm net, increasing the gravel fill extended the wedge further towards the front end of the net without creating a large hump. In the 3.6 mm net, the 50% gravel fill extended the height of the hump rather than extending the hump towards the front of the net. The Photo for 3.6 mm net with 50% fill was flipped vertically for comparison with the other photos.

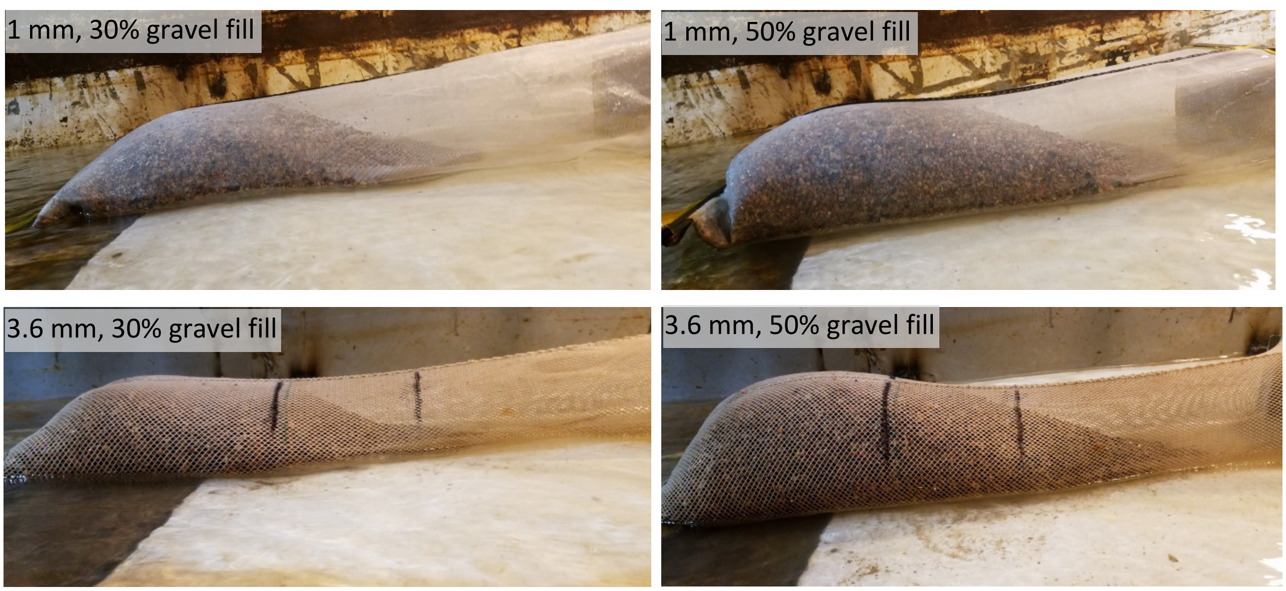


Figure 8: TR2 sampler bags: post-run side view of gravel wedge in a 1-mm and 3.6 mm bags filled to 30% and 50% with gravel. In the 1 mm net, an increased gravel fill extends further towards the front of the net while also increasing the hump. In the 3.6 mm net, much of the 50% gravel fill extends the size of the hump rather than extending the gravel fill towards the front of the net. Photos for 3.6 mm net with30 and 50% fill were flipped vertically.

2.5 Percent open area of a sampler bag (%Ao_{final})

2.5.1 Combined parameter to include several factors that affect bag openness

The through flow rate of a sampler bag is not only determined by the density of the weave *%Ao*, but also by the percent of the bag surface area blocked with organic material and gravel ($\%A_{clogged}$) as well as by broad, impermeable seams ($\%A_{seam}$). As stiffer material with wider mesh widths is used for netting, seams become broader especially if they are covered with cordura cloth to protect the netting material from unravelling. The areal extent of watertight seams blocked between 1 and 8% of the surface areas of the tested bags. Finally, the bag surface area through which water can pass is reduced by the contact between the bag and the channel surface, a factor not taken into account in the analyses.

The various sources of net blockage are likely additive in their effects on permeability of a sampler bag and prompted the mathematical combination of the three factors into a combined blockage parameter $\%Ao_{final}$. Its value was computed by subtracting the various blocked areas ($\%A_{clogged}$ and $\%A_{seam}$) from the % total bag area ($\%A_{tot}$) and multiplying the remaining percentage of unblocked area by the density of the weave (*%Ao*).

$$\%Ao_{final} = (\%A_{tot} - \%A_{clogged} - \%A_{seam}) \cdot (\%Ao) \qquad \text{(Eq. 2)}$$

For example, if 50% of a bag surface is entirely clogged by debris or gravel, and 4% of the bag surface area is covered by an impermeable seam, the remaining unclogged bag area of 100% - 50% - 4% = 46% is multiplied by the netting material's % open area of e.g., 57% *Ao*. The resulting final percent bag open area is then 46% · 0.57 = 26.2 $\%Ao_{final}$. The computed $\%Ao_{final}$ is inversely and linearly related to the % bag area clogged, with a specific relation for each netting material (Figure 9).

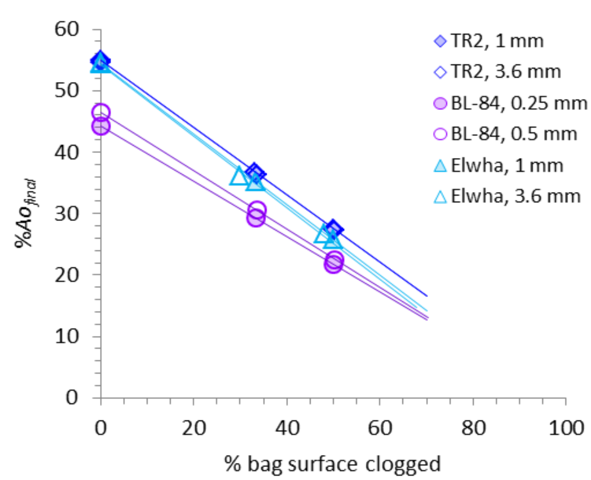


Figure 9: Relation of $\%Ao_{final}$ to % bag area clogged with a specific relation for each net.

Values of $\%Ao_{final}$ computed for the nets in this study ranged from 20 to 55% (Table 3), while leaving a wide gap between 55 and 100% Ao_{final}. It would have been scientifically interesting to fill this gap with at least a few data point and test nets with 70-90% Ao_{final}. Such values could be attained by very coarse nets. For example, a net with a 6 mm mesh and a 0.8 mm thread would have 73% Ao_{final} and a 10 mm net with 1.2 mm thread would result in 78% Ao_{final} (see open blue triangles in Figure 3), while a 25 mm mesh with 2.5 mm thread yields 83% Ao_{final}. For mesh widths of 0.5 to 2 mm, thread diameters that result in an Ao_{final} >70% produce nets too flimsy for use in gravel-bed streams unless flows are tranquil and gravel loads are very small. Considering their limited use, nets with Ao_{final} >70% were not included in the tests.

Table 3: Netting properties for bags used with the various samplers: Mesh widths, density of the weave (%*Ao*), percent of bag area clogged or blocked by liner or gravel fill (%$A_{clogged}$) and resulting % bag openness (%Ao_{final}).

Mesh width (mm)	%$A_{clogged}$	TR2 sampler			Elwha sampler			Mesh width (mm)	%$A_{clogged}$	BL-84 sampler		
		%Ao	%A_{seam}	%Ao_{final}	%Ao	%A_{seam}	%Ao_{final}			%Ao	%A_{seam}	%Ao_{final}
0.55	0	37.8	4	36	37.8	8	35	0.25	0	45.2	2	44
2	0	52.9	3	51	52.9	-	54	0.5	0	47.5	2	46
3.6	0	55.6	2	55	55.6	2	-	-	0	-	-	-
1	0	57.4	1	55	57.4	5	54	-	0	-	-	-
no net	-	100	-	100	100	-	100	no net	-	100	-	100
1	30	57.4	1	36	57.4	5	35	0.25	30	45.2	2	29
1	30	57.4	1	27	57.4	5	26	0.25	30	45.2	2	22
3.6	50	55.6	2	37	55.6	2	36	0.5	50	47.5	2	31
3.6	50	55.6	2	27	55.6	2	27	0.5	50	47.5	2	23

2.5.2 Unresolved matters of net blockages

Theoretically, the effects of seam blockage on hydraulic efficiency could be reduced if large seams were positioned along the bottom side of the net. Unfortunately, a bottom seam position faces practical obstacles. With the current sampler designs, thick-seamed sampler bags can only be attached with be seam along the sampler's central top side where the flaps squeezing the bag to the sampler body have a gap. Also, a thick seam placed along the bottom of the bag is subject to abrasion from rubbing against the channel bed and therefore undesirable.

Computations of a bag's %Ao_{final} did not include the contact area between the bag and the flume floor where water outflow is reduced. This area expands as gravel accumulates in the bag. Blockage by gravel fill is taken into account up to the computed fill level, but not over the size of the entire wedge.

Computations of %Ao_{final} were based on 33% clogging, but because net stretching during the flume experiments, 30% may be a more representative value for clogging. 50% was considered to be a representative value.

3. Methods and Testing

3.1 Facility and testing flume

Testing for this project was completed at Colorado State University's (CSU) Engineering Research Center (ERC) hydraulics laboratory. The experiments for this project were conducted in a tilting flume 6 feet wide, 4 feet deep, and 40 feet long. The flume is located approximately 12 feet above ground level in order to facilitate downward tilting and steep channel slopes (Figure 11). Water exits the flume in a free-fall section and lands in a walled tail box from which the flow is directed into a grated return to the underground sump.

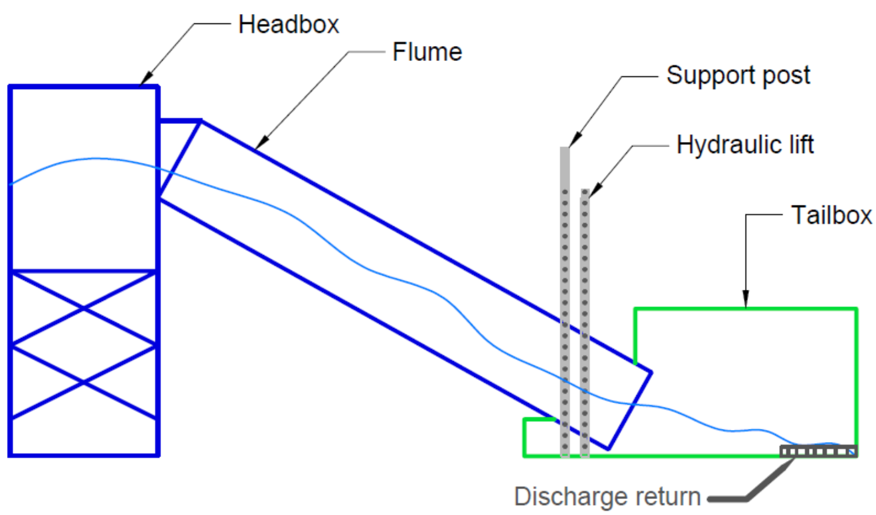


Figure 10: Tilting 6-ft flume used for testing. Diagram with slope exaggerated for illustration (top; from Klema (2017)). Photo showing testing flume during one of the runs (bottom).

3.1.1 Water supply and adjustment of flow

Three inlet pipes fed water into the head box at the upstream end of the flume. Two pipes with 24” and 12” diameters and equipped with pumps of 75 and 40 horsepower, respectively, delivered water from the large sump underneath the lab floor to the head box. Each of the two pumped lines had a bypass line to help prevent back-flow from the head-box when the pumps were shut off and to allow discharge to the flume to be adjusted via butterfly valves. The 12” pipe was equipped with a mag-meter that measured the discharge in the pipe by tracking the ions in the water. The 24” pipe was equipped with a Rosemount Annubar device that used pressure differential to measure the flow rate. The flow meters on each of the three pipes had digital readouts that displayed the volumetric flow-rates being delivered to the head-box. Readings could be made to $^{1}/_{100}$ of a cfs, hence accuracy of the readings was about $^{5}/_{1000}$ cfs. Readings from the mag-meter and the Annubar were used to provide basic flow settings. A run’s flow rate was then adjusted to obtain the specified target velocity and a 2.2 ft flow depth by operating the sluice gates at the downstream end of the flume (Figure 11). On a few occasions, a third pipe was engaged. This pipe has a 16” diameter and delivers water via gravity to the headbox directly from Horsetooth Reservoir above the city of Fort Collins and the ERC.

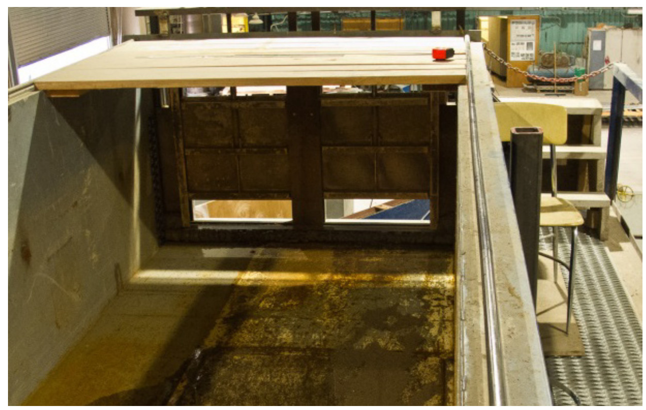


Figure 11: Head box of the 6-ft flume with three feeder pipes (left). Sluice gates at the downstream end of the flume (right).

3.1.2 Two series of flume experiments

The pipe system feeding the flume started to break down 2/3 of the way through the experiments and caused widely fluctuating flow velocities to be measured in front of the samplers for the runs with the highest target velocities. Repairs changed the discharge and pipe settings, and this would have caused difficulties in the comparison of pre- and post-repair flow velocities. It was therefore decided to conduct a second series of flume experiments and to use the opportunity of a new start to mitigate fluctuations in samped flow velocities by improving the flume set-up, the ADV equipment, and the sampling scheme. The set-ups for the first and seond series of flume experiments are decribed below.

3.1.3 Flume set-up

The gradient of the tilting flume was set with a slope of 0.0024° (0.0042 m/m). The flume was used over its full 6 ft width because a wide channel flume was preferable to lessen the hydraulic effects that walls would have on experiments. Flow depth was set to 2.2 ft for all runs to ensure that even the largest sampler was inundated by four times the sampler height. The downside of flow 6 ft wide and 2.2 ft deep was the high water demand that required multiple pumps to be running which caused slight variability in discharge and high turbulence of flow.

3.1.4 Flow straightener and diffuser/dampener

To straighten the turbulent flow as it exited the pumps in the head box, a flow straightener and diffuser/ dampener was constructed at the interface between the head-box and the flume (Figure 12). The flow straightener was built from an array of 2 ft long, 4 inch diameter, schedule 20 PVC pipe. These pipe baffles directed the flow downstream from the turbulent mixing that occurred in the head-box as the inlet pipes discharged into various directions. Preliminary testing had shown that without a flow

Figure 12: Flume inlet with pipe baffles to straighten flow and a diffuser to dampen it.

straightener, the bulk of the flow accelerated in the downstream direction and caused large changes in the lateral and vertical velocity components. A high spatial variability of flow in the testing section was to be avoided because it would make it more difficult to identify differences in the flow field caused by the deployment of different samplers with their various bags.

The flow diffuser/dampener was constructed from 2-inch *ScourStop*^{tm} and hung by chains from the flume rails. The *ScourStop*^{tm} dampened and reduced surface turbulence as well as effects of a hydraulic jump that occurred at the expansion of the flume width immediately downstream of the pipe baffles. The diffuser reduced water surface fluctuations at the testing location by 1-2 inches, as observed on a point gauge (depending on flow-rate) with the flow dampener in place.

3.1.5 Flume testing sections

The testing section for the first series of flume experiments was located 16 feet downstream from the head box (= 14 feet upstream of the sluice gates). The second testing section was moved 6 ft further downstream with its center located 22 feet downstream from the head-box (Figure 13).

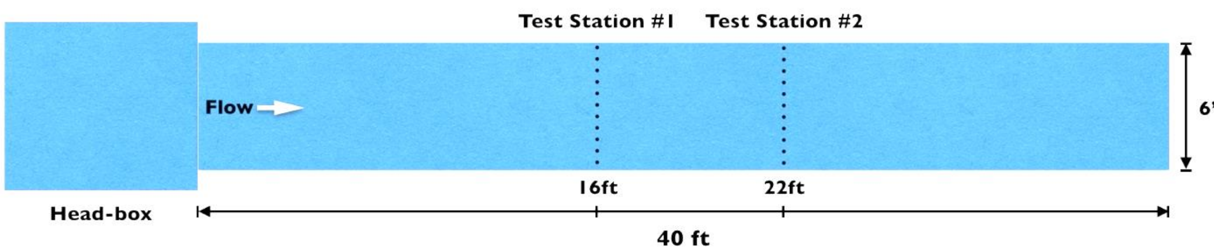


Figure 13: Schematic drawing of the flume with its two test sections (from: Klema, 2017).

3.1.6 Installation of a false floor and sampler deployment

The samplers had wall thicknesses of either ¼ or $^3/_8$ inch. When set onto the metal floor of the flume bed, the lip at the sampler entrance would have protruded into flow and introduced turbulence right at the sampler entrance. To avoid this lip—the effects of which would have been less on a rough gravel-cobble bed than in a smooth flume—a false floor was installed in the flume bottom that extended over the flume width and a downstream length of 12 ft in the central portion of the flume (Figure 14). At a distance of 8 ft downstream from the upstream end of the false floor, shallow cutouts were made that traced the outline of each sampler's body. Setting the samplers into their respective cutouts ensured a smooth transition between the flume bed and the sampler opening (Figure 15). For the second sampling section, the plywood subfloor and sampler cutouts were moved downstream.

The samplers were held in place in their cut-outs by a threaded piece of cast iron pipe which was bolted into the pipe fitting that otherwise receives the sampler handle. The upper end of the pipe was bolted through a piece of angle iron secured across the top of the flume.

Figure 14: Testing section of the first series of flume runs with false floor.

Figure 15: False floor installed in the flume center and the cutout for each sampler's shape (left) ensures a smooth transition of flow into the sampler opening (right).

3.2 Hydraulic measurements

3.2.1 Point gauge

A point gage was secured to a piece of horizontal angle iron placed across the flume four feet upstream of the first sampler testing section and set to touch the water surface at a flow depth of 2.2 ft. This flow depth was held constant for all runs and ensured that even the largest sampler, the TR2, was submerged in flow four times deeper than the sampler height. This point gauge was kept in place and served to maintain a consistent flow depth between runs at the upstream and the downstream testing sections.

3.2.2 Flow velocity measurements with ADV Vectrino

Velocity measurements in the first series of experiments as well as the velocity measurements at the upstream measurement section in the second series of flume experiments were made using a Nortek® Acoustic Doppler Velocimeter Vectrino (ADV). This instrument emits pulses of acoustic waves from a central emitter and then measures the time of return to four receptor arms that correspond to the x, y, z_1, and z_2 directions (the z direction is repeated for accuracy) in a Cartesian coordinate system. The acoustic bursts travel through the water column and are reflected off suspended particles in the water column. When the reflected acoustic burst returns to the receiving arms, the return time is calculated for each of the Cartesian directions. Software then calculates the fluid velocity in each direction. An average velocity for the time interval of data collection is determined during post-processing. The ADV measures velocity at a frequency of up to 200 cycles per second (Hz), and the typical range of operation is for fluid velocities between 0.03 and 4 m/s. The ADV is able to calculate velocities outside of this range, but the closer one approaches the limits of this instrument, the more the accuracy drops off.

For the first series of flume experiments, the ADV was mounted on a standard point gauge to ensure accurate and consistent measurement locations in both the horizontal and vertical directions for each run (Figure 16, left). The x-direction receiving arm of the ADV was mounted parallel with the walls of the flume, i.e., the dominant downstream flow direction. In order to collect flow velocity measurements as close as possible to the bedload sampler entrance (about 1 inch distance), the probe was mounted laterally to the point gage (Figure 16, right). The ADV was connected to a laboratory PC for data recording, and the entire data recording and measurement apparatus was placed onto a flume cart that served as a mobile testing platform from which the measurements were made.

3.2.2 Flow velocity measurements with ADV Vectrino II (Profiler)

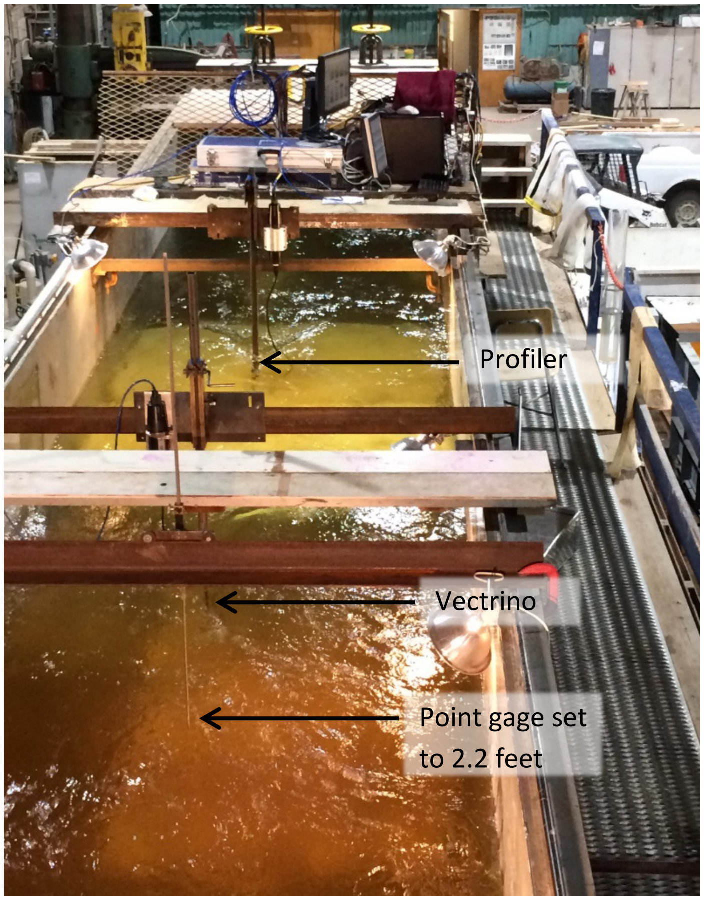
For the second series of flume runs, a Nortek® Acoustic Doppler Velocimeter Vectrino II (Profiler) was used which is more capable of collecting velocity measurements close to the bed. The instrument has the exact same overall dimensions and design as the Vectrino used in the first set of tests, and it was mounted on a standard point gauge in the same configuration as the Vectrino. The Profiler ADV relies on the same theory of acoustic pulses and travel time to determine flow velocities in the Cartesian directions, but instead of measuring the flow velocity at a single point in the water column, the Profiler measures up to 30 points simultaneously in a 3-cm section of a velocity profile in three Cartesian directions. While the Profiler was mounted to measure velocities at the entrance of the bedload

Figure 16: Point gage can be precisely positioned in space (left) and ADV mounted sideways on the point gage (right) to ensure close proximity to the sampler entrance.

samplers, the Vectrino was kept in its upstream place in the first test section to measure the target velocity, six inches above the flume bed in the centerline of the flume. The setup of the Profiler and Vectrino in the second series of flume experiments is shown in Figure 17 (left), and an example of data collection set up in Figure 17 (right).

3.2.3 ADV output

Sampling time for each velocity point was 1-2 minutes. The output from the ADV Vectrino included time-averaged flow velocity in the *x*, *y*, and *z* directions as well as the magnitude of the time-averaged velocity vector. Analyses in this study focused on the downstream v_x component. The magnitude of the time-averaged velocity vector was typically a fraction of a percent higher than v_x.



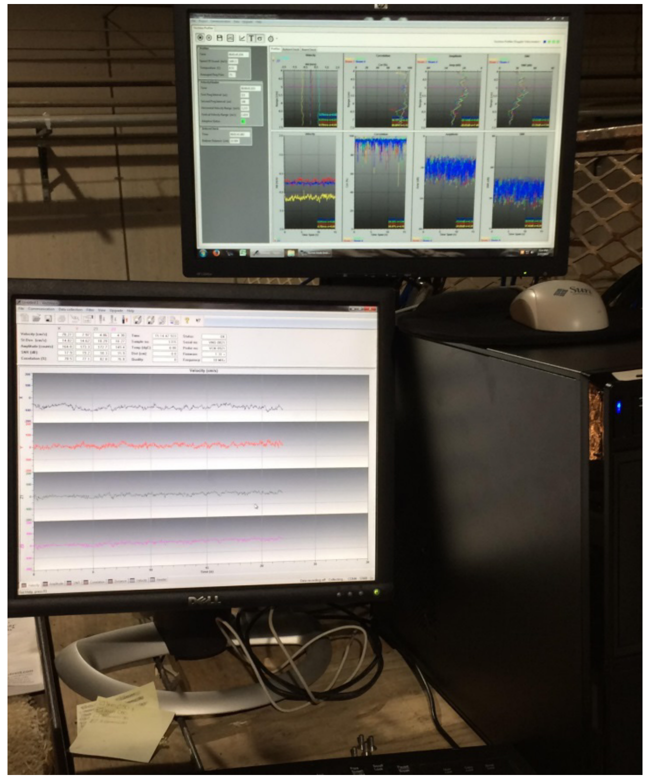


Figure 17: Setup during the second series of flume experiments. Downstream overview (left) of the flume channel and screen display of velocity measurements recorded with the Profiler (right).

4. Flume runs

4.1 Setting the target flow velocity

Target velocities for the flume runs were 1.5, 2.5, and 3.5 ft/s. The latter value was a reduction from the original value of 4 ft/s that could not be reliably maintained by the pumps and the supplemental flow from Horsetooth Reservoir. In a first approximation, the flume discharge Q was set such that the target velocity v_{tar} was obtained at $v_{tar} = Q/w \cdot h_{tar}$, where w is the flume width (= 6 ft) and h_{tar} is the target flow depth of 2.2 ft for all runs. Application of the continuity equation is not quite correct because $v_{tar} \neq v_m$, the depth-(and width) averaged flow velocity.

A decision needed to be made regarding the height above the flume bed at which v_{tar} was to be measured for each sampler. Two opposing considerations needed to be combined as part of thus decision: On the one hand, a statement “Samples were collected at a flow velocity of 2.5 ft/s” typically refers to a depth-averaged velocity, be that a cross-sectionally averaged v_m or the mean vertical velocity measured at a distance of 0.4 h from the ground. If v_{tar} was set equal to $v_m = Q/w \cdot h_{tar}$, then the near-bottom flow velocity a few inches above ground at the sampler opening would be considerably lower than v_{tar}. On the other hand, if v_{tar} was set to occur within the central part of each sampler, then v_m would be much higher than v_{tar}, and v_m would differ among samplers. As a compromise, v_{tar} was assigned to a flow depth h_{rep} of 6 inches above ground (Figure 18) for all samplers and all runs. That depth is lower ($h_{rep} = 0.225\ h_{tar}$) than the 0.4 h_{tar} (= 26.4·0.4 = 10.6 inches above ground) at which the depth-averaged mean velocity is expected to occur in a logarithmic velocity profile.

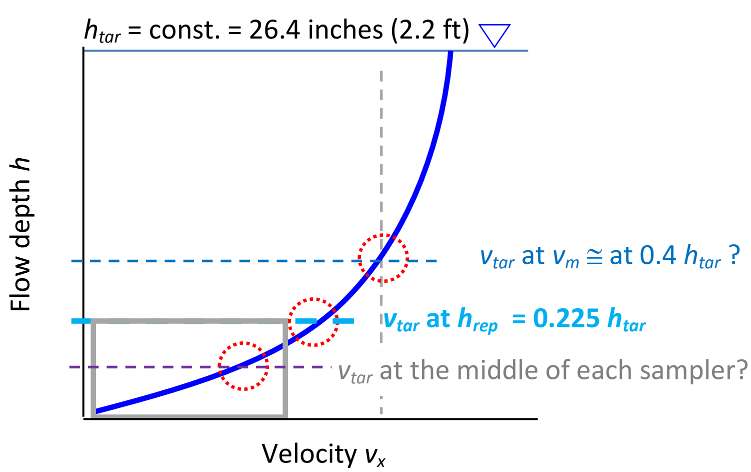


Figure 18: Setting the vertical location of target flow velocity.

Flume settings were adjusted to match the target velocity for runs with no sampler in the flume. The target velocity could not be checked in runs with a sampler installed because velocity measurements were located only a short distance upstream from a sampler and the velocity was affected by the presence of the samplers.

Discharges Q and mean (cross-sectionally averaged) flow velocities (v_m) associated with the three target velocities are listed in Table 4. Flow depth and flow width were constant at 2.2 ft and 6 ft, respectively. As a result, v_m increased linearly with Q. The target velocities at 6" above ground were slightly smaller than v_m but still increased linearly with Q. The product $v_m \cdot h_{tar}$ indicates the product number defined by Abt et al. (1989) to assess wadeability of a flow.

Table 4: Discharge and mean flow velocity for flume runs with the three target velocities. Values in parentheses refer to metric units.

v_{tar} (ft/s)	1.5	2.5	3.5
Q (cfs, m^3/s)	19.9 (0.56)	33.3 (0.94)	42.4 (1.20)
h_{tar} (ft, m)	2.2 (0.67)	2.2 (0.67)	2.2 (0.67)
w (ft, m)	6 (1.83)	6 (1.83)	6 (1.83
v_m (ft/s, m/s)	1.66 (0.51)	2.78 (0.85)	3.54 (1.08)
Q/w ($m^3/m\cdot s$)	3.32 (0.32)	5.55 (0.52)	7.08 (0.67)
$h_{tar}\cdot v_m$ (ft^2/s)	3.7	6.1	7.8

4.2 Comparison of flume hydraulics with natural stream channels

In order to place the flow conditions of the flume experiments into context with natural conditions, flow depth and unit discharge $q = Q/w$ obtained in the flume were compared with data from a wide range of Rocky Mountain and other streams. For a target velocity of 1.5 ft/s, the combination of a flow depth of 2.2 ft/s = 0.67 m and a unit flow of 0.52 m^2/s obtained in the flume did not match conditions encountered in natural streams very well (Figure 19). For target velocities of 2.5 and 3.5 ft/s, flume conditions matched the upper range of natural streams, i.e., conditions in relatively deep reaches.

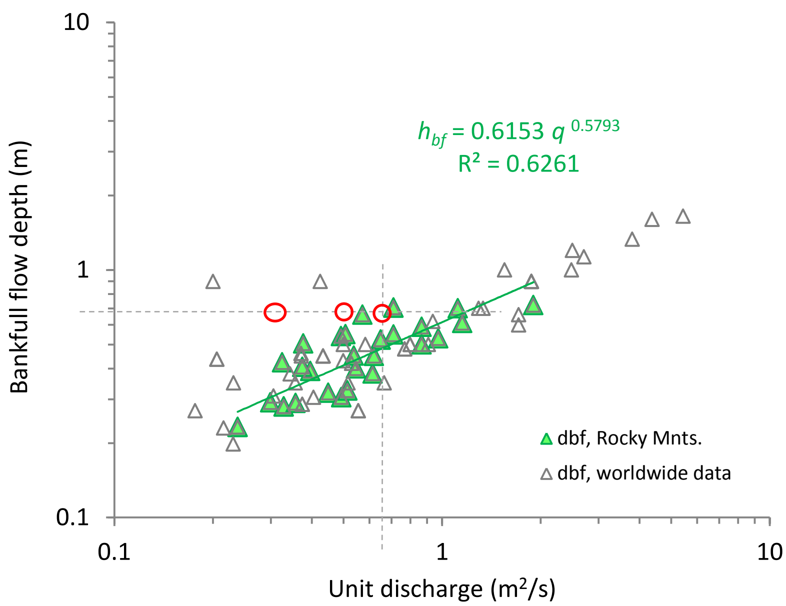


Figure 19: Relation of bankfull flow depth and bankfull unit discharge for Rocky Mountain and worldwide streams. Red circles represent flume conditions for the three target velocities. The triangle closest to the right red circle represents a stream site with partially stagnant flow at Halfmoon Creek, CO.

Among Rocky Mountain streams, a 0.67 m flow depth at a bankfull unit flow of 0.67 m^2/s might be obtained in a locally deep and low-gradient section of Halfmoon Creek, CO, for example, a mid-sized gravel-bed stream that is on average 9 m wide, has a bankfull discharge near 6.1 m^3/s and drains a 61 km^2 basin area. Typically, a bankfull flow depth of 0.67 m is associated with larger streams and unit discharges of 1.1 to 1.2 m^2/s. A vertically averaged flow velocity of 3.5 ft/s (1.07 m/s) is also somewhat slow for the central part of a Rocky Mountain stream channel. In short, flow conditions obtained at v_{tar} = 3.5 ft/s in the flume might be encountered at bankfull flow in a locally deep and slowly flowing section of a mid-sized Rocky Mountain stream where wadeability is exceeded at 70-80% of bankfull flow.

4.3 Sampling schemes

Two different sampling schemes were used for the two series of flume experiments. The sampling schemes are explained below.

4.3.1 Vertical sampling scheme for first series of flume experiments

During the first series of experiments, a detailed matrix of flow velocities was measured in front of each sampler. Within a vertical, the near-bottom velocity is more important for a sampler's efficiency of collecting gravel bedload than velocities higher in the water column, hence vertical measuring points were spaced more closely near the bottom of the sampler and wider near the top. The bottom point was fixed at 0.5 inches above ground for all samplers, while the highest point was set near 83% of each sampler's height. The lowest point at 0.5 inches above ground amounted to 8.3% of the sampler's height for the TR2, 12.5% for the Elwha, and 16.7% for the BL-84. The remaining points were placed to approximate an exponential function of measuring location with height above ground for each sampler (Figure 20).

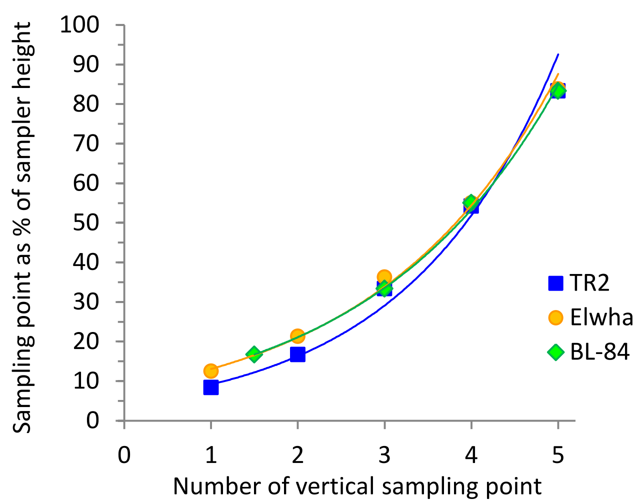


Figure 20: Vertical arrangement of velocity measurement points for each sampler

4.3.2 Lateral sampling scheme for both series of flume experiments

The sampling scheme featured nine verticals for the TR2 and the Elwha samplers. Three verticals covered the central part of the sampler opening at 25, 50, and 75% of the sampler width. Four verticals were close to the inside and the outside sampler walls (at about 1 inch distance), while the remaining two verticals were further away from the sampler walls mirroring the distance of the 25 and the 75% locations inside the sampler (Figure 21).

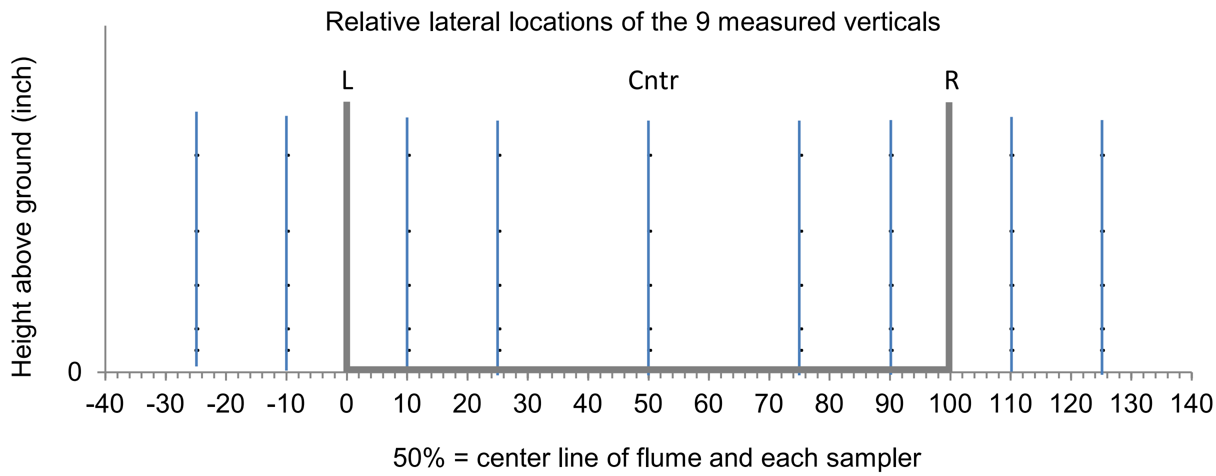


Figure 21: Lateral arrangement of sampled verticals in relation of the TR2 and Elwha sampler's width.

The sampling scheme with a matrix of 45 points was overly dense for the BL-84 with its small 3 by 3” opening. The matrix was therefore reduced to seven verticals with four points each, a total of 28 points. Because the point matrix was set in relation to the dimensions of the sampler entrance, absolute sampling locations differed among samplers. The point matrices for the three samplers are shown below (Figure 22).

In the flume, the test matrix for each sampler translated into x-y coordinates of a point gage to which the ADV was mounted. An appropriate offset in the point gage ensured that the ADV head (rather than the point gage tip) was at the specified point.

4.3.3 Testing matrix for second series of flume runs

Analyses of the first set of flume experiments had indicated that velocities measured at 2” above ground (see Section 5.4) were suitable for comparison of hydraulic efficiency among samplers and their bag configurations. With respect to a comparison of flow velocity among samplers, among target velocities and among bag configurations, not much more useful information appeared to have been gained from (laboriously) measuring 5-point velocity profiles at the sampler entrance than was likely to be gained from measuring velocity at one representative location per vertical. Also, considering that the need for second series of flume experiments was unplanned and unbudgeted, the study could only afford to

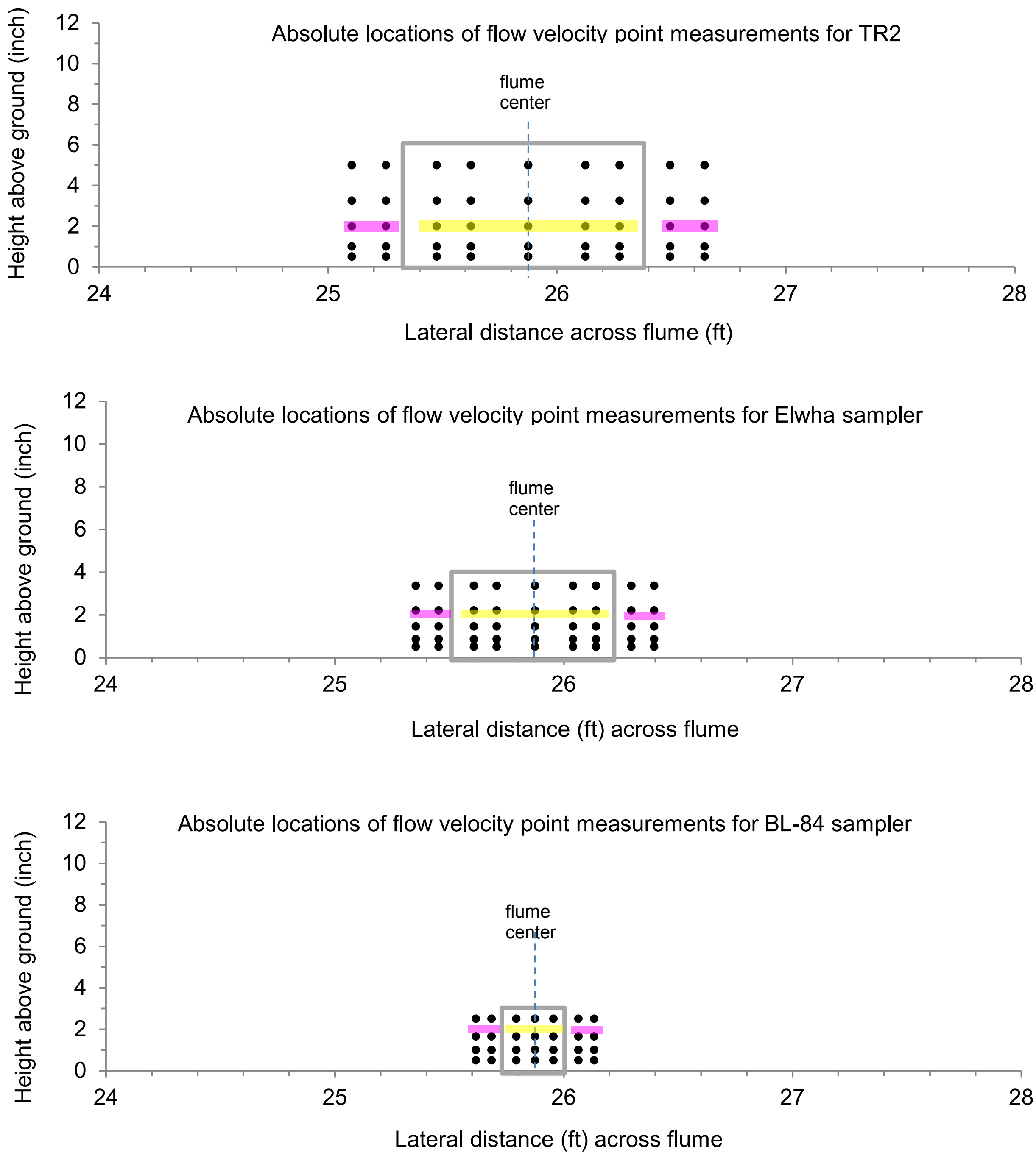


Figure 22: Absolute location of measured velocity points within the matrix for each sampler. Colored bars mark the data points (or their value interpolated for a measuring height of 2" above ground) within the inside (yellow) the sampler ($v_{xin,2}$) and the outside (pink) of each sampler ($v_{xout,2}$).

measure v_x at one height per vertical. Hence, velocity measurements in the second series of flume experiments were conducted at the same verticals as in the first series (Figure 22), but at a constant height of 2 inchs above ground for each vertical and for all samplers. Taking only one measurement per vertical reduced the number of sampled points by 75-80%, and this allowed us to include tests with clogged nets for all target velocities and all samplers. The test matrix for all flume runs is listed in Table 5. Conducting two series of flume experiments more than doubled the number of runs originally planned.

Table 5: Test matrix of flume runs conducted for the study. Runs within the first series of experiments are indicated by gray coloring. Runs within the second series of experiments are indicated by ”x”. Numbers of runs in parentheses refer to first series of runs.

Test configuration					BL-84 (3”x 3”)			Elwha (8” x 4”)			TR2 (12” x 6”)			# of Runs
		Velocity (f/s)			Velocity (f/s)			Velocity (f/s)			Velocity (f/s)			
		1.5	2.5	3.5	1.5	2.5	3.5	1.5	2.5	3.5	1.5	2.5	3.5	
No sampler					x	x	x	x	x	x	x	x	x	9
													Total:	**9**
Flume runs to evaluate the effects of nets with various mesh widths														
BL-84	no net				x	x	x							3
	0.25 mm				x	x	x							3
	0.5 mm				x	x	x							3
Elwha	No net							x	x	x				3
	0.5 mm							x	x	x				3
	1 mm							x	x	x				3
	3.6 mm							x	x	x				3
TR2	No net										x	x	x	3
	0.5 mm										x	x	x	3
	1 mm										x	x	x	3
	2 mm										x	x	x	3
	3.6 mm										x	x	x	3
													Total:	**36**
Flume runs to evaluate the effects of mesh clogging for various mesh widths														
BL-84	0.25 mm	30% clogged			x	x	x							3 (2)
		50% clogged			x	x	x							3 (2)
	0.5 mm	30% clogged			x	x	x							3 (2)
		50% clogged			x	x	x							3 (2)
Elwha	1 mm	30% clogged						x	x	x				3 (2)
		50% clogged						x	x	x				3 (2)
	3.6 mm	30% clogged						x	x	x				3 (2)
		50% clogged						x	x	x				3 (2)
TR2	1 mm	30% clogged									x	x	x	3
		50% clogged									x	x	x	3
	3.6 mm	30% clogged									x	x	x	3
		50% clogged									x	x	x	3
													Total:	**36 (28)**
													Grand total:	**77 (69)**

4.3.4 Hydraulic variability among flume runs

Discharge typically varied by only a few percent among runs. Those variations were generally on the lower side when flume settings remained the same among runs, and the only alteration was to shut the flume on and off for an exchange of samplers and their bags. More variability among runs was probably introduced by the high turbulence of flow exiting the head box than by discharge fluctuations. This turbulence caused lateral shifts in the flow field within the lower central part of the flume where measurements were taken.

5. Data analysis

Data analysis focused on condensing the matrix of velocities measured in the flume into single values of a hydraulic parameter that could subsequently be compared to the various configurations of samplers, bags, and target velocities (Sect. 6). This entailed vertical and lateral averaging of measured velocities.

5.1 Plotted velocity profiles

Flow velocity measured at all 45 points of the sampling matrix for the TR2 and the Elwha sampler (28 points for the BL-84) during the first series of flume experiments was plotted as velocity profiles, color-coded for lateral position. An example for the TR2 sampler at a target velocity of 2.5 ft/s is shown in the left panel of Figure 23. All measured velocity data are provided in separate tables for each sampler, each net, each fill level and each target velocity in the appendix.

5.2 Lateral averaging of vertical velocities

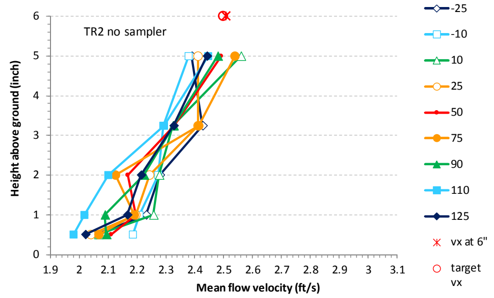
The shape of individual velocity profiles was affected by local turbulence, and this caused profiles not only to differ between neighboring verticals but also not to be symmetrical along the sampler center line. Those disturbances were smoothed out by averaging verticals laterally. Another reason for lateral averaging was that flow velocities among samplers, target velocities and bag configurations were easier to compare for lateral averages that represent a sampler section than for functions that might describe the lateral change of flow velocity over a sampler.

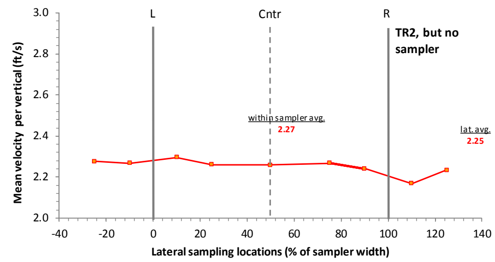
Velocity measured at the five (or three for the BL-84 sampler) verticals within a sampler (marked by yellow bars in Figure 22), as well as at the four verticals outside of a sampler (marked pink bars in Figure 22), and at the three central verticals in within a sampler at 25, 50, and 75% of its width were combined into lateral averages. All subsequently computed hydraulic parameters were computed as those lateral averages. For the BL-84 sampler, only three verticals were measured inside the sampler, rendering results for inside verticals and central verticals identical.

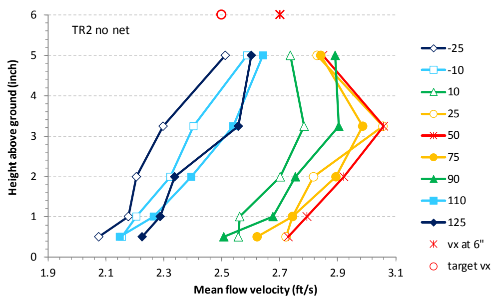
5.3 Vertically averaged and integrated hydraulic parameters

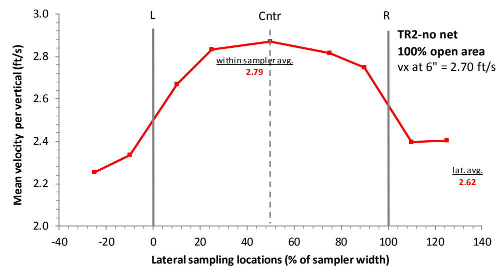
In order to compare flow velocity measurements on a vertical (v_{xy}) among runs with different samplers, bag configurations, and target velocities, the measurements needed to be expressed as some hydraulic parameter that either averages or integrates over all vertical measurement points or otherwise selects a representative vertical location for the measurements before lateral averaging (Section 5.2).

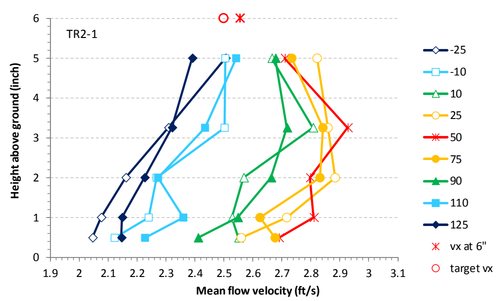
Figure 23: Velocities measured at the 45-point matrix for six TR2 for runs with a target velocity of 2.5 ft/s and bags unclogged. Open symbols refer to verticals left of the center, closed symbols to vertical right of the flume center (left panels). Vertically averaged velocity of each vertical plotted on the lateral sampling locations (right panels). The % open area refers to the netting material. THE FIGURE IS PRESENTED BELOW.

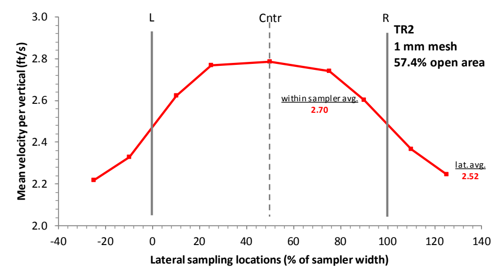

TR2 no sampler
Height above ground (inch)
Mean flow velocity (ft/s)
-25
-10
10
25
50
75
90
110
125
vx at 6"
target vx

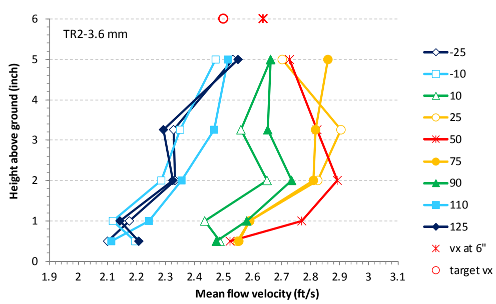

L
Cntr
R
TR2, but no sampler
within sampler avg.
2.27
lat.avg.
2.25
Mean velocity per vertical (ft/s)
Lateral sampling locations (% of sampler width)

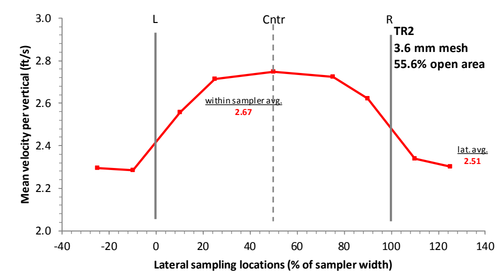

TR2 no net
Height above ground (inch)
Mean flow velocity (ft/s)
-25
-10
10
25
50
75
90
110
125
vx at 6"
target vx

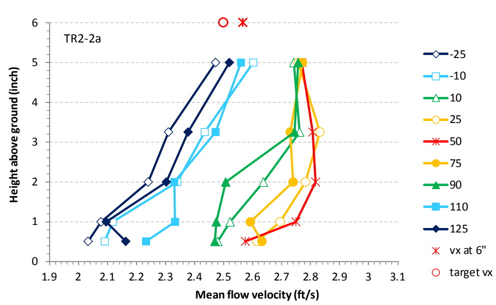

L
Cntr
R
TR2-no net
100% open area
vx at 6" = 2.70 ft/s
within sampler avg.
2.79
lat.avg.
2.62
Mean velocity per vertical (ft/s)
Lateral sampling locations (% of sampler width)

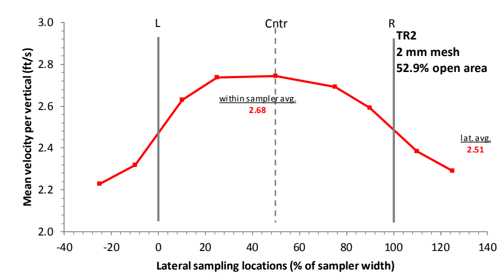

TR2-1
Height above ground (inch)
Mean flow velocity (ft/s)
-25
-10
10
25
50
75
90
110
125
vx at 6"
target vx

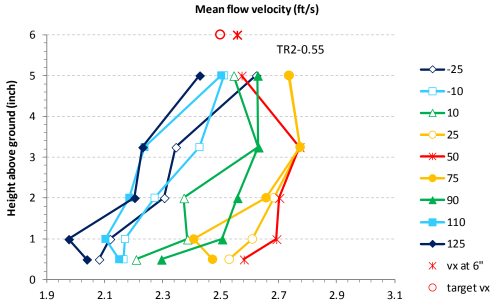

L
Cntr
R
TR2
1 mm mesh
57.4% open area
within sampler avg.
2.70
lat.avg.
2.52
Mean velocity per vertical (ft/s)
Lateral sampling locations (% of sampler width)

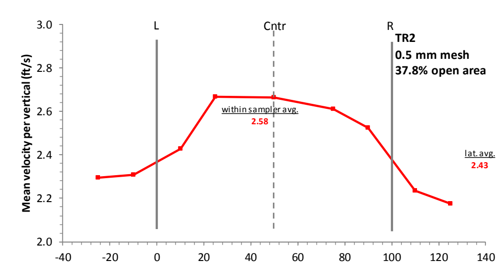

TR2-3.6 mm
Height above ground (inch)
Mean flow velocity (ft/s)
-25
-10
10
25
50
75
90
110
125
vx at 6"
target vx


L
Cntr
R
TR2
3.6 mm mesh
55.6% open area
within sampler avg.
2.67
lat.avg.
2.51
Mean velocity per vertical (ft/s)
Lateral sampling locations (% of sampler width)


TR2-2a
Height above ground (inch)
Mean flow velocity (ft/s)
-25
-10
10
25
50
75
90
110
125
vx at 6"
target vx


L
Cntr
R
TR2
2 mm mesh
52.9% open area
within sampler avg.
2.68
lat.avg.
2.51
Mean velocity per vertical (ft/s)
Lateral sampling locations (% of sampler width)


TR2-0.55
Height above ground (inch)
Mean flow velocity (ft/s)
-25
-10
10
25
50
75
90
110
125
vx at 6"
target vx


L
Cntr
R
TR2
0.5 mm mesh
37.8% open area
within sampler avg.
2.58
lat.avg.
2.43
Mean velocity per vertical (ft/s)
Lateral sampling locations (% of sampler width)

5.3.1 Vertically-averaged velocities

In a first step of analysis, a vertically averaged velocity was computed as the arithmetic mean over all measured points within the vertical; hence, all measured points exerted equal influence on the mean value. This procedure placed more emphasis on the near-bottom sampling points that were sampled more tightly spaced than the points towards the roof of the sampler. This practice was considered acceptable because near-bottom velocities exert a greater influence on bedload sampling efficiency than flow velocities near the sampler's roof. The vertically averaged velocities were plotted over the sampled width in front of the samplers. Examples for the TR2 sampler at a target velocity of 2.5 ft/s are shown on the right panel of Figure 23.

5.3.2 Discharge passing inside and outside of a sampler

From the velocity profiles measured in the first series of flume experiments, discharge passing through the inside and the outside of a sampler was computed by first multiplying a vertical's point velocity v_{xv} by the height increment associated with a data point (i.e., half the distance to the next point above and below). The representative heights for the lowest and the highest sampling points were bounded by the limits of the sampler body (Figure 24). Subsequently, each vertical discharge increment was multiplied by the respective width increment (i.e., half the distance of the left and right neighbor). For the two verticals outside of the samplers, half the distance to the next vertical facing towards the sampler was added along the side facing away from the sampler to arrive at a representative width increment. Finally, all discharge increments were summed over the areas inside and outside of the sampler.

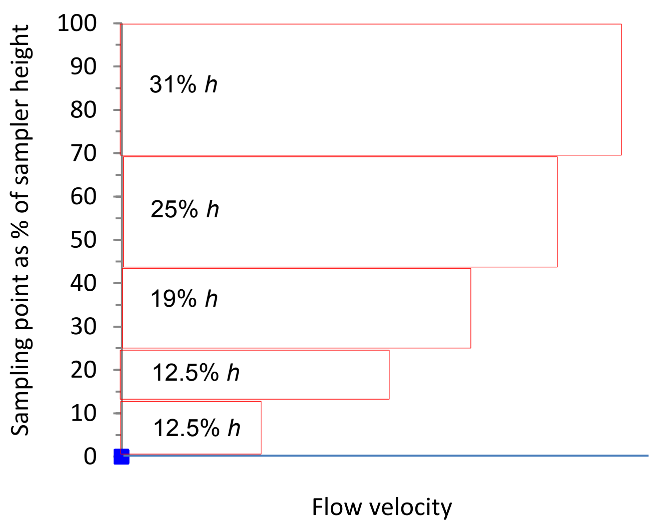


Figure 24: Percentage of depth represented by each vertical sampling point within the point matrix measured for the TR2 sampler.

5.3.3 Shear stress

Shear stress τ_0 can be computed from the steepness of a velocity profile as $\tau_0 = (0.4\ a)^2$, where a is the coefficient of a logarithmic function fitted to the velocity profile $v_{xv} = a \cdot \ln(h) + b$ where v_{xv} is the velocity measured at a specified height in the vertical averaged over all verticals inside the sampler, and h is the flow depth. In the presence of a bedload sampler, the velocity at the top point of the profile is slowed down by the wall effect from the sampler roof, and that point was excluded from the fitted logarithmic regression. τ_0 was then laterally averaged over the verticals inside the sampler ($\tau_{0,in}$).

For a set of runs with various bag configurations for a specified sampler and target velocity, shear stress, i.e., the steepness of the velocity profile, was found to be related either negatively or non-monotonically to flow velocity measured in front of the samplers, and τ_0 was also unrelated to the permeability of the various nets ($\%Ao_{final}$). Those unexplained results as well as doubt that the shape of velocity profiles—that seemed highly affected by local hydraulics within the sampler—would actually affect sampled gravel bedload transport rates prompted us to drop further analyses of shear stress and focus our attention on other hydraulic parameters.

5.4 Vertically representative velocity at 2” above ground

5.4.1 Selection of a height above ground for inter-sampler comparison

If a single velocity measurement is selected for comparison among all samplers, target velocities, and bag configurations, the selected height should be fixed and should not influenced from wall effects at a sampler’s roof, nor should the sampling height be affected by measuring problems close to the bed. A fixed elevation of 2” above ground was selected as a representative velocity ($v_{x,2}$) within a vertical for all samplers. A higher elevation was not suitable because it would approach the upper rim of the 3” by 3” BL-84 sampler. Velocities measured at 0.5” above ground likely had uncertainty due to near-bed turbulence and were close to the limit to which the ADV can measure near the ground. Considering that inter-sampler effects were to be evaluated in this study, a measuring height of 2” above ground provided a good compromise between avoiding effects from the near-bottom and the sampler roofs.

5.4.2 Velocity profiles, their shapes, and fitted regressions

For the first series of flume experiments, *v*elocity profiles were laterally averaged over the five inside verticals (3 verticals for the BL84) for each run, as well as over the four outside verticals and the central three verticals and plotted over the sampling height *h*. Examples of the velocity profiles $v_{xin,h} = f(h)$ are shown in Figure 25 and Figure 26.

For the case when no sampler was present in the flume, laterally averaged velocity profiles were best described by logarithmic functions in the form of $v_x = a \ln(h) + b$ (Figure 25). Those profiles are relatively similar among “samplers” because the only difference is that the velocity points were measured at different point matrices (Figure 22). Ideally, the no-sampler velocity profiles for a specified target velocity would be almost identical among “samplers”, and any variability indicated hydraulic variability among flume runs.

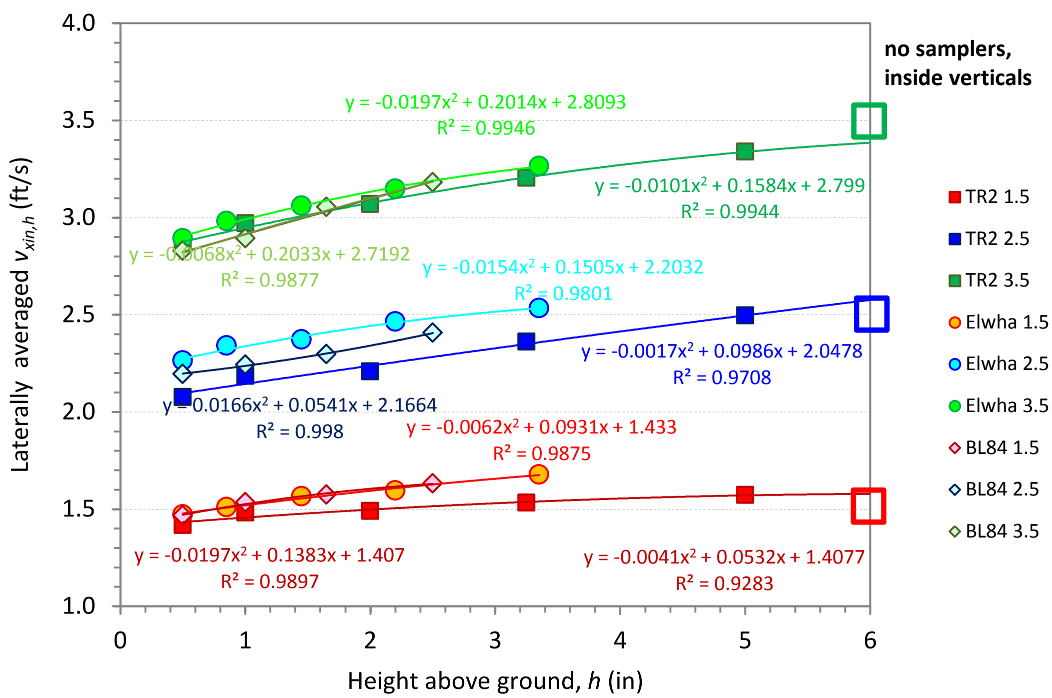


Figure 25: Velocity profiles averaged over the verticals measured inside of each sample at the three target velocities with no sampler in the flume.

Velocity profiles measured in the presence of samplers were more curved than those measured without samplers. For the Elwha and the TR2 samplers, the velocity at the top of the profile was almost as slow as the bottom point, and flow was fastest slightly above the each sampler's midpoint. The parabolic shape of the velocity profiles was best described by second-order polynomial functions in the form of $y = ax^2 + bx + c$ for which r^2 exceeded 0.9 in 50 out of the 73 runs (Figure 26). Velocities were generally highest for the TR2 sampler but profiles were most strongly curved for the Elwha (the *a*-term of the fitted polynomial functions was approximately twice as large for the Elwha than the TR2). Velocities were lower for the small opening of the BL-84 sampler. The profile curvature is similar to those for the Elwha, but maximum velocities for the BL-84 occurred towards the top rather than near the center of the sampler. Velocity profiles were most strongly curved for the samplers with no net, followed by samplers with the 3.6 mm net attached. Curvature also increases with the target flow velocity in the flume.

5.4.3 Intrapolation of $v_{x,2}$ from regression functions

The velocity at a height *h* = 2" above ground was computed for verticals inside ($v_{xin,2}$), outside ($v_{xout,2}$), and within the center of each sampler ($v_{ctr,2}$) for each run by solving the fitted polynomial regression for *x* = 2. Values of $v_{x,2}$ were also interpolated for the runs with the TR2 sampler, for which v_x had been actually measured at 2" above ground. Interpolation smoothed out slight irregularities in the velocity profiles. During the second series of experiments, the velocity was measured at 2" above ground ($v_{xin,2}$).

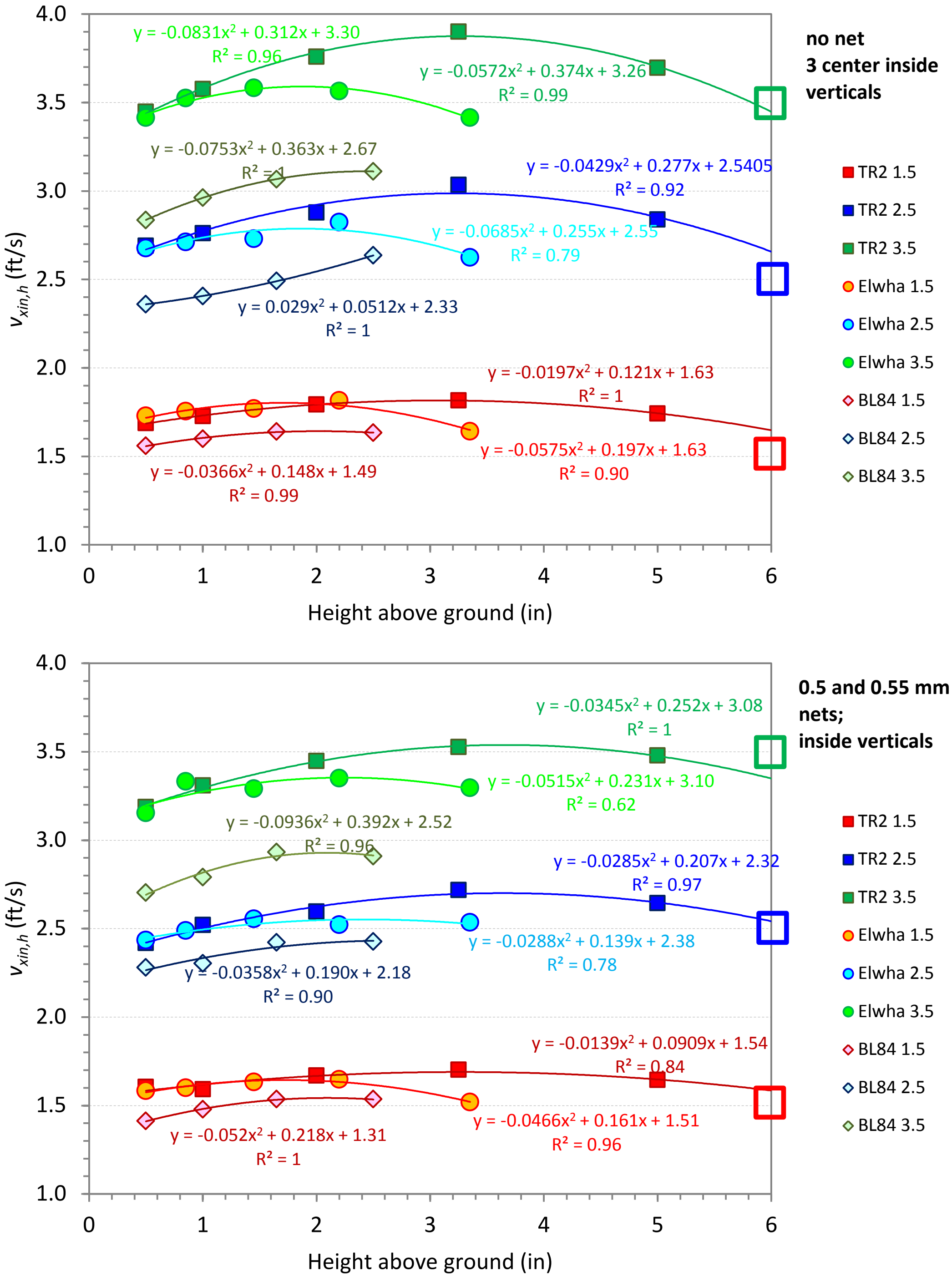


Figure 26: Velocity profiles averaged over the verticals measured in the inside of the samplers at the three target velocities for similar sampler-bag configurations for all three samplers: samplers with no net (=100% Ao_{final}) (top panel) and unclogged 0.55 and 0.5 mm nets with Ao_{final} values of 34 to 45% (bottom panel).

5.4.4 $v_{x,2}$ determined from the central and for all inside verticals

Whether $v_{x,2}$ is determined from the center 3 or all 5 inside verticals had no effect on the accuracy of the value for $v_{x,2}$. The velocity profile laterally averaged over the three center verticals visually looked as smooth as the velocity profile averaged over all verticals inside the sampler. Values of r^2 from the polynomial regressions fitted to profiles from either the three central or all five inside verticals differed unsystematically by a few % between individual runs, but those differences averaged out over all runs conducted for one target flow velocity. Hence, narrowing the focus laterally did not increase the uncertainty in to the estimate of $v_{x,2}$.

5.4.5 Comparison of $v_{xin,2}$ with vertically averaged velocity $v_{xin,m}$

In order to determine whether the velocity at 2" above ground ($v_{x,2}$) indeed provided a representative parameter to characterize the velocity averaged over the velocity profiles ($v_{x,m}$), $v_{xin,2}$ was regressed against the vertically averaged velocity $v_{xin,m}$ for the inside verticals (Figure 27). The regression of $v_{xin,2}$ against $v_{xin,m}$ showed a linear relation almost parallel to the 1:1 line. $v_{xin,2}$ was 0.05 ft/s larger than $v_{xin,m}$ at a target velocity of 1.5 ft/s (3.3%) and 0.08 ft/s larger at a target velocity of 3.5 ft/s (2.2%). Basing the analyses on $v_{xin,2}$ or $v_{xin,m}$ affected neither a comparison of v_x among samplers nor among bag configurations, and only very slightly deemphasized differences among target velocities. Results confirmed that velocities measured at 2" above ground (see Section 5.4) were suitable for comparison of flow velocity and hydraulic efficiency among samplers and their bag configurations.

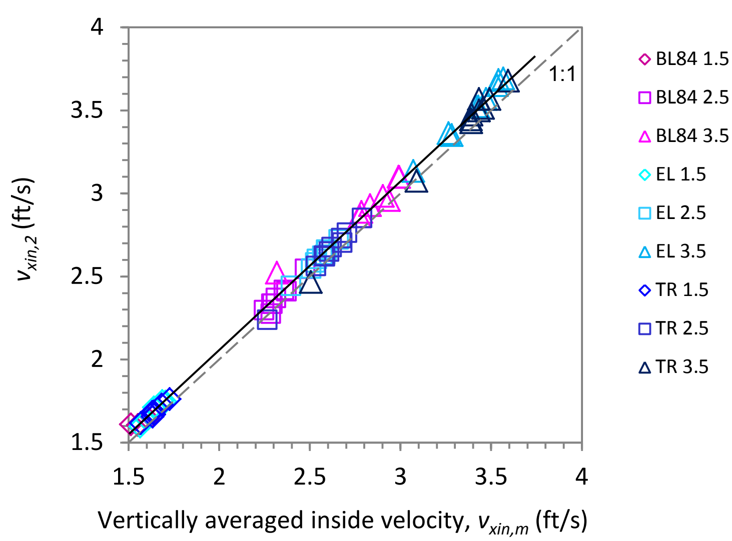


Figure 27: Linear relation between $v_{xin,2}$ and $v_{xin,m}$, both measured during the 1st series of flume experiments.

5.5 Hydraulic efficiency

Hydraulic efficiency is the ratio of v_x measured in the presence of a sampler to the velocity v_{xNS} measured at the same flume locations in the absence of a sampler. Hydraulic efficiency is the parameter best suited for the analysis of the sampler-and-bag performance because the predominant influence of target velocity on any measured velocity is avoided by using velocity ratios. Hydraulic efficiency (HE) is expressed as a percentage; a 1:1 ratio of v_x/v_{xNS} is defined as 100% and computed as

$$HE(\%) = v_x \cdot 100/v_{xNS}. \qquad \text{(Eq. 4)}$$

Computation of hydraulic efficiency seemed most representative when based on $v_{xin,2}$, the flow velocity measured 2” above ground and averaged over all inside verticals in the second series of flume experiments (Section 5.2). Hydraulic efficiency based on $v_{xin,2}$ is accordingly termed $HE_{in,2}$.

5.6 Graphical presentations of hydraulic parameters and $\%Ao_{final}$

Basis for evaluating the effects of sampler entrance area, target flow velocity and the combined % net open area ($\%Ao_{final}$) on flow velocity measured in front of each sampler and its various bag configuration were plots of various hydraulic parameters vs. the combined % net open area ($\%Ao_{final}$). Flow velocity and the various hydraulic parameters computed from it were either averaged over all inside and all outside verticals, or focused on the center three verticals.

The patterns used for plotted data points of some hydraulic parameter vs. $\%Ao_{final}$ reflected a net’s mesh widths with a coarser pattern for a coarser mesh and a finer pattern for a finer mesh width. An open symbol was selected when no net was attached to the sampler (= 100$\%Ao_{final}$). The same patterns were used for all plots of hydraulic parameter vs. $\%Ao_{final}$ throughout Section 6, except for the relations of discharge vs. $\%Ao_{final}$ for which mesh width was not indicated. It seemed reasonable to present the velocity (or any other hydraulic parameter) measured in the flume in the absence of a sampler as well. For lack of a better alternative, those no-sampler values were plotted along the y-axis but using a different symbol to indicate that those data points are not part of the relations of some hydraulic parameter = $f(\%Ao_{final})$.

5.7 A note on terminology: “sampler entrance area” and “sampler size”

This study frequently refers to the entrance area of bedload samplers a being an important parameter that influences flow hydraulics entering the sampler. Please note that use of the terminology “sampler entrance area” or “sampler size” is not general, but refers specifically to the three pressure-difference samplers tested in this study, the BL-84, Elwha, and TR2, all of which have expansion ratios of 1.4. The size of the sampler entrance area is a much less important parameter with respect to influencing flow hydraulics when dealing with unflared sampler bodies (expansion ratio = 1), such as bedload traps.

6. Results and Discussion

Presentation of study results starts with describing the general attributes of the relations between a hydraulic parameter (such as $v_{x,2}$, discharge, and hydraulic efficiency) and $\%Ao_{final}$ in Sections 6.1 to 6.3. The effects of specific nets with their specific fabric properties and degrees of net blocking and fill on the relations of $v_{x,2} = f(\%Ao_{final})$ are discussed in Section 6.4. Most of the results obtained from this study are based on the second series of flume experiments.

6.1 Relations of $v_{x,2}$ with $\%Ao_{final}$

Relations between downstream flow velocity measured in front of a sampler 2" above ground ($v_{x,2}$) and the various degrees of sampler bag openness ($\%Ao_{final}$) were examined for three lateral sampling locations: the average of all verticals measured inside the sampler ($v_{xin,2}$) (Section 6.1.1 - 6.1.3), of the three central verticals ($v_{xctr,2}$) (Section 6.1.4), and of the four verticals outside the sampler walls ($v_{xout,2}$) (Section 6.1.5). Note that velocity was measured 1-inch upstream from the sampler opening, hence wording of "inside", "center", and "outside" of a sampler refers to a 1-inch upstream extension of the sampler body. Please also note that the term "vertical" is used to denote the sampling location even if velocity was measured at only one height within a vertical.

6.1.1 Determining the function type to describe the relations of $v_{xin,2} = f(\%Ao_{final})$

Flow velocity $v_{xin,2}$ averaged over all verticals measured inside the sampler showed an increasing trend with $\%Ao_{final}$ for all samplers and all target velocities (Figure 28). The trends of the relations $v_{xin,2} = f(\%Ao_{final})$ rose steeply for low values of $\%Ao_{final}$ (20-40%) and flattened over the range of 60 to 100% Ao_{final}. At very low values of $\%Ao_{final} < 10$, that might be attained when a sampler bag is almost clogged, $v_{xin,2}$ is likewise expected to reach very low values.

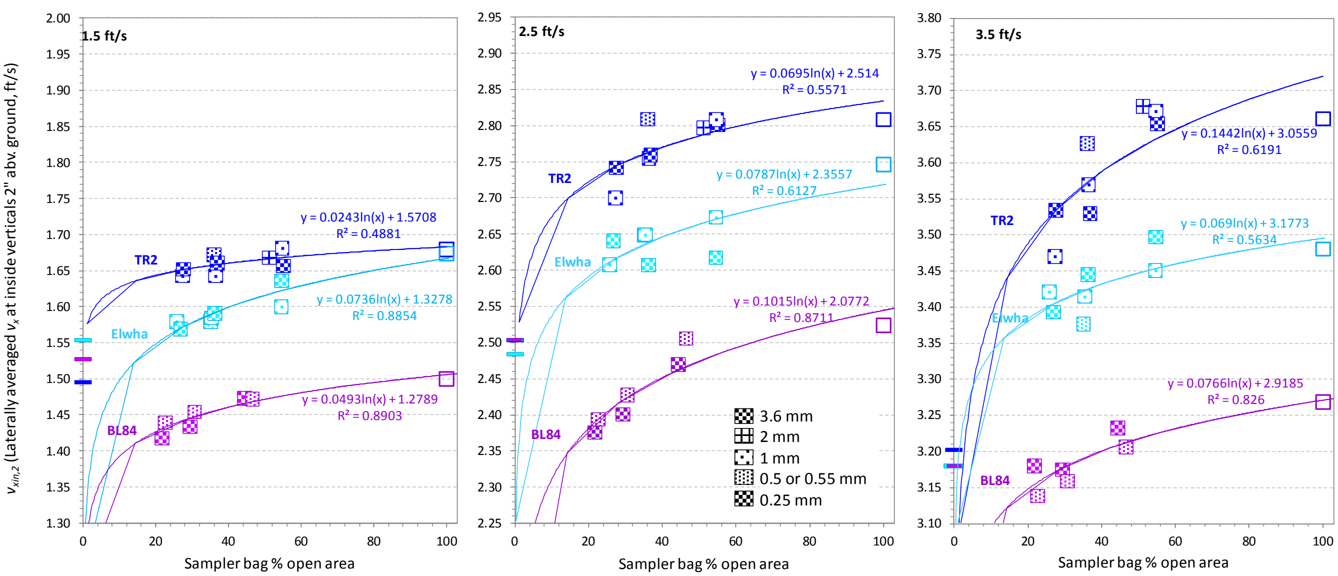


Figure 28: Relations of $v_{xin,2} = f(\%Ao_{final})$ for the average of all inside verticals. Values of $v_{xin,2}$ measured with no sampler present in the flume are plotted on the y-axis. For each target velocity, values of $v_{xin,2}$ are plotted over the same range of $v_{xin,2}$. The legend in the top row center panel indicates mesh size and refers to all panels.

Several considerations went into selecting the functions with which to describe the relations of $v_{xin,2}$ vs. $\%Ao_{final}$. This study selected logarithmic (as well as power) functions because they generally describe steeply increasing and then flattening trends. However, logarithmic (and power) functions fitted to the data of $v_{xin,2}$ vs. $\%Ao_{final}$ overpredicted measured values of $v_{xin,2}$ at 100 $\%Ao_{final}$ (i.e., when no net was attached to the sampler) in several cases. One option was to ascribe the misfit to data scatter and keep the choice of logarithmic (or power) functions. If, however, the misfit was considered systematic and grounds for rejecting logarithmic (or power) functions, then a steep rising trend with subsequent flattening could also indicate a broken function. In this case, the steep and flat branches of the relations $v_{xin,2} = f(\%Ao_{final})$ would need to be fitted with separate functions connected by a joining algorithm. This measure was not practicable in this study because only a few data points would have fallen onto each branch. Besides, data were not evenly spread over the range of $\%Ao_{final}$.

Another option was to describe the relations $v_{xin,2} = f(\%Ao_{final})$ by second order polynomial functions. Their fitted regressions described the data range between 20 and 60 $\%Ao_{final}$ quite well with r^2-values notably higher than those obtained from the fitted logarithmic functions. However, second order polynomial functions failed to describe very low values of $v_{xin,2}$ expected for very low values of % Ao_{final}. Not much practical consequence would have resulted from this misfit because bedload samplers are typically not used when entirely clogged, but it seemed unacceptable that the fitted relations would not accurately describe the entire data range. Furthermore, fitted polynomial functions had the tendency to peak between 60 and 100 $\%Ao_{final}$ but there is no physical explanation for such a peak in the relation of $v_{xin,2} = f(\%Ao_{final})$.

Logarithmic functions obtained slightly higher r^2-values than power functions and best captured the steeply rising and then flattening trend. The latter factor weighed in most in the selection of a function type. Hence, logarithmic functions in the form of

$$v_{xin,2} = a \ln (\%Ao_{final}) + b \qquad \text{(Eq. 3)}$$

were fitted to the relations of $v_{xin,2} = f(\%Ao_{final})$ averaged over the verticals measured within the inside of the samplers. Plotted logarithmic functions (Eq. 3) had similar shapes among the three samplers and the three target velocities but differed notably in their *y*-axis offset and slightly in steepness (Figure 29).

6.1.2 Relative effects of target velocity, sampler size and $\%Ao_{final}$ on $v_{xin,2}$

Target velocity, sampler entrance area, and net openness ($\%Ao_{final}$) all affected measured values of $v_{xin,2}$, and the next step was to determine which parameter exerted the most control. The approximately parallel course of the nine fitted logarithmic functions $v_{xin,2} = f(\%Ao_{final})$ (Figure 29) justified to base the comparison of $v_{xin,2}$ among samplers and target velocities on one specific value of $\%Ao_{final}$. The value of 50% Ao_{final} was selected because most nets used for bedload sampler bags likely have a bag openness of near 50%. Values of $v_{xin,2}$ were predicted for 50% Ao_{final} (bottom part of Table 6) from the *a*- and *b*-coefficients of the fitted logarithmic regressions (top part of Table 6). Slightly different values of $v_{xin,2}$

would have been predicted for 30 or 60% Ao_{final} but since the analyses were based on percent increases, results would not have been significantly different.

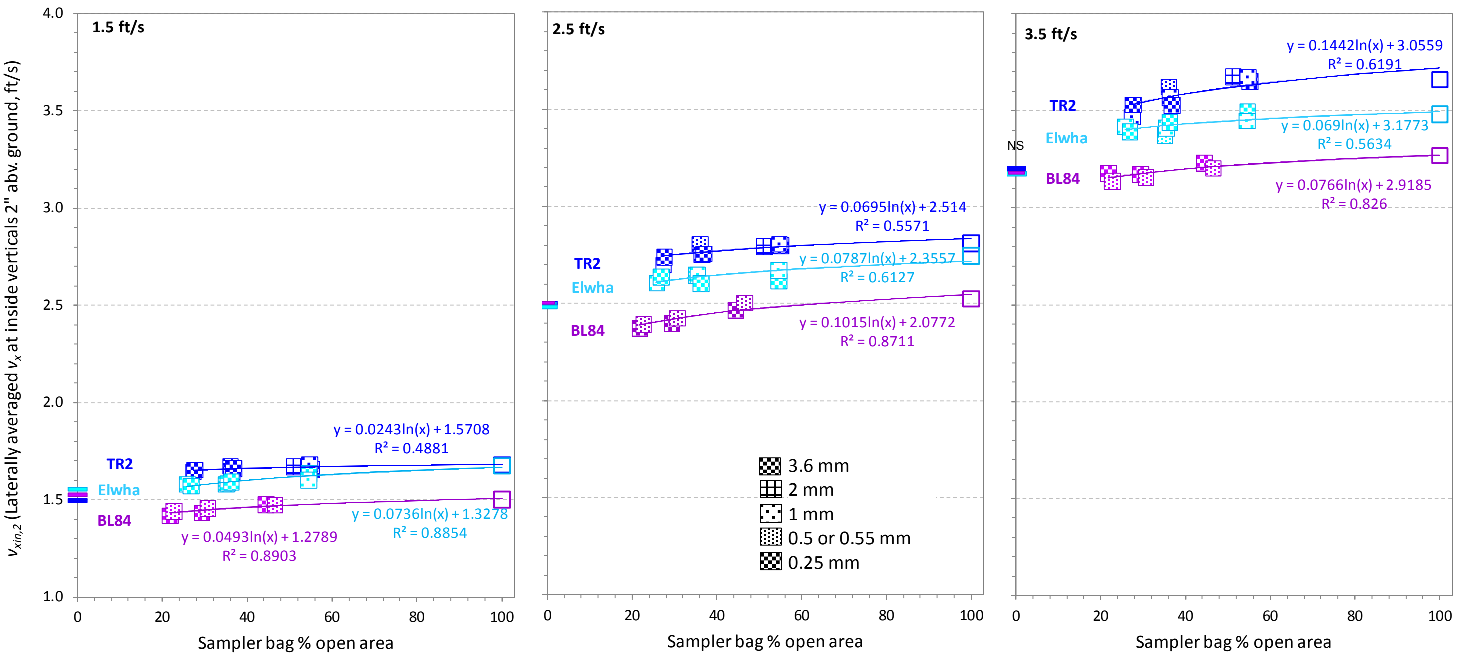


Figure 29: Logarithmic regression functions fitted to the relations of $v_{xin,2} = f(\%Ao_{final})$ computed for the $v_{xin,2}$ averaged over the inside verticals. To improve visual comparison of $v_{xin,2}$ among target velocities and samplers, all data were plotted over the same range of $v_{xin,2}$. The legend in the center panel indicates mesh width and refers to all panels.

Table 6: Regression coefficients (a, b) of logarithmic functions $v_{xin,2} = a \ln(Ao_{final}) + b$ averaged over all inside verticals.

Target velocity (ft/s)	TR2		Elwha		BL84	
	a	*b*	*a*	*b*	*a*	*b*
1.5	0.0243	1.5708	0.0654	1.3615	0.0493	1.2789
2.5	0.0695	2.5140	0.0787	2.3557	0.1015	2.0772
3.3	0.1442	3.0559	0.0690	3.1773	0.0766	2.9185

$v_{xin,2}$ (ft/s) for all inside verticals predicted for 50% Ao_{final}

Target velocity (ft/s)	Samplers and their entrance area (in^2)		
	TR2 (72)	Elwha (32)	BL-84 (9)
1.5	1.67	1.62	1.47
2.5	2.79	2.66	2.47
3.3	3.62	3.45	3.22

Visually, Figure 29 suggested that $v_{xin,2}$ was mainly determined by the target velocity and to lesser degrees by sampler entrance area and bag openness ($\%Ao_{final}$). The relative effects of target velocity and sampler size on $v_{xin,2}$ were quantified by computing how much $v_{xin,2}$ at a value of 50% Ao_{final} would increase following a doubling in target velocity and in sampler size. Similarly, the relative effect of bag openness on $v_{xin,2}$ was assessed by computing the response of $v_{xin,2}$ to a doubling in $\%Ao_{final}$.

The well-defined linear relations of $v_{xin,2}$ vs. target velocity showed direct proportional increases in $v_{xin,2}$ with target velocity (Figure 30) for all three samplers. Averaged over the three samplers, a doubling in target velocity from 1.5 to 3 ft/s (= increase by 100%) resulted in a 85% increase in $v_{xin,2}$ (Table 7).

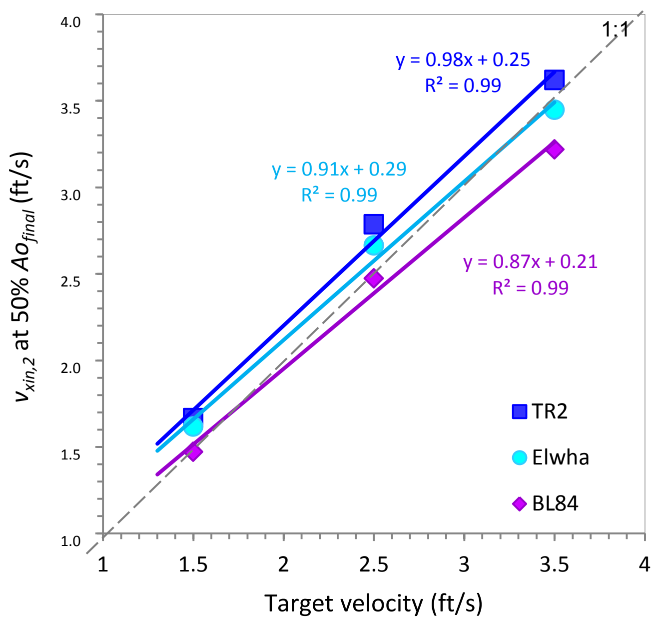


Figure 30: Relations of $v_{xin,2}$ predicted for 50% Ao_{final} with target velocity for the three samplers.

Table 7: Increase (%) in $v_{xin,2}$ due to doubling (=100% increase) in affecting parameters

Sampler	$2 \cdot v_{xtar}$ (ft/s)	v_{xtar} (ft/s)	$2 \cdot A_{sampler}$ (in^2)	$2 \cdot \%Ao_{final}$ for TR2	Elwha	BL-84
TR2	85.5	1.5	4.1	1.0	2.9	2.4
Elwha	82.6	2.5	3.9	1.8	2.1	2.9
BL-84	86.5	3.5	3.9	2.8	1.4	1.7
mean	**84.9**	**mean**	**3.9**	**1.9**	**2.1**	**2.3**

The likewise very well defined relations of $v_{xin,2}$ vs. sampler entrance area showed that a doubling in sampler entrance area (from 30 to 60 in^2) increased $v_{xin,2}$ by 4% averaged over the three target velocities (Figure 31, left panel; Table 7). Of more practical value than doubling the entrance area is stepping up from a BL-84 to an Elwha sampler which is a 2.25 fold increase in entrance area and resulted in a 4.6% increase in $v_{xin,2}$. Stepping up from a BL-84 to a TR2 sampler increases the entrance area eightfold and resulted in an increase of $v_{xin,2}$ by about 13%.

When assessing the effects of sample entrance area, it was assumed that sampler height played the predominant role, while width was less important. However, the relations of $v_{xin,2}$ vs. the sampler height (Figure 31, right panel) showed a knickpoint, indicating that the increase in $v_{xin,2}$ depended on sampler entrance area rather than sampler entrance height alone. Hence, sampler width also affected $v_{xin,2}$ in

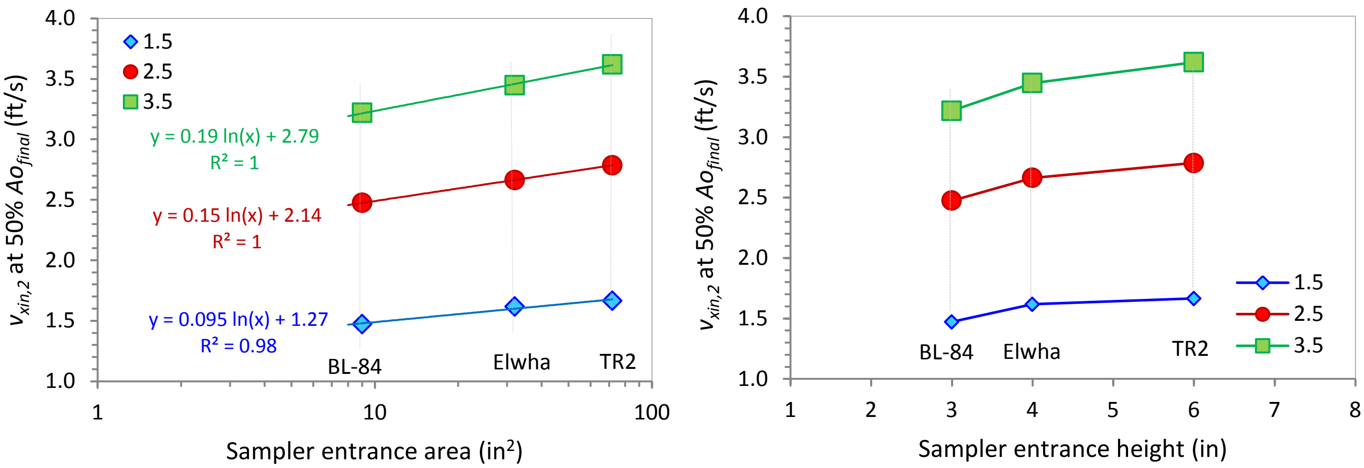


Figure 31: Relation of $v_{xin,2}$ predicted for 50% Ao_{final} with sampler entrance area (left) and sampler height (right) for three pressure difference samplers with 1.4 expansion ratios.

front of a sampler. Based on sampler entrance height alone, one might have expected that the relations of $v_{xin,2} = f(\%Ao_{final})$ were more similar between the BL-84 and the Elwha because the height of both samplers differed by just 1 inch. However, while the BL-84 is only 3 inch wide, the Elwha is 8 inch wide. Those results suggested that not only protrusion into fast flow but sampler width as well influenced $v_{xin,2}$ in front of a sampler.

To evaluate the effect of doubling the degree of net openness on $v_{xin,2}$, $v_{xin,2}$ was predicted from the logarithmic functions of $v_{xin,2} = f(\%Ao_{final})$ in Figure 29 for 30 and 60% Ao_{final} which represents the central range of Ao_{final}. Here, doubling of net openness increased $v_{xin,2}$ by 1-3% for all samplers and target velocities with an average of 2% (Table 7). The effect of net openness on $v_{xin,2}$ would have been slightly larger had a steeper part of the functions of $v_{xin,2} = f(\%Ao_{final})$ been evaluated, e.g., a doubling from 20 to 40% Ao_{final}.

Taken together, the study showed that $v_{xin,2}$ was primarily determined by the ambient flow velocity. Doubling the sampler entrance area increased $v_{xin,2}$ by 4%, but switching from a BL-84 to an Elwha sampler increased $v_{xin,2}$ by 4.6%, while switching from a BL-84 to a TR2 increased by $v_{xin,2}$ by 13%. By comparison, the 2% decrease in $v_{xin,2}$ resulting from densely woven or half-clogged nets was small; netting properties exerted about half the influence on $v_{xin,2}$ as sampler entrance area.

6.1.3 Comparison of $v_{x,2} = f(\%Ao_{final})$ between the three center and all inside verticals

Flow velocity inside the sampler bodies was slowed along the sampler walls, hence $v_{xctr,2}$ averaged over the center 3 verticals (Figure 32) was faster than $v_{xin,2}$ averaged over all inside verticals (Figure 28). (Note that $v_{xin,2}$ and $v_{xctr,2}$ were identical for the BL-84 sampler because velocity was measured on three verticals only for the BL-84 sampler). The difference between $v_{xctr,2}$ and $v_{xin,2}$ at 50% Ao_{final} amounted to about 2% for the TR2 at all target velocities and to 1-2% for the Elwha sampler.

Apart from quantifying the difference in velocities between the inside and the center of the bedload samplers, another reason for comparing $v_{xctr,2}$ and $v_{xin,2}$ was to determine whether data scatter was less if analyses were based on the central verticals, in which case subsequent analyses would have focused on $v_{xctr,2}$. The logarithmic functions fitted to the relations of $v_{xctr,2} = f(\%Ao_{final})$ (Figure 32) were steeper (i.e., *a*-coefficients increased by 15 to 31%) than the respective curves for $v_{xin,2} = f(\%Ao_{final})$ (Figure 28). This indicated that net openness ($\%Ao_{final}$) had a slightly larger effect on $v_{xctr,2}$ than on $v_{xin,2}$ (i.e., the values of 1.9 and 2.1% for $v_{xin,2}$ in Table 7 increased to 2.1 and 2.7% for $v_{xctr,2}$). The steeper regression functions for $v_{xctr,2}$ in Figure 32 produced slightly higher r^2-values than those $v_{xin,2}$ in Figure 29, but visually, data scatter around the fitted regression of $v_{xctr,2} = f(\%Ao_{final})$ was not less than for $v_{xin,2} = f(\%Ao_{final})$. Also, the plotting locations of individual data points in relation to other data points did not shift significantly depending on whether the analyses were based on the three central or on all inside verticals. Taken, together, there were no compelling reasons to focus further analyses on $v_{xctr,2}$ rather than $v_{xin,2}$.

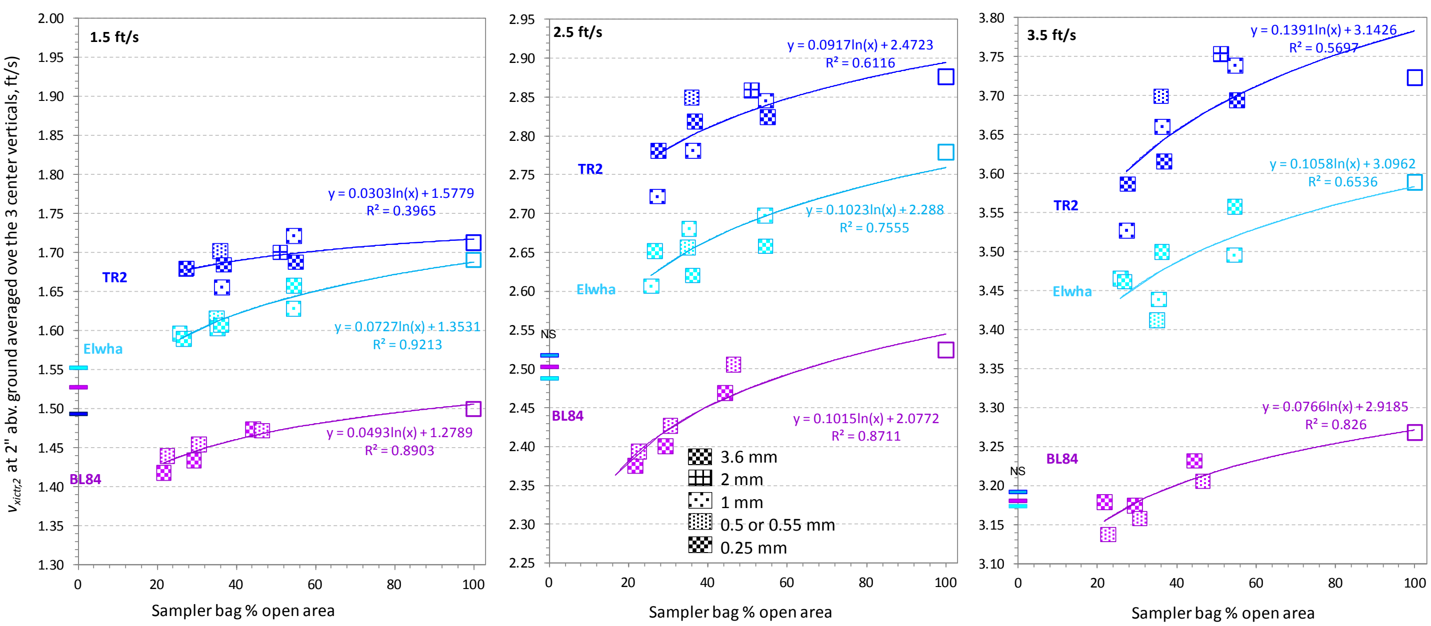


Figure 32: Relations of $v_{xctr,2} = f(\%Ao_{final})$ for the average of the center 3 verticals. Values of $v_{xctr,2}$ measured with no sampler present in the flume are plotted on the *y*-axis. In analogy to Figure 28, $v_{xctr,2}$ was plotted over a different range for each target velocity, but in the same absolute scale for all target velocities. The legend in the center panel refers to all panels.

6.1.4 Comparison of $v_{x,2}$ between inside and outside verticals

The velocities averaged over the four verticals outside the sampler entrance ($v_{xout,2}$) were likewise plotted vs. $\%Ao_{final}$ (Figure 33). Values of $v_{xout,2}$ were considerably slower than values of $v_{xin,2}$ (Figure 28) for the Elwha and the TR2 that suck flow into the samplers, but largely similar for the narrow BL-84 sampler. Relations of $v_{xout,2}$ with $\%Ao_{final}$ were mostly positive, but lacked well defined trends.

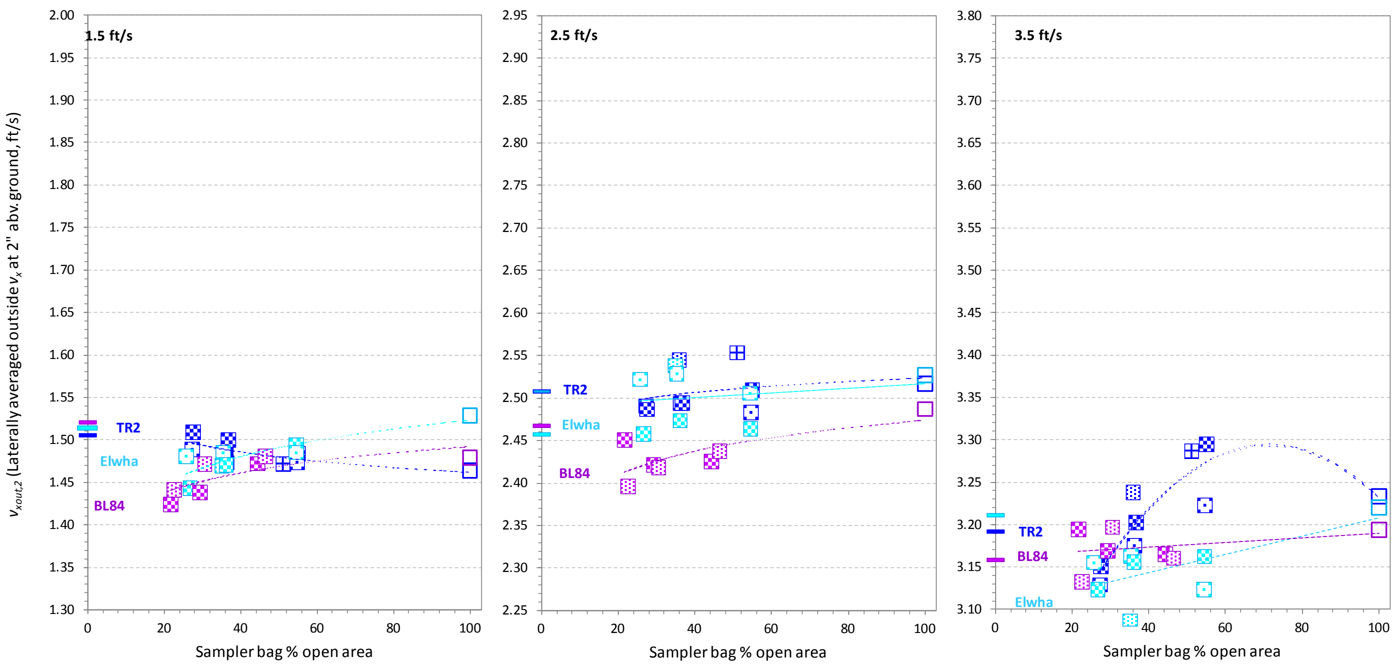


Figure 33: Relations of $v_{xout,2} = f(\%Ao_{final})$. Values of $v_{xout,2}$ measured with no sampler present in the flume are plotted on the *y*-axis. For each target velocity, $v_{xout,2}$-values are plotted in the same scale as in Figure 28. The dashed best-fit regression lines for $v_{xout,2} = f(\%Ao_{final})$ serve to guide the observer's eye to the data points for a specific sampler.

More interesting than measured values of $v_{xout,2}$ are the ratios between $v_{xin,2}$ and $v_{xout,2}$ ($=R_{in/out}$) that approximate hydraulic efficiency. The relations of $R_{in/out}$ with $\%Ao_{final}$ differed among samplers (Figure 34). The logarithmic functions fitted to $R_{in/out} = f(\%Ao_{final})$ showed that target velocity had no systematic effect on $R_{in/out}$, $R_{in/out}$ increased with the sampler entrance area and with $\%Ao_{final}$. Based on the fitted functions $R_{in/out} = f(\%Ao_{final})$, $v_{xin,2}$ was 1.10 - 1.11 times higher than the $v_{xout,2}$ for the nets with 50% Ao_{final} on the TR2 sampler and 1.12 - 1.13 times higher for the TR2 with unclogged nets. The $R_{in/out}$ ratios for the Elwha sampler dropped to around 1.05 - 1.09 for nets 50% clogged and to 1.07 - 1.09 for unclogged nets. For the BL-84 sampler, $R_{in/out}$ ratios were around 0.99 for the 50% clogged nets and 1.02 for unclogged nets. The range of $R_{in/out}$ reported for a specified degree of net clogging and a specified sampler reflected the unsystematic effects of target flow velocity. Overall, results suggested that among equally flared pressure-difference samplers, sampler entrance area affected the $R_{in/out}$ ratios more than bag openness. The effects of target flow velocity were of similar magnitude as the bags' percent open areas, but unsystematic.

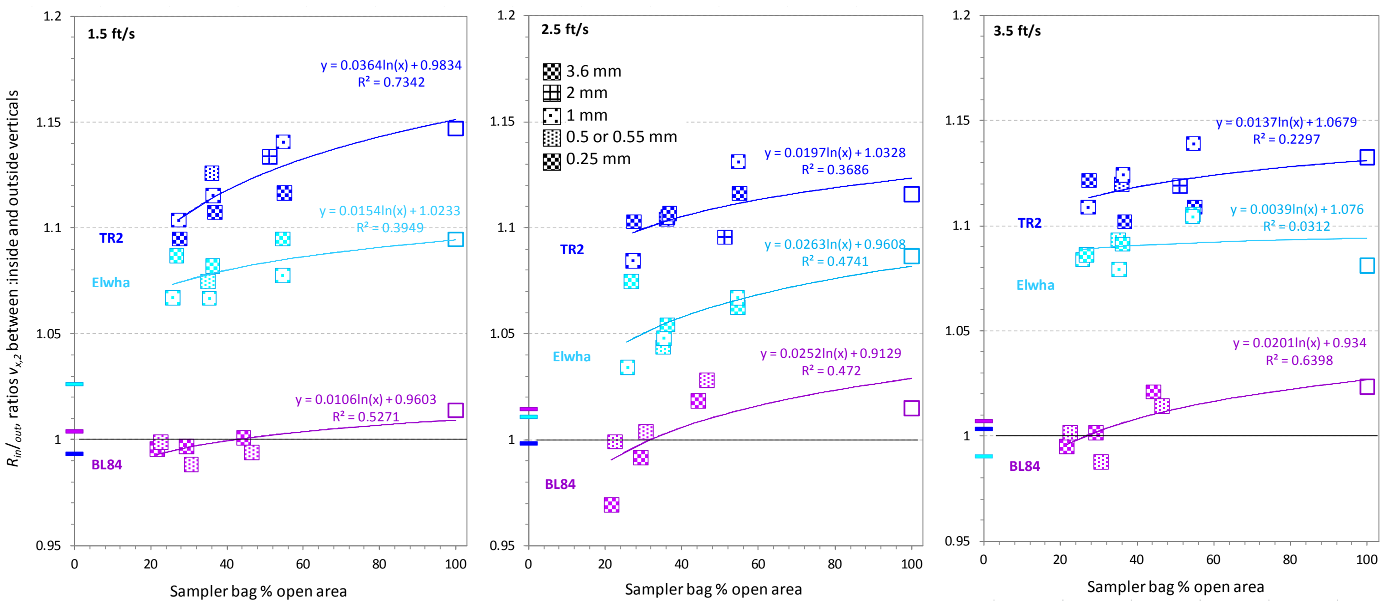


Figure 34: Relations of $R_{in/out} = f(\%Ao_{final})$. The legend in the center panel indicates the bags' mesh width and refers to all panels. Values of $R_{in/out}$ with no sampler present in the flume were plotted along the *y*-axis.

6.2 Discharge passing inside of the samplers

Quantification of the discharge passing through a bedload sampler and knowledge of how this discharge was affected by the magnitude of flow, the sampler entrance area, and the degree of net clogging are important when computing transport rates for sediment captured in bedload samplers but actually moving as suspended load.

6.2.1 Relations of $Q_{in} = f(\%Ao_{final})$

The discharge passing through the inside of the samplers (Q_{in}) was computed from the velocity profiles measured in the first series of flume experiments (Section 5.2). Similar to $v_{xin,2}$, the relations of $Q_{in} = f(\%Ao_{final})$ were described by logarithmic functions in the form of $Q_{in} = a \ln(\%Ao_{final}) + b$ (Figure 35). Regression parameters are listed in Table 8. Because Q_{in} was obtained by multiplying the point velocities v_x by the width and depth increments that represented v_x in each sampler, Q_{in} emphasized differences among samplers and among flows, while visually minimizing data scatter in the relations of $Q_{in} = f(\%Ao_{final})$. Values of r^2 were within 0.6 to 0.9, similar to r^2-values obtained for $v_{xin,2} = a \ln(\%Ao_{final}) + b$ in the second set of flume experiments (Figure 29), except for the target velocity of 3.5 ft/s when pump failure started to set in.

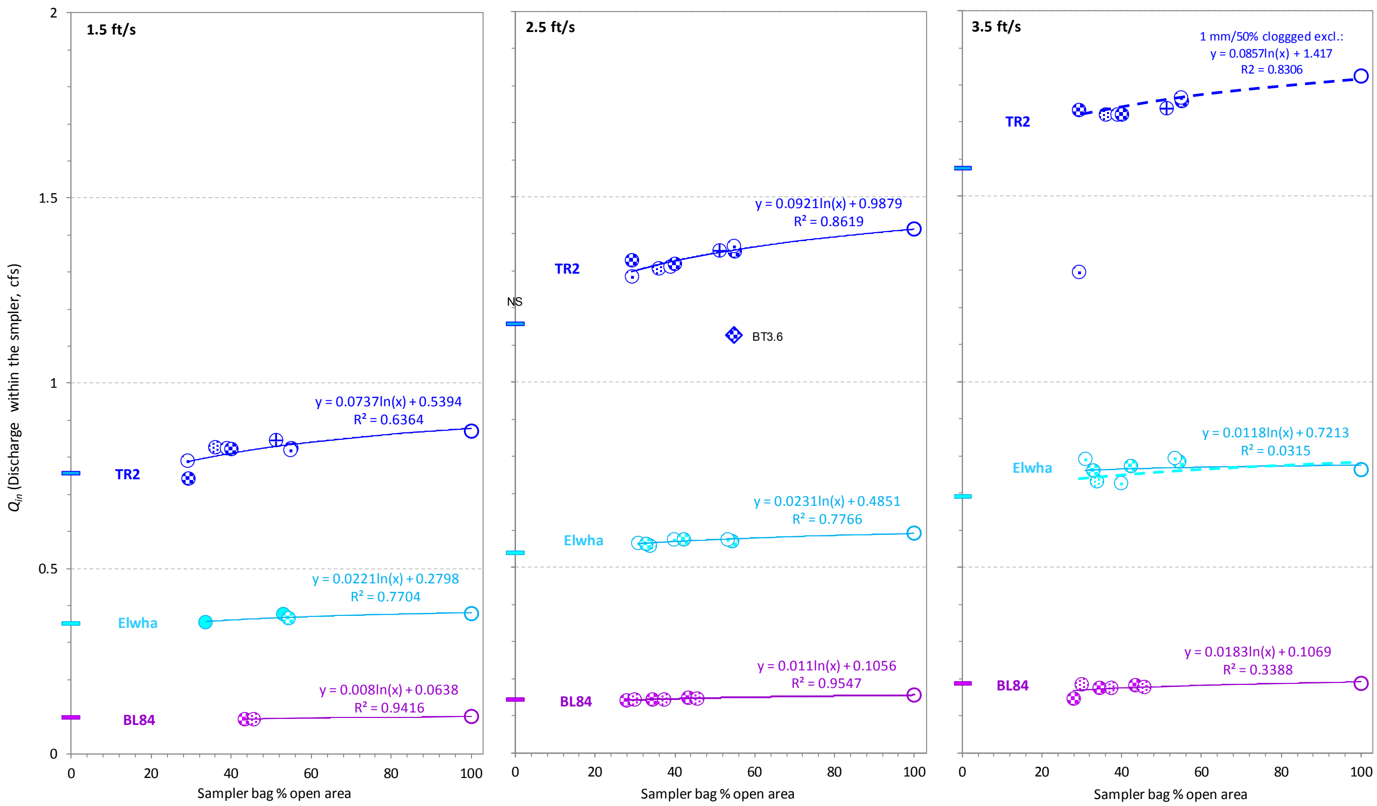


Figure 35: Relations of discharge passing through the inside of the TR2, the Elwha, and the BL-84 samplers (Q_{in}) with % Ao_{final}. The Q_{in} for no sampler present in the flume but passing through the same area as each sampler is plotted along the y-axis. Specific sampler bag configurations are not indicated.

Table 8: Regression coefficients (a, b) of logarithmic functions fitted to $Q_{in} = a \cdot \ln(Ao_{final}) + b$

Target velocity (ft/s)	TR2		Elwha		BL-84	
	a	*b*	*a*	*b*	*a*	*b*
1.5	0.0737	0.5394	0.0221	0.2798	0.00798	0.06379
2.5	0.0921	0.9879	0.0231	0.4851	0.01095	0.10559
3.5	0.0857	1.4170	0.0118	0.7213	0.01830	0.10690

Q_{in} predicted for 50% Ao_{final} (cfs)

Target velocity (ft/s)	Samplers and their entrance area (in^2)		
	TR2 (72)	Elwha (32)	BL-84 (9)
1.5	0.83	0.37	0.10
2.5	1.35	0.58	0.15
3.5	1.75	0.77	0.18

6.2.2 Relative control by target velocity, sampler size and %Ao_{final} on Q_{in}

In contrast to the relations of $v_{xin,2} = f(\%Ao_{final})$ that were primarily determined by the target velocity and only to a minor degree by sampler entrance area (Figure 29), the relations of $Q_{in} = f(\%Ao_{final})$ were affected by both flume discharge and sampler size (Figure 35). To assess whether target velocity or sampler entrance area exerted larger control on the relations $Q_{in} = f(\%Ao_{final})$, analyses were conducted just as they were done for $v_{xin,2}$ in Section 6.1.2.

Discharges inside the samplers scaled linearly with the magnitude of target velocity, but the increase in Q_{in} with target velocity was considerably more pronounced for the large-bodied TR2 than the small-bodied BL-84 (Figure 36), suggesting that both target velocity and the sampler entrance area determined the discharge passing through the sampler. Focusing the analyses of Q_{in} at 50% Ao_{final} (as had been down for the other hydraulic parameters) showed that sampler entrance area directly controlled Q_{in} and exerted a larger influence on Q_{in} than target velocity. A doubling sampler entrance area (=100% increase) increased Q_{in} by 104% (Figure 36 right), whereas a doubling in target velocity increased Q_{in} by 76% (Figure 36 left) (Table 9). By comparison, variations in the percent net open area ($\%Ao_{final}$) affected Q_{in} minimally. A doubling in $\%Ao_{final}$ increased Q_{in} by 1 – 7% (Figure 35).

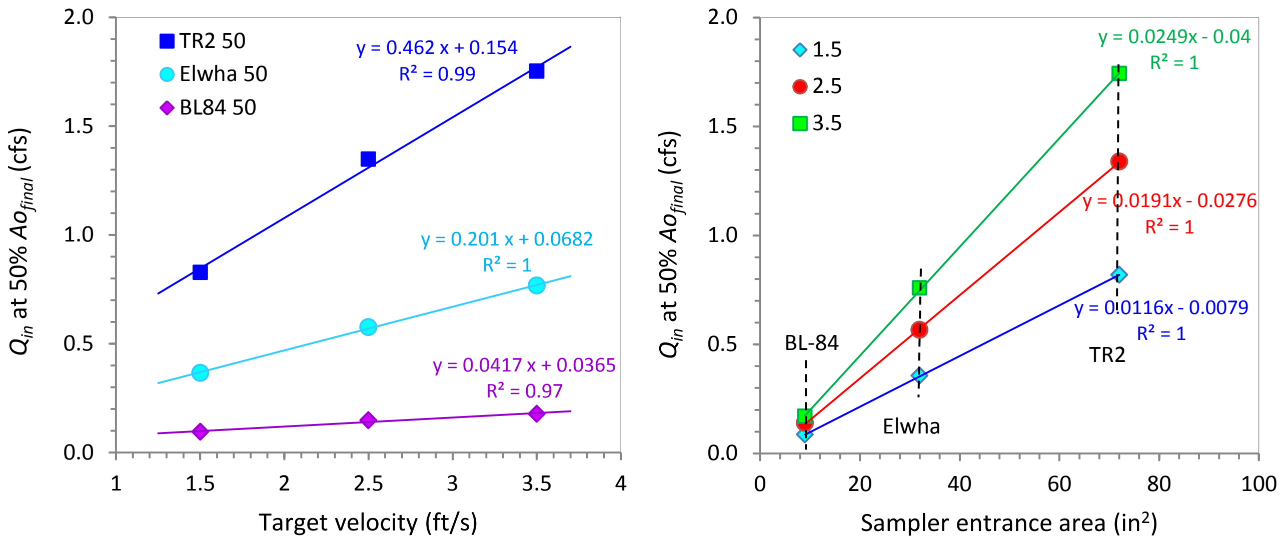


Figure 36: Increase in Q_{in} at 50% Ao_{final} with target velocity (left) and sampler entrance area (right).

Table 9: Increase (%) in Q_{in} due to doubling (=100% increase) in affecting parameters.

Sampler	$2 \cdot v_{xtar}$ (ft/s)	v_{xtar} (ft/s)	$2 \cdot A_{sampler}$ (in^2)	$2 \cdot \%Ao_{final}$ for TR2	Elwha	BL-84
TR2	82	1.5	102	6.5	4.3	6.1
Elwha	82	2.5	105	4.9	2.8	5.3
BL-84	63	3.5	106	3.5	1.1	7.5
mean	**76**	**mean**	**104**	**4.9**	**2.7**	**6.3**

6.2.3 Implications for computing transport rates of sediment in near-bed suspension

Discharge passing through the TR2 is necessarily larger than discharge passing through the Elwha and the BL-84 samplers because the TR2 has a larger entrance area than either the Elwha or the BL84. However, the amount of water passing through the TR2 (with an entrance area 2.25 times larger than that of the Elwha) was 2.27 to 2.35 times more than through the Elwha at target velocities of 1.5 to 3.5 ft/s. Similarly, the Elwha (with an entrance area 3.56 times that of the BL-84) passed 3.8 to 4.2 times more discharge than the BL-84. The fact that more discharge passed through the samplers' entrance than suggested by their respective entrance areas reflected the sampler's hydraulic efficiency that increased with sampler size and target velocity (see Section 6.3). Consequently, even when adjusted for the sampler opening size, the TR2 will collect more suspended sand-sized sediment than the Elwha sampler, and especially more than the BL-84.

The passage of more discharge through a TR2 than a BL-84 sampler for a specified flow needs to be taken into account when computing transport rates for sediment that travels in suspension but is collected in bedload samplers. When particles roll or slide into the sampler as true bedload, transport rates are computed as collected sediment mass per sampler width per sampling time (e.g., kg/m·s). By contrast, the collected mass of suspended sand needs to be apportioned to the sampler entrance area and be computed as mass per sampler area per sampling time (e.g., $kg/m^2 \cdot s$). Differentiating between bedload and suspended load in sampled sediment may be problematic. An additional complication may be introduced if the vertical extent of sand transport varies with flow in which case a user needs to apportion the sampled sand to the appropriate level of the sampler height.

An appropriate apportioning of sampled mass to sampler width for bedload and to entrance area for suspended sediment is important for accurate comparisons of transport rates collected with different bedload samplers, particularly when comparing sand samples collected with a BL-84 and a TR2. The following considerations neglect differences in hydraulic efficiency, which exacerbate differences in Q_{in} among samplers. A bedload transport rate of 10 g/s collected in a BL-84 (=131 g/m·s) is equivalent to 40 g/s collected in a TR2 the entrance of which is 4 times wider (=131 g/m·s). By contrast, for sand suspended within the lower 6 inches of the water column, a transport rate of 10 g/s sand collected in the BL-84 (1722 $g/m^2 \cdot s$) is equivalent to 80 g/s collected in the TR2 (1722 $g/m^2 \cdot s$) because the TR2's entrance area is eight times larger. Computing a transport rate for suspended sand in analogy to a bedload transport rate would overpredict the transport rate sampled in a TR2 by a factor of two in comparison to transport rates collected in a BL-84 sampler. This twofold overprediction of suspended sand collected in a TR2 vs. a BL-84 will increase with increasing flow, considering that the amount of flow passing the TR2 was 8.7 times larger than the amount passing through the BL-84 at a target velocity of 1.5 ft/s and 9.8 times large as the target velocity increased to 3.5 ft/s.

6.3 Hydraulic efficiency (*HE*) for $v_{xin,2}$

Hydraulic efficiency was computed by dividing the values of $v_{xin,2}$ measured with the various nets attached to a sampler by the values of $v_{xin,2}$ in the absence of that sampler (Section 5.5). The plots of $HE_{in,2}$ vs. $\%Ao_{final}$ (Figure 37) with the fitted logarithmic functions $HE_{in,2} = a \cdot \ln(\%Ao_{final}) + b$ showed that $HE_{in,2}$ generally increased with sampler entrance area, increased with target velocity, and also increased with the sampler bag % open area $\%Ao_{final}$. For the TR2 and Elwha samplers, values of $HE_{in,2}$ ranged from 101 to 115%, showing that flow was sucked into the samplers for all target flows and net configurations, even for clogged nets. For the BL-84, $HE_{in,2}$ ranged from 93 to 103% over the range of 20 to 100% Ao_{final}. For a target flow velocity of 1.5 ft/s, $HE_{in,2}$ in the BL-84 always remained below 100%, while at a target velocity of 3.5 ft/s, unclogged nets just exceeded 100% $HE_{in,2}$.

The relative positions of individual data points to each other for a specified sampler and v_{tar} were almost identical in the plots of $v_{xin,2} = f(\%Ao_{final})$ and $HE_{in,2} = f(\%Ao_{final})$. Consequently, any patterns observed in the relations of $v_{xin,2} = f(\%Ao_{final})$ (Figure 29) referred likewise to the relations $HE_{in,2} = f(\%Ao_{final})$ (Figure 37).

6.3.1 Relative effects of target velocity, sampler size and %Ao_{final} on $HE_{in,2}$

Following the same procedure used to evaluate the relative influences of target velocity, sampler size, and %Ao_{final} on $v_{xin,2}$ (Section 6.1.2), $HE_{in,2}$ was predicted for 50% Ao_{final} from logarithmic regressions functions $HE_{in,2} = a \cdot \ln(\%Ao_{final}) + b$ (Eq. 4) fitted to runs with each sampler and each target velocity (Figure 37). The values of $HE_{in,2}$ for 50% Ao_{final} were then related to target velocity and sampler entrance size (Figure 38).

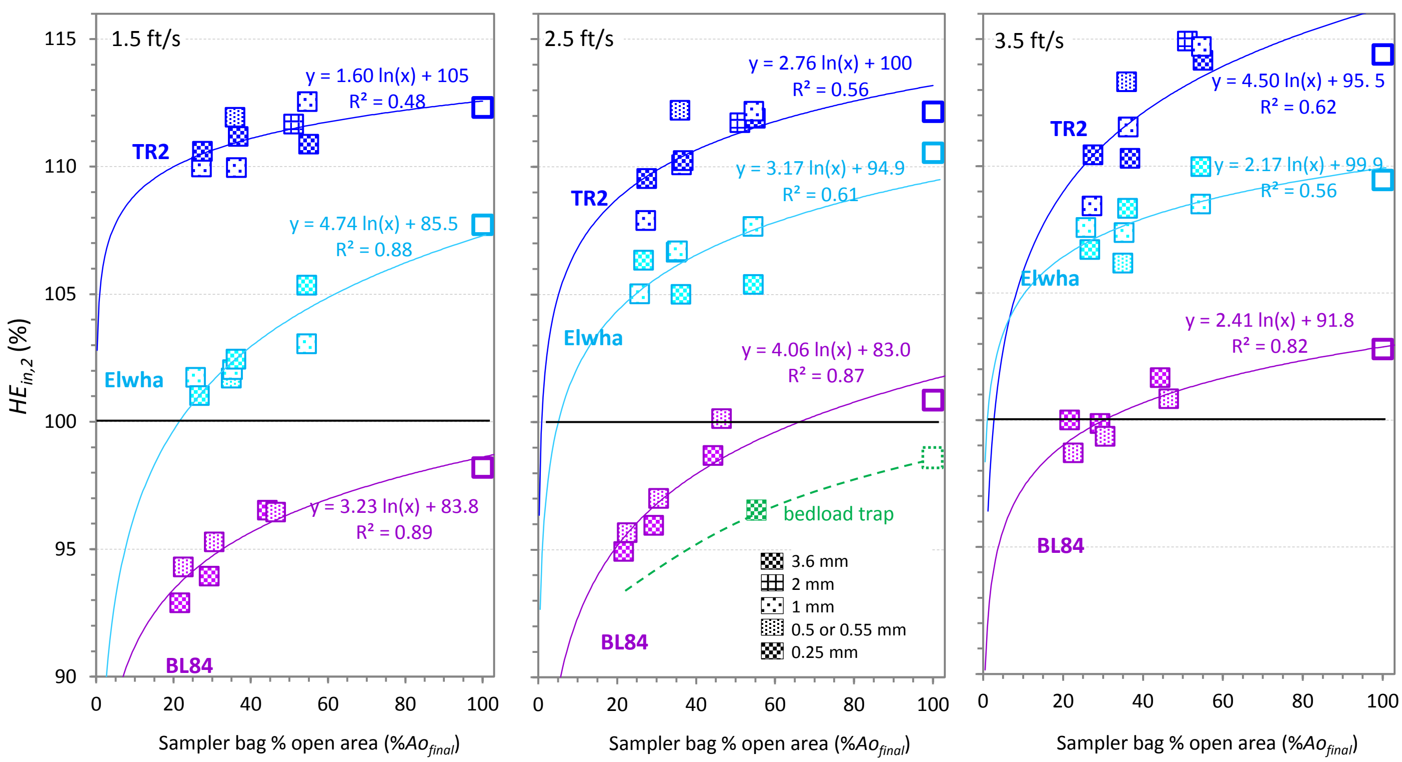


Figure 37: Hydraulic efficiency $HE_{in,2}$ for the three samplers and three target velocities. All panels are plotted in the same scale. The legend in the center panel refers to all panels. The green data point indicates $HE_{in,2}$ for a bedload trap with an empty 3.6 mm net measured during the first set of flume experiments.

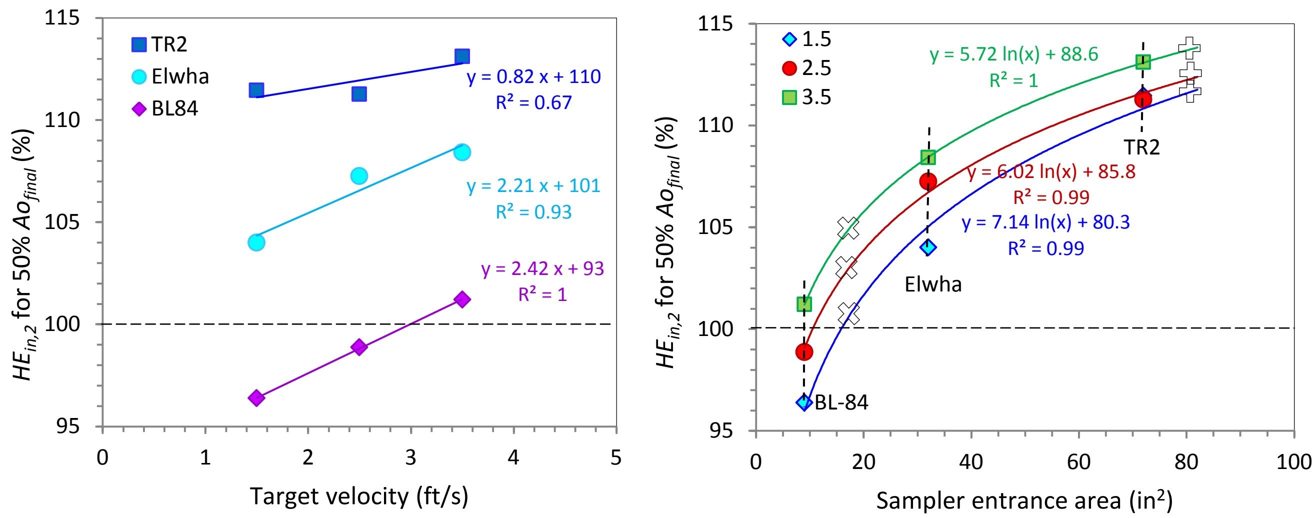


Figure 38: Increase in $HE_{in,2}$ for 50% Ao_{final} with target flow velocity (left) and with sampler entrance area (right). Open symbols in the right panel indicate $HE_{in,2}$ predicted for a downscaled Elwha sampler with a 3" by 6" opening (crosses) and plus signs for TR2 sampler upscaled by 9 in^2 to a 6.5" by 12.5" opening.

Compared to the predominant influence of target flow velocity on $v_{xin,2}$ (Section 6.1.2) and the predominant influences of both sampler size and target velocity on Q_{in} (Section 6.2.2), the influence of target velocity, sampler entrance area, and $\%Ao_{final}$ on $HE_{in,2}$ were moderate (Table 10 and Table 11).

Table 10: Increase (%) in $HE_{in,2}$ due to doubling (=100% increase) of affecting parameters v_{tar}, $A_{sampler}$, and $\%Ao_{final}$

Sampler	$2 \cdot v_{xtar}$	v_{xtar} (ft/s)	$2 \cdot A_{sampler}$	$2 \cdot \%Ao_{final}$ for TR2	Elwha	BL-84
TR2	1.1	1.5	4.7	1.0	3.2	2.4
Elwha	3.2	2.5	3.9	1.7	2.1	2.9
BL-84	3.8	3.5	3.7	2.8	1.4	1.7
Mean	**2.7**	**mean**	**4.1**	**1.9**	**2.2**	**2.3**

Table 11: Increase (%) in affected hydraulic parameter $v_{xin,2}$, Q_{in}, and $HE_{in,2}$ resulting from a doubling (=100% increase) in affecting parameters. Summary of Table 7, Table 9, and Table 10.

Affected hydraulic parameter	Affecting parameter: Target v_x	Sampler entrance area	Net density & clogging ($\%Ao_{final}$)
$v_{xin,2}$	85	4	2
$HE_{in,2}$	3	4	1-3
Q_{in}	76	104	1-7

Sampler entrance area had the largest effect on $HE_{in,2}$. Averaged over all samplers and target velocities, doubling the sampler entrance area increased $HE_{in,2}$ by 4% (Figure 38 right). Practically though, the effect of sampler size was larger than 4%. Switching from a BL-84 to a TR2 sampler (an eightfold increase in sampler area) increased $HE_{in,2}$ by 12% at a target velocity of 3.5 ft/s, and by 4% at 1.5 ft/s (Figure 38 right). Figure 37 and Figure 38 right also indicated that a downscaled version of the Elwha sampler with a 3" by 6" opening would have produced a $HE_{in,2}$ of around 100%. This finding poses a possibility for the development of a new "handy" sampler.

Target velocity generally had the second largest effect, but target velocity affected $HE_{in,2}$ in an unexpected way among the three samplers (Figure 38 left). Doubling target velocity increased $HE_{in,2}$ by only 1% for the largest sampler (TR2), but by 3% for the Elwha sampler, and 4% for the small BL-84 sampler, with an average of 3% for all samplers. While $HE_{in,2}$ was highest for the largest sampler and for the largest target velocity, the rate at which $HE_{in,2}$ increased with target velocity and sampler size was most pronounced for the slowest velocity and the smallest sampler (Figure 38 left). That means upscaling a 3" by 3" BL-84 (= 9 in^2) to a 3" by 6" opening (a small 18 in^2 version of an Elwha) would increase $HE_{in,2}$ more strongly than upscaling the opening of a TR2 sampler from 6" by 12" (=72 in^2) by 9 in^2 to 6.5" by 12.5" ($\cong$ 81 in^2).

The degree of net openness, on average, had the smallest influence on $HE_{in,2}$, and the effects of $\%Ao_{final}$ on $HE_{in,2}$ summarized in Table 10 closely mirrored the effects that $\%Ao_{final}$ had on $v_{xin,2}$ (Section 6.1.2, Table 7). Overall, doubling the Ao_{final} from 30 to 60% increased $HE_{in,2}$ by about 2% averaged over all samplers and target velocities. But in contrast to the consistent patterns with which target velocity and sampler size affected $HE_{in,2}$ (discussed above), sampler-specific patterns emerged in the influence of $\%Ao_{final}$ on $HE_{in,2}$ among samplers size and target velocity.

6.3.2 Effects of $\%Ao_{final}$ on hydraulic efficiency differed among samplers

The relations $HE_{in,2} = f(\%Ao_{final})$ in Figure 37 were generally flatter at their high ends (Ao_{final} >50%) and steeper at their low ends (Ao_{final} <50%) than indicated by the fitted logarithmic functions. To avoid errors that might stem from less than optimal curve fitting, analyses focused on three characteristic values of $HE_{in,2}$ for each sampler and target velocity. Those were the $HE_{in,2}$ for samplers without a net (100% Ao_{final}), the average of empty, unclogged nets with Ao_{final} of 50-55%, and the average of the two nets for each sampler that were half filled with gravel (21 - 28 % Ao_{final}) (Figure 39 left). Also presented were the differences between empty and absent nets as well as the differences between nets with 50% gravel fill and empty (Figure 39 right).

Results indicated that for the TR2 sampler, empty (=unclogged) nets with Ao_{final} around 50% did not reduce the TR2's high $HE_{in,2}$ at any target flow velocity, whereas the difference between nets half filled with gravel and empty nets—representing approximately a doubling of $\%Ao_{final}$—strongly increased with target velocity. In the Elwha and BL-84 samplers, hydraulic efficiency responded differently to the properties of sampler bags. For the BL-84, differences between no net and empty nets were generally less than the differences between nets half filled with gravel and empty nets. Also, in contrast to the

TR2, the differences between half-filled and empty nets decreased with increasing flows for the BL-84. The Elwha sampler had its own patterns with almost linear increases in $HE_{in,2}$ with $\%Ao_{final}$ that lacked a trend with target velocity.

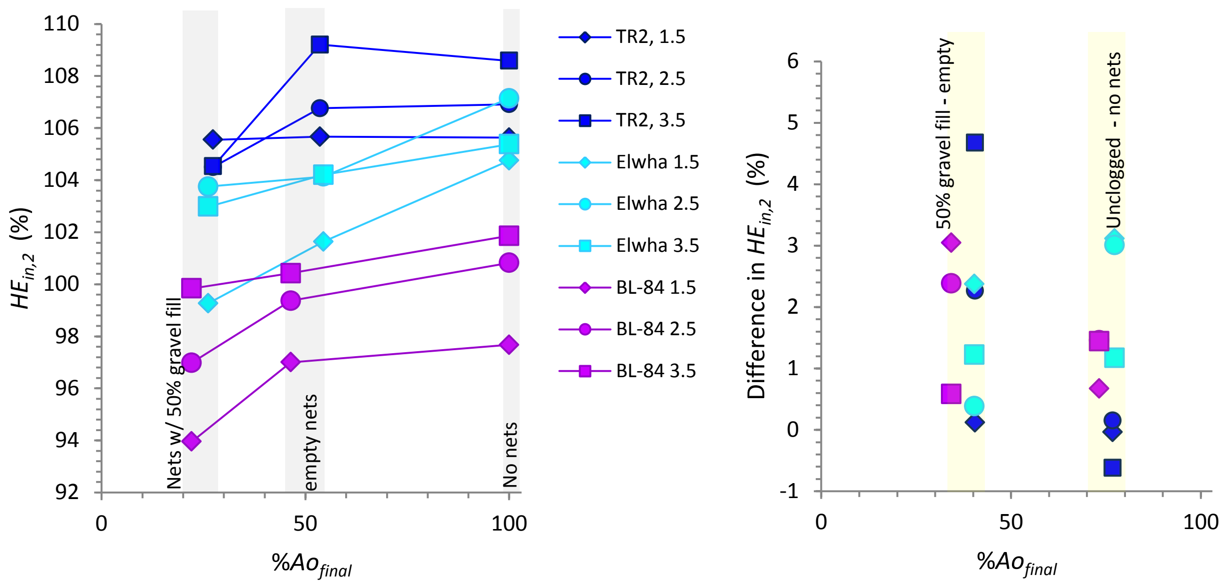


Figure 39: Three characteristic data points for the relations of $HE_{in,2}$ vs. $\%Ao_{final}$ for each sampler and target velocity were plotted inside of the three gray bars: no net attached to the sampler (100 % Ao_{final}), the average value for empty nets with Ao_{final} of 50-55%, %, and the average value of the two nets half filled with gravel with % Ao_{final} of 21-28% (left panel). Differences in $HE_{in,2}$ between empty nets and no nets as well as nets half filled with gravel and empty nets (right panel). The legend refers to both panels.

In summary, empty nets did not reduce the high hydraulic efficiency of the TR2, suggesting that it did not matter which coarse net was attached to a TR2 as long as the net had an Ao_{final} >50%, a value exceeded by most coarse nets (Figure 3). However, net clogging notably decreased $HE_{in,2}$ in the TR2 sampler and especially in faster flow, suggesting that the TR2 sampler bag should not be filled to 50%. For the BL-84 sampler, the choice among coarse nets is likewise less important than avoiding overfilling, but the effect of gravel fill was most pronounced in the lowest flow. In the Elwha sampler, $HE_{in,2}$ was equally effected by gravel fill and the sheer presence of a net, regardless of flow velocity.

6.3.3 $HE_{in,2}$ likely influenced by specific flume hydraulics and net shapes

Results indicated that in each of the samplers the various bag configuration exerted their particular effects on $HE_{in,2}$. It is unclear whether the observed effects are general or if they reflected the particular responses of each sampler-and-bag configuration to the specific hydraulic conditions encountered in this flume study that probably varied somewhat among runs, that would be different for other flume studies, and that were certainly different from conditions encountered on rough gravel and cobble beds.

Although not specifically tested in this flume study, the specific net dimensions and shapes of the bags tested in this study probably also had some effect on the velocity measured in front of the sampler and hence on $HE_{in,2}$. An effort had been made in this study to select nets of similar shape and adjust the net length to equalize the bags' surface area, but bags still differed in flexibility and stretchability, and consequently their shapes were not identical. Further analyses regarding details of net configurations are presented in Sections 6.4.3 and 6.4.4.

6.3.4 Huge effect of sampler body expansion ratio on hydraulic efficiency

Effects of expansion ratios of the sampler body on hydraulic efficiency were not specifically investigated in this study except for a single run performed during the first series of flume experiment with a bedload trap. The bedload trap has an 8" by 12" opening, an expansion ratio of 1.0, and uses a 3.6 mm net. Flow velocity was measured at the same 45 locations as measured for the TR2 sampler, interpolated for 2 inches above ground and averaged over the 5 verticals inside the bedload trap ($v_{xin,2}$). The bedload trap's value for $v_{xin,2}$ was slightly less than $v_{xin,2}$ for no sampler present in the flume and resulted in a $HE_{in,2}$ of 97%. A value of 99% $HE_{in,2}$ was assumed for the bedload trap with no net attached, and a logarithmically shaped curve was drawn through the two data points (Figure 37).

Comparing the functions $HE_{in,2} = f(\%Ao_{final})$ between the TR2 sampler and the bedload trap clearly demonstrated the tremendous effect of sampler body flaring on $HE_{in,2}$, and this influence by far exceeded any influence exerted by target velocity, sampler entrance area, and $\%Ao_{final}$. The difference in the functions $HE_{in,2} = f(\%Ao_{final})$ between the TR2 and the bedload trap can be used to estimate the expansion ratio that would have resulted in a $HE_{in,2}$ close to 100% in this study. Assuming $HE_{in,2}$ scaled linearly with the expansion ratio, then Figure 37 suggests that a lightly flared sampler body with a 12" by 6" or 12" by 8" opening area and a expansion ratio near 1.1 might have obtained a $HE_{in,2}$ of ≅ 100% in this study. For the Elwha's smaller entrance area, an expansion ratio of around 1.2 might have produced a $HE_{in,2}$ ≅ 100%. Detailed flume and field experiments are required to pinpoint the exact relation between expansion ratios and hydraulic efficiency.

6.3.5 Possible relation between hydraulic efficiency and sampling efficiency?

It would be useful to know how a sampler's hydraulic efficiency affects the sampling efficiency of that sampler. However, due to the highly complex nature of bedload transport which is much governed by sediment supply, and due to the interference of bedload samplers with flow hydraulics and particle entrainment, there is no generally applicable direct transfer from hydraulic efficiency to transport efficiency.

However, in order to arrive at a rough estimate of how increases in hydraulic efficiency might increase sampling efficiency if all complexities are neglected, this study made several assumptions and provided a numerical assessment. One assumption was that the mean flow velocity v_m in natural channels with steep banks is related to discharge Q by a power function $v = c \cdot Q^d$ with $d = 0.5$; the value of the c-coefficient does not affect the analyses here and is set to 1. $HE_{vin,2}$ values observed in this study ranged between 105 and 115% for the TR2 and Elwha samplers (Figure 37), equivalent to increases in flow velocity $v_{xin,2}$ by 5, 10, and 15%. It was further assumed that $v_{in,2}$ is representative of the mean flow velocity in a steep-banked channel, v_m. If the exponent d = 0.5, then an increase of v_m by 5, 10, and 15% increases Q by close to 10, 20, and 30%, respectively.

Sediment transport rating curves in the form of power functions $Q_B = x\,Q^y$ exhibit a wide range of exponents from about 1 to 20 (Bunte et al., 2014, 2015), depending largely on bed mobility, sediment supply, the particle size spectrum that is part of bedload transport, as well as on the kind of bedload sampler used. Again, x-coefficients may be neglected here and are set to 1. Four different y-exponents of 1.5, 3, 6, and 9 were assumed for a transport relation. A y-exponent of 1.5 that is typical of sand transport, an exponent of 3 is typical of samples collected in a Helley-Smith sampler or of highly mobiles beds. Exponents of 6 are typically obtained when using bedload samplers other than pressure-difference samplers and exponents of 9 are obtained in supply-limited channels in which rarely moving large particles contribute to transport at high flows. Assuming that bedload transport rates responded directly to changes in flow velocity and discharge, then increasing v_m by 5 to 15% would cause transport rates to increase by 20 to 50% when y=1.5 and to approximately double when y=3. Not considering gravel transport processes and sediment supply, but solely on mathematical grounds, increases in v_m by 5-15% would increase transport rates by factors of 2 to 5 when y=6 and by factors of 2 to 11 for y=9 (Table 12).

Table 12: Mathematical multiplier factors with which Q_B increases following an increase in mean flow velocity v_m for various exponents y of a power function bedload transport equation $Q_B = x\,Q^y$.

Increase in v_m	Associated increase	Multiplier factors for Q_B for increases in v_m for various exponents y			
(%)	in Q (%)	y = 1.5	y = 3	y = 6	y = 9
0.05	0.1	1.2	1.3	1.8	2.4
0.10	0.2	1.3	1.7	3.0	5.2
0.15	0.3	1.5	2.2	4.8	10.6

6.3.6 Effects of hydraulic efficiency on sampling efficiency are process-dependent

Rather than a direct transfer between hydraulic efficiency and sampling efficiency, one should consider that the role of hydraulic efficiency on oversampling varies depending on how a sampler interacts with bed material conditions, flow hydraulics and sediment transport processes.

- Gravel transport rates are approaching a sampler much controlled by upstream sediment supply and inertia of moving particles. Placement of a sampler with a 110% hydraulic efficiency onto a concrete sill that is flush with the bed surface may accelerate oncoming particles that are about to enter the sampler or steer a particle that approaches at the edge of a sampler into the sampler, and those processes may unduly increase sampled transport rates. However, a 110% hydraulic efficiency is unlikely to increase collected transport rates by scouring particles stuck in an immobile gravel bed in front of a sampler.

- When sampling suspended sand, streamlines that expand in front of a pressure-difference sampler collect sediment from an area that is larger than the sampler entrance area. In this case there may be a direct connection between a hydraulic efficiency > 100% and oversampling, but oversampling likely decreases with sampling time as the bag pores starts to clog from the captured sand.
- Placement of a pressure-difference sampler onto a sand bed may cause scour at the sampler entrance, and a hydraulic efficiency > 100% will subsequently suck the scoured material into the sampler.
- Placement of a pressure-difference sampler onto a gravel bed may dislodge a few gravel particles that—now lacking inter-particle support—may be sucked into sampler. The rate of oversampling increases depending on the number of deployments made to arrive at a cross-sectional sample.

Considering the various assumptions and processes, relations between hydraulic efficiency and sampling efficiency are complex and not easily quantifiable.

6.4 Differences among specific nets and their relations of $HE_{in,2} = f(\%Ao_{final})$

Results of this study have shown that the combined net openness ($\%Ao_{final}$) affected hydraulic parameters less than the target velocity or the entrance area of the three pressure-difference samplers. However, considering that examination of the effects of bag properties and clogging on flow hydraulics was a focal point of this study, a closer look was taken on how $\%Ao_{final}$ affected $v_{xin,2}$ and $HE_{in,2}$. It should be noted that the relation of individual data points to each other between runs were almost identical in the plots of $v_{xin,2} = f(\%Ao_{final})$ and $HE_{in,2} = f(\%Ao_{final})$. Consequently, any patterns observed for $v_{xin,2} = f(\%Ao_{final})$ refer likewise to plots of $HE_{in,2} = f(\%Ao_{final})$.

6.4.1 Mesh width is not the determining factor for %*Ao*

Nets with mesh widths of 1, 2, and 3.6 mm used in this study had similar %*Ao* between 53 and 58%. A 0.5 mm netting material with a 56% *Ao* is generally available (Sefar, 2006) and could have been used, but the 0.55 mm net used for the TR2 and Elwha in this study happened to have a denser weave with 38% *Ao* (see Table 1). Mesh width is generally poorly related to the %*Ao* (see Figure 3 in Section 2.1).

6.4.2 Clogging the bag end with plastic liner reduced $v_{xin,2}$ and $HE_{in,2}$ more than a gravel wedge

Results from the first and the second series of flume experiments both produced positive logarithmic functions of $v_{xin,2} = f(\%Ao_{final})$ that increased with target velocity and with sampler entrance area. However, in the first series of flume experiments (Figure 40), the fitted logarithmic functions $v_{xin,2} = a \cdot \ln(\%Ao_{final}) + b$ were notably steeper and the a-coefficients were between 1.3 and 6 times (mean of 2.5 times) larger than in the second series of experiments (Figure 34). Similarly, the ratios of the velocities $v_{xin,2}$ measured in the two series of flume experiments averaged for each particular net over all employments (with gross outliers in the 1st series excluded), exhibited a positive trend over $\% Ao_{final}$ (Figure 41).

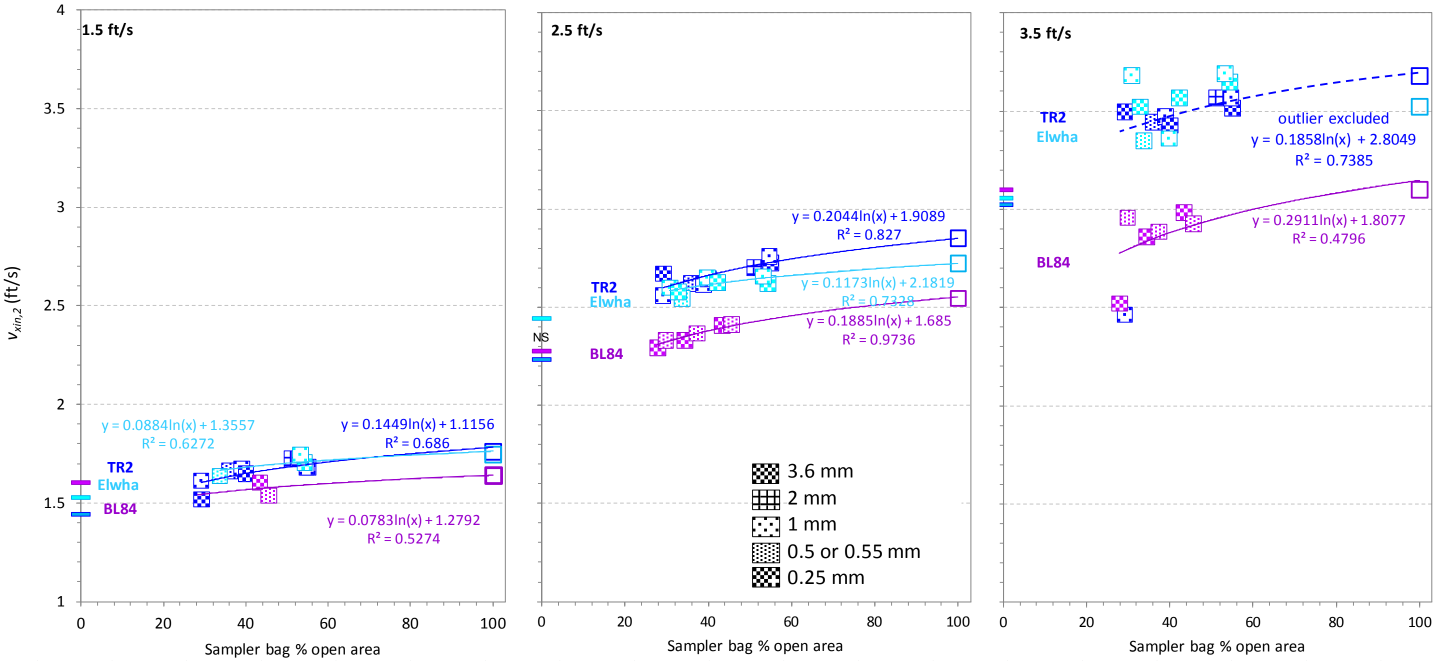


Figure 40: Flow velocity measured at 2" above ground ($v_{xin,2}$) in the various runs of the first series of experiments. Note the indifference in flow velocity between the TR2 and the Elwha sampler as well as the large data scatter for runs with a target velocity of 3.5 ft/s. The legend in the center panel refers to all panels. The green data point in the center panel refers to the one run with a bedload trap and an empty 3.6 mm net attached.

Empty nets had an average ratio of $v_{xin,2}$ of 1.01 between the first and second series of flume experiments, while nets clogged by 30 and 50% had average ratios of 0.96 and 0.97 (Figure 41). All of those results indicated that the velocities measured at samplers with clogged nets were lower during the 1st series of flume experiments when nets were blocked with a plastic liner (see Figure 5) than during the 2nd series when bags were accordingly filled with gravel (Figure 7 and Figure 8). Blocking the bag ends symmetrically with a sewn-in plastic liner (see Figure 5) simulated clogging by organic debris that travels in suspension (e.g., algae at any flow, duff-like particulates at moderate and particulate organic material high flows) and by sand grains that lodge within mesh openings at high flows). In the second series of experiments, clogging was simulated by pouring fine gravel into the nets up to the same levels previously covered with a plastic liner. The gravel fill formed a wedge along the bottom of the bags, and water could exit the bags above the wedge (see Figure 7 and Figure 8) without much retardation. Hence, for the same nominal degree of blockage of the bag surface area (i.e., %Ao_{final}), symmetrical clogging of the bag end (typical of organic debris and sand) reduced v_x and hence hydraulic efficiency more than an equivalent gravel fill.

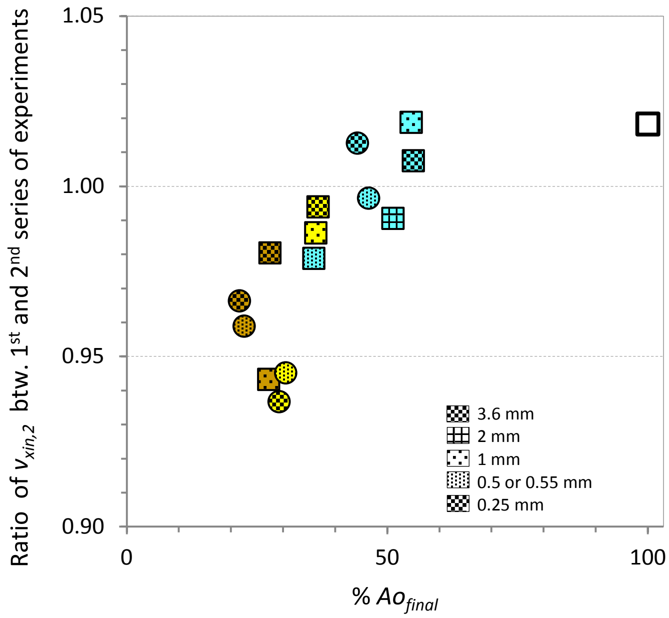


Figure 41: Ratios of $v_{xin,2}$ between the 1st and 2nd series of flume experiments for all nets and fill level (empty = blue, 30% fill = yellow, 50% fill = brown; round symbols refer to nets used with the BL-84 sampler, square sybmols to nets used with the TR2 and Elwha samplers). The open symbol refers to the average ratio for no nets attached to a sampler.

6.4.3 Variable responses of sampler bags to $v_{xin,2}$ and $HE_{in,2}$ are attributable to net shape

Net shape was not a factor explicitly tested in this study, but some of the differences observed between nets and how they affected v_{xin2} and $HE_{in,2}$ could only be attributed to differences net shapes.

- 1 and 3.6 mm nets for the TR2 and Elwha

The 1 and the 3.6 mm nets had similar values of $\%Ao_{final}$, both for empty nets as well as for the nets clogged by 30 and 50%, but the two nets did not produce the same $v_{xin,2}$. For the TR2 sampler, the three data points for $v_{xin,2}$ with 55, 36, 27% Ao_{final} associated with the three levels of bag clogging (empty, 30, and 50%) followed separate trends for each net (Figure 29, Figure 42). For the 3.6 mm net, the three data points fell approximately onto one line for each target velocity, and those lines were close to the general trends of the logarithmic regressions $v_{xin,2} = a \cdot \ln(\%Ao_{final}) + b$ as well as $HE_{in,2} = a \cdot \ln(\%Ao_{final}) + b$). By contrast, the three data points for the 1 mm net fell onto steeper lines for all target velocities. While flow passed a little faster through the empty 1 mm net which resulted in higher values for $v_{xin,2}$ and $HE_{in,2}$, the 1 mm net half filled with gravel retarded flow more than the 3.6 mm net.

The different responses of the two nets were attributed to differences in net shape. The shape of the 1 mm precision net did not change much between the various flume runs, whereas the 3.6 mm net stretched and became longer and thinner as target velocities and gravel fill increased. In the long 3.6 mm nets, the gravel fill at the net end (Figure 8) was far away from the sampler entrance, and a 50% gravel fill slowed $v_{xin,2}$ less than in the 3.6 mm net than in the 1 mm net that kept its shape and where the gravel fill stayed closer to the net entrance. The stretchy 3.6 mm nets coped with gravel fill better than the 1 mm precision net and as a result, hydraulic efficiency was less affected by net clogging when a 3.6 mm net was attached. Nets that have a long distance between gravel fill and sampler appear to maintain hydraulic efficiency at a more constant level over a range of flows and fill levels than nets with a shorter distance.

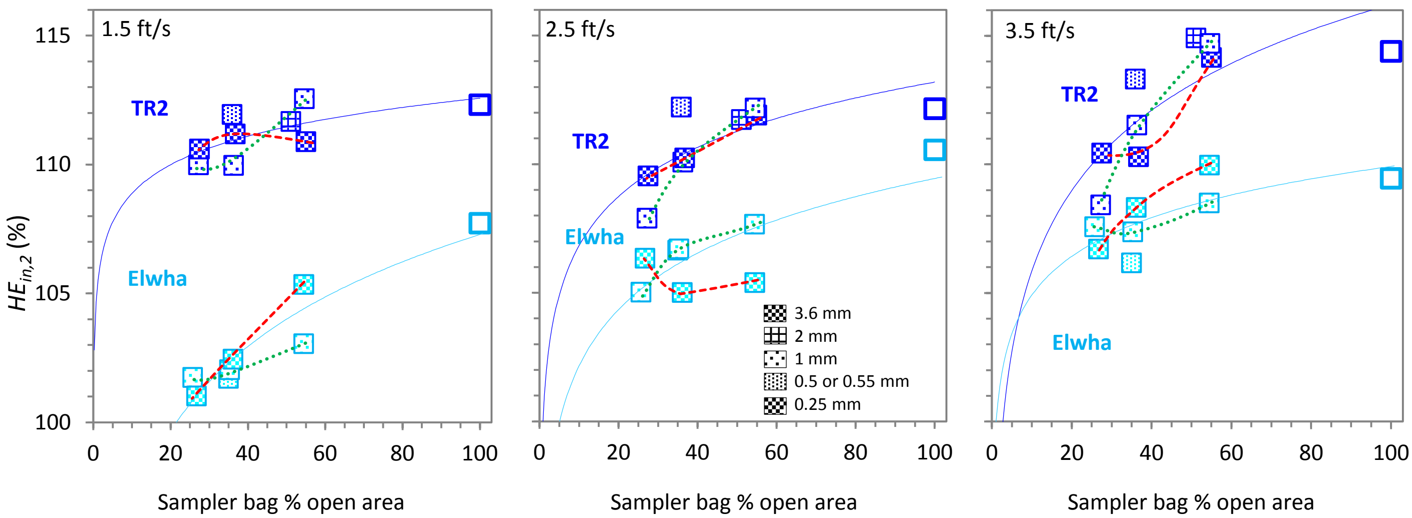


Figure 42: Excerpt from Figure 37 showing $HE_{in,2}$ for the TR2 and the Elwha samplers. The red dashed lines connect data points for the 3.6 mm nets and the green dotted lines connect data points for the 1 mm net.

The trends described for the two nets on the TR2 were almost opposite for the Elwha sampler. One reason may be that the 1-mm net attached to the Elwha sampler was relatively long and thin, such that the 1 and 3.6 mm nets attached to the Elwha sampler were more similar in shape than the 1 and 3.6 mm nets attached to the TR2. Another possible reason for the different trends may be that the TR2 protruded further into fast flow and sucked flow faster through the sampler entrance. The TR2's higher hydraulic efficiency might enable the TR2, better than the Elwha sampler, to override turbulent flow structures that developed in the flume and hence to develop a more clearly defined sampler-specific response.

- Different responses of 0.55 mm net for TR2 and Elwha sampler

In the plots of $v_{xin,2} = f(\%Ao_{final})$ and $HE_{in,2} = f(\%Ao_{final})$ (Figure 29 and Figure 37), the densely woven 0.55 mm with 36% Ao_{final}, a value almost identical to the 1 mm nets with 30% gravel fill, followed particular patterns. Attached on the TR2 sampler, the 0.55 mm net produced $v_{xin,2}$ and $HE_{in,2}$ higher than the 1 mm net with 30% gravel fill, i.e., the 0.55 mm net acted like a "fast" net. By contrast, the 0.55 mm net acted like a "slow" net for the Elwha sampler with $v_{xin,2}$ and $HE_{in,2}$ less than for the 1 mm net with 30% gravel fill. A reason for the different responses of the 0.55 net may be bag shape. Compared to the 1 mm net, the 0.55 mm bag used with the TR2 was relatively long, narrow, and somewhat tapered, whereas the 0.55 mm net for Elwha sampler was relatively short, wide, and blocky. Flow could probably pass the longer, narrower bag better than a wider, shorter bag, although sampler-specific hydraulic effects could not be ruled out entirely.

- 0.25 and 0.5 mm nets for BL-84 sampler

At a target velocity of 3.5 ft/s, the 0.25 mm net attached to the BL-84 produced higher $v_{xin,2}$ and $HE_{in,2}$ than the 0.5 mm net, and this is explainable by the 0.25 mm net being slightly larger than the 0.5 mm net. It is not known why the response was the opposite at the two slower flows.

6.4.4 Interchangeable use of different nets?

Coming back to the question that was posed at the beginning of this study: Can nets with different mesh widths be used interchangeably on the various pressure difference samplers? Coarse nets with Ao_{final} larger than 50% can be used interchangeably on the TR2 sampler, and on the Elwha in fast flow, as long as fill levels in the nets remain very low. The bags of 0.25 and 0.5 mm for the BL-84 can also be used interchangeably as long as bags are of similar size and shape. This prerequisite of net form is easier to fulfill for the BL-84 than for other samplers because bags for the BL-84 sampler are typically bought from a retailer rather than custom sewn. The answer for interchangeably using different nets is less clear for densely woven nets and for bags clogged or filled with gravel because a complex interaction set in between gravel fill level, the particular shape of an individual net, ambient flow velocity, and sampler opening size. Here, hydraulic efficiency for a specified level of $\%Ao_{final}$ varied by a few percent between bags. More studies to help entangle that web would be desirable.

Effects exerted on hydraulic efficiency by differences in netting properties were generally smaller compared to the influence of sampler size and ambient velocity. Put into larger perspective of bedload sampling in natural streams, the effects of netting size on sampling results are likely small. There is typically a 10-fold natural variability of gravel transport rates at a specified discharge over a highflow season or within an event. There are also sampling errors that can greatly contribute to variability in a measured bedload transport relation, and they include infrequent sampling over the high flow season (or event), uneven coverage of the hydrograph's flows or not sampling at all times within the hydrograph. Finally, scooping a few gravel particles into a sampler, scouring a sand bed at the sampler entrance, and sucking suspended sand into a sampler may well introduce more error into a bedload sample than is likely introduced by using bags with different mesh sizes and different $\%Ao$.

7. Transferability of study results

- **Results can be interpolated to upscaled or downscaled versions of the study samplers**

Results obtained in this study may be interpolated to upsized or downsized cousins of the Elwha sampler as long as those samplers retain a 1.4 expansion ratio.

- **Results are not applicable to samplers with other expansion ratios**

Study results reported here refer exclusively to pressure-difference samplers with a 1.4 expansion ratio between entrance and exit opening. Results obtained for an Elwha sampler (32 in^2 opening, 1.4 expansion ratio) are not applicable to a 6” by 6” Helley-Smith sampler (36 in^2 opening, 3.22 expansion ratio. Similarly, results for the BL-84 sampler are not applicable to the 3 by 3” inch opening Helley-Smith sampler with a 3.22 flaring ratio, and neither are results from the TR2 sampler applicable to the similarly sized but unflared bedload traps.

- **Limited transfer to coarse beds**

Results from this flume study are not directly transferrable to gravel and cobble beds because they have a much high bottom roughness than the smooth flume bed. Velocity profiles on rough beds start with much smaller near-bed velocities (e.g., at 0.5” above ground) and increase steeply with height above bed, whereas the near-bed velocity in the flume was already quite high and increased less with depth. For the same target flow velocity at 6” above ground, the velocity at 2” above the bed is likely slower on a coarse bed, hence all regression functions $v_{xin,2} = f(\%Ao_{final})$ shown in this study would likely be lower on coarse beds as well. The steepness of the relations $v_{xin,2} = f(\%Ao_{final})$ might remain similar, but the scatter around the curve might increase because local bed conditions may allow more or less water to exit the lower sides of the net.

- **Limited transfer to natural channels**

The results obtained in this study pertain to relatively deep and slow flows and to flow hydraulics with constant width and depth for all target velocities, whereas in natural channels at least depth or width would increase with discharge. Hence, the effects of target velocities on the relations of $v_{xin,2}$ and $HE_{in,2}$ with the $\%Ao_{final}$ would not be identical.

- **No direct transfer to samplers with massive external lead frames**

Hydraulic efficiency determined in this study pertains to pressure difference samplers in handheld deployment. The external frame around the sampler used with cable-deployment slows velocity passing through the bag, and this would decrease hydraulic efficiency.

- **Transferability affected by net shape**

The study indicated that net shape exerts a large effect on hydraulic efficiency. Hence, results obtained for a specified net may not necessarily transfer to another net with the same mesh width and $\%Ao_{final}$, but effects of net shape need to be taken into account.

8. Summary, conclusions, and recommendations

8.1 Summary and conclusions from study results

- **Netting and bag properties**

Mesh width is only loosely related to the density of the weave (*%Ao*). The amount of flow through a net is determined by the additive combination of weave density, net surface area blocked by seams, as well as by clogged mesh pores and accumulated gravel fill (=$\%Ao_{final}$).

- **Selection of the most meaningful velocity parameter**

Flow velocity measured at 2 inch above ground and averaged over all inside verticals ($v_{xin,2}$) was considered the most meaningful velocity parameter and therefore used as the basis for subsequent analyses.

- **Logarithmic functions best described the relations $v_{xin,2} = f(\%Ao_{final})$**

Logarithmic functions are characterized by a steeply rising and then flattening trend, and they best described the relations of flow velocity ($v_{xin,2}$), discharge passing the sampler (Q_{in}), and hydraulic efficiency ($HE_{in,2}$) with $\%Ao_{final}$. However, data scattered with r^2-values of 0.5 to 0.9. Velocity outside the samplers ($v_{xout,2}$) was unrelated to $\%Ao_{final}$.

- **Ambient flow velocity directly controlled $v_{xin,2}$ for all samplers**

Velocity encountered on verticals inside the sampler width was predominantly determined by the ambient flow velocity, while sampler entrance area and $\%Ao_{final}$ had comparatively minor influences.

- **Sampler entrance area had larger effect on $v_{xin,2}$ than netting properties/bag blockage**

Switching from a BL-84 to an Elwha sampler increased $v_{xin,2}$ by 4.6%, and by 13% when switching from a BL-84 to a TR2. By comparison, the 2% decrease in $v_{xin,2}$ resulting from the difference between a densely woven or half-clogged net to an empty net was small: netting properties were about half as effective as sampler entrance area in determining $v_{xin,2}$.

- **Sampler width also controlled $v_{xin,2}$**

The notable difference in relations of $v_{xin,2} = f(\%Ao_{final})$ between the BL-84 and the Elwha—unexpected because the two samplers differ by just one inch in height—suggested that not only protrusion into fast flow but sampler width likewise controlled $v_{xin,2}$.

- **Flow faster in central sampler than over the sampler width and more controlled by $\%Ao_{final}$**

Flow velocity averaged within the central three inside verticals ($v_{xctr,2}$) was about 2% higher than $v_{xin,2}$ averaged over all inside verticals. The logarithmic functions $v_{xctr,2} = f(\%Ao_{final})$ were also steeper, hence netting properties and bag clogging had more effect on $v_{xctr,2}$ than on $v_{xin,2}$.

- **Inside/outside velocity ratio moderately affected by sampler size, ambient velocity and $\%Ao_{final}$**

The ratio of flow velocity inside and outside of samplers ($R_{in/out}$) was indicative of hydraulic efficiency. Sampler entrance area affected $R_{in/out}$ twice as much as the bags' percent open area and target flow velocity. However, similar to hydraulic efficiency (see below), the effects of sampler size, ambient velocity and $\%Ao_{final}$ on $R_{in/out}$ were generally moderate.

- **Q_{in} predominantly controlled by sampler entrance area and target velocity;**

Sampler entrance area directly controlled Q_{in} and exerted a larger influence than target velocity. By comparison, the influence of $\%Ao_{final}$ was minimal. Suspended sediment collected in a bedload sampler needs to be related to sampler entrance area rather than to the sampler width to avoid overprediction.

- **Results for hydraulic efficiency generally reflected results for flow velocity**

The relative positions of individual data points to each other was largely maintained in the relations of both flow velocity ($v_{xin,2}$) and hydraulic efficiency ($HE_{in,2}$) to $\%Ao_{final}$, but the predominant control of target velocity canceled out in the analyses of hydraulic efficiency.

- **Hydraulic efficiency ($HE_{in,2}$) always >100% for TR2 and Elwha samplers**

$HE_{in,2}$ ranged from 101 to 115% for the TR2 and Elwha samplers, showing that flow was sucked into the samplers at all target velocities and net configurations, even for clogged nets. $HE_{in,2}$ for the BL-84 was near 100%.

- **Hydraulic efficiency highest for the largest sampler (TR2), the fastest flow, and the most open net**

Hydraulic efficiency increased with sampler entrance area, with target velocity, and with the % bag open area. None of the three parameters exerted an overwhelming control, but the parameters interact in their influences on hydraulic efficiency.

- **Sampler size and target velocity more important to hydraulic efficiency than bag fill level**

Hydraulic efficiency is slightly more affected by sampler size than by target velocity. Netting properties/bag fill levels ($\%Ao_{final}$) ranked third in their effects on $HE_{in,2}$. A TR2 sampler half filled with gravel had a higher hydraulic efficiency than an Elwha with empty bags, and an Elwha with half-clogged nets has a higher efficiency than an empty BL-84 sampler.

- **Effects of bag clogging on hydraulic efficiency not even among samplers**

Hydraulic efficiency of the TR2 sampler was not reduced by any of the empty coarse-mesh nets (Ao_{final} >50), while net clogging notably decreased $HE_{in,2}$, suggesting that choice of a coarse mesh matters little for the TR2 sampler bag, but bags should not be filled to 50%, especially not for the shape-retaining 1-mm bag and not in faster flow. For the BL-84 sampler, the choice among coarse nets was likewise less important than avoiding filling the bag to 50%, especially in slower flow. In the Elwha sampler, gravel fill and the sheer presence of a coarse net equally reduced $HE_{in,2}$, particularly at slower flow.

- **Different responses by the 1 and 3.6 mm nets on TR2 sampler reflect differences in net shape**

The 1 mm precision net largely kept its bulky shape as flow velocity and gravel fill increased. The bulky net resulted in slightly faster flows and higher hydraulic efficiencies for empty 1 mm nets on the TR2 sampler than for the slender, empty 3.6 mm nets, particularly in fast flow. By contrast, the 3.6 mm net stretched as velocity and gravel fill increased. Being a long distance from the sampler entrance, the gravel fill slowed $v_{xin,2}$ less in the 3.6 mm than in the 1 mm net with a shorter distance between gravel fill and entrance. The stretchy 3.6 mm nets coped better with gravel fill and kept hydraulic efficiency more even over different fill levels than the 1 mm precision net. The 1 mm attached to Elwha sampler was even a bit more slender than the 3.6 mm bag, and hydraulic efficiency displayed almost the opposite trends for the two nets as observed for the TR2. Effects of net shape posed an extra layer of complexity when comparing results from custom-sewn nets.

- **Sampler bags from precision netting should not be filled to more than 30% of their volume**

Averaged over all samplers and nets, hydraulic efficiency dropped steeply as the gravel fill increased, indicating that bags should not be filled to more than about 30% of their volumes. The value approximates the commonly referenced value of 40% as a threshold for bag filling.

- **Slight shape difference in 0.55 mm nets on TR2 and Elwha was reflected in hydraulic efficiency**

The densely woven 0.55 mm net had a 36$\%\ Ao_{final}$ similar to the 1 mm net with a 30% gravel fill. The 0.55 mm bag used with the TR2 was relatively long, narrow, and tapered and produced higher $v_{xin,2}$ and $HE_{in,2}$ than the 1 mm net with 30% gravel fill, i.e., the 0.55 mm net acted like a “fast” net. By contrast, the 0.55 mm net for Elwha sampler was relatively short and wide, and it tended to act like a “slow” net.

- **Semi-consistent responses in $v_{xin,2}$ and $HE_{in,2}$ from particular nets and samplers**

The hydraulic efficiency for specific nets and their fill levels differed not only depending on the particular net shape. Hydraulic efficiency was also influenced by ambient flow and possibly by turbulent flow structures that affect samplers differently. This complexity may cause problems when transferring study results.

- **Bag clogging: bag end clogging reduced $v_{xin,2}$ and $HE_{in,2}$ more than gravel fill**

Blocking the ends of sampler bags symmetrically with a sewn-in plastic liner simulates clogging by suspended organic debris and sand. This type of net blockage reduced $v_{xin,2}$ and $HE_{in,2}$ more than a gravel fill that extended to the same levels as covered by the liner because water could easily exit the bags above the gravel wedge.

- **Huge effect of sampler body expansion ratio on hydraulic efficiency**

Hydraulic efficiency for an unflared bedload trap—with an opening even larger than the TR2—was just below 100%. The effects of expansion ratio on $HE_{in,2}$ far exceeded effects from target velocity, sampler entrance area, and $\%Ao_{final}$. Extrapolating this finding suggested that a lightly flared sampler body with a 12” by 6” or 12” by 8” opening area and a 1.1 expansion ratio might have obtained a $HE_{in,2}$ of ≅ 100%.

- **No direct relation between hydraulic efficiency and sampling efficiency**

Due to the highly complex nature of bedload transport and the interaction of a sampler with flow hydraulics and bed material, a degree of hydraulic efficiency does not transfer direct to sampling efficiency. Even estimates of possible relations between hydraulic efficiency and sampling efficiency need to be based on several assumptions.

- **Processes-dependent effects of hydraulic efficiency to sampling efficiency**

Increased hydraulic efficiency may cause pronounced oversampling under specific conditions: When sampling suspended sand; When sandy material scoured at the sampler entrance is sucked into the sampler; When gravel particles dislodged by sampler placement on the bed are sucked into sampler.

- **Limited transferability of flume results**

Study results can be interpolated to upscaled or downscaled versions of the study samplers, but study results may not be directly transferable to natural channels, to coarse-bedded streams, and samplers with external lead frames. Results are not applicable to samplers with other expansion ratios.

8.2 Recommendations for deployment of high-efficiency pressure-difference samplers

In an effort to reduce potential oversampling from hydraulic efficiency, it might be useful to limit the number of sampler deployments while increasing sampling time. In order to avoid a quick fill-up of the sampler bag with sand and pea gravel, a coarse net should be used to limit the sample to gravel and extend the sampling time. Placing the sampler onto ground plates installed at low flows or onto a sill flush with the stream bed is recommended to avoid scooping or dislodging particles during sampler placement. Avoiding particle scooping and dislodgment is the more important the higher the deployment frequency. Alternatively, oversampling due particle scooping and dislodgment could be monitored with an underwater camera and then mathematically accounted for during data analysis.

Sand, especially if travelling suspended a few inches above ground, should be sampled separately for several reasons. One reason is that a fine mesh bag is required which limits sampling time due to bag clogging. For sand transport, long sampling times are not important in terms of collecting infrequently transported large particles, and short sampling times may actually be helpful to avoid clogging mesh pores. On sand beds, an underwater camera is useful not only to monitor scour development and if necessary adjust sample mass during data analysis but also to determine the upward extent of suspended sand transport to determine the appropriate portion of the sampler entrance area to which collected sand should be attributed when computing a transport rate.

8.3 Recommendations for improvements of future studies and new study focal points

- **A long flume is required**

Flume experiments with flows 6 ft wide and 2.2 ft deep and near-bottom velocities of more than 3 ft/s require large discharges. Turbulence is created within the head box, and it takes more than 20 feet of downstream distance to straighten the flowlines.

- **A large number of runs to determine variability**

To determine variability among flume runs, multiple repetitions for most runs would be beneficial.

- **Studies are required to isolate the effects of net shape and develop standardized sewing patterns**

The nets used in this study had various dimensions and shapes. Net shapes affected hydraulic efficiency about as much as $\%Ao_{final}$, but net shapes were not explicitly tested in this study. Equalizing bag surface areas in this study was useful, but not sufficient. To isolate the effects of net shape on hydraulic efficiency, shapes should have been identical for all nets and a set of different net shapes should have been tested for each mesh size. The effects of net shape also suggest that standardized patterns need to be developed for the gores from which sampler bags are sewn.

- **New sampler development: expansion ratios should decreasing with sampler size**

In order to use multiple samplers interchangeably, samplers should have the same hydraulic efficiency. The parameter that most strongly controls hydraulic efficiency is the sampler body's expansion ratio. First estimates suggested that reducing the TR2's expansion ratio to around 1.1 and the Elwha's expansion ration to about 1.2 might accomplish this goal. Also, a hydraulic efficiency of near 100% may be expected for an Elwha sampler downsized to a 3" by 6" in opening. Detailed studies in flumes and on coarse gravel beds are required to determine appropriate designs.

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Notation

a, b	Regression parameters
d	Thread diameter
h	Flow depth
HE	Hydraulic efficiency
$HE_{in,2}$	Hydraulic efficiency associated with $v_{xin,2}$
Q	Discharge
Q_{in}	Discharge passing within the inside of a sampler
v_m	Mean flow velocity per vertical or cross-sectionally averaged flow velocity
v_x	Downstream velocity
$v_{x,2}$	Downstream velocity measured at 2" above ground
$v_{xctr,2}$	Downstream velocity measured at 2" above ground averaged over the three central sampling locations inside a sampler at 25, 50, and 75% of the sampler width
$v_{xin,2}$	Downstream velocity measured at 2" above ground averaged over all 3 or 5 sampling locations inside a sampler at (10), 25, 50, 75, and (90)% of the sampler width
$v_{xout,2}$	Downstream velocity measured at 2" above ground averaged over all sampling locations outside a sampler at -10, -25, 110, and 125% of the sampler width
$v_{xin,m}$	Vertically averaged downstream velocity, laterally averaged over the inside verticals

v_{tar} Downstream target velocity measured at 6” above ground in the flume center at 12 ft downstream of the head box

v_{xv} Downstream velocity measured at some location within a vertical

w width (of flume channel or mesh width)

$\%Ao$ Percent openness of a net’s weave

$\%Ao_{final}$ Percent openness of a net resulting from the combined effects of weave density and bag surface area blocked by seams and by net clogging by either a plastic liner or gravel fill

Appendix: Data for flume runs

TR2, 1.5 ft/s

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**TR2**			
	Bag configuration									**No sampler**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.371	1.365	1.433	1.386	1.434	1.365	1.467	1.365	1.371	1.40	1.42	1.37	1.39
1	1.355	1.411	1.469	1.469	1.456	1.491	1.526	1.426	1.460	1.45	1.48	1.41	1.47
2	1.346	1.396	1.455	1.519	1.456	1.488	1.533	1.482	1.481	1.46	1.49	1.43	1.49
3.25	1.424	1.492	1.535	1.454	1.568	1.551	1.558	1.512	1.569	1.52	1.53	1.50	1.52
5	1.392	1.514	1.578	1.608	1.587	1.517	1.573	1.521	1.566	1.54	1.57	1.50	1.57
2 (interpolated)											1.50	1.45	1.44
	Discharge (cfs) per vertical												
	0.10	0.13	0.13	0.15	0.19	0.15	0.14	0.13	0.11	1.23	0.76	0.47	0.16
	2nd series of flume experiments, 22 ft downstream from head box												
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.49	1.48	1.47	1.45	1.53	1.50	1.53	1.52	1.54	1.50	1.50	1.50	1.49

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**TR2**			
	Bag configuration									**No net**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.319	1.475	1.600	1.685	1.700	1.678	1.595	1.425	1.392	1.54	1.65	1.40	1.69
1	1.450	1.461	1.634	1.687	1.796	1.697	1.641	1.486	1.473	1.59	1.69	1.47	1.73
2	1.518	1.491	1.683	1.759	1.849	1.772	1.729	1.542	1.522	1.65	1.76	1.52	1.79
3.25	1.504	1.554	1.735	1.816	1.810	1.824	1.781	1.568	1.487	1.68	1.79	1.53	1.82
5	1.540	1.562	1.673	1.780	1.739	1.710	1.768	1.598	1.555	1.66	1.73	1.56	1.74
2 (interpolated)											1.76	1.51	1.79
	Discharge (cfs) per vertical												
	0.11	0.13	0.15	0.18	0.22	0.17	0.15	0.14	0.11	1.36	0.87	0.49	0.19
	2nd series of flume experiments, 22 ft downstream from head box												
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.372	1.459	1.605	1.659	1.748	1.731	1.653	1.520	1.506	1.58	1.68	1.46	1.71

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	v_x at 6" abv. ground at the sampler (ft/s)									1.592			
	Sampler tested									**TR2**			
	Bag configuration									**0.55 mm net**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.296	1.347	1.505	1.623	1.718	1.644	1.526	1.349	1.401	1.49	1.60	1.35	1.66
1	1.306	1.400	1.535	1.611	1.657	1.616	1.536	1.398	1.338	1.49	1.59	1.36	1.63
2	1.336	1.400	1.611	1.714	1.665	1.772	1.576	1.469	1.388	1.55	1.67	1.40	1.72
3.25	1.450	1.449	1.670	1.667	1.769	1.732	1.666	1.492	1.477	1.60	1.70	1.47	1.72
5	1.459	1.532	1.602	1.660	1.751	1.601	1.604	1.521	1.471	1.58	1.64	1.50	1.67
2 (interpolated)											1.67	1.41	1.70
	Discharge (cfs) per vertical												
	0.10	0.13	0.14	0.17	0.22	0.17	0.14	0.13	0.11	1.30	0.83	0.47	0.18
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.44	1.47	1.62	1.71	1.71	1.69	1.64	1.53	1.50	1.59	1.67	1.49	1.70

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	v_x at 6" abv. ground at the sampler (ft/s)									1.592			
	Sampler tested									**TR2**			
	Bag configuration									**1 mm net**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.252	1.292	1.469	1.606	1.613	1.633	1.531	1.383	1.345	1.46	1.57	1.32	1.62
1	1.228	1.467	1.515	1.674	1.703	1.714	1.564	1.450	1.392	1.52	1.63	1.38	1.70
2	1.374	1.375	1.576	1.684	1.755	1.667	1.584	1.432	1.422	1.54	1.65	1.40	1.70
3.25	1.373	1.389	1.624	1.764	1.856	1.681	1.667	1.515	1.457	1.59	1.72	1.43	1.77
5	1.463	1.513	1.566	1.665	1.589	1.567	1.523	1.555	1.525	1.55	1.58	1.51	1.61
2 (interpolated)											1.68	1.40	1.74
	Discharge (cfs) per vertical												
	0.10	**0.12**	**0.14**	**0.17**	**0.21**	**0.16**	**0.14**	**0.13**	**0.11**	**1.29**	**0.82**	**0.47**	**0.18**
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	**1.44**	**1.43**	**1.62**	**1.68**	**1.74**	**1.75**	**1.62**	**1.56**	**1.47**	**1.59**	**1.68**	**1.47**	**1.72**

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**TR2**			
	Bag configuration									**2 mm net**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.382	1.340	1.530	1.718	1.686	1.562	1.592	1.355	1.382	1.51	1.62	1.36	1.66
1	1.361	1.411	1.631	1.660	1.709	1.666	1.595	1.474	1.445	1.55	1.65	1.42	1.68
2	1.537	1.445	1.641	1.785	1.819	1.722	1.676	1.544	1.490	1.63	1.73	1.50	1.78
3.25	1.433	1.458	1.738	1.735	1.826	1.769	1.691	1.499	1.480	1.63	1.75	1.47	1.78
5	1.464	1.546	1.654	1.692	1.688	1.612	1.669	1.526	1.495	1.59	1.66	1.51	1.66
2 (interpolated)											1.73	1.47	1.76
	Discharge (cfs) per vertical												
	0.11	0.13	0.14	0.17	0.22	0.17	0.14	0.13	0.11	1.33	0.85	0.48	0.19
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.44	1.45	1.61	1.68	1.74	1.69	1.63	1.52	1.48	1.58	1.67	1.47	1.70

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**TR2**			
	Bag configuration									**3.6 mm net**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.267	1.351	1.508	1.608	1.630	1.574	1.493	1.425	1.425	1.48	1.56	1.37	1.60
1	1.326	1.400	1.550	1.651	1.647	1.685	1.562	1.467	1.422	1.52	1.62	1.40	1.66
2	1.412	1.469	1.607	1.698	1.716	1.703	1.667	1.508	1.419	1.58	1.68	1.45	1.71
3.25	1.418	1.468	1.716	1.734	1.777	1.724	1.633	1.527	1.372	1.60	1.72	1.45	1.74
5	1.497	1.469	1.596	1.669	1.627	1.637	1.593	1.549	1.495	1.57	1.62	1.50	1.64
2 (interpolated)											1.69	1.43	1.72
	Discharge (cfs) per vertical												
	0.11	0.13	0.14	0.17	0.21	0.17	0.14	0.13	0.11	1.30	0.83	0.47	0.18
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.44	1.48	1.58	1.68	1.71	1.68	1.64	1.50	1.52	1.58	1.66	1.48	1.69

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**TR2**			
	Bag configuration									**1 mm net, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.327	1.285	1.475	1.529	1.593	1.594	1.484	1.379	1.396	1.45	1.53	1.35	1.57
1	1.381	1.426	1.493	1.643	1.696	**1.628**	**1.555**	1.362	1.444	1.51	1.60	1.40	1.66
2	1.464	1.511	1.586	1.696	1.719	1.705	1.592	1.467	1.477	1.58	1.66	1.48	1.71
3.25	1.409	1.479	1.688	1.743	1.783	1.709	1.721	1.585	1.471	1.62	1.73	1.49	1.75
5	1.488	1.499	1.586	1.622	1.643	1.680	1.617	1.588	1.583	1.59	1.63	1.54	1.65
2 (interpolated)											1.68	1.46	1.72
	Discharge (cfs) per vertical												
	0.11	0.13	0.14	0.17	0.21	0.17	0.14	0.13	0.11	1.30	0.82	0.48	0.18
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.40	1.47	1.60	1.64	1.66	1.67	1.65	1.52	1.50	1.57	1.64	1.47	1.66

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**TR2**			
	Bag configuration									**1 mm net, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.319	1.301	1.442	1.496	1.522	1.498	1.355	1.376	1.354	1.41	1.46	1.34	1.51
1	1.445	1.373	1.507	1.572	1.569	1.544	1.501	1.437	1.423	1.49	1.54	1.42	1.56
2	1.417	1.402	1.565	1.605	1.647	1.557	1.630	1.503	1.387	1.52	1.60	1.43	1.60
3.25	1.445	1.498	1.657	1.695	1.701	1.676	1.595	1.557	1.505	1.59	1.66	1.50	1.69
5	1.505	1.535	1.511	1.570	1.576	1.617	1.569	1.554	1.576	1.56	1.57	1.54	1.59
2 (interpolated)											1.62	1.44	1.63
	Discharge (cfs) per vertical												
	0.11	0.13	0.14	0.16	0.20	0.16	0.14	0.13	0.11	1.27	0.79	0.48	0.17
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.47	1.49	1.57	1.67	1.68	1.68	1.61	1.52	1.48	1.58	1.64	1.49	1.68

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**TR2**			
	Bag configuration									**3.6 mm net, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.345	1.341	1.549	1.588	1.612	1.660	1.433	1.340	1.391	1.47	1.57	1.35	1.62
1	1.393	1.414	1.587	1.631	1.687	1.771	1.557	1.378	1.408	1.54	1.65	1.40	1.70
2	1.443	1.466	1.601	1.609	1.745	1.661	1.578	1.482	1.457	1.56	1.64	1.46	1.67
3.25	1.430	1.510	1.665	1.706	1.718	1.604	1.668	1.603	1.535	1.60	1.67	1.52	1.68
5	1.574	1.580	1.631	1.633	1.690	1.596	1.653	1.551	1.505	1.60	1.64	1.55	1.64
2 (interpolated)											1.65	1.46	1.68
	Discharge (cfs) per vertical												
	0.11	0.13	0.14	0.16	0.21	0.16	0.14	0.13	0.11	1.30	0.82	0.48	0.18
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.47	1.50	1.61	1.68	1.68	1.70	1.64	1.53	1.50	1.59	1.66	1.50	1.69

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**TR2**			
	Bag configuration									**3.6 mm net, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.292	1.270	1.348	1.433	1.418	1.429	1.330	1.169	1.184	1.32	1.39	1.23	1.43
1	1.300	1.307	1.416	1.496	1.454	1.379	1.411	1.255	1.318	1.37	1.43	1.29	1.44
2	1.312	1.385	1.502	1.567	1.534	1.497	1.455	1.377	1.324	1.44	1.51	1.35	1.53
3.25	1.276	1.419	1.564	1.579	1.595	1.532	1.567	1.363	1.376	1.47	1.57	1.36	1.57
5	1.405	1.519	1.475	1.423	1.473	1.467	1.444	1.454	1.390	1.45	1.46	1.44	1.45
2 (interpolated)											1.52	1.33	1.54
	Discharge (cfs) per vertical												
	0.10	0.12	0.13	0.15	0.19	0.15	0.13	0.12	0.10	1.18	0.74	0.44	0.16
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.47	1.49	1.59	1.68	1.66	1.70	1.63	1.55	1.53	1.59	1.65	1.51	1.68

TR2, 2.5 ft/s

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**TR2**			
	Bag configuration									**No sampler**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.059	2.185	2.067	2.040	2.111	2.068	2.095	1.982	2.022	2.07	2.08	2.06	2.07
1	2.231	2.209	2.255	2.197	2.196	2.192	2.088	2.018	2.167	2.17	2.19	2.16	2.19
2	2.279	2.274	2.276	2.245	2.169	2.127	2.223	2.100	2.213	2.21	2.21	2.22	2.18
3.25	2.427	2.291	2.325	2.411	2.328	2.414	2.327	2.295	2.327	2.35	2.36	2.33	2.38
5	2.388	2.379	2.558	2.411	2.492	2.539	2.478	2.446	2.441	2.46	2.50	2.41	2.48
2 (interpolated)											2.24	2.23	2.23
	Discharge (cfs) per vertical												
	0.17	0.20	0.21	0.23	0.29	0.23	0.20	0.20	0.17	1.90	1.16	0.74	0.25
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.48	2.52	2.49	2.53	2.53	2.50	2.48	2.52	2.52	2.51	2.50	2.51	2.52

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**TR2**			
	Bag configuration									**No net**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.075	2.156	2.557	2.722	2.730	2.622	2.508	2.147	2.226	2.42	2.63	2.15	2.69
1	2.177	2.206	2.561	2.745	2.794	2.744	2.678	2.266	2.289	2.50	2.70	2.23	2.76
2	2.206	2.322	2.702	2.816	2.922	2.894	2.754	2.395	2.338	2.59	2.82	2.32	2.88
3.25	2.297	2.402	2.785	3.055	3.060	2.987	2.904	2.539	2.558	2.73	2.96	2.45	3.03
5	2.513	2.588	2.737	2.828	2.850	2.840	2.891	2.642	2.602	2.72	2.83	2.59	2.84
2 (interpolated)											2.85	2.33	2.92
	Discharge (cfs) per vertical												
	0.17	**0.21**	**0.24**	**0.29**	**0.36**	**0.28**	**0.24**	**0.22**	**0.18**	**2.19**	**1.41**	**0.78**	**0.31**
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	**2.52**	**2.52**	**2.76**	**2.85**	**2.94**	**2.84**	**2.66**	**2.53**	**2.51**	**2.68**	**2.81**	**2.52**	**2.88**

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**TR2**			
	Bag configuration									**0.55 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.080	2.166	2.208	2.530	2.578	2.471	2.295	2.150	2.039	2.28	2.42	2.11	2.53
1	2.117	2.169	2.384	2.611	2.692	2.408	2.506	2.104	1.975	2.33	2.52	2.09	2.57
2	2.306	2.274	2.373	2.685	2.703	2.658	2.557	2.186	2.204	2.44	2.60	2.24	2.68
3.25	2.346	2.428	2.630	2.774	2.773	2.775	2.629	2.239	2.229	2.54	2.72	2.31	2.77
5	2.622	2.511	2.545	2.734	2.572	2.738	2.628	2.502	2.427	2.59	2.64	2.52	2.68
2 (interpolated)											2.62	2.21	2.70
	Discharge (cfs) per vertical												
	0.18	0.21	0.22	0.27	0.33	0.27	0.22	0.20	0.17	2.06	1.31	0.75	0.29
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.58	2.58	2.77	2.83	2.89	2.84	2.73	2.49	2.53	2.69	2.81	2.54	2.85

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**TR2**			
	Bag configuration									**1 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.045	2.122	2.551	2.559	2.690	2.677	2.410	2.228	2.145	2.38	2.58	2.13	2.64
1	2.076	2.242	2.528	2.717	2.810	2.626	2.548	2.360	2.148	2.45	2.65	2.21	2.72
2	2.161	2.269	2.567	2.883	2.796	2.832	2.661	2.272	2.226	2.52	2.75	2.23	2.84
3.25	2.308	2.502	2.808	2.859	2.926	2.841	2.717	2.434	***2.320***	2.64	2.83	2.39	2.88
5	2.505	2.506	2.664	2.822	2.710	2.734	2.676	2.542	2.389	2.62	2.72	2.49	2.76
2 (interpolated)											2.76	2.27	2.83
	Discharge (cfs) per vertical												
	0.17	0.21	0.23	0.28	0.35	0.28	0.23	0.21	0.17	2.13	1.37	0.76	0.30
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.44	2.44	2.78	2.80	2.92	2.81	2.72	2.57	2.48	2.66	2.81	2.48	2.85

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**TR2**			
	Bag configuration									**2 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.032	2.091	2.480	2.616	2.574	2.633	2.469	2.233	2.162	2.37	2.55	2.13	2.61
1	2.079	2.119	2.523	2.695	2.748	2.593	2.476	2.332	2.097	2.41	2.61	2.16	2.68
2	2.240	2.340	2.638	2.782	2.817	2.739	2.508	2.330	2.302	2.52	2.70	2.30	2.78
3.25	2.311	2.436	2.763	2.833	2.807	2.729	2.745	2.473	2.377	2.61	2.78	2.40	2.79
5	2.472	2.602	2.741	2.756	2.770	2.772	2.756	2.559	2.521	2.66	2.76	2.54	2.77
2 (interpolated)											2.70	2.29	2.76
	Discharge (cfs) per vertical												
	0.17	0.21	0.23	0.28	0.35	0.27	0.23	0.21	0.18	2.12	1.36	0.77	0.30
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.49	2.60	2.70	2.79	2.88	2.91	2.71	2.62	2.51	2.69	2.80	2.55	2.86

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**TR2**			
	Bag configuration									**3.6 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.101	2.194	2.488	2.548	2.524	2.551	2.476	2.113	2.209	2.36	2.52	2.15	2.54
1	2.174	2.117	2.434	2.590	2.770	2.591	2.580	2.244	2.142	2.40	2.59	2.17	2.65
2	2.334	2.286	2.649	2.824	2.891	2.809	2.735	2.356	2.325	2.58	2.78	2.33	2.84
3.25	2.328	2.351	2.560	2.903	2.822	2.817	2.653	2.469	2.292	2.58	2.75	2.36	2.85
5	2.531	2.473	2.662	2.702	2.728	2.860	2.661	2.514	2.550	2.63	2.72	2.52	2.76
2 (interpolated)											2.73	2.28	2.81
	Discharge (cfs) per vertical												
	0.18	0.20	0.23	0.27	0.35	0.28	0.23	0.21	0.18	2.12	1.35	0.76	0.30
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.42	2.51	2.76	2.74	2.91	2.82	2.77	2.60	2.51	2.67	2.80	2.51	2.83

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**TR2**			
	Bag configuration									**1 mm, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.046	2.050	2.287	2.428	2.530	2.532	2.372	2.143	2.085	2.27	2.43	2.08	2.50
1	2.044	2.189	2.307	2.547	2.580	2.573	2.383	2.114	2.159	2.32	2.48	2.13	2.57
2	2.253	2.220	2.602	2.731	2.736	2.673	2.612	2.244	2.318	2.49	2.67	2.26	2.71
3.25	2.264	2.326	2.714	2.643	2.774	2.670	2.491	2.361	2.331	2.51	2.66	2.32	2.70
5	2.462	2.465	2.652	2.725	2.796	2.651	2.588	2.549	2.482	2.60	2.68	2.49	2.72
2 (interpolated)											2.62	2.23	2.67
	Discharge (cfs) per vertical												
	0.17	0.20	0.22	0.26	0.34	0.26	0.22	0.20	0.17	2.06	1.31	0.75	0.29
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.38	2.45	2.69	2.73	2.81	2.80	2.74	2.58	2.56	2.64	2.76	2.49	2.78

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**TR2**			
	Bag configuration									**1 mm, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.100	2.028	2.223	2.390	2.509	2.478	2.331	2.143	2.140	2.26	2.39	2.10	2.46
1	2.077	2.169	2.425	2.537	2.560	2.505	2.311	2.258	2.195	2.34	2.47	2.17	2.53
2	2.154	2.289	2.455	2.660	2.638	2.553	2.498	2.271	2.192	2.41	2.56	2.23	2.62
3.25	2.326	2.276	2.538	2.676	2.700	2.558	2.670	2.401	2.394	2.50	2.63	2.35	2.64
5	2.492	2.496	2.637	2.574	2.619	2.670	2.619	2.486	2.482	2.56	2.62	2.49	2.62
2 (interpolated)											2.56	2.24	2.61
	Discharge (cfs) per vertical												
	0.17	0.20	0.22	0.26	0.33	0.26	0.22	0.21	0.17	2.04	1.28	0.75	0.28
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.42	2.55	2.64	2.68	2.73	2.76	2.70	2.51	2.47	2.61	2.70	2.49	2.72

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**TR2**			
	Bag configuration									**3.6 mm, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.945	2.006	2.488	2.460	2.571	2.515	2.266	2.057	2.129	2.27	2.46	2.03	2.52
1	2.114	2.183	2.506	2.611	2.643	2.584	2.453	2.189	2.127	2.38	2.56	2.15	2.61
2	2.159	2.297	2.611	2.745	2.687	2.624	2.486	2.310	2.203	2.46	2.63	2.24	2.69
3.25	2.341	2.400	2.799	2.714	2.806	2.791	2.485	2.329	2.294	2.55	2.72	2.34	2.77
5	2.462	2.503	2.646	2.714	2.677	2.700	2.552	2.455	2.514	2.58	2.66	2.48	2.70
2 (interpolated)											2.65	2.24	2.70
	Discharge (cfs) per vertical												
	0.17	0.20	0.23	0.27	0.34	0.27	0.22	0.20	0.17	2.07	1.32	0.75	0.29
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.42	2.49	2.62	2.79	2.85	2.82	2.72	2.51	2.56	2.64	2.76	2.49	2.82

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**TR2**			
	Bag configuration									**3.6 mm, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.068	2.131	2.284	2.500	2.540	2.545	2.350	2.211	2.126	2.068	2.131	2.284	2.500
1	2.130	2.216	2.430	2.571	2.564	2.586	2.523	2.256	2.313	2.130	2.216	2.430	2.571
2	2.203	2.152	2.582	2.716	2.649	2.677	2.677	2.359	2.300	2.203	2.152	2.582	2.716
3.25	2.256	2.395	2.578	2.845	2.751	2.842	2.836	2.455	2.635	2.256	2.395	2.578	2.845
5	2.383	2.482	2.599	2.746	2.718	2.770	2.629	2.643	2.645	2.383	2.482	2.599	2.746
2 (interpolated)											2.67	2.07	2.71
	Discharge (cfs) per vertical												
	0.17	0.20	0.22	0.27	0.33	0.27	0.23	0.21	0.19	2.10	1.33	0.77	0.29
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.41	2.47	2.65	2.74	2.84	2.76	2.71	2.60	2.47	2.63	2.74	2.49	2.78

TR2, 3.5 ft/s

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**TR2**			
	Bag configuration									**No sampler**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.870	2.915	2.853	2.852	2.872	2.904	2.824	2.834	2.667	2.84	2.86	2.82	2.88
1	2.931	2.804	2.920	2.975	3.097	2.999	2.861	2.886	2.777	2.92	2.97	2.85	3.02
2	3.120	3.043	3.085	3.073	3.150	3.183	2.850	2.851	2.883	3.03	3.07	2.97	3.14
3.25	3.212	3.222	3.283	3.233	3.141	3.215	3.149	3.100	3.053	3.18	3.20	3.15	3.20
5	3.436	3.417	3.318	3.407	3.436	3.326	3.212	3.273	3.187	3.33	3.34	3.33	3.39
2 (interpolated)											3.08	2.98	3.02
	Discharge (cfs) per vertical												
	0.24	0.28	0.28	0.32	0.40	0.32	0.27	0.27	0.22	2.58	1.58	1.01	**0.35**
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.08	3.16	3.15	3.14	3.13	3.31	3.29	3.28	3.24	3.20	3.20	3.19	3.19

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**TR2**			
	Bag configuration									**No net**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.663	2.823	3.295	3.437	3.484	3.422	3.258	2.720	2.656	3.08	3.38	2.72	3.45
1	2.809	2.910	3.411	3.522	3.648	3.562	3.244	2.752	2.790	3.18	3.48	2.82	3.58
2	2.874	3.076	3.661	3.816	3.801	3.658	3.387	2.937	2.876	3.34	3.66	2.94	3.76
3.25	3.050	3.176	3.704	3.888	3.985	3.828	3.559	3.027	3.024	3.47	3.79	3.07	3.90
5	3.268	3.385	3.602	3.662	3.741	3.688	3.589	3.273	3.278	3.50	3.66	3.30	3.70
2 (interpolated)											3.68	2.93	3.78
	Discharge (cfs) per vertical												
	0.23	0.28	0.31	0.37	0.47	0.37	0.30	0.26	0.23	2.81	1.82	0.99	0.40
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.18	3.22	3.54	3.66	3.80	3.70	3.60	3.29	3.25	3.47	3.66	3.23	3.72

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**TR2**			
	Bag configuration									**0.55 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.880	2.893	3.059	3.238	3.337	3.218	3.077	2.612	2.580	2.99	3.19	2.74	3.26
1	3.009	2.680	3.204	3.362	3.435	3.356	3.187	2.772	2.662	3.07	3.31	2.78	3.38
2	3.176	2.900	3.354	3.629	3.560	3.482	3.207	2.896	2.767	3.22	3.45	2.93	3.56
3.25	3.274	2.941	3.407	3.620	3.640	3.574	3.387	3.109	2.942	3.32	3.53	3.07	3.61
5	3.139	3.170	3.301	3.573	3.610	3.474	3.433	3.140	3.122	3.33	3.48	3.14	3.55
2 (interpolated)											3.44	2.94	3.54
	Discharge (cfs) per vertical												
	0.23	0.26	0.29	0.35	0.44	0.35	0.29	0.26	0.22	2.69	1.72	0.97	0.38
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.19	3.26	3.48	3.67	3.78	3.66	3.56	3.33	3.16	3.45	3.63	3.24	3.70

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**TR2**			
	Bag configuration									**1 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.651	2.678	3.211	3.269	3.435	3.451	3.196	2.743	2.573	3.02	3.31	2.66	3.38
1	2.636	2.742	3.311	3.425	3.587	3.502	3.274	2.830	2.680	3.11	3.42	2.72	3.50
2	2.758	2.973	3.470	3.502	3.792	3.654	3.410	3.050	2.805	3.27	3.57	2.90	3.65
3.25	2.929	2.938	3.561	3.751	3.710	3.684	3.496	3.008	2.994	3.34	3.64	2.97	3.71
5	3.091	3.186	3.398	3.564	3.663	3.562	3.423	3.261	3.141	3.37	3.52	3.17	3.60
2 (interpolated)											3.57	2.86	3.57
	Discharge (cfs) per vertical												
	0.22	0.26	0.30	0.35	0.46	0.36	0.30	0.27	0.22	2.73	1.77	0.96	0.39
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.20	3.26	3.49	3.66	3.82	3.73	3.65	3.25	3.18	3.47	3.67	3.22	3.74

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**TR2**			
	Bag configuration									**2 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.641	2.707	3.096	3.363	3.332	3.360	3.077	2.631	2.538	2.97	3.25	2.63	3.35
1	2.715	2.705	3.235	3.339	3.485	3.410	3.198	2.760	2.575	3.05	3.33	2.69	3.41
2	2.896	2.909	3.389	3.594	3.587	3.627	3.387	2.914	2.804	3.23	3.52	2.88	3.60
3.25	2.924	3.021	3.392	3.648	3.632	3.632	3.442	2.997	2.951	3.29	3.55	2.97	3.64
5	3.227	3.296	3.518	3.540	3.540	3.524	3.460	3.189	3.208	3.39	3.52	3.23	3.53
2 (interpolated)											3.57	2.84	3.57
	Discharge (cfs) per vertical												
	0.22	**0.26**	**0.30**	**0.35**	**0.44**	**0.35**	**0.29**	**0.26**	**0.22**	**2.70**	**1.74**	**0.96**	**0.38**
	2nd series of flume experiments, 22 ft downstream from head box												
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.22	3.38	3.58	3.68	3.81	3.77	3.55	3.29	3.25	3.50	3.68	3.29	3.75

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**TR2**			
	Bag configuration									**3.6 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.538	2.619	3.076	3.333	**3.433**	3.264	3.050	2.643	2.607	2.538	2.619	3.076	3.333
1	2.646	2.738	3.256	3.437	**3.513**	3.366	3.254	2.768	2.723	2.646	2.738	3.256	3.437
2	2.853	2.823	3.430	3.604	**3.586**	3.602	3.290	2.822	2.827	2.853	2.823	3.430	3.604
3.25	2.942	3.061	3.563	3.728	**3.803**	3.562	3.445	2.903	2.903	2.942	3.061	3.563	3.728
5	3.132	3.276	3.602	3.623	**3.712**	3.502	3.345	3.119	3.148	3.132	3.276	3.602	3.623
2 (interpolated)											3.51	2.82	3.60
	Discharge (cfs) per vertical												
	0.22	0.26	0.30	0.36	0.46	0.35	0.29	0.25	0.22	2.71	1.76	0.95	0.39
	2nd series of flume experiments, 22 ft downstream from head box												
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.26	3.32	3.58	3.67	3.73	3.69	3.61	3.34	3.26	3.49	3.65	3.30	3.70

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**TR2**			
	Bag configuration									**1 mm, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.582	2.728	3.143	3.108	3.313	3.222	3.037	2.596	2.565	2.92	3.16	2.62	3.21
1	2.677	2.712	3.253	3.269	3.483	3.361	3.094	2.727	2.731	3.03	3.29	2.71	3.37
2	2.834	2.920	3.430	3.536	3.602	3.507	3.354	2.821	2.907	3.21	3.49	2.87	3.55
3.25	2.978	3.013	3.546	3.574	3.750	3.560	3.359	2.956	2.928	3.30	3.56	2.97	3.63
5	3.219	3.261	3.483	3.459	3.443	3.559	3.379	3.103	3.168	3.34	3.46	3.19	3.49
2 (interpolated)											3.47	2.84	3.55
	Discharge (cfs) per vertical												
	0.22	0.26	0.30	0.34	0.44	0.35	0.29	0.25	0.22	2.68	1.72	0.96	0.38
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.08	3.18	3.38	3.57	3.75	3.67	3.49	3.27	3.18	3.39	3.57	3.18	3.66

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**TR2**			
	Bag configuration									**1 mm, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.568	2.488	2.311	2.169	2.170	2.211	2.104	2.523	2.574	2.35	2.19	2.54	2.18
1	2.800	2.563	2.391	2.335	2.281	2.269	2.290	2.436	2.663	2.45	2.31	2.62	2.29
2	2.881	2.797	2.541	2.601	2.487	2.460	2.458	2.669	2.814	2.63	2.51	2.79	2.52
3.25	2.966	2.914	2.729	2.603	2.601	2.561	2.546	2.745	2.911	2.73	2.61	2.88	2.59
5	3.173	3.003	2.935	2.929	2.943	2.800	2.894	3.114	3.292	3.01	2.90	3.15	2.89
2 (interpolated)											2.47	2.75	2.46
	Discharge (cfs) per vertical												
	0.22	0.25	0.23	0.26	0.32	0.25	0.22	0.24	0.22	2.23	1.30	0.93	0.28
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.07	3.09	3.38	3.51	3.54	3.53	3.39	3.18	3.18	3.32	3.47	3.13	3.53

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**TR2**			
	Bag configuration									**3.6 mm, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.553	2.790	3.111	3.274	3.266	3.225	3.086	2.803	2.697	2.98	3.19	2.71	3.26
1	2.701	2.780	3.217	3.241	3.426	3.397	3.154	2.929	2.725	3.06	3.29	2.78	3.35
2	2.898	2.953	3.375	3.434	3.601	3.448	3.295	3.024	2.942	3.22	3.43	2.95	3.49
3.25	3.032	3.095	3.535	3.560	3.595	3.538	3.386	3.003	3.007	3.31	3.52	3.03	3.56
5	3.230	3.296	3.485	3.446	3.596	3.555	3.504	3.217	3.314	3.40	3.52	3.26	3.53
2 (interpolated)											3.43	2.92	3.49
	Discharge (cfs) per vertical												
	0.22	0.27	0.30	0.34	0.44	0.35	0.29	0.27	0.23	2.70	1.72	0.98	0.38
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.05	3.21	3.34	3.62	3.67	3.56	3.47	3.31	3.24	3.38	3.53	3.20	3.62

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-3	-1.2	1.2	3	6	9	10.8	13.2	15	Absol. loc. (in) 0"=LB inside sampler wall			
	1.8	2.1	2.1	2.4	3	2.4	2.1	2.1	1.8	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**TR2**			
	Bag configuration									**3.6 mm, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.517	2.688	3.049	3.219	3.611	3.492	3.195	2.716	2.703	2.517	2.688	3.049	3.219
1	2.643	2.710	3.168	3.309	3.540	3.443	3.259	2.745	2.693	2.643	2.710	3.168	3.309
2	2.802	2.959	3.351	3.469	3.471	3.682	3.430	2.899	2.843	2.802	2.959	3.351	3.469
3.25	2.967	2.960	3.429	3.610	3.527	3.845	3.516	3.091	2.909	2.967	2.960	3.429	3.610
5	3.348	3.245	3.325	3.400	3.504	3.580	3.423	3.139	3.103	3.348	3.245	3.325	3.400
2 (interpolated)											3.50	2.85	3.57
	Discharge (cfs) per vertical												
	0.22	0.26	0.29	0.34	0.44	0.36	0.30	0.26	0.22	2.69	1.73	0.96	0.38
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.06	3.09	3.44	3.53	3.66	3.57	3.47	3.27	3.19	3.36	3.53	3.15	3.59

Elwha, 1.5 ft/s

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**No sampler**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.433	1.375	1.414	1.512	1.481	1.511	1.445	1.409	1.411	1.44	1.47	1.41	1.50
1	1.490	1.426	1.445	1.490	1.520	1.563	1.535	1.506	1.483	1.50	1.51	1.48	1.52
2	1.500	1.485	1.490	1.627	1.536	1.624	1.554	1.605	1.575	1.56	1.57	1.54	1.60
3.25	1.517	1.538	1.571	1.577	1.555	1.637	1.640	1.649	1.573	1.58	1.60	1.57	1.59
5	1.596	1.615	1.688	1.691	1.672	1.627	1.712	1.675	1.658	1.66	1.68	1.64	1.66
2 (interpolated)											1.59	1.57	1.53
	Discharge (cfs) per vertical												
	0.07	0.06	0.06	0.07	0.09	0.07	0.06	0.06	0.07	0.61	0.35	0.26	0.08
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.49	1.56	1.53	1.55	1.56	1.55	1.58	1.51	1.49	1.54	1.55	1.51	1.55

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**No net**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.447	1.531	1.662	1.686	1.762	1.736	1.624	1.541	1.467	1.61	1.69	1.50	1.73
1	1.453	1.488	1.573	1.736	1.751	1.781	1.602	1.507	1.494	1.60	1.69	1.49	1.76
2	1.536	1.538	1.662	1.750	1.764	1.798	1.660	1.656	1.543	1.66	1.73	1.57	1.77
3.25	1.578	1.568	1.721	1.836	1.834	1.778	1.633	1.635	1.603	1.69	1.76	1.60	1.82
5	1.670	1.634	1.702	1.612	1.629	1.685	1.620	1.636	1.666	1.65	1.65	1.65	1.64
2 (interpolated)											1.74	1.59	1.80
	Discharge (cfs) per vertical												
	0.07	0.06	0.07	0.08	0.10	0.08	0.06	0.06	0.07	0.64	0.38	0.26	0.08
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.52	1.49	1.64	1.69	1.69	1.69	1.66	1.56	1.54	1.61	1.67	1.53	1.69

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**0.55 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.370	1.424	1.528	1.632	1.644	1.594	1.518	1.355	1.403	1.50	1.58	1.39	1.62
1	1.421	1.376	1.559	1.594	1.635	1.686	1.524	1.450	1.436	1.52	1.60	1.42	1.64
2	1.443	1.404	1.583	1.692	1.703	1.603	1.575	1.418	1.468	1.54	1.63	1.43	1.67
3.25	1.452	1.470	1.642	1.674	1.660	1.669	1.585	1.508	1.475	1.57	1.65	1.48	1.67
5	1.530	1.509	1.516	1.551	1.526	1.560	1.433	1.521	1.505	1.52	1.52	1.52	1.55
2 (interpolated)											1.64	1.47	1.67
	Discharge (cfs) per vertical												
	0.06	0.06	0.06	0.07	0.09	0.07	0.06	0.06	0.07	0.60	0.35	0.24	0.08
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.47	1.45	1.51	1.62	1.62	1.62	1.54	1.46	1.50	1.53	1.58	1.47	1.62

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**1 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.382	1.460	1.584	1.676	1.618	1.690	1.569	1.422	1.469	1.54	1.63	1.43	1.66
1	1.477	1.466	1.546	1.705	1.696	1.726	1.606	1.487	1.492	1.58	1.66	1.48	1.71
2	1.566	1.510	1.654	1.844	1.798	1.762	1.688	1.520	1.517	1.65	1.75	1.53	1.80
3.25	1.504	1.560	1.699	1.716	1.780	1.733	1.760	1.612	1.554	1.66	1.74	1.56	1.74
5	1.583	1.567	1.648	1.674	1.702	1.616	1.646	1.629	1.629	1.63	1.66	1.60	1.66
2 (interpolated)											1.75	1.56	1.78
	Discharge (cfs) per vertical												
	0.07	0.06	0.06	0.08	0.10	0.08	0.06	0.06	0.07	0.63	0.38	0.26	0.08
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.46	1.46	1.53	1.64	1.63	1.61	1.59	1.54	1.48	1.55	1.60	1.49	1.63

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**3.6 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.267	1.351	1.508	1.608	1.630	1.574	1.493	1.425	1.425	1.48	1.56	1.37	1.60
1	1.326	1.400	1.550	1.651	1.647	1.685	1.562	1.467	1.422	1.52	1.62	1.40	1.66
2	1.412	1.469	1.607	1.698	1.716	1.703	1.667	1.508	1.419	1.58	1.68	1.45	1.71
3.25	1.418	1.468	1.716	1.734	1.777	1.724	1.633	1.527	1.372	1.60	1.72	1.45	1.74
5	1.497	1.469	1.596	1.669	1.627	1.637	1.593	1.549	1.495	1.57	1.62	1.50	1.64
2 (interpolated)											1.71	1.46	1.74
	Discharge (cfs) per vertical												
	0.06	0.06	0.06	0.07	0.09	0.07	0.06	0.06	0.06	0.61	0.37	0.24	0.08
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.45	1.51	1.57	1.65	1.63	1.69	1.64	1.54	1.48	1.57	1.64	1.49	1.66

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**1 mm, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-
3.25	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-
2 (interpolated)											-	-	-
	Discharge (cfs) per vertical												
	-	-	-	-	-	-	-	-	-	-	-	-	-
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.43	1.45	1.54	1.59	1.63	1.59	1.57	1.52	1.54	1.54	1.59	1.49	1.60

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0”=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**1 mm, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-
3.25	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-
2 (interpolated)											-	-	-
	Discharge (cfs) per vertical												
	-	-	-	-	-	-	-	-	-	-	-	-	-
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.45	1.49	1.57	1.60	1.64	1.55	1.54	1.46	1.53	1.54	1.58	1.48	1.60

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0”=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**3.6 mm, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-
3.25	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-
2 (interpolated)											-	-	-
	Discharge (cfs) per vertical												
	-	-	-	-	-	-	-	-	-	-	-	-	-
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.46	1.44	1.55	1.60	1.63	1.59	1.59	1.49	1.50	1.54	1.59	1.47	1.61

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**3.6 mm, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	-	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	-
3.25	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-
2 (interpolated)											-	-	-
	Discharge (cfs) per vertical												
	-	-	-	-	-	-	-	-	-	-	-	-	-
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	1.40	1.41	1.52	1.57	1.62	1.58	1.56	1.47	1.50	1.51	1.57	1.44	1.59

Elwha, 2.5 ft/s

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**No sampler**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.139	2.356	2.222	2.345	2.280	2.263	2.209	2.153	2.214	2.24	2.26	2.22	2.30
1	2.364	2.360	2.437	2.392	2.299	2.297	2.285	2.239	2.334	2.33	2.34	2.32	2.33
2	2.413	2.366	2.410	2.326	2.369	2.388	2.370	2.274	2.367	2.37	2.37	2.36	2.36
3.25	2.484	2.458	2.444	2.557	2.458	2.457	2.406	2.441	2.481	2.47	2.46	2.47	2.49
5	2.547	2.569	2.443	2.603	2.600	2.484	2.539	2.556	2.589	2.55	2.53	2.57	2.56
2 (interpolated)											2.44	2.44	2.44
	Discharge (cfs) per vertical												
	0.11	0.10	0.09	0.11	0.14	0.11	0.09	0.09	0.11	0.94	0.54	0.40	0.12
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.42	2.41	2.44	2.47	2.46	2.53	2.52	2.48	2.52	2.47	2.48	2.46	2.49

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0”=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**No net**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.089	2.165	2.405	2.667	2.817	2.548	2.494	2.269	2.259	2.41	2.59	2.20	2.68
1	2.320	2.321	2.614	2.728	2.691	2.719	2.548	2.420	2.308	2.52	2.66	2.34	2.71
2	2.233	2.449	2.605	2.671	2.745	2.772	2.612	2.356	2.374	2.54	2.68	2.35	2.73
3.25	2.364	2.371	2.568	2.832	2.880	2.760	2.625	2.439	2.451	2.59	2.73	2.41	2.82
5	2.457	2.463	2.688	2.615	2.615	2.643	2.609	2.562	2.595	2.58	2.63	2.52	2.62
2 (interpolated)											2.72	2.41	2.79
	Discharge (cfs) per vertical												
	0.10	0.09	0.10	0.12	0.15	0.12	0.10	0.09	0.11	0.99	0.59	0.40	0.13
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.52	2.54	2.72	2.75	2.74	2.85	2.67	2.52	2.53	2.65	2.75	2.53	2.78

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0”=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**0.55 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.142	2.151	2.359	2.420	2.515	2.486	2.390	2.164	2.108	2.30	2.43	2.14	2.47
1	2.164	2.079	2.380	2.602	2.612	2.476	2.373	2.253	2.222	2.35	2.49	2.18	2.56
2	2.254	2.207	2.527	2.553	2.637	2.587	2.469	2.331	2.315	2.43	2.55	2.28	2.59
3.25	2.189	2.355	2.492	2.447	2.658	2.548	2.461	2.434	2.300	2.43	2.52	2.32	2.55
5	2.454	2.360	2.545	2.545	2.516	2.495	2.570	2.485	2.446	2.49	2.53	2.44	2.52
2 (interpolated)											2.55	2.32	2.58
	Discharge (cfs) per vertical												
	0.10	0.09	0.10	0.11	0.14	0.11	0.10	0.09	0.10	0.94	0.56	0.38	0.12
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.54	2.57	2.57	2.66	2.69	2.62	2.71	2.57	2.47	2.60	2.65	2.54	2.66

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**1 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									Lateral averages over verticals			
										all	**inside**	**outside**	**3 ctr.**
0.5	1.994	2.121	2.437	2.597	2.557	2.538	2.345	2.232	2.125	2.33	2.49	2.12	2.56
1	2.183	2.195	2.586	2.719	2.583	2.693	2.573	2.310	2.298	2.46	2.63	2.25	2.67
2	2.316	2.239	2.519	2.613	2.805	2.648	2.506	2.301	2.382	2.48	2.62	2.31	2.69
3.25	2.314	2.305	2.591	2.719	2.744	2.704	2.530	2.415	2.383	2.52	2.66	2.35	2.72
5	2.442	2.373	2.575	2.583	2.560	2.502	2.516	2.472	2.436	2.50	2.55	2.43	2.55
2 (interpolated)											2.66	2.36	2.72
	Discharge (cfs) per vertical												
	0.10	0.09	0.10	0.12	0.15	0.12	0.10	0.09	0.10	0.96	0.58	0.39	0.13
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.44	2.45	2.62	2.71	2.75	2.64	2.66	2.60	2.53	2.60	2.67	2.51	2.70

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**3.6 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									Lateral averages over verticals			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.087	2.124	2.386	2.506	2.743	2.532	2.492	2.239	2.142	2.36	2.53	2.15	2.59
1	2.156	2.136	2.527	2.646	2.575	2.639	2.445	2.343	2.300	2.42	2.57	2.23	2.62
2	2.132	2.130	2.504	2.697	2.707	2.664	2.447	2.317	2.248	2.43	2.60	2.21	2.69
3.25	2.221	2.130	2.552	2.632	2.701	2.676	2.600	2.429	2.368	2.48	2.63	2.29	2.67
5	2.360	2.249	2.572	2.519	2.483	2.480	2.517	2.543	2.406	2.46	2.51	2.39	2.49
2 (interpolated)											2.62	2.27	2.68
	Discharge (cfs) per vertical												
	0.10	0.08	0.10	0.12	0.15	0.11	0.10	0.09	0.10	0.95	0.57	0.38	0.13
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.46	2.46	2.48	2.69	2.61	2.67	2.63	2.49	2.45	2.55	2.62	2.46	2.66

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**1 mm, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.095	2.123	2.364	2.591	2.546	2.669	2.411	2.362	2.250	2.38	2.52	2.21	2.60
1	2.228	2.277	2.496	2.599	2.682	2.689	2.532	2.421	2.278	2.47	2.60	2.30	2.66
2	2.221	2.212	2.575	2.617	2.715	2.669	2.581	2.261	2.358	2.47	2.63	2.26	2.67
3.25	2.285	2.341	2.703	2.714	2.596	2.677	2.557	2.486	2.465	2.54	2.65	2.39	2.66
5	2.293	2.423	2.543	2.581	2.549	2.586	2.556	2.462	2.579	2.51	2.56	2.44	2.57
2 (interpolated)											2.66	2.35	2.67
	Discharge (cfs) per vertical												
	0.10	0.09	0.10	0.12	0.14	0.12	0.10	0.09	0.11	0.97	0.58	0.39	0.13
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.52	2.59	2.63	2.63	2.71	2.70	2.57	2.49	2.52	2.60	2.65	2.53	2.68

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**1 mm, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.157	2.107	2.406	2.424	2.604	2.493	2.472	2.206	2.121	2.33	2.48	2.15	2.51
1	2.274	2.207	2.509	2.488	2.514	2.538	2.340	2.307	2.216	2.38	2.48	2.25	2.51
2	2.274	2.387	2.518	2.621	2.586	2.597	2.525	2.332	2.373	2.47	2.57	2.34	2.60
3.25	2.427	2.466	2.599	2.602	2.630	2.626	2.673	2.340	2.432	2.53	2.63	2.42	2.62
5	2.560	2.577	2.456	2.514	2.594	2.651	2.483	2.431	2.453	2.52	2.54	2.51	2.59
2 (interpolated)											2.60	2.41	2.62
	Discharge (cfs) per vertical												
	0.11	0.09	0.10	0.11	0.14	0.12	0.10	0.09	0.10	0.96	0.57	0.39	0.12
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.53	2.47	2.60	2.64	2.59	2.59	2.62	2.53	2.57	2.57	2.61	2.52	2.61

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**3.6 mm, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.041	2.126	2.331	2.546	2.643	2.588	2.453	2.136	2.155	2.34	2.51	2.11	2.59
1	2.109	2.173	2.484	2.574	2.692	2.679	2.520	2.262	2.270	2.42	2.59	2.20	2.65
2	2.294	2.232	2.474	2.686	2.598	2.718	2.555	2.304	2.322	2.46	2.61	2.29	2.67
3.25	2.207	2.315	2.551	2.659	2.757	2.614	2.535	2.384	2.378	2.49	2.62	2.32	2.68
5	2.402	2.517	2.556	2.614	2.608	2.595	2.592	2.550	2.483	2.55	2.59	2.49	2.61
2 (interpolated)											2.63	2.33	2.68
	Discharge (cfs) per vertical												
	0.10	0.09	0.10	0.12	0.15	0.12	0.10	0.09	0.10	0.96	0.58	0.39	0.13
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.41	2.54	2.60	2.69	2.61	2.57	2.57	2.50	2.45	2.55	2.61	2.47	2.62

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**3.6 mm, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.114	2.046	2.298	2.551	2.593	2.467	2.409	2.132	2.190	2.31	2.46	2.12	2.54
1	2.265	2.198	2.460	2.598	2.561	2.551	2.404	2.223	2.289	2.39	2.51	2.24	2.57
2	2.168	2.188	2.490	2.474	2.655	2.705	2.526	2.390	2.408	2.44	2.57	2.29	2.61
3.25	2.394	2.280	2.498	2.599	2.702	2.553	2.520	2.372	2.521	2.49	2.57	2.39	2.62
5	2.432	2.406	2.482	2.573	2.533	2.562	2.482	2.458	2.465	2.49	2.53	2.44	2.56
2 (interpolated)											2.58	2.37	2.62
	Discharge (cfs) per vertical												
	0.10	0.09	0.10	0.11	0.14	0.11	0.10	0.09	0.11	0.95	0.56	0.39	0.12
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	2.37	2.45	2.57	2.68	2.61	2.66	2.68	2.52	2.49	2.56	2.64	2.46	2.65

Elwha, 3.5 ft/s

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**No sampler**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.860	2.940	2.862	2.868	2.893	2.936	2.910	2.902	2.843	2.89	2.89	2.89	2.90
1	2.995	2.888	2.984	2.960	3.037	3.043	2.887	2.924	2.980	2.97	2.98	2.95	3.01
2	3.032	3.094	2.964	3.091	3.098	3.071	3.081	3.002	3.029	3.05	3.06	3.04	3.09
3.25	3.170	3.144	3.105	3.155	3.092	3.209	3.183	3.120	3.208	3.15	3.15	3.16	3.15
5	3.235	3.331	3.253	3.355	3.160	3.330	3.229	3.197	3.202	3.25	3.27	3.24	3.28
2 (interpolated)											3.13	3.13	3.05
	Discharge (cfs) per vertical												
	0.14	0.12	0.12	0.14	0.17	0.14	0.12	0.12	0.14	1.21	0.69	0.52	0.15
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.20	3.22	3.17	3.14	3.19	3.18	3.21	3.28	3.15	3.19	3.18	3.21	3.17

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**No net**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.731	2.855	3.163	3.374	3.513	3.359	3.202	2.919	2.847	3.11	3.32	2.84	3.42
1	2.828	2.773	3.332	3.540	3.567	3.466	3.333	2.907	2.893	3.18	3.45	2.85	3.52
2	2.934	3.042	3.368	3.608	3.590	3.550	3.388	3.059	2.991	3.28	3.50	3.01	3.58
3.25	2.942	3.015	3.442	3.531	3.646	3.519	3.378	3.109	3.079	3.30	3.50	3.04	3.57
5	3.227	3.156	3.295	3.460	3.376	3.411	3.303	3.257	3.207	3.30	3.37	3.21	3.42
2 (interpolated)											3.52	3.04	3.59
	Discharge (cfs) per vertical												
	0.13	0.12	0.13	0.16	0.20	0.15	0.13	0.12	0.14	1.27	0.76	0.50	0.17
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.14	3.16	3.25	3.58	3.59	3.59	3.39	3.28	3.29	3.36	3.48	3.22	3.59

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**0.55 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.714	2.605	3.145	3.159	3.180	3.282	3.002	2.896	2.789	2.97	3.15	2.75	3.21
1	2.590	2.848	3.225	3.401	3.400	3.391	3.237	2.916	2.947	3.11	3.33	2.83	3.40
2	2.878	3.043	3.151	3.318	3.383	3.401	3.194	3.055	3.052	3.16	3.29	3.01	3.37
3.25	2.936	3.001	3.291	3.331	3.442	3.368	3.313	3.211	3.090	3.22	3.35	3.06	3.38
5	3.065	3.117	3.247	3.305	3.272	3.469	3.181	3.230	3.237	3.24	3.29	3.16	3.35
2 (interpolated)											3.35	3.06	3.40
	Discharge (cfs) per vertical												
	0.13	0.12	0.13	0.15	0.19	0.15	0.12	0.12	0.14	1.23	0.73	0.50	0.16
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.00	3.03	3.28	3.38	3.48	3.39	3.36	3.12	3.20	3.25	3.38	3.09	3.41

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**1 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.766	2.831	3.284	3.607	3.552	3.400	3.346	2.950	2.843	3.18	3.44	2.85	3.52
1	2.861	2.866	3.313	3.745	3.742	3.607	3.392	2.980	2.940	3.27	3.56	2.91	3.70
2	2.962	3.054	3.430	3.821	3.728	3.600	3.494	3.102	3.084	3.36	3.61	3.05	3.72
3.25	3.046	3.082	3.580	3.828	3.811	3.791	3.562	3.193	3.243	3.46	3.71	3.14	3.81
5	3.274	3.271	3.359	3.565	3.520	3.582	3.509	3.376	3.325	3.42	3.51	3.31	3.56
2 (interpolated)											3.69	3.12	3.79
	Discharge (cfs) per vertical												
	0.13	0.12	0.13	0.16	0.20	0.16	0.14	0.12	0.14	1.31	0.80	0.52	0.18
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.04	3.12	3.37	3.44	3.57	3.47	3.39	3.12	3.21	3.31	3.45	3.12	3.50

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**3.6 mm**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.791	2.944	3.330	3.473	3.511	3.512	3.105	2.859	2.826	3.15	3.39	2.85	3.50
1	2.890	2.950	3.333	3.708	3.750	3.715	3.381	3.014	2.971	3.30	3.58	2.96	3.72
2	2.990	3.009	3.489	3.601	3.662	3.726	3.521	3.124	3.033	3.35	3.60	3.04	3.66
3.25	3.153	3.025	3.693	3.692	3.662	3.674	3.467	3.225	3.122	3.41	3.64	3.13	3.68
5	3.227	3.247	3.321	3.574	3.518	3.425	3.464	3.274	3.227	3.36	3.46	3.24	3.51
2 (interpolated)											3.65	3.12	3.70
	Discharge (cfs) per vertical												
	0.14	0.12	0.13	0.16	0.20	0.16	0.13	0.12	0.14	1.30	0.79	0.51	0.17
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.10	3.05	3.41	3.55	3.61	3.51	3.40	3.28	3.22	3.35	3.50	3.16	3.56

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**1 mm, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.779	2.687	3.011	3.249	3.344	3.190	2.991	2.705	2.707	2.96	3.16	2.72	3.26
1	2.784	2.872	3.120	3.370	3.339	3.326	3.166	2.842	2.815	3.07	3.26	2.83	3.34
2	2.872	2.965	3.216	3.350	3.411	3.483	3.224	2.910	2.849	3.14	3.34	2.90	3.41
3.25	3.070	2.969	3.239	3.391	3.435	3.379	3.305	3.014	2.959	3.20	3.35	3.00	3.40
5	3.214	3.197	3.185	3.259	3.214	3.294	3.122	3.108	3.090	3.19	3.21	3.15	3.26
2 (interpolated)											3.36	2.98	3.42
	Discharge (cfs) per vertical												
	0.13	0.12	0.12	0.15	0.19	0.15	0.12	0.11	0.13	1.22	0.73	0.49	0.16
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.13	3.14	3.35	3.42	3.43	3.46	3.41	3.22	3.16	3.30	3.41	3.16	3.44

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0”=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**1 mm, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.895	3.046	3.263	3.426	3.466	3.473	3.148	2.866	2.758	3.15	3.36	2.89	3.45
1	3.099	2.999	3.487	3.672	3.574	3.543	3.299	3.021	3.003	3.30	3.52	3.03	3.60
2	3.122	3.171	3.589	3.701	3.829	3.613	3.370	3.176	2.972	3.39	3.62	3.11	3.71
3.25	3.347	3.412	3.605	3.774	3.831	3.694	3.481	3.160	3.093	3.49	3.68	3.25	3.77
5	3.486	3.442	3.522	3.674	3.615	3.460	3.406	3.274	3.230	3.46	3.54	3.36	3.58
2 (interpolated)											3.68	3.22	3.77
	Discharge (cfs) per vertical												
	0.14	0.13	0.14	0.16	0.20	0.16	0.13	0.12	0.14	1.32	0.79	0.53	0.17
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.21	3.36	3.41	3.52	3.47	3.35	3.19	3.16	3.30	3.42	3.16	3.47	3.21

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0”=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**3.6 mm, 30% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.865	2.973	3.264	3.424	3.438	3.406	3.199	2.852	2.958	3.15	3.35	2.91	3.42
1	2.934	3.061	3.455	3.515	3.607	3.478	3.344	3.060	3.086	3.28	3.48	3.04	3.53
2	3.094	3.087	3.382	3.600	3.654	3.583	3.455	3.089	3.071	3.33	3.53	3.09	3.61
3.25	3.156	3.239	3.498	3.529	3.627	3.615	3.500	3.127	3.218	3.39	3.55	3.18	3.59
5	3.277	3.216	3.427	3.549	3.470	3.406	3.357	3.312	3.283	3.37	3.44	3.27	3.48
2 (interpolated)											3.57	3.17	3.62
	Discharge (cfs) per vertical												
	0.14	0.12	0.13	0.16	0.20	0.16	0.13	0.12	0.14	1.30	0.77	0.52	0.17
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.07	3.08	3.33	3.51	3.50	3.49	3.39	3.25	3.23	3.32	3.44	3.16	3.50

	1	2	3	4	5	6	7	8	9	Vertical #			
	-25	-10	10	25	50	75	90	110	125	Relat. loc. (%) 0% =LB inside sampler wall			
	-2	-0.8	0.8	2	4	6	7.2	8.8	10	Absol. loc. (in) 0"=LB inside sampler wall			
	1.6	1.4	1.4	1.6	2	1.6	1.4	1.4	1.6	Width increment (in)			
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**			
	Sampler tested									**Elwha**			
	Bag configuration									**3.6 mm, 50% clogged**			
	1st series of flume experiments, 16 ft. downstream from head box												
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**			
										all	**inside**	**outside**	**3 ctr.**
0.5	2.781	2.829	3.308	3.335	3.400	3.373	3.223	2.890	2.839	3.11	3.33	2.83	3.37
1	2.909	3.000	3.236	3.521	3.437	3.476	3.277	2.987	2.914	3.20	3.39	2.95	3.48
2	3.076	3.126	3.406	3.554	3.664	3.496	3.346	3.041	3.010	3.30	3.49	3.06	3.57
3.25	3.114	3.125	3.487	3.598	3.598	3.588	3.372	3.339	3.263	3.39	3.53	3.21	3.59
5	3.281	3.245	3.310	3.295	3.434	3.345	3.367	3.342	3.277	3.32	3.35	3.29	3.36
2 (interpolated)											3.52	3.18	3.60
	Discharge (cfs) per vertical												
	0.14	0.12	0.13	0.15	0.19	0.15	0.13	0.12	0.14	1.28	0.76	0.52	0.17
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical												
2	3.07	3.10	3.26	3.47	3.50	3.42	3.32	3.18	3.15	3.27	3.39	3.12	3.46

BL-84, 1.5 ft/s

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**No sampler**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		1.529	1.451	1.476	1.449	1.477	1.474	1.449		1.47	1.47	1.48
1		1.537	1.478	1.462	1.573	1.569	1.551	1.551		1.53	1.53	1.53
1.65		1.545	1.566	1.541	1.610	1.573	1.569	1.557		1.57	1.57	1.56
2.5		1.628	1.483	1.621	1.642	1.631	1.626	1.594		1.60	1.63	1.58
2 (interpolated)											1.60	1.57
	Discharge (cfs) per vertical											
		0.027	0.029	0.032	0.032	0.033	0.030	0.026		0.210	0.097	0.113
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		1.49	1.49	1.53	1.53	1.52	1.55	1.55		1.52	1.53	1.52

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**No net**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		1.456	1.492	1.578	1.575	1.525	1.507	1.500		1.52	1.56	1.49
1		1.590	1.582	1.598	1.604	1.597	1.557	1.573		1.59	1.60	1.58
1.65		1.637	1.647	1.624	1.657	1.640	1.577	1.588		1.62	1.64	1.61
2.5		1.627	1.616	1.634	1.653	1.611	1.575	1.651		1.62	1.63	1.62
2 (interpolated)											1.64	1.63
	Discharge (cfs) per vertical											
		0.027	0.031	0.034	0.033	0.034	0.030	0.027		0.216	0.101	0.116
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		1.46	1.47	1.49	1.51	1.49	1.50	1.49		1.49	1.50	1.48

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.25 mm**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		1.434	1.392	1.393	1.369	1.312	1.319	1.444		1.38	1.36	1.40
1		1.577	1.588	1.556	1.527	1.505	1.447	1.521		1.53	1.53	1.53
1.65		1.563	1.551	1.544	1.587	1.578	1.479	1.519		1.55	1.57	1.53
2.5		1.620	1.612	1.638	1.580	1.564	1.642	1.589		1.61	1.59	1.62
2 (interpolated)											1.61	1.59
	Discharge (cfs) per vertical											
		0.027	0.030	0.032	0.031	0.031	0.029	0.026		0.207	0.095	0.112
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		1.50	1.44	1.44	1.50	1.48	1.47	1.48		1.47	1.47	1.47

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.5 mm**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		1.412	1.362	1.418	1.394	1.423	1.365	1.371		1.39	1.41	1.38
1		1.468	1.430	1.540	1.462	1.431	1.456	1.415		1.46	1.48	1.44
1.65		1.477	1.483	1.527	1.551	1.526	1.501	1.496		1.51	1.53	1.49
2.5		1.565	1.491	1.559	1.528	1.514	1.493	1.573		1.53	1.53	1.53
2 (interpolated)											1.54	1.55
	Discharge (cfs) per vertical											
		0.026	0.028	0.032	0.030	0.031	0.028	0.025		0.201	0.093	0.108
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		1.46	1.47	1.49	1.45	1.48	1.49	1.51		1.48	1.47	1.48

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.25 mm, 30% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		-	-	-	-	-	-	-		-	-	-
1		-	-	-	-	-	-	-		-	-	-
1.65		-	-	-	-	-	-	-		-	-	-
2.5		-	-	-	-	-	-	-		-	-	-
											-	-
	Discharge (cfs) per vertical											
		0.027	0.030	0.032	0.031	0.031	0.029	0.026		0.207	0.095	0.112
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		1.41	1.45	1.40	1.43	1.47	1.44	1.46		1.44	1.43	1.44

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.25 mm, 50% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		-	-	-	-	-	-	-		-	-	-
1		-	-	-	-	-	-	-		-	-	-
1.65		-	-	-	-	-	-	-		-	-	-
2.5		-	-	-	-	-	-	-		-	-	-
2 (interpolated)											-	-
	Discharge (cfs) per vertical											
		0.027	0.030	0.032	0.031	0.031	0.029	0.026		0.207	0.095	0.112
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		1.44	1.38	1.43	1.39	1.44	1.41	1.47		1.42	1.42	1.42

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.5 mm, 30% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		-	-	-	-	-	-	-		-	-	-
1		-	-	-	-	-	-	-		-	-	-
1.65		-	-	-	-	-	-	-		-	-	-
2.5		-	-	-	-	-	-	-		-	-	-
2 (interpolated)											-	-
	Discharge (cfs) per vertical											
		0.026	0.028	0.032	0.030	0.031	0.028	0.025		0.201	0.093	0.108
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		1.46	1.47	1.43	1.44	1.49	1.47	1.49		1.46	1.46	1.47

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**1.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.5 mm, 50% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		-	-	-	-	-	-	-		-	-	-
1		-	-	-	-	-	-	-		-	-	-
1.65		-	-	-	-	-	-	-		-	-	-
2.5		-	-	-	-	-	-	-		-	-	-
2 (interpolated)											-	-
	Discharge (cfs) per vertical											
		0.026	0.028	0.032	0.030	0.031	0.028	0.025		0.201	0.093	0.108
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		1.43	1.41	1.44	1.45	1.43	1.45	1.47		1.44	1.44	1.44

BL-84, 2.5 ft/s

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**No sampler**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.136	2.070	2.236	2.240	2.111	2.234	2.145		2.17	2.20	2.15
1		2.242	2.283	2.284	2.174	2.269	2.348	2.112		2.24	2.24	2.25
1.65		2.255	2.324	2.226	2.304	2.360	2.334	2.408		2.32	2.30	2.33
2.5		2.412	2.296	2.444	2.322	2.454	2.503	2.466		2.41	2.41	2.42
2 (interpolated)											2.28	2.53
	Discharge (cfs) per vertical											
		0.039	0.044	0.049	0.046	0.049	0.046	0.040		0.312	0.143	0.169
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		2.44	2.44	2.52	2.48	2.51	2.47	2.52		2.48	2.50	2.47

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**No net**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.288	2.162	2.332	2.332	2.415	2.247	2.263		2.29	2.36	2.24
1		2.329	2.339	2.493	2.342	2.382	2.349	2.409		2.38	2.41	2.36
1.65		2.384	2.369	2.488	2.506	2.478	2.467	2.474		2.45	2.49	2.42
2.5		2.444	2.518	2.715	2.559	2.633	2.573	2.457		2.56	2.64	2.50
2 (interpolated)											2.54	2.47
	Discharge (cfs) per vertical											
		0.041	0.046	0.053	0.050	0.053	0.047	0.041		0.331	0.155	0.175
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		2.47	2.46	2.49	2.58	2.50	2.49	2.53		2.50	2.52	2.49

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.25 mm**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.124	2.216	2.317	2.381	2.262	2.115	2.152		2.22	2.32	2.15
1		2.231	2.222	2.312	2.298	2.330	2.364	2.319		2.30	2.31	2.28
1.65		2.311	2.381	2.380	2.380	2.419	2.365	2.359		2.37	2.39	2.35
2.5		2.386	2.347	2.391	2.514	2.473	2.460	2.477		2.44	2.46	2.42
2 (interpolated)											2.41	2.40
	Discharge (cfs) per vertical											
		0.039	0.045	0.050	0.049	0.050	0.046	0.040		0.318	0.149	0.170
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		2.47	2.38	2.48	2.43	2.51	2.44	2.40		2.44	2.47	2.43

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.5 mm**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.145	2.199	2.243	2.342	2.251	2.176	2.121		2.21	2.28	2.16
1		2.170	2.182	2.288	2.317	2.302	2.194	2.252		2.24	2.30	2.20
1.65		2.427	2.319	2.431	2.425	2.403	2.300	2.336		2.38	2.42	2.35
2.5		2.258	2.400	2.389	2.469	2.418	2.373	2.442		2.39	2.43	2.37
2 (interpolated)											2.42	2.35
	Discharge (cfs) per vertical											
		0.039	0.045	0.049	0.049	0.050	0.044	0.040		0.315	0.148	0.167
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		2.42	2.41	2.52	2.51	2.49	2.39	2.53		2.47	2.51	2.44

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.25 mm, 30% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.027	2.112	2.310	2.215	2.215	2.131	2.172		2.17	2.25	2.11
1		2.178	2.209	2.190	2.260	2.249	2.120	2.180		2.20	2.23	2.17
1.65		2.287	2.223	2.386	2.343	2.318	2.320	2.346		2.32	2.35	2.29
2.5		2.308	2.343	2.330	2.307	2.396	2.437	2.331		2.35	2.34	2.35
2 (interpolated)											2.33	2.36
	Discharge (cfs) per vertical											
		0.038	0.044	0.049	0.046	0.049	0.044	0.039		0.309	0.144	0.165
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		2.44	2.44	2.35	2.47	2.38	2.42	2.39		2.41	2.40	2.42

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.25 mm, 50% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.195	2.179	2.114	2.202	2.243	2.186	2.135		2.18	2.19	2.17
1		2.265	2.125	2.214	2.288	2.102	2.214	2.137		2.19	2.20	2.19
1.65		2.334	2.320	2.302	2.385	2.217	2.389	2.260		2.32	2.30	2.33
2.5		2.298	2.315	2.306	2.299	2.300	2.300	2.370		2.31	2.30	2.32
2 (interpolated)											2.30	2.31
	Discharge (cfs) per vertical											
		0.039	0.044	0.047	0.047	0.047	0.044	0.038		0.307	0.141	0.166
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		2.46	2.46	2.43	2.36	2.34	2.44	2.44		2.42	2.38	2.45

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.5 mm, 30% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.136	2.188	2.101	2.330	2.295	2.199	2.120		2.20	2.24	2.16
1		2.153	2.308	2.238	2.339	2.234	2.321	2.189		2.25	2.27	2.24
1.65		2.293	2.299	2.372	2.459	2.320	2.218	2.342		2.33	2.38	2.29
2.5		2.490	2.489	2.389	2.340	2.341	2.389	2.396		2.40	2.36	2.44
2 (interpolated)											2.37	2.36
	Discharge (cfs) per vertical											
		0.039	0.046	0.048	0.048	0.049	0.045	0.039		0.313	0.145	0.169
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		2.38	2.41	2.35	2.49	2.44	2.44	2.44		2.42	2.43	2.42

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**2.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.5 mm, 50% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.108	2.156	2.179	2.219	2.200	2.156	2.183		2.17	2.20	2.15
1		2.240	2.185	2.207	2.314	2.239	2.263	2.266		2.24	2.25	2.24
1.65		2.414	2.213	2.370	2.381	2.347	2.335	2.404		2.35	2.37	2.34
2.5		2.352	2.294	2.380	2.331	2.302	2.368	2.342		2.34	2.34	2.34
2 (interpolated)											2.33	2.36
	Discharge (cfs) per vertical											
		0.039	0.043	0.048	0.047	0.048	0.045	0.040		0.310	0.143	0.167
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		2.38	2.37	2.39	2.40	2.39	2.43	2.40		2.40	2.39	2.40

BL-84, 3.5 ft/s

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**No sampler**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.859	2.940	2.869	2.852	2.765	2.846	2.744		2.84	2.83	2.85
1		2.904	2.984	2.794	2.955	2.930	2.810	2.980		2.91	2.89	2.92
1.65		3.124	2.920	3.168	2.992	3.001	2.968	3.032		3.03	3.05	3.01
2.5		3.088	3.217	3.176	3.152	3.215	3.164	3.172		3.17	3.18	3.16
2 (interpolated)											3.10	3.10
	Discharge (cfs) per vertical											
		0.052	0.059	0.064	0.061	0.063	0.058	0.051		0.408	0.188	0.220
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		3.14	3.11	3.12	3.22	3.20	3.17	3.22		3.17	3.18	3.16

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**No net**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.798	2.778	2.801	2.828	2.878	2.727	2.800		2.80	2.84	2.78
1		2.832	2.907	3.019	2.971	2.898	2.871	2.859		2.91	2.96	2.87
1.65		2.924	2.954	3.056	3.135	3.008	2.881	2.912		2.98	3.07	2.92
2.5		3.024	2.943	3.117	3.137	3.078	2.895	3.034		3.03	3.11	2.97
2 (interpolated)											3.10	2.95
	Discharge (cfs) per vertical											
		0.050	0.057	0.063	0.061	0.063	0.056	0.050		0.400	0.188	0.212
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		3.19	3.26	3.27	3.28	3.25	3.14	3.19		3.23	3.27	3.19

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.25 mm**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.752	2.715	2.831	2.816	2.717	2.657	2.656		2.73	2.79	2.70
1		2.847	2.785	2.843	2.845	2.935	2.779	2.759		2.83	2.87	2.79
1.65		2.906	2.906	3.031	3.007	2.905	2.786	2.873		2.92	2.98	2.87
2.5		2.972	2.979	2.973	3.006	2.932	2.969	2.949		2.97	2.97	2.97
2 (interpolated)											2.98	2.92
	Discharge (cfs) per vertical											
		0.049	0.056	0.062	0.059	0.061	0.055	0.048		0.390	0.182	0.209
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		3.10	3.24	3.21	3.28	3.21	3.15	3.17		3.19	3.23	3.17

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.5 mm**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.549	2.679	2.670	2.734	2.703	2.670	2.624		2.66	2.70	2.63
1		2.801	2.715	2.808	2.810	2.750	2.799	2.728		2.77	2.79	2.76
1.65		2.649	2.734	2.965	2.911	2.918	2.783	2.839		2.83	2.93	2.75
2.5		3.019	2.888	2.923	2.936	2.865	2.816	3.068		2.93	2.91	2.95
2 (interpolated)											2.93	2.85
	Discharge (cfs) per vertical											
		0.048	0.054	0.060	0.058	0.059	0.054	0.049		0.382	0.177	0.204
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		3.05	3.19	3.15	3.29	3.18	3.21	3.19		3.18	3.21	3.16

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.25 mm, 30% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.452	2.593	2.562	2.720	2.676	2.566	2.566		2.59	2.65	2.54
1		2.770	2.622	2.732	2.757	2.691	2.704	2.604		2.70	2.73	2.68
1.65		2.812	2.789	2.943	2.838	2.736	2.849	2.892		2.84	2.84	2.84
2.5		2.821	2.848	2.804	2.848	3.003	2.958	2.905		2.88	2.88	2.88
2 (interpolated)											2.86	2.86
	Discharge (cfs) per vertical											
		0.047	0.053	0.058	0.057	0.059	0.054	0.047		0.376	0.174	0.202
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		3.17	3.16	3.16	3.25	3.12	3.15	3.20		3.17	3.18	3.17

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.25 mm, 50% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.530	2.322	1.995	2.015	2.029	2.507	2.593		2.28	2.01	2.49
1		2.642	2.569	2.188	2.142	2.230	2.619	2.724		2.44	2.19	2.64
1.65		2.791	2.653	2.377	2.397	2.515	2.726	2.831		2.61	2.43	2.75
2.5		2.987	2.830	2.596	2.640	2.703	2.897	3.005		2.81	2.65	2.93
2 (interpolated)											2.52	2.83
	Discharge (cfs) per vertical											
		0.047	0.051	0.049	0.047	0.051	0.053	0.048		0.346	0.147	0.199
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		3.21	3.16	3.13	3.21	3.20	3.22	3.18		3.19	3.18	3.20

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.5 mm, 30% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.626	2.642	2.658	2.587	2.648	2.528	2.627		2.62	2.63	2.61
1		2.739	2.740	2.730	2.682	2.734	2.673	2.603		2.70	2.72	2.69
1.65		2.885	2.813	2.840	2.787	2.910	2.829	2.951		2.86	2.85	2.87
2.5		3.060	2.928	2.885	3.004	2.952	3.021	3.072		2.99	2.95	3.02
2 (interpolated)											2.89	2.93
	Discharge (cfs) per vertical											
		0.049	0.055	0.059	0.057	0.060	0.054	0.049		0.382	0.175	0.207
	2nd series of flume experiments, 22 ft downstream from head box											
	Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		3.18	3.16	3.17	3.15	3.16	3.21	3.23		3.18	3.16	3.20

		1	2	3	4	5	6	7		Vertical #		
		-45	-17.5	17.5	50	82.5	117.5	145		Relat. loc. (%) 0% =LB inside sampler wall		
		-1.35	-0.525	0.525	1.5	2.475	3.525	4.35		Absol. loc. (in) 0"=LB inside sampler wall		
		0.825	0.9375	1.0125	0.975	1.0125	0.9375	0.825		Width increment (in)		
	Target flow velocity (ft/s) 6" above ground 12 ft downstream from head box									**3.5**		
	Sampler tested									**BL-84**		
	Bag configuration									**0.5 mm, 50% clogged**		
	1st series of flume experiments, 16 ft. downstream from head box											
height abv. ground (in)	Flow velocities v_x (ft/s) measured per vertical									**Lateral averages over verticals**		
										all	**Inside=ctr.3**	**outside**
0.5		2.844	2.842	2.891	2.928	2.887	2.728	2.752		2.84	2.90	2.79
1		2.846	2.811	2.923	2.915	2.882	2.947	2.980		2.90	2.91	2.90
1.65		3.013	2.894	2.926	2.947	2.941	2.871	2.938		2.93	2.94	2.93
2.5		2.998	2.968	2.995	3.051	2.951	3.101	2.997		3.01	3.00	3.02
2 (interpolated)											2.96	2.98
	Discharge (cfs) per vertical											
		0.050	0.056	0.062	0.060	0.062	0.057	0.050		0.398	0.184	0.214
	2nd series of flume experiments, 22 ft downstream from head box Flow velocities $v_{x,2}$ (ft/s) measured per vertical											
2		3.17	3.09	3.13	3.12	3.16	3.10	3.17		3.14	3.14	3.13