BIOLOGICAL DESIGN CRITERIA FOR IMPROVED WET-SEPARATOR EFFICIENCY AND HIGH-VELOCITY FLUME DEVELOPMENT, 1997

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Delivery Order E86910060

December 2000

EXECUTIVE SUMMARY

During the 1997 spring and summer juvenile salmonid outmigrations, we continued research to provide biological design criteria for the improvement of wet separators used in fish passage facilities at hydroelectric dams on the Snake and Columbia Rivers. In addition, we conducted evaluations to develop new concepts in juvenile salmonid wet separation.

Two evaluation separator units were used to trap river-run smolts from Gatewell 6B at McNary Dam: a unit simulating an existing conventional wet separator and an experimental high-velocity flume (HVF) separator. In the simulated conventional wet separator, we compared six treatments consisting of different on/off combinations of spray bars, light stripes added to darker-colored separation bars, and a reverse flow orifice. Evaluation criteria were salmonid separation efficiency, separator exit efficiency, and descaling. No significant differences in separation efficiency, separator exit efficiency, or descaling were found among the six on/off treatments evaluated using the simulated conventional wet separator.

Separation efficiency, separator exit efficiency, and descaling were also the criteria used in assessments of the experimental high-velocity flume (HVF) separator, in which 24 treatments were compared. The 24 treatments consisted of different combinations of separation-bar angles, separation-bar lengths, separation-bar sumbergence depths, and water velocities.

Using the experimental HVF separator during the spring outmigration, mean separation efficiency was significantly higher with 12-m-long separation bars than with 6-m-long bars for small smolts (< 180 mm fork length), and significantly higher with 6-m-long bars than with 12-m-long bars for larger fish ($\geq$180 mm). This was probably a result of using a separation-bar gap of 19 mm, which allowed the larger fish to sound (dive) between and move below the bars, decreasing efficiency. Separation efficiency was not statistically different among steeply angled (4 and 8^o) separation-bar conditions for either length group.

Small subyearling chinook salmon (< 180 mm) comprised over 99% of the total catch during summer outmigration testing with the experimental HVF separator. Mean separation efficiency was again higher with 12-m-long separation bars than with 6-m-long bars. Using the more steeply angled separation bars, separation efficiency was significantly higher at the 4^o angle with water velocity at 1 m/s than at 2 m/s. In addition, subyearling chinook salmon separation efficiency was significantly lower with 1.5-m-long bars than with 3.0- or 4.5-m-long bars.

Mean separator exit efficiency for the experimental HVF separator was over 90% for both size groups analyzed from spring outmigration data, and over 85% during the summer for all treatments. In general, exit efficiency was significantly higher at 2 m/s than at 1 m/s.

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INTRODUCTION

Separation of smolts by size is a key objective for juvenile fish bypass and transportation systems at hydroelectric dams on the Columbia and Snake Rivers. Juvenile chinook salmon (*Oncorhynchus tshawytscha*) that are transported with juvenile steelhead (*O. mykiss*) may experience higher levels of stress than those transported with other chinook salmon because the steelhead are generally larger than chinook salmon smolts (McCabe et al. 1979). Separation allows segregation of smolts by size for transport and provides the option to bypass selected species (based on size) to the river downstream from a dam, while transporting other species.

Separation has evolved from an initial dry separation process where fish were sorted using inclined pipes (described in McComas et al. 1998), to a wet separation process which relies on behavioral responses to induce smolts to attempt to sound (dive) between separation bars just under the water surface. The wet separation method was developed and evaluated by Gessel et al. (1985) and is used in bypass systems at dams operated by the U.S. Army Corps of Engineers (COE). Because the wet process keeps fish submerged during separation, it is considered less stressful to migrants.

Conventional wet separators use a three-stage process designed to remove, in order, small migrant juvenile salmonids, larger migrant juvenile salmonids, and finally adult salmonids and non-salmonid incidental species. The spacing of separation bars determines the size of fish removed at each stage. Under ideal conditions, the first compartment, (A section), segregates smaller chinook, coho (*O. kisutch*), and sockeye (*O. nerka*) salmon from the larger, predominantly steelhead smolts, which are sorted in the second compartment (B section).

However, in practice there are several problems with the existing wet separators. The conventional wet separation method requires low velocities to be effective, and thus creates a bottleneck that impedes the movement of fish through the system. This method not only requires slowing the water, dewatering, and then reintroducing velocity, it also creates the possibility of migration delay and increased stress within the separator unit. In addition, this method can result in poor separation efficiency. For example, the McNary Dam separator exhibited poor performance in the A section in 1994, when separation efficiencies were only 32.2, 24.1, and 27.7% for yearling chinook, coho, and sockeye salmon, respectively (Brad Eby, U. S. Army Corps of Engineers, McNary Dam Juvenile Fish Passage Facility, Umatilla, OR 97882 , Pers. commun., July 1995). Possible reasons included flow surges, which carried small fish past the A section with insufficient time to sound through the separation bars, and an inadequate stimulus to generate a sounding response.

Video monitoring associated with fish behavior and physiology studies has indicated that fish also hold under separation bars for extended periods, rather than exit expeditiously from the separator unit (Shreck et al. in prep). This suggests that some fish may exit only when fatigued from swimming against hydraulic conditions within the unit. The result is increased overall stress, which could ultimately affect survival.

During the 1996 spring and summer outmigration periods, personnel of the National Marine Fisheries Service (NMFS), in cooperation with the Idaho Cooperative Fish and Wildlife Research Unit of the University of Idaho and the COE, initiated studies to establish biological design criteria that could be used to increase separation efficiency and reduce holding time for salmonid smolts in wet separators. Interagency planning meetings were also initiated to address prioritized changes for improving wet-separator efficiency and to explore possible alternatives to conventional wet-separator design. One promising alternative to emerge from these meetings was the development of a high-velocity flume (HVF) separator.

Preliminary studies to evaluate the extent to which smolts would sound between separation bars in an HVF were conducted in a small experimental flume at McNary Dam during the latter part of the fall chinook outmigration in 1996 (McComas et al. 1998). The resulting data demonstrated that if a sufficient bar length was used, a substantial proportion of fall chinook salmon would sound through separation bars at higher water velocities than are normally present in conventional wet separators. Conservative interpretation of a regression analysis from these data indicated that a flume length of approximately 8 m would be required to achieve maximal subyearling chinook salmon separation at flume discharges of about 0.5 m^3/s. The degree to which steelhead and spring chinook salmon would separate under high velocity was unknown.

During the 1997 spring and summer outmigration periods, NMFS, the Idaho Cooperative Fish and Wildlife Research Unit of the University of Idaho, and the COE continued research to establish objectives for improving the performance of wet separators based on biological design criteria. In addition, we began to evaluate criteria for developing a prototype high-velocity flume separator.

Specific research objectives in 1997 were:

1) Evaluate the effects of spray bars, separator-bar striping, and a reverse flow orifice on separation efficiency in a simulated conventional wet separator.

2) Evaluate the effects of separation-bar length, water velocity, and submergence of separation bars on volitional sounding response and separation efficiency in an experimental high-velocity flume.

3) Evaluate the effects of separation-bar length, water velocity, and angle of separation bars on non-volitional sounding response and separation efficiency in an experimental high-velocity flume.

OBJECTIVE 1: EVALUATE THE EFFECTS OF FLOW JETS, SEPARATOR-BAR STRIPING, AND A REVERSE FLOW ORIFICE ON SEPARATION IN A SIMULATED CONVENTIONAL WET SEPARATOR

Approach

A separator unit was constructed to simulate the small-fish separation portion of a conventional wet separator (McComas et al. 1998). The simulated separator measured 0.9 m wide by 3.35 m long by 1.2 m high (3 × 11 × 4 ft). Maximum depth was 0.8 m, with water supplied through two 15-cm (6-in) siphons drawing from the forebay. Flow from the siphons entered the unit near the floor along one side, and flow was diffused through sloped, perforated-plate false bottoms within the upstream 2.75-m (9 ft) of the unit. A solid plate was used for the downstream, 61-cm (2-ft) floor section. This arrangement reduced volume under the separator bars and dispersed inflow through the unit, except in the vicinity of the exit orifices.

River-run fish were introduced into the separator unit through an opening in the upper end, just downstream from the area where flows from the north orifice of Gatewell 6B were dewatered. Two exit orifices were provided, both of which were set flush with the inside walls of the separator unit. An 81-cm-wide (32-in), rectangular overflow orifice in the downstream end allowed non-separated fish to pass through the unit without negotiating the separator-bar array.

Flow over the overflow orifice was less than 0.1 m/s, with a depth of 2.54 cm (1 in) for all tests. Fish sounding between the separation bars (separated fish) were provided access to a 7.6- by 25.4-cm (3 × 10 in) rectangular orifice set into downstream end of the unit. The top of the submerged orifice was 23 cm (9 in) below the water surface with the bottom edge even with the solid-plate false floor. Velocity through the submerged orifice was approximately 2 m/s.

Separation bars were contained in arrays oriented parallel to flow on the long axis of the simulated separator unit. Each array measured 0.89 m wide by 3.3 m long (35 × 139 in), and was held in place by angle brackets along the sides of the unit. Arrays were constructed of 2.54-cm (1-in) aluminum tubing painted gray, with 16-mm (0.625-in) spacing between individual bars. To evaluate the effect on sounding response of an apparent increase in the gap between bars, the separation bars of one array had a 1-cm-wide (0.4-in) white stripe painted on the upper surface along the length of each bar. The stripe was intended to provide an optical illusion that would encourage sounding without actually increasing the space between bars (and thereby decreasing separation efficiency).

The effect of upwelling between separation bars on juvenile salmonid sounding response was evaluated using spray bars with water jets directed upward between the separation bars. Six 2.75-m-long (9-ft) spray bars were centered 15.2-cm (6-in) apart across the unit and 7.6 cm (3 in) under the bars. Each spray bar was composed of jets incorporated into 5-cm (2-in) aluminum tubes running parallel to the water surface. Individual jets were 0.95-cm (0.38-in) circular openings orientated perpendicular to the water surface. Jets were placed at 10-cm (4-in) intervals along each tube. The 61-cm (2 ft) downstream section of the simulated separator unit was left without spray bars so that attraction flow to the orifices would be uninterrupted. Water was pumped to the spray bars from the forebay siphons through a manifold in the upstream end of the unit, and flow to each spray bar was individually regulated with a valve.

The rectangular exit orifice under the separator bars was enclosed along the top and sides with spray jets directed into the separator unit to provide attraction flows to the orifice for fish that had sounded through the bars (Fig. 1). Side jets were fixed at 90° to the face of the orifice, while jets along the top were set at 15° from the horizontal, to point slightly into the orifice outflow. Individual jets were 8-mm (0.3215-in) circular irrigation nozzles mounted flush with the inside wall of the separator unit. Pump pressure to the jets was supplied through a jacket surrounding the orifice outfall pipe, similar to the device described by McComas et al. (1997).

Replicates were conducted in blocks, with treatments composed of either on or off factors for spray bars, separation bar striping, and the reverse flow orifice, for a total of eight treatment configurations (Table 1). However, fabrication of the reverse flow orifice was not complete until after 16 May, which delayed testing with that device. Also, power limitations in the collection channel prevented simultaneous operation of the spray bars and the pumps for the reverse flow orifice. Therefore, Treatments 1 and 5, the two treatments for which the spray bars and reverse flow orifice were on simultaneously, had to be eliminated. The remaining six treatments were randomized within successive blocks.

One test series was completed during the spring outmigration and one during the summer outmigration, with both series involving multiple blocks of the six treatments listed. The spring outmigration test series began 28 April and lasted through 2 June. From 28 April through 14 May, replicates were completed between 0600 and 2200 h. Low fish numbers prompted the addition of a third shift after 14 May, so that tests were conducted 24 hours each day for the remainder of the spring outmigration and for the entire summer outmigration. The summer outmigration test series lasted 16 June through 25 July. No testing was done between 3 and 15 June.

Before beginning a replicate, water depth in the separator was stabilized using the conditions of the treatment under consideration. A replicate was initiated by opening the gatewell orifice, which allowed fish to enter the unit along with enough additional water to maintain approximately 3-cm (1.25-in) depth across the separator overflow orifice. Replicate

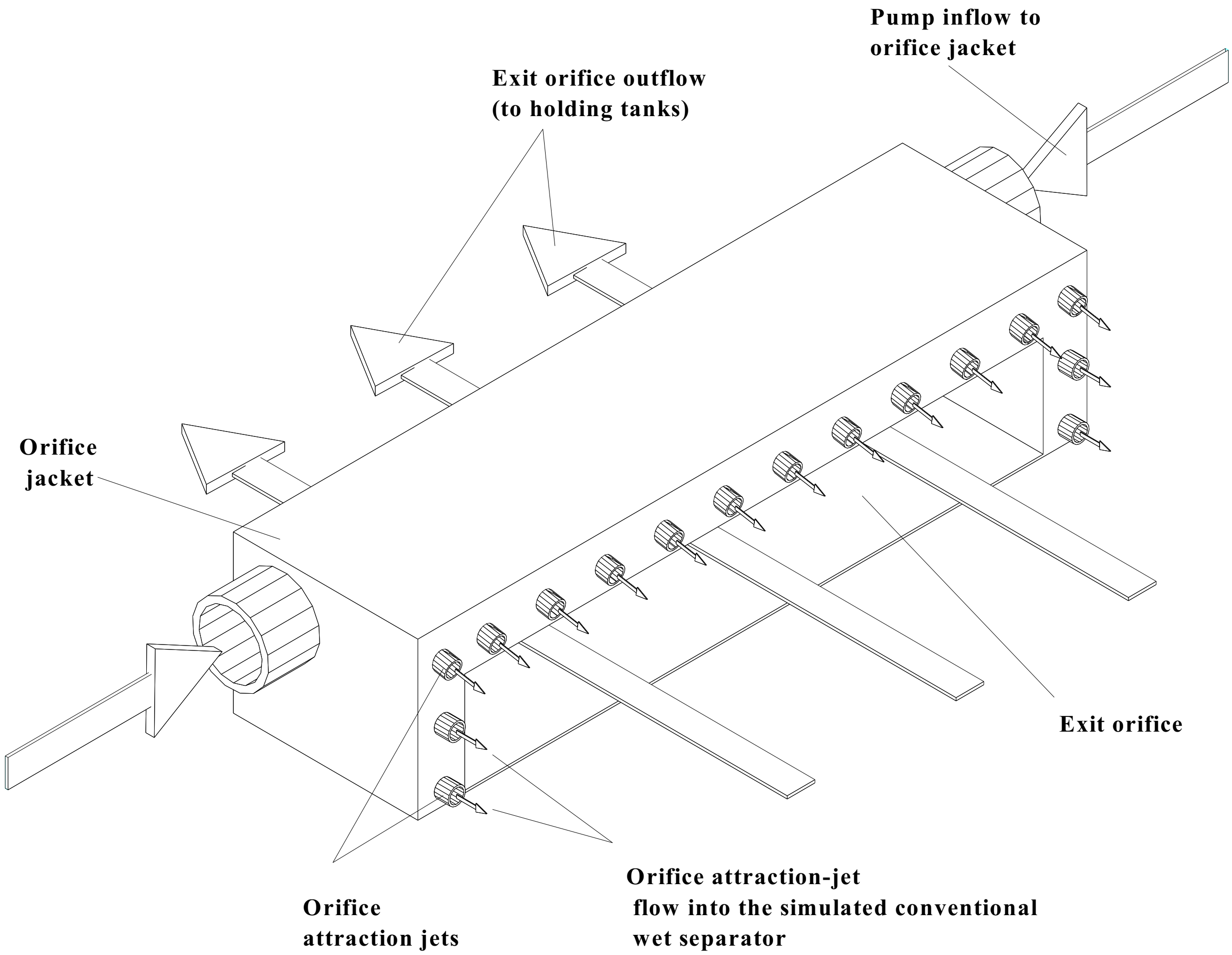


Figure 1. Configuration of orifice attraction jets in relation to the rectangular (7.6 × 61 cm) submerged exit orifice used during separation and orifice exit efficiency studies at McNary Dam, 1997. Arrows indicate direction of major flow components.

Table 1. Combinations of separation bar striping, spray bar, and reverse flow orifice conditions comprising a single treatment block during separation and orifice exit efficiency studies at McNary Dam, 1997.

Treatment	Factors		
	Separation bar striping	Spray bars	Reverse flow orifice
1*	on	on	on
2	on	on	off
3	on	off	on
4	on	off	off
5*	off	on	on
6	off	on	off
7	off	off	on
8	off	off	off

* Treatments that had to be eliminated because of insufficient power to run the spray jets and reverse flow orifice simultaneously.

duration was dependent on numbers of fish entering the separator rather than on time. After more than 25 chinook salmon had entered the experimental unit, recruitment was halted by closing the gatewell orifice.

Four groups of fish were isolated from the separator unit in turn. Fish were first collected from above, then from below, the separation bars. Animals from the two holding tanks were examined last. Each group was anesthetized separately using tricaine methane sulfonate (MS-222); individual fish were measured to fork length and enumerated by species. Fish condition was also noted as percent descaling for each species using Fish Transportation Oversight Team descaling criteria (Ceballos et al. 1992).

Separation efficiency (*SEF*) was calculated as the fraction of separated fish, by species, of a given length group compared to the total number of smolts from that length group entering the simulated conventional separator during the test interval:

$$SEF = \frac{F}{T} \times 100\%$$

where SEF = separation efficiency
F = number of separated smolts
T = total number entering the evaluation separator

However, separation has a slightly different behavioral implication for each of the two length groups. For small smolts (<180 mm), separation efficiency was calculated using the number of fish sounding between the separation bars, whereas separation efficiency of larger fish ($\geq$180 mm) was calculated using the fraction that did not sound between the bars.

Separator exit efficiency (*SEE*) was calculated by species as the ratio of fish in each length group that exited the simulated wet separator to the total number of fish in that length group that entered the separator during the test interval.

$$SEE = \frac{A}{T} \times 100\%$$

where SEE = separator exit efficiency
A = fish number from length group A exiting orifice
T = total number from length group A entering the separator

Following recovery from anesthetic, all fish were released directly into the juvenile fish bypass channel.

Results and Discussion

Using the simulated wet-separator unit, a total of 7,213 smolts were included in treatments compared during the spring outmigration. Yearling chinook salmon made up approximately 68% of the collection of small fish (<180 mm), while steelhead made up about 82% of larger fish ($\geq$180 mm). For the summer outmigration period, subyearling chinook salmon made up over 99% of the smolts in a total collection of 6,768. Salmonid collection data are presented by test replicate in Appendix Table A1, and non-target incidental collection data in Appendix Table A2.

Analyses were initially conducted using all observed data. However, a few outliers were found that had very large, standardized residuals. Generally one or zero outliers were identified for each analysis. These outliers were removed and the data reanalyzed. A third analysis was done using square-root transformed data. Results of analyses using raw and square-root transformed data were fairly comparable; therefore, analyses using raw data are reported here.

Sufficient numbers of smolts were available for analysis of total catch (<180 and $\geq$180 mm) from the spring outmigration test series, and for analysis of small subyearling chinook salmon (<180 mm) from the summer test series. Evaluations were made for separation efficiency, separator exit efficiency, and descaling. Of the six treatments evaluated during the spring series, only the four that used bar striping and spray bars had sufficient numbers of replicates for statistical analysis. Treatments 3 and 7 had too few replicates and were therefore omitted from spring evaluations. Treatments 2, 4, 6, and 8 were analyzed using a 2 × 2 factorial analysis of variance (ANOVA).

For subyearling chinook salmon, data were analyzed as a six-treatment ANOVA using all treatments. Evaluations where nearly all the replicates for separator exit efficiency were 100%, or where descaling was 0%, did not require formal analysis. Replicates with fewer than 25 fish were pooled with similar treatment replicates from adjacent blocks, since these were closest in time. Nearly all pooling involved only two replicates.

Mean values for each comparison analyzed are listed by treatment in Table 2, and results of statistical comparisons are listed in Appendix Table A3. No statistically significant differences were found among any of the comparisons during either outmigration period using the simulated conventional wet separator.

Table 2. Mean separation efficiency and separator exit efficiency values by treatment and length group analyzed, using a simulated conventional wet separator at McNary Dam, 1997. All subyearling chinook salmon descaling values were 0%.

Spring outmigration, 28 April-20 May			
Comparision	Treatment	Mean (%)	SE
Total salmonids < 180 mm			
Separation efficiency	Spray bars on	49.0	3.34
	Spray bars off	54.5	4.42
	Separation bar striping on	50.4	4.03
	Separation bar striping off	53.1	3.80
Separator exit efficiency	Spray bars on	91.1	1.51
	Spray bars off	94.2	1.95
	Separation bar striping on	93.3	1.81
	Separation bar striping off	92.0	1.68
Descaling	Spray bars on	1.8	0.39
	Spray bars off	1.6	0.42
	Separation bar striping on	1.3	0.39
	Separation bar striping off	2.1	0.35
Total salmonids ≥ 180 mm			
Separation efficiency	Spray bars on	83.5	3.63
	Spray bars off	78.0	4.20
	Separation bar striping on	85.8	4.06
	Separation bar striping off	75.7	3.80
Separator exit efficiency*	Spray bars on	93.5	1.16
	Spray bars off	95.7	1.35
	Separation bar striping on	95.4	1.30
	Separation bar striping off	93.3	1.21
Descaling	Spray bars on	3.4	0.73
	Spray bars off	4.7	0.85
	Separation bar striping on	4.2	0.82
	Separation bar striping off	3.9	0.76

Table 2. Continued.

Summer outmigration, 16 June-7 July			
Comparision	Treatment	Mean (%)	SE
Subyearling chinook salmon < 180 mm			
Separation efficiency	Spray bars on, bar striping on, reverse flow orifice off	84.0	3.40
	Spray bars off, bar striping on, reverse flow orifice on	81.8	3.04
	Spray bars off, bar striping on, reverse flow orifice off	85.4	3.04
	Spray bars on, bar striping off, reverse flow orifice off	81.9	3.04
	Spray bars off, bar striping off, reverse flow orifice on	76.7	3.04
	Spray bars off, bar striping off, reverse flow orifice off	84.2	3.05
Separator exit efficiency	Spray bars on, bar striping on, reverse flow orifice off	93.7	2.00
	Spray bars off, bar striping on, reverse flow orifice on	94.0	1.90
	Spray bars off, bar striping on, reverse flow orifice off	91.7	1.90
	Spray bars on, bar striping off, reverse flow orifice off	96.1	1.90
	Spray bars off, bar striping off, reverse flow orifice on	95.0	1.81
	Spray bars off, bar striping off, reverse flow orifice off	91.1	1.90

* Exit efficiency for fish $\geq$180 mm that exited through the overflow orifice above the separation bars.

OBJECTIVE 2: EVALUATE THE EFFECTS OF SEPARATION-BAR LENGTH, WATER VELOCITY, AND SUBMERGENCE OF SEPARATION BARS ON VOLITIONAL SOUNDING RESPONSE AND SEPARATION EFFICIENCY IN AN EXPERIMENTAL HIGH-VELOCITY FLUME

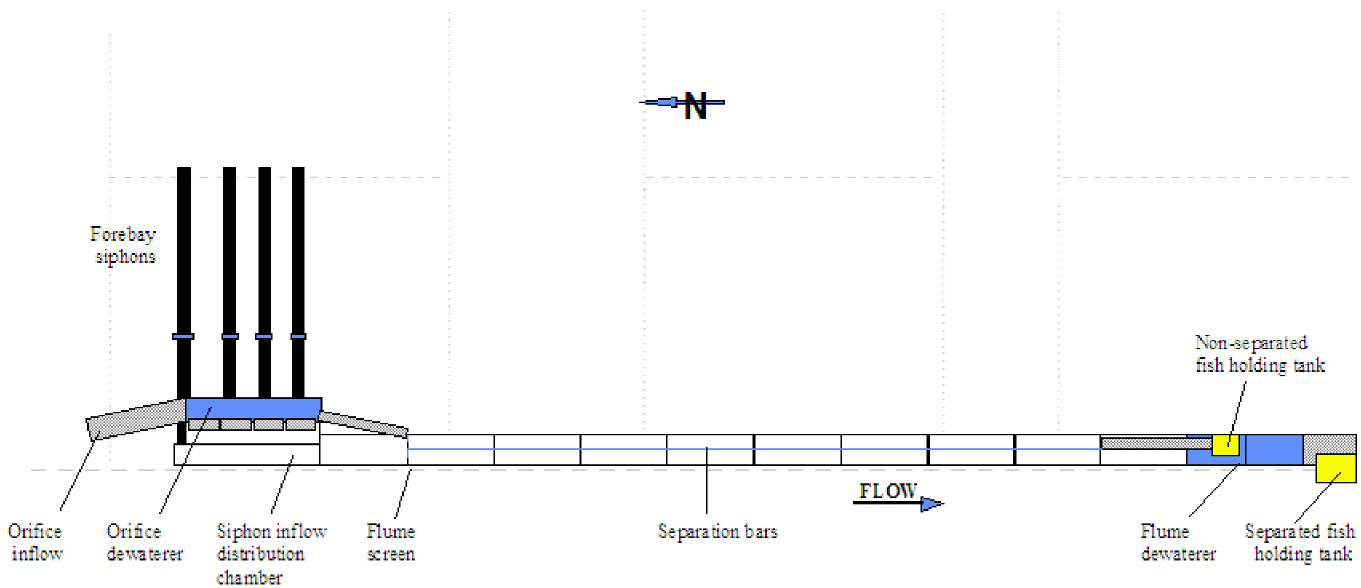
Approach

An experimental high-velocity flume (HVF) separator was constructed and installed on a platform over the McNary Dam juvenile fish bypass channel to intercept flows from the south orifice of Gatewell 6B (Fig. 2). The flume measured 76 cm (30 in) across, with an overall length (including dewatering sections) of approximately 18.6 m (62 ft) and a maximum separation-bar length of 12 m (40 ft). Flow in the 12-m-long working flume section was controlled by changing the slope through a 0.5° arc, by varying the height of a lift gate near the downstream end of the flume, or by varying water volume. Makeup water, supplied through forebay siphons and gatewell orifice dewatering, produced maximum flows of about 0.3 m^3/s (10 cfs).

Separation bars were constructed of 32-mm-od (1.25-in) aluminum tubing. There was concern that at the increased velocities in the HVF separator, fish could become impinged on the bars if the spacing between bars was left at the 16 mm normally used in wet separators. Spacing between individual bars was therefore increased to 19 mm (0.75 in). The separation-bar array was fabricated in 1.5-m-long (5-ft) interlocking sections to facilitate changes in angle and length. Individual sections were suspended from chains set into vertical slots along the sides of the flume so that the chains did not intrude on flow through the flume. Chain links were held by dogging pockets at the top of each vertical slot, and tags placed on individual chain links provided marks for repeatable separation-bar array positioning of angles and depths for successive replicates.

Volitional sounding relies on innate behavior of the fish to sound without structural inducement. For example, steeply angled separation bars, which would induce fish to sound between bars to avoid being forced toward the surface while passing the array, would constitute a non-volitional response. To ensure volitional separation conditions for this objective, the separation-bar array was oriented flat, or at a very shallow positive angle (approximately 0.7°), relative to the water surface.

For the flat bar-array treatments, water depths of 5 and 10 cm over the array were also evaluated (2 and 4 in, respectively). With the 7° angled bar array, water depth was approximately 10 cm (4 in) over the separation bars at the start of the angle, and about 3 cm (1.25 in) over the downstream end of the bars. Each of these combinations of conditions was repeated at separation-bar array lengths of 6 and 12 m (20 and 40 ft), and all orientation/length combinations were evaluated at water velocities of 1 and 2 m/s (3.2 and 6.4 fps).



Evaluation high velocity flume (HVF) separator elevation view showing the relationship between major components used during separation efficiency testing at McNary Dam, 1997.

Figure 2. Elevation view of the experimental high-velocity flume wet separator showing the relationship among major components used during separation efficiency testing at McNary Dam, 1997.

During sample periods, velocities were verified for each replicate using a hand-held velocity meter manufactured by Swoffer Marine Instruments, Inc.[1] After the summer outmigration season, a more sophisticated acoustic velocity meter was used to confirm three-dimensional vector velocities above and below the separation bars at both 1 and 2 m/s.

Replicates were randomized by separation-bar length, so that all treatments at a given bar length were completed before beginning treatments at the next bar length. River-run migrant fish exiting the gatewell orifice were introduced to the upstream end of the flume by partially dewatering the gatewell orifice flows. Smolts were allowed to accumulate in the flume until at least 25 chinook salmon had entered the holding tanks. Recruitment from the gatewell was then terminated, and fish were removed from the unit in four groups (above bars, below bars, large-fish holding tank, small-fish holding tank), and processed similarly to fish for Objective 1.

Results and Discussion

As with the simulated wet separator unit, sufficient numbers of salmonid smolts (<180 and $\geq$180 mm) were available for accurate statistical analyses in evaluations of the experimental HVF during the spring outmigration test series. There were also sufficient numbers for evaluations of small subyearling chinook salmon (over 99% of the total catch were <180 mm) using the experimental HVF during the summer test series. Total catch for all HVF separator testing comprised 3,827 chinook, 2,344 coho, 913 sockeye salmon, and 4,298 steelhead. During the summer outmigration, 31,324 subyearling chinook salmon were included in evaluations.

Catch data are presented by replicate in Appendix Table A4. Evaluations where nearly all replicates for separator exit efficiency were 100%, or where descaling was 0%, did not warrant formal analysis. A complete list of statistical procedures and results can be found in Appendix Table A3.

In general, velocities recorded using the acoustic velocity meter correlated with those recorded by replicate during treatment evaluations. An explanation of procedures used to obtain vector measurements is presented, along with resultant velocity calculations and flume transect locations, in Appendix B.

[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Volitional Separation Efficiency

For total small species (<180 mm), there was a significant interaction between separation-bar angle and water velocity. With bars angled at 0.7° (bars submerged 3-10 cm), mean separation efficiency was higher at 1 m/s (67.5%, SE = 4.45) than at 2 m/s (55.1%, SE = 4.45). With flat bars at 10 cm below the surface, mean separation was lower at 1 m/s (56.4%, SE = 4.45) than at 2 m/s (68.1%, SE = 4.72; F = 4.20, df = 2, P = 0.032). With flat bars at 5 cm below the surface, there was no significant difference in separation efficiency between 1 m/s (76.7%, SE = 4.45) and 2 m/s (71.3%, SE = 4.98) water-velocity treatments.

For small salmonids (<180 mm), mean separation efficiency was higher with 12-m-long separation bars (76.1%, SE = 2.62) than with 6-m-long bars (55.6%, SE = 2.68; F = 29.98, df = 1, P < 0.001). However, for larger fish (≥180 mm), mean separation efficiency was significantly higher with the 6-m-long bars (67.2%, SE = 2.64) than with the 12-m-long bars (49.2%, SE = 2.79; F = 21.94, df = 1, P < 0.001). These results indicate that bar spacing used in the experimental HVF (19 mm) was too large. The increase in separation-bar length from 6 to 12 m allowed more time for fish from both size groups to sound between the bars, resulting in decreased separation efficiency for larger smolts.

For small subyearling chinook salmon (<180 mm), the 12-m-long separation bars also produced significantly higher mean separation efficiency (85.9%, SE = 2.39) than the 6-m-long bars (50.0%, SE = 2.37; F = 113.55, df = 1, P < 0.001). Significantly higher separation efficiency was also observed in subyearling chinook salmon treatments with either the angled bars or the flat bars submerged at 5-cm (71.5 and 71.8%, SE = 2.899 and 2.2.84, respectively) than with the flat bars submerged 10-cm (60.5%, SE = 2.899; F = 4.88, df = 2, P = 0.010).

Volitional Separator Exit Efficiency

Volitional separator exit efficiency among treatments using the experimental HVF separator was near 100% of total catch for small fish (<180 mm) and over 90% of total catch for large fish (≥180 mm) during the spring outmigration. For large yearling fish (≥180 mm), separator exit efficiency was significantly higher at 2 m/s (97.7%, SE = 1.35) than at 1 m/s (90.6%, SE = 1.29; F = 14.60, df = 1, P = 0.001). For all 12 treatments using subyearling chinook salmon, mean exit efficiency was near 100%.

Descaling

Mean descaling with the experimental HVF using the 12-m-long bar configuration ranged from 1.8 to 3.2% for the total catch of small fish (<180 mm) and from 2.8 to 4.5% for the total catch of larger fish (≥180 mm), under all conditions tested during the spring outmigration. Mean percent descaling by length group for each condition analyzed is reported in Table 3. Descaling with 7° angled bars was significantly higher than with flat bars submerged at either 5 or 10 cm (F = 19.56, df = 2, P = 0.034). No difference in descaling was found attributable to separation-bar length (F = 0.81, df = 1, P = 0.371) or water velocity (F = 0.65, df = 1, P = 0.424).

Table 3. Mean percent descaling by fish length group for the total salmonid collection during separation and separator exit efficiency studies at McNary Dam, 28 April-3 June 1997.

Source	Descaling by fish length group	
	<180 mm % (SE)	≥180 mm % (SE)
Separation bar length, 6 m	2.4 (0.4)	4.5 (1.1)
Separation bar length, 12 m	1.8 (0.5)	2.8 (1.1)
Angled separation bars (0.7°)	3.2 (0.5)	4.5 (1.4)
Flat separation bars, submerged 5 cm	1.4 (0.5)	2.4 (1.3)
Flat separation bars, submerged 10 cm	1.6 (0.6)	4.2 (1.3)
Water velocity, 1 m/s	2.3 (0.4)	3.6 (1.1)
Water velocity, 2 m/s	1.8 (0.5)	3.8 (1.1)

OBJECTIVE 3: EVALUATE THE EFFECTS OF SEPARATION-BAR LENGTH, WATER VELOCITY, AND SEPARATION BAR ANGLE ON NON-VOLITIONAL SOUNDING RESPONSE AND SEPARATION EFFICIENCY IN AN EXPERIMENTAL HIGH-VELOCITY FLUME

Approach

Non-volitional separation was evaluated in the experimental high-velocity flume (HVF) using bars at discrete angles of 4 and 8° and at water velocities of 1 and 2 m/s for each angle. In addition, each angle and velocity was evaluated at separation-bar lengths of 1.5 m (5 ft), 3.0 m (10 ft), and 4.5 m (15 ft). The 4.5-m length was the longest separation-bar array that could be accommodated using the 90-cm flume height at an 8° angle.

Water depth over the downstream end of the separation bars was approximately 3 cm for all replicates. There are two ways of changing separation-bar length while maintaining a constant angle. One way is to place the upstream end of the array on the flume bottom at each length. This would require decreased water depth with decreased array length. The other method, used for this study, is to keep the total water depth constant at each angle by leaving the total separation-bar array length constant at 4.5 m. To effect shorter separation-bar length, the downstream end of the array was covered with 13-mm (0.5-in) mesh hardware cloth in 1.5-m increments to obtain working bar lengths of 3.0- and 1.5-m for evaluation.

To eliminate timing bias, we alternated treatment blocks for Objectives 2 and 3 throughout the study period. Water velocities and separation-bar angles were randomized within each separation-bar length condition, and all treatments for a given length were completed before beginning the next bar length.

Data collection and analysis proceeded generally as in Objective 2. However, since the 4.5-m separation-bar array used for non-volitional evaluation was placed at the downstream end of the flume (for proximity to separation structures and holding tanks), a 7.5-m section (25 ft) of the upstream end was not directly involved in testing efficiency of the system under consideration. Therefore, fish holding in this upstream section at the end of a replicate period were excluded from data analyses.

Results and Discussion

Low fish numbers resulted in fewer replicates for some treatments during the spring outmigration test series. Only three replicates were completed for all treatments with 1.5-m-long separation bars. Five replicates were completed for all treatments with 4.5-m-long bars and for treatments with 3.0-m-long bars angled 4° and water velocity at 1 m/s. Four replicates were completed for the remaining three treatments with 3.0-m-long bars. During the summer outmigration test series (subyearling chinook salmon), sample size was 10 for all treatments.

Non-Volitional Separation Efficiency

There were no significant differences in mean separation efficiency among treatments for either size group during the spring outmigration, although for smaller smolts (<180 mm), the 1.5-m-long separation bars produced lower separation efficiency (46.0%, SE = 5.58) than either the 3.0-m-long (59.0%, SE = 4.50) or 4.5-m-long bars (59.9%, SE = 3.998; F = 2.30, df = 2, P = 0.117). The failure to detect a significant difference between these values may have been a consequence of small sample sizes.

For smaller subyearling chinook salmon (<180 mm) with 10 samples per treatment, mean separation efficiency for treatments with 1.5-m-long bars (51.9%, SE = 2.49) was significantly lower (F = 12.61, df = 2, P = 0.000) than for those with 3.0- or 4.5-m-long bars (68.5 and 64.9%, SE = 2.42 and 2.42, respectively). In addition, there was a significant interaction between separation-bar angle and water velocity for subyearling chinook salmon separation efficiency: with bars at the 4° angle, mean separation efficiency was significantly higher at 1 m/s (71.9%, SE = 2.85) than at 2 m/s (53.0%, SE = 2.85; F = 6.92, df = 1, P = 0.010). A similar trend occurred with the separation bars at 8° (63.1 and 59.0%, SE = 2.79 and 2.79, for 1 m/s and 2 m/s, respectively), but the difference was not significant.

Non-Volitional Separator Exit Efficiency

Separator exit efficiency data for small smolts (<180 mm) from the spring run displayed a significant interaction between bar length and water velocity. The difference between mean efficiency values for 1 and 2 m/s decreased as separation bar length increased (F = 31.97, df = 1, P = 0.000).

For total catch of larger fish (≥180 mm), there was a significant difference between angle conditions (F = 4.34, df = 1, P = 0.051): mean exit efficiency was 61.2% (SE = 5.13) with the bars at 4° and 74.4% (SE = 3.97) with the bars at 8°. Also, at a water velocity of 2 m/s, exit efficiency for this group (83.5%, SE = 4.8) was higher than at 1 m/s (52.48%, SE = 4.37; F = 22.85, df = 1, P = 0.000; Table 4).

Subyearling chinook salmon exit efficiencies followed a similar trend. At the 8° bar angle, exit efficiency was 94.4% (SE = 1.6), significantly higher than the 89.4% (SE = 1.6) observed with the 4° bar angle (F = 4.81, df = 1, P = 0.031). Exit efficiency for combined treatments with water velocities at 2 m/s (98.4%, SE = 1.6) was significantly higher than at 1 m/s (85.5%, SE = 1.6; F = 32.59, df = 1, P = 0.000).

Descaling

Mean descaling among the 12 treatments ranged from 1.9 to 2.5% for total catch of small fish (<180 mm) during the spring sample period, and 4.4 to 5.4% for larger fish (≥180 mm) (Table 5). Subyearling chinook salmon descaling was near 0% for all treatments. No statistically significant differences were found among non-volitional descaling comparisons.

Table 4. Mean separator exit efficiency values by separation bar length and water velocity for the total salmonid collection using angled separation-bar arrays during separation and separator exit efficiency studies at McNary Dam, 28 April-3 June, 1997.

	Exit efficiency		
Separation bar length (m)	Water velocity 1 m/s % (SE)	Water velocity 2 m/s % (SE)	Difference (%)
1.5	68.6 (4.67)	95.1 (4.67)	26.4
3.0	76.7 (3.61)	97.9 (3.90)	21.2
4.5	89.9 (3.23)	97.1 (3.43)	7.2

Table 5. Mean percent descaling by treatment condition for the total salmonid collection during separation and separator exit efficiency studies at McNary Dam, 28 April-3 June 1997.

	Descaling by fish length group	
Source	<180 mm % (SE)	≥180 mm % (SE)
Separation bar length, 1.5 m	1.9 (0.8)	4.4 (1.7)
Separation bar length, 3.0 m	2.4 (0.6)	5.3 (1.5)
Separation bar length, 4.5 m	2.3 (0.6)	5.2 (1.4)
Separation bar angle, 4°	1.8 (0.6)	5.3 (1.4)
Separation bar angle, 8°	2.5 (0.5)	4.7 (1.1)
Water velocity, 1 m/s	1.9 (0.6)	5.4 (1.2)
Water velocity, 2 m/s	2.5 (0.5)	4.5 (1.3)

CONCLUSIONS

Simulated Conventional Wet-Separator

Using the simulated conventional wet separator, there were no statistically significant differences for separation efficiency, separator exit efficiency, or descaling among treatments involving the six on/off combinations of separation-bar striping, spray bars, and a reverse flow orifice for combined juvenile salmonid catch ($<$180 mm or $\geq$180 mm fork length) during the spring outmigration, or for subyearling chinook salmon ($<$180 mm) during the summer outmigration.

Experimental High-Velocity Flume

Volitional Separation

1) Using the experimental high-velocity flume (HVF), there was a significant interaction between separation-bar orientation and water velocity for small smolts ($<$180 mm) during the spring outmigration. Mean separation efficiency was higher at 1 than at 2 m/s using 0.7° angled bars, and lower at 1 than at 2 m/s using flat bars submerged 10 cm below the water surface.

2) Using the experimental HVF separator, mean separation efficiency was higher with 12-m-long separation bars than with 6-m-long bars for all small salmonids ($<$180 mm fork length), but lower for larger fish ($\geq$180 mm). The decrease in efficiency for the larger fish was probably a function of having the separation-bar gap too large (19 mm).

3) For small subyearling chinook salmon ($<$180 mm), configurations with 0.7° angled bars (submerged 3-10 cm) and flat bars submerged to 5 cm produced significantly higher mean separation efficiency values than the configuration using flat bars submerged to 10 cm.

Non-Volitional Separation

1) Using the experimental HVF separator with steeply angled separation bar arrays, the 1.5-m-long bars produced significantly lower mean separation efficiency than either the 3.0- or 4.5-m-long bars for small subyearling chinook salmon ($<$180 mm).

2) Interaction between water velocity and separation-bar angle resulted in significantly higher subyearling chinook salmon separation efficiency at 1 than at 2 m/s with the 4° angled separation bar. This trend was similar but not statistically significant with the 8° angled separation bar.

Separator Exit Efficiency

Mean separator exit efficiency with the experimental HVF separator using flat bar orientation was significantly higher at a water velocity of 2 m/s than at 1 m/s for all groups and treatments, except total catch of small fish (<180 mm). Exit efficiency was over 85% across all HVF treatments for subyearling chinook salmon <180 mm, and over 90% for yearling fish (<180 and ≥180 mm).

Descaling

Descaling for total catch of small fish (<180 mm) in the experimental HVF was significantly higher using 0.7° angled separation bars than for flat bars at either submergence level during the spring outmigration. No other statistically significant differences in descaling were found in any other comparisons using the experimental HVF separator.

ACKNOWLEDGMENTS

We express our appreciation to our seasonal employees for their interest and efforts in this project. We extend special thanks to Ms. Rebecca Kalamasz and Ms. Billie Guille of the Walla Walla District COE, and at McNary Dam, to Mr. David Coleman, Mr. William Pruit, and the rigging crew for their invaluable support and cooperation. We also extend special thanks to our support staff, especially Mr. Ira Brickey and Mr. Wayne Henry for their efforts and insight during this study.

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APPENDIX A

Data Tables

Appendix Table A1. Total catch, by species, for individual replicates of separation efficiency and orifice exit efficiency tests using an simulated conventional wet separator at McNary Dam, 1997.

		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 1, Treatment 2, 28 April											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			6			7				
	non-separated			4							
Separator	separated					2					
Series 1, Treatment 2, 29 April											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			5	1	3	10			1	
	non-separated			9	3	3	31			2	
Separator	separated										
	non-separated			2			1				
Series 1, Treatment 3, 29 April											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			7		7	10				
	non-separated			2	5	5	20				
Separator	separated					1					
	non-separated						3				
Series 1, Treatment 6, 30 April											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			20	8	2	14				
	non-separated			4							
Separator	separated										
	non-separated										
Series 1, Treatment 6, 30 April											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			14	9		9				
	non-separated			2							
Separator	separated										
	non-separated										
	non-separated										
Series 1, Treatment 7, 29 April											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			9	1	8	16				
	non-separated			4	2	3	21			3	
Separator	separated										
	non-separated						1				
Series 1, Treatment 8, 30 April											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			24	11	4	18			1	
	non-separated			4	5	1	4				
Separator	separated										
	non-separated										

Appendix Table A1. Continued.

		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 1, Treatment 2, 30 April											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			7		6	11				
	non-separated			10	3	4	41			1	
Separator	separated										
	non-separated										
Series 1, Treatment 2, 30 April											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			4		3	3			1	
	non-separated			20		4	49			2	
Separator	separated										
	non-separated										
Series 1, Treatment 3, 30 April											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			9		2	9				
	non-separated			11	5		24				
Separator	separated										
	non-separated										
Series 1, Treatment 4, 1 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			11	4	7	1			2	
	non-separated	1		7	10	3	14			1	1
Separator	separated										
	non-separated										
Series 1, Treatment 6, 1 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			23	9		15				
	non-separated			11	3	1	6				
Separator	separated										
	non-separated										
Series 1, Treatment 7, 29 April											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			9	1	5	8			1	
	non-separated			4	5	1	9				
Separator	separated										
	non-separated										
Series 1, Treatment 8, 30 April											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			30	2	6	34			3	
	non-separated			11		6	19			1	
Separator	separated										
	non-separated										

Appendix Table A1. Continued.

Source		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 3, Treatment 2, 2 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			13	4	2	4			1	
	non-separated			6	15	1	31			1	
Separator	separated										
	non-separated										
Series 3, Treatment 2, 2 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			14	4	2	7			2	
	non-separated			21	14		11			3	
Separator	separated										
	non-separated										
Series 3, Treatment 3, 2 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			20	1	3	6			4	1
	non-separated	1		27	7	1	19				
Separator	separated										
	non-separated										
Series 3, Treatment 4, 2 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			19		3	1				
	non-separated			8	17	2	25				
Separator	separated										
	non-separated										
Series 3, Treatment 6, 3 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			38	8		21			2	
	non-separated			2	4		6				
Separator	separated										
	non-separated										
Series 3, Treatment 7, 5 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			17	3	8	21			2	
	non-separated			8	2	1	7			1	
Separator	separated										
	non-separated										
Series 3, Treatment 7, 5 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			7		4	5				
	non-separated			3	4	1	57				
Separator	separated						1				
	non-separated			6	1		12				

Appendix Table A1. Continued.

		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 3, Treatment 8, 3 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			5	3	2	16				
	non-separated			4	2		12				
Separator	separated										
	non-separated										
Series 4, Treatment 2, 5 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			5	1	8	9				
	non-separated			4		4	13				
Separator	separated										
	non-separated										
Series 4, Treatment 2, 6 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			2		2	6			4	
	non-separated			6	6		22			2	
Separator	separated			9	1	4	5				
	non-separated						10				
Series 4, Treatment 3, 5 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			8		1	9				
	non-separated			7	4		8				
Separator	separated										
	non-separated										
Series 4, Treatment 4, 5 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			19	1	4	11			3	
	non-separated			7	2	1	29				
Separator	separated										
	non-separated										
Series 4, Treatment 6, 6 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			4	1	3	5			5	
	non-separated			13	2		26			1	
Separator	separated			2		1					
	non-separated			7	3		4				
Series 4, Treatment 6, 6 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			9		4	3				
	non-separated			16	1	1	44			1	1
Separator	separated			3		1	1				
	non-separated			1	1		9				

Appendix Table A1. Continued.

		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 5, Treatment 6, 1 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			35	7	10	11			6	
	non-separated			15	4	2	17			8	
Separator	separated										
	non-separated										
Series 5, Treatment 6, 2 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			30	10	5	24				
	non-separated			19	3	1	24			2	
Separator	separated										
	non-separated										
Series 5, Treatment 6, 7 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			7		4	2			2	
	non-separated			14	2		26			1	
Separator	separated			1							
	non-separated										
Series 5, Treatment 6, 7 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			8		2	6				
	non-separated			18	3	7	37			1	
Separator	separated			2							
	non-separated				1		8				
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			10		2	3			3	
	non-separated			22	3	5	39			3	
Separator	separated			2							
	non-separated			1		1	3				
Series 5, Treatment 6, 7 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			11	1	3	3			1	
	non-separated			7	5	2	23			2	
Separator	separated			4			2				
	non-separated						3				
Series 5, Treatment 6, 7 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			15		1	1				
	non-separated			10	7		19				
Separator	separated			2		1	1				
	non-separated				2		3				

Appendix Table A1. Continued.

		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 5, Treatment 6, 8 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated					1	1				
	non-separated			6			16				
Separator	separated			1			1				
	non-separated										
Series 5, Treatment 6, 8 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			10			7			4	
	non-separated			12	6	3	40				
Separator	separated			3		2					
	non-separated					1	1				
Series 5, Treatment 7, 8 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			6		3				1	
	non-separated			2	9		17			1	
Separator	separated			3		2					
	non-separated			2		3					
Series 5, Treatment 8, 8 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			3		3	4			2	
	non-separated			7	6	1	27				
Separator	separated			3		1					
	non-separated			1			1				
Series 6, Treatment 7, 9 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			3		2	1				
	non-separated			27	3	1	38				
Separator	separated	1		2		2	2				
	non-separated			1		1	5			1	
Series 6, Treatment 8, 9 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	1		10		4	5				
	non-separated			15	7	3	20			1	
Separator	separated			3							
	non-separated				1		2				
Series 7, Treatment 2, 12 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated	1		25		12	5	2		8	
	non-separated			20	2	14	42	2			
Separator	separated					1	1				
	non-separated			3	3	1	4				

Appendix Table A1. Continued.

Source		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 7, Treatment 2, 13 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			12		6	1			4	
	non-separated			13	8		25			2	
Separator	separated			11		2	1				
	non-separated						3				
Series 7, Treatment 2, 13 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			8		2	1	1			
	non-separated			11	3	5	36	3		2	
Separator	separated						1				
	non-separated					1	1				
Series 7, Treatment 2, 15 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			9		10	7	2		5	
	non-separated	1		19	8	26	103	8		1	
Separator	separated					3		1			
	non-separated						1				
Series 7, Treatment 3, 12 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			21		4	1			10	
	non-separated			6	5	1	24			2	
Separator	separated				1						
	non-separated				1		1				
Series 7, Treatment 4, 13 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			16		1	6	8		1	
	non-separated			20	2	5	48			1	
Separator	separated										
	non-separated										
Series 7, Treatment 6, 14 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			13		3	2	1		3	
	non-separated			9	6	5	22			1	
Separator	separated			2		1	1				
	non-separated						1				
Series 7, Treatment 6, 14 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			24	1	6	8			2	
	non-separated			6	5	3	38			1	
Separator	separated			6				1			
	non-separated			2	2		10				

Appendix Table A1. Continued.

Source		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 7, Treatment 7, 14 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			3		2		1			
	non-separated			22	1	10	22	10			
Separator	separated					1					
	non-separated						1				
Series 7, Treatment 8, 12 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	2		21		3	1			11	
	non-separated			4	1	1	19			3	
Separator	separated				1						
	non-separated										
Series 8, Treatment 2, 15 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			13		8	8			9	
	non-separated			11	9	2	83			5	
Separator	separated			5			8				
	non-separated			12	1		4				
Series 8, Treatment 3, 16 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			6		8	5	1		4	
	non-separated			12	3	2	26			2	
Separator	separated			5			1	1			
	non-separated						4				
Series 8, Treatment 4, 15 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			12	1	3	4	1		2	
	non-separated			8	3	4	28			1	
Separator	separated			7			4			1	
	non-separated			1			3				
Series 8, Treatment 6, 16 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			12	1	7	6	2		1	
	non-separated			34	9	11	88	2			
Separator	separated						1				
	non-separated										
Series 8, Treatment 6, 16 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			5		1		1		3	
	non-separated			32	5	5	37	7		5	
Separator	separated			4	1	3	1	5			
	non-separated			1							

Appendix Table A1. Continued.

Source		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 8, Treatment 7, 16 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			12		8	6			1	
	non-separated			34	3	12	103			4	
Separator	separated			1	1						
	non-separated			1	2						
Series 8, Treatment 8, 15 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			4		1				1	
	non-separated			23	7	3	21	1			
Separator	separated			2							
	non-separated										
Series 9, Treatment 2, 17 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			12				3		2	
	non-separated			15	1	2	32				
Separator	separated			17		2	1				
	non-separated				1		1	3			
Series 9, Treatment 2, 17 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			9		2	2	3			
	non-separated			35	6	15	70			15	1
Separator	separated			7		3	1				
	non-separated			2		1	3				
Series 9, Treatment 3, 17 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			27		3	2	5		3	
	non-separated			46	7	6	57	5		4	
Separator	separated			5							
	non-separated			1		1	8				
Series 9, Treatment 3, 18 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			14		1	3	11		2	
	non-separated			20	4	2	48	37	1	3	
Separator	separated			7			2				
	non-separated			2	2						
Series 9, Treatment 3, 18 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			13		1		12			
	non-separated			15	1	1	6	32			
Separator	separated			2							
	non-separated			5	2		3	6			

Appendix Table A1. Continued.

Source		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 9, Treatment 4, 17 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			6		5	1	3		2	
	non-separated			28	5	5	23			2	
Separator	separated			5		1		1			
	non-separated						2				
Series 9, Treatment 6, 18 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			15			1	2		1	
	non-separated			43	4	1	22	10			
Separator	separated	1		10		1		1			
	non-separated						3				
Series 9, Treatment 6, 18 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			12		3		1		1	
	non-separated			74	4	7	31	7		4	
Separator	separated			9				2			
	non-separated			1			1				
Series 9, Treatment 7, 17 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated			13		6	5	3			
	non-separated			40	2	7	71	37		1	
Separator	separated			3				1			
	non-separated			1		2	3				
Series 9, Treatment 8, 18 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	1		6		2	1	2			
	non-separated			32	1	2	13	5		3	
Separator	separated			9							
	non-separated			1			1				
Series 10, Treatment 2, 19 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			9						2	
	non-separated			32		2	7	3		2	
Separator	separated			2		1					
	non-separated										
Series 10, Treatment 2, 18 May											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated			13		1	2	8		1	
	non-separated			22	2	5	26	32			
Separator	separated			2						1	
	non-separated			2							

Appendix Table A1. Continued.

Source		Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 10, Treatment 4, 19 May											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated			4				3			
	non-separated			30	1	3	22	12			
Separator	separated			3		1					
	non-separated						1				
Series 10, Treatment 6, 19 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			9				3			
	non-separated			28	1	2	15	3			
Separator	separated			3		1	1				
	non-separated										
Series 10, Treatment 6, 19 May											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated			16				5		1	
	non-separated			42	2	1	35	4		3	
Separator	separated			6		1	3				
	non-separated						5				
Series 10, Treatment 7, 27 June											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	92									
	non-separated	23									
Separator	separated										
	non-separated										
Series 10, Treatment 8, 20 May											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	1		7				1			
	non-separated			78	2		21		17	4	
Separator	separated			6			1	1			
	non-separated						7				
Series 11, Treatment 2, 17 June											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated	1		1		1				1	
	non-separated	6		2	1						
Separator	separated	1									
	non-separated										
Series 11, Treatment 3, 18 June											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	17		1						2	
	non-separated	13		9			8	4		3	
Separator	separated	1									
	non-separated					1					

Appendix Table A1. Continued.

		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 11, Treatment 4, 19 June											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	38						1			
	non-separated	16						5	1		
Separator	separated	2									
	non-separated										
Series 11, Treatment 6, 20 June											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated	56								1	
	non-separated	16					1				
Separator	separated	13									
	non-separated										
Series 11, Treatment 7, 20 June											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	74									
	non-separated	66			2		2		2		
Separator	separated	9									
	non-separated										
Series 11, Treatment 8, 23 June											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	60									
	non-separated	20								1	
Separator	separated	18									
	non-separated										
Series 12, Treatment 2, 24 June											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated	97									
	non-separated	25									
Separator	separated										
	non-separated										
Series 12, Treatment 3, 25 June											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	254									
	non-separated	124									
Separator	separated	6									
	non-separated										
Series 12, Treatment 4, 23 June											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	110									
	non-separated	24									
Separator	separated										
	non-separated										

Appendix Table A1. Continued.

Source		Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 12, Treatment 6, 26 June											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated	23									
	non-separated	20									
Separator	separated										
	non-separated										
Series 12, Treatment 7, 27 June											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	66		1							
	non-separated	15									
Separator	separated										
N	non-separated										
Series 12, Treatment 8, 25 June											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	63					1				
	non-separated	26									
Separator	separated										
	non-separated										
Series 13, Treatment 2, 1 July											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated	74									
	non-separated	21									
Separator	separated										
	non-separated										
Series 13, Treatment 3, 30 June											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	44									
	non-separated	3									
Separator	separated										
	non-separated										
Series 13, Treatment 4, 30 June											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	57									
	non-separated	6									
Separator	separated	3									
	non-separated										
Series 13, Treatment 6, 1 July											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated	123									
	non-separated	11									
Separator	separated	4									
	non-separated										

Appendix Table A1. Continued.

Source		Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 13, Treatment 7, 30 June											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	30									
	non-separated	17									
Separator	separated	2									
	non-separated										
Series 13, Treatment 8, 1 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	54									
	non-separated	4									
Separator	separated	12									
	non-separated										
Series 14, Treatment 2, 30 June											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated	4									
	non-separated	84									
Separator	separated										
	non-separated										
Series 14, Treatment 3, 2 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	56									
	non-separated	6									
Separator	separated	2									
	non-separated										
Series 14, Treatment 4, 1 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	57									
	non-separated	9									
Separator	separated										
	non-separated	2									
Series 14, Treatment 6, 2 July											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated	152									
	non-separated	33									
Separator	separated	2									
	non-separated										
Series 14, Treatment 7, 2 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	60									
	non-separated	5									
Separator	separated	5									
	non-separated										

Appendix Table A1. Continued.

		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 14, Treatment 8, 2 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	74									
	non-separated	18									
Separator	separated	6									
	non-separated										
Series 15, Treatment 2, 3 July											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated	102									
	non-separated	18									
Separator	separated	8									
	non-separated										
Series 15, Treatment 3, 3 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	106									
	non-separated	15									
Separator	separated	11									
	non-separated										
Series 15, Treatment 4, 3 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	92									
	non-separated	14									
Separator	separated	13									
	non-separated										
Series 15, Treatment 6, 3 July											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated	124									
	non-separated	15									
Separator	separated	4									
	non-separated										
Series 15, Treatment 7, 3 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	158									
	non-separated	19									
Separator	separated	4									
	non-separated										
Series 15, Treatment 8, 3 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	100									
	non-separated	9									
Separator	separated	2									
	non-separated										

Appendix Table A1. Continued.

		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 16, Treatment 2, 3 July											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated	66									
	non-separated	6									
Separator	separated	3									
	non-separated										
Series 16, Treatment 3, 3 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	122									
	non-separated	27									
Separator	separated	4									
	non-separated										
Series 16, Treatment 4, 3 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	113									
	non-separated	6									
Separator	separated	4									
	non-separated										
Series 16, Treatment 6, 3 July											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated	63									
	non-separated	6									
Separator	separated	4									
	non-separated										
Series 16, Treatment 7, 4 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	52									
	non-separated	25									
Separator	separated	10									
	non-separated										
Series 16, Treatment 8, 3 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	44									
	non-separated	11									
Separator	separated	14									
	non-separated										
Series 17, Treatment 2, 4 July											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated	151									
	non-separated	13									
Separator	separated	1									
	non-separated										

Appendix Table A1. Continued.

Source		Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 17, Treatment 3, 4 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	293									
	non-separated	65									
Separator	separated	42									
	non-separated										
Series 17, Treatment 4, 4 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	54									
	non-separated	17									
Separator	separated	15									
	non-separated										
Series 17, Treatment 6, 4 July											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated	56									
	non-separated	9									
Separator	separated										
	non-separated										
Series 17, Treatment 7, 4 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	76									
	non-separated	179									
Separator	separated										
	non-separated	21									
Series 17, Treatment 8, 4 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	84									
	non-separated	24									
Separator	separated	3									
	non-separated										
Series 18, Treatment 2, 5 July											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated	56									
	non-separated	15									
Separator	separated	11									
	non-separated										
Series 18, Treatment 3, 5 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	76									
	non-separated	14									
Separator	separated	12									
	non-separated										

Appendix Table A1. Continued.

Source		Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 18, Treatment 4, 5 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	64									
	non-separated	4									
Separator	separated	22									
	non-separated										
Series 18, Treatment 6, 5 July											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated	114									
	non-separated	27									
Separator	separated	3									
	non-separated										
Series 18, Treatment 7, 6 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	68									
	non-separated	16									
Separator	separated	6									
	non-separated										
Series 18, Treatment 8, 5 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	61									
	non-separated	7									
Separator	separated										
	non-separated										
Series 19, Treatment 2, 6 July											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated	49									
	non-separated	12									
Separator	separated	7									
	non-separated										
Series 19, Treatment 3, 6 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	97									
	non-separated	16									
Separator	separated	12									
	non-separated										
Series 19, Treatment 4, 6 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	47									
	non-separated	14									
Separator	separated	2									
	non-separated										

Appendix Table A1. Continued.

		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 19, Treatment 6, 6 July											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated	117									
	non-separated	38									
Separator	separated	6									
	non-separated										
Series 19, Treatment 7, 6 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	72									
	non-separated	43									
Separator	separated	5									
	non-separated										
Series 19, Treatment 8, 6 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	83									
	non-separated	13									
Separator	separated	11									
	non-separated										
Series 20, Treatment 2, 7 July											
Spray bars on, bar striping on, reverse orifice flow off											
Tanks	separated	89									
	non-separated	23									
Separator	separated	30									
	non-separated										
Series 20, Treatment 3, 7 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	95									
	non-separated	28									
Separator	separated	13									
	non-separated										
Series 20, Treatment 4, 7 July											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	52									
	non-separated	8									
Separator	separated	9									
	non-separated										
Series 20, Treatment 6, 7 July											
Spray bars on, bar striping off, reverse orifice flow off											
Tanks	separated	168									
	non-separated	7									
Separator	separated	60									
	non-separated										

Appendix Table A1. Continued.

Source		Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
		<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 20, Treatment 7, 7 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	61									
	non-separated	12									
Separator	separated	4									
	non-separated										
Series 20, Treatment 8, 7 July											
Spray bars off, bar striping off, reverse orifice flow off											
Tanks	separated	57									
	non-separated	10									
Separator	separated	6									
	non-separated										
Series 1, Treatment 4, 29 April											
Spray bars off, bar striping on, reverse orifice flow off											
Tanks	separated	1		18	1	3	9			1	
	non-separated			27	9	1	18			1	
Separator	separated	1									
	non-separated										

Appendix Table A2. Incidental species encountered during separator efficiency studies using a simulated conventional wet separator and an experimental high-velocity flume separator at McNary Dam, 28 April-25 July 1997. Species are listed in order of total capture frequency.

Common name	Scientific name	Simulated conventional wet separator	Experimental high-velocity flume	Total catch
lamprey	*Entosphenus tridentata*	116	1,741	1,875
sucker	*Catostomus* spp.	13	25	38
chiselmouth	*Acrocheilus alutaceus*	9	22	31
shad	*Alosa sapidissima*	1	24	25
yellow perch	*Perca flavescens*	6	3	9
bass	*Micropterus* spp.	6	21	7
carp	*Cyprinus carpio*		6	6
channel catfish	*Ictalurus punctatus*		2	2
sand roller	*Percopsis transmontana*	2		2
northern pikeperch	*Ptychocheilus oregonensis*		2	2
whitefish	*Prosopium williamsoni*		2	2
bluegill	*Lepomis macrochirus*	1		1
peamouth	*Mylocheilus caurinus*		1	1
redside shiner	*Richardsonius balteatus*		1	1

Appendix Table A3. Statistical analyses of mean separation efficiency, separator exit efficiency, and descaling estimates by length group for treatment evaluations using a simulated conventional wet separator and an experimental high-velocity flume separator at McNary Dam, 1997.

Comparison Subject					Calculated		
Separator type	Test dates	Length group	Analysis type	Treatment factors	Test statistic	df	P
Separation Efficiency							
Wet separator[a]	28 - 30 April	Total catch <180 mm[b]	2 x2 ANOVA[c]	Spray bars	F = 1.01	1	0.319
	1 - 17 May		2 x2 ANOVA	Bar striping	F = 0.25	1	0.620
			2 x2 ANOVA	Spray bars vs separation bar striping	F = 0.40	1	0.531
		Total catch ≥180 mm[d]	2 x2 ANOVA	Spray bars	F = 0.97	1	0.330
			2 x2 ANOVA	Bar striping	F = 3.27	1	0.620
			2 x2 ANOVA	Spray bars vs separation bar striping	F = 0.47	1	0.531
	16 - 30 June	Subyearling chinook	6 ANOVA[e]	Spray bars, separation bar striping			
	1 - 7 July	salmon <180 mm[f]		reverse flow orifice	F = 1.02	5	0.417
HVF, flat bars[g]	5 - 31 May	Total catch <180 mm	2 x3 x2 ANOVA[h]	Separation bar length	F = 29.98	1	<0.001
	1 - 2 June			Separation bar orientation	F = 4.60	2	0.015
				Water velocity	F = 0.30	1	0.585
				Separation bar length vs orientation	F = 2.68		
				Separation bar length vs water velocity	F = 2.75	1	0.104
				Separation bar orientation vs			
				water velocity	F = 3.72	2	0.032
				Separation bar length vs orientation			
				vs water velocity	F = 0.06	2	0.937
HVF, flat bars	5 - 31 May	Total catch ≥180 mm	2 x 3 x 2 ANOVA	Separation bar length	F = 21.94	1	<0.001
	1 - 2 June			Separation bar orientation	F = 0.54	2	0.588
				Water velocity	F = 0.00	1	0.951
				Separation bar length vs orientation	F = 0.52	2	0.579
				Separation bar length vs water velocity	F = 2.77	1	0.105
				Separation bar orientation vs			
				water velocity	F = 0.08	2	0.922
				Separation bar length vs orientation			
				vs water velocity	F = 0.43	2	0.652

Appendix Table A3. Continued.

Comparison Subject: Separator type	Test dates	Length group	Analysis type	Treatment factors	Calculated: Test statistic	df	P
Separation Efficiency							
HVF, flat bars	16 - 30 June 1 - 25 July	Subyearling chinook salmon <180 mm	2 x 3 x 2 ANOVA	Separation bar length	F = 113.50	1	0.001
				Separation bar orientation	F = 4.88	2	0.010
				Water velocity	F = 1.85	1	0.178
				Separation bar length vs orientation	F = 2.13	2	0.124
				Separation bar length vs water velocity	F = 0.78	1	0.381
				Separation bar orientation vs water velocity	F = 0.49	2	0.617
				Separation bar length vs orientation vs water velocity	F = 0.62	2	0.538
HVF, angled bars[i]	5 - 31 May 1 - 2 June	Total catch <180 mm	2 x 2 x 3 ANOVA	Separation bar length	F = 2.30	2	0.177
				Separation bar angle	F = 0.08	1	0.784
				Water velocity	F = 0.87	1	0.359
				Separation bar length vs angle	F = 1.54	2	0.229
				Separation bar length vs water velocity	F = 1.31	2	0.283
				Separation bar angle vs water velocity	F = 0.23	1	0.638
	5 - 31 May 1 - 2 June	Total catch <180 mm	2 x 2 x 3 ANOVA	Separation bar length vs angle vs water velocity	F = 0.19	2	0.825
		Total catch ≥180 mm	2 x 2 x 3 ANOVA	Separation bar length	F = 0.97	2	0.398
				Separation bar angle	F = 1.26	1	0.275
				Water velocity	F = 2.78	1	0.112
				Separation bar length vs angle	F = 0.27	2	0.765
				Separation bar length vs water velocity	F = 1.12	2	0.348
				Separation bar angle vs water velocity	F = 0.10	1	0.755
				Separation bar length vs angle			

vs water velocity	F = 0.38	2	0.692

Appendix Table A3. Continued.

Comparison Subject Separator type	Test dates	Length group	Analysis type	Treatment factors	Calculated Test statistic	df	P
Separation Efficiency							
HVF, flat bars	16 - 30 June 1 - 25 July	Subyearling chinook salmon <180 mm	2 x 3 x 2 ANOVA	Separation bar length	F = 12.61	2	0.000
				Separation bar orientation	F = 0.23	1	0.634
				Water velocity	F = 16.54	1	0.000
				Separation bar length vs orientation	F = 0.37	2	0.689
				Separation bar length vs water velocity	F = 2.59	2	0.080
				Separation bar orientation vs water velocity	F = 6.92	1	0.00
				Separation bar length vs orientation vs water velocity	F = 2.20	2	0.116
Separator Exit Efficiency							
Wet separator	28 - 30 April 1 - 17 May	Total catch <180 mm	2 x2 ANOVA	Spray bars	F = 1.61	1	0.211
			2 x2 ANOVA	Bar striping	F = 0.29	1	0.592
			2 x2 ANOVA	Spray bars vs separation bar striping	F = 0.47	1	0.496
	28 - 30 April 1 - 17 May	Total catch $\geq$180 mm	2 x2 ANOVA	Spray bars	F = 1.59	1	0.213
			2 x2 ANOVA	Bar striping	F = 0.76	1	0.387
			2 x2 ANOVA	Spray bars vs separation bar striping	F = 0.03	1	0.866
	16 - 30 June 1 - 7 July	Subyearling chinook salmon <180 mm	6 ANOVA	Spray bars, separation bar striping reverse flow orifice	F = 1.03	5	0.408

Appendix Table A3. Continued.

Comparison Subject Separator type	Test dates	Length group	Analysis type	Treatment factors	Calculated Test statistic	df	P
Separator Exit Efficiency							
HVF, flat bars	5 - 31 May 1 - 2 June	Total catch <180 mm	2 x3 x2 ANOVA	Separation bar length	All near 100%, no analysis		
				Separation bar orientation	All near 100%, no analysis		
				Water velocity	All near 100%, no analysis		
				Separation bar length vs orientation	All near 100%, no analysis		
				Separation bar length vs water velocity	All near 100%, no analysis		
				Separation bar orientation vs water velocity	All near 100%, no analysis		
				Separation bar length vs orientation vs water velocity	All near 100%, no analysis		
		Total catch $\geq$180 mm	2 x 3 x 2 ANOVA	Separation bar length	F = 1.33	1	<0.257
				Separation bar orientation	F = 0.02	2	0.982
				Water velocity	F = 14.60	1	0.001
				Separation bar length vs orientation	F = 1.14	2	0.332
				Separation bar length vs water velocity	F = 0.00	1	0.946
				Separation bar orientation vs water velocity	F = 0.06	2	0.942
				Separation bar length vs orientation vs water velocity	F = 1.48	2	0.243
HVF, flat bars	16 - 30 June 1 - 25 July	Subyearling chinook salmon <180 mm	2 x 3 x 2 ANOVA	Separation bar length	All near 100%, no analysis		
				Separation bar orientation	All near 100%, no analysis		
				Water velocity	All near 100%, no analysis		
				Separation bar length vs orientation	All near 100%, no analysis		
				Separation bar length vs water velocity	All near 100%, no analysis		
				Separation bar orientation vs water velocity	All near 100%, no analysis		
				Separation bar length vs orientation vs water velocity	All near 100%, no analysis		

Appendix Table A3. Continued.

Comparison Subject Separator type	Test dates	Length group	Analysis type	Treatment factors	Calculated Test statistic	df	P
Separator Exit Efficiency							
HVF, angled bars	5 - 31 May 1 - 2 June	Total catch <180 mm	2 x 2 x 3 ANOVA	Separation bar length	F = 4.35	2	0.021
				Separation bar angle	F = 0.21	1	0.647
				Water velocity	F = 31.97	1	0.000
				Separation bar length vs angle	F = 0.66	2	0.524
				Separation bar length vs water velocity	F = 3.46	2	0.043
				Separation bar angle vs water velocity	F = 0.01	1	0.913
				Separation bar length vs angle vs water velocity	F = 0.19	2	0.831
		Total catch ≥180 mm	2 x 2 x 3 ANOVA	Separation bar length	F = 0.25	2	0.780
				Separation bar angle	F = 4.34	1	0.051
				Water velocity	F = 22.85	1	0.000
				Separation bar length vs angle	F = 1.09	2	0.356
				Separation bar length vs water velocity	F = 1.12	2	0.683
				Separation bar angle vs water velocity	F = 0.00	1	0.998
				Separation bar length vs angle vs water velocity	F = 2.45	2	0.113
Separator Exit Efficiency							
HVF, angled bars	16 - 30 June 1 - 25 July	Subyearling chinook salmon <180 mm	2 x 3 x 2 ANOVA	Separation bar length	F = 0.68	2	0.511
				Separation bar orientation	F = 4.81	1	0.031
				Water velocity	F = 32.59	1	0.000
				Separation bar length vs orientation	F = 0.08	2	0.921
				Separation bar length vs water velocity	F = 1.59	2	0.320
				Separation bar orientation vs water velocity	F = 2.71	1	0.103
				Separation bar length vs orientation vs water velocity	F = 0.07	2	0.935

Appendix Table A3. Continued.

Comparison Subject Separator type	Test dates	Length group	Analysis type	Treatment factors	Calculated Test statistic	df	P
Descaling							
Wet separator	28 - 30 April 1 - 17 May	Total catch <180 mm	2 x 2 ANOVA	Spray bars	F = 0.04	1	0.883
			2 x 2 ANOVA	Bar striping	F = 2.70	1	0.106
			2 x 2 ANOVA	Spray bars vs separation bar striping	F = 0.03	1	0.853
		Total catch $\geq$180 mm	2 x 2 ANOVA	Spray bars	F = 1.43	1	0.236
			2 x 2 ANOVA	Bar striping	F = 0.06	1	0.813
			2 x 2 ANOVA	Spray bars vs separation bar striping	F = 0.64	1	0.428
	16 - 30 June 1 - 7 July	Subyearling chinook salmon <180 mm	6 ANOVA	Spray bars, separation bar striping reverse flow orifice	All near 0%, no analysis		
HVF, flat bars	5 - 31 May 1 - 2 June	Total catch <180 mm	2 x 3 x 2 ANOVA	Separation bar length	F = 0.81	1	0.371
				Separation bar orientation	F = 3.65	2	0.034
				Water velocity	F = 0.65	1	0.424
				Separation bar length vs orientation	F = 0.42	2	0.660
				Separation bar length vs water velocity	F = 0.40	1	0.529
				Separation bar orientation vs water velocity	F = 1.30	2	0.282
HVF, flat bars	5 - 31 May 1 - 2 June	Total catch <180 mm	2 x 3 x 2 ANOVA	Separation bar length vs orientation vs water velocity	F = 0.16	2	0.850
		Total catch $\geq$180 mm	2 x 3 x 2 ANOVA	Separation bar length	F = 1.20	1	0.281
				Separation bar orientation	F = 0.73	2	0.488
				Water velocity	F = 0.02	1	0.894
				Separation bar length vs orientation	F = 2.33	2	0.114
				Separation bar length vs water velocity	F = 0.03	1	0.886
				Separation bar orientation vs water velocity	F = 0.62	2	0.544
				Separation bar length vs orientation			

				vs water velocity	F = 0.06	2	0.945

Appendix Table A3. Continued.

Comparison Subject Separator type	Test dates	Length group	Analysis type	Treatment factors	Calculated Test statistic	df	P
Descaling							
	16 - 30 June 1 - 25 July	Subyearling chinook salmon <180 mm	2 x 3 x 2 ANOVA	Separation bar length	All near 0%, no analysis		
				Separation bar orientation	All near 0%, no analysis		
				Water velocity	All near 0%, no analysis		
				Separation bar length vs orientation	All near 0%, no analysis		
				Separation bar length vs water velocity	All near 0%, no analysis		
				Separation bar orientation vs water velocity	All near 0%, no analysis		
				Separation bar length vs orientation vs water velocity	All near 0%, no analysis		
51 HVF, angled bars	5 - 31 May 1 - 2 June	Total catch <180 mm	2 x 2 x 3 ANOVA	Separation bar length	F = 0.13	2	0.846
				Separation bar angle	F = 0.86	1	0.362
				Water velocity	F = 0.50	1	0.483
				Separation bar length vs angle	F = 0.13	2	0.883
				Separation bar length vs water velocity	F = 0.98	2	0.386
				Separation bar angle vs water velocity	F = 2.33	1	0.137
Descaling							
HVF, angled bars	5 - 31 May 1 - 2 June	Total catch <180 mm	2 x 2 x 3 ANOVA	Separation bar length vs angle vs water velocity	F = 0.64	2	0.533
		Total catch ≥180 mm	2 x 2 x 3 ANOVA	Separation bar length	F = 0.10	2	0.905
				Separation bar angle	F = 0.10	1	0.755
				Water velocity	F = 0.29	1	0.559
				Separation bar length vs angle	F = 1.10	2	0.353

				Separation bar length vs water velocity	F = 1.26	2	0.306
				Separation bar angle vs water velocity	F = 0.38	1	0.547
				Separation bar length vs angle vs water velocity	F = 0.32	2	0.730

Appendix Table A3. Continued.

Comparison Subject Separator type	Test dates	Length group	Analysis type	Treatment factors	Calculated Test statistic	df	P
Descaling	16 - 30 June 1 - 25 July	Subyearling chinook salmon <180 mm	2 x 3 x 2 ANOVA	Separation bar length	All near 0%, no analysis		
				Separation bar orientation	All near 0%, no analysis		
				Water velocity	All near 0%, no analysis		
				Separation bar length vs orientation	All near 0%, no analysis		
				Separation bar length vs water velocity	All near 0%, no analysis		
				Separation bar orientation vs water velocity	All near 0%, no analysis		
				Separation bar length vs orientation vs water velocity	All near 0%, no analysis		

[a] Simulated conventional wet separator.
[b] Total catch of yearling chinook, coho and sockeye salmon and steelhead <180 mm fork length captured during the spring outmigration.
[c] Two-way factorial analysis of variance.
[d] Total catch of yearling chinook, coho and sockeye salmon and steelhead $\geq$180 mm fork length captured during the spring outmigration.
[e] Six-factor analysis of variance.
[f] Total catch of subyearling chinook salmon <180 mm fork length captured during the summer outmigration.
[g] Experimental high-velocity flume separator using 6 and 12 m separation bars oriented either flat or at a shallow (0.7^{o}) angle in relation to the water surface.
[h] Three-way factorial analysis of variance.
[i] Experimental high-velocity flume separator using 1.5-m, 3.0-m, or 4.5-m separation bars at discrete angles of either 4^{o} or 8^{o}.

Appendix Table A4. Total catch, by species, for individual replicates of separation efficiency and exit efficiency tests using a high-velocity flume separator at McNary Dam, 1997.

	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 1, Treatment 1, 13 May										
Separation bar length 12 m, angled 0.7°, water velocity 1 m/s										
Tanks: separated			22	2	5	13	3		5	
non-separated			3	2		10				
Separator: separated						1				
non-separated						4				
Series 1, Treatment 2, 12 May										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated			16		3	19			2	
non-separated			10	2	2	23	1		4	
Separator: separated										
non-separated										
Series 1, Treatment 3, 7 May										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated			28	4	4	19			1	
non-separated			2	2	1	11				
Separator: separated						3				
non-separated										
Series 1, Treatment 5, 8 May										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated			40	7	4	16			1	
non-separated			10	1		15				
Separator: separated				1						
non-separated										
Series 1, Treatment 6, 8 May										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated			28	3	8	9			1	
non-separated			3			12				
Separator: separated										
non-separated						1				
Series 1, Treatment 7, 12 May										
Separation bar length 6 m, angled (0.7°), water velocity 1 m/s										
Tanks: separated			16	2	2	1			2	
non-separated			17	2		10			2	
Separator: separated			1							
non-separated						1				
Series 1, Treatment 8, 12 May										
Separation bar length 6 m, angled (0.7°), water velocity 2 m/s										
Tanks: separated			14	4	1	7			5	
non-separated			22	2	3	10			9	
Separator: separated										
non-separated						1				

Appendix Table A4. Continued.

	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source	<180	>180	<180	>180	<180	>180	<180	>180	<180	>180
Series 1, Treatment 9, 9 May										
Separation bar length 6 m, flat (0)°, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated			10		4	16	2		3	
non-separated			13	1	1	14				
Separator: separated			1			3				
non-separated						3				
Series 1, Treatment 10, 8 May										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated			1	2	3	10				
non-separated			14	2	6	22			5	
Separator: separated										
non-separated										
Series 1, Treatment 11, 9 May										
Separation bar length 6 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated			15	1	5	6			4	
non-separated			16	6	5	33	1		4	
Separator: separated										
non-separated					1	18				
Series 1, Treatment 12, 8 May										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated			7	5	1	3		1		
non-separated			13	2	1	25	2			
Separator: separated										
non-separated										
Series 1, Treatment 13, 5 May										
Separation bar length 4.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated			22	2	2	4				
non-separated			6	2	2	1				
Separator: separated										
non-separated			2	5		15				
Series 1, Treatment 14, 5 May										
Separation bar length 4.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated			11		2	5			1	
non-separated			4	3		4				
Separator: separated										
non-separated										
Series 1, Treatment 15, 5 May										
Separation bar length 4.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	4		9	3	2	8				
non-separated	1		5	4		11	1			
Separator: separated										
non-separated										

Appendix Table A4. Continued.

	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 1, Treatment 16, 5 May										
Separation bar length 4.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated			20	6	3	6				
non-separated			12	8		11				
Separator: separated										
non-separated										
Series 1, Treatment 17, 5 May										
Separation bar length 3.0 m, angled 4°, water velocity 1 m/s										
Tanks: separated			12	5	6	18				
non-separated			8	2	1	17				
Separator: separated										
non-separated			8	3	1	23				
Series 1, Treatment 18, 6 May										
Separation bar length 3.0 m, angled 4°, water velocity 2 m/s										
Tanks: separated			9	1	3	6				
non-separated			7	3	1	20			1	
Separator: separated										
non-separated					2	9				
Series 1, Treatment 19, 6 May										
Separation bar length 3.0 m, angled 8°, water velocity 1 m/s										
Tanks: separated			10	1	2	12				
non-separated			6	3		26				
Separator: separated			3		1	11				
non-separated				3		19				
Series 1, Treatment 20, 3 May										
Separation bar length 3.0 m, angled 8°, water velocity 2 m/s										
Tanks: separated			19	5	5	3				
non-separated			7	6		16			1	
Separator: separated										
non-separated										
Series 1, Treatment 21, 7 May										
Separation bar length 1.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated			5			5				
non-separated			8		1	12				
Separator: separated			1							
non-separated			8	9	3	25				
Series 1, Treatment 22, 7 May										
Separation bar length 1.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated			5	1	1	4				
non-separated			15	4		4	1			
Separator: separated						1				
non-separated						8				

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 1, Treatment 23, 6 May										
Separation bar length 1.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated			4		2	4	1		2	
non-separated			13	4	6	37			1	
Separator: separated										
non-separated			12	1	10	56				
Series 1, Treatment 24, 6 May										
Separation bar length 1.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated			8	1	2	10				
non-separated			13	7	3	38			1	
Separator: separated										
non-separated					3	10				
Series 2, Treatment 1, 13 May										
Separation bar length 12 m, angled 0.7°, water velocity 1 m/s										
Tanks: separated			23	10	3	22	3		4	
non-separated			8	2	2	28				
Separator: separated						1				
non-separated						1				
Series 2, Treatment 2, 13 May										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated			12	12		17	1		8	
non-separated			7	1	2	17	1		2	
Separator: separated										
non-separated						1				
Series 2, Treatment 3, 14 May										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated			23	5	3	18	7		2	
non-separated			6	2	1	15				
Separator: separated						2				
non-separated						2				
Series 2, Treatment 4, 14 May										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated			11	1	7	18	1		4	
non-separated	1		6	1		9				
Separator: separated						1				
non-separated										
Series 2, Treatment 5, 14 May										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated			25	3	3	35			1	
non-separated			15	8	3	29			4	
Separator: separated						2				
non-separated				3						

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 2, Treatment 6, 14 May										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated			22	6	5	5	3			
non-separated			4			12	1			
Separator: separated										
non-separated										
Series 2, Treatment 7, 15 May										
Separation bar length 6 m, angled (0.7°), water velocity 1 m/s										
Tanks: separated			22	7	8	33	16			
non-separated			7	4	2	54	4	1	1	
Separator: separated										
non-separated						1				
Series 2, Treatment 8, 15 May										
Separation bar length 6 m, angled (0.7°), water velocity 2 m/s										
Tanks: separated	1		18	3	4	15			1	
non-separated			15	1	2	61			3	
Separator: separated						4				
non-separated				1	1	10				
Series 2, Treatment 9, 16 May										
Separation bar length 6 m, flat (0)°, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated			18	3	4	16			4	
non-separated			12	6	2	42	3		1	
Separator: separated						2				
non-separated						2				
Series 2, Treatment 10, 15 May										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated			5	4	4	10	1		5	
non-separated			18	4	5	8			1	
Separator: separated										
non-separated										
Series 2, Treatment 11, 16 May										
Separation bar length 6 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated			6		5	5				
non-separated			45	2	10	47	7		3	
Separator: separated						4				
non-separated						4				
Series 2, Treatment 12, 15 May										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	1		7		2	18	2		2	
non-separated			7	3	2	15	1	1	1	
Separator: separated						1				
non-separated						4				

Appendix Table A4. Continued.

	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 2, Treatment 13, 17 May										
Separation bar length 4.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated			19		1	4	14		4	
non-separated	1		21		2	21	11		4	
Separator: separated			1		1	5	1			
non-separated										
Series 2, Treatment 14, 16 May										
Separation bar length 4.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated			32	7	8	23				
non-separated			13	3	2	43				
Separator: separated						7				
non-separated				1	4	23				
Series 2, Treatment 15, 17 May										
Separation bar length 4.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated			18	1	2	5	2		1	
non-separated			47	3	30	4	11		3	
Separator: separated										
non-separated					5	30				
Series 2, Treatment 16, 17 May										
Separation bar length 4.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	1		28	3	4	16			1	
non-separated			14	6	3	14				
Separator: separated										
non-separated						4				
Series 2, Treatment 17, 17 May										
Separation bar length 3.0 m, angled 4°, water velocity 1 m/s										
Tanks: separated			21			4	3		3	
non-separated			13			5	8		6	
Separator: separated			3		1					
non-separated			34	3	10	35	6		1	
Series 2, Treatment 18, 18 May										
Separation bar length 3.0 m, angled 4°, water velocity 2 m/s										
Tanks: separated	3		18			7	23		2	
non-separated			14	2	2	9	15		3	
Separator: separated			1							
non-separated						3	1			
Series 2, Treatment 19, 17 May										
Separation bar length 3.0 m, angled 8°, water velocity 1 m/s										
Tanks: separated			11		5	10	6		1	
non-separated			34	2	3	20	2		2	
Separator: separated										
non-separated			16		1	45	6			

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 2, Treatment 20, 18 May										
Separation bar length 3.0 m, angled 8°, water velocity 2 m/s										
Tanks: separated	1		4	1			5		1	
non-separated	1		17	1	4	17	32		1	
Separator: separated										
non-separated				1	1	2	1			
Series 2, Treatment 21, 18 May										
Separation bar length 1.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	1		4		1	7	15	1	3	
non-separated			12			12	20	1	11	
Separator: separated			1			5	5	1		
non-separated			6	5	3	76	51	1	1	
Series 2, Treatment 22, 19 May										
Separation bar length 1.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated			4		1	1	2		3	
non-separated			23	2	3	5	23		3	
Separator: separated			1							
non-separated						3				
Series 2, Treatment 23, 19 May										
Separation bar length 1.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated			5		5	14	12			
non-separated	1		11		4	29	16	1		
Separator: separated					2	1	2			
non-separated			3		1	34	11			
Series 2, Treatment 24, 19 May										
Separation bar length 1.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	1		12		3	14	17	1		
non-separated			16	1	3	36	25	1	2	
Separator: separated					1		1			
non-separated					2	3	2			
Series 3, Treatment 1, 20 May										
Separation bar length 12 m, angled 0.7°, water velocity 1 m/s										
Tanks: separated			20	1	13	37	19			
non-separated			16	1	1	33	17			
Separator: separated						2				
non-separated			1			1				
Series 3, Treatment 2, 20 May										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated	1		12	1	5	18	31	1		
non-separated			25	1		33	27		2	
Separator: separated			1			1	2			
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 3, Treatment 3, 20 May										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	2		47		11	22	26		9	
non-separated			21	1	1	32	8		3	
Separator: separated			1			3				
non-separated										
Series 3, Treatment 4, 20 May										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	1		26	1	4	19	10		3	
non-separated			22		2	31	11		1	
Separator: separated										
non-separated										
Series 3, Treatment 5, 20 May										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	1		26	4	8	45	55		5	
non-separated	1		14	3		27	12	1		
Separator: separated			1			5				
non-separated						3				
Series 3, Treatment 6, 20 May										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	1		26		6		11	19	1	
non-separated			10		2	15	17			
Separator: separated										
non-separated										
Series 3, Treatment 7, 21 May										
Separation bar length 6 m, angled (0.7°), water velocity 1 m/s										
Tanks: separated	3		19	1	8	18	30		6	
non-separated	5		16		1	35	17		10	
Separator: separated						2	3			
non-separated						6	1			
Series 3, Treatment 8, 22 May										
Separation bar length 6 m, angled (0.7°), water velocity 2 m/s										
Tanks: separated	4		19			4	10			
non-separated	1		9	1		12	3			
Separator: separated										
non-separated					1					
Series 3, Treatment 9, 21 May										
Separation bar length 6 m, flat (0)°, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	4		23	2	3	5	12		3	
non-separated	1		17	5	1	8	4			
Separator: separated										
non-separated						1				

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 3, Treatment 10, 21 May										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	5		33	2	3	10	25	1	4	
non-separated			13	4	1	16			1	
Separator: separated										
non-separated						3	2			
Series 3, Treatment 11, 20 May										
Separation bar length 6 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	1		18	2	3	19				
non-separated			12	2	5	16	11		2	
Separator: separated										
non-separated						3				
Series 3, Treatment 12, 20 May										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated			27	1	10	58	3	25	2	
non-separated	1		15	1	2	31	4		2	
Separator: separated										
non-separated					1	6				
Series 3, Treatment 13, 23 May										
Separation bar length 4.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	10		12	2	1	4	11		8	
non-separated	3		24		2	6	17	1	4	
Separator: separated			1		1		1			
non-separated			8	2	3	16	22			
Series 3, Treatment 14, 22 May										
Separation bar length 4.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	10		23	1	4	14	10		6	
non-separated			6	1	1	12	3			
Separator: separated										
non-separated					1					
Series 3, Treatment 15, 22 May										
Separation bar length 4.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	6		17	1	3	11	32	2	8	
non-separated	3		10	7		21	19		26	
Separator: separated										
non-separated						5	1			
Series 3, Treatment 16, 22 May										
Separation bar length 4.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	17		11			16	25		5	
non-separated	4		18	2	2	17	30		10	
Separator: separated										
non-separated						2				

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 3, Treatment 17, 23 May										
Separation bar length 3.0 m, angled 4°, water velocity 1 m/s										
Tanks: separated	12		16			12	33			
non-separated	10		25		2	4	8		13	
Separator: separated			6	1			4			
non-separated			4	2	3	24	16			
Series 3, Treatment 18, 23 May										
Separation bar length 3.0 m, angled 4°, water velocity 2 m/s										
Tanks: separated	3		20	3	6	19	5		6	
non-separated	1		9		1	11			4	
Separator: separated										
non-separated						2	1			
Series 3, Treatment 19, 24 May										
Separation bar length 3.0 m, angled 8°, water velocity 1 m/s										
Tanks: separated	1		29	1	6	11	6		1	
non-separated			3			7				
Separator: separated										
non-separated			1			10				
Series 3, Treatment 20, 23 May										
Separation bar length 3.0 m, angled 8°, water velocity 2 m/s										
Tanks: separated	7		16		3	7	7		1	
non-separated	4		14		3	10	11		7	
Separator: separated						1				
non-separated						4				
Series 3, Treatment 21, 24 May										
Separation bar length 1.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	8		21		2	13	15	2	15	
non-separated	13		13		1	18	12		12	
Separator: separated										
non-separated			5		1	1	2			
Series 3, Treatment 22, 25 May										
Separation bar length 1.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	5		16		4	4	5		2	
non-separated	10		18	1	5	11	6	1	7	
Separator: separated			1				1			
non-separated			2			7	2			

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 3, Treatment 23, 24 May										
Separation bar length 1.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	3		16	1	6	9	9		10	
non-separated	6		9	1		11	4		19	
Separator: separated			1		1	3	1			
non-separated			1		3	20	10			
Series 3, Treatment 24, 24 May										
Separation bar length 1.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	8		15	3	2	15	3		3	
non-separated	1		15		3	17	3		2	
Separator: separated										
non-separated						4				
Series 4, Treatment 1, 25 May										
Separation bar length 12 m, angled 0.7°, water velocity 1 m/s										
Tanks: separated	8		22	2	2	3	25		3	
non-separated	4		8			12	3		6	
Separator: separated						1				
non-separated										
Series 4, Treatment 2, 25 May										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated			26		1	4	10		8	
non-separated			15		3	3	10		5	
Separator: separated					1					
non-separated										
Series 4, Treatment 3, 26 May										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	12		28	1	1	6	7	1	5	
non-separated			3	2		5	1		1	
Separator: separated										
non-separated										
Series 4, Treatment 4, 25 May										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	12		24			2	26	3	1	
non-separated	6		12		1	5	6		1	
Separator: separated			1							
non-separated										
Series 4, Treatment 5, 25 May										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	6		18	2	1	9	30	2	5	
non-separated	2		12		9		4		1	
Separator: separated						1				
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 4, Treatment 6, 25 May										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	12		30	1	6	7	7		7	
non-separated	1		5		1	9	1		3	
Separator: separated										
non-separated										
Series 4, Treatment 7, 26 May										
Separation bar length 6 m, angled (0.7°), water velocity 1 m/s										
Tanks: separated	17		11	1	5	4	26	1	9	
non-separated	12		24	2	1	9	30		21	
Separator: separated							1			
non-separated						2	3			
Series 4, Treatment 8, 26 May										
Separation bar length 6 m, angled (0.7°), water velocity 2 m/s										
Tanks: separated	16		9	1	1	1	35	1	15	
non-separated	8		18	2	1	9	40		27	
Separator: separated										
non-separated										
Series 4, Treatment 9, 26 May										
Separation bar length 6 m, flat (0)°, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	20		31		12	10	39	1	35	
non-separated	11		4		1	23	13	1	10	1
Separator: separated										
non-separated						2				
Series 4, Treatment 10, 26 May										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	47		22		5	13	23	3	27	
non-separated	10		8	1	3	24	13		6	
Separator: separated							1			
non-separated						3		1		
Series 4, Treatment 11, 26 May										
Separation bar length 6 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	4						3		1	
non-separated	13		34	3		4	40	2	13	
Separator: separated							2			
non-separated						2	4			
Series 4, Treatment 12, 26 May										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	14		25	1	4	5	32	2	24	
non-separated	15		20	2		23	20		20	
Separator: separated										
non-separated						2	1			

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 4, Treatment 13, 27 May										
Separation bar length 4.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	97		23		4	7	21		11	
non-separated	58		14		1	7	13		10	
Separator: separated			7	1	1	2	5		1	
non-separated			9			31	4		2	
Series 4, Treatment 14, 27 May										
Separation bar length 4.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	12		26		1	6	26	2	8	
non-separated	20		33	1	16		17		20	
Separator: separated						1	6			
non-separated						7	5			
Series 4, Treatment 15, 27 May										
Separation bar length 4.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	41		16	1	2	6	14		9	
non-separated	19		1	16	1	5	13		19	
Separator: separated			1			1				
non-separated			4		13	2	9			
Series 4, Treatment 16, 27 May										
Separation bar length 4.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	45		7	1		3	24		8	
non-separated	20		20	5	1	18	41		23	
Separator: separated										
non-separated						1	6			
Series 4, Treatment 17, 28 May										
Separation bar length 3.0 m, angled 4°, water velocity 1 m/s										
Tanks: separated	88		24		3	2	7		11	
non-separated	24		9	1	1	3	5		5	
Separator: separated							3		1	
non-separated			2	2	3	19	9	1		
Series 4, Treatment 18, 28 May										
Separation bar length 3.0 m, angled 4°, water velocity 2 m/s										
Tanks: separated	69		19		1	2	12	1	5	
non-separated	30		16	1		5	15		11	
Separator: separated							3			
non-separated			3			6	3			
Series 4, Treatment 19, 28 May										
Separation bar length 3.0 m, angled 8°, water velocity 1 m/s										
Tanks: separated	53		17	2	4	6	9		5	
non-separated	34		15			2	20		16	
Separator: separated			5			1	5		2	
non-separated			13	2		22	45	2		

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 4, Treatment 20, 29 May										
Separation bar length 3.0 m, angled 8°, water velocity 2 m/s										
Tanks: separated	56		14			4	13		4	
non-separated	17		16	1	13	1	14	1	15	
Separator: separated										
non-separated						3				
Series 5, Treatment 1, 29 May										
Separation bar length 12 m, angled 0.7°, water velocity 1 m/s										
Tanks: separated	77		39	1	2	15	14	1	5	
non-separated	4		6	1	1	17			4	
Separator: separated						2				
non-separated						3				
Series 5, Treatment 2, 30 May										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated	33		20	1	1	3	13		8	
non-separated	15		13	2		10	7		5	
Separator: separated							1			
non-separated										
Series 5, Treatment 3, 30 May										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	64		30		1	3	23	1	12	
non-separated	6			2		7	2			
Separator: separated			6	1		8	6			
non-separated						2				
Series 5, Treatment 4, 29 May										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	44		28		1	8	2		6	
non-separated	5		2	1		11			1	
Separator: separated										
non-separated										
Series 5, Treatment 5, 30 May										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	70		28		3	11	15	1	10	
non-separated	8		3		1	18	1	1		
Separator: separated										
non-separated										
Series 5, Treatment 6, 29 May										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	44		31	1	1	14	44	1	9	
non-separated	13		3			21	3		1	
Separator: separated			2				2			
non-separated						1				

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 5, Treatment 7, 31 May										
Separation bar length 6 m, angled (0.7°), water velocity 1 m/s										
Tanks: separated	18		17		1	6	23		5	
non-separated	15		19		2	28	10		12	
Separator: separated			1							
non-separated						7	2			
Series 5, Treatment 8, 31 May										
Separation bar length 6 m, angled (0.7°), water velocity 2 m/s										
Tanks: separated	56		17	1	1	3	9		8	
non-separated	44		14	1		10	10		9	
Separator: separated										
non-separated										
Series 5, Treatment 9, 31 May										
Separation bar length 6 m, flat (0)°, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	32		23		1	13	18		9	
non-separated	14		10	1		34	12			
Separator: separated						2				
non-separated										
Series 5, Treatment 10, 1 June										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	48		19	1	4	16	42	3	12	
non-separated	18		10	3	5	33	8		4	
Separator: separated										
non-separated										
Series 5, Treatment 11, 1 June										
Separation bar length 6 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	29		23		3	4	18		6	
non-separated	6		8	2	1	12	8		2	
Separator: separated										
non-separated										
Series 5, Treatment 12, 1 June										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	34		15	1	3	3	6	1	9	
non-separated	21		16	2	3	25	10	1	13	1
Separator: separated										
non-separated										
Series 5, Treatment 13, 2 June										
Separation bar length 4.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	167		32	2	6	15	24		6	
non-separated	115		4			3	4		1	
Separator: separated			7		1	1	2	1		1
non-separated			20	3	6	41	16	1		

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 5, Treatment 14, 1 June										
Separation bar length 4.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	54		21	1	5	8	13	2	3	
non-separated	27		7	2		15	2			1
Separator: separated										
non-separated						2				
Series 5, Treatment 15, 2 June										
Separation bar length 4.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	116		13		1	2	12		6	
non-separated	67		15	4		12	17	1	8	
Separator: separated	2		1							
non-separated	1		2			1				
Series 5, Treatment 16, 3 June										
Separation bar length 4.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	87		19			4	12		2	
non-separated	50		13	2	1	15	9		2	
Separator: separated			1							
non-separated										
Series 5, Treatment 19, 3 June										
Separation bar length 3.0 m, angled 8°, water velocity 1 m/s										
Tanks: separated	70		11	1	1	22	7	1	2	
non-separated	65		6			4	10		5	
Separator: separated	4			1		2	2			
non-separated			11	4		9	42	1		
Series 6, Treatment 1, 20 June										
Separation bar length 12 m, angled 0.7°, water velocity 1 m/s										
Tanks: separated	76			2		1				
non-separated	37									
Separator: separated										
non-separated										
Series 6, Treatment 2, 20 June										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated	58						1			
non-separated	14									
Separator: separated										
non-separated										
Series 6, Treatment 3, 20 June										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	79						1			
non-separated	13									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 6, Treatment 4, 20 June										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	138									
non-separated	3									
Separator: separated										
non-separated										
Series 6, Treatment 5, 23 June										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	464		2			1				
non-separated	153		1			1				
Separator: separated	2									
non-separated										
Series 6, Treatment 6, 20 June										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	90						1			
non-separated	6									
Separator: separated										
non-separated										
Series 6, Treatment 7, 23 June										
Separation bar length 6 m, angled (0.7°), water velocity 1 m/s										
Tanks: separated	163									
non-separated	206			1						
Separator: separated										
non-separated										
Series 6, Treatment 8, 23 June										
Separation bar length 6 m, angled (0.7°), water velocity 2 m/s										
Tanks: separated	240		1							
non-separated	186				1	1				
Separator: separated										
non-separated										
Series 6, Treatment 9, 23 June										
Separation bar length 6 m, flat (0)°, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	222									
non-separated	602		2				1		2	
Separator: separated	4									
non-separated										
Series 6, Treatment 10, 23 June										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	213									
non-separated	34									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 6, Treatment 11, 23 June										
Separation bar length 6 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	108		1							
non-separated	343		1							
Separator: separated										
non-separated										
Series 6, Treatment 12, 23 June										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	209									
non-separated	193									
Separator: separated										
non-separated										
Series 6, Treatment 13, 17 June										
Separation bar length 4.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	50						1	1		
non-separated	18						1			
Separator: separated	8						1			
non-separated	18					2	3	2	2	
Series 6, Treatment 14, 18 June										
Separation bar length 4.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	37		4				1			
non-separated	17		6		1		2		2	
Separator: separated										
non-separated										
Series 6, Treatment 15, 17 June										
Separation bar length 4.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	19				1			1	1	
non-separated	12						1		2	
Separator: separated						1	1	3		
non-separated										
Series 6, Treatment 16, 17 June										
Separation bar length 4.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	76		7			1	1		1	
non-separated	39		1						1	
Separator: separated										
non-separated										
Series 6, Treatment 17, 19 June										
Separation bar length 3.0 m, angled 4°, water velocity 1 m/s										
Tanks: separated	55								3	2
non-separated	17				1				1	
Separator: separated										
non-separated	2		1							

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 6, Treatment 18, 18 June										
Separation bar length 3.0 m, angled 4°, water velocity 2 m/s										
Tanks: separated	21		3			1	1	1		
non-separated	17		3			2	5			
Separator: separated										
non-separated						5				
Series 6, Treatment 19, 19 June										
Separation bar length 3.0 m, angled 8°, water velocity 1 m/s										
Tanks: separated	64						1			
non-separated	29									
Separator: separated										
non-separated						3	2			
Series 6, Treatment 20, 19 June										
Separation bar length 3.0 m, angled 8°, water velocity 2 m/s										
Tanks: separated	65		2					1		
non-separated	32		2	1	1	1	1			
Separator: separated							2			
non-separated								1		
Series 6, Treatment 21, 20 June										
Separation bar length 1.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	8		1							
non-separated	68					1				
Separator: separated	1									
non-separated	3									
Series 6, Treatment 22, 20 June										
Separation bar length 1.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	25									
non-separated	82			1						
Separator: separated										
non-separated			1							
Series 6, Treatment 23, 19 June										
Separation bar length 1.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	15						1	1	1	
non-separated	18									
Separator: separated										
non-separated										
Series 6, Treatment 24, 20 June										
Separation bar length 1.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	64					1				
non-separated	47		1							
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 7, Treatment 1, 23 June										
Separation bar length 12 m, angled 0.7°, water velocity 1 m/s										
Tanks: separated	157									
non-separated	127									
Separator: separated										
non-separated										
Series 7, Treatment 2, 23 June										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated	170									
non-separated	78									
Separator: separated										
non-separated										
Series 7, Treatment 3, 23 June										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	68									
non-separated	8									
Separator: separated										
non-separated										
Series 7, Treatment 4, 23 June										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	70									
non-separated	67									
Separator: separated										
non-separated										
Series 7, Treatment 5, 23 June										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	126									
non-separated	25									
Separator: separated										
non-separated										
Series 7, Treatment 6, 23 June										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	64									
non-separated	115									
Separator: separated										
non-separated										
Series 7, Treatment 7, 25 June										
Separation bar length 6 m, angled (0.7°), water velocity 1 m/s										
Tanks: separated	83									
non-separated	76									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 7, Treatment 8, 25 June										
Separation bar length 6 m, angled (0.7°), water velocity 2 m/s										
Tanks: separated	44									
non-separated	25									
Separator: separated										
non-separated										
Series 7, Treatment 9, 25 June										
Separation bar length 6 m, flat (0)°, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	101									
non-separated	97									
Separator: separated										
non-separated										
Series 7, Treatment 10, 25 June										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	62									
non-separated	39									
Separator: separated										
non-separated										
Series 7, Treatment 11, 25 June										
Separation bar length 6 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	154									
non-separated	164									
Separator: separated										
non-separated										
Series 7, Treatment 12, 25 June										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	156									
non-separated	123									
Separator: separated										
non-separated										
Series 7, Treatment 13, 25 June										
Separation bar length 4.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	67									
non-separated	76									
Separator: separated										
non-separated										
Series 7, Treatment 14, 26 June										
Separation bar length 4.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	84									
non-separated	23									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 7, Treatment 15, 25 June										
Separation bar length 4.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	115									
non-separated	118									
Separator: separated	7									
non-separated	14									
Series 7, Treatment 16, 25 June										
Separation bar length 4.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	67									
non-separated	55									
Separator: separated										
non-separated										
Series 7, Treatment 17, 22 June										
Separation bar length 3.0 m, angled 4°, water velocity 1 m/s										
Tanks: separated	63									
non-separated	45		2							
Separator: separated	2									
non-separated	6									
Series 7, Treatment 18, 26 June										
Separation bar length 3.0 m, angled 4°, water velocity 2 m/s										
Tanks: separated	39									
non-separated	27									
Separator: separated										
non-separated										
Series 7, Treatment 19, 27 June										
Separation bar length 3.0 m, angled 8°, water velocity 1 m/s										
Tanks: separated	59									
non-separated	23		1							
Separator: separated										
non-separated										
Series 7, Treatment 20, 27 June										
Separation bar length 3.0 m, angled 8°, water velocity 2 m/s										
Tanks: separated	73									
non-separated	22									
Separator: separated										
non-separated										
Series 7, Treatment 21, 27 June										
Separation bar length 1.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	37									
non-separated	51									
Separator: separated	16									
non-separated	134									

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 7, Treatment 22, 27 June										
Separation bar length 1.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	48									
non-separated	91									
Separator: separated										
non-separated										
Series 7, Treatment 23, 27 June										
Separation bar length 1.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	72									
non-separated	59									
Separator: separated										
non-separated										
Series 7, Treatment 24, 27 June										
Separation bar length 1.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	46		1							
non-separated	34									
Separator: separated										
non-separated										
Series 8, Treatment 1, 30 June										
Separation bar length 12 m, angled 0.7°, water velocity 1 m/s										
Tanks: separated	105									
non-separated	3									
Separator: separated										
non-separated										
Series 8, Treatment 2, 30 June										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated	211									
non-separated	29									
Separator: separated										
non-separated										
Series 8, Treatment 3, 30 June										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	454									
non-separated	13									
Separator: separated										
non-separated										
Series 8, Treatment 4, 30 June										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	131									
non-separated	6									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 8, Treatment 5, 30 June										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	88									
non-separated	3									
Separator: separated										
non-separated										
Series 8, Treatment 6, 30 June										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	164									
non-separated	23									
Separator: separated										
non-separated										
Series 8, Treatment 7, 30 June										
Separation bar length 6 m, angled (0.7°), water velocity 1 m/s										
Tanks: separated	49									
non-separated	56									
Separator: separated										
non-separated										
Series 8, Treatment 8, 30 June										
Separation bar length 6 m, angled (0.7°), water velocity 2 m/s										
Tanks: separated	19									
non-separated	67									
Separator: separated										
non-separated										
Series 8, Treatment 9, 30 June										
Separation bar length 6 m, flat (0)°, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	70									
non-separated	49									
Separator: separated										
non-separated										
Series 8, Treatment 10, 30 June										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	59									
non-separated	75									
Separator: separated										
non-separated										
Series 8, Treatment 11, 30 June										
Separation bar length 6 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	20									
non-separated	68									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 8, Treatment 12, 30 June										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	84									
non-separated	77									
Separator: separated										
non-separated										
Series 8, Treatment 13, 1 July										
Separation bar length 4.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	95									
non-separated	18									
Separator: separated										
non-separated	10									
Series 8, Treatment 14, 1 July										
Separation bar length 4.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	84									
non-separated	92									
Separator: separated										
non-separated										
Series 8, Treatment 15, 1 July										
Separation bar length 4.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	55									
non-separated	38									
Separator: separated										
non-separated	7		2							
Series 8, Treatment 16, 1 July										
Separation bar length 4.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	103									
non-separated	40		1							
Separator: separated										
non-separated	1									
Series 8, Treatment 17, 1 July										
Separation bar length 3.0 m, angled 4°, water velocity 1 m/s										
Tanks: separated	100									
non-separated	32									
Separator: separated	12									
non-separated	50									
Series 8, Treatment 18, 1 July										
Separation bar length 3.0 m, angled 4°, water velocity 2 m/s										
Tanks: separated	245									
non-separated	95									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 8, Treatment 19, 1 July										
Separation bar length 3.0 m, angled 8^o, water velocity 1 m/s										
Tanks: separated	79									
non-separated	54									
Separator: separated										
non-separated	5									
Series 8, Treatment 20, 1 July										
Separation bar length 3.0 m, angled 8^o, water velocity 2 m/s										
Tanks: separated	108									
non-separated	55									
Separator: separated										
non-separated										
Series 8, Treatment 21, 1 July										
Separation bar length 1.5 m, angled 4^o, water velocity 1 m/s										
Tanks: separated	89									
non-separated	66									
Separator: separated	25									
non-separated	137									
Series 8, Treatment 22, 1 July										
Separation bar length 1.5 m, angled 4^o, water velocity 2 m/s										
Tanks: separated	102									
non-separated	335									
Separator: separated	9									
non-separated	8									
Series 8, Treatment 23, 1 July										
Separation bar length 1.5 m, angled 8^o, water velocity 1 m/s										
Tanks: separated	84									
non-separated	41									
Separator: separated	12									
non-separated	42									
Series 8, Treatment 24, 1 July										
Separation bar length 1.5 m, angled 8^o, water velocity 2 m/s										
Tanks: separated	39									
non-separated	106									
Separator: separated	4									
non-separated	4									
Series 9, Treatment 1, 1 July										
Separation bar length 12 m, angled 0.7^o, water velocity 1 m/s										
Tanks: separated	181									
non-separated	14									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 9, Treatment 2, 2 July										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated	379									
non-separated	39									
Separator: separated										
non-separated										
Series 9, Treatment 3, 1 July										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	204									
non-separated	44									
Separator: separated										
non-separated										
Series 9, Treatment 4, 1 July										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	132									
non-separated	18									
Separator: separated										
non-separated										
Series 9, Treatment 5, 2 July										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	143									
non-separated	5									
Separator: separated										
non-separated										
Series 9, Treatment 6, 2 July										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	248									
non-separated	14									
Separator: separated										
non-separated										
Series 9, Treatment 7, 2 July										
Separation bar length 6 m, angled (0.7°), water velocity 1 m/s										
Tanks: separated	66									
non-separated	26									
Separator: separated										
non-separated										
Series 9, Treatment 8, 2 July										
Separation bar length 6 m, angled (0.7°), water velocity 2 m/s										
Tanks: separated	71									
non-separated	56		1							
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 9, Treatment 9, 2 July										
Separation bar length 6 m, flat (0)°, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	79									
non-separated	25									
Separator: separated										
non-separated										
Series 9, Treatment 10, 2 July										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	93									
non-separated	56									
Separator: separated										
non-separated										
Series 9, Treatment 11, 2 July										
Separation bar length 6 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	94									
non-separated	44									
Separator: separated										
non-separated										
Series 9, Treatment 12, 2 July										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	25									
non-separated	103									
Separator: separated										
non-separated										
Series 9 Treatment 13, 2 July										
Separation bar length 4.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	75									
non-separated	88									
Separator: separated	37									
non-separated	50									
Series 9, Treatment 14, 2 July										
Separation bar length 4.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	67									
non-separated	81									
Separator: separated	3									
non-separated	1									
Series 9, Treatment 15, 2 July										
Separation bar length 4.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	47									
non-separated	23									
Separator: separated	20									
non-separated	36									

Appendix Table A4. Continued.

	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 9, Treatment 16, 2 July										
Separation bar length 4.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	75									
non-separated	82									
Separator: separated										
non-separated	1									
Series 9, Treatment 17, 3 July										
Separation bar length 3.0 m, angled 4°, water velocity 1 m/s										
Tanks: separated	77									
non-separated	26									
Separator: separated	86									
non-separated	21									
Series 9, Treatment 18, 3 July										
Separation bar length 3.0 m, angled 4°, water velocity 2 m/s										
Tanks: separated	111				1					
non-separated	76				1					
Separator: separated	7									
non-separated	22									
Series 9, Treatment 19, 3 July										
Separation bar length 3.0 m, angled 8°, water velocity 1 m/s										
Tanks: separated	62									
non-separated	8									
Separator: separated										
non-separated	68									
Series 9, Treatment 20, 3 July										
Separation bar length 3.0 m, angled 8°, water velocity 2 m/s										
Tanks: separated	187									
non-separated	136									
Separator: separated	3									
non-separated	6									
Series 9, Treatment 21, 3 July										
Separation bar length 1.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	61									
non-separated	33									
Separator: separated	17									
non-separated	184									
Series 9, Treatment 22, 3 July										
Separation bar length 1.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	36									
non-separated	38									
Separator: separated										
non-separated	9									

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 9, Treatment 23, 3 July										
Separation bar length 1.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	52									
non-separated	16									
Separator: separated										
non-separated	40			1						
Series 9, Treatment 24, 3 July										
Separation bar length 1.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	41									
non-separated	61									
Separator: separated										
non-separated	1									
Series 10, Treatment 1, 3 July										
Separation bar length 12 m, angled 0.7°, water velocity 1 m/s										
Tanks: separated	117									
non-separated	1									
Separator: separated										
non-separated										
Series 10, Treatment 2, 3 July										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated	104									
non-separated	45									
Separator: separated										
non-separated										
Series 10, Treatment 3, 3 July										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	101									
non-separated	64									
Separator: separated										
non-separated										
Series 10, Treatment 4, 3 July										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	97									
non-separated	19									
Separator: separated	5									
non-separated										
Series 10, Treatment 5, 3 July										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	104									
non-separated	18									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 10, Treatment 6, 3 July										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	162									
non-separated	20									
Separator: separated										
non-separated										
Series 10, Treatment 7, 4 July										
Separation bar length 6 m, angled (0.7°), water velocity 1 m/s										
Tanks: separated	171									
non-separated	15									
Separator: separated	3									
non-separated										
Series 10, Treatment 8, 4 July										
Separation bar length 6 m, angled (0.7°), water velocity 2 m/s										
Tanks: separated	165									
non-separated	63			1						
Separator: separated										
non-separated	3									
Series 10, Treatment 9, 4 July										
Separation bar length 6 m, flat (0)°, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	90									
non-separated	30									
Separator: separated							1			
non-separated										
Series 10, Treatment 10, 4 July										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	82									
non-separated	63									
Separator: separated										
non-separated										
Series 10, Treatment 11, 4 July										
Separation bar length 6 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	31									
non-separated	25									
Separator: separated										
non-separated										
Series 10, Treatment 12, 4 July										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	126									
non-separated	337		1							
Separator: separated	3									
non-separated	3									

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 10, Treatment 13, 5 July										
Separation bar length 4.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	109									
non-separated	42		1							
Separator: separated	100									
non-separated										
Series 10, Treatment 14, 4 July										
Separation bar length 4.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	90						1			
non-separated	53									
Separator: separated										
non-separated										
Series 10, Treatment 15, 4 July										
Separation bar length 4.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	56									
non-separated	87									
Separator: separated	71									
non-separated	133									
Series 10, Treatment 16, 4 July										
Separation bar length 4.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	45									
non-separated	27									
Separator: separated	1									
non-separated										
Series 10, Treatment 17, 5 July										
Separation bar length 3.0 m, angled 4°, water velocity 1 m/s										
Tanks: separated	181									
non-separated	22									
Separator: separated										
non-separated										
Series 10, Treatment 18, 5 July										
Separation bar length 3.0 m, angled 4°, water velocity 2 m/s										
Tanks: separated	44									
non-separated	52									
Separator: separated	2									
non-separated	7									
Series 10, Treatment 19, 5 July										
Separation bar length 3.0 m, angled 8°, water velocity 1 m/s										
Tanks: separated	103		1							
non-separated	20									
Separator: separated	31									
non-separated	128									

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 10, Treatment 20, 5 July										
Separation bar length 3.0 m, angled 8°, water velocity 2 m/s										
Tanks: separated	163									
non-separated	85									
Separator: separated	3									
non-separated	2									
Series 10, Treatment 21, 5 July										
Separation bar length 1.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	62									
non-separated	37									
Separator: separated	8									
non-separated	7									
Series 10, Treatment 22, 5 July										
Separation bar length 1.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	67									
non-separated	14								1	
Separator: separated										
non-separated	6									
Series 10, Treatment 23, 5 July										
Separation bar length 1.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	50									
non-separated	26									
Separator: separated	18									
non-separated										
Series 10, Treatment 24, 5 July										
Separation bar length 1.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	48									
non-separated	41									
Separator: separated										
non-separated										
Series 11, Treatment 1, 6 July										
Separation bar length 12 m, angled 0.7°, water velocity 1 m/s										
Tanks: separated	63									
non-separated										
Separator: separated	2									
non-separated										
Series 11, Treatment 2, 6 July										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated	61									
non-separated	32									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
Source	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 11, Treatment 3, 6 July										
Separation bar length 12 m, flat (0^{o}), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	172									
non-separated	3									
Separator: separated										
non-separated										
Series 11, Treatment 4, 6 July										
Separation bar length 12 m, flat (0^{o}), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	96									
non-separated	1									
Separator: separated										
non-separated										
Series 11, Treatment 5, 6 July										
Separation bar length 12 m, flat (0^{o}), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	43									
non-separated	10									
Separator: separated										
non-separated										
Series 11, Treatment 6, 6 July										
Separation bar length 12 m, flat (0^{o}), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	79									
non-separated	24									
Separator: separated										
non-separated										
Series 11, Treatment 7, 6 July										
Separation bar length 6 m, angled (0.7^{o}), water velocity 1 m/s										
Tanks: separated	61									
non-separated	77									
Separator: separated	1									
non-separated										
Series 11, Treatment 8, 6 July										
Separation bar length 6 m, angled (0.7^{o}), water velocity 2 m/s										
Tanks: separated	65									
non-separated	80									
Separator: separated										
non-separated										
Series 11, Treatment 9, 6 July										
Separation bar length 6 m, flat (0)^{o}, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	127									
non-separated	81									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 11, Treatment 10, 6 July										
Separation bar length 6 m, flat (0^o), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	175									
non-separated	46									
Separator: separated										
non-separated										
Series 11, Treatment 11, 6 July										
Separation bar length 6 m, flat (0^o), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	43									
non-separated	155				1					
Separator: separated	1									
non-separated										
Series 11, Treatment 12, 6 July										
Separation bar length 6 m, flat (0^o), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	15									
non-separated	66									
Separator: separated										
non-separated						1				
Series 11, Treatment 13, 6 July										
Separation bar length 4.5 m, angled 4^o, water velocity 1 m/s										
Tanks: separated	111									
non-separated	46									
Separator: separated	20									
non-separated	10		1							
Series 11, Treatment 14, 6 July										
Separation bar length 4.5 m, angled 4^o, water velocity 2 m/s										
Tanks: separated	70									
non-separated	42			1						
Separator: separated										
non-separated										
Series 11, Treatment 15, 6 July										
Separation bar length 4.5 m, angled 8^o, water velocity 1 m/s										
Tanks: separated	181									
non-separated	85									
Separator: separated	12									
non-separated	11									
Series 11, Treatment 16, 6 July										
Separation bar length 4.5 m, angled 8^o, water velocity 2 m/s										
Tanks: separated	117				1					
non-separated	66									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 11, Treatment 17, 7 July										
Separation bar length 3.0 m, angled 4^{o}, water velocity 1 m/s										
Tanks: separated	77									
non-separated	20									
Separator: separated	43									
non-separated										
Series 11, Treatment 18, 7 July										
Separation bar length 3.0 m, angled 4^{o}, water velocity 2 m/s										
Tanks: separated	161									
non-separated	106									
Separator: separated	18									
non-separated										
Series 11, Treatment 19, 7 July										
Separation bar length 3.0 m, angled 8^{o}, water velocity 1 m/s										
Tanks: separated	129									
non-separated	67									
Separator: separated	34									
non-separated										
Series 11, Treatment 20, 7 July										
Separation bar length 3.0 m, angled 8^{o}, water velocity 2 m/s										
Tanks: separated	70									
non-separated	54			1						
Separator: separated	2									
non-separated	5									
Series 11, Treatment 21, 6 July										
Separation bar length 1.5 m, angled 4^{o}, water velocity 1 m/s										
Tanks: separated	46									
non-separated	18		1							
Separator: separated	26									
non-separated	8									
Series 11, Treatment 22, 15 July										
Separation bar length 1.5 m, angled 4^{o}, water velocity 2 m/s										
Tanks: separated	69									
non-separated	10									
Separator: separated										
non-separated										
Series 11, Treatment 23, 5 July										
Separation bar length 1.5 m, angled 8^{o}, water velocity 1 m/s										
Tanks: separated	31									
non-separated	82									
Separator: separated	8									
non-separated	9									

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 11, Treatment 24, 5 July										
Separation bar length 1.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	60									
non-separated	58									
Separator: separated	2									
non-separated	8									
Series 12, Treatment 1, 7 July										
Separation bar length 12 m, angled 0.7°, water velocity 1 m/s										
Tanks: separated	145									
non-separated	0									
Separator: separated										
non-separated										
Series 12, Treatment 2, 7 July										
Separation bar length 12 m, angled 0.7°, water velocity 2 m/s										
Tanks: separated	482									
non-separated	17									
Separator: separated										
non-separated										
Series 12, Treatment 3, 8 July										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	90									
non-separated	2									
Separator: separated										
non-separated										
Series 12, Treatment 4, 8 July										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	76								1	
non-separated	31					1				
Separator: separated										
non-separated										
Series 12, Treatment 5, 7 July										
Separation bar length 12 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	90									
non-separated	3									
Separator: separated										
non-separated										
Series 12, Treatment 6, 8 July										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	66									
non-separated	28									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 12, Treatment 7, 8 July										
Separation bar length 6 m, angled (0.7°), water velocity 1 m/s										
Tanks: separated	55									
non-separated	23									
Separator: separated										
non-separated										
Series 12, Treatment 8, 8 July										
Separation bar length 6 m, angled (0.7°), water velocity 2 m/s										
Tanks: separated	72		1							
non-separated	63									
Separator: separated										
non-separated										
Series 12, Treatment 9, 9 July										
Separation bar length 6 m, flat (0)°, water velocity 1 m/s, depth over separation bars 5 cm										
Tanks: separated	28									
non-separated	58									
Separator: separated										
non-separated										
Series 12, Treatment 10, 8 July										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated	43									
non-separated	44									
Separator: separated										
non-separated										
Series 12, Treatment 11, 9 July										
Separation bar length 6 m, flat (0°), water velocity 1 m/s, depth over separation bars 10 cm										
Tanks: separated	4									
non-separated	67									
Separator: separated										
non-separated						1				
Series 12, Treatment 12, 9 July										
Separation bar length 6 m, flat (0°), water velocity 2 m/s, depth over separation bars 10 cm										
Tanks: separated	16			1						
non-separated	62									
Separator: separated										
non-separated										
Series 12, Treatment 13, 9 July										
Separation bar length 4.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	31									
non-separated	54									
Separator: separated	27									
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook		Yearling chinook		Steelhead		Coho		Sockeye	
	<180	≥180	<180	≥180	<180	≥180	<180	≥180	<180	≥180
Series 12, Treatment 14, 9 July										
Separation bar length 4.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	106									
non-separated	59									
Separator: separated										
non-separated										
Series 12, Treatment 15, 9 July										
Separation bar length 4.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	68									
non-separated	24									
Separator: separated	6									
non-separated										
Series 12, Treatment 16, 9 July										
Separation bar length 4.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	85		1							
non-separated	39									
Separator: separated										
non-separated	1									
Series 12, Treatment 17, 10 July										
Separation bar length 3.0 m, angled 4°, water velocity 1 m/s										
Tanks: separated	60									
non-separated	109									
Separator: separated										
non-separated										
Series 12, Treatment 18, 14 July										
Separation bar length 3.0 m, angled 4°, water velocity 2 m/s										
Tanks: separated	30									
non-separated	17									
Separator: separated										
non-separated										
Series 12, Treatment 19, 11 July										
Separation bar length 3.0 m, angled 8°, water velocity 1 m/s										
Tanks: separated	130									
non-separated	68									
Separator: separated										
non-separated										
Series 12, Treatment 20, 10 July										
Separation bar length 3.0 m, angled 8°, water velocity 2 m/s										
Tanks: separated	125									
non-separated	48									
Separator: separated										
non-separated										

Appendix Table A4. Continued.

Source	Subyearling chinook <180	Subyearling chinook ≥180	Yearling chinook <180	Yearling chinook ≥180	Steelhead <180	Steelhead ≥180	Coho <180	Coho ≥180	Sockeye <180	Sockeye ≥180
Series 12, Treatment 21, 15 July										
Separation bar length 1.5 m, angled 4°, water velocity 1 m/s										
Tanks: separated	78									
non-separated	15									
Separator: separated	10									
non-separated										
Series 12, Treatment 22, 14 July										
Separation bar length 1.5 m, angled 4°, water velocity 2 m/s										
Tanks: separated	14									
non-separated	26									
Separator: separated										
non-separated										
Series 12, Treatment 23, 14 July										
Separation bar length 1.5 m, angled 8°, water velocity 1 m/s										
Tanks: separated	44									
non-separated	43									
Separator: separated										
non-separated	6									
Series 12, Treatment 24, 14 July										
Separation bar length 1.5 m, angled 8°, water velocity 2 m/s										
Tanks: separated	33									
non-separated	31									
Separator: separated										
non-separated										
Series 1, Treatment 4, 8 May										
Separation bar length 12 m, flat (0°), water velocity 2 m/s, depth over separation bars 5 cm										
Tanks: separated			16	4	5	5				
non-separated			1	1		6				
Separator: separated										
non-separated										

APPENDIX B

Analysis of Flow Velocity Measurements at McNary Juvenile Fish Facility in an Experimental High-Velocity Flume Separator

INTRODUCTION

Hydraulic conditions in fish separators are thought to have important effects on fish separation efficiency and delay. This report describes hydraulic tests performed on seven configurations of the experimental high-velocity flume (HVF) separator. Tests were conducted in the McNary Lock and Dam Juvenile Fish Collection Channel in September 1997. Their purpose was to duplicate and record hydraulic conditions (including water depths and flow velocities) of biological tests conducted on the same configurations earlier in 1997.

FIELD CONDITIONS

Juvenile Fish Facility Collection Channel

The experimental HVF (Fig. 2) was set up on a grating above the water surface of the fish collection channel. Water (about 16.0 cfs) exited the gatewell of Orifice 6B (the south orifice of the center intake of Turbine Unit 6) and passed through a bend-diffuser which turned the orifice flow 90 degrees and expanded it from the 12-in-diameter orifice to the 30-in-wide rectangular dewatering unit. The dewatering unit removed about 12.0 to 14.0 cfs (estimated) of the flow.

The separator was positioned after the dewatering unit so that all fish and the remaining transport water (about 3.0 cfs) were introduced into the flume in a skimming flow above the separator bars. The dewatered flow was added back to the flume underneath the transport water, along with more add-in water from the forebay. Depending on the separator bar configuration, the add-in water was introduced under the separator bars (in the “volitional” separator described below) or upstream from the separator bars (in the “non-volitional” separator).

Flume Geometry

The high-velocity flume in which the separator bars rested was a rectangular, smooth aluminum flume 0.76 m wide and 16.46 m long, with 0.76 m high walls. Its longitudinal slope was set at approximately 0.00781 m/m. A hinged weir was available to control the downstream water surface. Its crest could be set between 0.0 and 0.305 m above the channel bottom.

Separator Configuration

Two basic separator configurations were tested (Appendix Figs. B1 to B15). Each separator was composed of 13 parallel separator bars (0.032 m diameter) spaced 0.019 m apart. The bars were segmented in 1.52 m sections and length could be varied by adding or removing bars. The joined bars could be placed either flat or sloped, at any depth in the flume. The bars connected in a straight line. The first configuration was a non-volitional separator, with 4.57 m bars oriented on an adverse slope. Hydraulic conditions were recorded for three variations of the non-volitional separator (two different flow rates with bars on a 4-degree slope and one flow rate with bars on an 8-degree adverse slope). The second configuration was a volitional separator, in which 12.19-m separator bars were oriented parallel to the flume bottom. Hydraulic conditions for the volitional separator were recorded for a total of four combinations: two flow rates and two bar depths.

METHODS

Velocity Measurement

Velocity was measured along the flume at intervals of 1.52 m, corresponding to the ends of the 1.52-m long bar segments. Velocity was measured both above and below the separator bars. Velocity was measured with an acoustic Doppler flow meter (SONTEK ADV) with sensors capable of detecting water movement in three dimensions (vertical, across the flume, and along the flume) at each point. The flow meter produced acoustic pulses in the water. The frequency and Doppler shift received by the probe's three sensors were transmitted to a laptop computer in which software calculated the flow velocity.

The velocities that were measured in each dimension were converted to a resultant magnitude, and a horizontal and vertical angle. The resultant magnitude was calculated for each measurement and then averaged to find the magnitude for the measurement point[a] (Appendix Tables B1 to B15; Appendix Figs. B1 to B15).

Velocities were measured for 1 to 2 minutes at each point, at a rate of two measurements per second. Therefore, the velocity at each measurement point is represented by 120 to 240 separate measurements. This sampling rate was chosen to provide a low standard error of measurement and to adequately sample the effects of changes in flume flow rate through time. Typically, the two cross-sections farthest upstream and the farthest downstream cross-section were sampled for 2 minutes, because wave action tended to make the velocity less stable. The other cross-sections were only sampled for 1 minute since the hydraulic conditions were more stable.

[a] This is the most accurate way to estimate the average velocity magnitude at each point. It yields a larger resultant than estimating a magnitude from averaged velocities in each of the three coordinate directions. The two methods would only be equivalent if there were no measured variation in flow direction.

Depth Measurement

Depth measurements for each separator test were made to determine the flow profile over the separator. Measurements were made with a tape measure and are only accurate to about ± 0 mm due to wave action.

Discharge

No attempt was made to precisely determine the discharge, since the important hydraulic variables in fish separation are thought to be velocity near the separator bars (above and below) and depth above the bars. However, discharge at any cross section can be estimated by multiplying the average velocity (Appendix Tables B1 to B15) by the cross-sectional flow area (flume width (0.76 m) times flow depth (approximate flow depth is reported below and also can be scaled directly from Appendix Figs. B1 to B15).

ANALYSIS OF RESULTS

General

The water depth in the separator was determined by channel slope and a downstream control (the submerged triangular weir) when velocity was subcritical. This was the case in four of the seven tested conditions (Conditions 1, 2, 5, and 6 below). The other three conditions were approximately critical flow and depth was probably controlled by a combination of resistance caused by the separator bars and the channel boundary (Conditions 3, 4, and 7 below).

Wave action was apparent in each of the seven cases but was only prominent in the critical flow conditions. In general, wave action was significant when flow velocity was near critical and the separator bars were set close to the water surface. Wave action was less significant where the separator bars were deeper than about 12 in. When flow velocity was about 1 m/s, the wavelength was about 0.76 m (half the length of a separator bar segment). When flow velocity approached 2 m/s (near critical velocity) the wavelength doubled, to about 1.5 m. In both cases, wave crests coincided with the transverse separator support bars.

Non-volitional Separation

Condition 1

Separator bars were set on an 11% adverse slope. Three bar segments were used, for a total bar length of 4.57 m. The upstream end of the bars rested on the flume bottom, while the downstream end was elevated 0.51 m. Water depth was a constant 0.58 m; therefore the water depth over the separator bars varied from 0.53 m upstream to 0.02 m at the downstream end. Flow velocity was nearly constant at each point, with a downstream component on the flume axis and a vertical component that was slightly upward when measured above the separator bars and slightly downward when measured below the bars (Appendix Tables B1 and B2; Appendix Figs. B1 and B2). The slight bias toward leftward flow (looking downstream) may represent a minor misalignment of the measurement probe.

Condition 2

Separator bars were set on a 5.6% adverse slope. Three bar segments were used, for a total bar length of 4.57 m. The upstream end of the bars rested on the flume bottom, while the downstream end was elevated 0.330 m. Water depth averaged 0.33 m, with a standing wave pattern which caused the water depth to vary 0.03 m about its average. Wavelength was about 0.76 m, with wave crests coinciding with the support bars and halfway between the support bars. The water depth over the separator bars varied from about 0.36 m upstream to about 0.08 m at the downstream end. Flow velocity was stable at each point, directed downstream along the flume axis. No significant vertical or sideways velocity components were measured (Appendix Tables B6 and B7; Appendix Figs. B6 and B7).

Condition 3

Separator bars were set on a 5.6% adverse slope. Three bar segments were used, for a total bar length of 4.57 m. The upstream end of the bars rested on the flume bottom, while the downstream end was elevated 0.330 m. Water depth averaged 0.38 m, with a standing wave pattern which caused the water depth to vary 0.02 m about its average. Wavelength was not recorded. The water depth over the separator bars varied from about 0.31 m upstream to about 0.05 m at the downstream end. Flow velocity was stable at each point, directed downstream along the flume axis. No significant vertical or sideways velocity components were measured (Appendix Tables B3, B4, and B5; Appendix Figs. B3, B4, and B5).

Volitional Separation

Condition 4

Separator bars were set parallel to the flume bottom. Eight bar segments were used, for a total bar length of 12.19 m. The bars were set so their top surfaces were 0.36 m above the flume invert. Water depth averaged 0.47 m, with a standing wave pattern which caused the water depth to vary 0.05 m about its average. Wavelength was about 1.52 m, with wave crests coinciding with the support bars. The water depth over the separator bars averaged about 0.11 m. Flow velocity was stable within 6.1 m of the downstream end of the separator. At the farthest upstream measurement cross-section (7.6 m from the downstream end), flow was turbulent and aerated due to the high-velocity incoming flow. The flow was too turbulent to measure at any point upstream from this cross section. In general, downward flow was recorded above the separator bars, and upward flow was recorded below the bars. The vertical component was not over one-fifth of the downstream component and generally less than a tenth of the downstream component (Appendix Tables B8 and B9; Appendix Figs. B8 and B9).

Condition 5

Separator bars were set parallel to the flume bottom. Eight bar segments were used, for a total bar length of 12.19 m. The bars were set so their top surfaces were 0.36 m above the flume invert. Water depth averaged 0.46 m, with a standing wave pattern which caused the water depth to vary 0.04 m about its average. Wavelength was about 0.76 m, again with wave crests coinciding with the support bars and halfway between supports. The water depth over the separator bars averaged about 0.10 m. Flow velocity was stable within 7.6 m of the downstream end of the separator. Farther upstream flow was too turbulent and aerated to measure. In general, upward flow was recorded both above and below the separator bars. The vertical component averaged about a tenth of the downstream component. There was no significant cross-current (Appendix Tables 10 and 12; Appendix Figs. 10 and 12).

Condition 6

Separator bars were set parallel to the flume bottom. Eight bar segments were used, for a total bar length of 12.19 m. The bars were set so their top surfaces were 0.36 m above the flume invert. Water depth averaged 0.49 m, with a standing wave pattern which caused the water depth to vary 0.02 m about its average. Wavelength was about 0.76 m, with wave crests coinciding with the support bars. The water depth over the separator bars averaged about 0.13 m. In general, upward flow was recorded both above and below the separator bars, with the upward magnitude higher above the bars. This may be because flow velocity was recorded near the bar supports, which coincided with the upstream half of the wave crests (Appendix Tables 11 and 13; Appendix Figs. 11 and 13).

Condition 7

Separator bars were set parallel to the flume bottom. Eight bar segments were used, for a total bar length of 12.19 m. The bars were set so their top surfaces were 0.36 m above the flume invert. Water depth averaged 0.46 m, with a standing wave pattern which was very pronounced at the upstream end (± 0.06 m) and minor at the downstream end of the separator bars (± 0.01 m). Wavelength was about 1.56 m, with wave crests coinciding with the support bars. The water depth over the separator bars averaged about 0.10 m. Upward flow was recorded both above and below the separator bars, with the upward magnitude about the same above and below (about one-fifth the magnitude of the downstream component). The velocity and depth recordings, along with the observed wave pattern, suggest that hydraulic conditions were nearly critical flow (Appendix Tables 14 and 15; Appendix Figs. 14 and 15).

Statistics

Standard deviation and standard error are reported in Appendix Tables B1 to B15 for both velocity magnitude and direction for each measurement location. In each test, both the standard deviation and the standard error were generally low. Flow was typically stable and did not fluctuate much, either randomly or systematically, through time. The exceptions were in cross sections near the upstream end of the flume, where the entering transport water was plunging and mixing with the add-in water. Large standard deviations in either magnitude or direction indicate unsteady flow.

Appendix Table B1. Coordinate velocity measurements and resultants obtained from flows above separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B1.

	Coordinate velocities			Resultants									
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	0.05	1.48	0.22	1.5	0.05	0	2.02	1.12	0.05	8.57	1.21	0.06
2	0.04	1.51	0.22	1.53	0.05	0	1.34	1.33	0.06	8.27	1.15	0.05
3	0.03	1.54	0.20	1.56	0.07	0	0.94	1.50	0.07	7.49	1.52	0.07
4	0.06	1.55	0.06	1.55	0.06	0	2.16	0.91	0.04	2.10	6.66	0.3
5	0.01	1.49	0.05	1.49	0.04	0	0.32	2.08	0.10	1.74	6.97	0.32
6	-0.01	1.53	0.03	1.53	0.06	0.00	-0.2	2.50	0.11	1.02	7.71	0.35
7	0.06	1.67	0.07	1.67	0.08	0.00	1.95	1.01	0.05	2.29	6.50	0.30
8	0.06	1.58	0.08	1.59	0.07	0.00	2.03	1.41	0.06	2.73	6.04	0.28
9	0.08	1.58	0.08	1.58	0.07	0.00	2.73	1.08	0.05	2.81	5.98	0.27
10	0.00	1.81	0.12	1.82	0.10	0.00	0.06	2.55	0.12	3.67	5.11	0.23
11	0.01	1.84	0.05	1.85	0.10	0.00	0.29	2.55	0.12	1.51	7.25	0.33
12	0.04	1.86	0.11	1.86	0.11	0.01	1.32	4.03	0.18	3.43	5.80	0.26

Appendix Table B2. Coordinate velocity measurements and resultants obtained from flows below separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B2.

	Coordinate velocities			Resultants								
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	0.05	1.68	0.00	1.68	0.10	0.00	1.58	3.60	0.16	-0.08	1.58	0.07
2	-0.01	1.39	0.08	1.39	0.20	0.01	-0.32	5.44	0.25	3.13	3.62	0.17
3	-0.02	1.56	-0.03	1.56	0.07	0.00	-0.81	3.77	0.17	-1.25	1.90	0.09
4	0.01	1.73	-0.15	1.73	0.08	0.00	0.21	2.12	0.10	-5.12	5.22	0.24
5	0.02	1.68	-0.01	1.68	0.06	0.00	0.59	1.70	0.08	-0.26	1.14	0.05
6	0.05	1.67	-0.03	1.67	0.06	0.00	1.75	1.10	0.05	-1.04	1.41	0.06

Appendix Table B3. Coordinate velocity measurements and resultants obtained from flows above separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B3.

	Coordinate velocities			Resultants									
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	0.003	1.326	0.129	1.332	0.051	0.005	0.143	1.320	0.120	5.565	5.799	0.529
2	-0.019	1.310	0.156	1.319	0.053	0.005	-0.811	1.692	0.154	6.807	7.068	0.645
3	0.011	1.336	0.105	1.340	0.049	0.005	0.478	1.262	0.115	4.497	4.681	0.427
4	-0.001	1.465	-0.041	1.465	0.050	0.005	-0.055	1.461	0.133	-1.592	1.623	0.148
5	-0.01	1.458	-0.039	1.459	0.049	0.004	-0.391	1.981	0.181	-1.517	1.467	0.134
6	-0.002	1.465	-0.036	1.466	0.045	0.004	-0.072	1.534	0.140	-1.413	1.548	0.141
7	0.054	1.522	-0.006	1.523	0.072	0.007	2.050	2.184	0.199	-0.223	2.666	0.243
8	0.020	1.534	-0.06	1.535	0.054	0.005	0.731	1.508	0.138	-2.241	1.214	0.111
9	0.010	1.559	-0.01	1.559	0.059	0.005	0.362	1.485	0.136	-0.376	2.628	0.240
10	0.069	1.540	0.073	1.543	0.166	0.015	2.557	2.455	0.224	2.704	5.446	0.497
11	0.007	1.627	0.001	1.627	0.062	0.006	0.247	1.870	0.171	0.029	2.882	0.263
12	0.014	1.633	0.044	1.633	0.128	0.012	0.483	2.323	0.212	1.561	4.430	0.404

Appendix Table B4. Coordinate velocity measurements and resultants obtained from flows below separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B4.

	Coordinate velocities			Resultants								
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	0.013	1.532	0.072	1.534	0.042	0.004	0.495	0.859	0.078	2.690	2.780	0.254
2	0.014	1.537	0.096	1.540	0.041	0.004	0.510	0.921	0.084	3.576	3.632	0.332
3	2.314	1.571	0.129	1.576	0.050	0.005	-0.131	0.749	0.068	4.703	4.758	0.434
4	0.057	1.586	0.079	1.589	0.052	0.005	2.066	2.887	0.264	2.838	3.059	0.279
5	-0.006	1.573	0.065	1.575	0.062	0.006	-0.217	1.131	0.103	2.362	2.612	0.238
6	-0.052	1.630	-0.028	1.631	0.065	0.006	-1.817	1.620	0.148	-0.985	1.130	0.103
7	-0.024	1.374	0.069	1.376	0.332	0.030	-1.021	14.715	1.343	2.864	9.353	0.854
8	-0.031	1.058	0.028	1.059	0.177	0.016	-1.692	3.820	0.349	1.528	2.381	0.217
9	-0.044	1.231	0.012	1.232	0.143	0.013	-2.034	2.706	0.247	0.562	1.789	0.163

Appendix Table B5. Coordinate velocity measurements and resultants obtained from flows above separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B5.

	Coordinate velocities			Resultants								
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	-0.030	1.352	0.004	1.353	0.080	0.007	-1.256	1.934	0.177	0.182	3.909	0.357
2	0.002	1.280	-0.023	1.280	0.093	0.008	0.083	2.603	0.238	-1.032	3.241	0.296
3	-0.006	1.259	-0.025	1.259	0.090	0.008	-0.295	2.580	0.236	-1.146	3.145	0.287

Appendix Table B6. Coordinate velocity measurements and resultants obtained from flows above separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B6.

	Coordinate velocities			Resultants								
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	-0.019	0.989	0.003	0.989	0.117	0.011	-1.090	4.484	0.409	0.178	5.968	0.545
2	-0.014	1.042	0.016	1.042	0.114	0.010	-0.794	4.785	0.437	0.899	4.826	0.441
3	-0.011	1.101	0.021	1.101	0.103	0.009	-0.565	3.413	0.312	1.096	5.048	0.461

Appendix Table B7. Coordinate velocity measurements and resultants obtained from flows above separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B7.

	Coordinate velocities			Resultants								
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
4	0.009	1.017	0.042	1.017	0.074	0.007	0.500	2.499	0.228	2.343	2.752	0.251
5	-0.018	0.903	0.110	0.910	0.063	0.006	-1.130	3.755	0.343	6.931	4.621	0.422
6	-0.005	0.959	0.075	0.962	0.069	0.006	-0.276	2.642	0.241	4.477	2.589	0.236
7	0.001	1.036	0.017	1.036	0.059	0.005	0.048	1.687	0.154	0.964	3.266	0.298
8	-0.004	0.977	0.036	0.977	0.065	0.006	-0.212	2.532	0.231	2.109	2.594	0.237
9	0.005	1.124	-0.058	1.125	0.064	0.006	0.261	1.802	0.164	-2.931	7.137	0.652
10	0.024	1.059	-0.027	1.059	0.062	0.006	1.289	2.509	0.229	-1.487	5.733	0.523
11	0.029	1.086	-0.023	1.087	0.079	0.007	1.537	2.224	0.203	-1.226	5.632	0.514
12	-0.007	1.017	-0.070	1.019	0.088	0.008	-0.398	3.433	0.313	-3.946	8.313	0.759
13	0.011	1.091	-0.126	1.098	0.125	0.011	0.599	10.668	0.974	-6.615	11.005	1.005
14	-0.021	1.074	-0.097	1.079	0.106	0.010	-1.099	4.015	0.366	-5.180	9.816	0.896
15	-0.020	1.004	0.103	1.010	0.040	0.004	-1.158	1.935	0.177	5.879	2.369	0.216
16	-0.002	0.930	0.115	0.937	0.048	0.004	-0.119	1.571	0.143	7.029	3.450	0.315
17	-0.016	1.001	0.106	1.006	0.046	0.004	-0.937	1.785	0.163	6.058	2.533	0.231

Appendix Table B8. Coordinate velocity measurements and resultants obtained from flows above separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B8.

	Coordinate velocities			Resultants								
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	0.020	1.168	-0.049	1.169	0.396	0.018	1.001	20.981	0.958	-2.422	13.628	0.622
2	0.093	1.102	-0.003	1.106	0.410	0.019	4.834	16.251	0.742	-0.134	11.320	0.517
3	0.020	0.866	0.002	0.866	0.450	0.021	1.329	27.096	1.237	0.146	14.530	0.663
4	0.078	1.434	0.049	1.437	0.171	0.008	3.095	4.441	0.203	1.973	5.243	0.239
5	0.089	1.437	0.069	1.441	0.140	0.006	3.536	4.523	0.206	2.763	5.677	0.259
6	0.050	1.405	0.071	1.408	0.198	0.009	2.042	4.690	0.214	2.870	5.778	0.264
7	0.050	1.555	-0.103	1.559	0.127	0.006	1.853	2.445	0.112	-3.798	2.124	0.097
8	0.088	1.623	-0.134	1.631	0.090	0.004	3.121	3.371	0.154	-4.722	2.929	0.134
9	0.035	1.589	-0.073	1.591	0.097	0.004	1.274	1.977	0.090	-2.615	1.973	0.090
10	0.046	1.560	-0.157	1.568	0.084	0.004	1.689	1.915	0.087	-5.754	3.553	0.162
11	0.077	1.580	-0.193	1.593	0.075	0.003	2.792	4.250	0.194	-6.952	4.701	0.215
12	0.026	1.499	-0.143	1.506	0.089	0.004	1.011	2.046	0.093	-5.432	3.378	0.154
13	0.022	1.382	-0.114	1.387	0.081	0.004	0.922	1.970	0.090	-4.718	3.450	0.157
14	0.038	1.382	-0.129	1.389	0.087	0.004	1.560	1.835	0.084	-5.34	3.903	0.178
15	0.082	1.459	-0.158	1.470	0.096	0.004	3.231	3.010	0.137	-6.167	4.275	0.195
16	0.062	1.345	0.109	1.351	0.110	0.005	2.621	2.530	0.115	4.632	7.806	0.356
17	0.070	1.183	0.070	1.188	0.091	0.004	3.383	3.399	0.155	3.389	6.470	0.295
18	0.026	1.251	0.052	1.252	0.106	0.005	1.178	3.739	0.171	2.370	6.343	0.290

Appendix Table B9. Coordinate velocity measurements and resultants obtained from flows below separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B9.

	Coordinate velocities			Resultants									
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	0.096	1.657	0.028	1.660	0.092	0.004	3.328	1.649	0.075	0.967	1.502	0.069
2	0.052	1.690	0.003	1.691	0.082	0.004	1.759	1.345	0.061	0.096	1.261	0.058
3	0.029	1.547	-0.032	1.548	0.066	0.003	1.081	1.560	0.071	-1.202	1.868	0.085
4	0.056	1.474	-0.058	1.476	0.064	0.003	2.193	2.520	0.115	-2.265	2.597	0.119
5	0.071	1.642	0.006	1.643	0.090	0.004	2.463	2.874	0.131	0.208	1.370	0.063
6	0.112	1.599	0.067	1.604	0.097	0.004	3.998	4.182	0.191	2.387	2.653	0.121
7	0.095	1.595	0.007	1.598	0.104	0.005	3.413	3.714	0.170	0.238	1.631	0.074
8	0.112	1.635	0.081	1.640	0.099	0.005	3.925	4.181	0.191	2.821	3.098	0.141
9	0.091	1.445	-5.619	1.448	0.061	0.003	3.601	3.905	0.178	-0.865	1.626	0.074
10	0.086	1.416	-0.036	1.419	0.069	0.003	3.472	3.794	0.173	-1.469	2.101	0.096
11	0.149	1.648	0.287	1.679	0.096	0.004	5.153	5.413	0.247	9.827	9.903	0.452
12	0.079	1.658	0.245	1.678	0.107	0.005	2.740	3.229	0.147	8.382	8.494	0.388
13	0.113	1.656	0.246	1.678	0.124	0.006	3.918	4.365	0.199	8.416	8.502	0.388
14	0.135	1.595	0.229	1.617	0.098	0.004	4.846	5.244	0.239	8.160	8.268	0.377
15	0.084	1.376	0.178	1.390	0.086	0.004	3.476	3.940	0.180	7.356	7.525	0.343

Appendix Table B10. Coordinate velocity measurements and resultants obtained from flows above separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B10.

	Coordinate velocities			Resultants								
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	0.005	1.098	-0.001	1.098	0.155	0.007	0.274	4.912	0.224	-0.034	7.055	0.322
2	-0.049	1.110	0.006	1.111	0.192	0.009	-2.541	14.234	0.650	0.287	7.111	0.325
3	-0.039	0.983	0.064	0.986	0.147	0.007	-2.256	7.696	0.351	3.699	6.143	0.280
4	0.000	1.056	0.019	1.056	0.140	0.009	0.002	4.323	0.279	1.058	4.321	0.279
5	-0.047	1.094	-0.037	1.096	0.127	0.008	-2.462	5.909	0.381	-1.935	5.549	0.358
6	0.004	1.078	0.088	1.082	0.110	0.007	0.196	2.946	0.190	4.664	7.594	0.490
7	-0.009	1.234	0.167	1.245	0.156	0.010	0.001	3.131	0.202	7.691	8.688	0.561
8	0.010	1.198	0.141	1.206	0.141	0.009	0.487	3.102	0.200	6.706	8.597	0.555
9	0.002	1.168	0.099	1.173	0.175	0.011	0.114	3.310	0.214	4.832	6.478	0.418
10	0.032	1.252	0.204	1.269	0.146	0.009	1.472	3.208	0.207	9.250	10.075	0.650
11	0.023	1.187	0.177	1.200	0.139	0.009	1.122	3.354	0.217	8.502	9.575	0.618
12	4.557	1.246	0.218	1.265	0.166	0.011	-0.418	3.799	0.245	9.948	10.852	0.701
13	-0.013	1.271	0.223	1.290	0.128	0.008	-0.595	3.345	0.216	9.957	10.792	0.697
14	0.019	1.286	0.199	1.301	0.140	0.009	0.869	3.017	0.195	8.798	9.710	0.627
15	0.032	1.338	0.243	1.360	0.170	0.011	1.361	3.507	0.226	10.292	11.129	0.718
16	-0.013	1.390	0.172	1.401	0.176	0.008	-0.53	8.747	0.399	7.046	8.767	0.400
17	0.030	1.332	0.138	1.339	0.151	0.007	1.288	8.276	0.378	5.917	6.964	0.318
18	0.020	1.310	0.123	1.316	0.124	0.006	0.895	2.822	0.129	5.370	6.474	0.295

Appendix Table B11. Coordinate velocity measurements and resultants obtained from flows below separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B11.

	Coordinate velocities			Resultants									
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	-0.046	1.085	0.140	1.095	0.069	0.003	-2.414	2.880	0.131	7.341	3.493	0.159
2	0.010	1.123	0.221	1.145	0.060	0.003	0.519	2.312	0.106	11.126	1.513	0.069
3	-0.019	1.160	0.199	1.177	0.075	0.003	-0.934	5.871	0.268	9.735	1.873	0.085
4	0.002	1.217	0.194	1.232	0.059	0.004	0.084	1.258	0.081	9.081	1.745	0.113
5	0.014	1.168	0.179	1.182	0.057	0.004	0.670	1.714	0.111	8.734	2.100	0.136
6	-0.038	1.141	0.142	1.150	0.056	0.004	-1.889	2.327	0.150	7.118	3.550	0.229
7	-0.020	1.113	0.157	1.124	0.053	0.003	-1.033	1.729	0.112	8.006	2.749	0.177
8	0.014	1.170	0.218	1.191	0.060	0.004	0.679	1.487	0.096	10.527	1.221	0.079
9	-0.014	1.197	0.164	1.209	0.063	0.004	-0.669	1.432	0.092	7.786	2.933	0.189
10	0.029	1.142	0.116	1.149	0.054	0.003	1.438	2.010	0.130	5.773	4.877	0.315
11	-0.012	1.199	0.221	1.219	0.058	0.004	-0.552	1.481	0.096	10.431	1.068	0.069
12	-0.030	1.141	0.152	1.152	0.068	0.004	-1.485	2.259	0.146	7.596	3.128	0.202
13	0.009	1.062	0.160	1.074	0.052	0.003	0.460	1.175	0.076	8.571	2.300	0.148
14	-0.023	1.117	0.145	1.126	0.062	0.004	-1.196	1.845	0.119	7.377	3.320	0.214
15	0.012	1.226	0.235	1.248	0.063	0.004	0.575	1.243	0.080	10.865	1.097	0.071
16	0.023	1.173	0.204	1.190	0.067	0.003	1.147	1.609	0.073	9.845	1.251	0.057
17	-0.007	1.160	0.186	1.175	0.067	0.003	-0.351	1.334	0.061	9.102	1.757	0.080
18	-0.011	1.103	0.174	1.117	0.069	0.003	-0.546	1.411	0.064	8.955	1.934	0.088

Appendix Table B12. Coordinate velocity measurements and resultants obtained from flows below separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B12.

	Coordinate velocities			Resultants								
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	-0.014	1.165	0.200	1.183	0.076	0.003	-0.679	2.994	0.137	9.752	2.718	0.124
2	-0.018	1.203	0.198	1.219	0.078	0.004	-0.842	2.858	0.130	9.348	2.394	0.109
3	0.015	1.227	0.220	1.247	0.079	0.004	0.684	4.235	0.193	10.156	3.089	0.141
4	-0.002	1.247	0.191	1.262	0.075	0.005	-0.087	3.540	0.229	8.707	1.917	0.124
5	-0.025	1.266	0.246	1.290	0.069	0.004	-1.125	2.639	0.170	11.001	3.910	0.252
6	-0.013	1.187	0.216	1.207	0.078	0.005	-0.637	3.018	0.195	10.304	3.311	0.214
7	-0.011	1.192	0.212	1.211	0.065	0.004	-0.519	3.240	0.209	10.098	3.119	0.201
11	-0.020	1.231	0.207	1.249	0.065	0.004	-0.908	2.974	0.192	9.563	2.589	0.167
12	-0.019	1.157	0.192	1.173	0.056	0.004	-0.931	2.844	0.184	9.423	2.511	0.162
13	-0.055	1.147	0.141	1.157	0.060	0.004	-2.750	1.543	0.100	7.021	1.407	0.091
14	0.045	1.248	0.213	1.267	0.069	0.004	2.076	5.729	0.370	9.654	2.664	0.172
15	0.005	1.290	0.208	1.306	0.099	0.006	0.205	8.479	0.547	9.156	2.619	0.169
16	0.020	1.215	0.165	1.226	0.097	0.004	0.924	4.801	0.219	7.738	2.250	0.103
17	0.002	1.134	0.213	1.154	0.085	0.004	0.079	4.285	0.196	10.661	3.747	0.171
18	-0.025	1.104	0.161	1.116	0.073	0.005	-1.277	2.950	0.190	8.297	2.003	0.129

Appendix Table B13. Coordinate velocity measurements and resultants obtained from flows above separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B13.

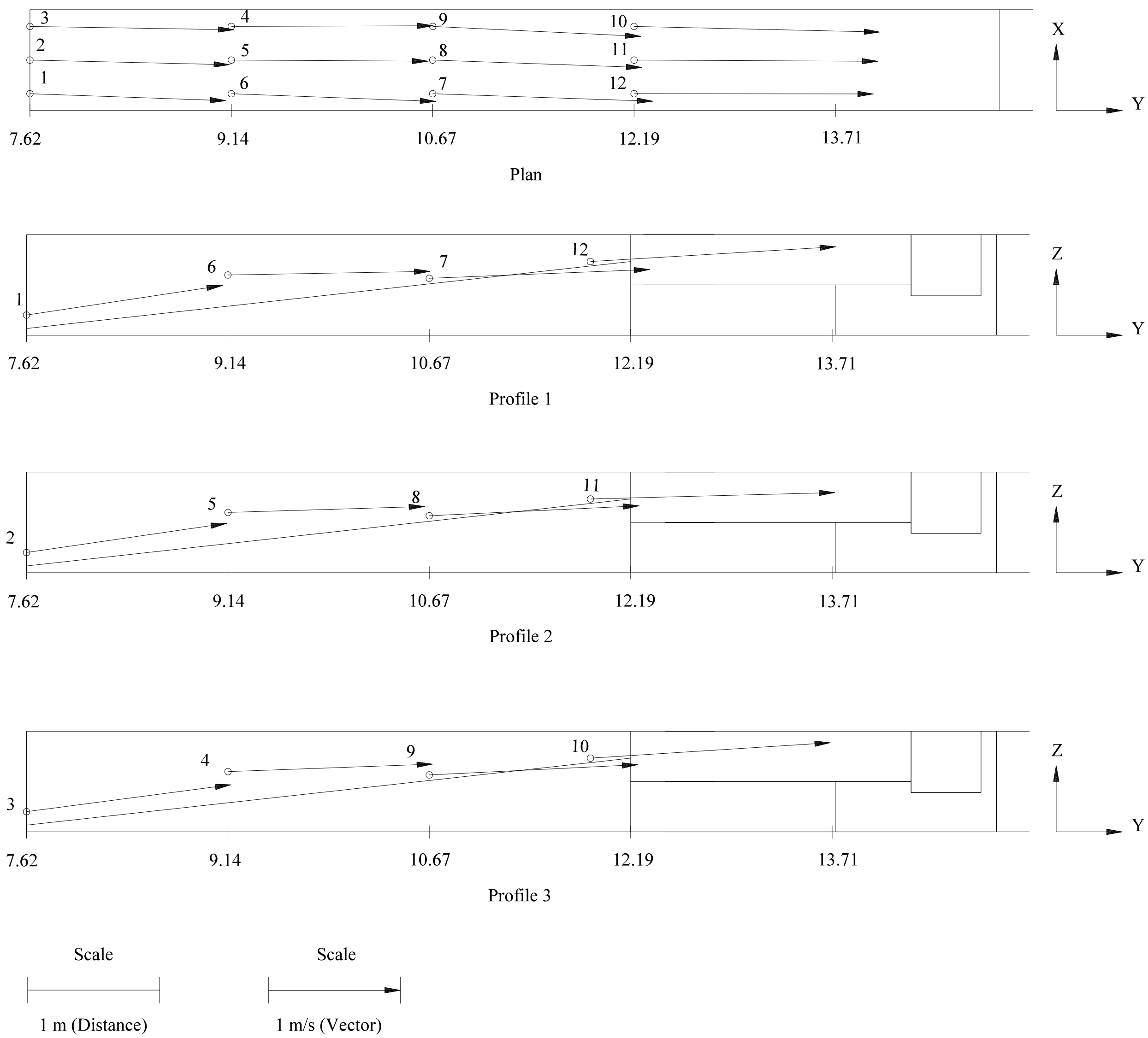
	Coordinate velocities			Resultants									
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	0.046	1.215	0.195	1.232	0.145	0.007	2.163	3.161	0.144	9.111	4.520	0.206
2	0.058	1.159	0.176	1.174	0.143	0.007	2.855	3.684	0.168	8.603	4.544	0.207
3	0.008	1.209	0.172	1.221	0.160	0.007	0.402	3.833	0.175	8.079	5.260	0.240
4	0.043	1.241	0.185	1.255	0.139	0.009	1.968	2.364	0.153	8.459	4.339	0.280
5	0.048	1.156	0.122	1.164	0.116	0.008	2.371	3.018	0.195	6.012	6.424	0.415
6	0.055	1.211	0.168	1.223	0.122	0.008	2.608	2.722	0.176	7.889	5.670	0.366
7	0.044	1.202	0.132	1.210	0.103	0.007	2.086	2.841	0.183	6.248	6.763	0.437
8	0.052	1.142	0.095	1.147	0.090	0.006	2.617	2.612	0.169	4.727	7.465	0.482
9	0.034	1.200	0.108	1.205	0.104	0.007	1.604	2.092	0.135	5.132	7.284	0.470
10	0.027	1.137	0.003	1.137	0.097	0.006	1.347	2.442	0.158	0.140	12.042	0.777
11	0.042	1.153	0.014	1.154	0.083	0.005	2.076	2.739	0.177	0.707	11.223	0.724
12	0.036	1.218	0.080	1.222	0.098	0.006	1.711	2.832	0.183	3.758	8.752	0.565
13	0.035	1.197	0.053	1.198	0.103	0.007	1.664	3.417	0.221	2.539	11.008	0.711
14	0.013	1.173	-0.006	1.173	0.094	0.006	0.634	2.794	0.180	-0.290	12.343	0.797
15	0.026	1.099	0.034	1.100	0.101	0.007	1.340	2.495	0.161	1.787	10.324	0.666
16	0.020	1.052	0.104	1.058	0.107	0.005	1.067	2.796	0.128	5.636	6.653	0.304
17	0.026	1.152	0.094	1.156	0.109	0.005	1.272	2.681	0.122	4.650	8.314	0.379
18	0.047	1.152	0.001	1.153	0.113	0.005	2.321	2.645	0.121	0.063	12.198	0.557

Appendix Table B14. Coordinate velocity measurements and resultants obtained from flows above separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B14.

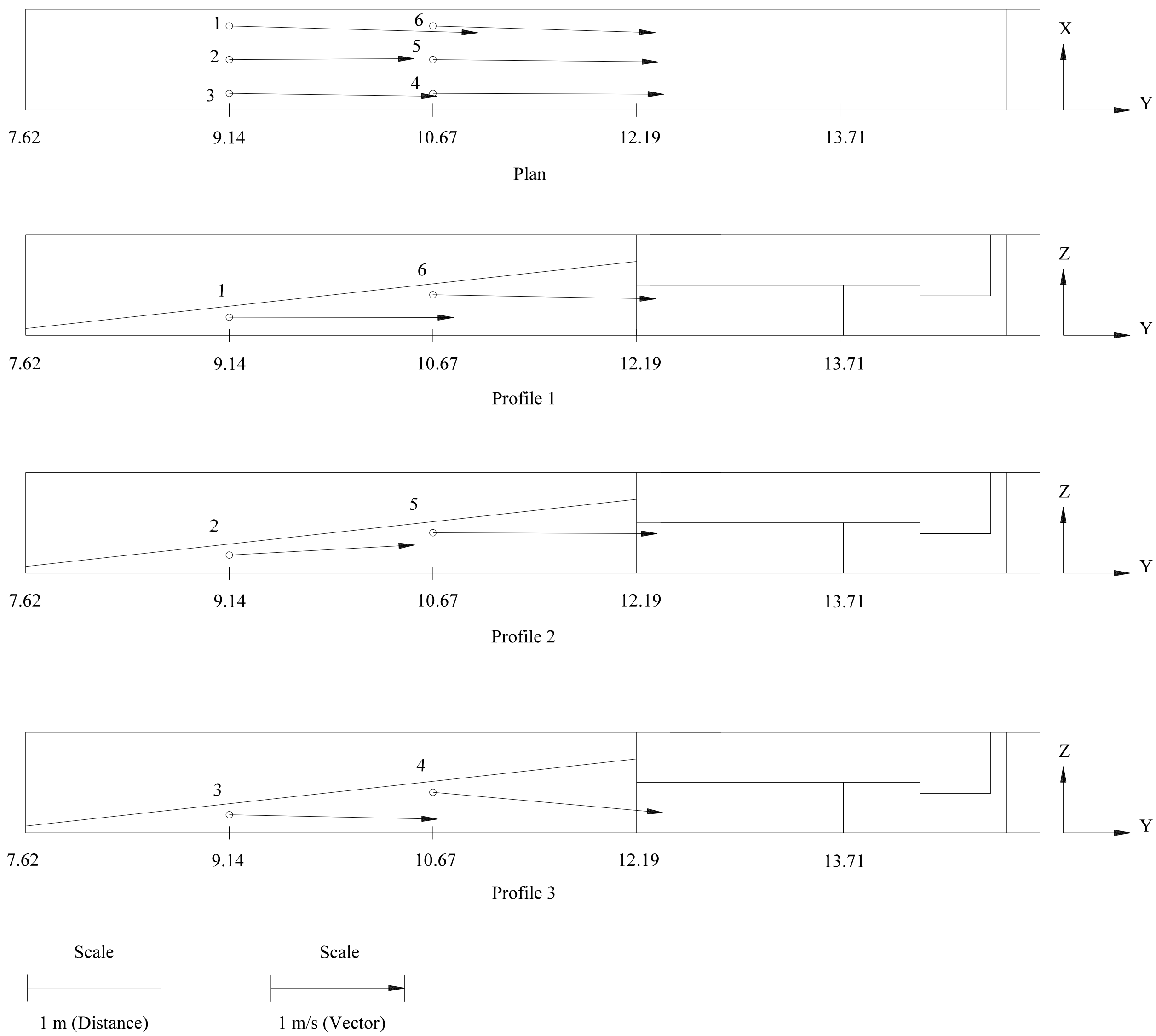
	Coordinate velocities			Resultants									
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	0.053	2.085	0.218	2.097	0.066	0.003	1.456	1.026	0.047	5.972	0.804	0.037
2	0.018	2.020	0.206	2.031	0.067	0.003	0.497	1.382	0.063	5.832	0.764	0.035
3	0.039	2.097	0.242	2.112	0.094	0.004	1.070	1.192	0.054	6.593	1.026	0.047
4	0.012	2.048	0.330	2.074	0.081	0.005	0.349	1.181	0.076	9.142	3.134	0.202
5	0.023	1.877	0.285	1.899	0.067	0.004	0.696	1.547	0.100	8.642	2.676	0.173
6	0.068	2.043	0.276	2.063	0.062	0.004	1.911	1.295	0.084	7.702	1.809	0.117
7	0.041	1.912	0.273	1.932	0.072	0.005	1.214	1.071	0.069	8.115	2.196	0.142
8	0.009	1.805	0.260	1.824	0.073	0.005	0.294	1.563	0.101	8.202	2.315	0.149
9	0.038	1.947	0.270	1.966	0.082	0.005	1.111	1.061	0.069	7.892	2.101	0.136
10	-0.020	1.855	0.282	1.877	0.081	0.005	-0.606	1.903	0.123	8.645	2.958	0.191
11	0.023	1.670	0.237	1.687	0.072	0.005	0.799	1.689	0.109	8.083	2.320	0.150
12	0.042	1.797	0.286	1.820	0.090	0.006	1.324	1.164	0.075	9.049	3.317	0.214
13	0.068	1.643	0.204	1.657	0.102	0.007	2.357	1.847	0.119	7.085	2.215	0.143
14	0.034	1.498	0.198	1.511	0.084	0.005	1.283	1.652	0.107	7.527	2.256	0.146
15	0.070	1.696	0.191	1.708	0.103	0.007	2.379	1.763	0.114	6.403	1.705	0.110
16	0.080	1.591	0.264	1.615	0.119	0.005	2.887	2.457	0.112	9.416	4.059	0.185
17	0.084	1.347	0.237	1.370	0.146	0.007	3.578	3.796	0.173	9.944	4.403	0.201
18	0.100	1.501	0.232	1.522	0.096	0.004	3.795	3.178	0.145	8.753	3.128	0.143

Appendix Table B15. Coordinate velocity measurements and resultants obtained from flows below separation bars in an experimental high-velocity flume separator during separation efficiency testing at McNary Dam, 1997. Plan and profile view graphs of transect point resultant velocity and direction vectors are presented in Appendix Figure B15.

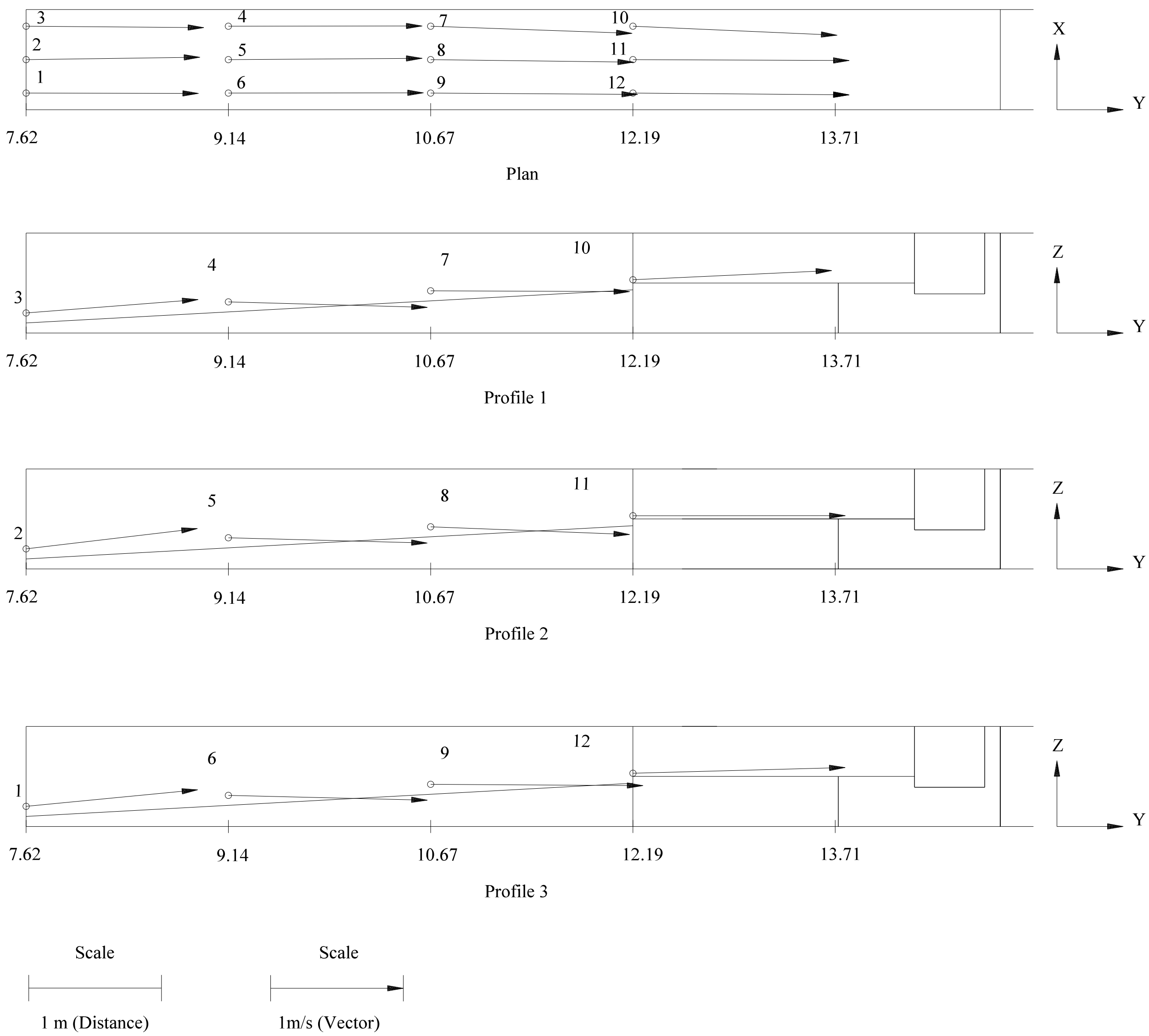
	Coordinate velocities			Resultants									
Sample Point	Vector X (m/s)	Vector Y (m/s)	Vector Z (m/s)	Magnitude (m/s)	Standard Deviation (m/s)	Standard Error (m/s)	Horizontal Direction (degrees (±) from positive Y-axis)	Standard Deviation of Horizontal Direction (degrees)	Standard Error of Horizontal Direction (degrees)	Vertical Direction (degrees (±) above or below X-Y plane)	Standard Deviation of Vertical Direction (degrees)	Standard Error of Vertical Direction (degrees)
1	0.052	1.498	0.279	1.525	0.084	0.004	1.979	3.523	0.161	10.530	2.107	0.096
2	0.115	1.667	0.350	1.708	0.090	0.004	3.952	1.963	0.090	11.839	1.282	0.059
3	0.073	1.592	0.238	1.611	0.097	0.004	2.640	2.937	0.134	8.502	3.948	0.180
4	0.049	1.609	0.221	1.625	0.084	0.005	1.735	3.653	0.236	7.820	4.510	0.291
5	0.015	1.640	0.257	1.660	0.080	0.005	0.527	4.792	0.309	8.904	3.548	0.229
6	-0.010	1.542	0.221	1.558	0.076	0.005	-0.379	5.596	0.361	8.164	4.155	0.268
7	0.044	1.638	0.235	1.655	0.054	0.003	1.556	3.720	0.240	8.149	4.107	0.265
8	0.039	1.669	0.246	1.687	0.068	0.004	1.324	4.030	0.260	8.394	3.885	0.251
9	0.110	1.640	0.226	1.659	0.062	0.004	3.821	1.749	0.113	7.814	4.431	0.286
10	0.102	1.640	0.245	1.662	0.058	0.004	3.575	1.828	0.118	8.475	3.729	0.241
11	0.079	1.654	0.233	1.673	0.066	0.004	2.721	2.581	0.167	8.024	4.212	0.272
12	0.060	1.586	0.283	1.612	0.055	0.004	2.167	3.043	0.196	10.096	2.223	0.143
13	-0.023	1.606	0.224	1.622	0.084	0.005	-0.828	6.042	0.390	7.946	4.227	0.273
14	0.045	1.698	0.314	1.727	0.107	0.007	1.526	3.950	0.255	10.465	1.792	0.116
15	0.108	1.699	0.308	1.730	0.093	0.006	3.630	2.125	0.137	10.259	1.953	0.126
16	0.029	2.024	0.280	2.044	0.058	0.004	0.826	4.306	0.278	7.887	4.262	0.275
17	0.058	2.040	0.276	2.060	0.050	0.002	1.621	3.529	0.161	7.712	4.427	0.202
18	0.066	1.951	0.288	1.973	0.056	0.003	1.952	3.183	0.145	8.392	3.752	0.171



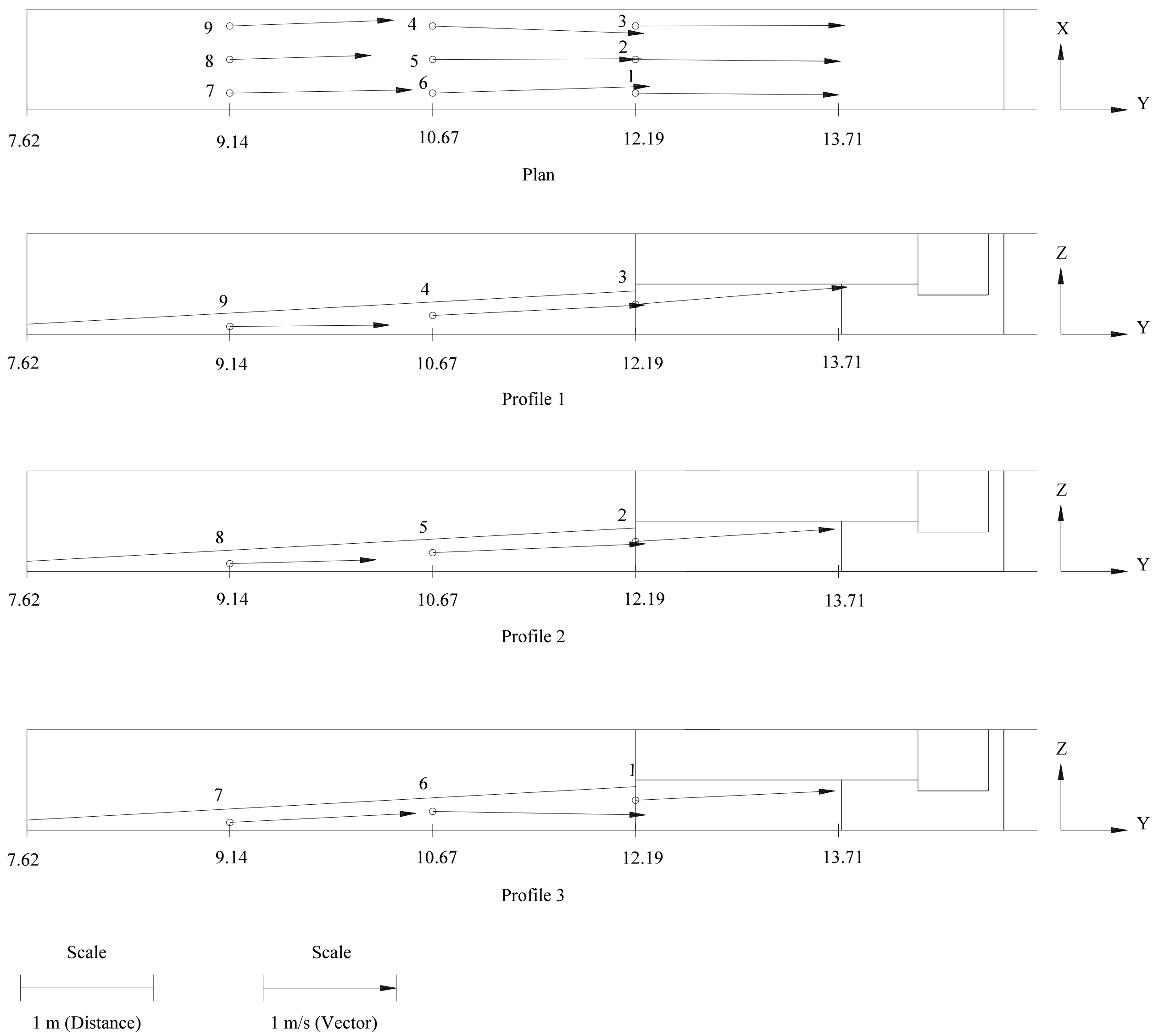
Appendix Figure B1. Plan and profile locations for resultant velocity and direction data points above separation bars in an experimental high-velocity flume separator, with 4.5-m separation bars angled eight degrees, McNary Dam, 16 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (°) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B1.



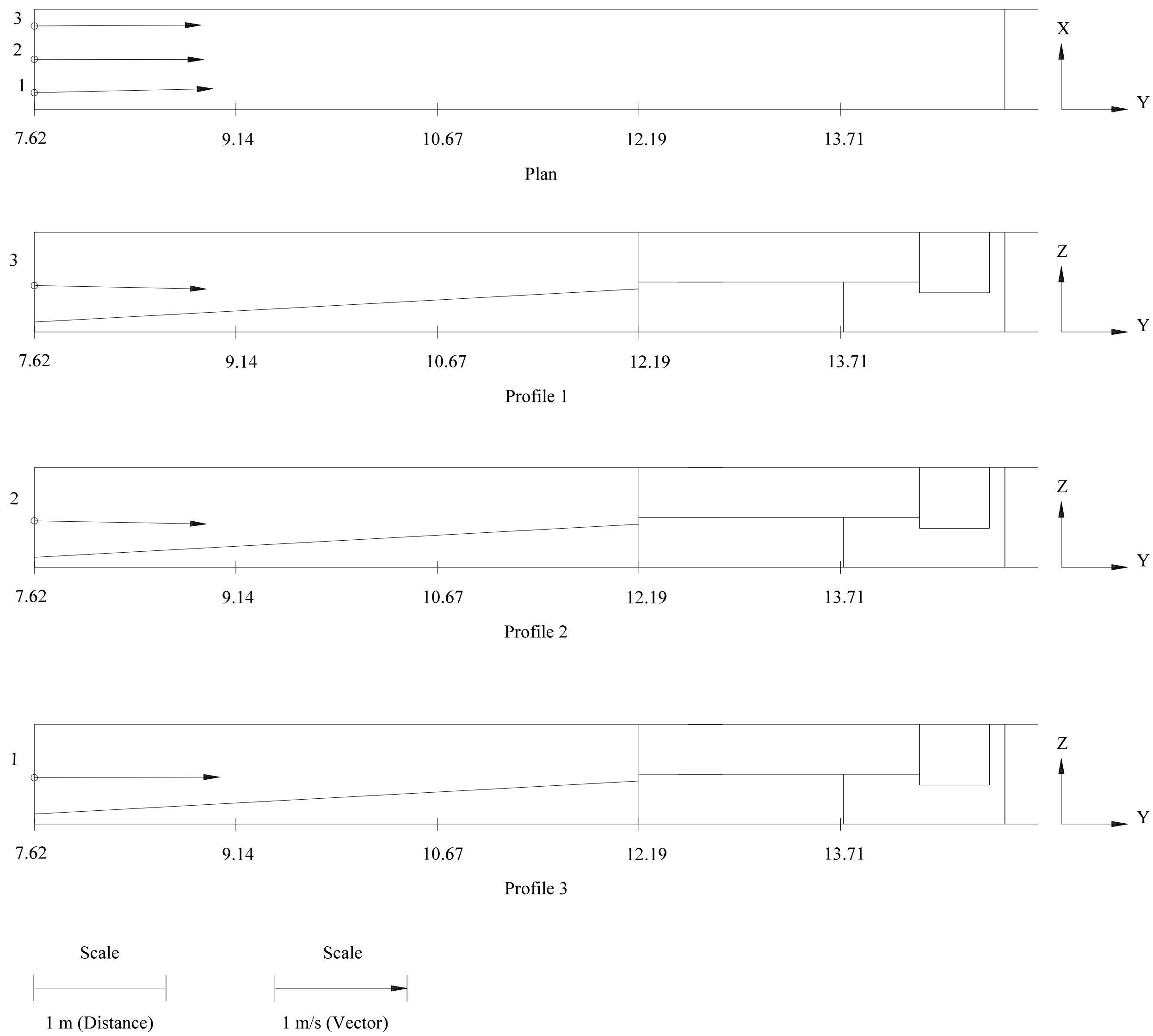
Appendix Figure B2. Plan and profile locations for resultant velocity and direction data points below separation bars in an experimental high-velocity flume separator, with 4.5-m separation bars angled eight degrees, McNary Dam, 16 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (º) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B2.



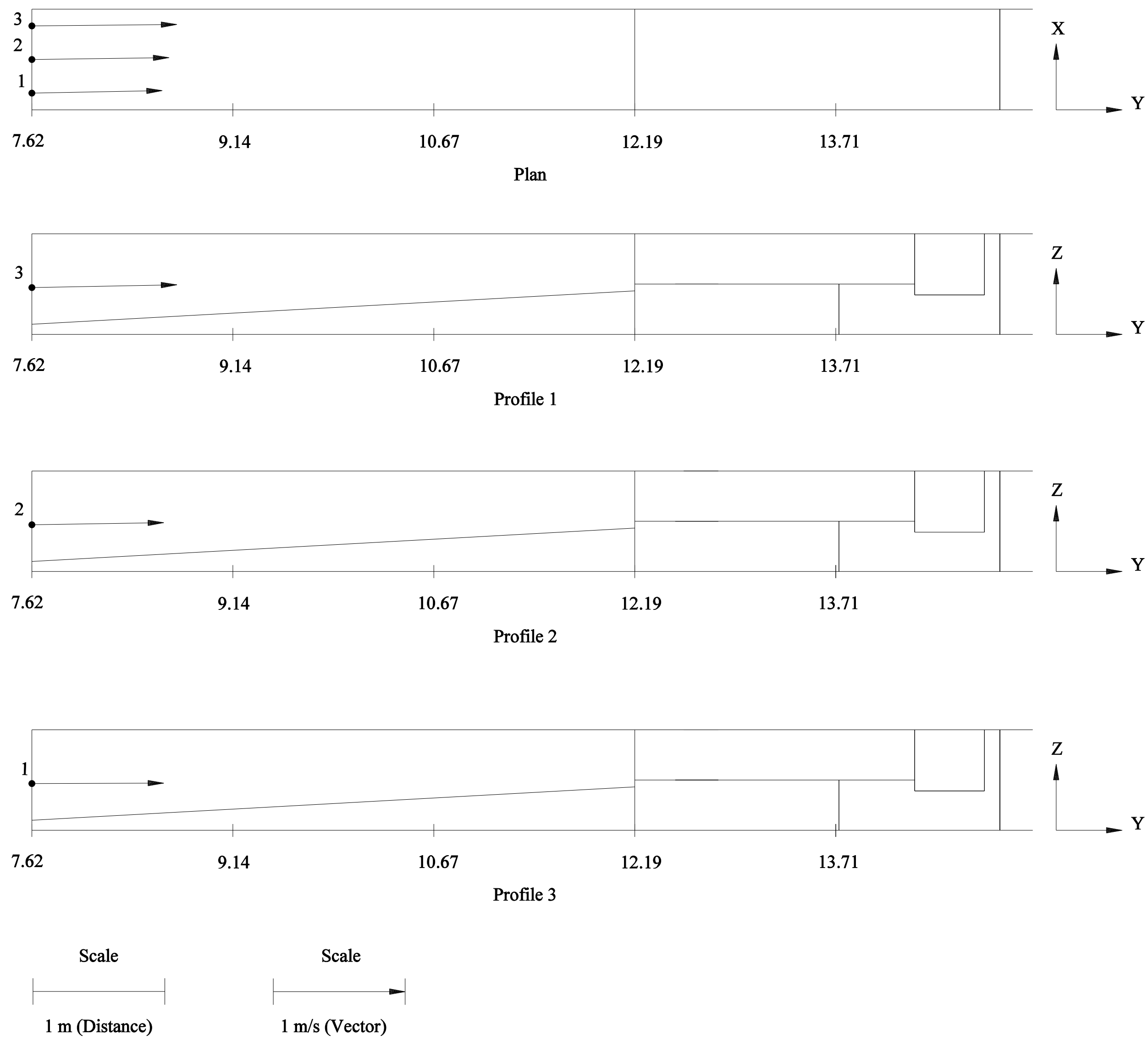
Appendix Figure B3. Plan and profile locations for resultant velocity and direction data points above separation bars in an experimental high-velocity flume separator, with 4.5-m separation bars angled four degrees, McNary Dam, 16 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (º) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B3.



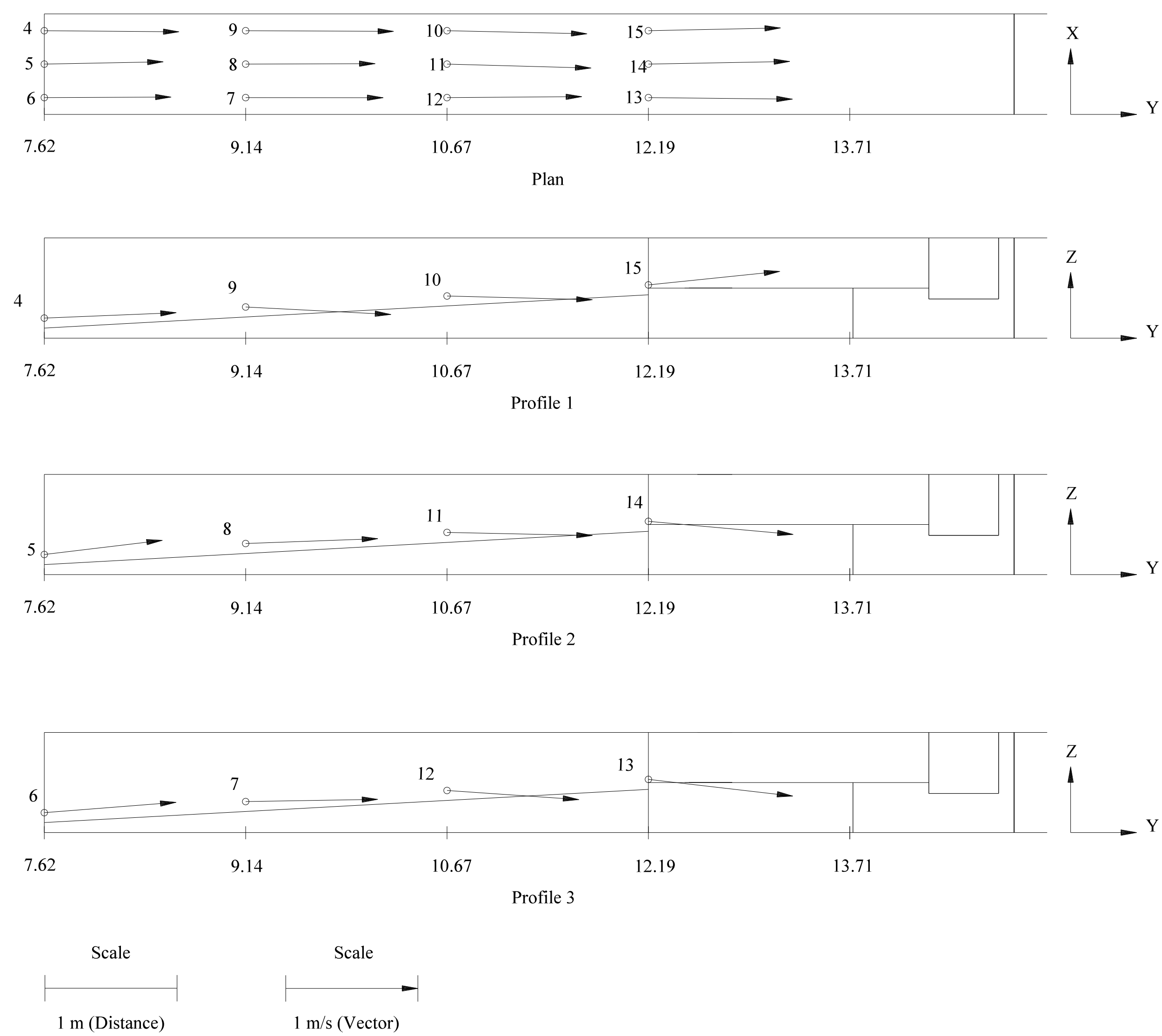
Appendix Figure B4. Plan and profile locations for resultant velocity and direction data points below separation bars in an experimental high-velocity flume separator, with 4.5-m separation bars angled four degrees, McNary Dam, 16 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (°) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B4.



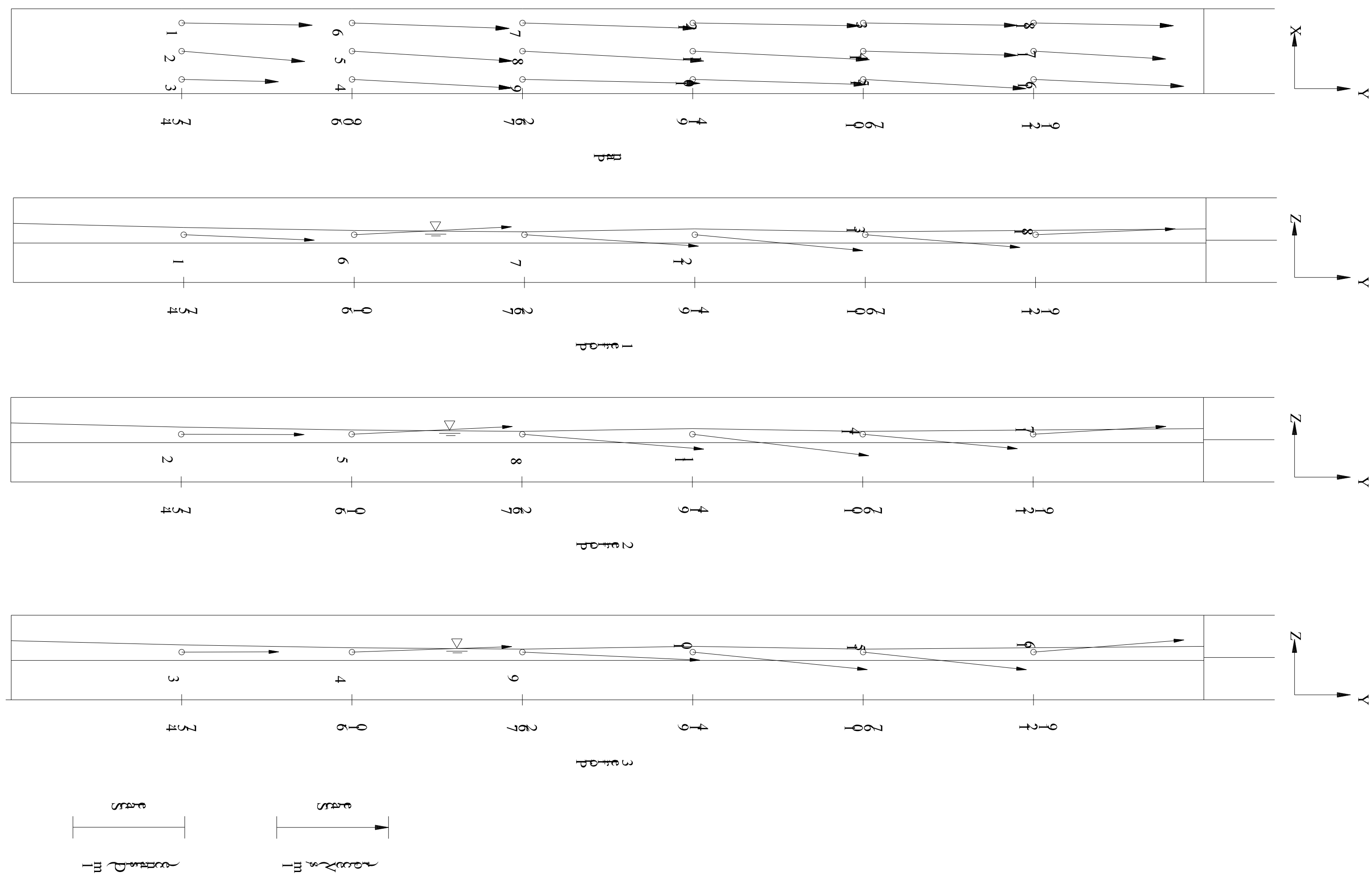
Appendix Figure B5. Plan and profile locations for resultant velocity and direction surface flow data points in an experimental high-velocity flume separator, with 4.5-m separation bars angled four degrees, McNary Dam, 17 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (°) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B5.



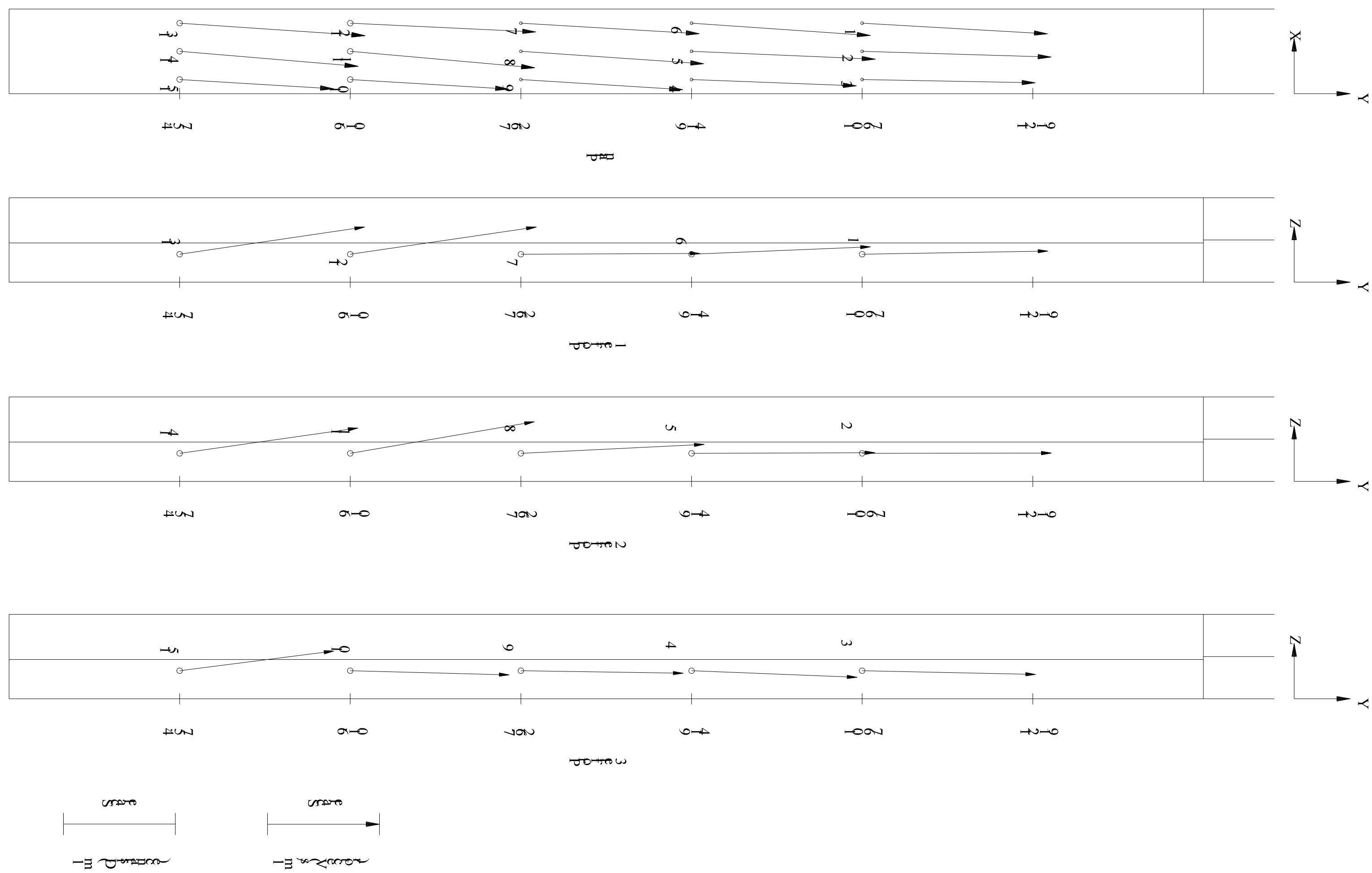
Appendix Figure B6. Plan and profile locations for resultant velocity and direction surface flow data points in an experimental high-velocity flume separator, with 4.5-m separation bars angled four degrees, McNary Dam, 17 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (°) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B6.



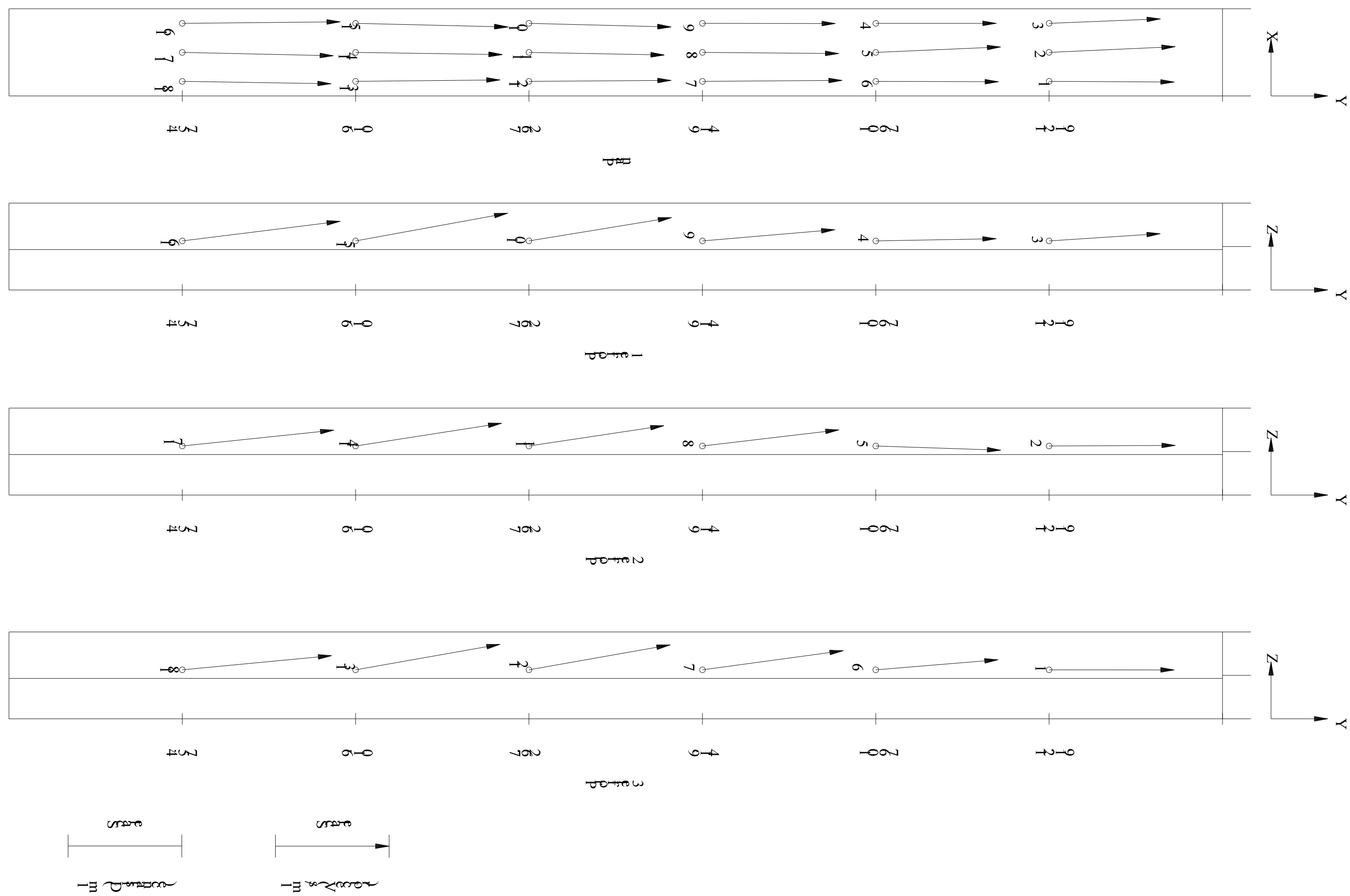
Appendix Figure B7. Plan and profile locations for resultant velocity and direction data points above separation bars in an experimental high-velocity flume separator, with 4.5-m separation bars angled four degrees, McNary Dam, 17 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (º) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B7.



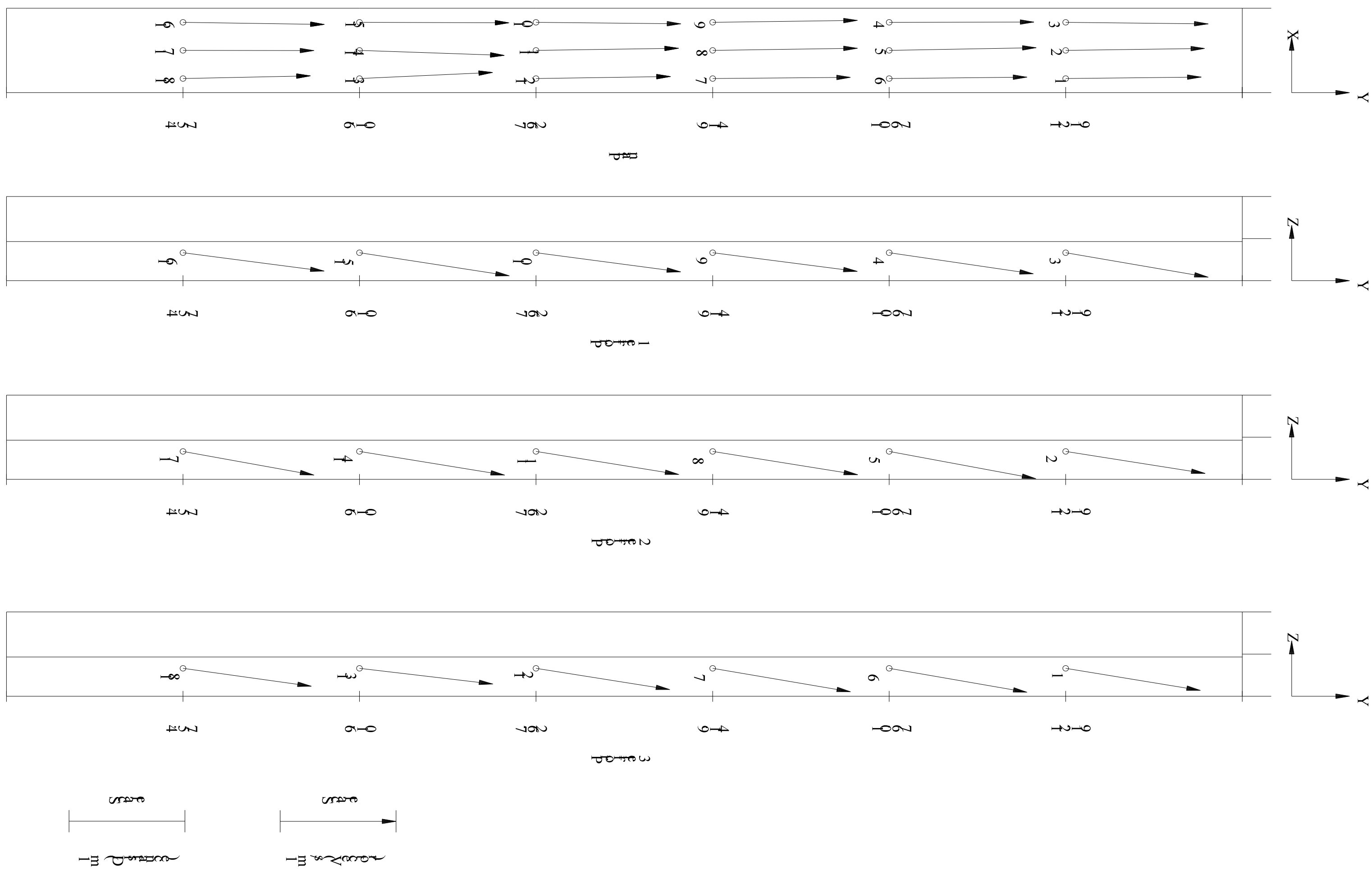
Appendix Figure B8. Plan and profile locations for resultant velocity and direction data points above separation bars in an experimental high-velocity flume separator, with 12-m separation bars flat, McNary Dam, 18 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (º) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B8.



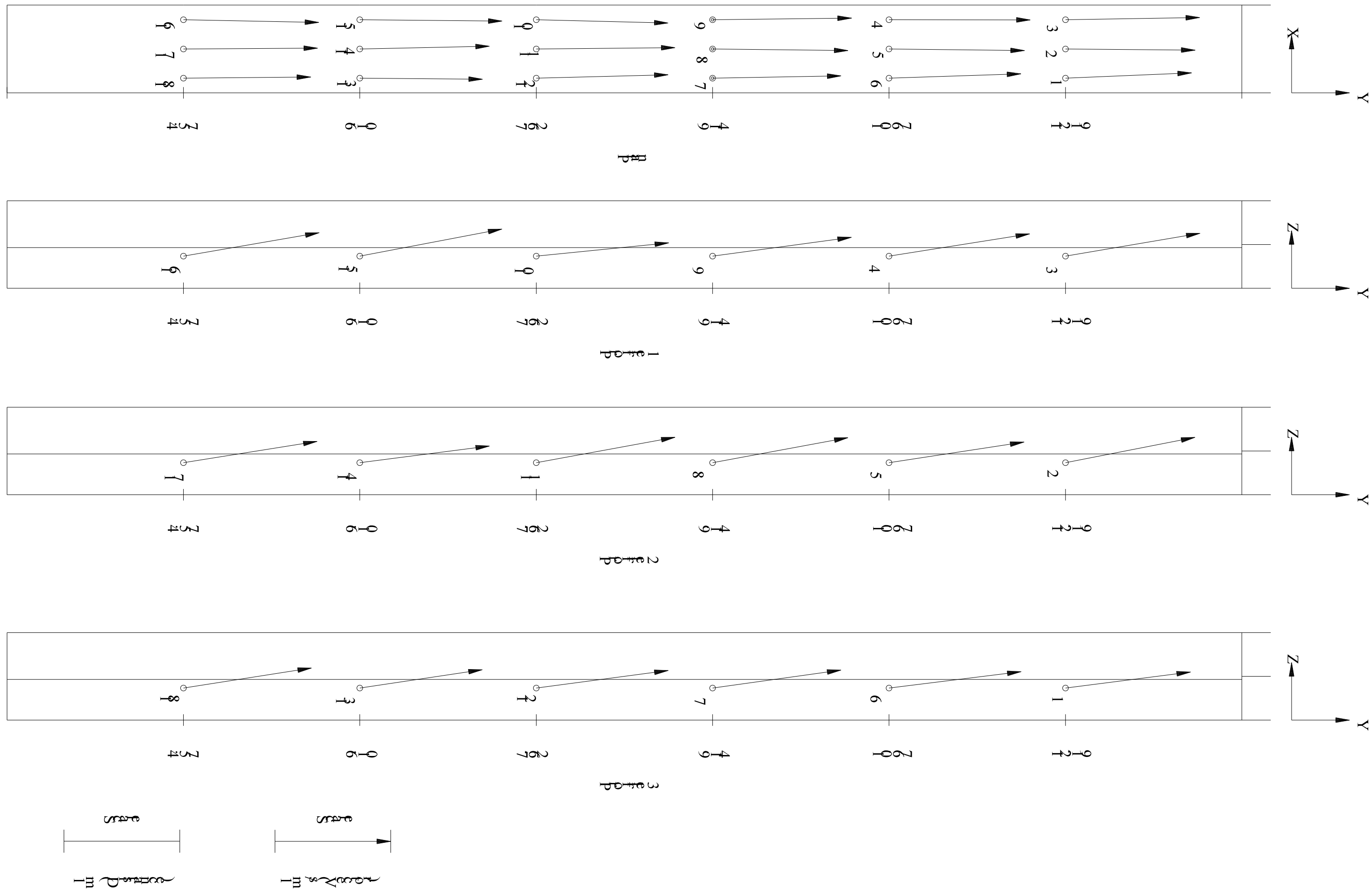
Appendix Figure B9. Plan and profile locations for resultant velocity and direction data points below separation bars in an experimental high-velocity flume separator, with 12-m separation bars flat, McNary Dam, 17 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (º) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B9.



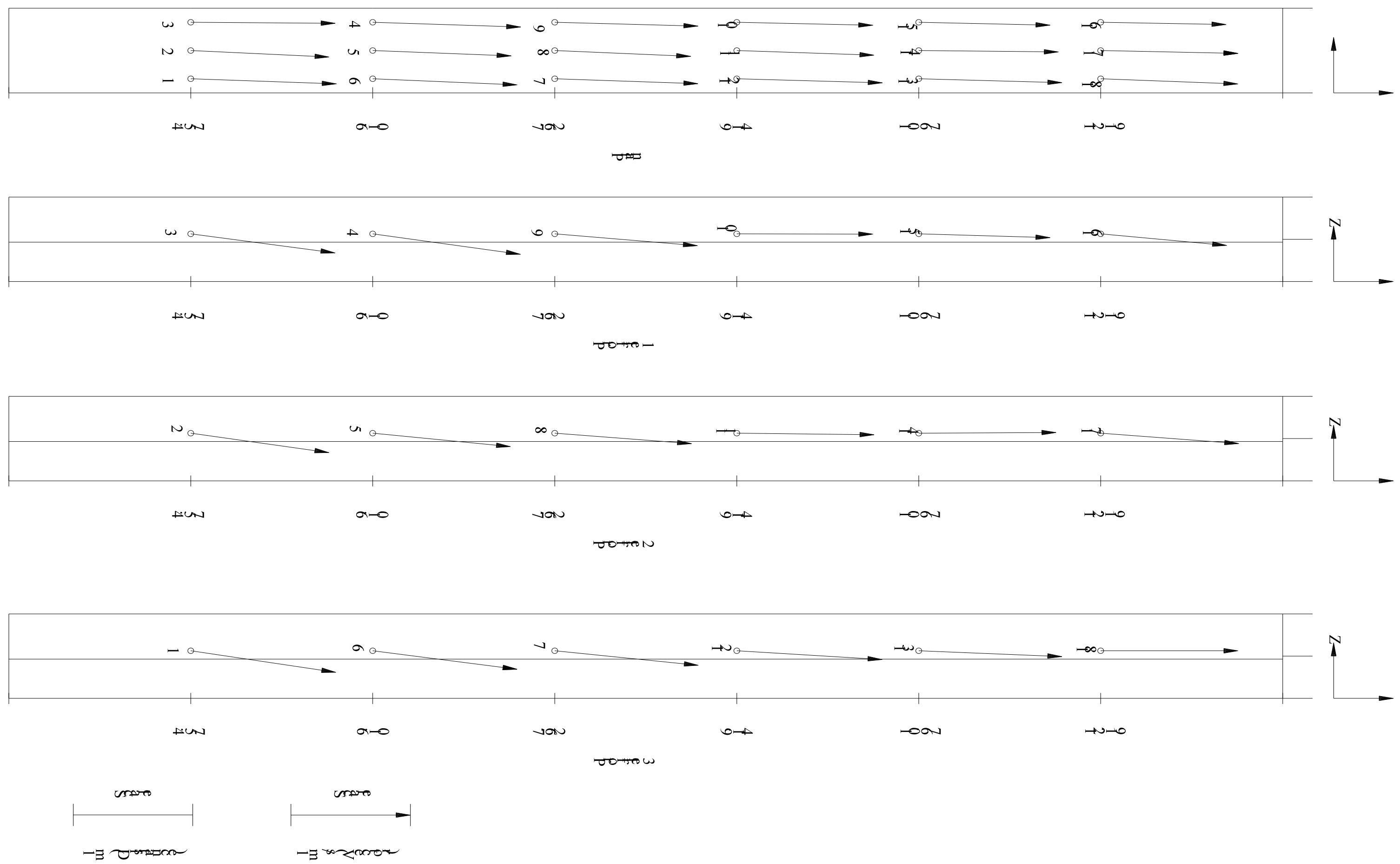
Appendix Figure B10. Plan and profile locations for resultant velocity and direction data points above separation bars in an experimental high-velocity flume separator, with 12-m separation bars flat, McNary Dam, 23 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (º) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B10.



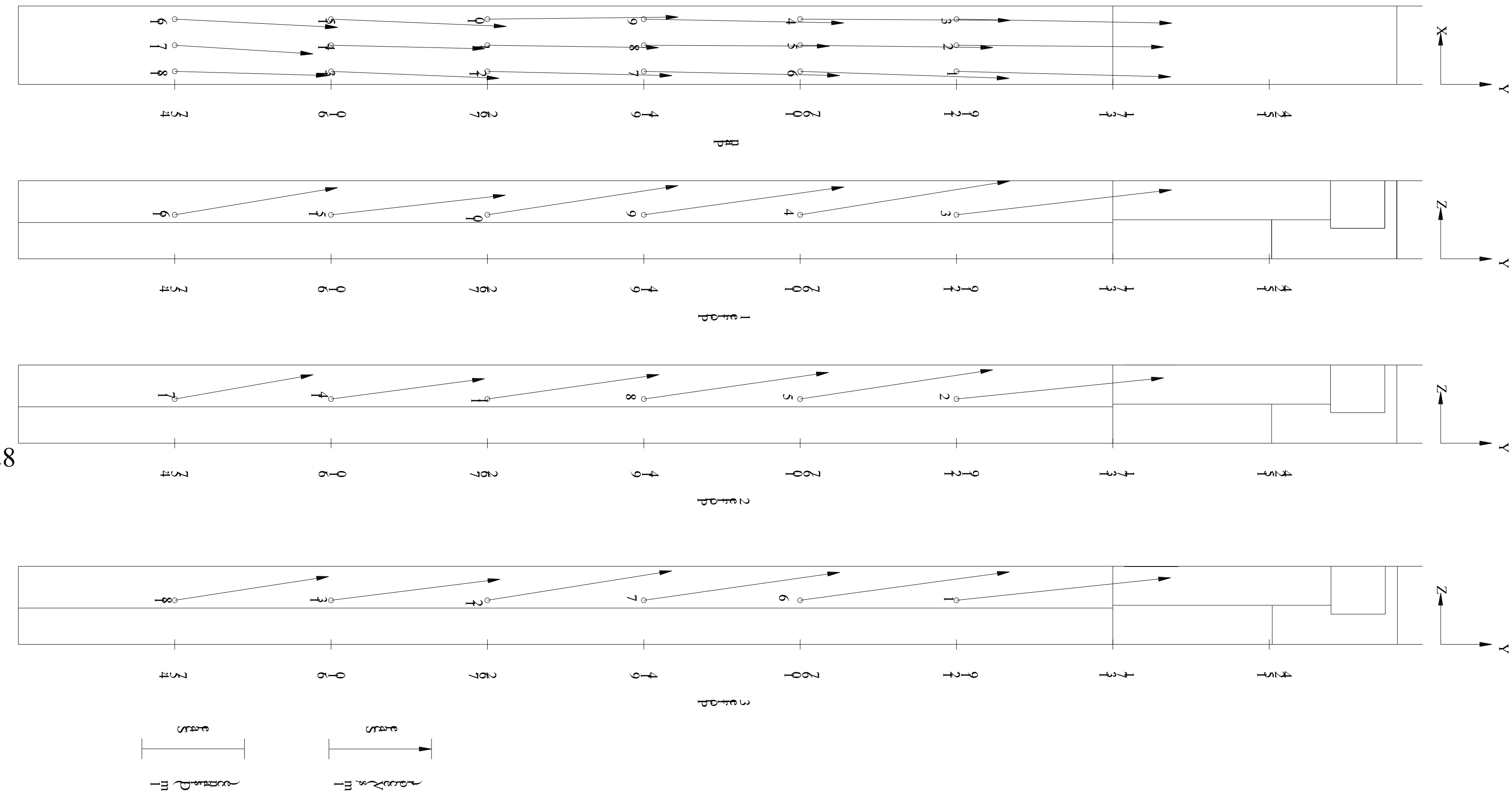
Appendix Figure B11. Plan and profile locations for resultant velocity and direction data points below separation bars in an experimental high-velocity flume separator, with 12-m separation bars flat, McNary Dam, 23 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (º) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B11.



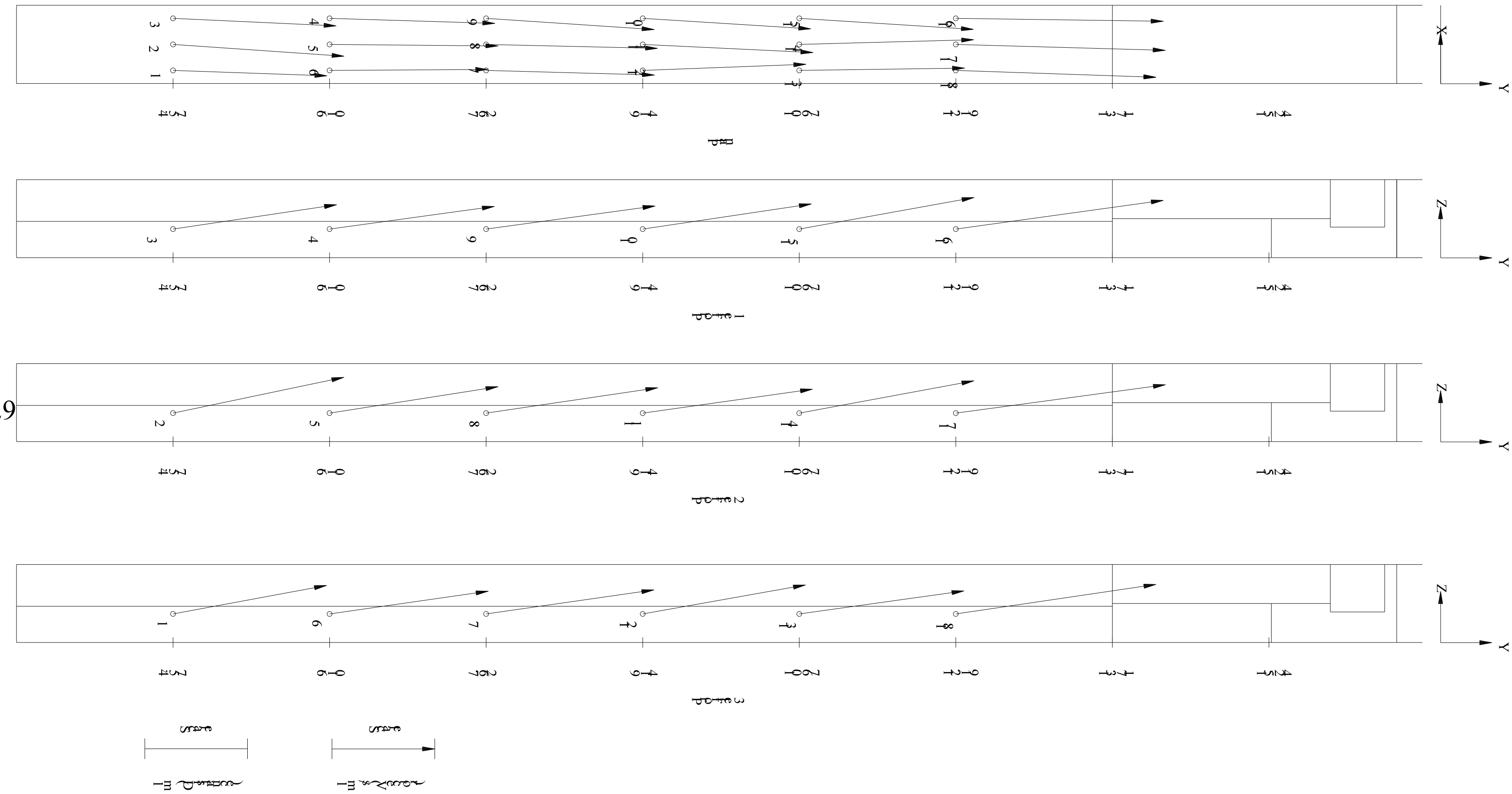
Appendix Figure B12. Plan and profile locations for resultant velocity and direction data points below separation bars in an experimental high-velocity flume separator, with 12-m separation bars flat, McNary Dam, 23 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (º) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B12.



Appendix Figure B13. Plan and profile locations for resultant velocity and direction data points above separation bars in an experimental high-velocity flume separator, with 12-m separation bars flat, McNary Dam, 24 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (º) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B13.



Appendix Figure B14. Plan and profile locations for resultant velocity and direction data points above separation bars in an experimental high-velocity flume separator, with 12-m separation bars flat, McNary Dam, 24 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (º) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B14.



Appendix Figure B15. Plan and profile locations for resultant velocity and direction data points below separation bars in an experimental high-velocity flume separator, with 12-m separation bars flat, McNary Dam, 24 Sept 1997. Arrows indicate average flow velocity for the specified measurement point (º) and coordinate plane. Stationing indicates distance (m) from the upstream end of the separator. Individual coordinate data are tabulated in Appendix Table B15.

REFERENCES

Lower Granite Lock and Dam Fingerling Facilities Additional Raceways - Contract Drawings. Inv. Number 82-B-55, June 1982; Sheets 3, 4, and 5.

SONTEK ADV Operation Manual Version 1.0, Copyright 1995.

SONTEK ADV Software Manual Ver. 2.3 Reference Manual, Copyright 1995.