PAP 928

Roza Fish Scren Facility Velocity Measurements With and Without Porosity Boards at an Intermediate Canal Flow Rate

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United States Department of the Interior
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STUDY SUMMARY

A comprehensive velocity evaluation was conducted in March 2004 at the Roza Fish Screens Facility to determine the flow conditions during a critical juvenile fish passage period. The facility was operated under design specified criteria at an intermediate flow rate. To determine the effect of porosity boards on drum screen performance, data was collected with porosity boards installed and with porosity boards removed downstream of the drum screens. Approach and sweep velocity components were measured at 0.2 and 0.8 times the water depth at three lateral locations across each drum screen. These measurements were taken approximately 3 inches in front of all drum screens in all bays.

Approach and sweep velocities were measured at approximately 3 inches in front of the first three traveling screens in the separation chamber at depths of 0.2 and 0.6 times the water depth (data collection at 0.8 times the water depth could not be achieved due to equipment limitations). Velocity data was analyzed for compliance with National Marine Fisheries Service (NMFS) federal fish protection criteria. Velocities were also measured at 0.2 and 0.8 times the water depth in all intermediate bypasses and in the terminal bypass to determine the bypass flow rates.

Conclusions from the evaluation include:

<u>Drums Screens</u>

- With porosity boards installed, approach velocities were less than the NMFS fish screen criteria of 0.4 ft/s at all locations on all drum screens. Without porosity boards, approach velocities exceeded the NMFS criteria in one location: the most upstream measurement location in Bay 1.
- With and without the porosity boards installed, the sweep velocity component was 2.7 to 5.4 times greater than the approach velocity at all locations.
- Vertical and lateral velocity distributions over the drum screen faces were relatively uniform with porosity boards installed and removed. The most upstream drum screen in each bay (screens 5, 10, 15, 20, and 27) showed the greatest nonuniformity.
- Sweep velocities at the drum screens indicate a gradual velocity increase into the intermediate bypass entrances.
- At this flow rate,. porosity boards produce better hydraulic conditions near the screens. With porosity boards, approach velocities are slightly lower and sweep to approach velocity ratios are slightly higher than without porosity boards.
- Drum screen submergence was 75% of the water depth at the screen seat for all tests.

Separation Chamber

- The approach velocity at 0.2 times the water depth in front of Screen 2 in the separation chamber exceeded the NMFS velocity criteria of 0.4 ft/s by 0.05 ft/s. Screens 1 and 3 were in compliance.
- Sweep velocities at the traveling screens were 2.5 to 8.7 times greater than approach velocities.

Fish Bypasses

- Downstream bays bypass more water than upstream bays (Bay 1 bypassed 5.2 cfs more water than Bay 5).
- Bypass flow rates compare closely with data collected in July 2003 (Bypass 1 flow rates are the same and Bypass 4 flow rates are within 1% of the same value).

INTRODUCTION

Roza Diversion Dam is part of the Roza Division of the Bureau of Reclamation's Yakima Project. The dam is located 10 miles north of the city of Yakima on the Yakima River at river mile 127.9. The dam diverts up to 2,000 cfs of water from the Yakima River into the Roza Irrigation Canal to provide irrigation water to approximately 72,500 acres of land north of the Yakima River. The canal headworks consist of a concrete structure in the right abutment with a trashrack at the inlet to protect a series of rotating fish screens. The Roza Dam fish screening facility protects fish from being entrained in the Roza Irrigation Canal. The facility consists of 27 drum screens (17.5 ft diameter, 12 ft width) in 5 bays with 7 screens in the upstream bay and 5 screens in each of the following bays. Each bay contains an intermediate fish bypass. An adjustable weir gate in each bypass controls flow through the fish bypass system. The intermediate bypasses converge into a separation chamber where excess water is recovered through four vertical traveling screens. The terminal fish bypass returns fish to the Yakima River at an outfall downstream of Roza Dam.

Juvenile fish trapping studies at Roza Dam indicate that the smallest juveniles pass by the facility early in the out-migration season in January and February when the canal operates at a reduced flow rate. Since small juveniles are at the greatest risk of entrainment into the canal, the hydraulic conditions at the drum screens are critical for juvenile survival during this time period. The National Marine Fisheries Service (NMFS), the fisheries division of the National Oceanic and Atmospheric Administration (NOAA), has developed fish screen criteria to promote safe passage of fish through screening facilities (NMFS, 1995). Criteria relevant to this particular study include:

- Approach velocities must be less than 0.4 ft/s.
- Sweeping velocities must be greater than approach velocities.
- A uniform velocity distribution should be maintained over the screen surface to minimize approach velocities.
- The minimum bypass entrance flow velocity must be greater than or equal to the maximum flow velocity vector resultant upstream of the screens. A gradual and efficient acceleration of flow into the bypass entrance is required to minimize delay by out-migrants.
- Drum screen submergence must be between 65 and 85% of the drum diameter.

To ensure that the NMFS screen criteria are satisfied, field velocity measurements near the fish drums and in the fish bypasses should be obtained periodically or when operational or structural changes occur at the screening facility.

Pacific Northwest National Laboratory (PNNL) has conducted many fish screen evaluations in the Yakima River Basin since 1985. Methods to evaluate screening facilities were developed and applied during the PNNL studies (Abernathy et al., 1988, 1990; Blanton et al., 1998, 1999; Carter et al., 2002; Chamness et al., 2001). In July 2003, Battelle-Pacific Northwest Division measured water velocities throughout the Roza fish screen facility under two operational conditions (McMichael et al., 2003):

1.) Fish bypass discharges operated at the design specified criteria.
2.) Fish bypass discharges operated at approximately half of the design specified criteria with a lower gravity weir elevation behind the traveling screens in the separation chamber.

Under these two conditions, researchers measured water velocities in front of screens in two of the five screen bays, in their associated intermediate fish bypasses, and in the separation chamber and terminal bypass at a canal flow rate of approximately 1,850 cfs. The results of the evaluation indicate that the NMFS screen criteria were not met at several screens when the fish bypasses were operated both in and out of criteria. Sediment sluicing devices, or porosity boards, were installed in 2001. Since the porosity boards were not included in the original design of the screens, the effect of the porosity boards on the hydraulic conditions at the screens was unknown at the time.

The objective of the March 2004 facility study was to perform a comprehensive velocity evaluation similar to the July 2003 evaluation under design specified bypass criteria with and without the porosity boards installed. For the March 2004 tests, approach and sweep velocities were measured in front of all drum screens in all bays. The tests occurred during a critical juvenile passage period at an intermediate canal flow rate of 820 cfs. Another velocity evaluation is proposed for Summer 2004 when the canal is operating at full capacity.

INSTRUMENTATION AND METHODS

Data collection occurred from March 4 – 10, 2004 at the Roza Fish Screens Facility prior to seasonal irrigation deliveries. The facility was operated under standard design criteria during field testing. A consistent canal flow rate of approximately 820 cfs was maintained during this time period, corresponding to forebay elevations of 1220.49 $\pm$ 0.05 ft and forebay water depths of 12.1 $\pm$ 0.05 ft. The drum screen submergence was 75% of the water depth at the screen seat. Porosity boards were installed in May 2003 as sediment sluicing devices. Located downstream of each rotating drum screen, the porosity boards are placed 1 ft from the channel bottom to increase velocities near the bed as a means of reducing fine sediment build-up in front of the screens. The top of the boards is about 1 ft below the water surface, allowing overtopping flow. The impact of the porosity boards on velocity magnitudes and distributions was examined in this study.

With the porosity boards removed, four extended workdays were needed to measure velocities at all drum screens, at the separation chamber traveling screens, and in the intermediate and terminal bypasses. After the first data set was collected, one day was needed for Roza fish screen facility operators to install all of the porosity boards. Two extended workdays were needed to collect velocity data at all drum screens with the porosity boards installed.

A downlooking SonTek Acoustic Doppler Velocimeter (ADV) was used to measure three-dimensional velocity data at a location 5 cm below the receiver at a sampling rate of 25 Hz for 60 seconds. The data were then time-averaged to obtain mean velocities at each measurement location.

Velocity data was measured with the ADV in the following locations:

1.) Approach and sweep velocities were measured approximately 3 inches in front of all 27 drum screens in all five bays at 0.2 and 0.8 of the water depth. Lateral measurements were taken at 3 ft, 6 ft, and 9 ft from the upstream edge of each screen. Complete data sets were collected with and without porosity boards.
2.) Velocity measurements were collected at 0.2 and 0.8 of the water depth in all five intermediate bypass channels and in the terminal bypass at the horizontal centerline of each bypass.
3.) Centerline velocity measurements were collected at 0.2 and 0.6 of the water depth in front of the first 3 screens of the separation chamber. A desired depth of 0.8 was not possible due to ADV deployment mount limitations. Screen 4 was inaccessible.

Drum Screen Measurements

Three-dimensional velocity data was measured with the ADV in front of all 27 drum screens in all 5 bays. Measurements were taken at three lateral locations across each drum screen: 3 ft, 6 ft, and 9 ft from the upstream edge of the 12 ft wide screen. Approach and sweep velocities are the typical velocity components analyzed during fish screen evaluations. According to NMFS, the approach velocity in a fish screen evaluation is defined as the water velocity component perpendicular to and approximately three inches in front of the screen face. The sweeping velocity is defined as the water velocity component parallel and adjacent to the screen face (NMFS, 1995).

In a previous PNNL study at the Roza facility by Abernathy et al. (1988), velocities were measured at multiple vertical locations in front of the drum screens. Their results indicated that velocities measured at 0.2 and 0.8 of the water depth accurately represent the vertical velocities experienced over the height of the drum screen. These specific depths were chosen because of their hydraulic significance in determining the mean velocity with a fully developed velocity profile for depths greater than 2 ft. This method has become the standard for evaluating velocities near fish screens in the Yakima River Basin.

The floor of the forebay is 1 ft higher than the aftbay floor due to a recessed floor at the drum screen. Based on the forebay elevation, measurements were taken at 0.2 and 0.8 of the water depth as measured from the water surface. With a typical 75% screen submergence, the 0.2 depth is just above the centerline of the drum, and the ADV can be accurately positioned close to the screen face (Figure 1). Since the 0.8 depth is well below the curvature of the drum screens, access to the screen face is difficult for large diameter drum screens such as the Roza screens.

Figure 1. – Placement of ADV at 0.2 of the water depth at a distance of about 3 inches from the drum screen.

Maintaining an upright probe orientation, it was not possible to obtain near-screen measurements of 3 inches from the rotating fish drum at the 0.8 depth in this study. Due to limitations in the ADV mount and the body shape of the ADV instrument, velocity measurements could only be taken approximately 12-15 inches from the screen face. Inverting the probe was considered but not performed due to the high probability of equipment damage. Without visual cues at the 0.8 depth, there were concerns of the unprotected probe transducers contacting the screen face, the probe cable hanging up on bottom debris, and silt deposition restricting movement (typically 4 to 6 inches of accumulated silt was felt at the bottom with a long rod). Since measurements were not taken as close to the screen face as criteria requires, a sensitivity analysis was conducted to determine the sensitivity of the velocity readings as a function of distance from the screen face. Velocities ranging from 3 to 15 inches from the screen face were analyzed at 0.2 of the water depth for the sensitivity analysis (Figure 2, Table 1).

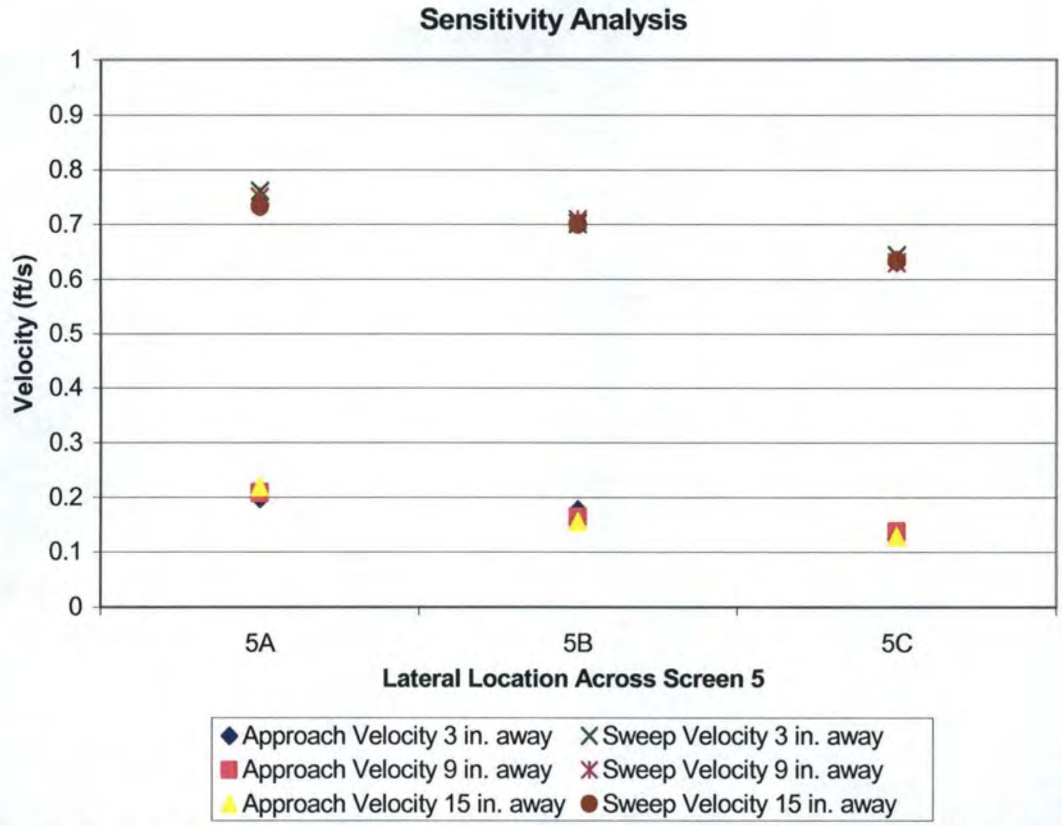

Figure 2. – Comparison of approach and sweep velocity data at 3, 9, and 15 inches from the screen face. Positions 5A, 5B, and 5C are located 3 ft, 6 ft, and 9 ft from the upstream edge of Screen 5, respectively.

Table 1. – Approach and sweep velocity data measured at 3, 9, and 15 inches from Screen 5 at 0.2 times the water depth. For velocities measured at 9 and 15 inches from the screen, the percent difference from the velocity data at the 3-inch criteria from the screen was calculated. Standard errors of the velocity readings are not reported since all error values were less than 0.01 ft/s.

Position	Distance from Upstream Edge	Approach Velocity (ft/s)	% Difference from 3 in. Velocity Data	Sweep Velocity (ft/s)	% Difference from 3 in. Velocity Data
5A	3 in.	0.20	--	0.76	--
5A	9 in.	0.21	5.2	0.75	1.4
5A	15 in.	0.22	10.8	0.73	3.7
5B	3 in.	0.18	--	0.70	--
5B	9 in.	0.16	7.2	0.71	1.0
5B	15 in.	0.16	11.7	0.70	0.1
5C	3 in.	0.13	--	0.64	--
5C	9 in.	0.14	3.3	0.63	2.1
5C	15 in.	0.13	3.0	0.63	1.5

The sensitivity analysis shows that velocity data collected farther away from the screen is not consistently lower or higher than data collected near to the screen. Velocities measured at 9 and 15 inches from the screen face were 0.1% to 11.7% different from velocities collected at the 3-inch criteria from the screen. Although the data for the sensitivity analysis was collected at 0.2 of the water depth, the results can be loosely compared to the anticipated velocity field at 0.8 depth.

The ADV deployment mount was reused from a previous velocity evaluation (McMichael et al., 2003). The 23 ft long L-shaped steel frame allowed adjustments for the depth of the ADV in the water column and the distance from the screen face (Figure 3). For the drum screen measurements, once the ADV was positioned at the proper depth, the assembly was fixed to a gantry crane and positioned laterally along the screens (Figure 4). In each bay, all lateral locations were measured at one depth before the mount was detached from the gantry crane and removed from the water. The probe was repositioned on the mount and the instrument was redeployed to measure all lateral locations at the other depth. Two complete sets of measurements were collected for the drum screen evaluation with porosity boards removed (Figure 5) and with porosity boards installed (Figure 6).

Figure 3. – The deployment mount positioned the instrument 3 inches from the screen face.


Figure 4. – The deployment mount was attached to a gantry crane that moved laterally across each drum screen in the bay. ADV data was collected at each location and stored in individual data files.

Figure 5. – Rotating drum screens at Roza screening facility with porosity boards removed.

Figure 6. – Rotating drum screens at Roza screening facility with porosity boards installed.

Separation Chamber Measurements
During data collection, the water elevation in the separation chamber was 1213.8 ± 0.1 ft, corresponding to a water depth of 12.7 ± 0.1 ft (Figure 7). Velocity measurements were collected at 0.2 and 0.6 of the water depth at the centerline of the first 3 screens in the separation chamber. Screen 4 was inaccessible due to the structural layout of the site. Data was collected at 0.6 instead of 0.8 times the depth due to insufficient length of the deployment mount.

Figure 7. – Velocity measurements were taken at the centerline of the first three traveling screens in the separation chamber.

Figure 8. – The deployment mount was used to position the ADV approximately 3 inches in front of the traveling screen face.

Fish Bypass Measurements

The ADV was also used to measure velocities in the intermediate and terminal fish bypass channels. In the intermediate bypasses, there is a 90-degree bend as water moves from the screening area into the bypass channel. A ramped floor increases the fish attraction flow over an adjustable weir into a closed conduit bypass. Velocity measurements were taken as far away from the bend as possible and upstream of the onset of the ramped floor. The ADV was positioned at 0.2 and 0.8 of the water depth and the steel mount was inserted into the 24-inch wide fish bypass channel and clamped in place as shown in Figure 9. To ensure that the flow was uniformly distributed across the width of the bypasses, velocity measurements were taken at the centerline of the Bay 5 bypass and 4 inches from each sidewall. When only the centerline velocities were used to calculate the flow rate, the discharge was within 0.5% of the value calculated by using all collected velocities. To expedite data collection, only centerline velocities were measured in the remaining bypasses.

Figure 9. – The ADV was attached to a deployment frame for bypass testing. The frame was positioned in the bypass wall slots immediately upstream of the ramp.

In the terminal bypass, a temporary ramped bottom was installed to guide fish to a juvenile trapping facility. Velocity measurements were taken immediately upstream of the ramp. Measurements were taken in the bypasses and the separation chamber with the porosity boards removed. When the porosity boards were installed, the forebay elevation did not change. Therefore, bypass and separation chamber data were not recollected.

RESULTS AND DISCUSSION

Drum Screen Results

In Figures 10 through 14 and 15 through 19, velocity data was measured with porosity boards installed and with porosity boards removed in bays 1 through 5, respectively. All screens and bays are numbered from downstream to upstream. Bay 1 is most downstream bay and bay 5 is most upstream bay. In each bay, the screens are numbered from right to left when looking downstream.

At this intermediate flow rate, flow patterns near the drum screens were highly consistent from bay to bay. With porosity boards installed, the average approach and sweep velocities were consistent throughout all of the bays. With porosity boards removed, the downstream bays passed more water than upstream bays, with slightly higher approach and sweep velocities.

With porosity boards installed, the NMFS approach velocity criteria of 0.4 ft/s was satisfied at all measurement locations in all bays. With porosity boards removed, the most upstream measurement in Bay 1 (location 5A) exceeded the 0.4 ft/s approach velocity criteria by 0.10 ft/s. All other locations satisfied the criteria. With and without the porosity boards, the sweep velocity was always greater than the approach velocity. The average sweep to approach velocity ratio per bay was 4.2 to 5.4 with boards installed and 2.7 to 4.9 with boards removed.

For both conditions, velocities were reasonably uniform over the screen surfaces in all bays, with vertical variations of less than 0.3 ft/s and lateral variations of less than 0.4 ft/s per screen. Near to the surface, the approach velocities were generally lower and the sweep velocities were generally higher than the deeper water measurements (Figures 10 to 19, Table 2).

In general, approach and sweep velocities were higher at the most upstream screen in each bay (left side of bay with downstream orientation) with particularly high velocities at position A (3 ft from the upstream edge of the screen). Velocities were typically lower and more consistent for screens in the middle of the bay and higher for screens nearest to the fish bypass. Although velocity measurements were only taken close to the drum screens, there appeared to be a gradual acceleration of flow into the fish bypass entrance.

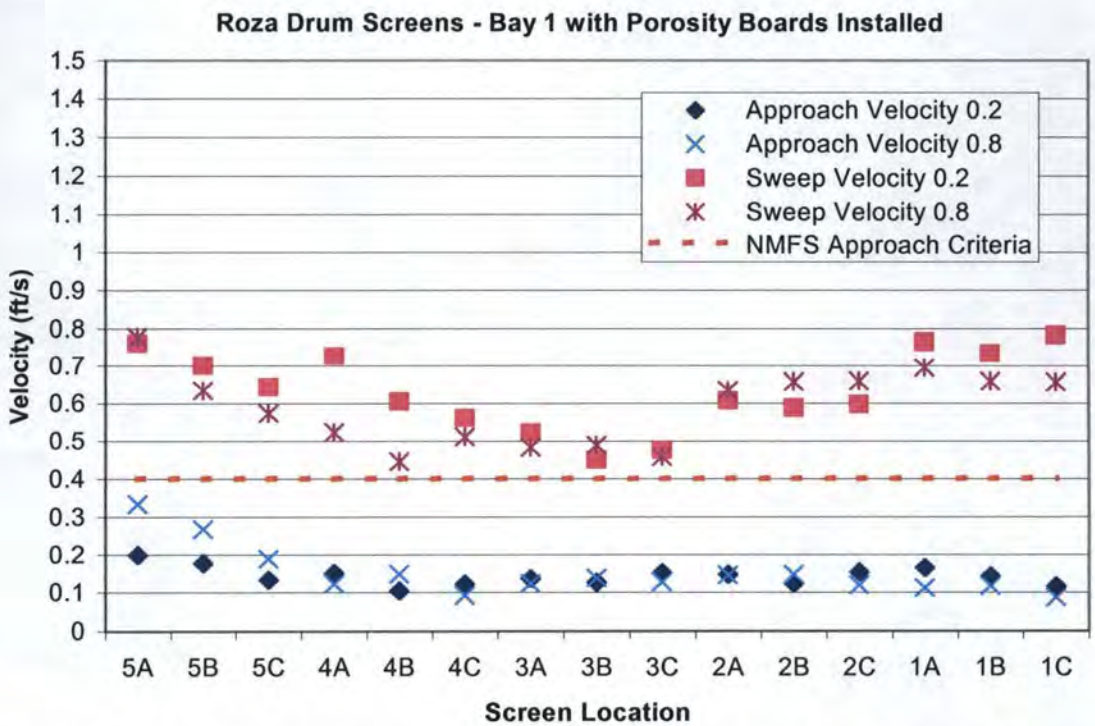

Figure 10. – Bay 1 approach and sweep velocities at 0.2 and 0.8 of the water depth with porosity boards installed. Labels A, B, and C correspond to measurements at 3 ft, 6 ft, and 9 ft from the upstream edge of the screen, respectively.

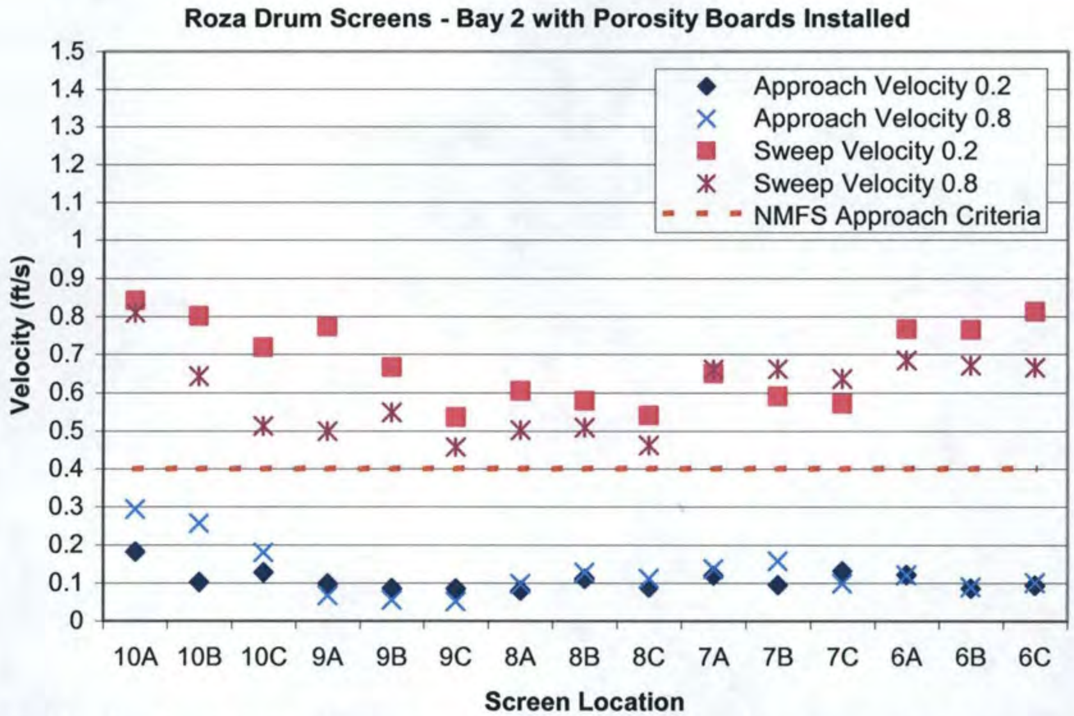

Figure 11. – Bay 2 approach and sweep velocities at 0.2 and 0.8 of the water depth with porosity boards installed. Labels A, B, and C correspond to measurements at 3 ft, 6 ft, and 9 ft from the upstream edge of the screen, respectively.

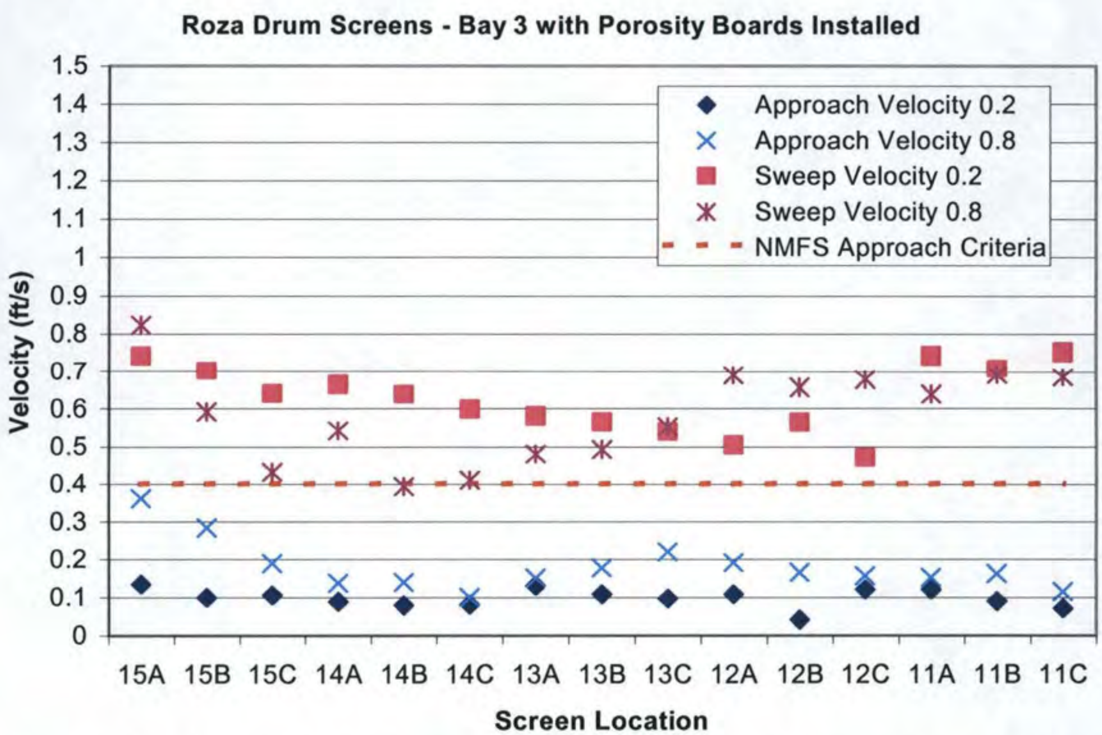

Figure 12. – Bay 3 approach and sweep velocities at 0.2 and 0.8 of the water depth with porosity boards installed. Labels A, B, and C correspond to measurements at 3 ft, 6 ft, and 9 ft from the upstream edge of the screen, respectively.

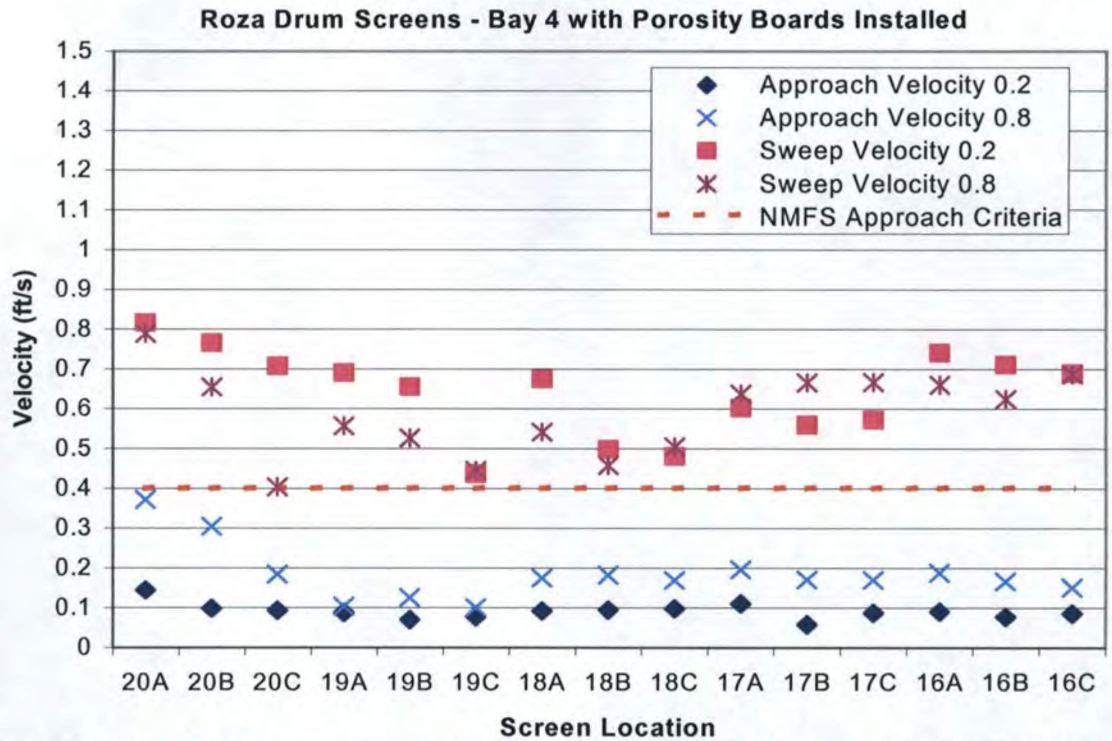

Figure 13. – Bay 4 approach and sweep velocities at 0.2 and 0.8 of the water depth with porosity boards installed. Labels A, B, and C correspond to measurements at 3 ft, 6 ft, and 9 ft from the upstream edge of the screen, respectively.

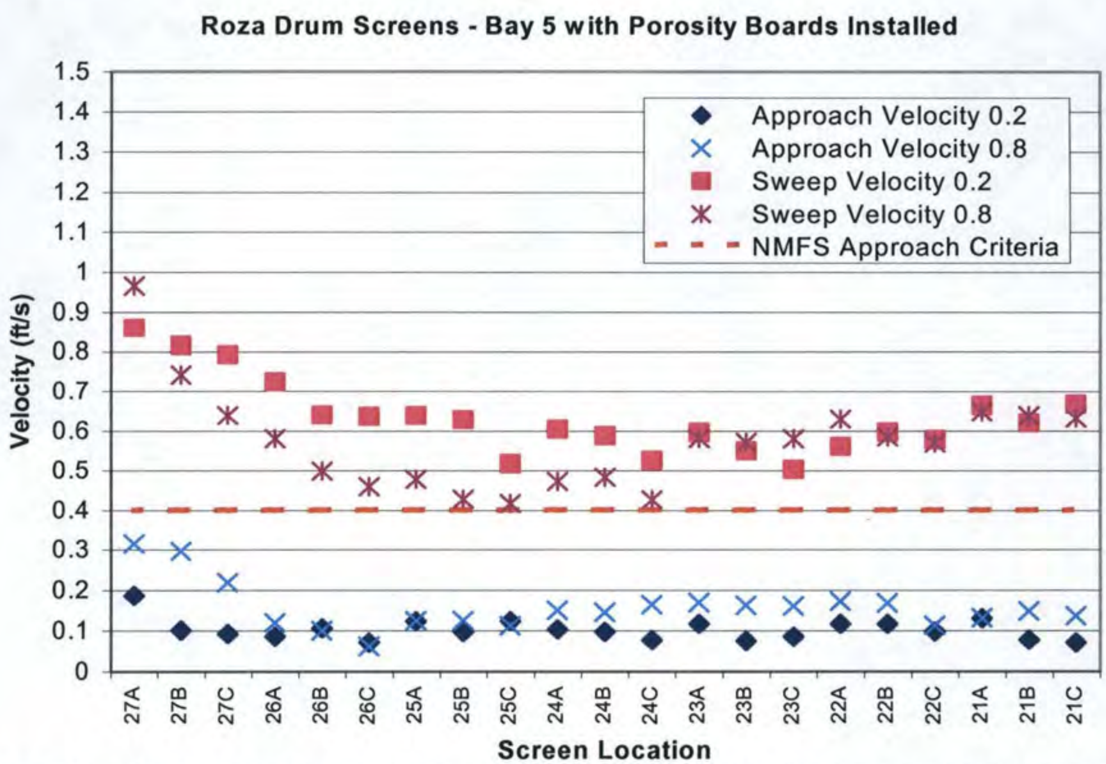

Figure 14. – Bay 5 approach and sweep velocities at 0.2 and 0.8 of the water depth with porosity boards installed. Labels A, B, and C correspond to measurements at 3 ft, 6 ft, and 9 ft from the upstream edge of the screen, respectively.

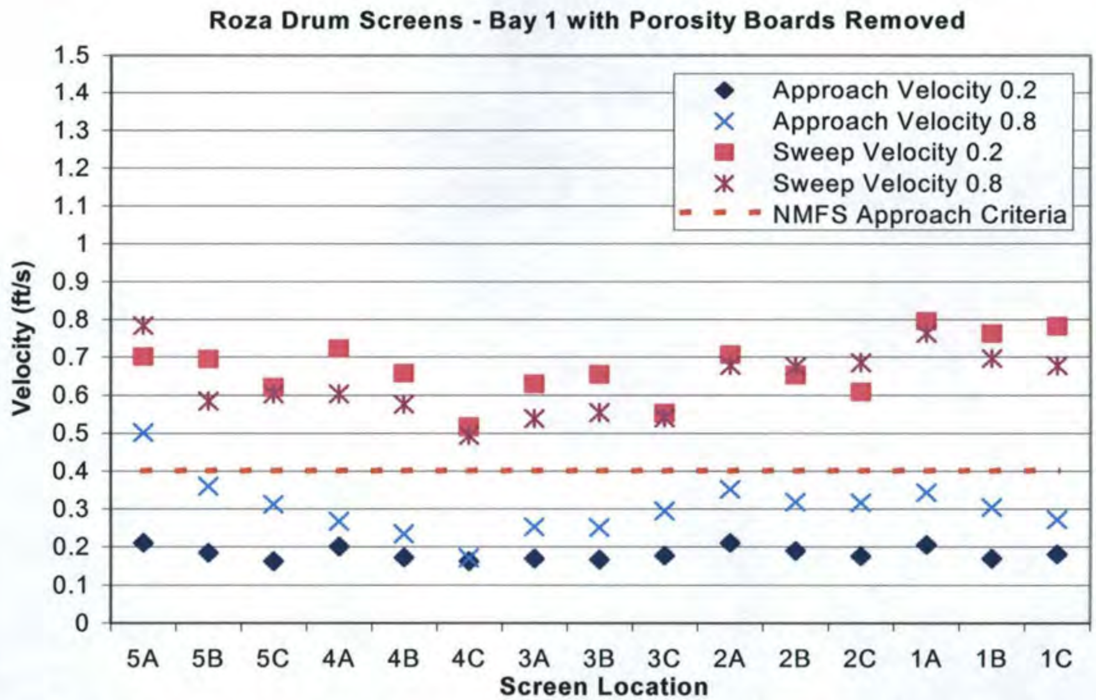

Figure 15. – Bay 1 approach and sweep velocities at 0.2 and 0.8 of the water depth without porosity boards. Labels A, B, and C correspond to measurements at 3 ft, 6 ft, and 9 ft from the upstream edge of the screen, respectively. The approach velocity at 0.8 of the depth at location 5A exceeds the NMFS fish screen criteria by 0.10 ft/s.

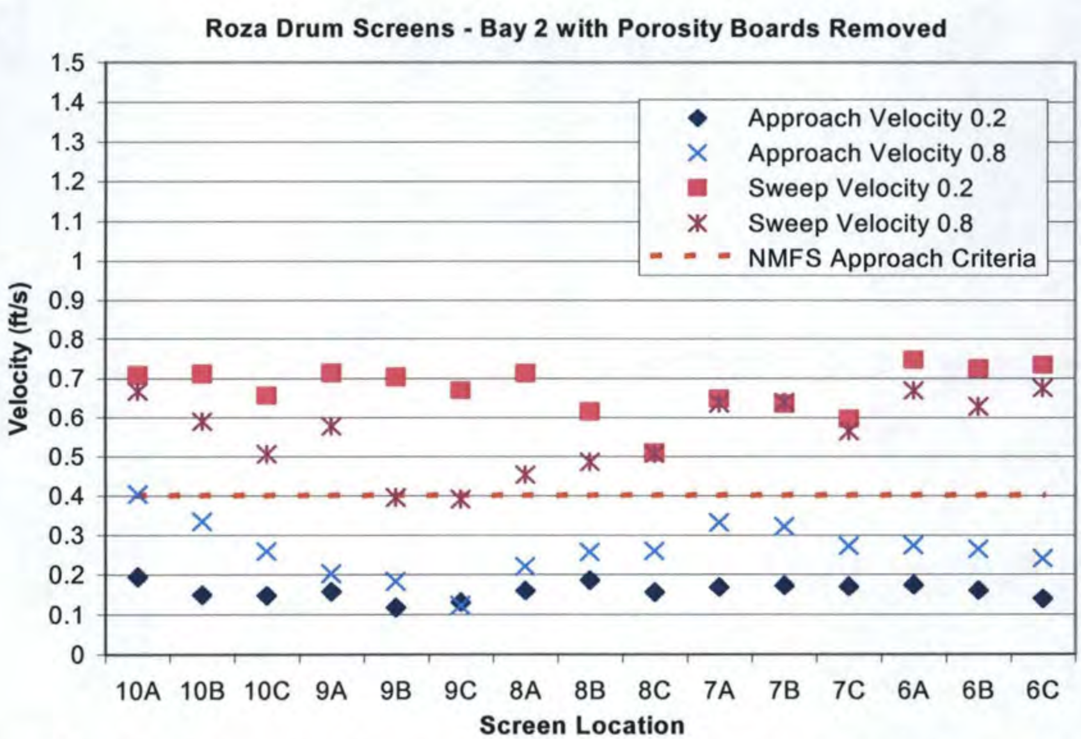

Figure 16. – Bay 2 approach and sweep velocities at 0.2 and 0.8 of the water depth without porosity boards. Labels A, B, and C correspond to measurements at 3 ft, 6 ft, and 9 ft from the upstream edge of the screen, respectively.

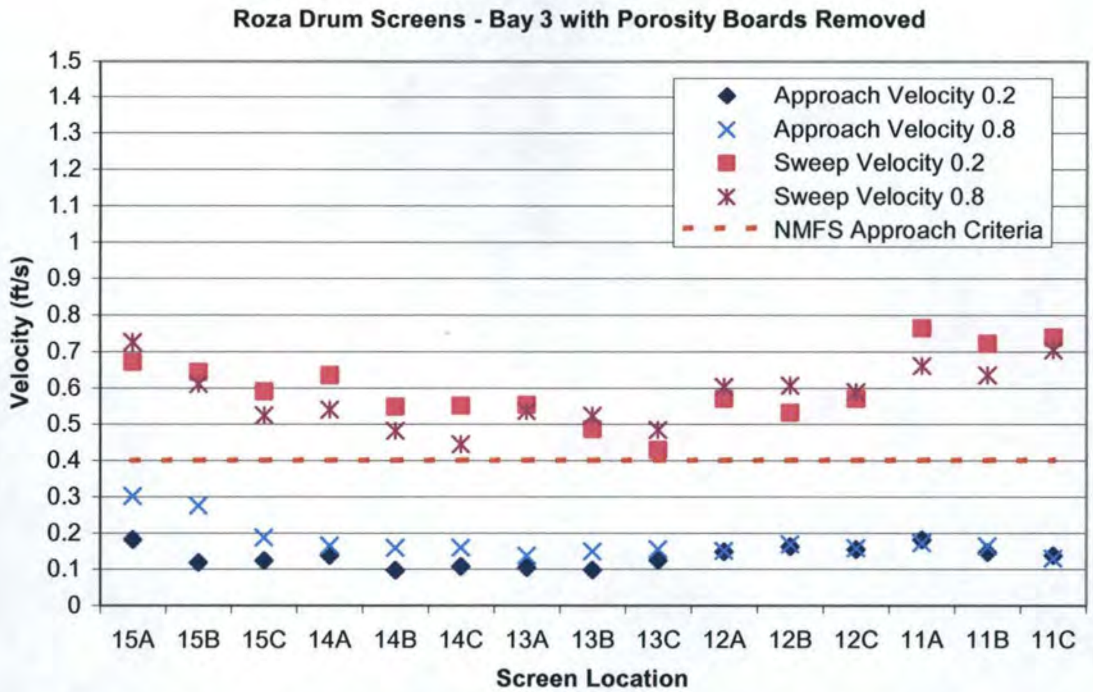

Figure 17. – Bay 3 approach and sweep velocities at 0.2 and 0.8 of the water depth without porosity boards. Labels A, B, and C correspond to measurements at 3 ft, 6 ft, and 9 ft from the upstream edge of the screen, respectively.

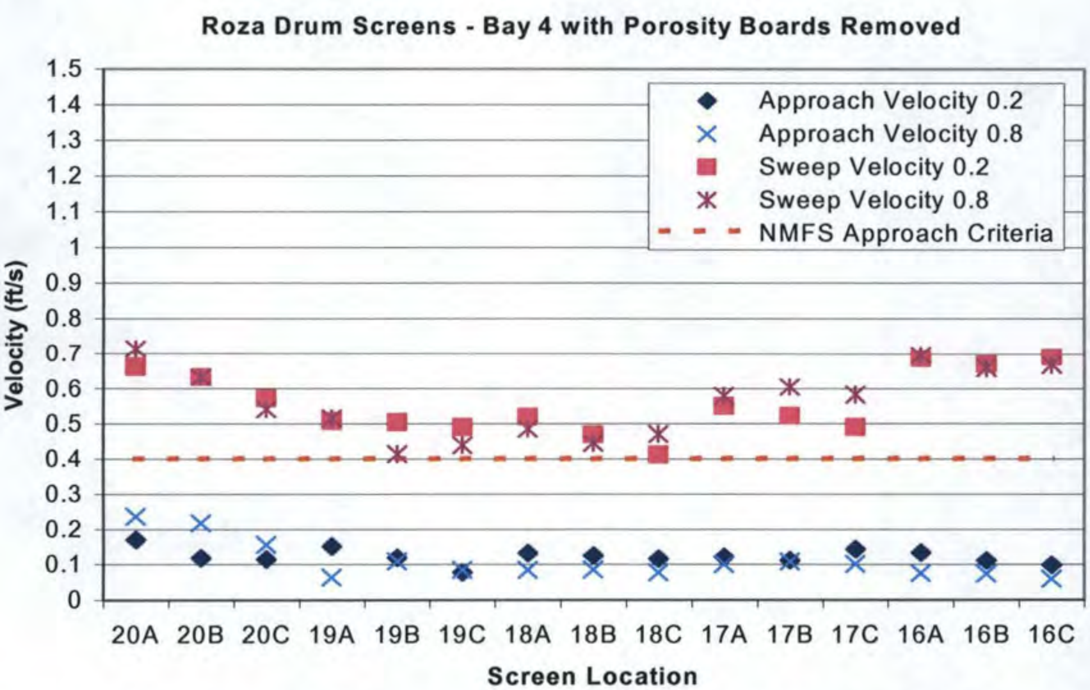

Figure 18. – Bay 4 approach and sweep velocities at 0.2 and 0.8 of the water depth without porosity boards. Labels A, B, and C correspond to measurements at 3 ft, 6 ft, and 9 ft from the upstream edge of the screen, respectively.

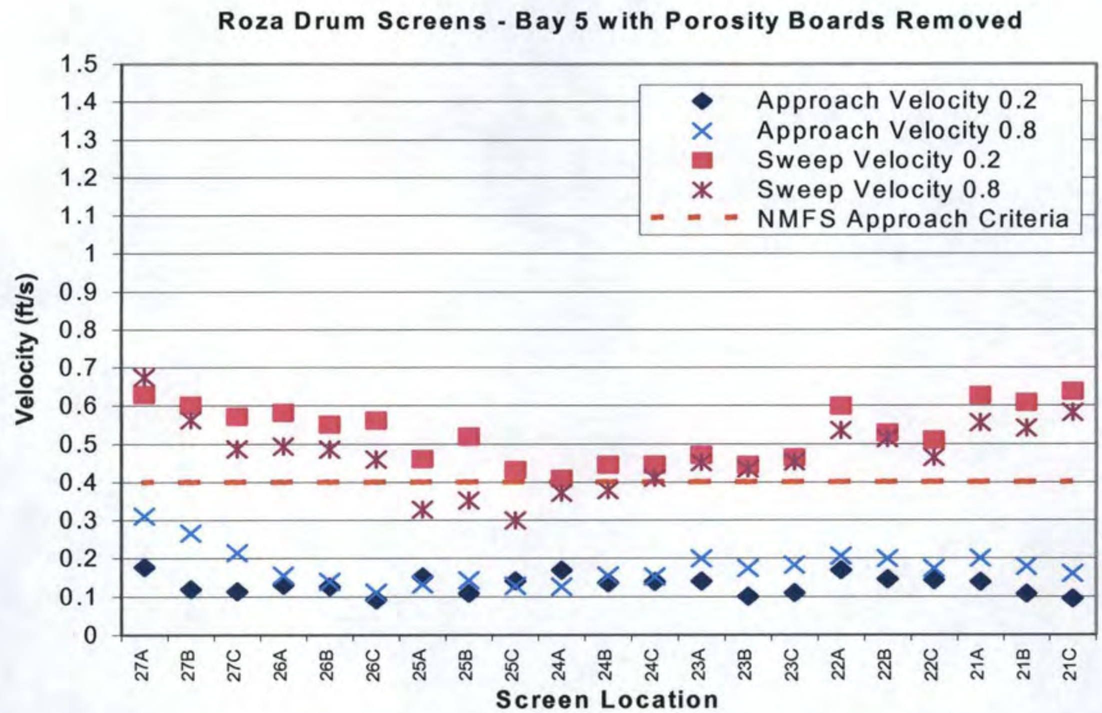

Figure 19. – Bay 5 approach and sweep velocities at 0.2 and 0.8 of the water depth without porosity boards. Labels A, B, and C correspond to measurements at 3 ft, 6 ft, and 9 ft from the upstream edge of the screen, respectively.

Table 2. – Average approach and sweep velocities per bay at 0.2 and 0.8 times the water depth. Standard errors of the velocity readings are not reported since all error values were less than 0.01 ft/s.

	DRUM SCREENS WITH POROSITY BOARDS					
	Approach Velocity 0.2 depth (ft/s)	Sweep Velocity 0.2 depth (ft/s)	Approach Velocity 0.8 depth (ft/s)	Sweep Velocity 0.8 depth (ft/s)	Approach Velocity Average (ft/s)	Sweep Velocity Average (ft/s)
BAY 1	0.14	0.63	0.15	0.59	0.15	0.61
BAY 2	0.11	0.68	0.13	0.59	0.12	0.64
BAY 3	0.10	0.63	0.18	0.58	0.14	0.61
BAY 4	0.09	0.64	0.18	0.59	0.14	0.61
BAY 5	0.10	0.63	0.16	0.57	0.13	0.60

	DRUM SCREENS WITHOUT POROSITY BOARDS					
	Approach Velocity 0.2 depth (ft/s)	Sweep Velocity 0.2 depth (ft/s)	Approach Velocity 0.8 depth (ft/s)	Sweep Velocity 0.8 depth (ft/s)	Approach Velocity Average (ft/s)	Sweep Velocity Average (ft/s)
BAY 1	0.18	0.67	0.30	0.63	0.24	0.65
BAY 2	0.16	0.67	0.26	0.56	0.21	0.61
BAY 3	0.13	0.60	0.18	0.58	0.16	0.59
BAY 4	0.12	0.56	0.11	0.56	0.12	0.56
BAY 5	0.13	0.53	0.18	0.47	0.15	0.50

The velocities measured at the drum screens are similar in pattern to the data collected by Battelle under the design bypass criteria in July 2003. Since a canal flow rate of approximately 1,850 cfs occurred during high flow operation in July 2003, the approach and sweep velocities collected in Bays 1 and 4 were higher than the March 2004 data at a canal flow rate of 820 cfs. In Bay 1, Battelle documented high approach velocities with large vertical and lateral variations over the screen faces. Although these patterns were not present in the March 2004 study, it is anticipated that similar velocity conditions will occur during testing at high flow operations.

From the collected field data, it appears that porosity boards not only reduce sediment load in front of the drum screens, but also produces better hydraulic conditions near the screens. With porosity boards, the approach velocities are slightly lower and the sweep to approach velocity ratio past the screens is slightly higher than without porosity boards. However, at an intermediate flow rate of 820 cfs the screen performance is not greatly different between facility operations with and without porosity boards. It is possible that screen performance may be more significantly affected at a higher canal flow rate.

Separation Chamber Results

Velocities collected near three traveling screens in the separation chamber and in the terminal bypass are presented in Table 3 and Figure 20.

Table 3. – Velocity data collected approximately 3 inches in front of the first three traveling screens in the separation chamber at 0.2 and 0.6 of the water depth. The standard error for each measurement is presented as the standard deviation of the sample set divided by the square root of the number of samples.

Screen Number	Measurement Depth (fraction of total depth in ft)	Approach Velocity (ft/s)	Sweep Velocity (ft/s)	Vertical Velocity (ft/s)
1	0.2	0.30 ± 0.01	0.82 ± 0.01	-0.11 ± 0.01
1	0.6	0.29 ± 0.01	2.32 ± 0.01	0.20 ± 0.01
2	0.2	0.45 ± 0.01	1.12 ± 0.02	0.19 ± 0.01
2	0.6	0.25 ± 0.01	2.18 ± 0.01	0.19 ± 0.01
3	0.2	0.31 ± 0.01	1.30 ± 0.01	0.12 ± 0.01
3	0.6	0.25 ± 0.01	1.69 ± 0.01	0.06 ± 0.01

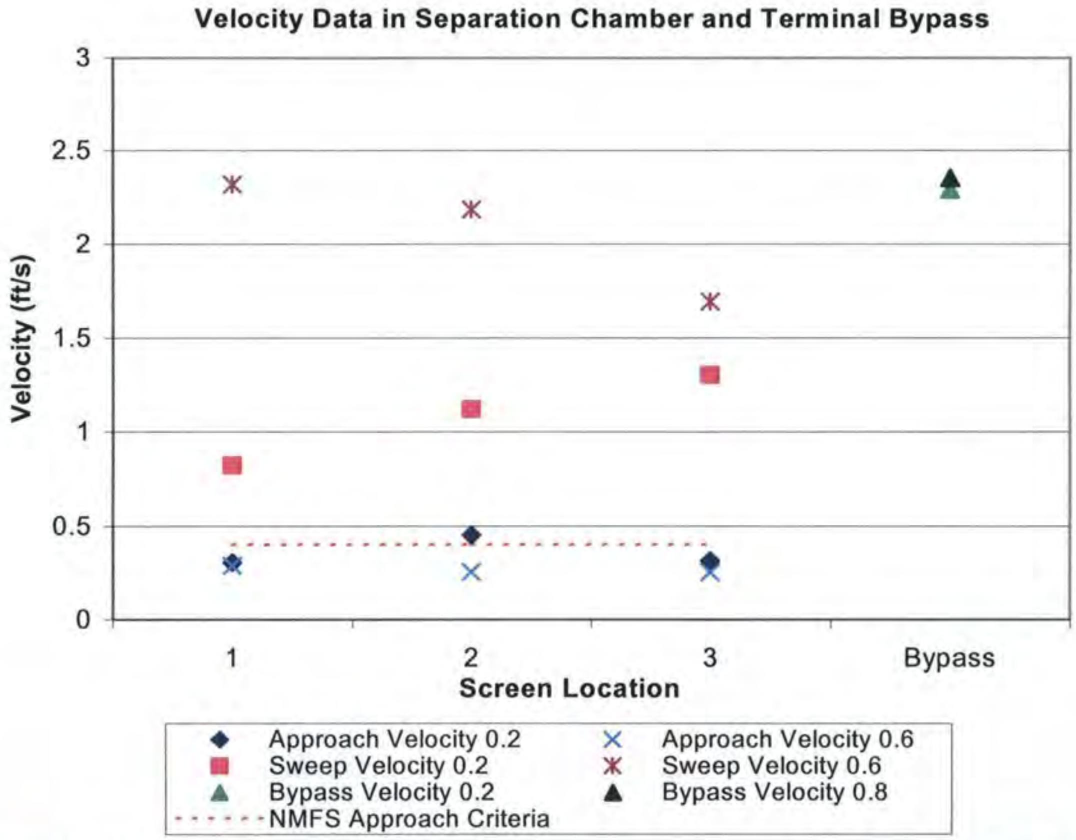

Figure 20. – Velocities measured in front of traveling screens 1 through 3 and in the terminal bypass.

Aside from the Screen 2 measurement of 0.45 ft/s at 0.2 depth, the approach velocities were within NMFS 0.4 ft/s velocity criteria. The approach velocities were vertically and laterally uniform. The sweep velocity components were 2.5 to 8.7 times greater than the approach velocity components. The sweep velocities were significantly varied, particularly at Screen 1. Turbulent flows entering the separation chamber near Screen 1 may reduce velocity uniformity.

Results from March 2004 show similar flow patterns to the July 2003 field evaluation. Approach velocities were slightly higher and exceeded criteria during the high flow tests in July 2003. Sweep velocities were similar in magnitude between the two sets of field data.

Fish Bypass Measurements

Table 4 displays bypass velocities measured in the intermediate bypass channels of each screening bay and the terminal bypass downstream of the separation chamber. Water depth was measured with a staff gauge and velocities were measured at 0.2 and 0.8 of the water depth. Mean velocity and bypass flow rate were estimated from the field data.

Table 4. – Measured bypass velocities and associated standard errors, measured forebay depths, and calculated flow rates in the intermediate and terminal bypasses. Standard errors of the velocity readings are not reported since all error values were less than 0.01 ft/s.

	$V_{0.2}$ (ft/s)	$V_{0.8}$ (ft/s)	V_{mean} (ft/s)	Forebay Depth (ft)	Bypass Flow Rate (cfs)
Terminal Bypass	2.29	2.35	2.32	6.21	28.8
Bay 1	2.69	2.87	2.78	12.05	67.0
Bay 2	2.70	2.81	2.75	12.05	66.3
Bay 3	2.63	2.76	2.69	12.05	64.9
Bay 4	2.52	2.68	2.60	12.05	62.6
Bay 5	2.44	2.69	2.57	12.00	61.8
				Total Bypass Flow Rate (cfs) =	322.7

The water depth was consistent across all intermediate bypasses. Bypass flows increased from upstream to downstream such that Bay 1 bypassed 5.2 cfs more water than Bay 5. Although the bypass flow rate was greater in Bay 1, the drum screen velocities were only slightly higher than other bays at an intermediate flow rate.

The March 2004 comprehensive bypass flow evaluation yielded similar results to the July 2003 bypass flow data. In July 2003, the Bay 1 and 4 bypass flows were 67.0 cfs and 63.2 cfs with a terminal bypass flow of 20.0 cfs. In March 2004, the Bay 1 and 4 bypass flows were 67.0 cfs and 62.6 cfs with a terminal bypass flow of 28.8 cfs.

RECOMMENDATIONS

The results of the March 2003 velocity evaluation show that juvenile fish passing through the screening facility at an intermediate flow rate are exposed to acceptable velocity conditions at the rotating drum screens both with and without the porosity boards. To verify the effect of the porosity boards on the performance of the drum screens at higher flow rates, it is recommended that a summer evaluation of all screens in all bays be conducted with and without the porosity boards at a full canal capacity of approximately 2,000 cfs.

In July 2003, velocity measurements were collected by Battelle in the separation chamber and the terminal bypass under high flow conditions of 1,850 cfs at standard bypass design criteria. Unless the flow rate is significantly different during the proposed summer evaluation or data verification is desired, it does not seem necessary to recollect this data. Velocities in the intermediate bypasses will need to be collected during the high flow evaluation if the bypasses are operated outside of design criteria or if the forebay water elevation is significantly different than the July 2003 tests.

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APPENDIX I: Drum Screen Velocity Data

BAY 1 Velocity Data with Porosity Boards

Screen Number	Distance from Leading Edge Of Screen (ft)	Fractional Depth (ft)	Notation	Approach Velocity Toward Screen (ft/s)	Sweep Velocity Toward Bypass (ft/s)	Vertical Velocity Upward (ft/s)
5	3	0.2	5A	0.198	0.761	-0.014
5	6	0.2	5B	0.176	0.701	-0.041
5	9	0.2	5C	0.132	0.643	-0.065
4	3	0.2	4A	0.151	0.727	-0.059
4	6	0.2	4B	0.104	0.605	-0.055
4	9	0.2	4C	0.122	0.561	-0.053
3	3	0.2	3A	0.136	0.522	-0.040
3	6	0.2	3B	0.126	0.450	0.002
3	9	0.2	3C	0.152	0.476	-0.063
2	3	0.2	2A	0.147	0.607	-0.065
2	6	0.2	2B	0.124	0.588	-0.048
2	9	0.2	2C	0.154	0.597	-0.041
1	3	0.2	1A	0.165	0.765	-0.073
1	6	0.2	1B	0.142	0.734	-0.062
1	9	0.2	1C	0.115	0.782	-0.074
5	3	0.8	5A	0.333	0.777	-0.252
5	6	0.8	5B	0.267	0.634	-0.220
5	9	0.8	5C	0.188	0.573	-0.168
4	3	0.8	4A	0.122	0.522	-0.091
4	6	0.8	4B	0.148	0.445	-0.133
4	9	0.8	4C	0.091	0.510	-0.085
3	3	0.8	3A	0.123	0.482	-0.102
3	6	0.8	3B	0.138	0.489	-0.119
3	9	0.8	3C	0.127	0.458	-0.101
2	3	0.8	2A	0.146	0.634	-0.132
2	6	0.8	2B	0.147	0.657	-0.155
2	9	0.8	2C	0.119	0.658	-0.141
1	3	0.8	1A	0.111	0.694	-0.142
1	6	0.8	1B	0.116	0.658	-0.128
1	9	0.8	1C	0.086	0.655	-0.126

BAY 2 Velocity Data with Porosity Boards

Screen Number	Distance from Leading Edge Of Screen (ft)	Fractional Depth (ft)	Notation	Approach Velocity Toward Screen (ft/s)	Sweep Velocity Toward Bypass (ft/s)	Vertical Velocity Upward (ft/s)
10	3	0.2	10A	0.182	0.842	-0.006
10	6	0.2	10B	0.102	0.800	-0.026
10	9	0.2	10C	0.128	0.719	-0.067
9	3	0.2	9A	0.099	0.773	-0.080
9	6	0.2	9B	0.086	0.666	-0.044
9	9	0.2	9C	0.085	0.535	-0.063
8	3	0.2	8A	0.080	0.604	-0.040
8	6	0.2	8B	0.111	0.579	-0.040
8	9	0.2	8C	0.088	0.540	-0.019
7	3	0.2	7A	0.119	0.649	-0.027
7	6	0.2	7B	0.095	0.590	-0.046
7	9	0.2	7C	0.132	0.571	-0.030
6	3	0.2	6A	0.122	0.766	-0.036
6	6	0.2	6B	0.086	0.764	-0.038
6	9	0.2	6C	0.094	0.811	-0.044
10	3	0.8	10A	0.294	0.808	-0.246
10	6	0.8	10B	0.257	0.642	-0.231
10	9	0.8	10C	0.179	0.513	-0.151
9	3	0.8	9A	0.068	0.499	-0.071
9	6	0.8	9B	0.056	0.548	-0.054
9	9	0.8	9C	0.052	0.457	-0.059
8	3	0.8	8A	0.098	0.502	-0.068
8	6	0.8	8B	0.128	0.508	-0.099
8	9	0.8	8C	0.112	0.461	-0.105
7	3	0.8	7A	0.137	0.660	-0.126
7	6	0.8	7B	0.157	0.661	-0.134
7	9	0.8	7C	0.099	0.636	-0.114
6	3	0.8	6A	0.121	0.684	-0.147
6	6	0.8	6B	0.089	0.671	-0.117
6	9	0.8	6C	0.100	0.665	-0.097

BAY 3 Velocity Data with Porosity Boards

Screen Number	Distance from Leading Edge Of Screen (ft)	Fractional Depth (ft)	Notation	Approach Velocity Toward Screen (ft/s)	Sweep Velocity Toward Bypass (ft/s)	Vertical Velocity Upward (ft/s)
15	3	0.2	15A	0.135	0.741	-0.032
15	6	0.2	15B	0.099	0.702	-0.073
15	9	0.2	15C	0.105	0.640	-0.085
14	3	0.2	14A	0.088	0.664	-0.079
14	6	0.2	14B	0.078	0.638	-0.077
14	9	0.2	14C	0.080	0.599	-0.091
12	3	0.2	13A	0.130	0.580	-0.064
12	6	0.2	13B	0.108	0.564	-0.025
12	9	0.2	13C	0.097	0.540	-0.066
13	3	0.2	12A	0.108	0.503	-0.025
13	6	0.2	12B	0.041	0.563	-0.037
13	9	0.2	12C	0.120	0.470	-0.050
11	3	0.2	11A	0.120	0.742	-0.083
11	6	0.2	11B	0.089	0.707	-0.080
11	9	0.2	11C	0.071	0.752	-0.090
15	3	0.8	15A	0.362	0.823	-0.171
15	6	0.8	15B	0.284	0.591	-0.124
15	9	0.8	15C	0.190	0.431	-0.143
14	3	0.8	14A	0.137	0.542	-0.034
14	6	0.8	14B	0.139	0.393	-0.015
14	9	0.8	14C	0.099	0.410	-0.019
13	3	0.8	13A	0.150	0.479	-0.034
13	6	0.8	13B	0.177	0.492	-0.061
13	9	0.8	13C	0.220	0.553	-0.081
12	3	0.8	12A	0.191	0.689	-0.067
12	6	0.8	12B	0.166	0.656	-0.080
12	9	0.8	12C	0.157	0.678	-0.076
11	3	0.8	11A	0.153	0.638	-0.065
11	6	0.8	11B	0.163	0.690	-0.065
11	9	0.8	11C	0.114	0.685	-0.074

BAY 4 Velocity Data with Porosity Boards

Screen Number	Distance from Leading Edge Of Screen (ft)	Fractional Depth (ft)	Notation	Approach Velocity Toward Screen (ft/s)	Sweep Velocity Toward Bypass (ft/s)	Vertical Velocity Upward (ft/s)
20	3	0.2	20A	0.144	0.815	-0.022
20	6	0.2	20B	0.098	0.765	-0.045
20	9	0.2	20C	0.093	0.707	-0.060
19	3	0.2	19A	0.087	0.690	-0.035
19	6	0.2	19B	0.070	0.655	-0.035
19	9	0.2	19C	0.076	0.436	-0.044
18	3	0.2	18A	0.092	0.675	-0.021
18	6	0.2	18B	0.094	0.497	-0.024
18	9	0.2	18C	0.098	0.480	-0.025
17	3	0.2	17A	0.110	0.602	-0.029
17	6	0.2	17B	0.057	0.559	-0.043
17	9	0.2	17C	0.086	0.572	-0.022
16	3	0.2	16A	0.089	0.740	-0.053
16	6	0.2	16B	0.077	0.711	-0.061
16	9	0.2	16C	0.084	0.688	-0.022
20	3	0.8	20A	0.371	0.789	-0.151
20	6	0.8	20B	0.304	0.654	-0.158
20	9	0.8	20C	0.185	0.402	-0.128
19	3	0.8	19A	0.103	0.557	-0.013
19	6	0.8	19B	0.125	0.526	0.010
19	9	0.8	19C	0.100	0.444	-0.024
18	3	0.8	18A	0.174	0.541	-0.034
18	6	0.8	18B	0.182	0.457	-0.063
18	9	0.8	18C	0.169	0.504	-0.060
17	3	0.8	17A	0.195	0.636	-0.069
17	6	0.8	17B	0.170	0.665	-0.057
17	9	0.8	17C	0.169	0.666	-0.061
16	3	0.8	16A	0.188	0.659	-0.051
16	6	0.8	16B	0.166	0.623	-0.050
16	9	0.8	16C	0.150	0.685	-0.039

BAY 5 Velocity Data with Porosity Boards

Screen Number	Distance from Leading Edge Of Screen (ft)	Fractional Depth (ft)	Notation	Approach Velocity Toward Screen (ft/s)	Sweep Velocity Toward Bypass (ft/s)	Vertical Velocity Upward (ft/s)
27	3	0.2	27A	0.186	0.860	0.015
27	6	0.2	27B	0.101	0.815	-0.011
27	9	0.2	27C	0.092	0.791	-0.040
26	3	0.2	26A	0.085	0.723	-0.034
26	6	0.2	26B	0.106	0.640	-0.044
26	9	0.2	26C	0.071	0.636	-0.056
25	3	0.2	25A	0.123	0.638	-0.070
25	6	0.2	25B	0.097	0.627	-0.037
25	9	0.2	25C	0.123	0.516	-0.045
24	3	0.2	24A	0.103	0.604	-0.036
24	6	0.2	24B	0.096	0.586	-0.045
24	9	0.2	24C	0.076	0.525	-0.039
23	3	0.2	23A	0.116	0.595	0.005
23	6	0.2	23B	0.075	0.548	-0.011
23	9	0.2	23C	0.085	0.502	-0.059
22	3	0.2	22A	0.116	0.560	-0.023
22	6	0.2	22B	0.116	0.596	-0.021
22	9	0.2	22C	0.098	0.577	-0.047
21	3	0.2	21A	0.129	0.663	-0.063
21	6	0.2	21B	0.076	0.620	-0.021
21	9	0.2	21C	0.070	0.667	-0.045
27	3	0.8	27A	0.315	0.965	-0.176
27	6	0.8	27B	0.296	0.741	-0.197
27	9	0.8	27C	0.218	0.638	-0.122
26	3	0.8	26A	0.120	0.580	-0.038
26	6	0.8	26B	0.100	0.498	-0.076
26	9	0.8	26C	0.062	0.459	-0.078
25	3	0.8	25A	0.125	0.477	0.016
25	6	0.8	25B	0.124	0.427	-0.033
25	9	0.8	25C	0.112	0.417	0.017
24	3	0.8	24A	0.149	0.472	-0.039
24	6	0.8	24B	0.144	0.482	-0.050
24	9	0.8	24C	0.163	0.426	-0.059
23	3	0.8	23A	0.168	0.580	-0.049
23	6	0.8	23B	0.161	0.570	-0.054
23	9	0.8	23C	0.160	0.579	-0.063
22	3	0.8	22A	0.172	0.629	-0.077
22	6	0.8	22B	0.167	0.584	-0.064
22	9	0.8	22C	0.113	0.569	-0.066
21	3	0.8	21A	0.130	0.647	-0.079
21	6	0.8	21B	0.148	0.637	-0.089
21	9	0.8	21C	0.136	0.631	-0.061

BAY 1 Velocity Data without Porosity Boards

Screen Number	Distance from Leading Edge Of Screen (ft)	Fractional Depth (ft)	Notation	Approach Velocity Toward Screen (ft/s)	Sweep Velocity Toward Bypass (ft/s)	Vertical Velocity Upward (ft/s)
5	3	0.2	5A	0.210	0.701	-0.011
5	6	0.2	5B	0.184	0.694	-0.007
5	9	0.2	5C	0.162	0.620	-0.031
4	3	0.2	4A	0.200	0.722	-0.041
4	6	0.2	4B	0.172	0.656	-0.042
4	9	0.2	4C	0.162	0.516	-0.022
3	3	0.2	3A	0.169	0.629	-0.042
3	6	0.2	3B	0.166	0.654	-0.073
3	9	0.2	3C	0.176	0.551	-0.045
2	3	0.2	2A	0.210	0.706	-0.060
2	6	0.2	2B	0.189	0.652	-0.063
2	9	0.2	2C	0.175	0.607	-0.049
1	3	0.2	1A	0.204	0.794	-0.052
1	6	0.2	1B	0.168	0.763	-0.033
1	9	0.2	1C	0.181	0.781	-0.074
5	3	0.8	5A	0.501	0.783	-0.320
5	6	0.8	5B	0.360	0.583	-0.277
5	9	0.8	5C	0.311	0.602	-0.220
4	3	0.8	4A	0.267	0.603	-0.120
4	6	0.8	4B	0.234	0.575	-0.102
4	9	0.8	4C	0.170	0.493	-0.121
3	3	0.8	3A	0.252	0.537	-0.132
3	6	0.8	3B	0.250	0.553	-0.106
3	9	0.8	3C	0.294	0.540	-0.136
2	3	0.8	2A	0.351	0.677	-0.179
2	6	0.8	2B	0.318	0.675	-0.201
2	9	0.8	2C	0.316	0.685	-0.210
1	3	0.8	1A	0.343	0.762	-0.208
1	6	0.8	1B	0.304	0.696	-0.187
1	9	0.8	1C	0.271	0.676	-0.190

BAY 2 Velocity Data without Porosity Boards

Screen Number	Distance from Leading Edge Of Screen (ft)	Fractional Depth (ft)	Notation	Approach Velocity Toward Screen (ft/s)	Sweep Velocity Toward Bypass (ft/s)	Vertical Velocity Upward (ft/s)
10	3	0.2	10A	0.194	0.707	0.001
10	6	0.2	10B	0.148	0.711	-0.024
10	9	0.2	10C	0.147	0.655	-0.031
9	3	0.2	9A	0.157	0.713	-0.036
9	6	0.2	9B	0.117	0.703	-0.034
9	9	0.2	9C	0.131	0.668	-0.049
8	3	0.2	8A	0.160	0.712	-0.035
8	6	0.2	8B	0.185	0.614	0.001
8	9	0.2	8C	0.156	0.509	-0.017
7	3	0.2	7A	0.168	0.647	-0.030
7	6	0.2	7B	0.172	0.635	-0.064
7	9	0.2	7C	0.170	0.596	-0.043
6	3	0.2	6A	0.174	0.746	-0.040
6	6	0.2	6B	0.159	0.724	-0.040
6	9	0.2	6C	0.139	0.733	-0.040
10	3	0.8	10A	0.403	0.666	-0.285
10	6	0.8	10B	0.334	0.589	-0.263
10	9	0.8	10C	0.258	0.505	-0.211
9	3	0.8	9A	0.202	0.577	-0.120
9	6	0.8	9B	0.183	0.394	-0.078
9	9	0.8	9C	0.122	0.390	-0.050
8	3	0.8	8A	0.220	0.453	-0.121
8	6	0.8	8B	0.257	0.485	-0.166
8	9	0.8	8C	0.259	0.506	-0.160
7	3	0.8	7A	0.331	0.635	-0.185
7	6	0.8	7B	0.321	0.638	-0.197
7	9	0.8	7C	0.271	0.564	-0.181
6	3	0.8	6A	0.273	0.668	-0.137
6	6	0.8	6B	0.264	0.627	-0.142
6	9	0.8	6C	0.240	0.675	-0.158

BAY 3 Velocity Data without Porosity Boards

Screen Number	Distance from Leading Edge Of Screen (ft)	Fractional Depth (ft)	Notation	Approach Velocity Toward Screen (ft/s)	Sweep Velocity Toward Bypass (ft/s)	Vertical Velocity Upward (ft/s)
15	3	0.2	15A	0.182	0.671	-0.004
15	6	0.2	15B	0.118	0.643	-0.022
15	9	0.2	15C	0.123	0.590	-0.058
14	3	0.2	14A	0.137	0.634	-0.047
14	6	0.2	14B	0.096	0.547	-0.029
14	9	0.2	14C	0.107	0.550	-0.065
13	3	0.2	13A	0.104	0.552	-0.039
13	6	0.2	13B	0.098	0.485	-0.031
13	9	0.2	13C	0.124	0.428	-0.026
12	3	0.2	12A	0.149	0.570	-0.019
12	6	0.2	12B	0.163	0.531	-0.022
12	9	0.2	12C	0.155	0.570	-0.036
11	3	0.2	11A	0.181	0.764	-0.079
11	6	0.2	11B	0.146	0.721	-0.073
11	9	0.2	11C	0.137	0.738	-0.047
15	3	0.8	15A	0.302	0.726	-0.251
15	6	0.8	15B	0.275	0.611	-0.245
15	9	0.8	15C	0.187	0.523	-0.149
14	3	0.8	14A	0.165	0.539	-0.146
14	6	0.8	14B	0.159	0.481	-0.144
14	9	0.8	14C	0.160	0.443	-0.167
13	3	0.8	13A	0.138	0.536	-0.124
13	6	0.8	13B	0.149	0.523	-0.112
13	9	0.8	13C	0.155	0.483	-0.130
12	3	0.8	12A	0.151	0.603	-0.179
12	6	0.8	12B	0.169	0.606	-0.181
12	9	0.8	12C	0.158	0.588	-0.182
11	3	0.8	11A	0.172	0.660	-0.202
11	6	0.8	11B	0.163	0.634	-0.142
11	9	0.8	11C	0.130	0.703	-0.163

BAY 4 Velocity Data without Porosity Boards

Screen Number	Distance from Leading Edge Of Screen (ft)	Fractional Depth (ft)	Notation	Approach Velocity Toward Screen (ft/s)	Sweep Velocity Toward Bypass (ft/s)	Vertical Velocity Upward (ft/s)
20	3	0.2	20A	0.170	0.662	-0.037
20	6	0.2	20B	0.117	0.632	-0.048
20	9	0.2	20C	0.114	0.572	-0.075
19	3	0.2	19A	0.151	0.507	-0.067
19	6	0.2	19B	0.118	0.504	-0.080
19	9	0.2	19C	0.077	0.489	-0.065
18	3	0.2	18A	0.132	0.519	-0.080
18	6	0.2	18B	0.124	0.469	-0.012
18	9	0.2	18C	0.116	0.411	-0.034
17	3	0.2	17A	0.121	0.549	-0.055
17	6	0.2	17B	0.111	0.522	-0.074
17	9	0.2	17C	0.143	0.490	-0.075
16	3	0.2	16A	0.133	0.684	-0.108
16	6	0.2	16B	0.111	0.669	-0.078
16	9	0.2	16C	0.097	0.689	-0.084
20	3	0.8	20A	0.235	0.714	-0.216
20	6	0.8	20B	0.216	0.632	-0.206
20	9	0.8	20C	0.156	0.540	-0.155
19	3	0.8	19A	0.062	0.515	-0.095
19	6	0.8	19B	0.108	0.413	-0.100
19	9	0.8	19C	0.084	0.438	-0.115
18	3	0.8	18A	0.084	0.485	-0.078
18	6	0.8	18B	0.085	0.445	-0.077
18	9	0.8	18C	0.077	0.470	-0.099
17	3	0.8	17A	0.100	0.578	-0.123
17	6	0.8	17B	0.107	0.603	-0.126
17	9	0.8	17C	0.100	0.581	-0.136
16	3	0.8	16A	0.074	0.695	-0.146
16	6	0.8	16B	0.073	0.657	-0.153
16	9	0.8	16C	0.058	0.666	-0.125

BAY 5 Velocity Data without Porosity Boards

Screen Number	Distance from Leading Edge Of Screen (ft)	Fractional Depth (ft)	Notation	Approach Velocity Toward Screen (ft/s)	Sweep Velocity Toward Bypass (ft/s)	Vertical Velocity Upward (ft/s)
27	3	0.2	27A	0.177	0.628	-0.007
27	6	0.2	27B	0.120	0.601	-0.028
27	9	0.2	27C	0.113	0.571	-0.038
26	3	0.2	26A	0.130	0.581	-0.046
26	6	0.2	26B	0.126	0.550	-0.047
26	9	0.2	26C	0.092	0.561	-0.057
25	3	0.2	25A	0.151	0.460	-0.049
25	6	0.2	25B	0.109	0.518	-0.053
25	9	0.2	25C	0.140	0.431	-0.027
24	3	0.2	24A	0.168	0.408	-0.033
24	6	0.2	24B	0.135	0.445	-0.051
24	9	0.2	24C	0.139	0.445	-0.061
23	3	0.2	23A	0.140	0.470	-0.032
23	6	0.2	23B	0.100	0.444	-0.037
23	9	0.2	23C	0.109	0.463	-0.026
22	3	0.2	22A	0.168	0.598	-0.067
22	6	0.2	22B	0.144	0.528	-0.059
22	9	0.2	22C	0.142	0.509	-0.052
21	3	0.2	21A	0.138	0.626	-0.065
21	6	0.2	21B	0.107	0.607	-0.051
21	9	0.2	21C	0.094	0.636	-0.053
27	3	0.2	27A	0.310	0.674	-0.191
27	6	0.2	27B	0.265	0.562	-0.197
27	9	0.2	27C	0.214	0.486	-0.163
26	3	0.2	26A	0.155	0.493	-0.086
26	6	0.2	26B	0.139	0.485	-0.093
26	9	0.2	26C	0.110	0.459	-0.082
25	3	0.2	25A	0.132	0.327	-0.082
25	6	0.2	25B	0.142	0.351	-0.083
25	9	0.2	25C	0.127	0.299	-0.062
24	3	0.2	24A	0.125	0.371	-0.115
24	6	0.2	24B	0.154	0.378	-0.091
24	9	0.2	24C	0.151	0.410	-0.112
23	3	0.2	23A	0.199	0.451	-0.114
23	6	0.2	23B	0.173	0.435	-0.090
23	9	0.2	23C	0.182	0.453	-0.103
22	3	0.2	22A	0.205	0.534	-0.109
22	6	0.2	22B	0.199	0.513	-0.124
22	9	0.2	22C	0.172	0.464	-0.115
21	3	0.2	21A	0.200	0.555	-0.137
21	6	0.2	21B	0.178	0.541	-0.118
21	9	0.2	21C	0.159	0.581	-0.133