VELOCITY MEASUREMENTS AT THREE FISH SCREENING FACILITIES IN THE YAKIMA RIVER BASIN, WASHINGTON

SUMMER 1989

Annual Report

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PREFACE

The Bonneville Power Administration and the U.S. Bureau of Reclamation are funding the construction and evaluation of fish passage and protection facilities at irrigation and hydroelectric diversions in the Yakima River Basin, Washington State. This construction implements Sections 903(d) and 803(b) of the Northwest Power Planning Council's 1984 and 1987 Columbia River Basin Fish and Wildlife Program.[(a)] The program provides offsite enhancement to compensate for fish and wildlife losses caused by hydroelectric development throughout the Columbia River Basin, and addresses natural propagation of salmon to help mitigate the impact of irrigation in the Yakima River Basin.

The Wapato, Chandler, and Easton screens are three of the juvenile screening facilities. This report evaluates the flow characteristics of the screening facilities. Studies consisted of velocity measurements taken in front of the rotary drum screens and within the fish bypass systems during peak flows. Measurements of approach velocity and sweep velocity were emphasized in these studies; however, vertical velocity was also measured. Results indicate that velocity patterns within the screening facilities often differ from design specifications, but are generally conducive to effective fish bypass.

[(a)]NPPC (Northwest Power Planning Council). 1984. Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council, Portland, Oregon.

NPPC (Northwest Power Planning Council). 1987. Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council, Portland, Oregon.

ACKNOWLEDGMENTS

The involvement and cooperation of many people during these studies are greatly appreciated. Thomas J. Clune of the Bonneville Power Administration was the Project Manager. Robert Pearce of the National Marine Fisheries Service, NMFS, and Ken Bates of the Washington Department of Fisheries reviewed the plans for measuring velocities. Chuck Keller of the Bureau of Reclamation and his operations and maintenance staffs provided critical support and assistance during site preparation and data collection. Alvin L. Jensen ,NMFS, provided the instrumentation used in our studies. The manuscript was reviewed by Regina E. Lundgren and Wallace H. Walters.

ABSTRACT

The Pacific Northwest Laboratory (PNL)[(a)] measured the velocity conditions at three fish screening facilities in the Yakima River Basin: Wapato, Chandler, and Easton Screens. The measurement objectives were different at the three screens. At Wapato, approach and sweep velocities were measured to evaluate the effect of rearing pens in the screen forebay. A complete survey was preformed at the Chandler Screens. At Easton, velocity was measured behind the screens to provide information for the installation of porosity boards to balance flow through the screens. Salmon-rearing pens used at the Wapato Canal had a minimal effect on the magnitude of approach and sweep velocities at the face of the drum screens, although the pens caused increased turbulence and variability in water velocities. The net pens did not appear to affect flows through the three fish bypasses. Approach velocities at the Chandler Screens ranged from 0.1 fps at the upper end of the screening facility to >0.5 fps at the downstream end of the facility. Sweep velocity was generally <1.0 fps in the screen forebay, especially under the curvature of the drum screens. Low sweep velocities and elevated

approach velocities under the curvature of the drum screens result in velocity conditions that do not meet the design criteria standards. Flow through each of the three fish bypasses was <2.0 fps. Sweep velocity in the separation chamber was <1.0 fps at 0.8 of the depth. Approach velocity at the face of traveling screens in the separation chamber was <0.5 fps. Water velocities in the fish return met design criteria. Approach velocities at the Easton Screens varied from 0.1 fps to>0.6 fps from the upstream to the downstream end of the screening facility. Imbalanced flows throughout the screen array may be partially attributable to water flow around a bend in the canal upstream of the screen forebay that results in high sweeping velocity along the outer wall of the screen forebay.

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[a]The Pacific Northwest Laboratory is operated by the Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

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INTRODUCTION

The Pacific Northwest Electric Power Planning and Conservation Act (Public Law 96-501) was passed to enable preparation and implementation of a regional Conservation and Electric Power Plan. The Northwest Power Planning Council administers the plan, and is charged with developing a program to protect and enhance fish and wildlife populations and to mitigate adverse effects from development, operation, and management of hydroelectric facilities.

The Yakima River Basin was selected as one site for enhancement of salmon (Oncorhynchus spp.). Under the Plan, the Bonneville Power Administration (BPA) and the U.S. Bureau of Reclamation (BR) are funding the construction of fish passage and protection facilities at 20 existing irrigation and hydroelectric diversions in the Yakima River Basin (Figure 1).

The improvement of fish screening facilities in irrigation canals is a major component in the overall fisheries enhancement program. Hydrologists and biologists from various agencies, including the National Marine Fisheries Service (NMFS), the Washington Department of Fisheries, and the Yakima Indian Nation (YIN) provided input for the design of the new facilities. The angled rotary drum screen design was chosen as the best alternative for fish screening in irrigation canals.

Pacific Northwest Laboratory (PNL) conducted fisheries evaluations at six of the new fish screening facilities from 1985 through 1989 (Neitzel et al. 1985; 1987; 1988; 1990a; 1990b). The scope of the studies included the quantification of injury and mortality, predation, and passage effectiveness for emigrating salmonids; however, it did not include evaluating hydraulic characteristics within the screening facilities. The hydraulic conditions in front of the drum screens as well as within components of the fish guidance system (fish bypasses, separation chamber, and fish return slot) are critical in providing optimum conditions for safe fish bypass. The screens were designed to provide an approach velocity (perpendicular to the screens) of 0.5 feet per second (fps) or less to minimize impingement of fish and a sweep velocity (parallel to the screen face) of at least twice the magnitude of the approach velocity to guide fish into the bypass system (Easterbrooks 1984).

Inadequate sweep velocities, excessive approach velocities, or unequal discharges through the drum screens and fish bypass system have been observed at several of the screening facilities during our fisheries evaluations. These flow pattern anomalies can affect the overall efficiency of a facility. Velocity measurements were taken at six screen sites in 1988 (Abernethy et al. 1989) to monitor the actual velocity characteristics at selected facilities during normal operation, as defined by the operating criteria for each facility.

This report describes additional velocity measurement studies conducted by PNL staff at the Wapato, Chandler, and Easton Screens in 1989. It describes the equipment and methods used to measure the hydraulic

characteristics and the operating conditions at each facility during data collection, and summarizes the results and conclusions. The raw data are included in three appendixes (one for each site) to allow independent analysis of the data.

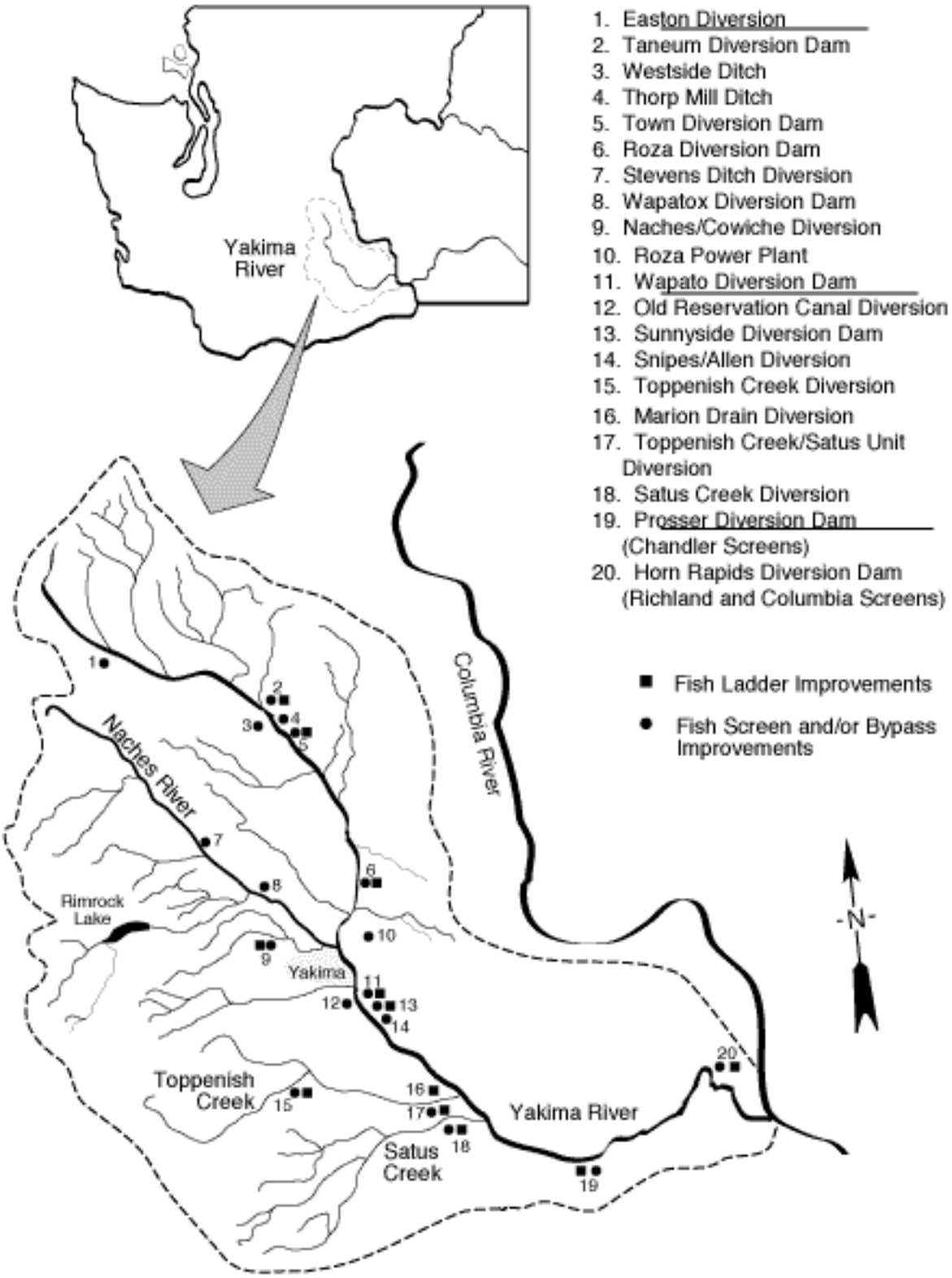


FIGURE 1. Yakima River Basin Fish Screening Facilities and Other Fish Protection and Passage Facilities

METHODS

Three monitoring protocols were used in our data collection based on the objectives of the measurements at each site. Measurements were taken at the Wapato Screens to evaluate the effect of the use of salmon-rearing pens in the canal forebay on flow parameters in front of the drum screens. Velocity readings for the X (approach velocity) and Y (sweep velocity) components were taken at 0.2 and 0.8 of the water depth in front of each drum screen and at the head of each fish bypass one day before and one hour after the net pens were removed from the Wapato Screens forebay. A complete survey, which included measurements at 0.05, 0.2, 0.5, 0.8, and 0.9 of the water depth in front of the drum screens and at 0.2 and 0.8 of the water depth in components of the fish bypass system was performed at the Wapato Screens in 1988 (Abernethy et al. 1989).

A complete survey was performed at the Chandler Screens. Velocity measurements were taken at 0.2 and 0.8 of the depth in front of each of the drum screens, in the fish bypasses, and in the separation chamber. Additional velocity measurements were taken at 0.05, 0.5, 0.8, and 0.9 of the depth in front of drum screens adjacent to each fish bypass (Figure 2). Velocity readings were taken to measure the X (approach velocity), Y (sweep velocity), and Z (vertical velocity) components at all locations. Velocity measurements were taken at 0.2 and 0.8 of the depth behind each of the drum screens at the Easton Screens to provide information for porosity board placement to balance flows through the screens. No flow measurements were taken in front of the drum screens or in the fish bypass system.

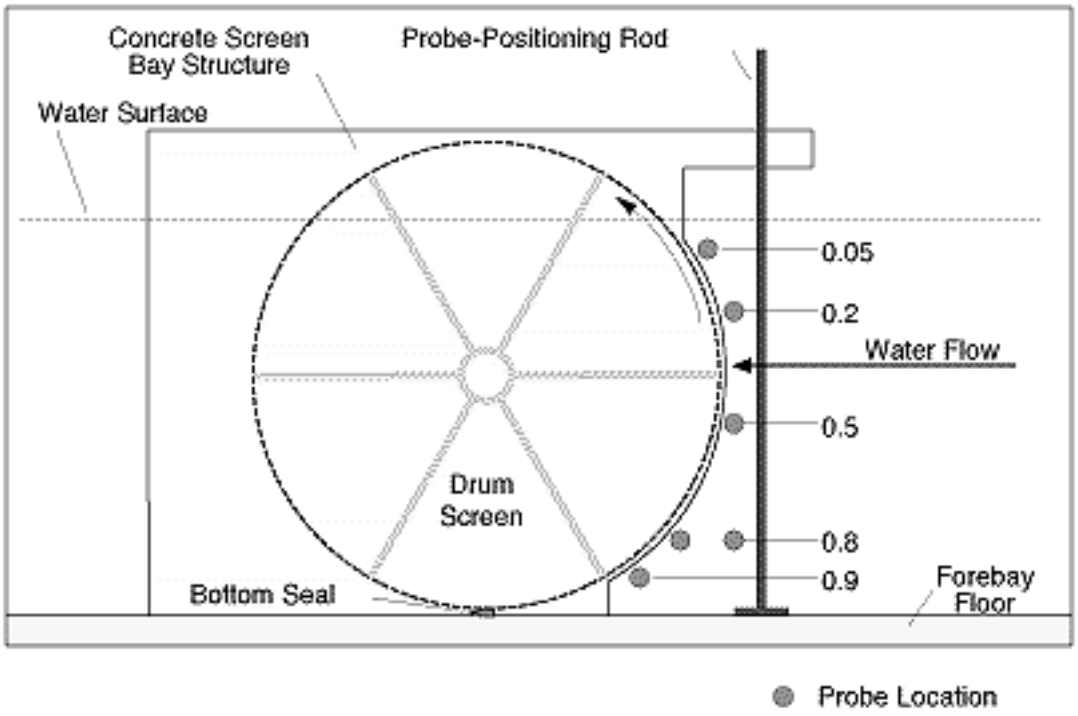


FIGURE 2. Measurement Depths and Probe Positioning Relative to the Front Face of Rotary Drum Screens in Complete Surveys

EQUIPMENT

Electromagnetic water current meters were used to monitor water velocities. Each meter used a bidirectional probe (Figure 3). Probes were mounted in pairs at the Chandler Screens so that one measured the X and Y and the other measured the Y and Z velocity components at a given depth. The vertical velocity (Z) component was not measured at the Wapato and Easton Screens; therefore, only one probe was necessary at each measurement location. A smaller electromagnetic water current meter, which measures flow in one direction only, was also used at the Easton Screens to compare the data obtained from different instruments. Outputs were read visually from panel gauges. The meter probes were securely fastened to a horizontal arm that

extended from a movable sleeve secured to a vertical pole. The length of the horizontal arm and the position of the sleeve on the vertical pole were adjustable. The probe support assembly was positioned at least 18 in. downstream or outside of the sensors so that the vertical pole and horizontal bracket arm would not disrupt velocity readings at the probes.

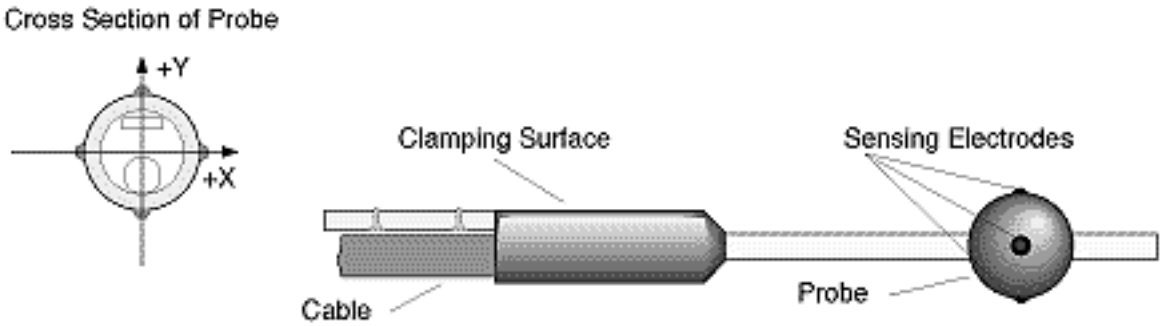


FIGURE 3. Bidirectional Electromagnetic Probes Used in Velocity Measurements

PROBE POSITIONING

The position of the probes was adjusted for each of the measurement locations within the facility. Measurements were taken in or near the drum screens, fish bypasses, separation chamber, vertical traveling screens, and the fish return.

Measurements Near Drum Screens

For velocity measurements at the Wapato and Chandler screens, the vertical pole was positioned close to the perimeter in front of the screen; however, none of the components of the probe assembly were in contact with the screen face. The bottom of the pole rested on the forebay floor, and the top end of the pole was clamped to a fixed object, such as the gantry frame or a girder. Measurements at 0.2, 0.5, and 0.8 of the depth were taken by mounting the probes on a horizontal arm pointing upstream (Figure 4), and measurements near the screen face at 0.05, 0.8, and 0.9 of the depth were taken by mounting the probes on a horizontal arm pointed inward toward the face of the screen. The length of the horizontal arm required to position the probes close to the screen face was calculated based on screen diameter, water depth, and the position of the vertical pole relative to the perimeter of the screen. The set of probes was within 5 (±1) in. of the screen face for the near-screen measurements. The drum screens are constructed at an angle to the canal flow; therefore, all measurements were taken with the probe orientation parallel and perpendicular to the screen face, not to the canal flow. All velocity measurements were taken at the centerline of the screen. For velocity measurements at the Easton Screens, the vertical pole was positioned at the centerline of each drum screen about 15 in. from the screen surface on the back side of the screen. The horizontal arm supporting the probe for the bidirectional flow meter was oriented upstream so that the X and Y components could be measured. The probe for the unidirectional flow meter was pointed directly at the screen face, then slowly rotated to achieve the highest stable reading on the panel gauge.

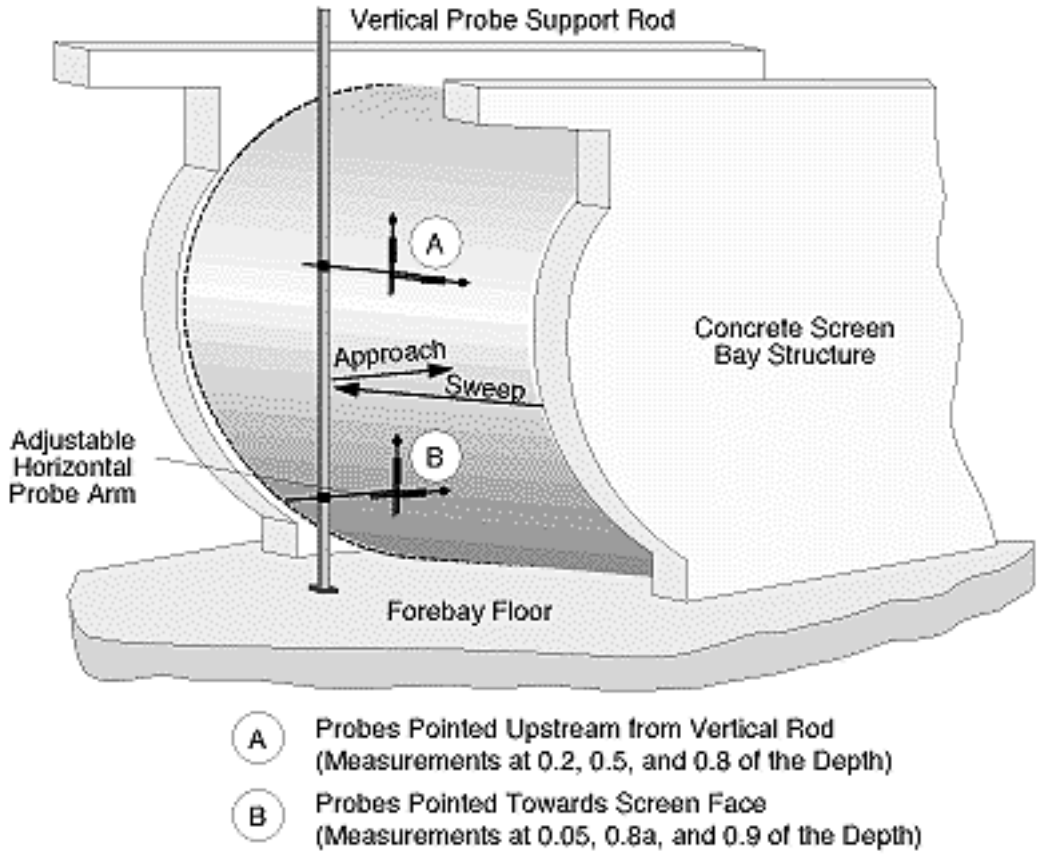


FIGURE 4. Relationship of Probe Support Assembly to Probes During Velocity Measurements

Measurements in the Fish Bypasses

Measurements were taken at 0.2 and 0.8 of the depth at the centerline of the 24-in.-wide fish bypasses at the Wapato and Chandler Screens. All bypasses had submerged ramps to guide fish and water up from the bottom of the screen structure and over an adjustable weir at the back of the ramp. The probes were positioned about 18 in. upstream of the ramp. This positioning generally placed the probes within the concrete structure of the bypass.

Measurements in the Separation Chamber

Measurements were taken at 0.2 and 0.8 of the depth in transects across the width of the separation chamber at the Chandler screens. Transects were made upstream of the vertical traveling screens and at the centerline of each traveling screen. The traveling screens were constructed perpendicular to the separation chamber flow, with the outer wall (distal to the traveling screens) angling toward the screens. The probes were positioned pointing upstream parallel to the traveling screens. Turbulent areas where bypass flows mix at the head of the separation chamber were not evaluated.

Measurements Near the Vertical Traveling Screens

Measurements were taken at 0.2 and 0.8 of the depth at the face of the traveling screens. The probes were positioned parallel to the screen face at the centerline and in the upper and lower quadrants at the Chandler Screens. The measurements along the screen face and the transects across the separation chamber merged to form a "T" pattern of velocity measurements.

Measurements in the Fish Return

Velocity measurements were taken at 0.2 and 0.8 of the depth in the fish return at the Chandler Screens near

the upstream end of the fish return slot. The vertical pole was positioned upstream of the submerged approach ramp, but within the concrete structure of the fish return slot.

DATA COLLECTION AND ANALYSIS

Ten sets of velocity measurements were recorded in a 3- to 5-min interval. Each set of readings provided a "snapshot" of all velocity measurements. Beginning and ending times were recorded for each series of data. Unusual operating or canal flow conditions were recorded as "Notes" on the data sheets. Analyses and comparisons were performed using the means of the data.

DESCRIPTION OF CONDITIONS AT EACH SITE

Our data were collected during the peak of the irrigation season under the existing operating conditions at each site. The Chandler Canal was not at full capacity because of the frequent flow adjustments required to meet in-river flow obligations during periods of low river flow. Surface elevation and/or forebay depth were determined from staff gages at each site. Actual daily canal flows were provided by the Bureau of Reclamation. Unusual flow or operating conditions were recorded at each site.

WAPATO CANAL

The Wapato Screens (Figure 5) are located in the Wapato Canal on the right bank of the Yakima River at RM 106.7. The facility consists of 15 rotary drum screens (14 ft diameter, 24 ft long) and a fish bypass system that includes three fish bypasses (two intermediate and a terminal), a separation chamber with two bypass water recovery pumps located behind vertical traveling screens, and a fish return. The YIN uses the Wapato Screens forebay to house three pens for rearing fall chinook salmon (*O. tshawytscha*). The floating pens are attached to the outer wing wall opposite the screens near the second fish bypass (Figure 6).

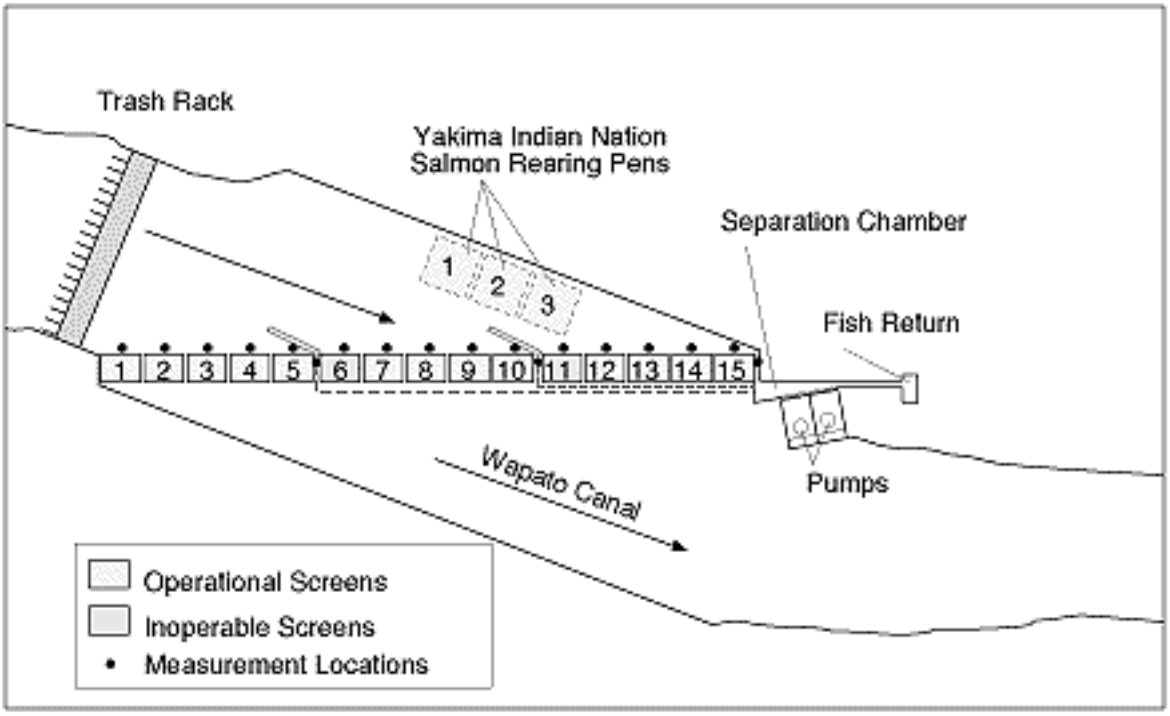


FIGURE 5. Locations of Facility Components and Rearing Pens at the Wapato Screens, Spring 1989

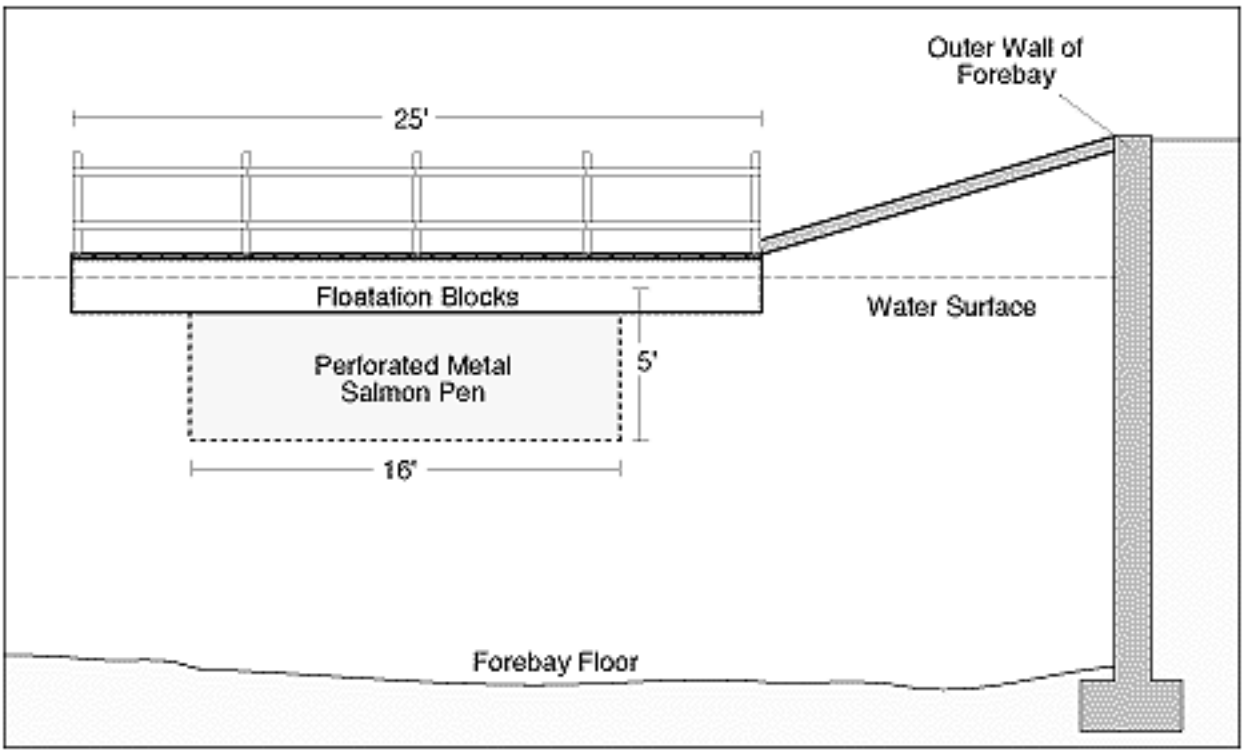


FIGURE 6. Pens Used by the Yakima Indian Nation to Rear Fall Chinook Salmon in the Wapato Screens Forebay

The forebay elevation is about 935 ft at the maximum canal flow of 1800 cubic feet per second (cfs). The first series of measurements was conducted at the Wapato Canal on June 1 and 2, 1989. Canal elevation was 934.9 ft, and the canal flow was 1830 cfs. Water depth in front of the screens was 140 in. Of the 168-in. drum screen diameter, 132 in. (79%) were submerged. We used the submerged screen depth as the basis for calculating probe positioning.

All operating conditions were normal (Appendix A) with the following exceptions:

- The vertical traveling screens in the separation chamber were not in service.
- Rotary drum screens 6 and 11 were not operational.
- Three YIN salmon-rearing pens were in use in the screen forebay.

The second series of velocity measurements was completed on June 5 and 6, 1989, after the YIN salmon pens were removed from the canal forebay. The surface elevation in the canal was 934.85 ft, and the canal flow was 1850 cfs. All other operating conditions were the same as during the first series of measurements except that the three salmon net pens had been removed.

CHANDLER CANAL

The Chandler Screens (Figure 7) are located in the Chandler Canal on the right bank of the Yakima River. The head gates of the Chandler Canal withdraw water from the Yakima River at the Prosser Diversion Dam at RM 47.0 near Prosser, Washington. The facility consists of 24 rotary drum screens (13.5 ft diameter, 12 ft long) and a fish bypass system that includes three fish bypasses (two intermediate and a terminal), a separation chamber with four bypass water recovery pumps located behind vertical traveling screens, and a fish return. The forebay elevation is about 631 ft at the maximum canal flow of 1400 cfs.

A complete survey was conducted at the Chandler Screens on July 26 to 28, 1989. Canal elevation was 630.1 ft, and the canal flow was 1050 to 1100 cfs. Water depth in front of the screens was 112 in. Of the 162-in. drum screen diameter, 108 in. (67%) were submerged. We used the submerged screen depth as the basis for calculating probe positioning.

All operating conditions were normal Appendix A) with the following exceptions:

- Screen 23 was inoperable and stoplogged shut.
- Only two of the four bypass water return pumps were operating.

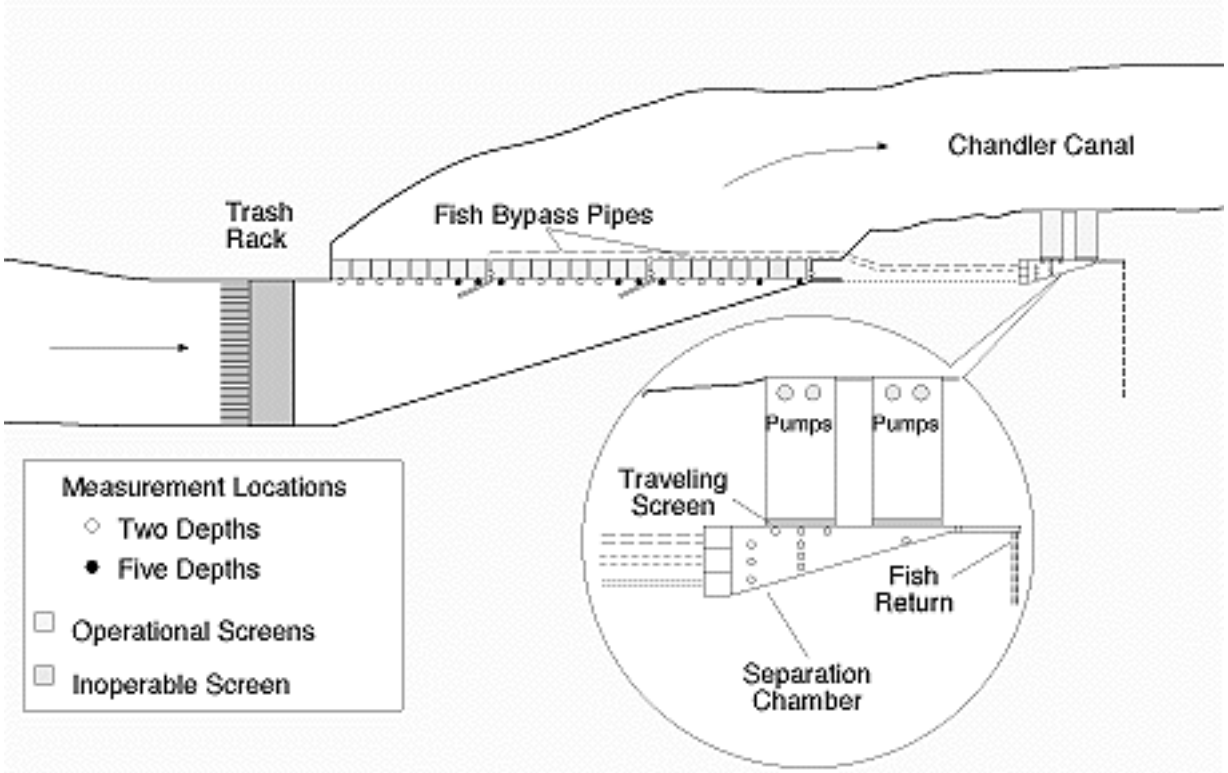


FIGURE 7. Locations of Facility Components at the Chandler Screens, Spring 1989

EASTON CANAL

The Easton Screens (Figure 8) are located in the Kittitas Main Canal on the right bank of the Yakima River at RM 202.5 near Easton, Washington. The facility consists of 18 rotary drum screens (15 ft diameter, 12 ft long) and a fish bypass system that includes two fish bypasses (intermediate and terminal), each with a flow of 20 cfs, and a fish return. The maximum canal flow is about 1200 cfs. Flow measurements were taken at the Easton Screens on June 14 and 15, 1989 with a canal flow of 1130 cfs. Water depth behind the screens was 139 in. All operating conditions were normal (Appendix A).

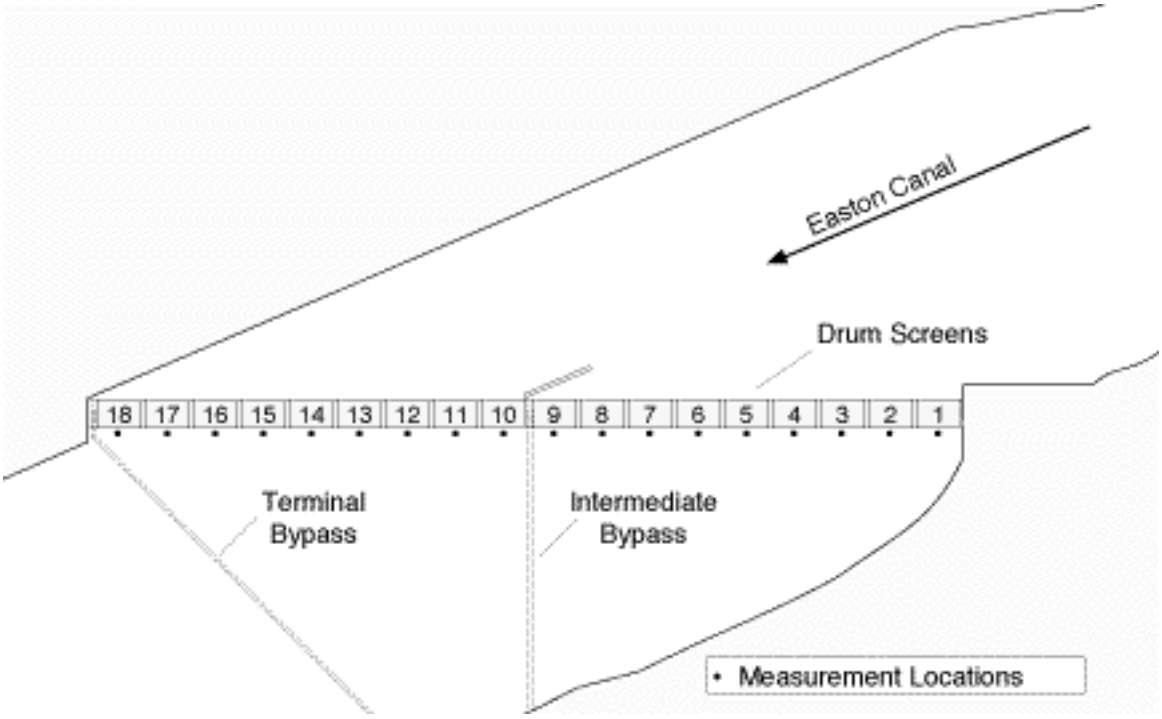


FIGURE 8. Probe Locations for Flow Velocity Measurements at the Easton Screens, Spring 1989

RESULTS

The objective of our velocity measurements differed at each of the three sites. Velocity measurements performed at the Wapato Screens evaluated flow conditions near the drum screens relative to the use of salmon-rearing pens in the screen forebay. A complete survey was performed at the Chandler Screens. Velocity measurements performed at the Easton Screens evaluated flow balance through the array of screens.

WAPATO SCREENS

Velocity measurements taken before and after the removal of three salmon-rearing pens from the Wapato Screens forebay indicated that although the pens had only a minimal effect on actual approach and sweep velocities at the face of the drum screens, the pens contributed to increased turbulence and instability of the water flow. Swirls and turbulence at the face of drum screens could result in intermittent increases in approach velocities. The net pens did not appear to affect flows through the three fish bypasses.

The magnitude of the approach velocity was not affected at 0.2 of the depth (Figure 9), 0.8 of the depth (Figure 10), or under the curvature of the screens at 0.8 of the depth (Figure 11). Variability of the approach velocity was greater at the two 0.8 readings when the pens were in use.

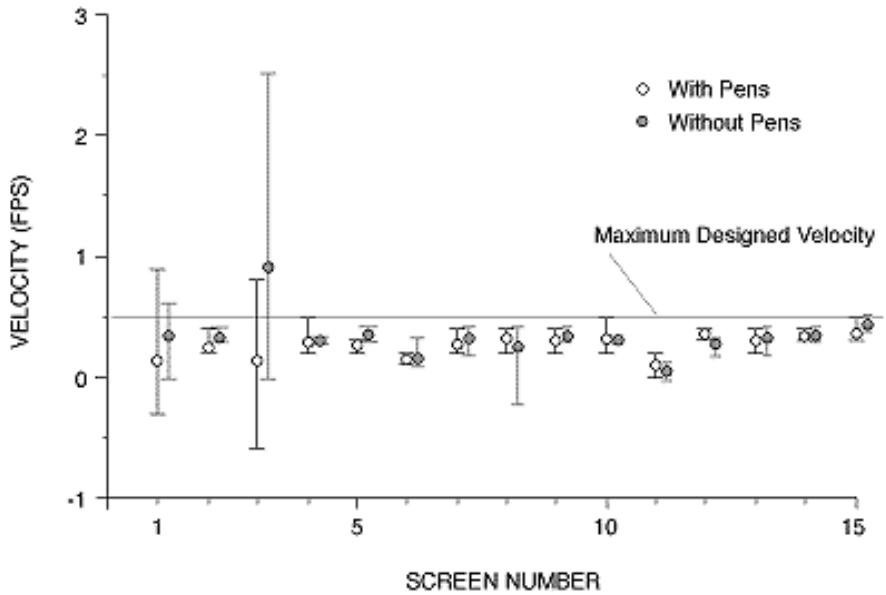


FIGURE 9. Approach Velocity at 0.2 of the Depth in Front of Drum Screens at the Wapato Canal, Spring 1989

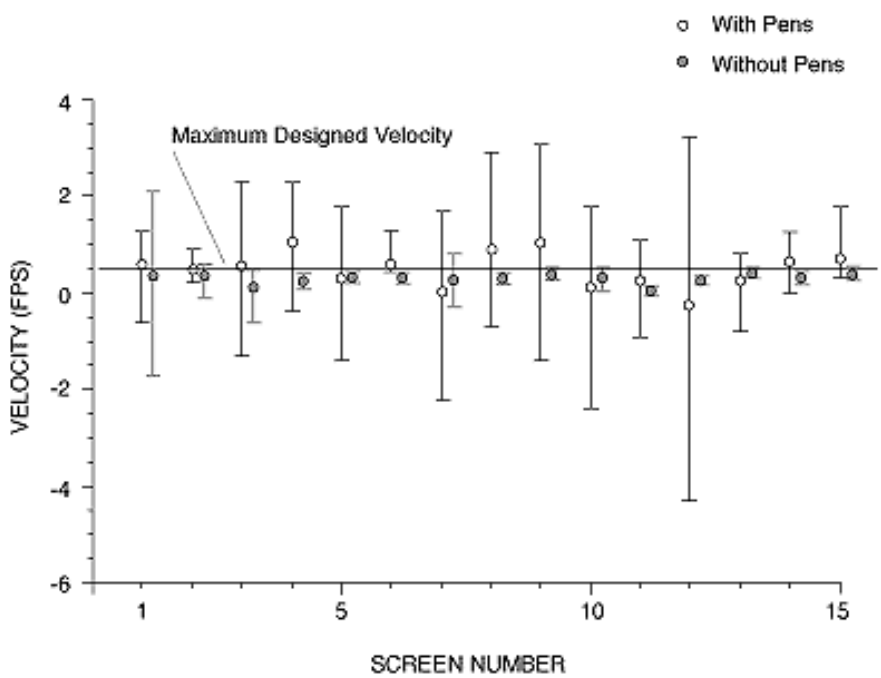


FIGURE 10. Approach Velocity at 0.8 of the Depth in Front of Drum Screens at the Wapato Canal, Spring 1989

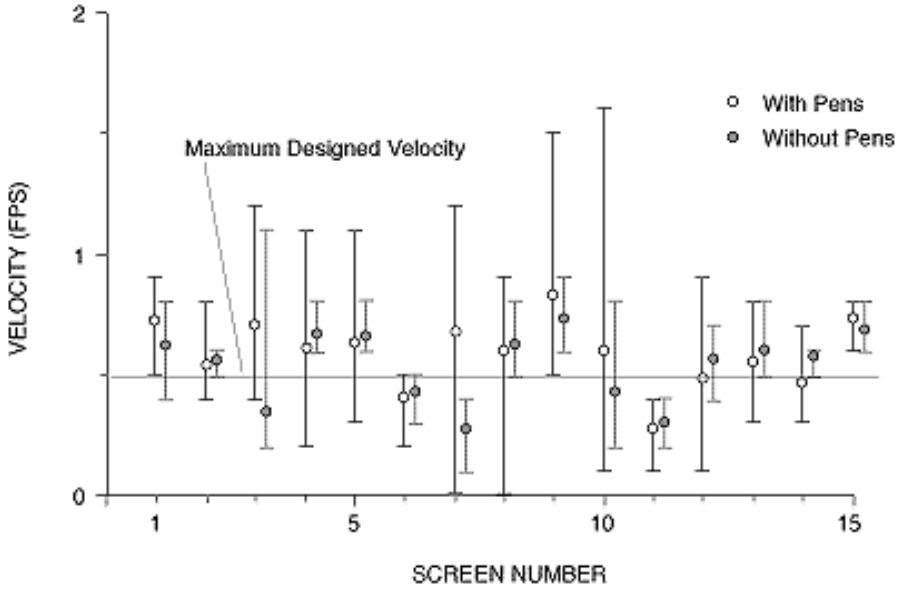


FIGURE 11. Approach Velocity at 0.8 of the Depth Under the Curvature of Drum Screens at the Wapato Canal, Spring 1989

Sweep velocity increased at 0.2 of the depth (Figure 12) and decreased at 0.8 of the depth (Figure 13) when the net pens were removed. Sweep velocity under the curvature of the drum screen at 0.8 of the depth was only slightly affected (Figure 14). Variation of the sweep velocity measurements was greater at all three of the measurement locations when the pens were in use.

Flow was balanced through the three fish bypasses both with and without the pens in the forebay. Velocity in each of the bypasses increased at 0.2 of the depth and decreased at 0.8 of the depth when the pens were removed (Table 1).

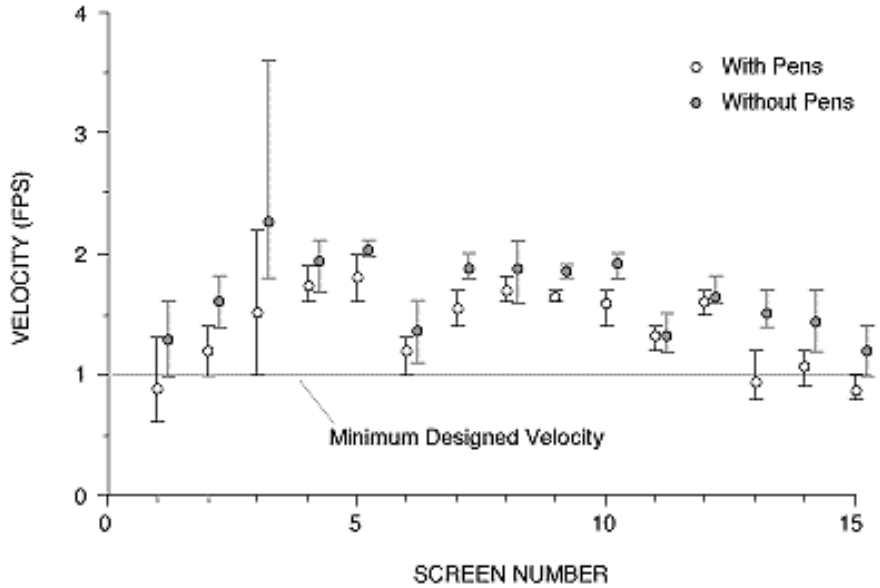


FIGURE 12. Sweep Velocity at 0.2 of the Depth in Front of Drum Screens at the Wapato Canal, Spring 1989

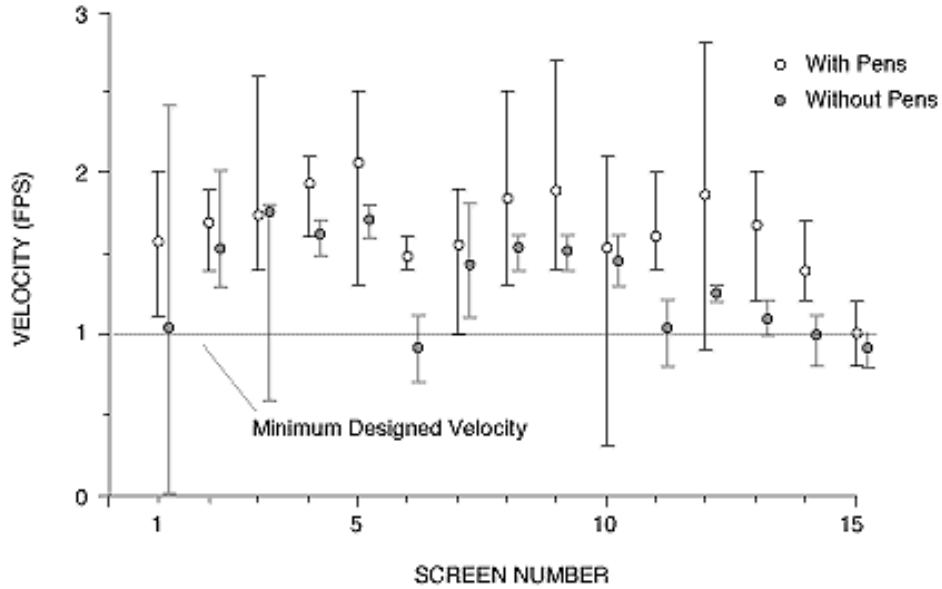


FIGURE 13. Sweep Velocity at 0.8 of the Depth in Front of Drum Screens at the Wapato Canal, Spring 1989

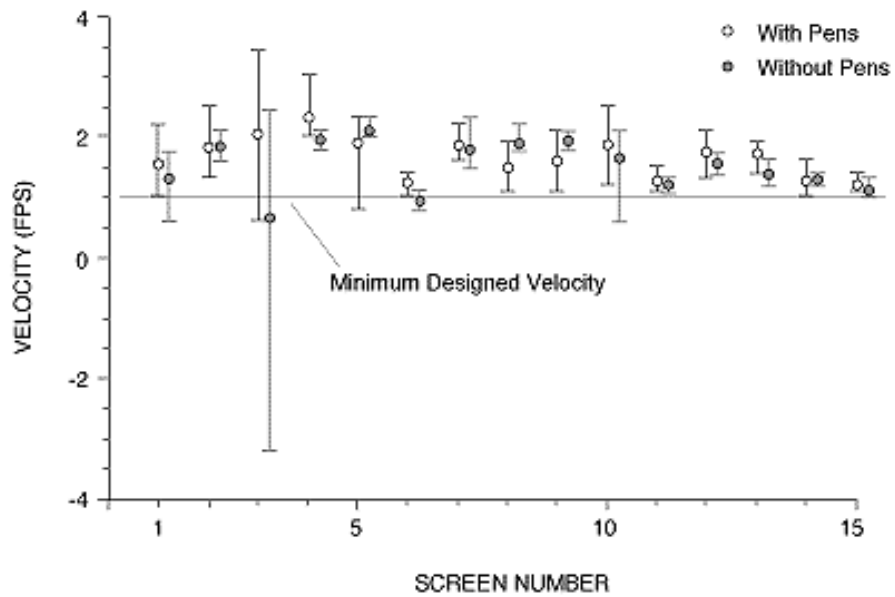


FIGURE 14. Sweep Velocity at 0.8 of the Depth Under the Curvature of Drum Screens at the Wapato Canal, Spring 1989

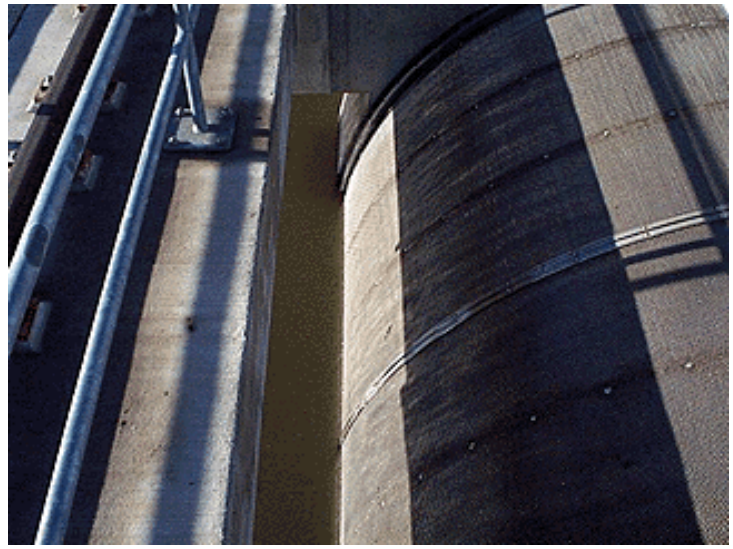
TABLE 1. Approach Velocities (fps) at the Head of Fish Bypasses at the Wapato Canal, Spring 1989

	0.2 Depth		0.8 Depth	
Bypass	With Pens	Without Pens	With Pens	Without Pens #
1	1.57	1.76	1.56	1.28
2	1.79	1.97	1.57	1.25
3	1.68	1.79	1.44	1.21

TABLE 1. Approach Velocities (fps) at the Head of Fish Bypasses at the Wapato Canal, Spring 1989

CHANDLER SCREENS

Velocity measurements varied throughout the facility. The variability resulted in measurements being different from the design criteria.



Approach velocity exceeded 0.5 fps by more than 10% at 12 of the 76 measurement locations (Table 2). Most of the high approach velocities occurred under the curvature of the drum screens at 0.8 and 0.9 of the depth. Approach velocity was low in front of screens at the upstream end of the facility but nearly equal to the 0.5-fps standard in front of screens at the downstream end of the facility. Wing walls had little affect on approach velocity.

TABLE 2. Summary of Approach (X), Sweep (Y), and Vertical (Z) Velocity Measurements (fps) in Front of the Drum Screens at the Chandler Canal, Summer 1989

	0.2			0.8			0.05			0.5			0.8(a)			0.9(a)		
Screen	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
1	0.10	0.48	-0.06	0.20	0.33	-0.02												
2	0.10	0.60	-0.09	0.10	0.55	-0.03												
3	0.11	0.71	-0.13	0.13	0.62	-0.04												
4	0.18	0.86	-0.07	0.19	0.72	-0.01												
5	0.20	0.87	-0.12	0.20	0.75	-0.03												
6	0.20	0.90	-0.11	0.21	0.78	-0.05												
7	0.29	0.97	-0.09	0.27	0.73	-0.01	0.24	0.92	-0.09	0.27	0.88	-0.08	0.70	1.82	-0.12	0.35	0.58	0.13
8	0.30	0.92	-0.12	0.28	0.68	-0.02	0.29	0.94	-0.17	0.28	0.79	-0.07	0.76	1.79	0.29	0.38	0.43	0.10
9	0.35	1.10	-0.11	0.39	0.77	0.05	0.30	1.14	-0.09	0.37	1.02	-0.14	0.79	1.69	-0.38	(b)	(b)	(b)
10	0.30	1.17	-0.13	0.34	1.16	-0.10												
11	0.30	1.23	-0.13	0.30	1.10	-0.06												
12	0.30	1.27	-0.10	0.30	1.07	-0.04												
13	0.30	1.04	-0.12	0.30	1.07	-0.04												
14	0.30	1.24	-0.10	0.30	1.00	-0.01												
15	0.40	1.02	-0.06	0.32	0.98	0.02	0.31	1.27	-0.08	0.36	1.12	-0.04	0.48	1.08	0.09	0.50	0.77	0.10
16	0.40	1.18	-0.03	0.32	0.91	0.33	0.40	1.14	-0.06	0.39	1.06	0.04	0.58	1.19	0.13	(b)	(b)	(b)
17	0.50	1.27	-0.12	0.74	0.86	-0.06	0.50	1.26	-0.10	0.59	0.88	-0.17	0.83	0.92	-0.15	0.83	0.63	0.01
18	0.39	1.18	-0.13	0.49	0.98	-0.05												
19	0.41	1.17	-0.12	0.48	1.02	-0.08												
20	0.40	0.99	-0.12	0.48	0.94	-0.07												
21	0.40	1.25	-0.12	0.52	0.80	-0.06												
22	0.50	1.05	-0.11	0.54	0.65	-0.01	0.40	1.15	-0.10	0.48	0.90	-0.06	0.67	0.97	-0.07	0.74	0.58	0.08
23	Not in operation																	
24	0.49	0.98	-0.10	0.50	0.94	-0.02	0.50	1.21	-0.10	0.51	1.03	-0.05	0.70	1.16	-0.01	0.69	1.01	0.10

(a) Measurement made under curvature of the screens; all others made in front of screens.
(b) Obstruction under the screens; no data.

Sweep velocity resulting in less than a 2:1 sweep-to-approach ratio occurred at 13 (17%) of the 76 measurement locations, and was <1.0 fps at 40 (53%) locations. Low sweep velocity was most evident at 0.9 of the depth. Sweep velocities under the curvature of the drum screens at 0.8 of the depth were comparable to sweep velocities measured in front of the drum screens; however, the high approach velocities under the curvature of the drum screen resulted in a poor sweep-to-approach ratio. Sweep velocity was low in the upstream third of the facility, highest in the middle third of the facility, and slightly reduced in the downstream third of the facility.

Vertical velocity was generally low throughout the facility. Disruptions in flow associated with vertical movement of water, such as upwelling and swirling, were not evident during our sampling.

Flow through the terminal fish bypass (bypass 3) was lower than through the two intermediate bypasses, based on sweep velocity measurements taken in the entrance of the three fish bypasses (Table 3). Additionally, overall fish bypass flow was less than is specified in the operating criteria. Only two of the four pumps in the separation chamber were operating during our measurement series.

TABLE 3. Summary of Approach (X), Sweep (Y), and Vertical (Z) Velocity Measurements (fps) at the Entrance to the Fish Bypasses at the Chandler Canal, Summer 1989

	0.2 Depth			0.8 Depth		
Bypass	X	Y	Z	X	Y	Z
1	-0.06	1.98	0.11	0.24	1.18	0.21
2	-0.11	1.73	0.19	-0.23	1.49	0.31
3	0.06	1.38	0.24	-0.54	1.26	0.47

TABLE 3. Summary of Approach (X), Sweep (Y), and Vertical (Z) Velocity Measurements (fps) at the Entrance to the Fish Bypasses at the Chandler Canal, Summer 1989

Sweep velocity in the upstream end of the separation chamber is surface-oriented (Figure 15, Table 4). Sweep velocity at 0.8 of the depth increases from zero at the upstream end of the separation chamber to about 60% of the sweep velocity at 0.2 of the depth near the entrance to the fish return slot. Based on the cross-sectional area in the fish return, the fish return flow was about 25 cfs, with slightly more water entering the fish return from the surface.

TABLE 4. Summary of Approach (X), Sweep (Y), and Vertical (Z) Velocity Measurements (fps) in the Separation Chamber and Fish Return at the Chandler Canal, Summer 1989

		0.2 Depth			0.8 Depth		
Transect[a]	Position[b]	X	Y	Z	X	Y	Z
Upper	Outer	0.52	1.67	-0.39	0.28	0.0	-0.01
	Center	0.19	1.76	-0.20	0.18	0.01	-0.20
	Inner	-0.41	1.90	-0.36	0.40	0.01	-0.18
Screen 1	Outer	0.20	1.84	-0.31	0.27	0.53	-0.25
	Center	0.09	1.87	-0.27	0.30	0.49	-0.08
	Inner	0.07	1.66	-0.20	0.37	0.32	-0.06
Screen 2	Center	0.29	1.64	-0.21	0.46	0.99	-0.18
Fish Return[c]		0.01	1.75	-0.04	0.02	1.33	0.04

a Upper transect is across the separation chamber upstream of the first traveling screen; Screen 1 and Screen 2 transects are adjacent to the centerline of each screen.

b Outer position is 1 ft from the outer wall; center position is midway between the outer wall and the catwalk in front of the traveling screens; inner position is adjacent to the catwalk, about 5 ft from the face of the traveling screens.

c Measurements were taken at the centerline of the fish return slot near the entrance.

TABLE 4. Summary of Approach (X), Sweep (Y), and Vertical (Z) Velocity Measurements (fps) in the Separation Chamber and Fish Return at the Chandler Canal, Summer 1989

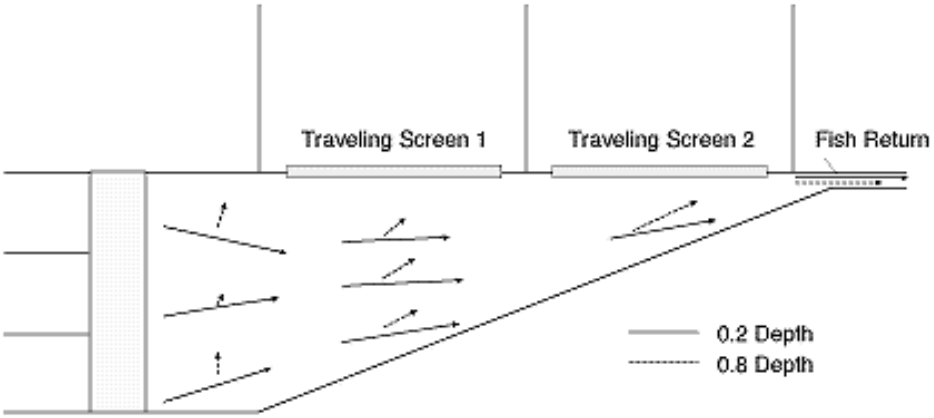


FIGURE 15. Flow Patterns (Plane View) in the Chandler Screens Separation Chamber as Described by Velocity Data and Visual Observations of the Water Surface

Approach velocity was less than 0.5 fps at the face of the first traveling screen (Table 5, Figure 16). The lack of sweep velocity at 0.8 of the depth observed in velocity measurements in the upstream end of the separation chamber persisted in front of the first traveling screen. Because of limited accessibility, no measurements were taken in front of the second traveling screen.

TABLE 5. Summary of Approach (X), Sweep (Y), and Vertical (Z) Velocity Measurements (fps) at the Face of the First Traveling Screen at the Chandler Canal, Summer 1989

	0.2 Depth			0.8 Depth		
Position	X	Y	Z	X	Y	Z
Upper	0.36	1.09	0.27	0.21	-0.05	0.29
Center	0.37	0.88	0.05	0.33	-0.17	0.43
Lower	0.24	0.86	0.06	0.46	-0.13	0.19

TABLE 5. Summary of Approach (X), Sweep (Y), and Vertical (Z) Velocity Measurements (fps) at the Face of the First Traveling Screen at the Chandler Canal, Summer 1989

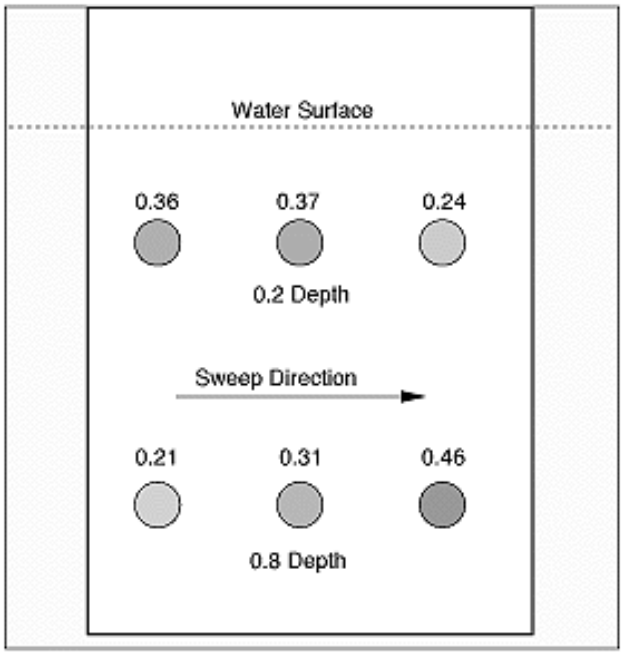


FIGURE 16. Approach (Impingement) Velocity at the Face (Side View) of the First Traveling Screen in the Chandler Screens Separation Chamber

EASTON SCREENS

The low flow through drum screens at the upstream end of the Easton Screens indicates that porosity boards are needed to balance flows. Flow through the screens may be partially attributable to water flow around a bend in the canal upstream of the screens forebay that results in high sweeping velocity along the outer wall of the screens forebay.

Velocity measurements taken on June 14 with a unidirectional water current meter and on June 15 with a two bidirectional (Figure 17) water current meters produced similar results. Overall, velocities measured with the unidirectional meter were slightly higher than the velocities measured with the bidirectional instruments; however, the difference may be a result of the maximum stable reading observed with the unidirectional meter, which was recorded for the data set, while ten velocity readings with the bidirectional meters were averaged to produce the data set.

Velocity through the drum screens was lowest through the screens at the upstream end of the facility and steadily increased throughout the length of the facility. The highest velocities were observed at the last three screens (Screens 16 through 18). Velocity across the screen face has little meaning because the velocity measurements were made in the screen bays behind the drum screens.

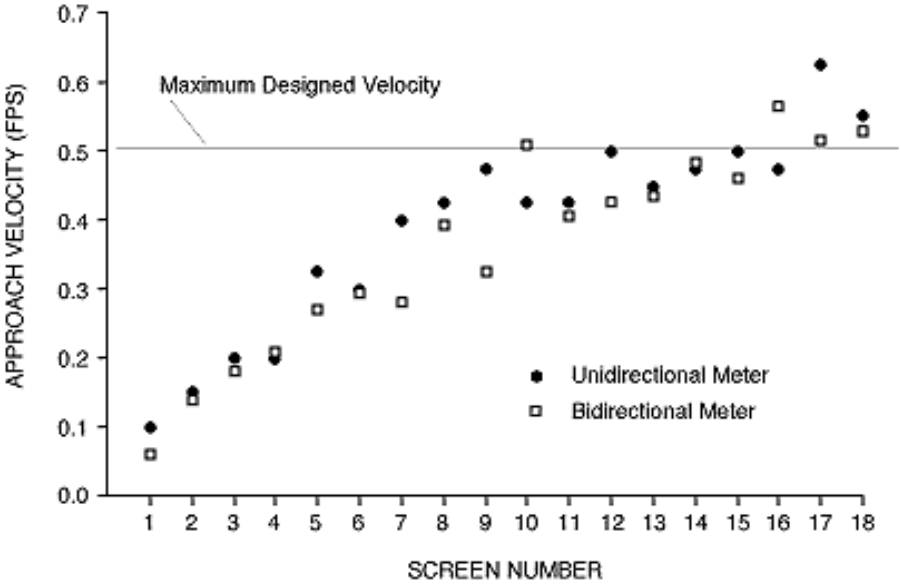


FIGURE 17. Velocity Measurements to Evaluate Flow Balance Through the Drum Screens at the Easton Canal, Summer 1989

DISCUSSION

The measurement objectives were different at each screen facility. At Wapato, approach and sweep velocity measurements were taken to evaluate the effect of rearing pens in the screen forebay. At Chandler, approach, sweep, and vertical velocity measurements were taken in front of the rotary drum screens. Velocities were also measured at the entrance of fish bypasses, in front of traveling screens in the separation chambers, and in the entrance to the fish return. At Easton, velocity was measured behind the screen to provide information for designing porosity boards to balance flow through the screens.

EFFECT OF SALMON-REARING PENS ON VELOCITY MEASUREMENTS AT THE WAPATO SCREENS

Velocity measurements taken at the Wapato Screens before and after the removal of the YIN salmon-rearing pens show that the pens can affect both the magnitude and stability of water velocity in front of the drum screens. Approach and sweep velocities were erratic in front of the drum screens when the pens were in the forebay and stable after the pens were removed. The magnitude of approach velocity at the screen face was not affected; however, the sweep velocity was less at 0.2 of the depth and greater at 0.8 of the depth when the pens were in place.

The unstable velocity readings we observed are believed to be the result of swirling water moving along the face of the drum screens, based on visual observations made during data collection. Swirling water could result in intermittent high impingement velocities for small fish as the swirl moves along the face of the screens; however, no fish impingement was observed on drum screens adjacent to the rearing pens in screen integrity tests conducted in 1988 (Neitzel et al. 1990b).

Velocity measurements taken at the Wapato Canal with the rearing pens in the screen forebay did not compare well with data collected in 1988 (Abernethy et al. 1989) under similar canal flow and operating conditions. Factors that might have caused differences in the two data sets are

- differences in sedimentation in the screen forebay
- the location and number of inoperable screens when the measurements were made
- the degree of algal fouling on the screen panels in the rearing pens
- day-to-day variation of hydraulic conditions within the canal.

The greatest discrepancies in velocities between the two data sets occurred in measurement locations that were adjacent to inoperable screens or wing walls.

VELOCITY CHARACTERISTICS AT THE CHANDLER SCREENS

Water flow in the Chandler Screens forebay was very uniform, based on visual observation. Few current lines or swirls were visible. However, it appeared that the canal forebay is too wide to maintain an adequate sweeping velocity in front of the screens. Additionally, our velocity measurements indicated that porosity boards will probably be required to achieve more flow through the drum screens at the upstream end of the facility.

Low flows through drum screens at the upstream end appear to be a common problem at screening facilities with the drum screens installed at an angle to canal flow. Modification in hydraulics resulting from installation of

porosity boards may be partially responsible for increased turbulence in the screen forebay.

Based on velocity measurements at the entrance of each of the three fish bypasses and in the separation chamber, fish return flow did not meet design criteria specifications. Although approach velocities did not exceed 0.5 fps during our data collection, only one of the two pumps behind each screen was operating. During four-pump operation of the separation chamber, impingement velocities could increase substantially at the face of the traveling screens.

FLOW BALANCE AT THE EASTON SCREENS

The low flow through drum screens at the upstream end of the Easton Screens indicates that porosity boards are needed to balance flows. Poor flow through the screens may be partially attributable to water flow around a bend in the canal upstream of the screen forebay that results in high sweeping velocity along the outer wall of the forebay. Porosity boards were installed following our measurement series, and flow balance through the screens was improved (Hosey & Associates 1989).

SUMMARY

Velocity measurements were conducted at three fish screening facilities in the Yakima River Basin: the Wapato, Chandler, and Easton Screens. Our objective at the Wapato Screens was to determine if the salmon-rearing pens in the forebay adversely affected flow parameters in front of the drum screens. At the Chandler Screens, our objective was to determine if velocity parameters in front of the rotary drum screens and within components of the fish bypass system were consistent with design specifications necessary to provide effective fish bypass. The objective of flow measurements at the Easton Screens was to determine where porosity boards were needed to equalize water flow through the drum screens.

WAPATO SCREENS

Velocity measurements taken before and after the removal of three salmon-rearing pens from the screen forebay indicated that although the pens had only a minimal effect on actual approach and sweep velocities at the face of the drum screens, the pens contributed to increased turbulence and instability of the water flow. Swirls and turbulence at the face of drum screens could result in intermittent increases in approach velocities. The net pens did not appear to affect flows through the three fish bypasses.

CHANDLER SCREENS

Approach velocity was low in front of the drum screens at the upstream end of the facility but steadily increased in front of drum screens at the downstream end of the facility. Porosity boards are needed to balance flow through the array of screens.

Sweep velocity was generally low in the Chandler Screens forebay, especially under the curvature of the drum screens. Low sweep velocities and elevated approach velocities under the curvature of the drum screens result in velocity conditions that do not meet the design criteria standards.

Flow through each of the three fish bypasses were less than specified in the operating criteria. Sweep velocity in the separation chamber was generally low. Approach velocity at the face of traveling screens in the separation chamber were within design criteria guidelines; however, only two of the four bypass pumps were operating when the measurements were taken. Flow out the fish return pipe appeared to be adequate.

EASTON SCREENS

The low flow through drum screens at the upstream end of the Easton Screens indicates that porosity boards are needed to balance flows. Poor flow through the screens may be partially attributable to water flow around a bend in the canal upstream of the screen forebay that results in high sweeping velocity along the outer wall of the forebay. Porosity boards were installed following our measurement series, and flow balance through the screens was improved (Hosey & Associates 1989).

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