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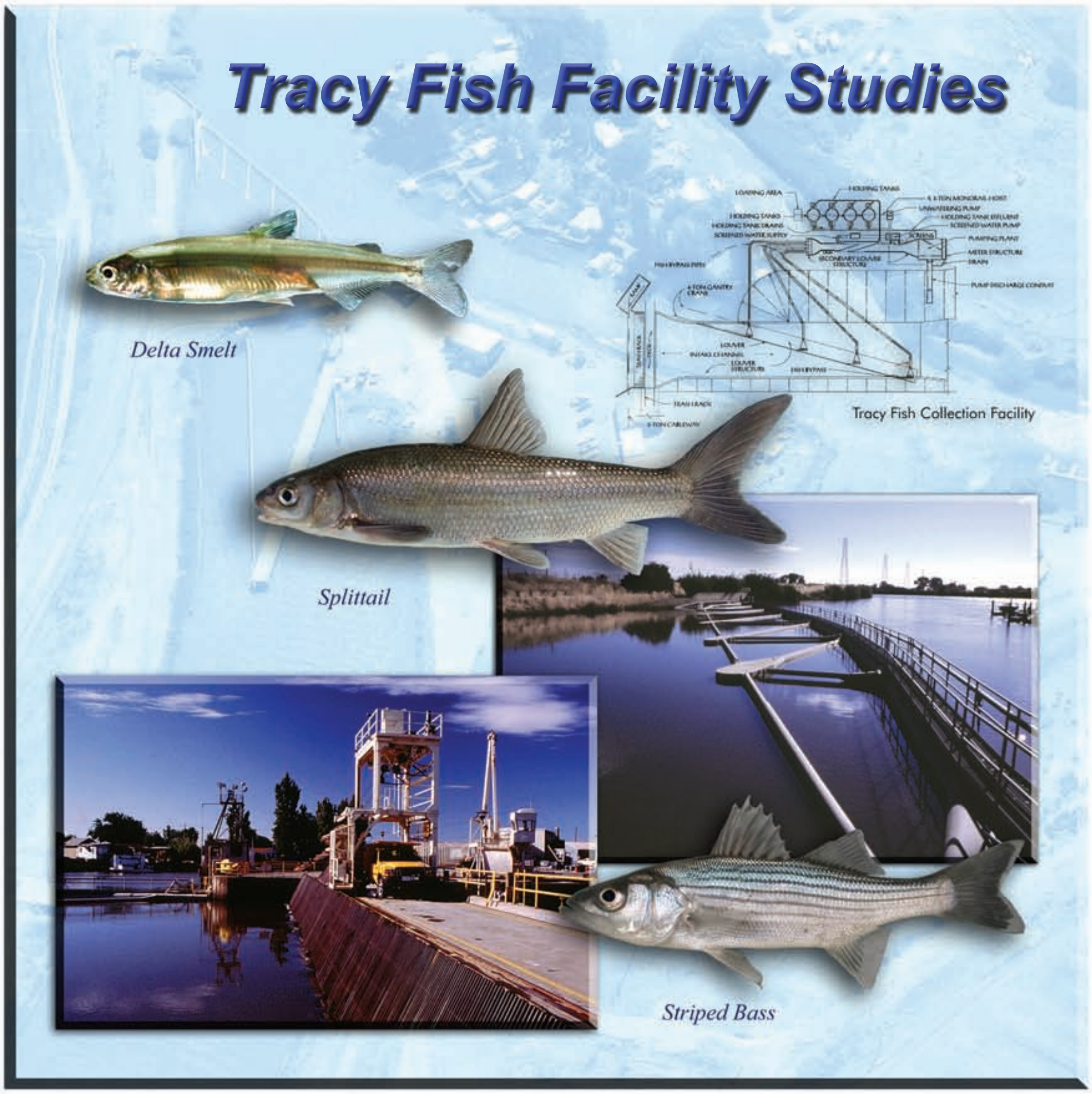

Hydraulic Performance Evaluation of the Replacement Primary Bypass Intakes and Transition Boxes at Tracy Fish Collection Facility

Volume 40

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14. ABSTRACT
To prevent fish entrainment at the Tracy Pumping Plant, the Tracy Fish Collection Facility (TFCF) was designed to guide fish along a diagonal line of louvers into one of four primary bypass intakes. Replacement primary bypass intakes and transition boxes with a new tapered choke design were installed in 2004 to improve hydraulic conditions for fish collection. The replacement intakes were developed in the laboratory for an expected range of field operating conditions. Hydraulic field evaluations were conducted to verify the performance of the new intakes. Velocity profiles were collected in the intake entrance and upstream of the intakes to document velocity field distributions.

Results show that common field conditions such as bypass ratios less than 1.0 and high debris loads adversely affect bypass performance by degrading uniformity in the vertical velocity profiles at the bypass entrances. Such uniformity is considered a performance indicator from past studies connected with fish salvage efficiency. Facility operation with bypass ratios greater than 1.0 provides the best hydraulic conditions for efficient fish collection by minimizing flow disruption and eddying and promoting smooth flow acceleration into the intakes. Since debris can affect approach velocity distributions, debris fouling on the trashrack and louvers should be minimized.

15. SUBJECT TERMS
Tracy Fish Collection Facility, hydraulic evaluation, bypass design, bypass intake, transition box, tapered choke, bypass ratio, debris, velocity profile, Acoustic Doppler Velocimeter

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by

Connie DeMoyer[1]

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COVER

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EXECUTIVE SUMMARY

The Tracy Fish Collection Facility (TFCF), located at the head of the Delta-Mendota intake channel near Tracy, California, was constructed to collect fish before entrainment at the Tracy Pumping Plant. The facility was designed to guide fish from the canal into one of four primary bypass intakes by way of a diagonal line of louvers in the primary channel.

Fish collection efficiencies are influenced by the hydraulic performance of the bypass intakes. Replacement primary bypass intakes and transition boxes were installed at the Tracy Fish Collection Facility in 2004. The original bypass intakes with internal curved vanes were replaced with a new intake design consisting of a tapered choke section. Hydraulic field evaluations were conducted to verify the performance of the new intakes. In order to minimize fish avoidance, the replacement intakes were designed to produce a near-uniform vertical velocity distribution throughout the water column.

The hydraulic evaluations were conducted in two phases. Phase I in November 2003 included development and shakedown of instrumentation, deployment equipment, and data collection procedures to assure a complete and efficient evaluation during the Phase II studies. A limited hydraulic evaluation of two existing primary bypass intakes was conducted while data collection procedures were examined. Phase II, completed in October 2004, focused on collecting performance data for all four-replacement bypass intakes along with operational data such as flow rates, depths, fouling condition, and pump operation. Centerline velocity profiles in the intake entrance and approach velocity profiles at locations 5 to 20 ft upstream from the bypass entrances were measured to document velocity field variations and to determine the influence of approach velocity distributions on intake entrance velocities. Profiles were collected over a range of operating bypass ratios from 0.37 to 1.63, flow rates from 3,337 to 6,128 ft^3/s, tidal phases (ebb, flood, and high tides), and louver fouling conditions.

The replacement intakes were developed in the laboratory for expected field operating conditions with bypass ratios from 1.2 to 1.6. Under similar field conditions, the replacement bypasses operate effectively. However, complex operating conditions such as debris fouling and a limited ability to achieve appropriate bypass ratios can adversely affect bypass performance, negating the intended improvement in flow conditions from the replacement bypasses. Since debris clogging can alter approach velocity distributions, minimizing the amount of debris on the trashrack and louvers should improve performance of the intakes. Bypass ratios less than 1.0 appear to restrict flow in the bypasses, causing secondary flow patterns or eddies to develop. Therefore, maintaining bypass ratios well above 1.0 will minimize flow disruption and produce an acceleration of flow into the intake.

When bypass ratios above 1.0 cannot be achieved using standard four bypass operations, one or two of the bypasses can be closed to increase flow through the remaining open bypasses. The intent of this operation is to increase the bypass ratio of the open bypasses while maintaining an acceptable velocity in the secondary channel. Building on the data collected from these studies, closing bypasses as an alternative operational method is recommended for field evaluation. If feasible, this type of operational change could be enacted after agency approval with no associated capital cost.

INTRODUCTION

Facility Overview

The Tracy Fish Collection Facility (TFCF) is located at the head of the Delta-Mendota intake channel at the south end of the Sacramento-San Joaquin Delta near Tracy, California. The facility was constructed in the 1950s to salvage fish (primarily striped bass and Chinook salmon) that would otherwise be entrained at the Tracy Pumping Plant. Figure 1 shows a plan view schematic of the facility and figure 2 shows the layout of the primary channel.

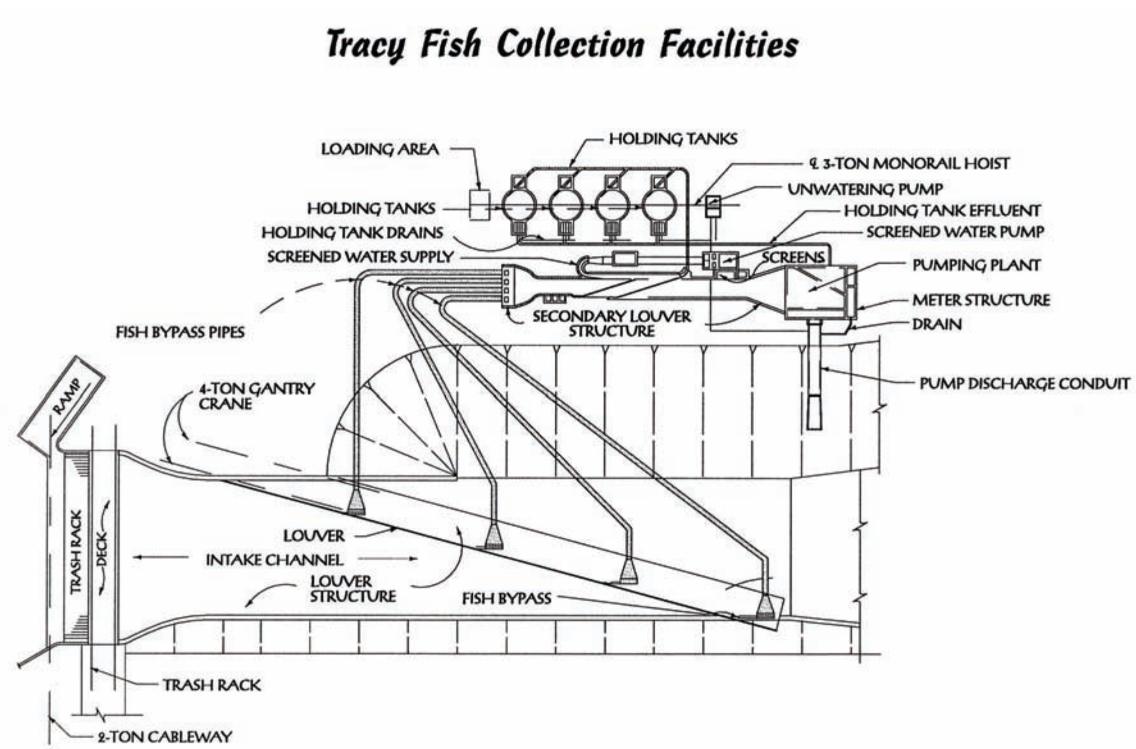

FIGURE 1.—Plan view schematic of Tracy Fish Collection Facility.

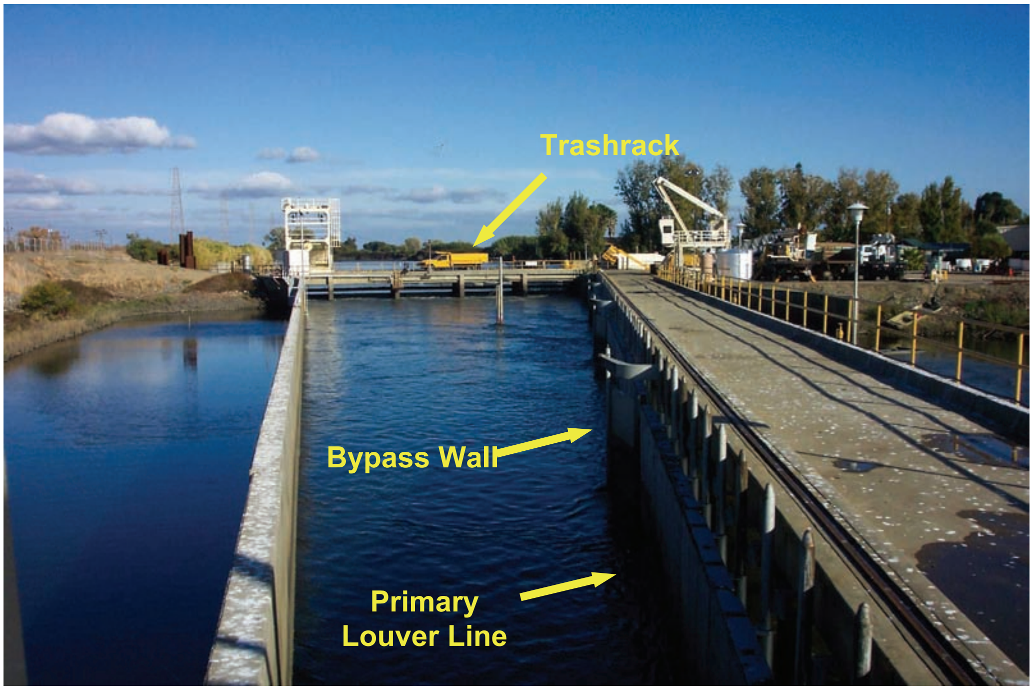

FIGURE 2.—Features in the primary channel looking upstream.

The facility consists of a diagonal line of primary louvers designed to guide fish into one of four primary bypass intakes. The bypass entrances are located at quarter points along the primary louver and at the downstream end of the louver line. Bypass conduits transport the collected fish from the primary louver channel to the secondary channel. The secondary channel flow rate is controlled by a bank of low head velocity control (VC) pumps positioned at the downstream end of the secondary screening facility. Two louver lines in the secondary channel guide fish into the secondary bypass. Fish are then concentrated in holding tanks until they are transported by tanker trucks to locations in the Delta out of the zone of influence of the pumping plant.

Fish collection efficiencies are influenced by the hydraulic performance of the bypass intakes. The louvers are intended to achieve fish exclusion by generating disturbances in the flow field that fish respond to and avoid. Fish maintain a distance off the louver face, while the sweeping flow is intended to guide the fish along the louver line and into the bypasses. Studies have shown that to achieve effective fish exclusion, the fish must be moved efficiently into the bypasses. Strong flow accelerations and decelerations can cause fish avoidance, making it more likely that fish will pass through the louvers rather than move toward the bypass intake (Bates *et al*., 1960). It is therefore important that the design of the bypass intakes generate a gradual acceleration into the bypass such that the bypass entrance velocity exceeds the local channel velocity.

The ratio of the average bypass entrance velocity for a specific bypass to the average approach velocity is defined as the bypass ratio. For positive fish barriers, the term approach velocity is defined as the velocity component perpendicular to the positive barrier. At the TFCF, approach velocity has traditionally been defined as the channel velocity approaching the bypasses. For the sake of consistency with previous literature, the approach velocity will be defined as the average channel velocity in this report.

Original Primary Bypass Intake Design

The unique geometry of the primary bypasses dictates the design of the bypass intakes. Water enters the primary bypass through a tall, narrow, rectangular cross-section 6-in wide by 20-ft tall and is turned down vertically through this section before transitioning into a horizontal 36-in diameter bypass pipe (figure 3). The transition geometry produces non-uniform vertical velocity distributions since elevations closer to the bottom have shorter flow paths, thereby producing higher velocities. The original primary bypass intake design was developed by W.B. McBirney (1956) from studies conducted at Reclamation's Water Resources Research Laboratory in Denver, Colorado. The hydraulic design chosen by McBirney included internal turning vanes within the bypass intake transition box to generate a near-uniform velocity profile at the bypass entrance. The full-width vanes were vertically spaced every foot in the bypass intake, starting 3 ft downstream from the entrance.

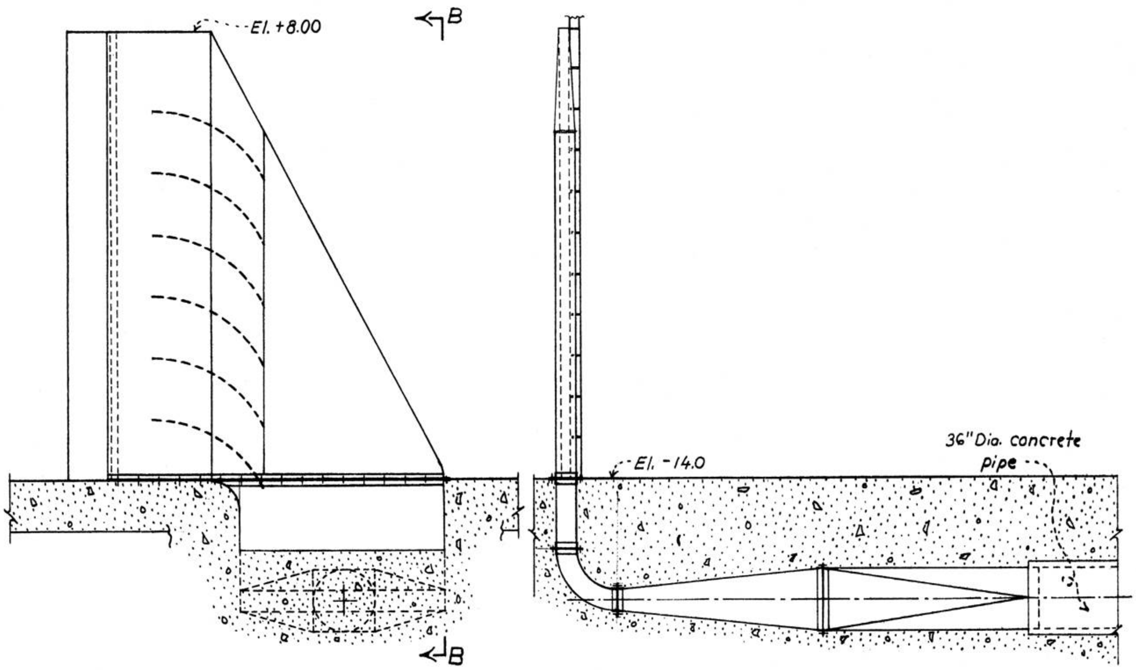

FIGURE 3.—Original bypass intake design using internal curved vanes from 1956.

Although the intakes were designed to generate near-uniform entrance velocity distributions, the vanes were not accessible for maintenance and cleaning. The vanes accumulated debris, causing flow blockages within the intake and degrading the uniformity of the entrance velocity profiles. As the bypass intakes corroded and deteriorated with time, vane failure reduced velocity distribution control effectiveness and holes in the bypass transition boxes were observed.

Replacement Primary Bypass Intake Design

Because of corrosion and failure of both the vanes and the skin of the transition boxes, an effort was initiated in 2001 to replace the four primary bypass intakes. The bypass intakes were repaired in the spring of 2003 and the replacement bypass intakes were installed at the TFCF in the spring of 2004. The intakes and transition boxes were designed based on physical and computational hydraulic model studies (Kubitschek, 2003). The replacement design used a tapered choke (vertically tapered section) to generate a near-uniform vertical velocity without the need for internal turning vanes (figure 4). This design constricts the intake flow path with a linear expansion from the bottom to the surface, vertically balancing the velocity potential at the intake entrances. The advantage of this design is that debris accumulation may be reduced to sustain effective operation.

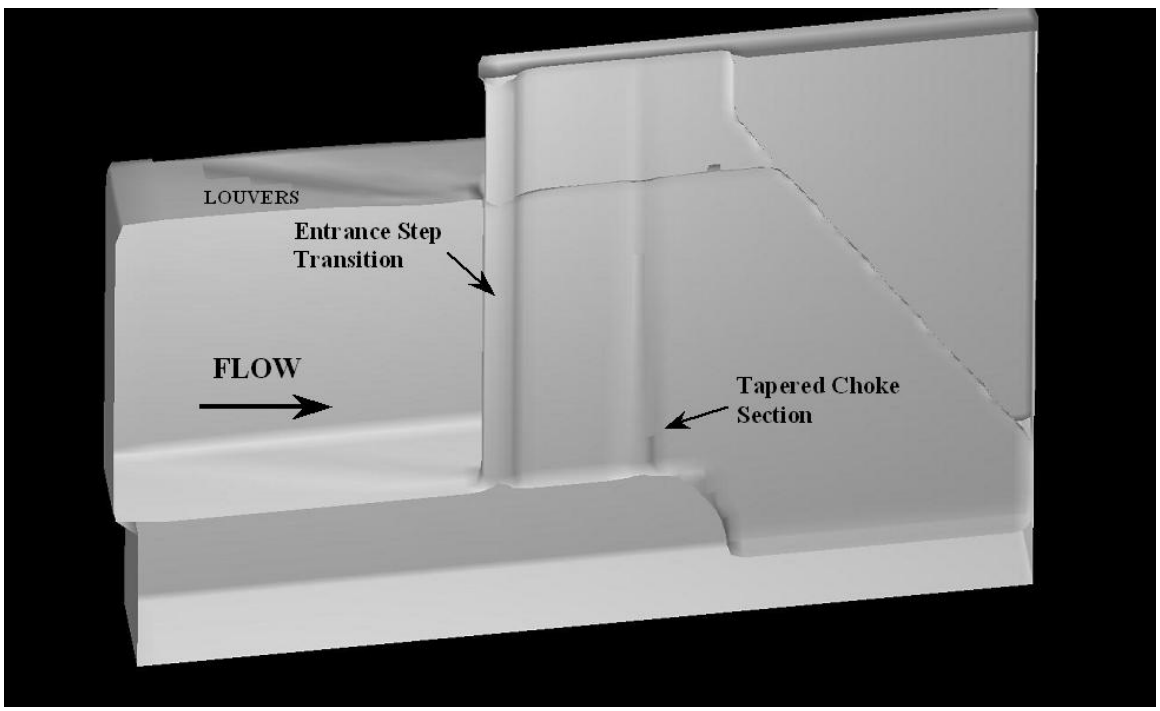

FIGURE 4.—Replacement bypass intake design using a tapered choke section (Kubitschek, 2003).

Additional laboratory hydraulic modeling was conducted to evaluate and refine the bypass near-field approach velocities (Johnson *et al*., 2004). These studies showed that vertical approach flow velocity distributions strongly influence velocity distributions within the bypass intake. Since trashrack and louver debris fouling can influence approach flow velocities, it is likely that the replacement intakes will perform best when debris fouling is minimized. Debris influences were documented during the field evaluations.

METHODOLOGY

Instrumentation and Procedures

A SonTek Acoustic Doppler Velocimeter (ADV) was used to collect three-dimensional point velocity data at a sampling rate of 25 Hz for at least 60 seconds at selected vertical locations along the bypass entrance centerline. The data were then time-averaged to obtain mean velocities at each measurement location. The accuracy of the ADV is 1 percent of the measured velocity $\pm$ 0.008 ft/s (0.25 cm/s). A new ADV deployment apparatus was designed and constructed to enable data collection at the entrance of the bypass, where the louver line ends and the 6-in wide bypass opening begins, with minimal disturbance to flow patterns. The deployment equipment used to evaluate the performance of the original primary bypass intakes in 2001 measured velocities approximately 6 in upstream from the bypass entrance. This equipment may have generated blockage of the bypass entrance, producing distorted entrance velocities and increasing flow through the louvers directly upstream from the intake. The new deployment apparatus consisted of an aluminum rail affixed directly to the louver panel with a moveable sled to control vertical measurement location (figures 5 and 6). The rail was oriented and mounted to minimize flow blockage and disruption. The ADV was mounted on the end of an arm extending from the moveable sled. With this apparatus in place, the ADV probe was positioned on the centerline of the bypass entrance (figure 7).

Near-field approach velocity profiles upstream from the intake were collected with the Nortek BoogieDopp instrument which was replaced by the Qmetrix QLiner in 2004 (figure 8). This instrument utilizes acoustic Doppler technology to measure velocity profiles with an accuracy of 1 percent of the measured value $\pm$ 0.016 ft/s (0.5 cm/s). A current profiler is mounted on the bottom of a boogie board. The BoogieDopp is easily deployed from land since it collects data in a Pocket PC through a wireless radio modem. The instrument records velocity values in a series of depth cells throughout the water column. Velocities are averaged over a 5-second period for each 15 cm depth cell during the measurement duration of 60 seconds.

Lateral movement of the instrument was minimized with careful positioning of the boogie board in the flow. Since the profiler emits acoustic beams only in the upstream and downstream directions parallel to the boat axis, velocity measurements can be taken within about 1 ft of a vertical boundary. Low signal strength, a spike in signal strength, or high scatter in the data is recognized as possible boundary interference.

FIGURE 5.—An ADV deployment rail was affixed to the louver panel just upstream from the bypass entrance.

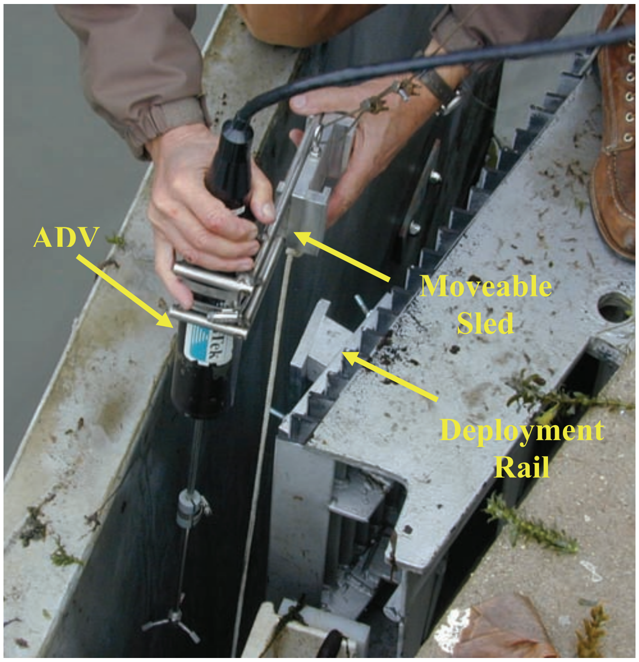

FIGURE 6.—The ADV was attached to a moveable sled to vertically position the instrument along the rail.

FIGURE 7.—The ADV was lowered down on the deployment rail into the bypass entrance.

FIGURE 8.—Nortek BoogieDopp velocity profiler.

To best define velocity field transitions approaching the intake entrances, an effort was made to evaluate velocity profiles as close to the intake entrance as possible. However, boundary interference and heavy turbulence in the confined space between the bypass guide wall and the louver panel face disrupted accurate data collection by shifting and plunging the boogie board and obstructing the projected beams. Therefore, velocity profiles were measured 5 to 20 ft upstream from the primary intake entrances in 5 ft increments.

The BoogieDopp was tethered to the primary louver cleaner device for proper positioning of the instrument upstream from the intake (figure 9). Measurement locations were marked on the louver line as distance from the intake entrance. The profiler was visually aligned with each louver markings. Profiles were measured directly against the louver panel face and between the louver panel face and the bypass guide wall (ranging from 2.7 to 5.3 ft away from the louver panel depending on the projected distance from the bypass entrance) as shown in figure 10.

FIGURE 9.—The BoogieDopp was positioned upstream from the intake entrance to document near-field approach velocity conditions.

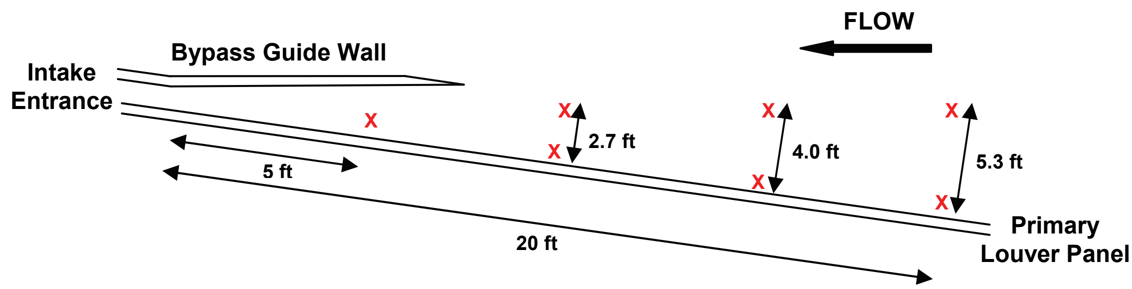

FIGURE 10.—Schematic of velocity profile locations (indicated by **X**) upstream from the intake entrance. Profiles were measured against the louver panel face and several feet away from the louvers.

Debris fouling can influence intake performance by reducing water depths downstream from the trashrack and producing uneven approach flow patterns. The extent of debris fouling during data collection was evaluated through the documentation of headloss across the trashrack and louvers. Debris was also qualitatively documented through visual observation and digital photographs. Heavy, seasonally variable debris loads can be seen at the debris boom during the fall 2004 data collection effort (figure 11). With a relatively clean trashrack, the average headloss differential over various depths and flow rates is about 0.8 ft, but can increase to 2-3 ft of headloss during high debris loads (figure 12). Debris passing through the trashrack collects at the primary louvers and throughout the system (figure 13).

FIGURE 11.—Debris collected upstream from the debris boom. Heavy debris loads clog the facility and affect the performance of the louver system.

FIGURE 12.—Trashrack fouling was documented during data collection.

FIGURE 13.—Louver panel fouling was documented during data collection.

Instrument accuracy, time variable conditions, and operational restraints contribute to measurement uncertainty in the data. Instrument accuracy includes the accuracy of the portable velocity meters and the facility instrumentation such as depth sensors and flowmeters. Due to tidal influences, the depths and flow rates are time variable over the length of a data collection period (typically 20 minutes). When debris levels were high, the deployment rail on the primary louvers needed to be cleaned to allow the sled to slide freely up and down in the bypass entrance. To clean the rail, the louver panel was pulled out of the water, shedding debris from the panel and producing a cleaner louver just upstream from the intake. Consequently, the overall primary louver differential was not necessarily representative of the local fouling conditions.

Test Conditions

Hydraulic conditions at the facility are a function of the pumping rate at the downstream Tracy Pumping Plant, variable debris loads, and tidal variations. Due to changing tidal phases, the flow rate through the primary louver structure will increase (flood) or decrease (ebb) as the canal between the TFCF and the Tracy Pumping Plant fills or drains. To describe the conditions during the tests, system hydraulics such as the flow rate and depths in the primary and secondary channels, flow rate in each of the primary bypass conduits, flow rate to the holding tanks, and local VC pumping plant operations were recorded.

The primary bypass ratio for a specific bypass is defined as the average bypass velocity divided by the average approach velocity. There are several ways to calculate primary bypass ratio at the TFCF depending on the type of instrumentation used. Using current facility instrumentation, the average bypass velocity is calculated from the flowmeter reading on the specific bypass pipe and the bypass entrance cross sectional area. The cross sectional area is the width of the bypass, 0.5 ft, multiplied by the water depth in the primary channel. The average approach velocity is calculated from the primary channel flowmeter reading and the channel cross sectional area, which is the width of the primary channel at the upstream end of the louvers multiplied by the primary channel depth.

To supplement the permanent facility instrumentation during the field experiments, portable instruments were used to collect velocity data that more closely describe the bypass ratio for each specific bypass. The bypass velocity was averaged from ADV profile data collected at the bypass entrance. For the average approach velocity, the local vertical velocity was measured 5 ft upstream from the intake entrance (or 10-15 ft upstream for bypass 4) with the BoogieDopp profiler. This local approach velocity collected near to the bypass entrance better describes the approach velocity to each specific bypass than a single average velocity calculated from the primary channel flowmeter reading.

Phase I

During Phase I testing on November 18-19, 2003, Tracy Pumping Plant was operating five pumps. Flow rates at the TFCF ranged from 4,132 to 5,025 ft^3/s with average primary channel velocities of 3.0 to 4.0 ft/s calculated from the measured flow rate and water depth in the primary channel. Local VC pumps were set for standard operations with all four primary bypasses fully open. Facility equipment was not manipulated to achieve specific criteria. Due to the recent removal of a temporary barrier immediately upstream from the fish facility, a large debris load occurred at the facility. Periodic cleaning of the primary louvers and the trashracks was required throughout the day. For all four tests in Phase I, the trashrack was generally clean of debris. Primary louver panels were cleaned before three of the tests and were left fouled for one of the tests at bypass 1.

With the repaired original primary bypass intakes installed in Phase I, ADV intake velocity profiles were collected at primary bypasses 1 and 4 at 2 ft incremental depths. These bypasses were chosen since bypass 1 likely experiences the greatest influences from variations in trashrack and louver fouling and the terminal bypass 4 has been shown to collect the largest proportion of fish and is therefore important for evaluation (Bates el al., 1960). It was anticipated that the BoogieDopp instrument might encounter boundary interference at close range to the bypass and near to the louver panel. In order to determine the best location for measurements during Phase II, profiles were collected directly against the louver panel face and also in a zone defined by the louver panel face and the bypass entrance guide wall. Primary bypass ratios ranged from 0.46-0.69 with facility instruments and 0.69-0.83 with portable instruments. A summary of system hydraulics during the 2003 data collection effort is shown in table 1.

Phase II

Phase II hydraulic evaluations on October 25-28, 2004, focused on an evaluation of the replacement bypass intakes and system performance. Five pumps were in operation at Tracy Pumping Plant. During these tests, primary channel flow rates ranged from 3,337 to 6,128 ft^3/s, with primary channel velocities of 2.4 to 4.4 ft/s. Bypass ratios ranged from 0.39 to 1.86 with facility instruments and 0.37 to 1.63 with portable instruments. Data was collected over a full range of tidal phases and fouling conditions.

For Tests 2, 3, and 4 in Phase II, data were collected with all four bypasses operating. For Tests 1 and 5, some bypasses were closed as part of an initial investigation to identify whether closing bypasses can be used as an operational strategy to increase primary bypass ratios while maintaining acceptable velocities in the secondary channel. ADV intake velocity profiles were collected at all four primary bypasses at 2 ft incremental depths. Near-field approach velocity profiles were collected 5 to 10 ft upstream from each bypass intake. Since the channel narrows at Intake 4 as the training wall converges, signal interference from the louver face and/or vertical walls required that velocity profiles be collected 15 ft upstream from the intake entrance. System wide hydraulics were recorded from facility instrumentation. Documented parameters include:

- Primary and secondary channel flow rates from the Accusonic flowmeter
- Water depths in the primary and secondary channels
- Water depth upstream from the trashrack, upstream from the primary louver line, downstream from the primary louver line, upstream from the secondary louvers, between the secondary louvers, and downstream from the secondary louvers.

TABLE 1.—Summary of system hydraulics for 2003 data collection with the original primary bypass intakes. All system hydraulics are listed in Appendix 1.

				Primary Channel					Secondary Channel	
Test	**Bypass**	**Bypass Operation**	**Cleaning Cycle**	**Flow Rate (ft^3/s)**	**Depth (ft)**	**Average Channel Velocity (ft/s)**	**Measured Bypass Ratio**	**Bypass Ratio with Facility Instruments**	**Secondary Channel Depth (ft)**	**Secondary Channel Velocity (ft/s)**
1A	1	All bypasses open	Clean louvers	Not recorded	14.75	Not recorded	Not recorded	Not recorded	Not recorded	Not recorded
1B	1	All bypasses open	Clean louvers	4,132	16.64	2.96	0.80	0.69	4.75	1.22
1C	1	All bypasses open	Fouled louvers	4,350	15.50	3.34	0.83	0.68	4.30	1.30
4A	4	All bypasses open	Clean louvers	5,440	16.28	3.98	0.69	0.46	Not recorded	Not recorded

- Flow rates for all four primary bypass conduits
- Flow rate to the holding tank
- VC pumps in use
- Time of trashrack and louver cleanings

Table 2 shows a summary of system hydraulics collected during the 2004 data collection.

RESULTS AND DISCUSSION

Bypass Entrance Velocity Profiles

All three-dimensional intake velocity profiles are given in Appendix 1 for data collected with the original bypass intakes in September 2003 and Appendix 2 for the replacement bypass evaluation in October 2004. The dominant velocity component is the downstream velocity into the bypass intake. Depending on primary channel conditions and primary bypass settings, the vertically averaged entrance values ranged from 1.45 to 5.77 ft/s. Examining all point velocities in the vertical profile, the downstream velocity component was as low as -0.5 ft/s due to recirculation zones at the intake entrance.

With the original intakes installed, the lateral velocity component was generally around 0.4-0.8 ft/s, whereas the replacement intakes produced lateral velocities of less than 0.5 ft/s under most conditions. Higher lateral velocities with the original intakes indicate that deterioration or blockage may have caused secondary flow patterns in the intakes and increased velocities through the louvers just upstream from the bypass intakes. Velocities in the vertical direction were typically $\pm$ 0.4 ft/s with a general trend toward drawing flow downward into the intake transition. Profiles collected with primary bypass ratios above 1.0 have larger downward velocity components.

The downstream velocity components are presented below for various bypass ratios, water depths, and debris conditions. Original intake velocity profiles for bypasses 1 and 2 are shown in figures 14 and 15 and the replacement intake velocity profiles for bypasses 1-4 are shown in figures 16-19, respectively. It is difficult to isolate the effect of intake and transition box condition on nonuniformity since approach velocity distributions, debris fouling, and bypass ratio also affect the entrance velocity profiles. However, for the velocity profiles in bypasses 1 and 4 that have similar operating conditions, the replacement intakes produce a slightly more uniform velocity profile than the existing original intakes. Most importantly, figure 19 shows that the replacement bypasses operate as intended when the standing operating procedure of bypass ratios above 1.0 can be achieved. Bypass ratios less than 1.0 show pronounced vertical nonuniformity.

TABLE 2.—Summary of system hydraulics for 2004 data collection with the replacement primary bypass intakes. All system hydraulics are listed in Appendix 2.

			Water Surface Differential		Primary Channel					Secondary Channel		
Test	**Bypass**	**Bypass Operation**	**Trashrack (ft)**	**Primary Louvers (ft)**	**Flow Rate (ft^3/s)**	**Depth (ft)**	**Average Velocity (ft/s)**	**Measured Bypass Ratio**	**Bypass Ratio with Facility Instruments**	**Depth (ft)**	**Average Velocity (ft/s)**	**Bypass Ratio**
2-1	1	All bypasses open	0.760	0.72	4,443	17.59	3.01	N/A	0.860	6.24	1.41	1.71
2-2	2	All bypasses open	1.45	0.73	3,337	16.90	2.35	0.950	0.680	5.20	1.55	0.570
2-3	3	All bypasses open	3.03	0.74	FAIL	14.86	N/A	0.690	N/A	3.35	1.77	1.53
2-4	4	All bypasses open	2.98	1.19	FAIL	14.33	N/A	0.370	N/A	3.31	1.93	1.21
3-1	1	All bypasses open	0.940	0.45	4,253	16.98	2.98	0.980	1.270	5.00	2.52	1.40
3-2	2	All bypasses open	1.11	0.55	4,989	17.04	3.49	1.02	0.790	5.27	2.45	1.34
3-3	3	All bypasses open	1.27	0.44	4,684	16.92	3.30	1.01	0.390	5.87	1.07	2.80
3-4	4	All bypasses open	2.01	0.70	4,859	17.25	3.35	0.750	0.710	5.61	2.36	1.34
4-1	1	All bypasses open	1.29	0.43	4,279	16.73	3.04	0.860	1.17	4.98	2.32	0.00
4-2	2	All bypasses open	1.35	0.62	6,128	17.77	4.11	0.840	0.720	6.34	2.21	1.25
4-3	3	All bypasses open	1.07	0.37	5,551	18.96	3.49	0.980	0.740	7.17	1.85	1.32
4-4	4	All bypasses open	1.27	0.49	4,152	16.70	2.96	0.870	0.900	4.79	2.54	1.40
1A	4	All bypasses open	1.06	0.45	4,252	17.29	2.93	1.05	1.02	5.12	2.64	1.29
1B	4	Bypass 1 closed	1.50	0.51	3,673	16.16	2.71	0.610	0.640	4.63	1.19	1.79
1C	4	Bypasses 1 and 2 closed	1.52	0.59	3,822	15.85	2.87	0.880	0.940	4.04	1.30	1.75
1D	4	Bypasses 1, 2, and 3 closed	1.81	0.49	5,652	15.40	4.37	1.32	0.970	2.64	1.54	0.0500
5A	4	Bypasses 1 and 2 closed	1.09	0.56	4,704	16.84	3.33	1.24	1.41	3.53	2.75	1.05
5B	4	Bypasses 1, 2, and 3 closed	0.800	0.59	4,337	17.00	3.04	1.63	1.86	2.19	2.73	0.07

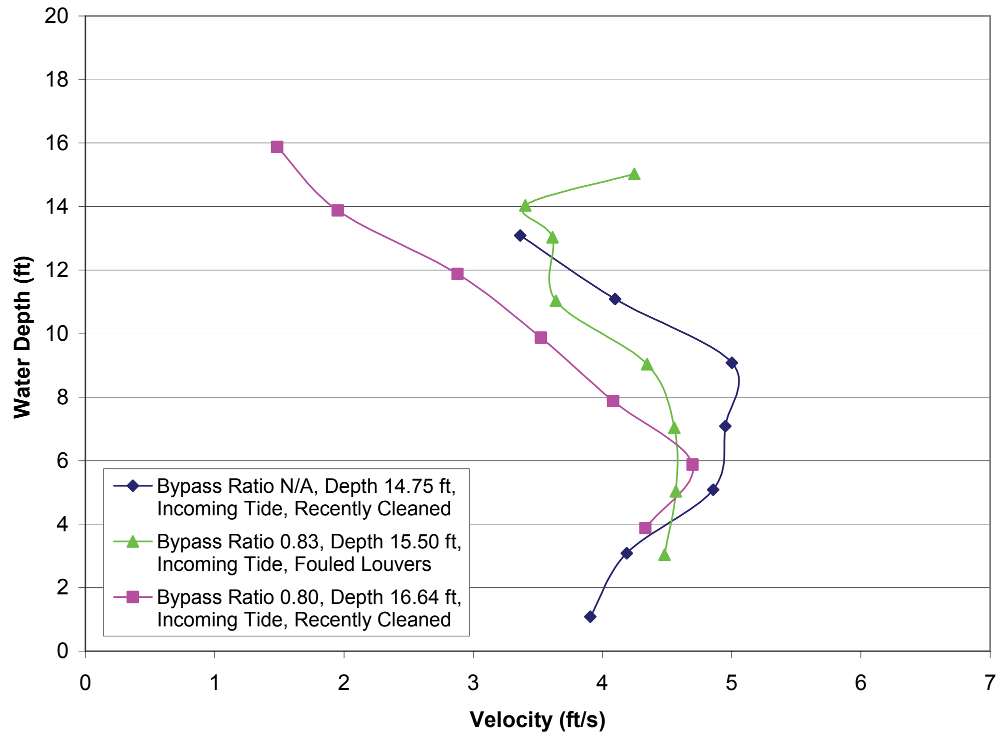

FIGURE 14.—Velocity profiles in the original primary bypass 1 intake entrance.

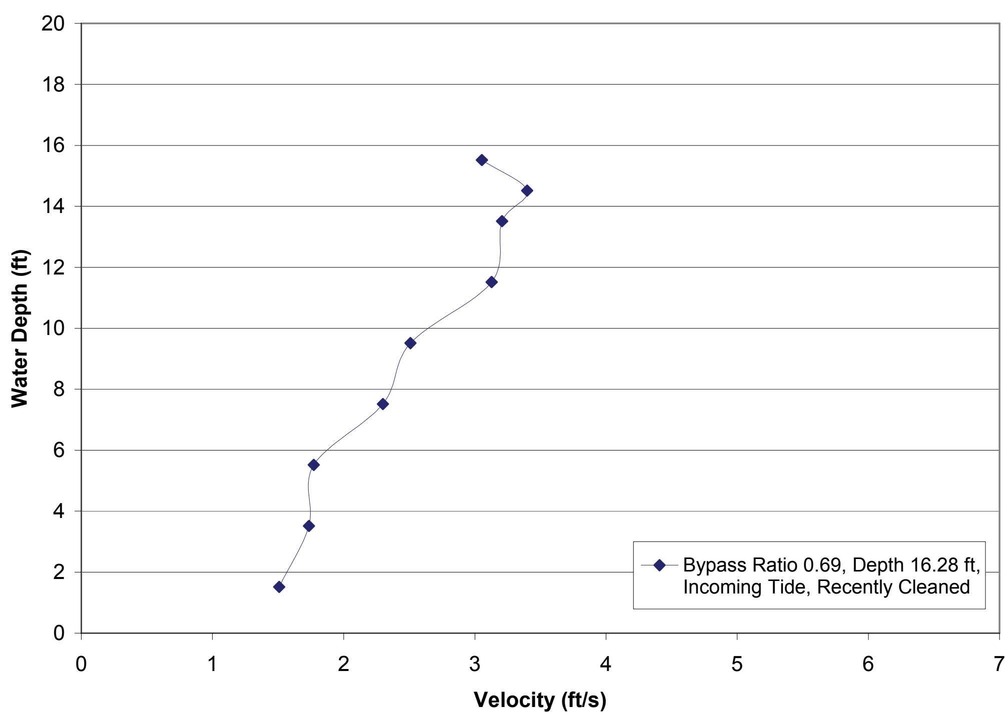

FIGURE 15.—Velocity profiles in the original primary bypass 4 intake entrance.

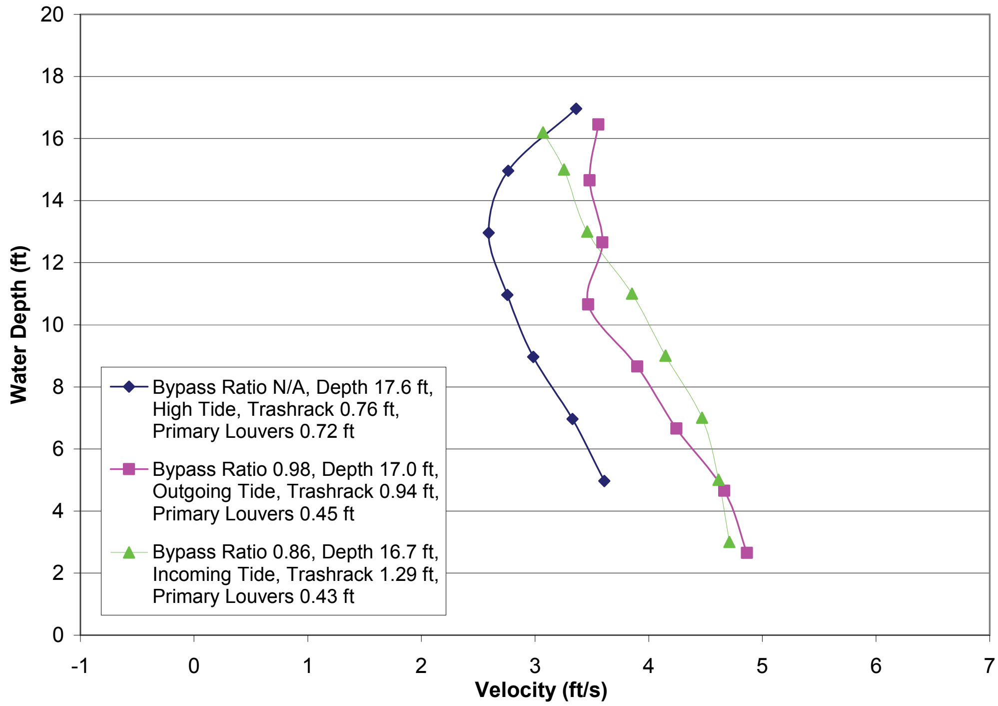

FIGURE 16.—Velocity profiles in the replacement primary bypass 1 intake entrance.

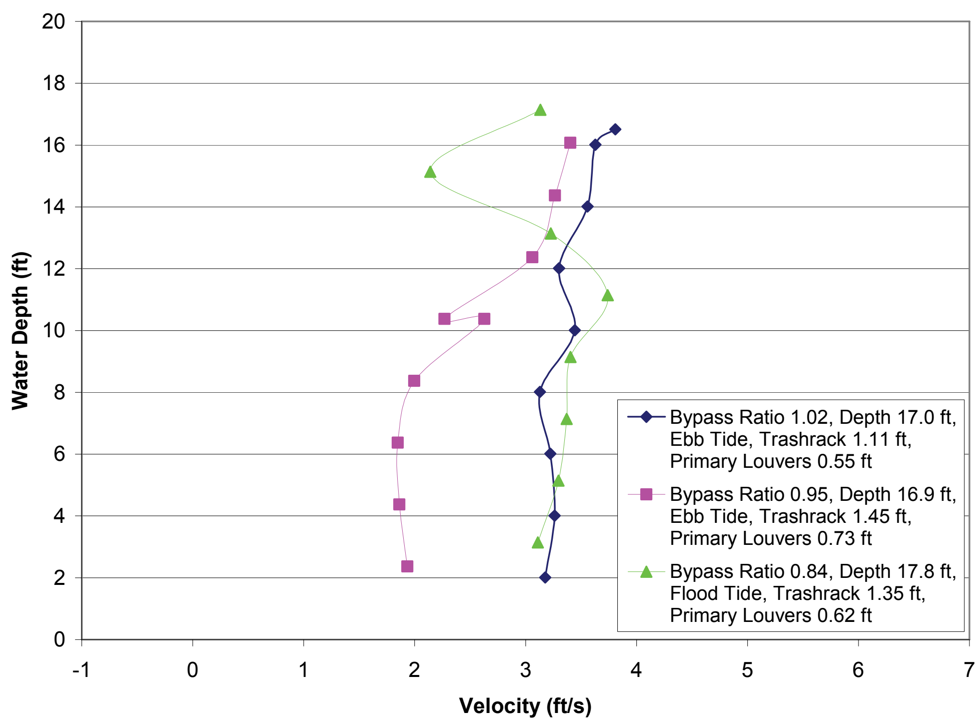

FIGURE 17.—Velocity profiles in the replacement primary bypass 2 intake entrance.

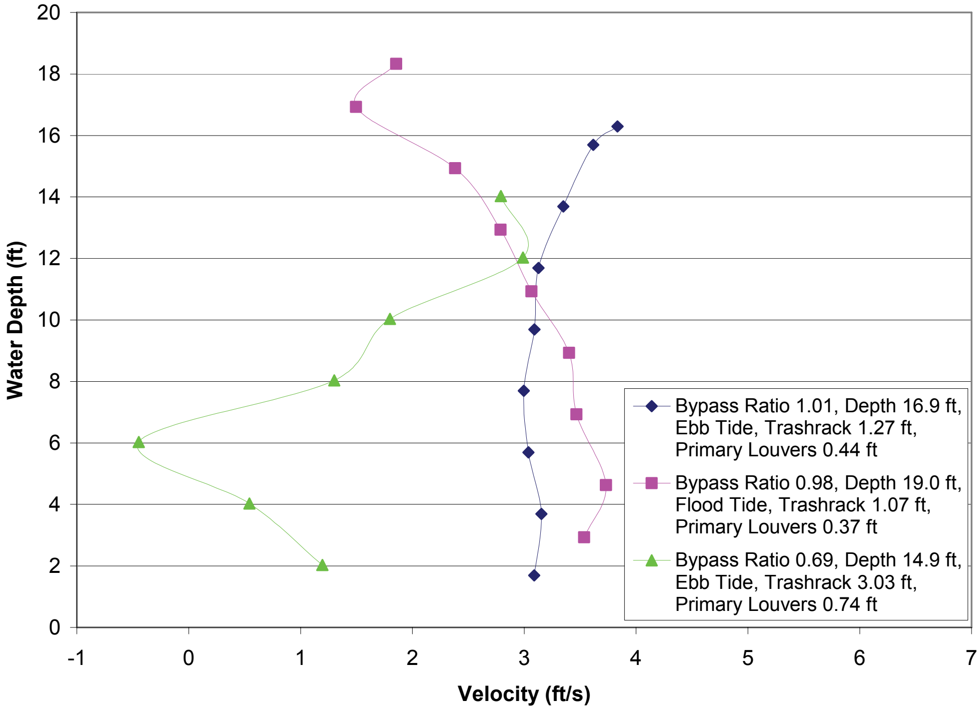

FIGURE 18.—Velocity profiles in the replacement primary bypass 3 intake entrance.

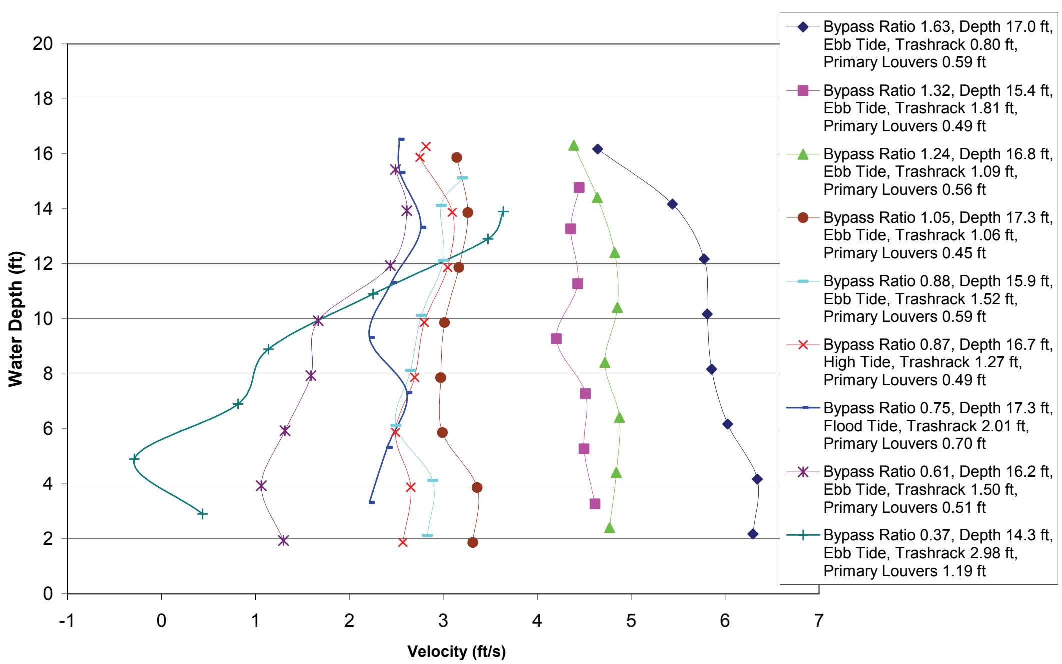

FIGURE 19.—Velocity profiles in the replacement primary bypass 4 intake entrance.

Approach Velocity Profiles

To maximize fish collection, velocities should gradually increase into the bypass with no strong flow accelerations or decelerations. The replacement intakes were developed to generate a near-uniform vertical velocity distribution by redistributing the velocity potential, so the profile generated at the bypass entrance experiences fairly uniform withdrawal energy from bottom to surface. Near-field approach velocity profiles are displayed with corresponding bypass entrance profiles in Appendices 1 and 2 to define the velocity field approaching the bypass entrance.

Data with the original bypass design are displayed in Appendix 1. In order to determine the best location for approach velocity measurements during the next phase, profiles were collected in a zone between the louver panel face and the bypass guide wall and also directly against the louver panel face. Near-field velocity profiles away from the louvers have fairly uniform velocities with slight velocity reductions near the floor due to boundary layer effects. Profiles against the louver panel have significantly lower velocities near the floor. After examining data quality and communicating with the instrument manufacturer, it appears that the profiles measured at 5 ft, 8 ft upstream from the intake were not distorted by beam interference, and flow patterns occurring at depth near the louver panel face were accurately represented. To simplify data collection for the replacement intakes, approach profiles were only collected away from the louver panel face. Appendix 2 contains approach velocity profiles and intake entrance profiles for the replacement bypass intakes. It is likely that test 2-1 was recorded too close to the louvers, since the approach flow distribution is similar to data collected against the louver face.

Johnson *et al*. (2004) and Kubitschek (2003) found that the tapered choke treatment under controlled laboratory conditions without debris influences has the potential to produce near-uniform entrance velocity profiles for a range of operating conditions. When the standing operating procedure cannot be achieved in the field, the bypasses do not appear to produce near-uniform entrance velocity profiles. Other factors such as bypass ratio, debris fouling of the trashrack and louvers, and local approach velocity distributions may have significant influences on the field effectiveness of the tapered choke treatment.

In the laboratory study, bypass ratios of 1.2 and 1.6 were tested due to their significance as TFCF operating criteria. In the field, bypass ratios greater than 1.0 can be difficult to achieve due to tidal conditions, debris influences, and facility limitations. When bypass ratios are well below 1.0, velocity profiles decelerate into the bypass intake (figure 20). This slowing trend negates the intended increase in velocity recommended for guiding fish into the bypass intake. Entrance profiles often show flow patterns that are not present in the approach velocities, indicating that secondary flow patterns and eddies are generated within the transition box due to flow restrictions. This causes non-uniform velocity fields at the bypass entrance and occasional reverse flows.

When bypass ratios are near 1.0, profiles measured in the intake are often similar in shape to near-field velocity profiles (figure 21). This similarity in flow distribution is consistent with scale physical model results (Johnson *et al*., 2004). Flow accelerates or decelerates gradually into the intake with little flow disruption. When bypass ratios are well above 1.0, the flow consistently accelerates into the intake as is recommended for efficient fish collection (figure 22). Since bypass ratios greater than 1.0 are difficult to achieve in the field, one or two of the four bypasses were closed during the field evaluations to force more water to pass through the open bypasses. This alternative operating method raises the bypass ratio of the open bypasses while maintaining an acceptable velocity in the secondary channel.

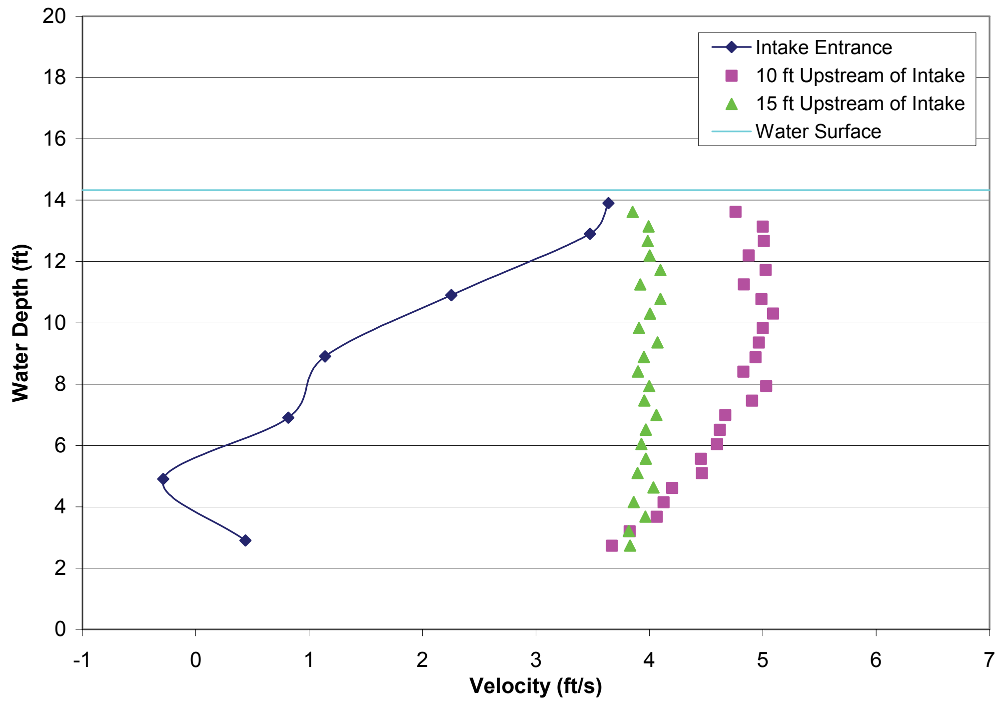

FIGURE 20.—Example of a profile collected with a bypass ratio of less than 1.0. Test 2-4, collected at bypass 4 with a measured bypass ratio of 0.37, shows significant slowing in the approach velocity fields and reverse flows at the intake entrance.

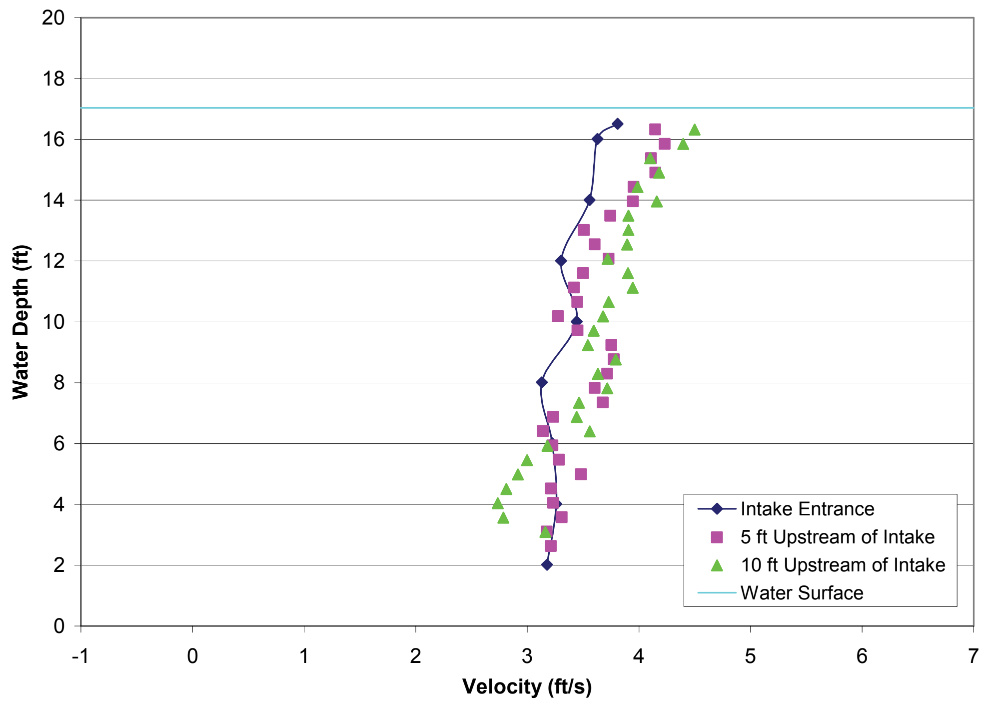

FIGURE 21.—Example of a profile collected with a bypass ratio near 1.0. Test 3-2, collected at bypass 2 with a measured bypass ratio of 1.02, shows similarly shaped approach profiles with a slight deceleration of flow into the intake.

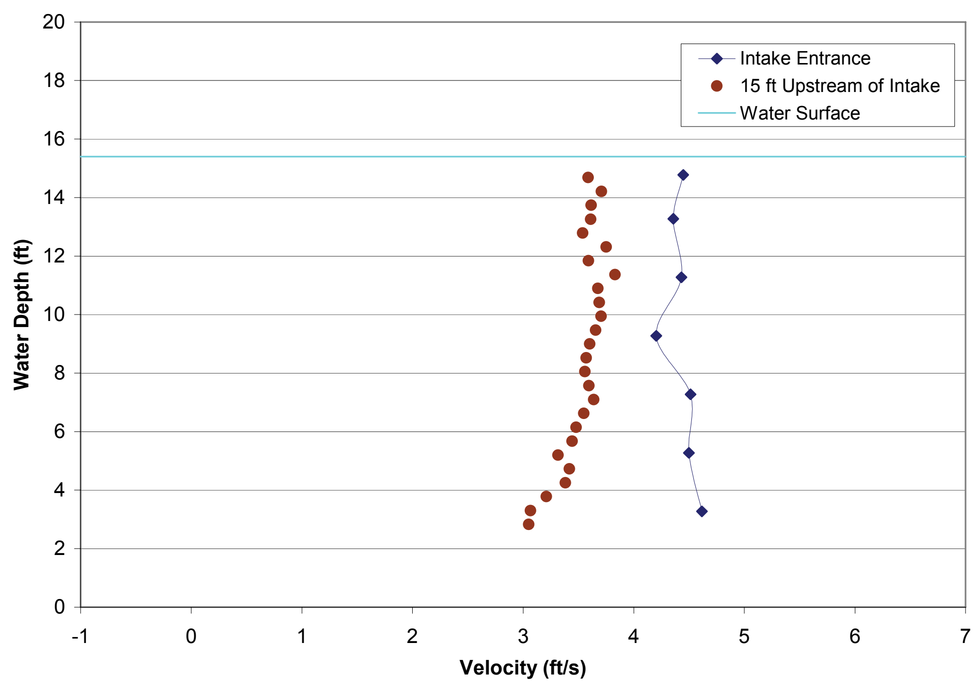

FIGURE 22.—Example of a profile collected with a bypass ratio greater than 1.0. Test 1D, collected at bypass 4 with a measured bypass ratio of 1.32, shows an acceleration of flow into the intake.

With the replacement intakes installed, the trashrack differential was above 2.0 ft during Tests 2-3 and 2-4. In both cases, the large differential produced enough air entrainment in the primary channel to fault the primary channel flowmeter. High louver differentials of 0.74 and 1.29 ft were also recorded for Tests 2-3 and 2-4, respectively. These were the only two tests with a negative downstream velocity component in the vertical profile, showing the presence of reverse flow out of the bypass intake. For both tests, the velocity profiles slowed down on the approach to the bypass entrance (Appendix 2, figures A2-5 and A2-7). Model testing has shown that velocity fields upstream from the bypass intake influence the distribution of flow into the intake (Johnson *et al*., 2004). It is possible for strong vertical gradients in the channel approach velocities to generate flow distribution concentrations at the bypass entrances that overwhelm the characteristics of the intake to produce near-uniform velocities. Since trashrack and louver debris fouling influence approach flow velocities, it is likely that any type of bypass intake will perform best when debris fouling is minimized.

CONCLUSIONS

Since the original primary bypass intakes and transition boxes were severely deteriorated, replacement of the structures was necessary to reduce fish loss and avoidance at the intakes. In the laboratory, the replacement intakes were developed for anticipated field operating conditions. However, the field evaluations show that facility limitations and complex field conditions at the TFCF facility can adversely affect bypass performance.

Certain facility limitations such as high pumping rates downstream at Tracy Pumping Plant, uncontrollable primary channel velocities, low water levels due to tidal effects and South Delta pumping rates, debris loading, and specific design parameters of the facility cannot be readily changed. However, debris management and bypass ratio operation can be more readily controlled through facility operations, although there are times of the year when fisheries criteria cannot be met regardless of operations (California State Water Control Board 1978, Table II). Unless there is a significant change to the design of the facility or a comprehensive change to water management in the South Delta, these two factors require careful management to ensure that the replacement bypass intakes are providing efficient fish collection hydraulics within the aforementioned constraints.

Minimizing the amount of debris on the trashrack and louvers will likely improve performance of the replacement intakes. Bypass ratios less than 1.0 appear to generate secondary flow patterns and eddies due to a restriction in flow. Flow decelerations and even reverse flows can occur on the approach to the bypass entrances. Bypass ratios of 1.0 or greater, had better sustain velocity fields entering the intake with little flow disruption. Bypass ratios well above 1.0 produce an efficient acceleration of flow into the intake. Therefore, the TFCF should be operated to maintain bypass ratios greater than 1.0 whenever possible.

Since increased bypass ratios improve the hydraulics at the intakes, when it is not possible to produce bypass ratios above 1.0 using standard four bypass operations, one or two of the bypasses may be closed to increase flow through the open bypasses. The bypass ratio of the open bypasses is increased while possibly maintaining an acceptable velocity in the secondary channel. A study to analyze closing bypasses as an alternative operational method is recommended. Sufficient field data was collected during the replacement bypass studies on TFCF system wide performance to establish the basis for these alternative operations. Other factors regarding fish behavior need to be considered: the majority of fish are collected through bypass 4 and the maximum fish exposure duration on the louver face is 60 seconds (National Marine Fisheries Service, 1995). Additional hydraulic and fisheries field evaluations may be needed to demonstrate recommended operations. It may be possible to estimate potential improvements in bypass operation with alternative operations by looking at the percent of time that bypass ratios are achievable considering TPP operations, tidal influences, and debris fouling. Operational changes can be enacted after agency approval with no associated capital cost.

ACKNOWLEDGMENTS

This report is published with memory of Perry Johnson. As a consultant to Reclamation on this project, Perry's contributions included helping to design the field experiments, collecting field data, and writing and editing sections of this report. Funding for this work was provided by Reclamation's Mid-Pacific Region - Tracy Office through the Fish Facility Operations and Maintenance and Research Programs. Thanks to Ron Silva and Joe Pennino for their support of this study and Brent Bridges, Lloyd Hess, and Joel Imai for their great help in carrying out the field evaluations. Joe Kubitschek and Warren Frizell, hydraulic engineers for the Bureau of Reclamation, peer reviewed this report.

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APPENDICES

Appendix 1 – Data Collected with Original Primary Bypass Intakes September 2003

Appendix 2 – Data Collected with Replacement Primary Bypass Intakes October 2004

APPENDIX 1

Data Collected with Original Primary Bypass Intakes
September 2003

TABLE A1-1.—System hydraulics during 2003 data collection with the original primary bypass intakes.

	Test Condition						
Test	Bypass	Bypass Operation	Date/Time	Tidal Cycle	Cleaning Cycle	Primary Channel Flow Rate (ft^3/s)	Depth in Primary Channel (ft)
1A	1	All bypasses open	11/18/03 at 1145-1215	Incoming tide	Clean louvers; periodic cleaning	Not recorded	14.75
1B	1	All bypasses open	11/19/03 at 1420-1520	Incoming tide	Clean louvers; recently cleaned	4,132	16.64
1C	1	All bypasses open	11/19/03 at 940-1100	Incoming tide	Fouled louvers; recently cleaned with fouled louver panel 1	4,350	15.5
4A	4	All bypasses open	11/18/03 at 1445-1600	Incoming tide	Clean louvers; periodic cleaning	5,440	16.28

	Bypass Conditions					
Test	Calculated Average Channel Velocity (ft/s)	Average Velocity Measured Near Intake (ft/s)	Calculated Bypass Velocity (ft/s)	ADV Measured Entrance Velocity (ft/s)	Measured Bypass Ratio	Bypass Ratio with Facility Instruments
1A	Not recorded	Not recorded	Not recorded	4.34	Not recorded	Not recorded
1B	2.96	4.12	2.03	3.28	0.80	0.69
1C	3.34	4.94	2.28	4.11	0.83	0.68
4A	3.98	3.66	1.84	2.51	0.69	0.46

	Secondary Channel								
Test	Bypass 1 Flow (ft^3/s)	Bypass 2 Flow (ft^3/s)	Bypass 3 Flow (ft^3/s)	Bypass 4 Flow (ft^3/s)	Secondary Channel Flow Rate (ft^3/s)	Depth in Secondary Channel (ft)	Secondary Channel Velocity (ft/s)	TFCF Pump Operation	Holding Tank Pumping Rate (ft^3/s)
1A	Not recorded	Not recorded	Not recorded	Not recorded	Not recorded	Not recorded	Not recorded	Not recorded	Not recorded
1B	16.9	13.0	8.2	8.1	46.2	4.75	1.22	1 small and 2 large pumps	9.1
1C	17.7	1.2	14.7	11.0	44.6	4.3	1.30	1 large pump	6.7
4A	21.6	20.7	13.7	15.0	71	Not recorded	Not recorded	Not recorded	Not recorded

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
13.09	3.36	0.65	0.00
11.09	3.91	0.51	-0.28
9.09	4.19	0.69	-0.14
7.09	4.86	0.21	-0.29
5.09	4.95	0.19	-0.06
3.09	5.00	0.34	0.16
1.09	4.10	-0.09	0.16

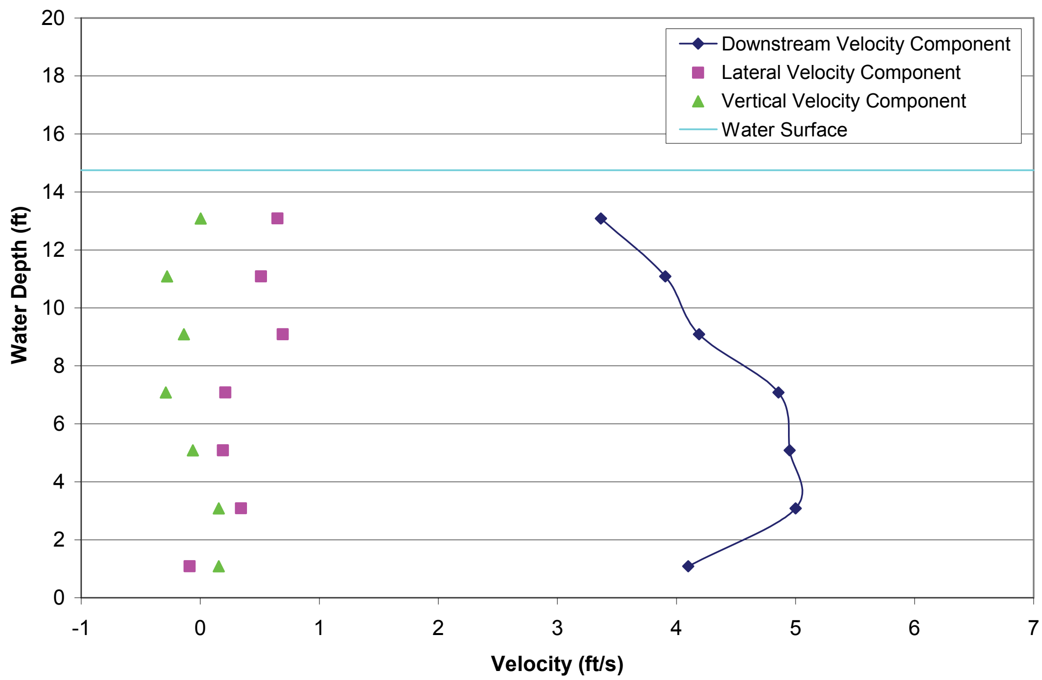

FIGURE A1-1.—Test 1A, bypass 1 intake profile with all bypasses open, measured bypass ratio = N/A, bypass ratio with facility instruments = N/A, incoming tide, water depth = 14.75 ft, recently cleaned trashrack and louvers.

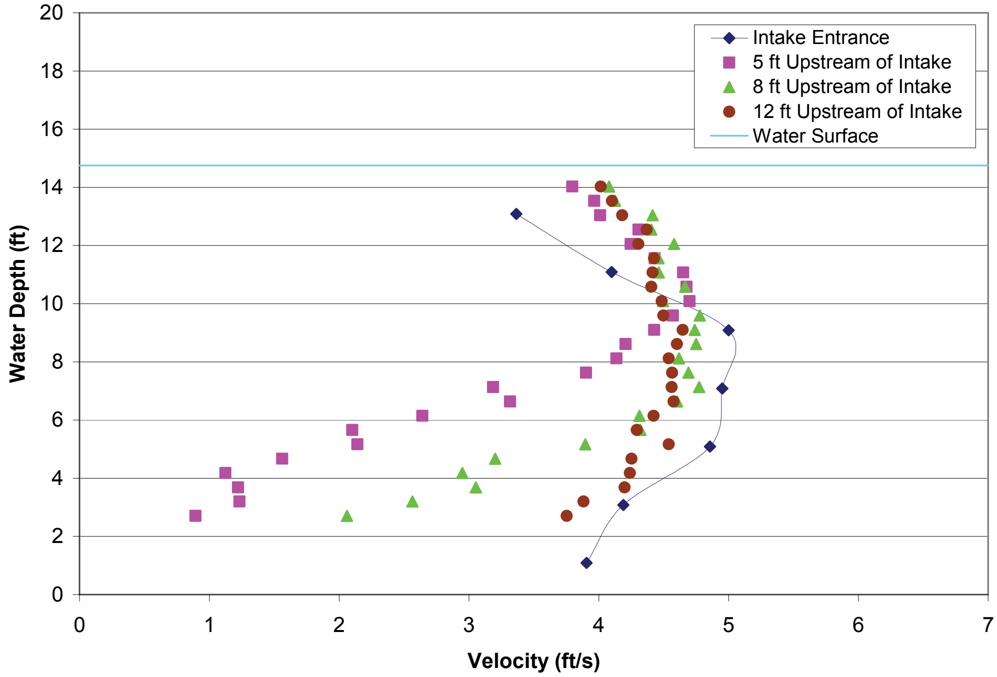

FIGURE A1-2.—Test 1A, bypass 1 approach velocity profiles against the louvers with all bypasses open, measured bypass ratio = N/A, bypass ratio with facility instruments = N/A, incoming tide, water depth = 14.75 ft, recently cleaned trashrack and louvers.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
15.88	1.48	0.67	0.00
13.88	1.95	0.70	0.15
11.88	2.88	0.72	0.18
9.88	3.53	0.70	0.35
7.88	4.08	0.50	-0.10
5.88	4.70	0.40	0.02
3.88	4.33	0.96	0.00

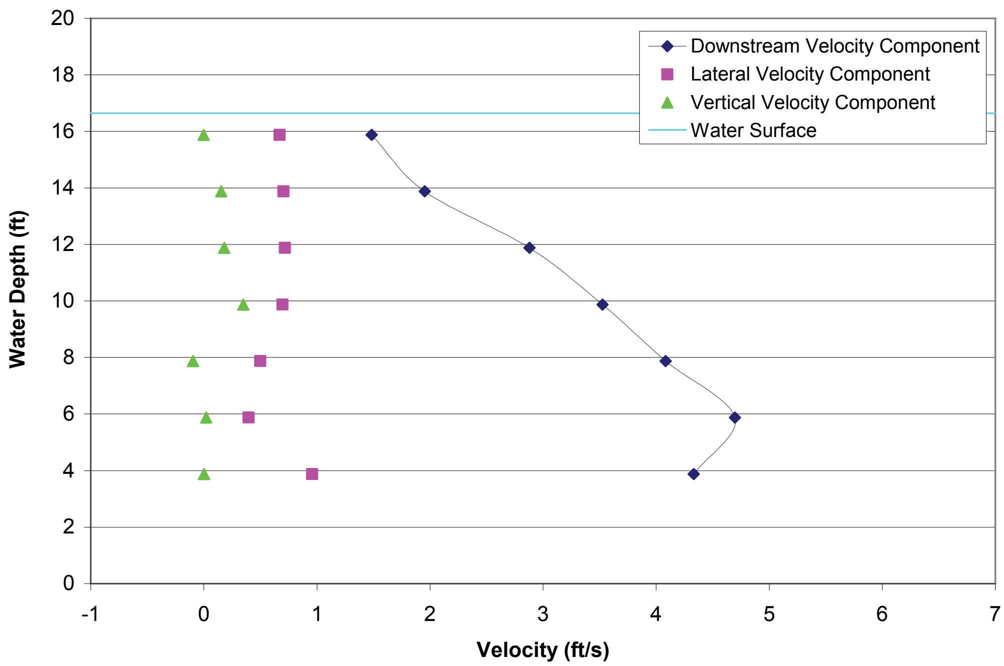

FIGURE A1-3.—Test 1B, bypass 1 intake profiles with all bypasses open, measured bypass ratio = 0.80, bypass ratio with facility instruments = 0.69, incoming tide, water depth = 16.64 ft, recently cleaned trashrack and louvers.

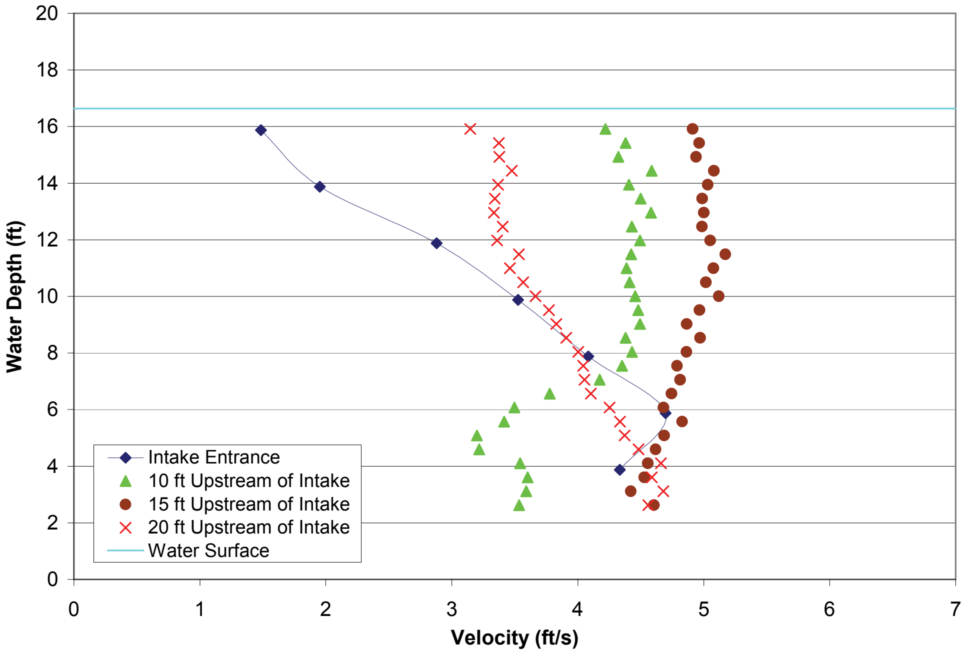

FIGURE A1-4.—Test 1B, bypass 1 approach velocity profiles away from louvers with all bypasses open, measured bypass ratio = 0.80, bypass ratio with facility instruments = 0.69, incoming tide, water depth = 16.64 ft, recently cleaned trashrack and louvers.

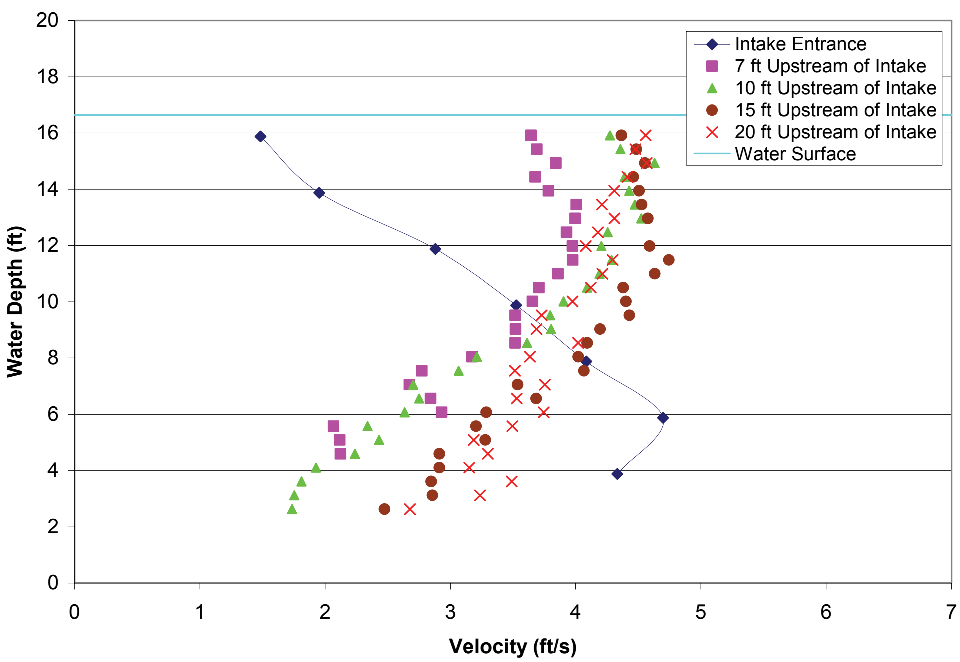

FIGURE A1-5.—Test 1B, bypass 1 approach velocity profiles against the louvers with all bypasses open, measured bypass ratio = 0.80, bypass ratio with facility instruments = 0.69, incoming tide, water depth = 16.64 ft, recently cleaned trashrack and louvers.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
15.04	4.25	0.99	-0.08
14.04	3.40	1.34	-0.31
13.04	3.61	1.19	-0.39
11.04	3.64	1.51	-0.26
9.04	4.35	0.98	-0.22
7.04	4.56	1.16	-0.10
5.04	4.57	1.51	0.07
3.04	4.48	0.76	0.31

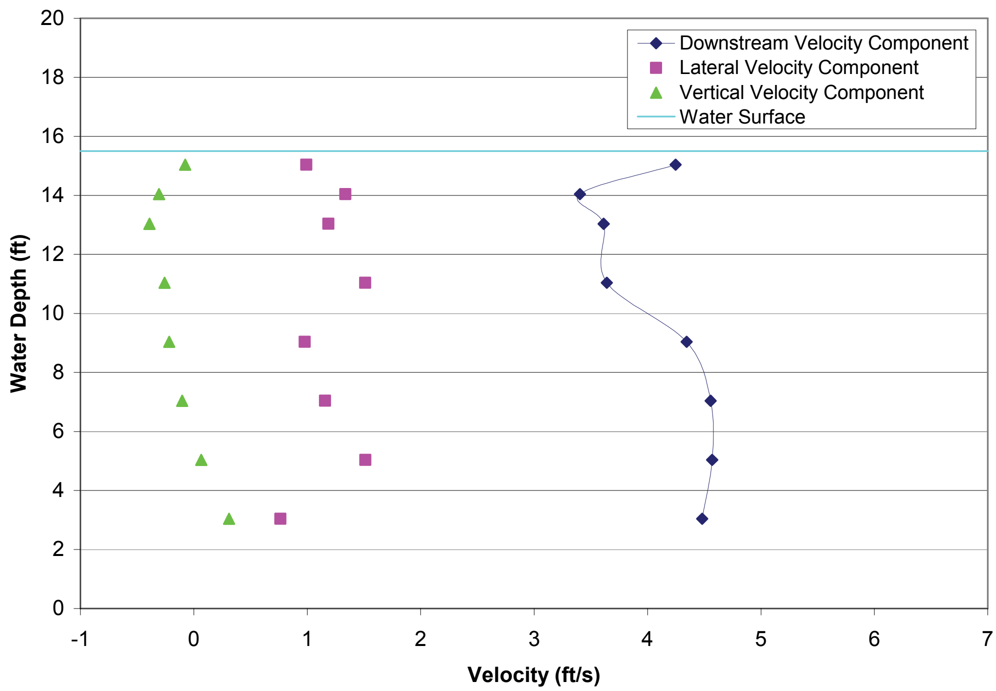

FIGURE A1-6.—Test 1C, bypass 1 intake profile with all bypasses open, measured bypass ratio = 0.83, bypass ratio with facility instruments = 0.68, incoming tide, water depth = 15.50 ft, fouled louver panel 1, clean trashrack.

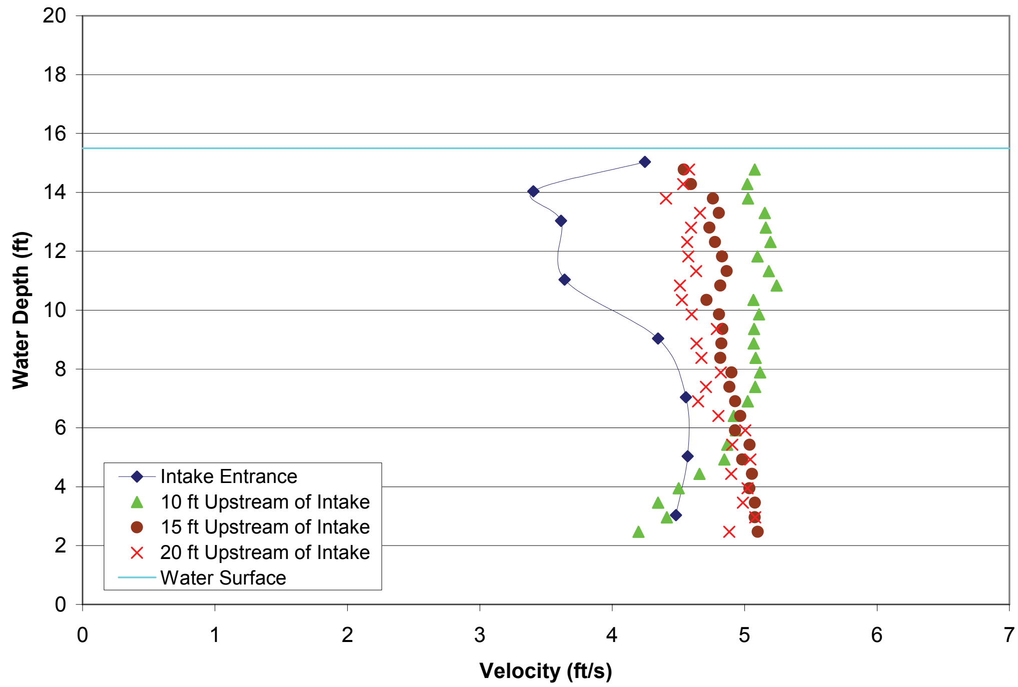

FIGURE A1-7.—Test 1C, bypass 1 approach velocity profiles away from louvers with all bypasses open, measured bypass ratio = 0.83, bypass ratio with facility instruments = 0.68, incoming tide, water depth = 15.50 ft, fouled louver panel 1, clean trashrack.

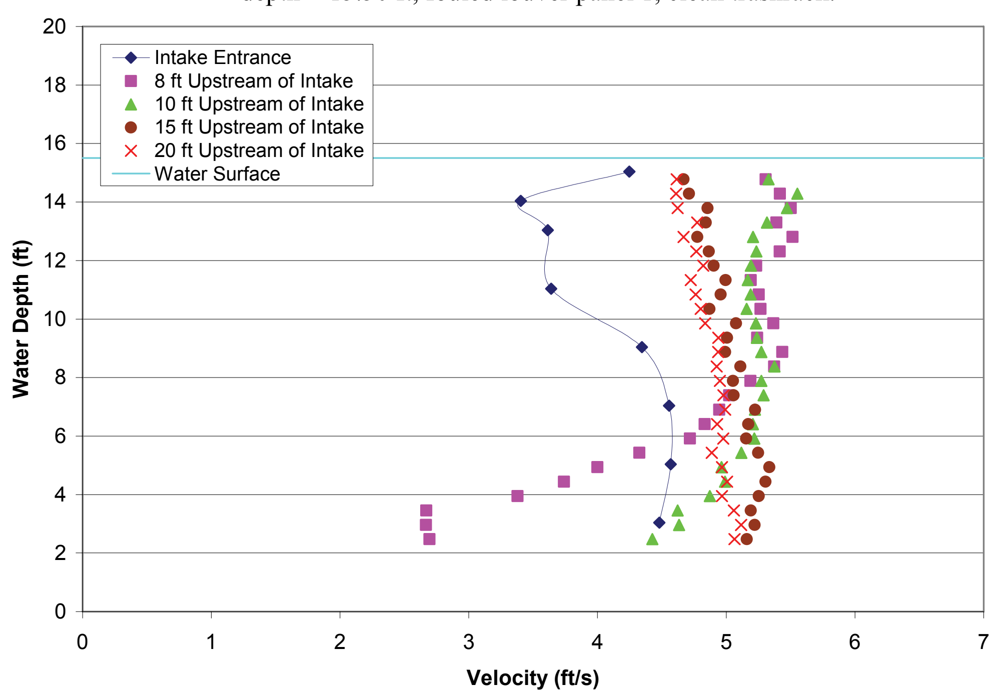

FIGURE A1-8.—Test 1C, bypass 1 approach velocity profiles against the louvers with all bypasses open, measured bypass ratio = 0.83, bypass ratio with facility instruments = 0.68, incoming tide, water depth = 15.50 ft, fouled louver panel 1, clean trashrack.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
15.52	3.05	0.44	-0.08
14.52	3.40	0.46	-0.18
13.52	3.21	0.61	-0.49
11.52	3.13	0.41	-0.47
9.52	2.51	0.71	-0.47
7.52	2.30	0.57	-0.48
5.52	1.77	0.62	-0.39
3.52	1.74	0.64	-0.30
1.52	1.51	0.27	-0.10

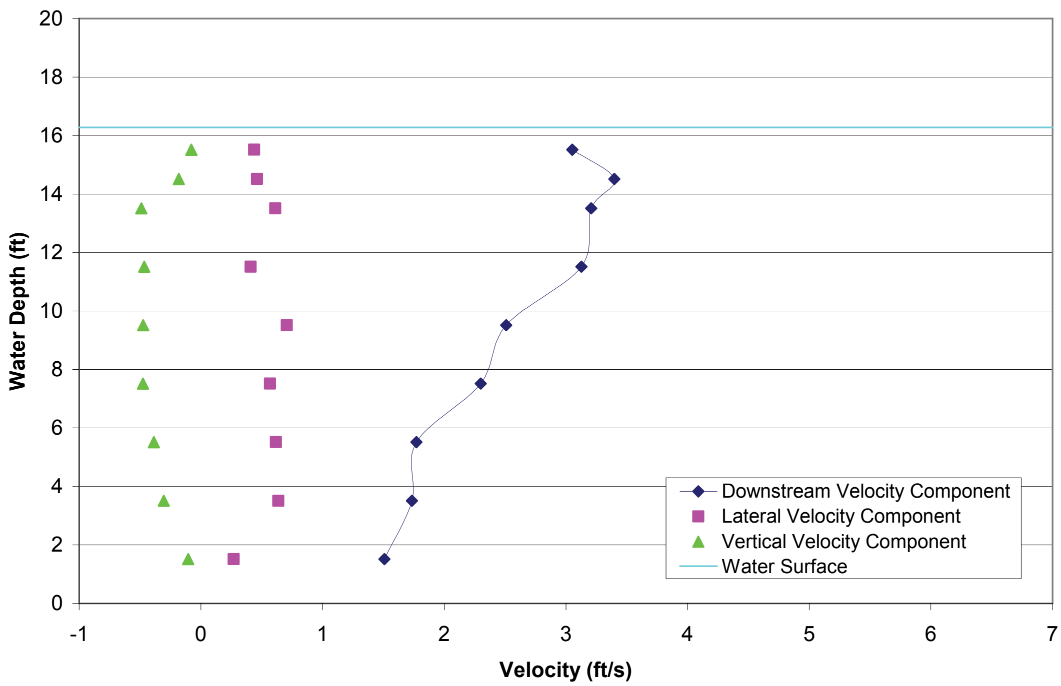

FIGURE A1-9.—Test 4A, bypass 4 intake profile with all bypasses open, measured bypass ratio = 0.69, bypass ratio for facility instruments = 0.46, incoming tide, water depth = 16.28 ft, recently cleaned trashrack and louvers.

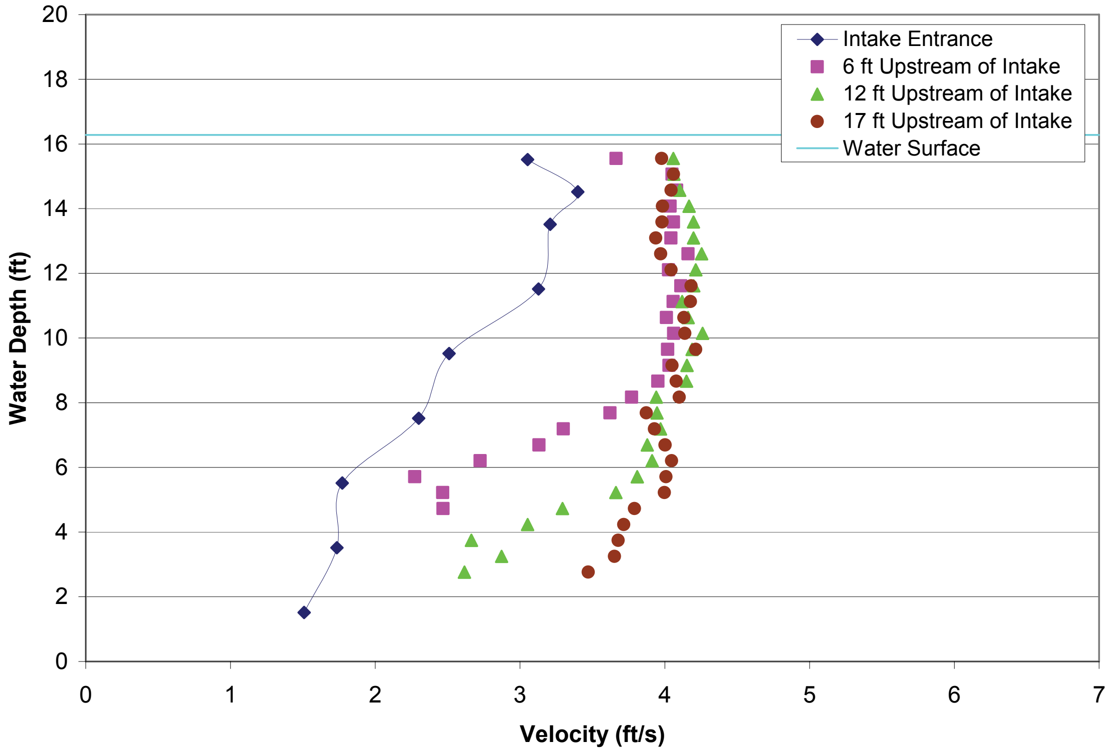

FIGURE A1-10.—Test 4A, bypass 4 approach velocity profiles away from louvers with all bypasses open, measured bypass ratio = 0.69, bypass ratio for facility instruments = 0.46, incoming tide, water depth = 16.28 ft, recently cleaned trashrack and louvers.

APPENDIX 2

Data Collected with Replacement Primary Bypass Intakes
October 2004

Table A2-1.—System hydraulics during 2004 data collection with the replacement primary bypass intakes.

		OPERATING CONDITIONS				
Test	**Bypass**	**Bypass Operation**	**Date/Time**	**Tidal Cycle**	**Time Since Louver Cleaning**	**Primary Channel Flow Rate (ft^3/s)**
2-1	1	All bypasses open	10/27/04 at 755	High tide	7 hrs	4,443
2-2	2	All bypasses open	10/27/04 at 950	Outgoing tide	9 hrs	3,337
2-3	3	All bypasses open	10/27/04 at 1115	Outgoing tide	10 hrs	FAIL
2-4	4	All bypasses open	10/27/04 at 1215	Outgoing tide	11 hrs	FAIL
3-1	1	All bypasses open	10/28/04 at 1155	Outgoing tide	4 hrs	4,253
3-2	2	All bypasses open	10/28/04 at 1100	Outgoing tide	3 hrs	4,989
3-3	3	All bypasses open	10/28/04 at 935	Outgoing tide	1.5 hrs	4,684
3-4	4	All bypasses open	10/27/04 at 1725	Incoming tide	1.5 hrs	4,859
4-1	1	All bypasses open	10/28/04 at 1510	Incoming tide	1 hr	4,279
4-2	2	All bypasses open	10/28/04 at 1800	Incoming tide	3 hrs	6,128
4-3	3	All bypasses open	10/28/04 at 1915	Incoming tide	4 hrs	5,551
4-4	4	All bypasses open	10/29/04 at 930	High tide	1.5 hrs	4,152
1A	4	All bypasses open	10/26/04 at 930	Outgoing tide	1.5 hrs	4,252
1B	4	Bypass 1 closed	10/26/04 at 1100	Outgoing tide	3.0 hrs*	3,673
1C	4	Bypasses 1 and 2 closed	10/26/04 at 1145	Outgoing tide	3.75 hrs*	3,822
1D	4	Bypasses 1, 2, and 3 closed	10/26/04 at 1230	Outgoing tide	4.5 hrs*	5,652
5A	4	Bypasses 1 and 2 closed	10/29/04 at 1010	Outgoing tide	2 hrs*	4,704
5B	4	Bypasses 1, 2, and 3 closed	10/29/04 at 1110	Outgoing tide	3 hrs	4,337

* Upstream louver panel not removed prior to test.

Table A2-1 (cont.)

		PRIMARY CHANNEL DEPTHS				
Test	**Bypass**	**Depth Upstream from Trashrack (ft)**	**Depth in Primary Channel (ft)**	**Depth Downstream from Primary Louvers (ft)**	**Differential Across Trashrack (ft)**	**Differential Across Primary Louvers (ft)**
2-1	1	18.35	17.59	16.87	0.76	0.72
2-2	2	18.35	16.9	16.17	1.45	0.73
2-3	3	17.89	14.86	14.12	3.03	0.74
2-4	4	17.31	14.33	13.14	2.98	1.19
3-1	1	17.92	16.98	16.53	0.94	0.45
3-2	2	18.15	17.04	16.49	1.11	0.55
3-3	3	18.19	16.92	16.48	1.27	0.44
3-4	4	19.26	17.25	16.55	2.01	0.7
4-1	1	18.02	16.73	16.3	1.29	0.43
4-2	2	19.12	17.77	17.15	1.35	0.62
4-3	3	20.03	18.96	18.59	1.07	0.37
4-4	4	17.97	16.7	16.21	1.27	0.49
1A	4	18.35	17.29	16.84	1.06	0.45
1B	4	17.66	16.16	15.65	1.5	0.51
1C	4	17.37	15.85	15.26	1.52	0.59
1D	4	17.21	15.4	14.91	1.81	0.49
5A	4	17.93	16.84	16.28	1.09	0.56
5B	4	17.8	17	16.41	0.8	0.59

Table A2-1 (cont.)

		PRIMARY CHANNEL VELOCITIES				
Test	**Bypass**	**Path 1 Accusonic Velocity (ft/s)**	**Path 2 Accusonic Velocity (ft/s)**	**Calculated Average Channel Velocity (ft/s)**	**Average Velocity Measured Near Intake (ft/s)**	**Difference Between Channel Velocity and Near Intake Velocity (%)**
2-1	1	3.6	3.05	3.01	N/A[1]	N/A
2-2	2	3.7	2.5	2.35	2.60	-9.59
2-3	3	FAIL	FAIL	N/A[2]	2.11	N/A
2-4	4	FAIL	FAIL	N/A[2]	4.49	N/A
3-1	1	3.39	3.1	2.98	4.07	-26.74
3-2	2	4.08	3.77	3.49	3.33	4.67
3-3	3	4.4	3.92	3.30	3.21	2.67
3-4	4	FAIL	3.72	3.35	3.29	1.93
4-1	1	4.3	3.4	3.04	4.58	-33.52
4-2	2	4.37	4.22	4.11	3.79	8.32
4-3	3	4.1	3.55	3.49	2.91	19.77
4-4	4	3.47	3.36	2.96	3.19	-7.22
1A	4	--	--	2.93	2.99	-2.09
1B	4	3.26	3.5	2.71	2.99	-9.50
1C	4	3.62	3.44	2.87	3.24	-11.40
1D	4	3.67	FAIL	4.37	3.36	30.04
5A	4	3.69	3.7	3.33	3.81	-12.72
5B	4	2.84	3.56	3.04	3.54	-14.21

[1] Velocity profile was collected too close to the primary louvers to be used as an average approach velocity.
[2] Primary flowmeter failed due to excessive air entrainment in the flow path caused by a high trashrack differential.

Table A2-1 (cont.)

		PRIMARY BYPASS CONDITIONS								
Test	**Bypass**	**Bypass 1 Flow (ft^3/s)**	**Bypass 2 Flow (ft^3/s)**	**Bypass 3 Flow (ft^3/s)**	**Bypass 4 Flow (ft^3/s)**	**Secondary Channel Flow Rate (ft^3/s)**	**Calculated Bypass Velocity (ft/s)**	**ADV Measured Entrance Velocity (ft/s)**	**Measured Bypass Ratio**	**Bypass Ratio with Facility Instruments**
2-1	1	22.8	16.2	16	15.6	70.6	2.59	3.06	N/A	0.86
2-2	2	22.2	13.6	13.8	14.9	64.5	1.61	2.47	0.95	0.68
2-3	3	22.9	8.5	5.5	10.5	47.4	0.74	1.45	0.69	N/A
2-4	4	22.1	12.5	8.2	8.4	51.2	1.17	1.64	0.37	N/A
3-1	1	32.1	23.4	23	22.1	100.6	3.78	3.97	0.98	1.27
3-2	2	33.3	23.6	24.1	22.2	103.2	2.77	3.39	1.02	0.79
3-3	3	21.6	14	11	3.8	50.4	1.30	3.26	1.01	0.39
3-4	4	36.4	25.3	23.5	20.5	105.7	2.38	2.47	0.75	0.71
4-1	1	29.7	21.2	21.9	19.7	92.5	3.55	3.95	0.86	1.17
4-2	2	34.6	26.1	26.3	25	112	2.94	3.18	0.84	0.72
4-3	3	32.5	25.4	24.5	23.6	106	2.58	2.86	0.98	0.74
4-4	4	29.7	22.2	23	22.3	97.2	2.67	2.77	0.87	0.90
1A	4	32.3	24.9	25.3	25.7	108.2	2.97	3.15	1.05	1.02
1B	4	0	15.9	14.1	13.9	43.9	1.72	1.81	0.61	0.64
1C	4	0	0	20.7	21.4	42.1	2.70	2.85	0.88	0.94
1D	4	0	0	0	32.6	32.6	4.23	4.44	1.32	0.97
5A	4	0	0	38.3	39.4	77.7	4.68	4.74	1.24	1.41
5B	4	0	0	0	47.9	47.9	5.64	5.77	1.63	1.86

Table A2-1 (cont.)

		SECONDARY CHANNEL DEPTHS					
Test	**Bypass**	**Depth Upstream from Secondary Louver 1 (ft)**	**Depth Between Secondary Louvers (ft)**	**Depth Downstream from Secondary Louver 2 (ft)**	**Differential Across Secondary Louver 1 (ft)**	**Differential Across Secondary Louver 2 (ft)**	**Differential Across Both Secondary Louver Lines (ft)**
2-1	1	6.24	6.02	6.1	0.22	-0.08	0.14
2-2	2	5.2	4.9	4.88	0.3	0.02	0.32
2-3	3	3.35	2.87	2.75	0.48	0.12	0.6
2-4	4	3.31	2.71	2.56	0.6	0.15	0.75
3-1	1	5	4.39	4.23	0.61	0.16	0.77
3-2	2	5.27	4.71	4.65	0.56	0.06	0.62
3-3	3	5.87	5.28	5.14	0.59	0.14	0.73
3-4	4	5.61	5.38	5.25	0.23	0.13	0.36
4-1	1	4.98	4.72	4.64	0.26	0.08	0.34
4-2	2	6.34	6.15	6.1	0.19	0.05	0.24
4-3	3	7.17	7	7	0.17	0	0.17
4-4	4	4.79	4.43	4.28	0.36	0.15	0.51
1A	4	5.12	4.29	4.12	0.83	0.17	1
1B	4	4.63	4.54	4.64	0.09	-0.1	-0.01
1C	4	4.04	3.95	3.95	0.09	0	0.09
1D	4	2.64	2.55	2.55	0.09	0	0.09
5A	4	3.53	3.22	2.79	0.31	0.43	0.74
5B	4	2.19	1.91	1.5	0.28	0.41	0.69

Table A2-1 (cont.)

		SECONDARY CHANNEL FLOW RATES					
Test	**Bypass**	**Holding Tank Flow Rate – Facility Flowmeter (ft^3/s)**	**Holding Tank Flow Rate - Portable Flowmeter (ft^3/s)**	**Notes on Bypass Readings**	**Secondary Channel Flow Rate from Flowmeter (ft^3/s))**	**Channel Flowmeter + Bypass Flow Rate (ft^3/s)**	**Difference Between Bypass Flowmeters and Channel Flowmeter (%)**
2-1	1	7.55	0	Interior flowmeter less reliable	59.7	67.25	-4.7
2-2	2	2.3	no reading	Holding tank flow shutting off	55	57.3	-11.2
2-3	3	4.53	4.47	OK	46	50.53	6.6
2-4	4	3.87	2.99	OK	44	47.87	-6.5
3-1	1	8.83	0	Interior flowmeter less reliable	89.6	98.43	-2.2
3-2	2	8.64	8.87	OK	89.7	98.34	-4.7
3-3	3	8.82	no reading	Bypass 4 reading low	48.4	57.22	13.5
3-4	4	8.86	8.75	OK	95.6	104.46	-1.2
4-1	1	0	0	Holding tank flow off	88.2	88.2	-4.6
4-2	2	8.73	no reading	OK	97.5	106.23	-5.2
4-3	3	8.72	8.99	OK	94.6	103.32	-2.5
4-4	4	8.49	8.62	OK	84	92.49	-4.8
1A	4	8.7	8.7	OK	103.72	112.42	3.9
1B	4	4.91	4.31	OK	42.3	47.21	7.5
1C	4	4.61	4.14	OK	39.17	43.78	4.0
1D	4	0.1	0	Holding tank flow off	26.9	27	-17.2
5A	4	5.09	5.57	OK	72.7	77.79	0.1
5B	4	0.2	0.48	Water depth too low to bypass	39	39.2	-18.2

Table A2-1 (cont.)

		SECONDARY BYPASS CONDITIONS				
Test	Bypass	TFCF Pump Operation	Velocity Entering Secondary Channel (ft/s)	Velocity in Front of Bypass (ft/s)	Secondary Bypass Velocity (ft/s)	Secondary Bypass Ratio
2-1	1	Pumps 4 and 5	1.41	1.47	2.51	1.71
2-2	2	Pumps 4 and 5	1.55	1.65	0.94	0.57
2-3	3	Pumps 4 and 5	1.77	2.06	3.16	1.53
2-4	4	Pumps 4 and 5	1.93	2.36	2.86	1.21
3-1	1	Pumps 1, 2, and 6	2.52	2.86	4.02	1.40
3-2	2	Pumps 1, 2, and 6	2.45	2.74	3.67	1.34
3-3	3	Pumps 5 and 6	1.07	1.19	3.34	2.80
3-4	4	Pumps 3, 4, and 6	2.36	2.46	3.29	1.34
4-1	1	Pumps 3, 4, and 6	2.32	2.45	0.00	0.00
4-2	2	Pumps 3, 4, and 6	2.21	2.28	2.84	1.25
4-3	3	Pumps 3, 4, and 6	1.85	1.89	2.49	1.32
4-4	4	Pumps 1, 2, and 5	2.54	2.74	3.83	1.40
1A	4	Pumps 3, 4, 5, and 6	2.64	3.15	4.06	1.29
1B	4	Pumps 5 and 6	1.19	1.21	2.16	1.79
1C	4	Pumps 5 and 6	1.30	1.33	2.33	1.75
1D	4	Pumps 5 and 6	1.54	1.60	0.08	0.05
5A	4	Pumps 1, 2, and 5	2.75	3.02	3.16	1.05
5B	4	Pumps 1, 2, and 5	2.73	3.13	0.21	0.07

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
16.96	3.36	-0.05	0.06
14.96	2.76	0.05	-0.10
12.96	2.59	0.16	0.06
10.96	2.76	-0.10	0.00
8.96	2.98	-0.03	-0.05
6.96	3.33	0.04	-0.06
4.96	3.61	-0.21	-0.14

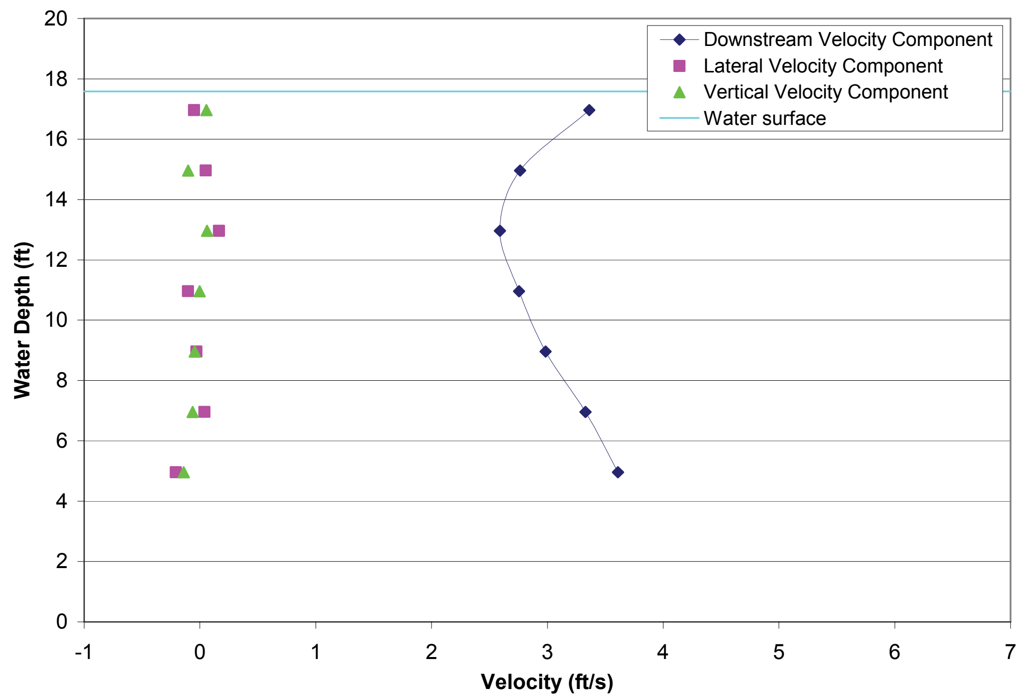

FIGURE A2-1.—Test 2-1, bypass 1 intake profile with all bypasses open, measured bypass ratio = N/A, bypass ratio with facility instruments = 0.86, high tide, water depth = 17.59 ft, trashrack differential = 0.76 ft, louvers differential = 0.72 ft.

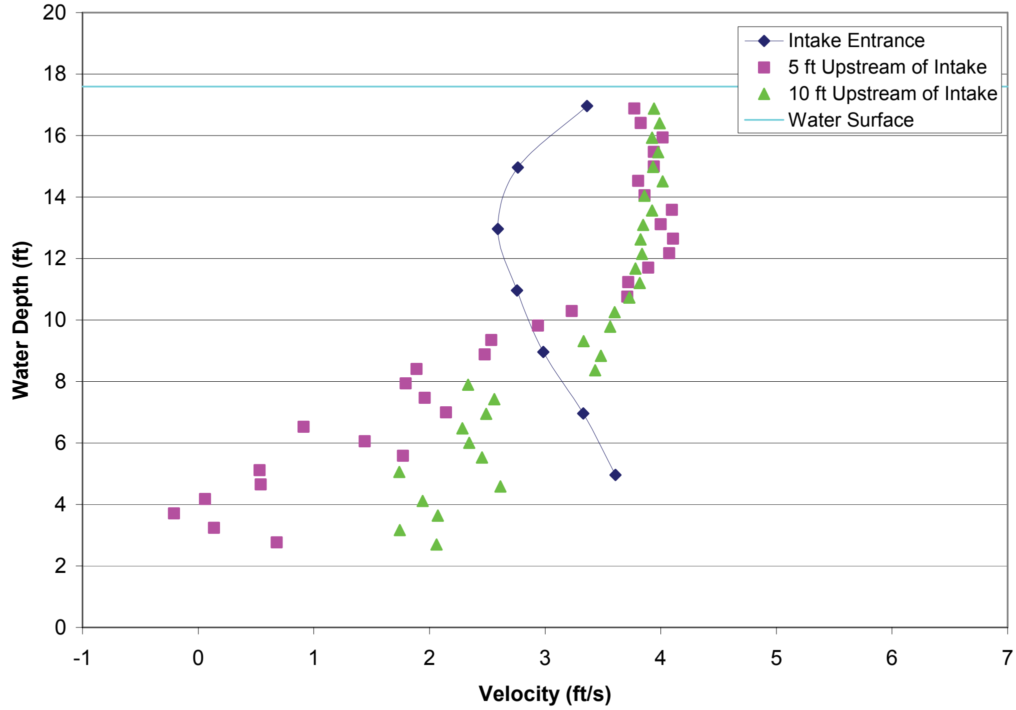

FIGURE A2-2.—Test 2-1, bypass 1 approach velocity profiles with all bypasses open, measured bypass ratio = N/A, bypass ratio with facility instruments = 0.86, high tide, water depth = 17.59 ft, trashrack differential = 0.76 ft, louvers differential = 0.72 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
16.07	3.40	0.13	-0.32
14.37	3.27	-0.08	-0.80
12.37	3.06	0.02	-0.69
10.37	2.63	0.25	-0.57
10.37	2.27	0.22	-0.50
8.37	2.00	0.09	-0.25
6.37	1.85	0.11	-0.06
4.37	1.86	0.14	0.03
2.37	1.93	0.01	0.08

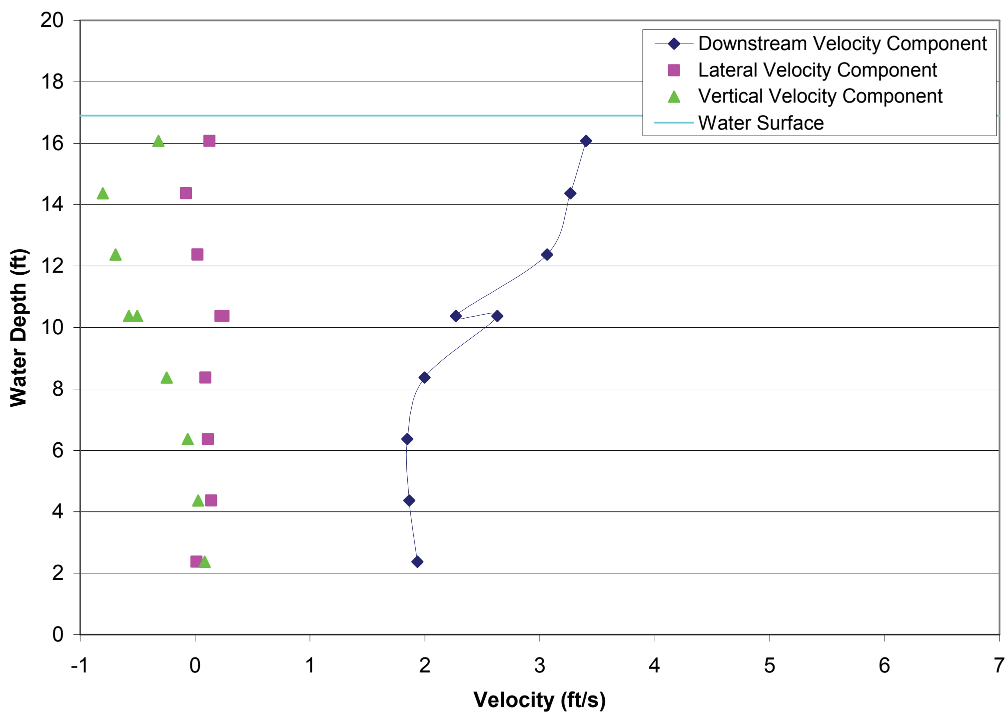

FIGURE A2-3.—Test 2-2, bypass 2 intake profile with all bypasses open, measured bypass ratio = 0.95, bypass ratio with facility instruments = 0.68, outgoing tide, water depth = 16.90 ft, trashrack differential = 1.45 ft, louvers differential = 0.73 ft.

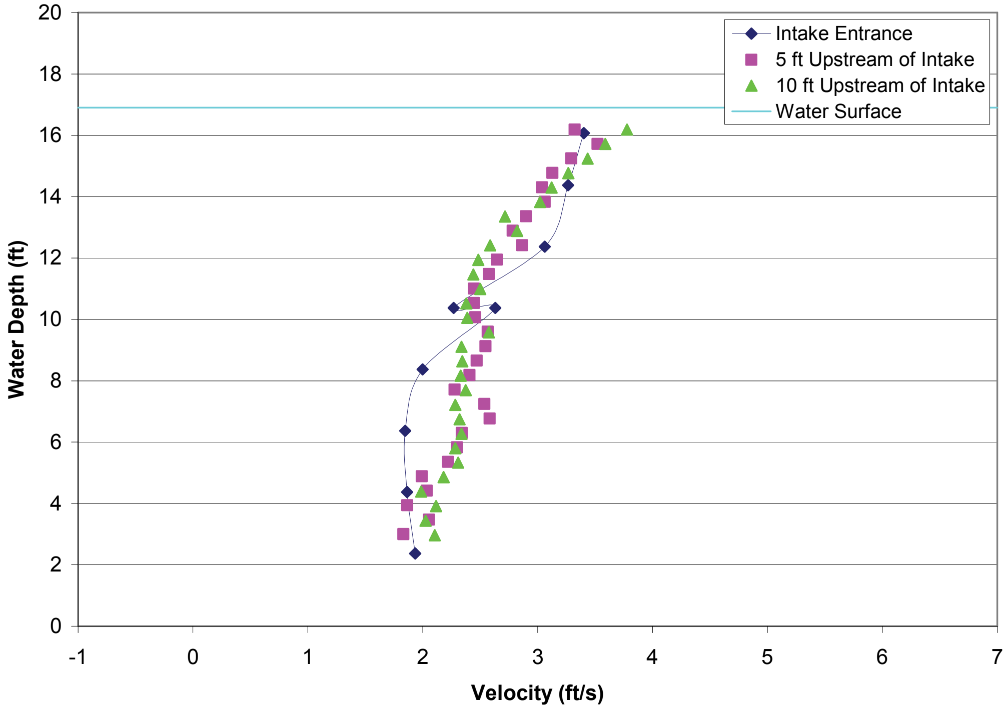

FIGURE A2-4.—Test 2-2, bypass 2 approach velocity profiles with all bypasses open, measured bypass ratio = 0.95, bypass ratio with facility instruments = 0.68, outgoing tide, water depth = 16.90 ft, trashrack differential = 1.45 ft, louvers differential = 0.73 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
14.03	2.79	0.14	0.14
12.03	2.99	-0.10	-0.49
10.03	1.80	0.09	-0.59
8.03	1.30	0.13	-0.48
6.03	-0.45	0.22	-0.31
4.03	0.54	0.18	0.09
2.03	1.19	0.04	0.05

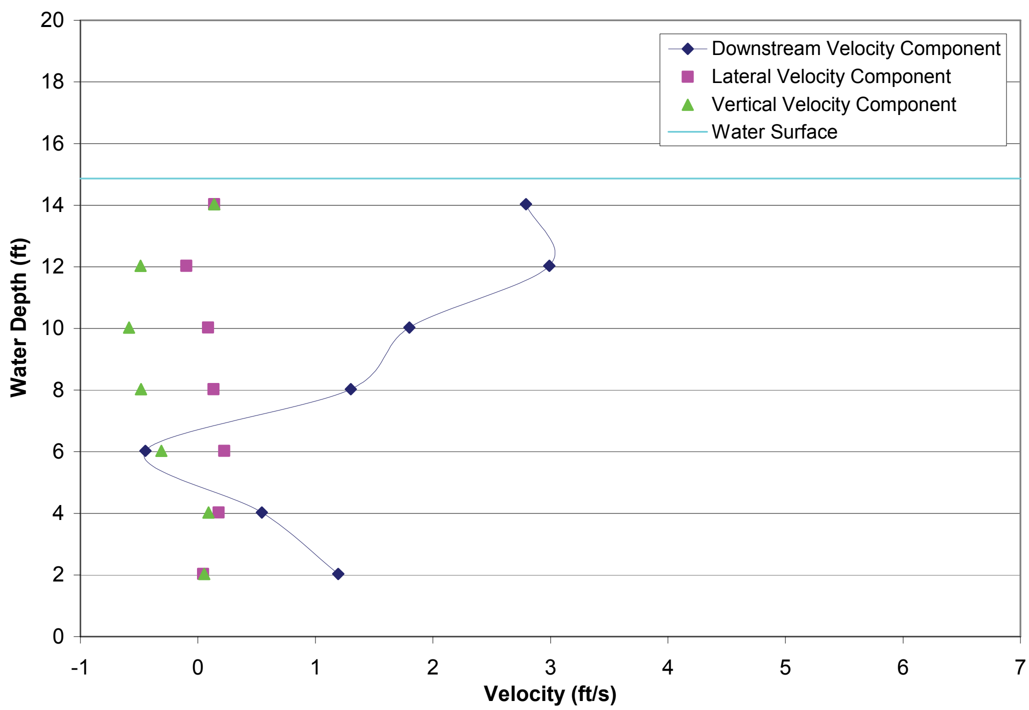

FIGURE A2-5.—Test 2-3, bypass 3 intake profile with all bypasses open, measured bypass ratio = 0.69, bypass ratio with facility instruments = N/A, outgoing tide, water depth = 14.86 ft, trashrack differential = 3.03 ft, louvers differential = 0.74 ft.

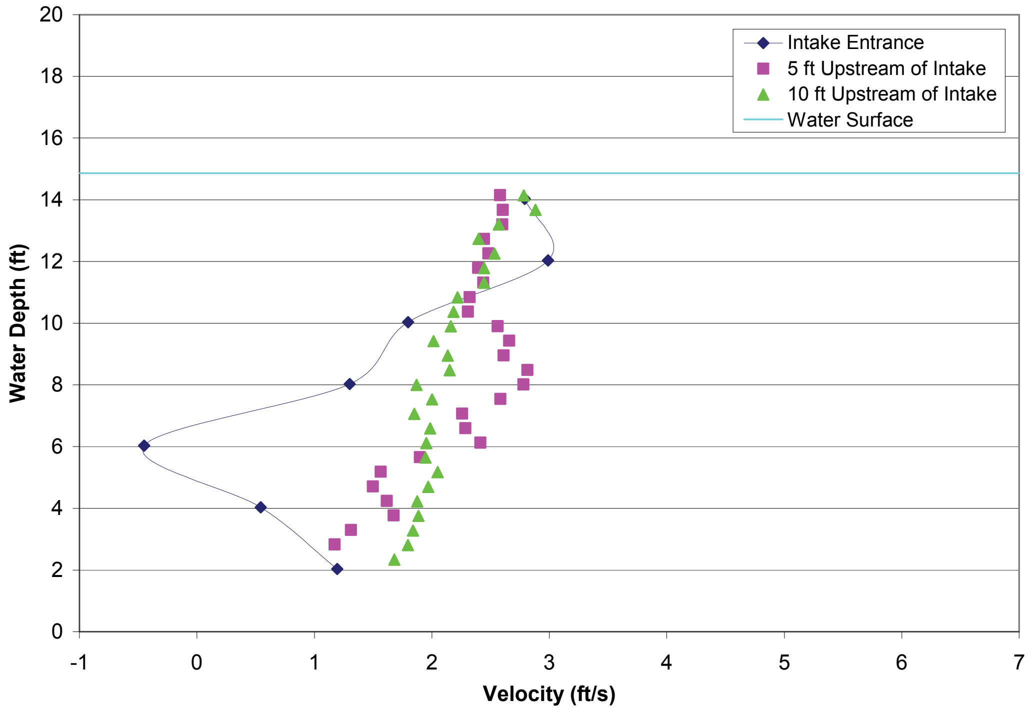

FIGURE A2-6.—Test 2-3, bypass 3 approach velocity profiles with all bypasses open, measured bypass ratio = 0.69, bypass ratio with facility instruments = N/A, outgoing tide, water depth = 14.86 ft, trashrack differential = 3.03 ft, louvers differential = 0.74 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
13.90	3.64	0.40	-0.34
12.90	3.48	-0.03	-0.16
10.90	2.25	0.17	-0.47
8.90	1.14	0.08	-0.06
6.90	0.82	0.00	-0.10
4.90	-0.29	0.12	-0.06
2.90	0.44	0.03	-0.23

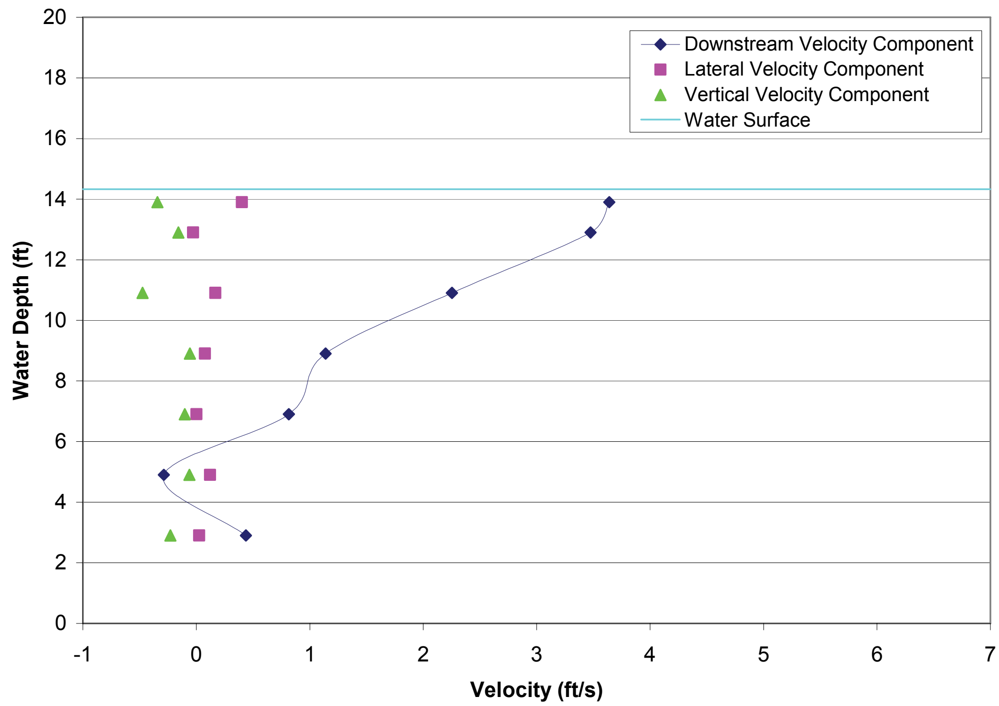

FIGURE A2-7.—Test 2-4, bypass 4 intake profile with all bypasses open, measured bypass ratio = 0.37, bypass ratio with facility instruments = N/A, outgoing tide, water depth = 14.33 ft, trashrack differential = 2.98 ft, louvers differential = 1.19 ft.

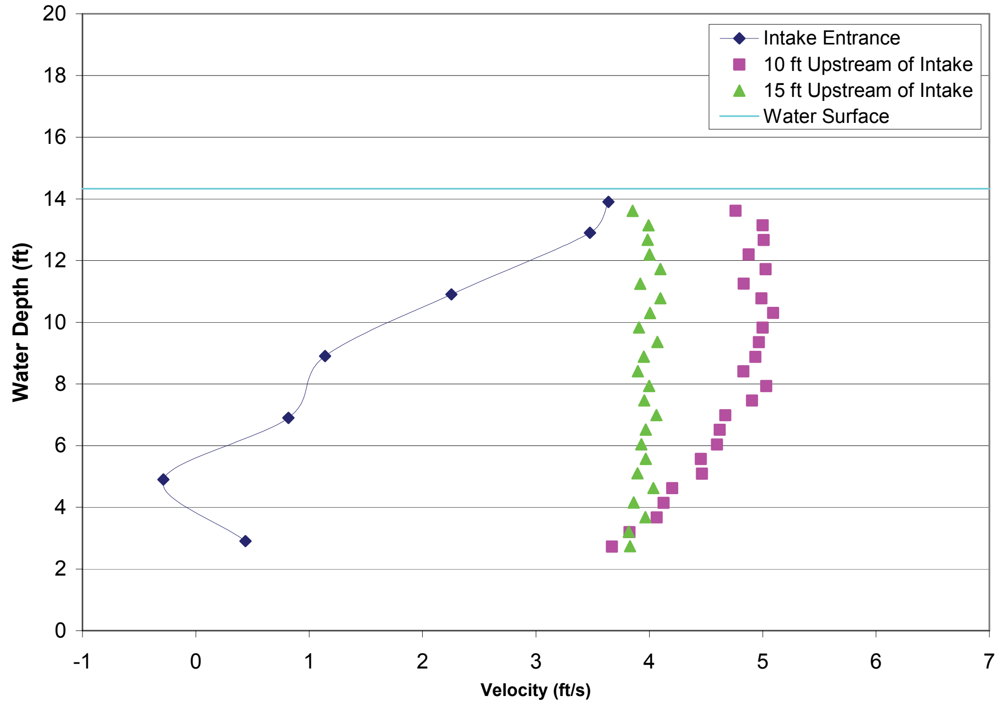

FIGURE A2-8.—Test 2-4, bypass 4 approach velocity profiles with all bypasses open, measured bypass ratio = 0.37, bypass ratio with facility instruments = N/A, outgoing tide, water depth = 14.33 ft, trashrack differential = 2.98 ft, louvers differential = 1.19 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
16.45	3.56	-0.07	-0.10
14.65	3.48	-0.18	-0.02
12.65	3.59	-0.21	0.07
10.65	3.47	-0.38	-0.06
8.65	3.90	-0.39	-0.09
6.65	4.25	-0.38	0.10
4.65	4.67	-0.64	-0.03
2.65	4.86	-1.09	0.22

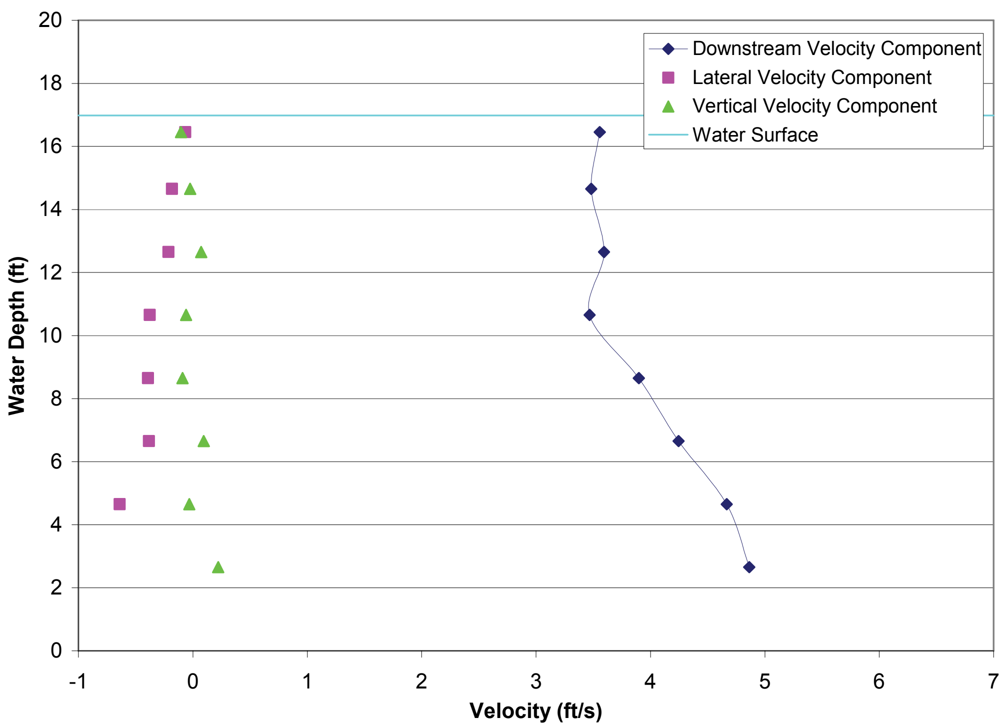

FIGURE A2-9.—Test 3-1, bypass 1 intake profile with all bypasses open, measured bypass ratio = 0.98, bypass ratio with facility instruments = 1.27, outgoing tide, water depth = 16.98 ft, trashrack differential = 0.94 ft, louvers differential = 0.45 ft.

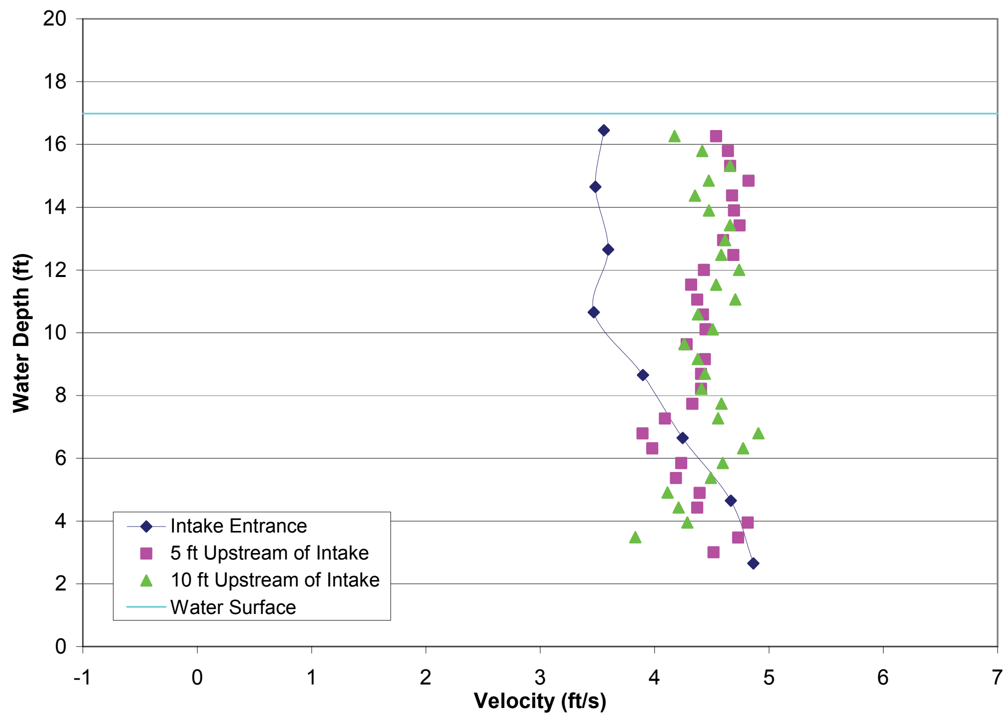

FIGURE A2-10.—Test 3-1, bypass 1 approach velocity profiles with all bypasses open, measured bypass ratio = 0.98, bypass ratio with facility instruments = 1.27, outgoing tide, water depth = 16.98 ft, trashrack differential = 0.94 ft, louvers differential = 0.45 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
16.51	3.81	0.13	-0.31
16.01	3.63	-0.14	-0.05
14.01	3.56	-0.10	-0.52
12.01	3.30	-0.04	-0.23
10.01	3.44	0.09	-0.06
8.01	3.13	-0.02	-0.07
6.01	3.22	-0.02	0.06
4.01	3.26	-0.07	0.01
2.01	3.18	-0.19	-0.07

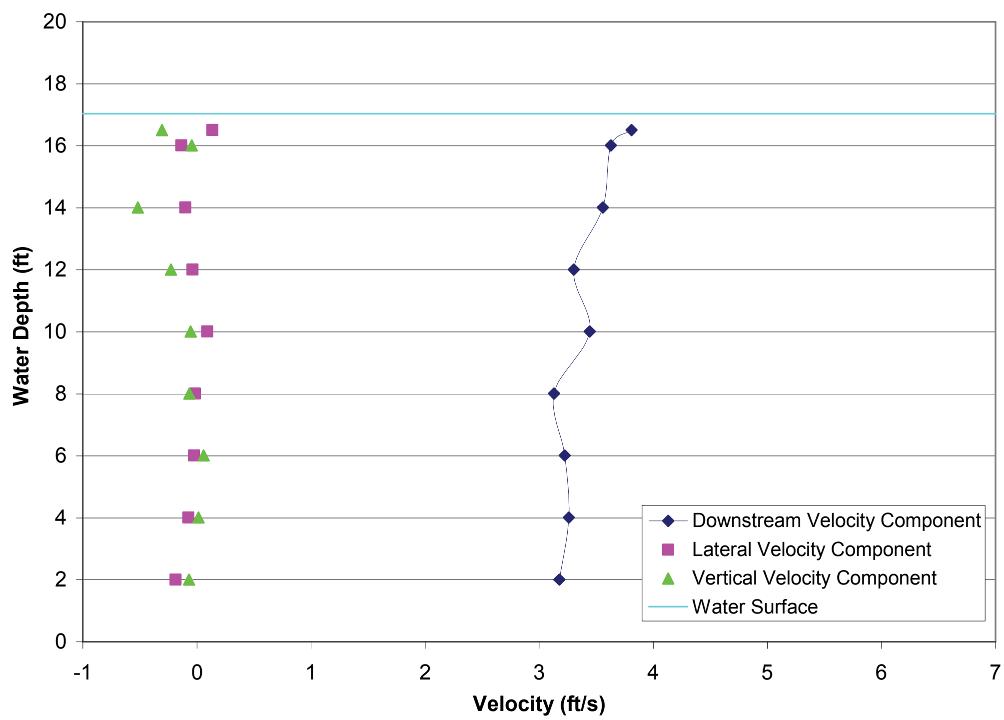

FIGURE A2-11.—Test 3-2, bypass 2 intake profile with all bypasses open, measured bypass ratio = 1.02, bypass ratio with facility instruments = 0.79, outgoing tide, water depth = 17.04 ft, trashrack differential = 1.11 ft, louvers differential = 0.55 ft.

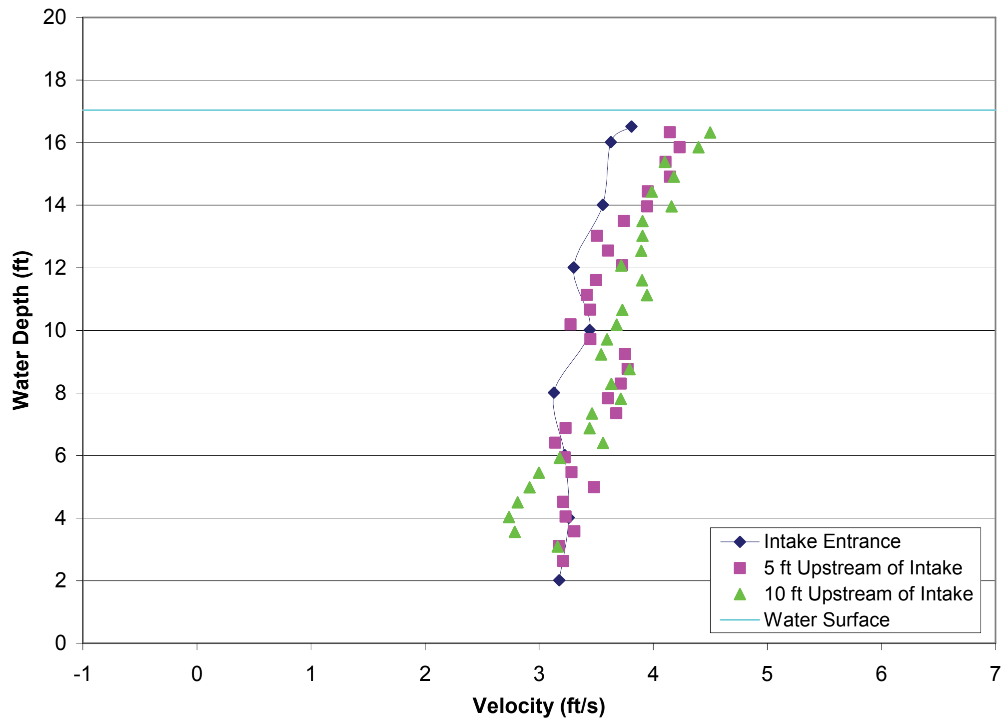

FIGURE A2-12.—Test 3-2, bypass 2 approach velocity profiles with all bypasses open, measured bypass ratio = 1.02, bypass ratio with facility instruments = 0.79, outgoing tide, water depth = 17.04 ft, trashrack differential = 1.11 ft, louvers differential = 0.55 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
16.29	3.83	0.07	-0.30
15.69	3.62	-0.05	-0.08
13.69	3.35	-0.10	-0.36
11.69	3.13	-0.15	-0.24
9.69	3.09	-0.03	-0.17
7.69	3.00	-0.08	-0.26
5.69	3.04	-0.08	-0.13
3.69	3.15	-0.13	0.04
1.69	3.09	-0.25	0.13

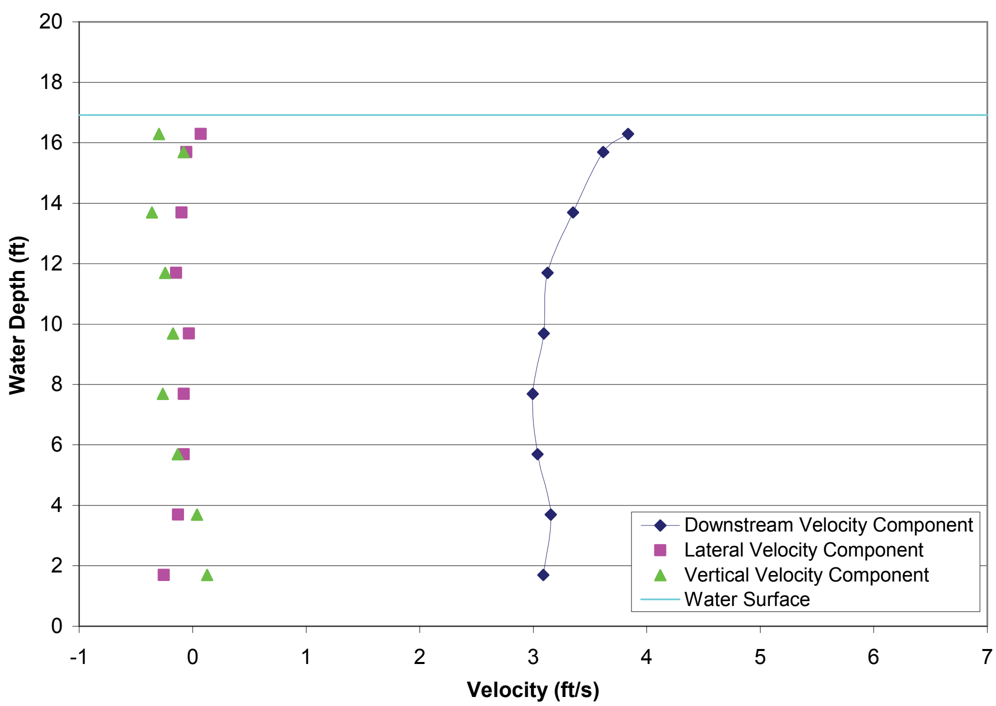

FIGURE A2-13.—Test 3-3, bypass 3 intake profile with all bypasses open, measured bypass ratio = 1.01, bypass ratio with facility instruments = 0.39, outgoing tide, water depth = 16.92 ft, trashrack differential = 1.27 ft, louvers differential = 0.44 ft.

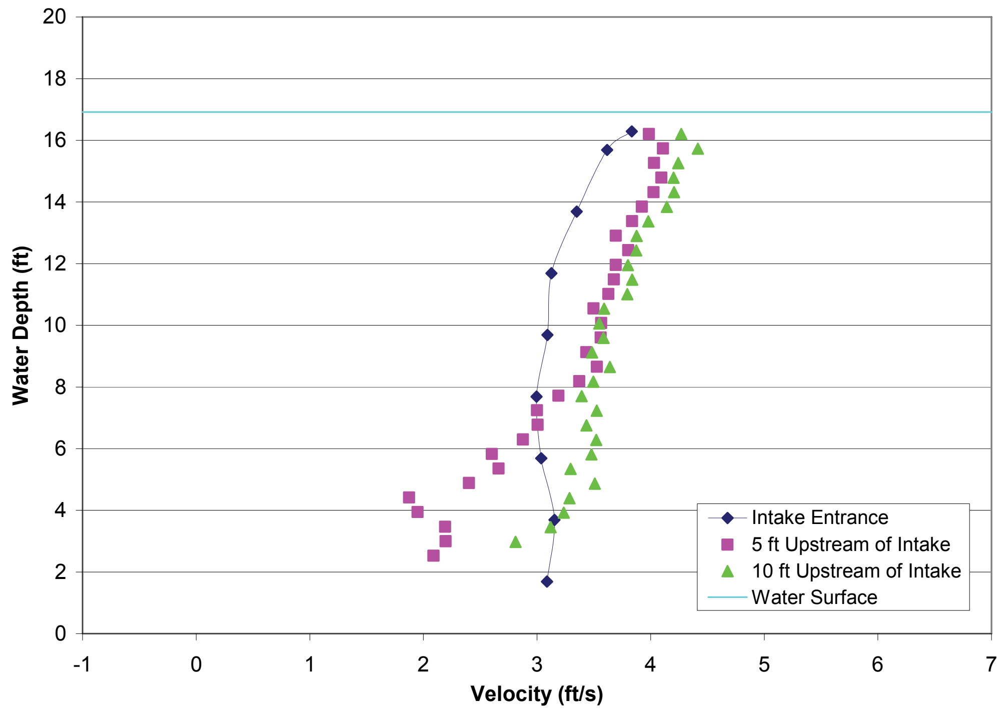

FIGURE A2-14.—Test 3-3, bypass 3 approach velocity profiles with all bypasses open, measured bypass ratio = 1.01, bypass ratio with facility instruments = 0.39, outgoing tide, water depth = 16.92 ft, trashrack differential = 1.27 ft, louvers differential = 0.44 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
16.52	2.53	0.20	-0.09
15.32	2.54	-0.03	-0.21
13.32	2.76	0.19	-0.21
11.32	2.45	0.02	-0.19
9.32	2.21	-0.02	-0.12
7.32	2.61	0.01	-0.08
5.32	2.40	-0.14	-0.25
3.32	2.21	-0.02	-0.13

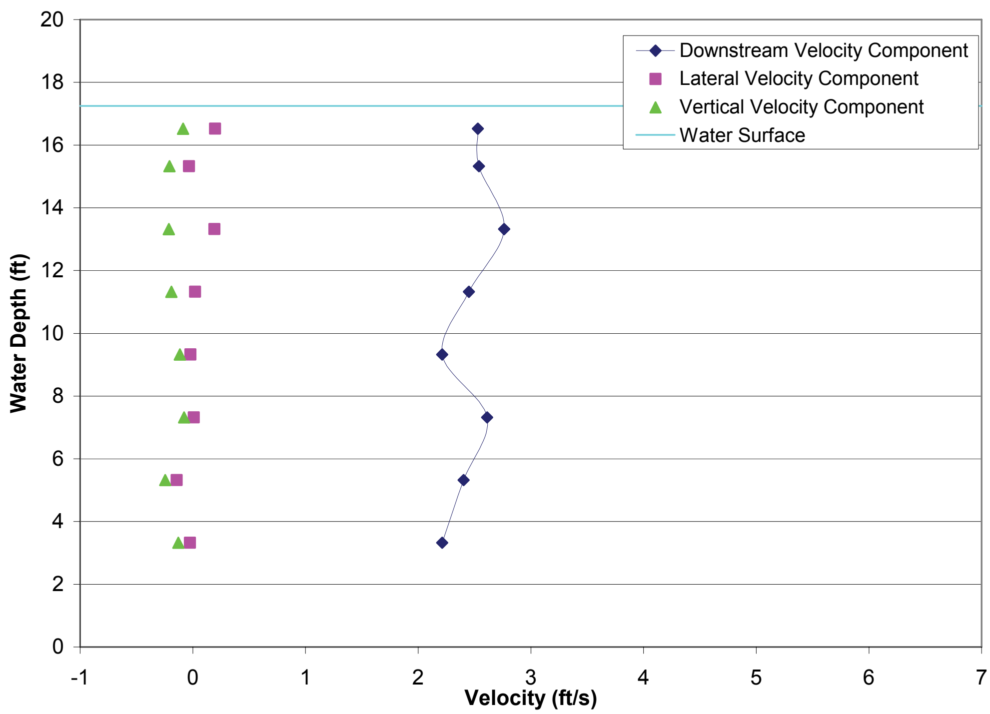

FIGURE A2-15.—Test 3-4, bypass 4 intake profile with all bypasses open, measured bypass ratio = 0.75, bypass ratio with facility instruments = 0.71, incoming tide, water depth = 17.25 ft, trashrack differential = 2.01 ft, louvers differential = 0.70 ft.

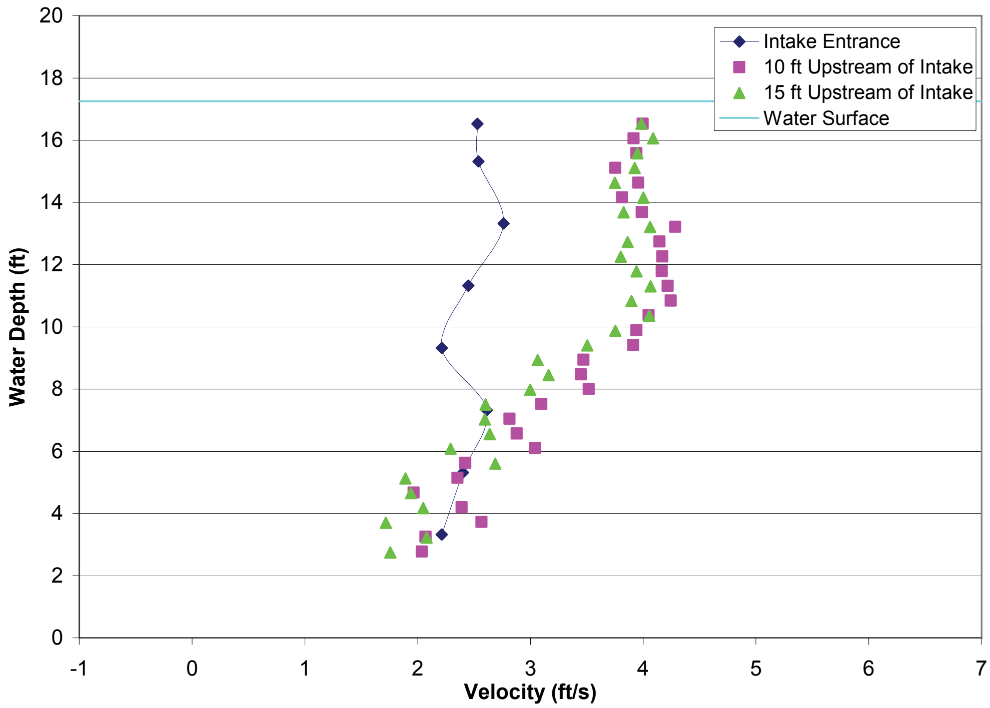

FIGURE A2-16.—Test 3-4, bypass 4 approach velocity profiles with all bypasses open, measured bypass ratio = 0.75, bypass ratio with facility instruments = 0.71, incoming tide, water depth = 17.25 ft, trashrack differential = 2.01 ft, louvers differential = 0.70 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
16.20	3.07	0.06	-0.07
15.00	3.26	-0.17	0.18
13.00	3.46	-0.05	0.24
11.00	3.85	-0.45	0.04
9.00	4.15	-0.49	0.05
7.00	4.47	-0.33	-0.01
5.00	4.61	-0.63	-0.03
3.00	4.71	-0.78	0.16

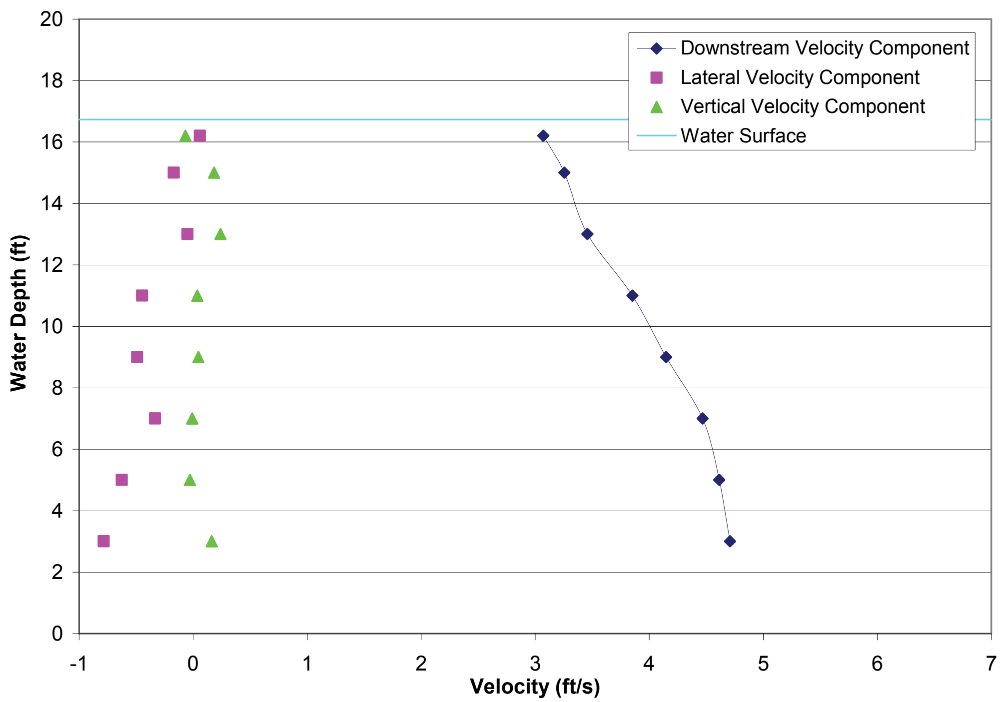

FIGURE A2-17.—Test 4-1, bypass 1 intake profile with all bypasses open, measured bypass ratio = 0.86, bypass ratio with facility instruments = 1.17, incoming tide, water depth = 16.73 ft, trashrack differential = 1.29 ft, louvers differential = 0.43 ft.

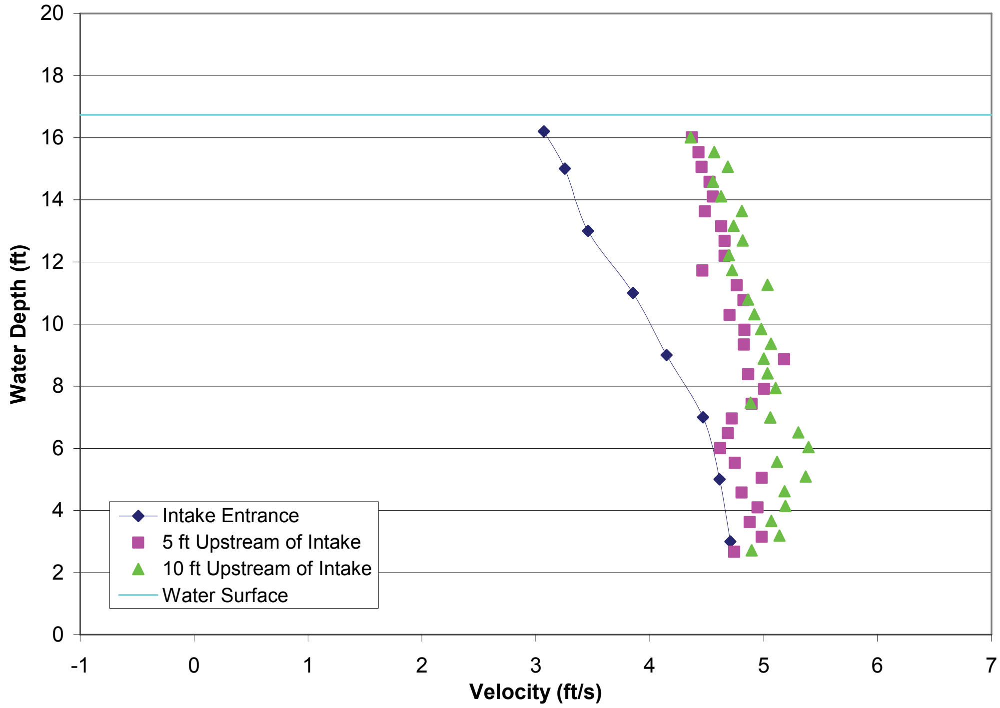

FIGURE A2-18.—Test 4-1, bypass 1 approach velocity profiles with all bypasses open, measured bypass ratio = 0.86, bypass ratio with facility instruments = 1.17, incoming tide, water depth = 16.73 ft, trashrack differential = 1.29 ft, louvers differential = 0.43 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
17.14	3.13	0.14	-0.09
15.14	2.14	0.03	-0.29
13.14	3.23	0.24	-0.30
11.14	3.74	-0.07	-0.45
9.14	3.41	0.06	-0.33
7.14	3.37	0.11	-0.29
5.14	3.30	0.04	-0.15
3.14	3.11	-0.05	0.10

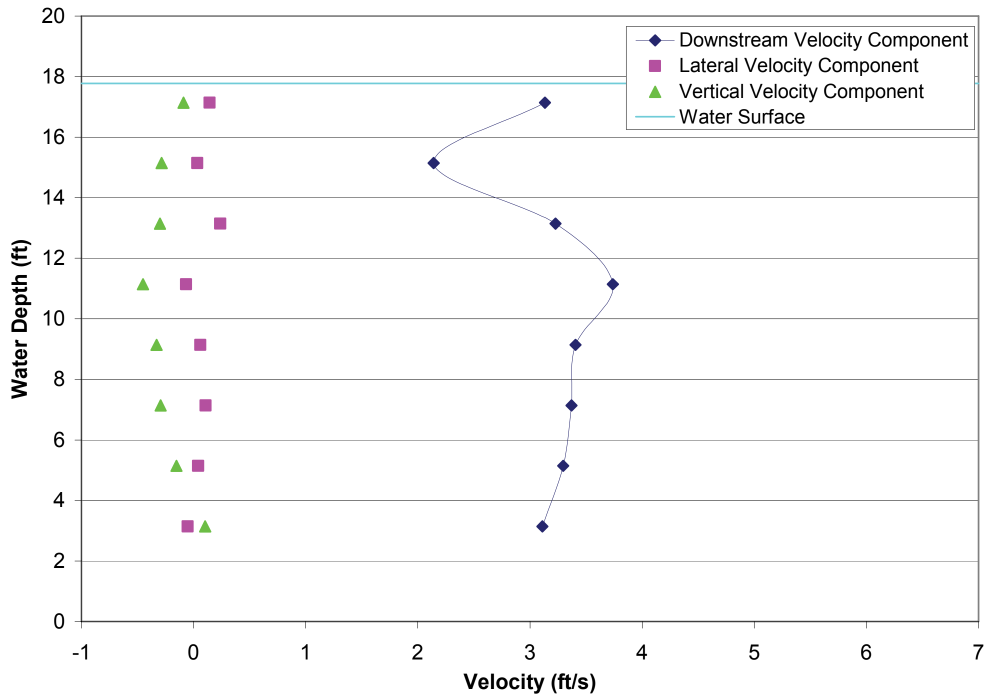

FIGURE A2-19.—Test 4-2, bypass 2 intake profile with all bypasses open, measured bypass ratio = 0.84, bypass ratio with facility instruments = 0.72, incoming tide, water depth = 17.77 ft, trashrack differential = 1.35 ft, louvers differential = 0.62 ft.

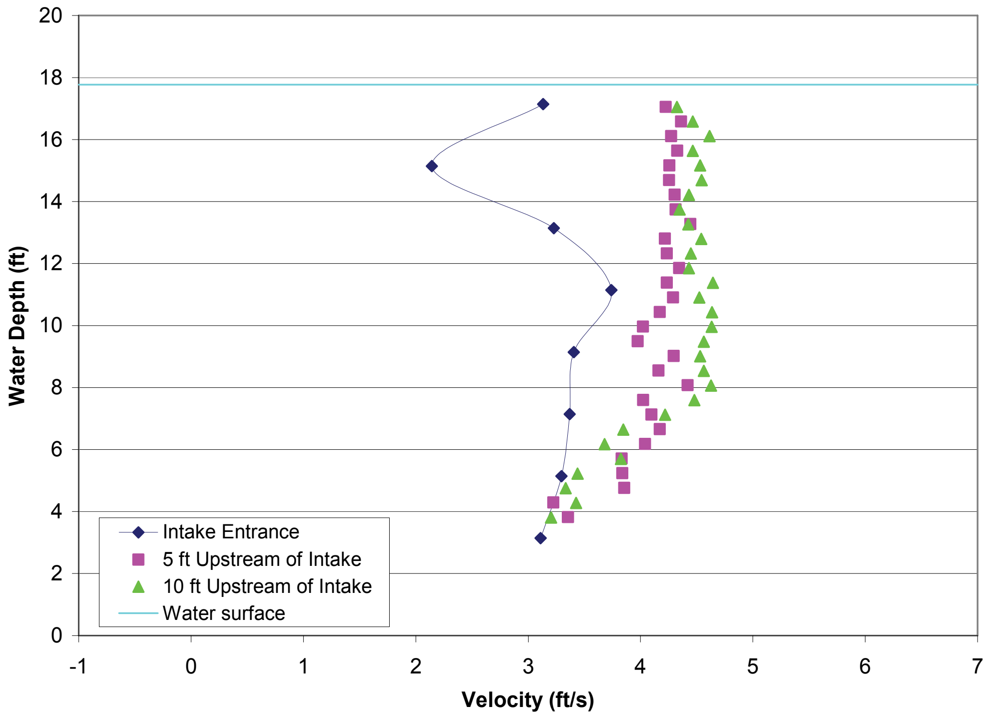

FIGURE A2-20.—Test 4-2, bypass 2 approach velocity profiles with all bypasses open, measured bypass ratio = 0.84, bypass ratio with facility instruments = 0.72, incoming tide, water depth = 17.77 ft, trashrack differential = 1.35 ft, louvers differential = 0.62 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
18.33	1.86	0.10	0.13
16.93	1.50	0.19	-0.04
14.93	2.38	0.03	0.10
12.93	2.79	-0.08	0.07
10.93	3.06	-0.01	-0.27
8.93	3.40	-0.11	-0.30
6.93	3.47	-0.11	-0.26
4.63	3.73	-0.08	-0.06
2.93	3.54	-0.30	0.11

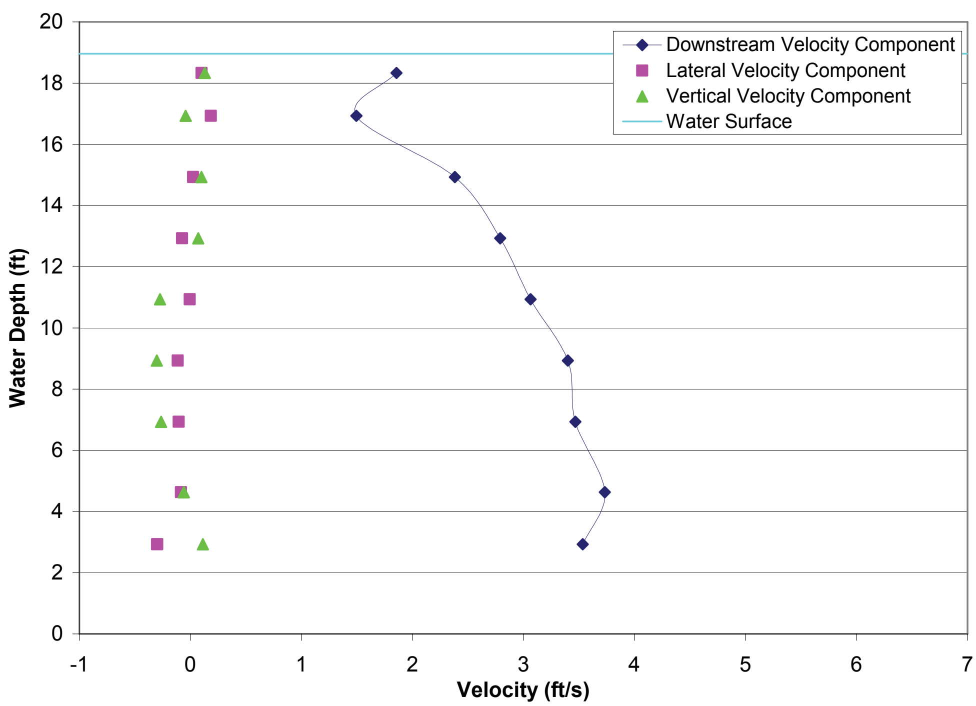

FIGURE A2-21.—Test 4-3, bypass 3 intake profile with all bypasses open, measured bypass ratio = 0.98, bypass ratio with facility instruments = 0.74, incoming tide, water depth = 18.96 ft, trashrack differential = 1.07 ft, louvers differential = 0.37 ft.

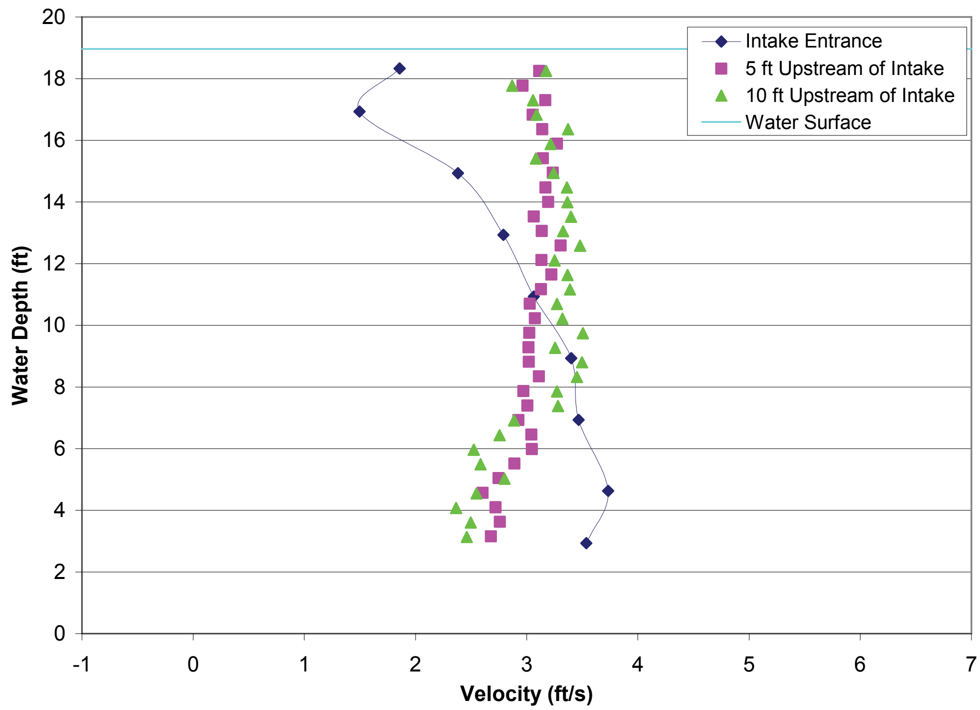

FIGURE A2-22.—Test 4-3, bypass 3 approach velocity profiles with all bypasses open, measured bypass ratio = 0.98, bypass ratio with facility instruments = 0.74, incoming tide, water depth = 18.96 ft, trashrack differential = 1.07 ft, louvers differential = 0.37 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
16.27	2.82	0.14	0.00
15.87	2.75	0.00	0.02
13.87	3.10	-0.08	-0.33
11.87	3.05	-0.03	-0.27
9.87	2.80	0.03	-0.11
7.87	2.70	-0.08	-0.21
5.87	2.49	-0.10	-0.16
3.87	2.65	-0.01	-0.04
1.87	2.57	-0.15	-0.06

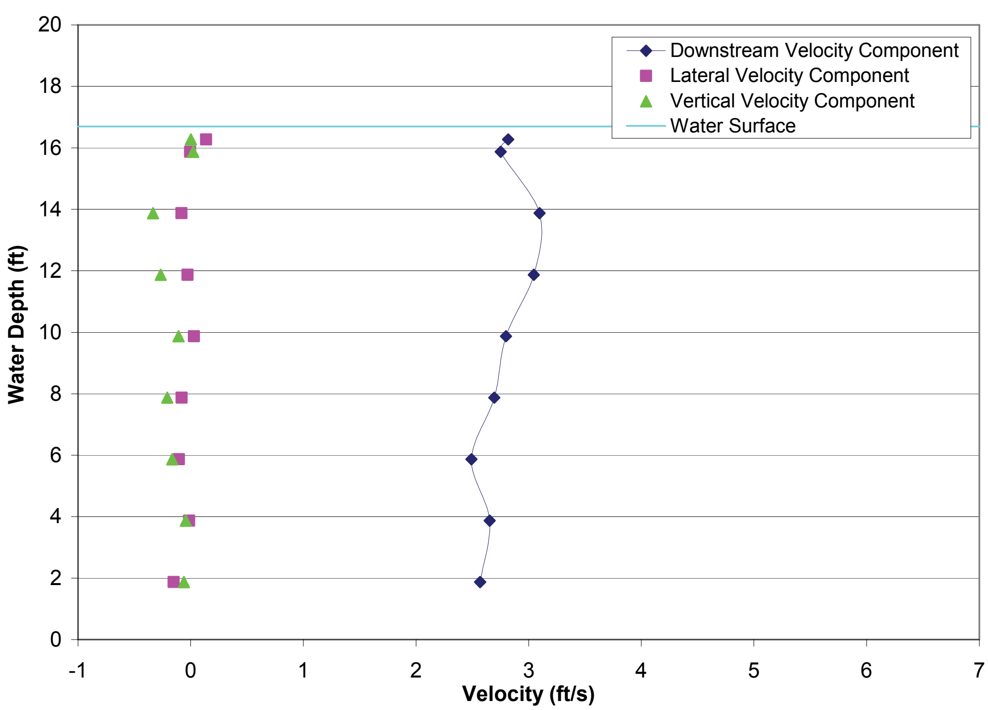

FIGURE A2-23.—Test 4-4, bypass 4 intake profile with all bypasses open, measured bypass ratio = 0.87, bypass ratio with facility instruments = 0.90, high tide, water depth = 16.70 ft, trashrack differential = 1.27 ft, louvers differential = 0.49 ft.

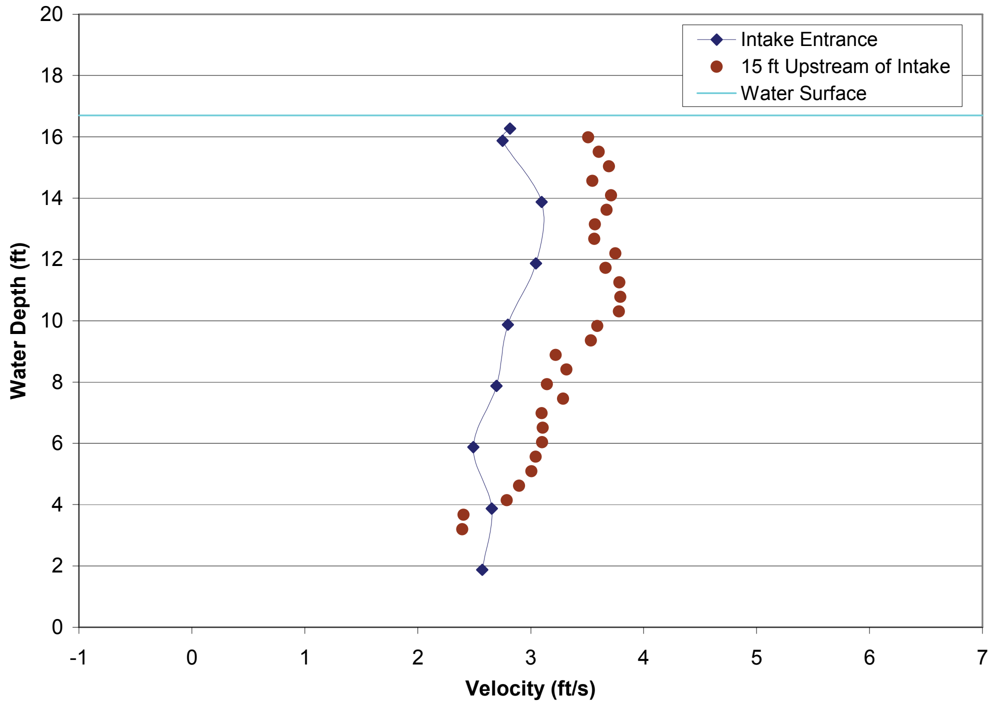

FIGURE A2-24.—Test 4-4, bypass 4 approach velocity profiles with all bypasses open, measured bypass ratio = 0.87, bypass ratio with facility instruments = 0.90, high tide, water depth = 16.70 ft, trashrack differential = 1.27 ft, louvers differential = 0.49 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
15.86	3.15	-0.06	0.01
13.86	3.26	-0.06	-0.33
11.86	3.17	-0.07	-0.24
9.86	3.01	-0.08	-0.14
7.86	2.97	-0.11	-0.20
5.86	2.99	-0.22	-0.15
3.86	3.36	-0.05	0.04
1.86	3.31	-0.23	-0.08

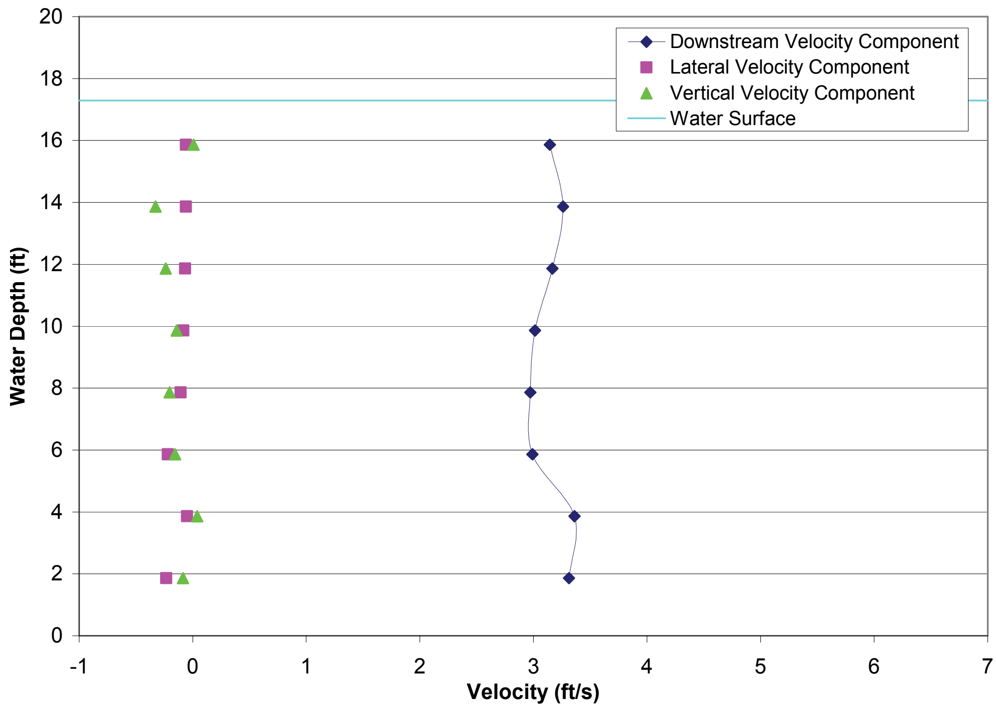

FIGURE A2-25.—Test 1A, bypass 4 intake profile with all bypasses open, measured bypass ratio = 1.05, bypass ratio with facility instruments = 1.02, outgoing tide, water depth = 17.29 ft, trashrack differential = 1.06 ft, louvers differential = 0.45 ft.

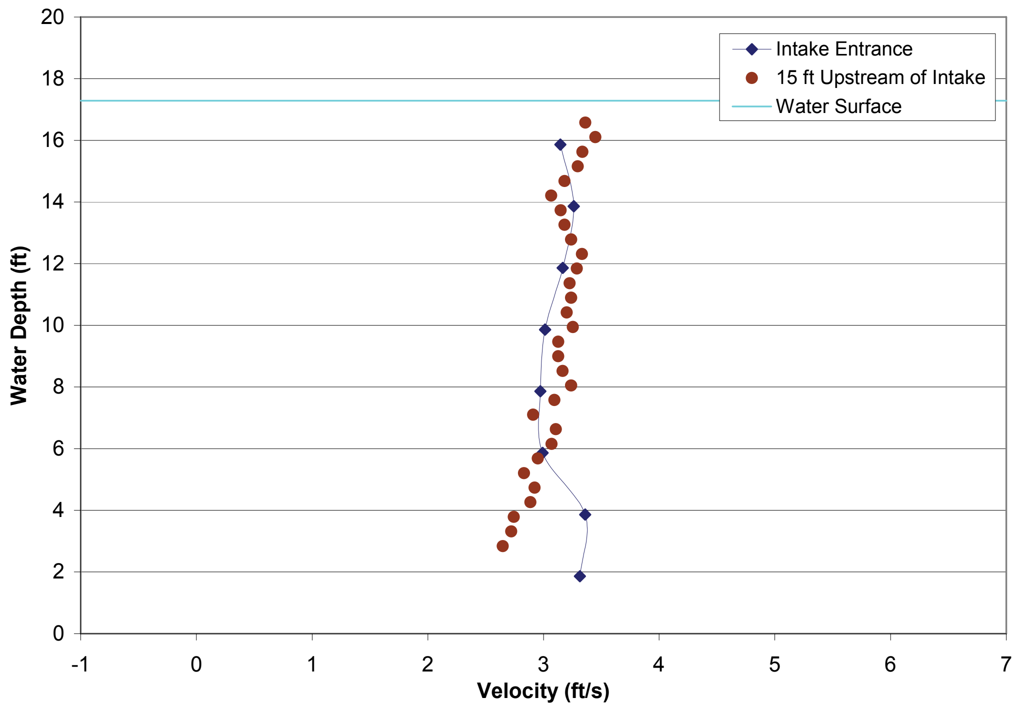

FIGURE A2-26.—Test 1A, bypass 4 approach velocity profiles with all bypasses open, measured bypass ratio = 1.05, bypass ratio with facility instruments = 1.02, outgoing tide, water depth = 17.29 ft, trashrack differential = 1.06 ft, louvers differential = 0.45 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
15.43	2.49	-0.04	0.03
13.93	2.61	-0.03	-0.31
11.93	2.44	0.00	-0.27
9.93	1.67	0.13	-0.10
7.93	1.59	-0.04	-0.24
5.93	1.32	-0.08	-0.18
3.93	1.06	0.09	-0.03
1.93	1.30	-0.02	-0.06

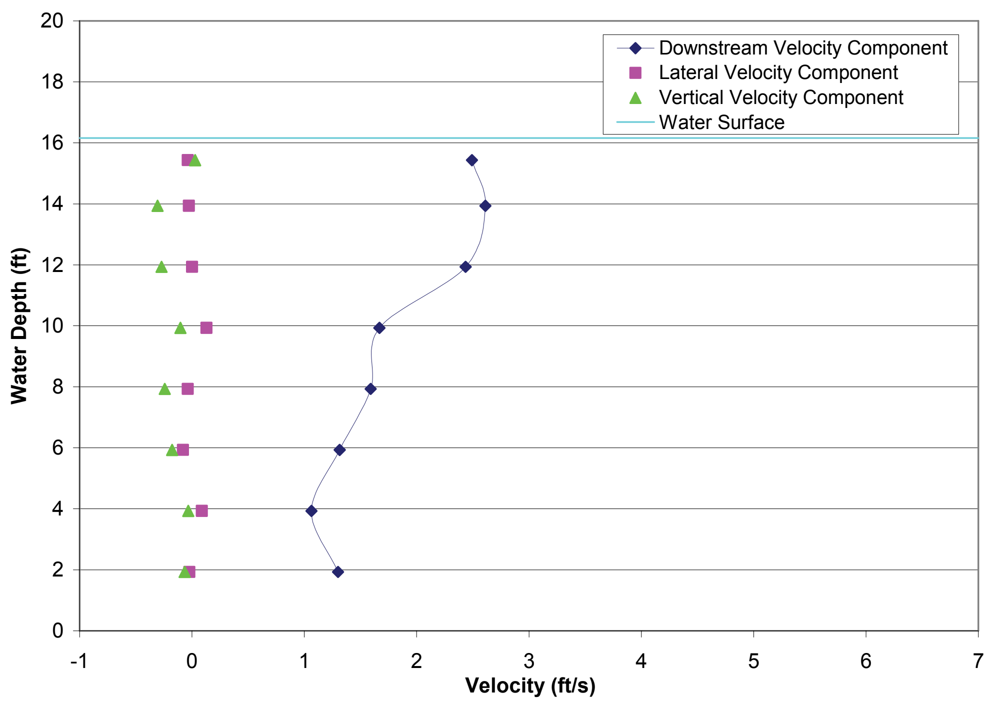

FIGURE A2-27.—Test 1B, bypass 4 intake profile with bypass 1 closed, measured bypass ratio = 0.61, bypass ratio with facility instruments = 0.64, outgoing tide, water depth = 16.16 ft, trashrack differential = 1.50 ft, louvers differential = 0.51 ft.

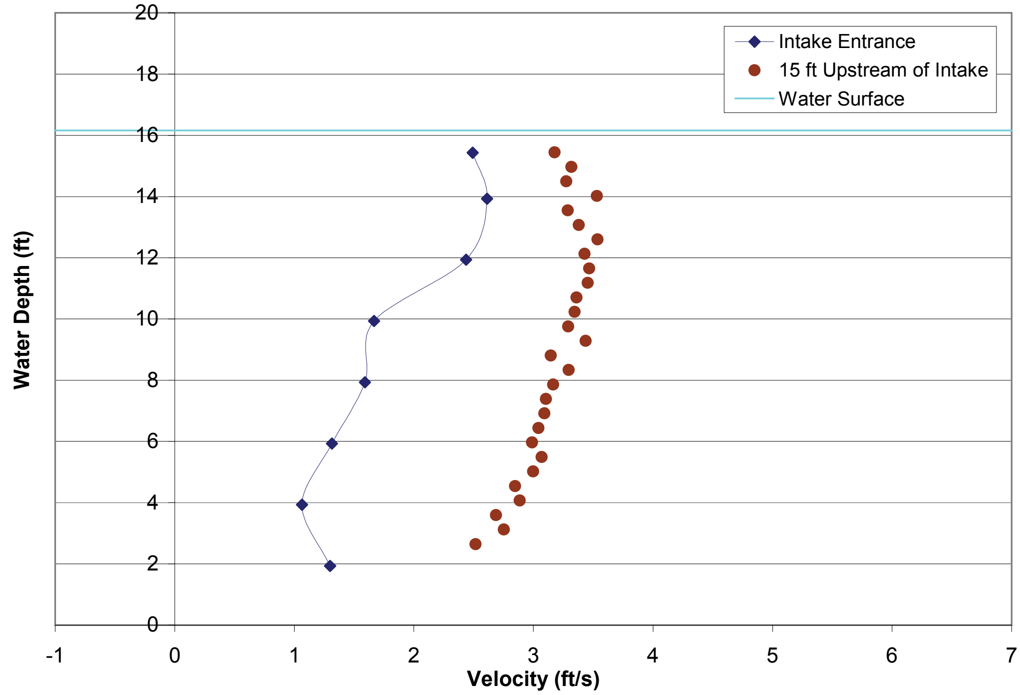

FIGURE A2-28.—Test 1B, bypass 4 approach velocity profiles with bypass 1 closed, measured bypass ratio = 0.61, bypass ratio with facility instruments = 0.64, outgoing tide, water depth = 16.16 ft, trashrack differential = 1.50 ft, louvers differential = 0.5 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
15.12	3.21	-0.08	-0.13
14.12	2.98	-0.02	-0.21
12.12	3.00	-0.05	-0.38
10.12	2.77	0.20	-0.23
8.12	2.65	-0.10	-0.27
6.12	2.50	-0.15	-0.22
4.12	2.89	-0.22	0.11
2.12	2.83	-0.18	-0.05

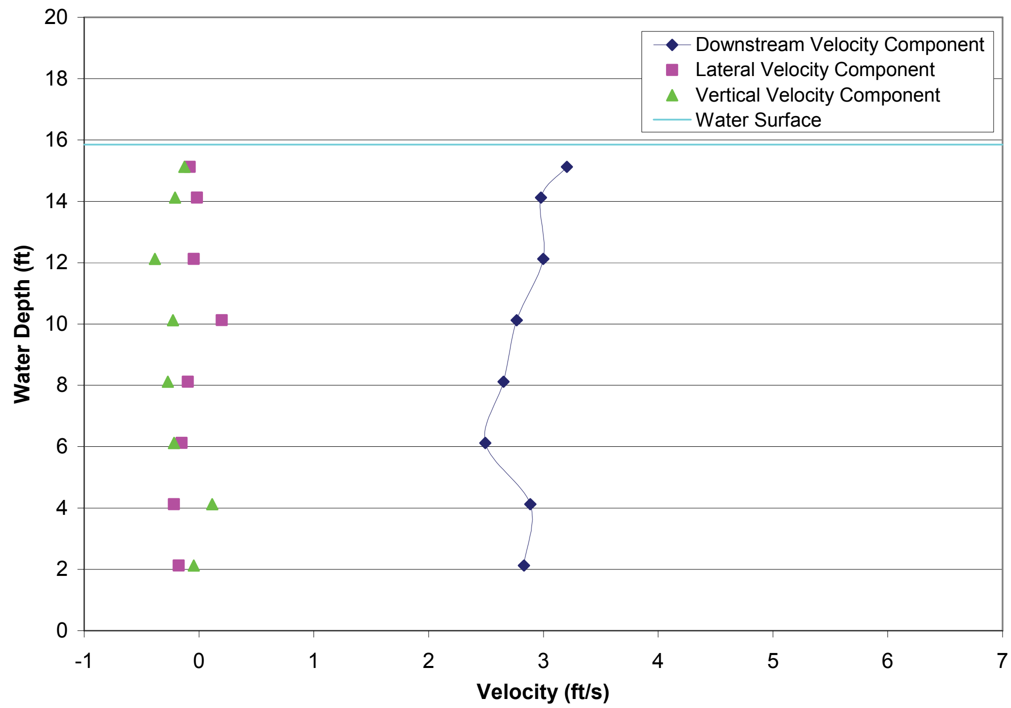

FIGURE A2-29.—Test 1C, bypass 4 intake profile with bypass 1 and 2 closed, measured bypass ratio = 0.88, bypass ratio with facility instruments = 0.94, outgoing tide, water depth = 15.85 ft, trashrack differential = 1.52 ft, louvers differential = 0.59 ft.

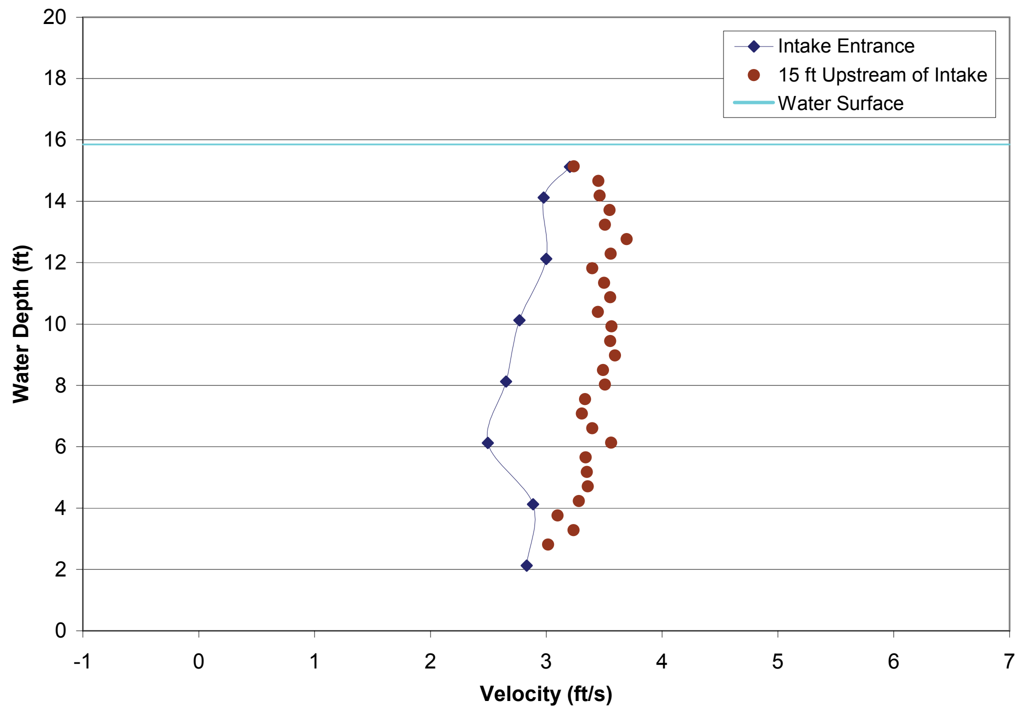

FIGURE A2-30.—Test 1C, bypass 4 approach velocity profiles with bypass 1 and 2 closed, measured bypass ratio = 0.88, bypass ratio with facility instruments = 0.94, outgoing tide, water depth = 15.85 ft, trashrack differential = 1.52 ft, louvers differential = 0.59 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
14.77	4.45	-0.10	-0.39
13.27	4.36	0.08	-0.45
11.27	4.43	-0.18	-0.61
9.27	4.20	-0.24	-0.36
7.27	4.51	-0.10	-0.35
5.27	4.50	-0.31	-0.14
3.27	4.62	-0.27	-0.42

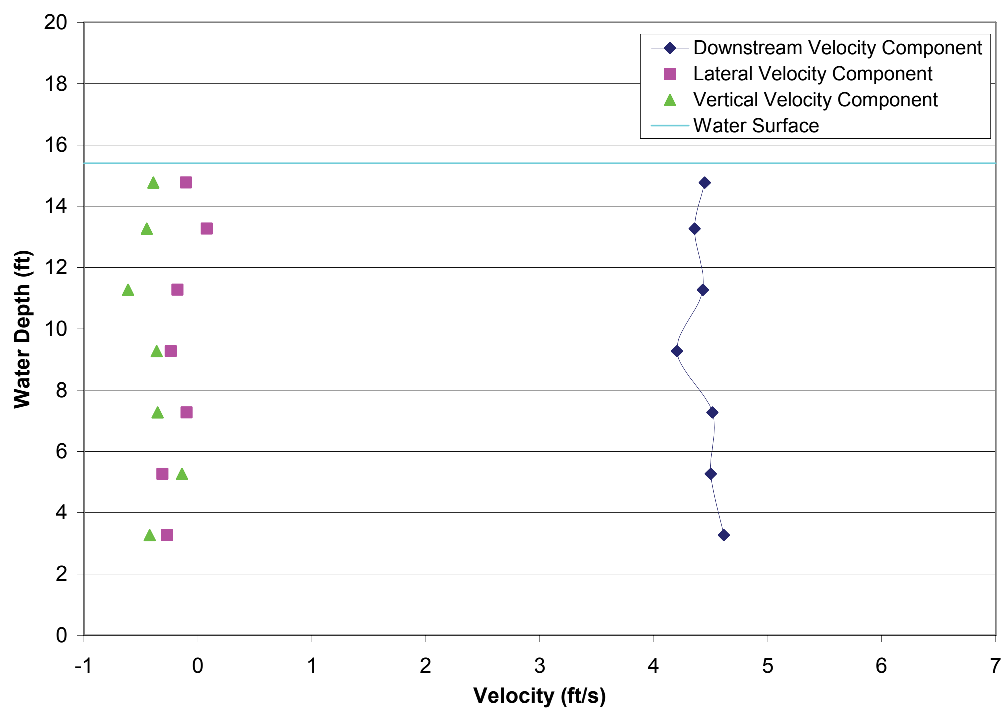

FIGURE A2-31.—Test 1D, bypass 4 intake profile with bypass 1, 2, and 3 closed, measured bypass ratio = 1.32, bypass ratio with facility instruments = 0.97, outgoing tide, water depth = 15.40 ft, trashrack differential = 1.81 ft, louvers differential = 0.49 ft.

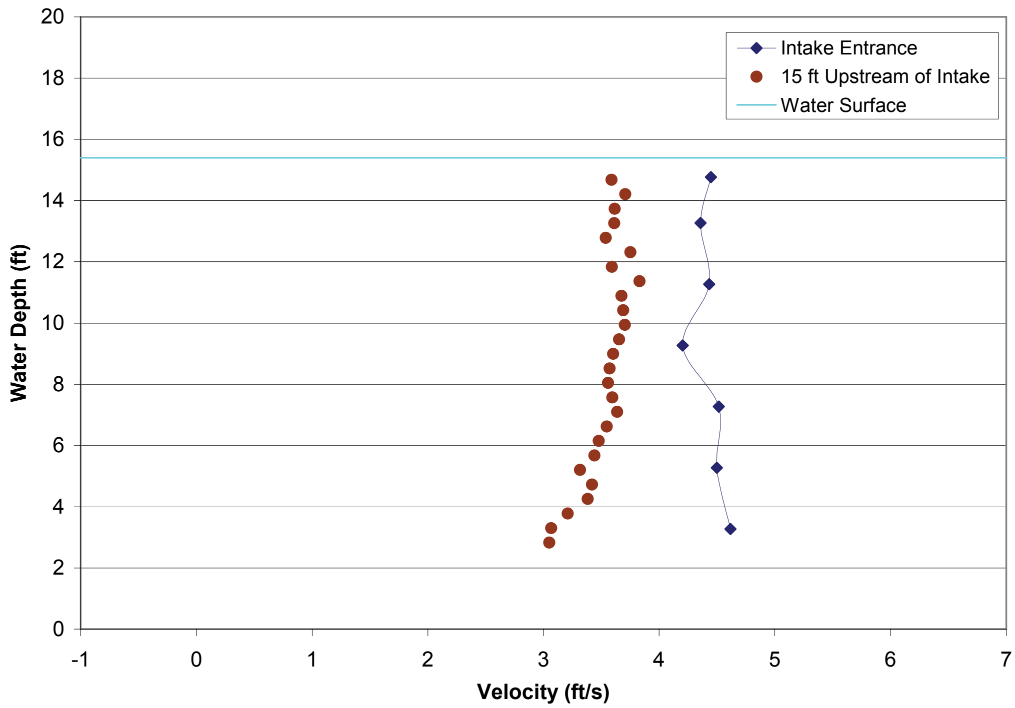

FIGURE A2-32.—Test 1D, bypass 4 approach velocity profiles with bypass 1, 2, and 3 closed, measured bypass ratio = 1.32, bypass ratio with facility instruments = 0.97, outgoing tide, water depth = 15.40 ft, trashrack differential = 1.81 ft, louvers differential = 0.49 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
16.31	4.39	-0.02	-0.82
14.41	4.64	-0.26	-0.68
12.41	4.83	-0.20	-0.55
10.41	4.85	-0.01	-0.42
8.41	4.72	-0.26	-0.55
6.41	4.88	-0.38	-0.41
4.41	4.84	-0.24	-0.29
2.41	4.77	-0.43	0.02

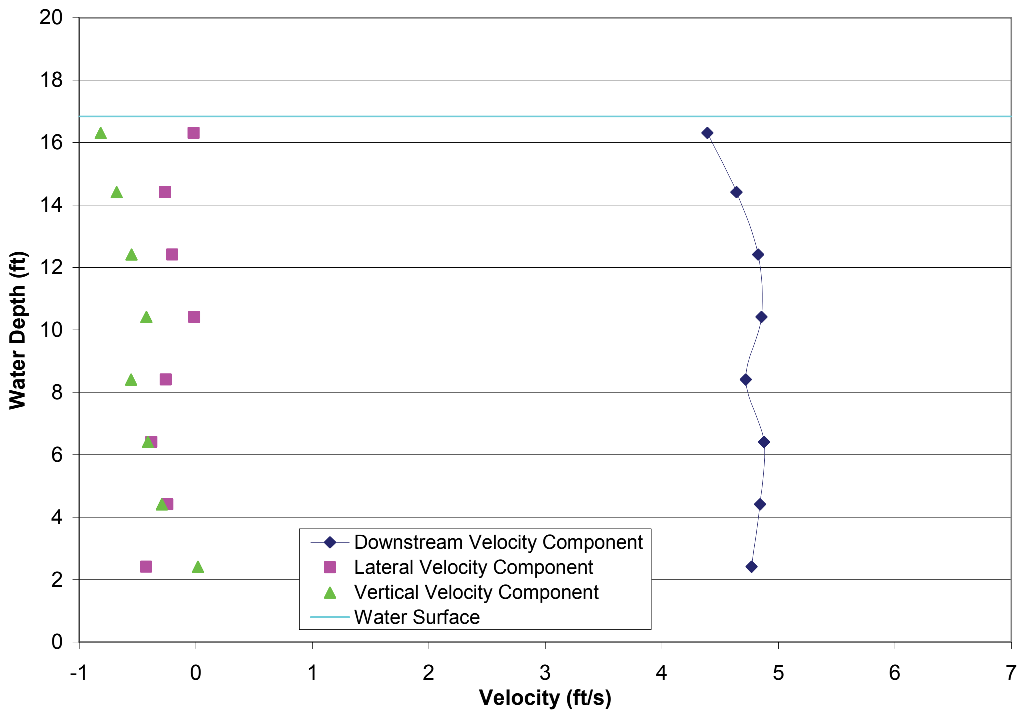

FIGURE A2-33.—Test 5A, bypass 4 intake profile with bypass 1 and 2 closed, measured bypass ratio = 1.24, bypass ratio with facility instruments = 1.41, outgoing tide, water depth = 16.84 ft, trashrack differential = 1.09 ft, louvers differential = 0.56 ft.

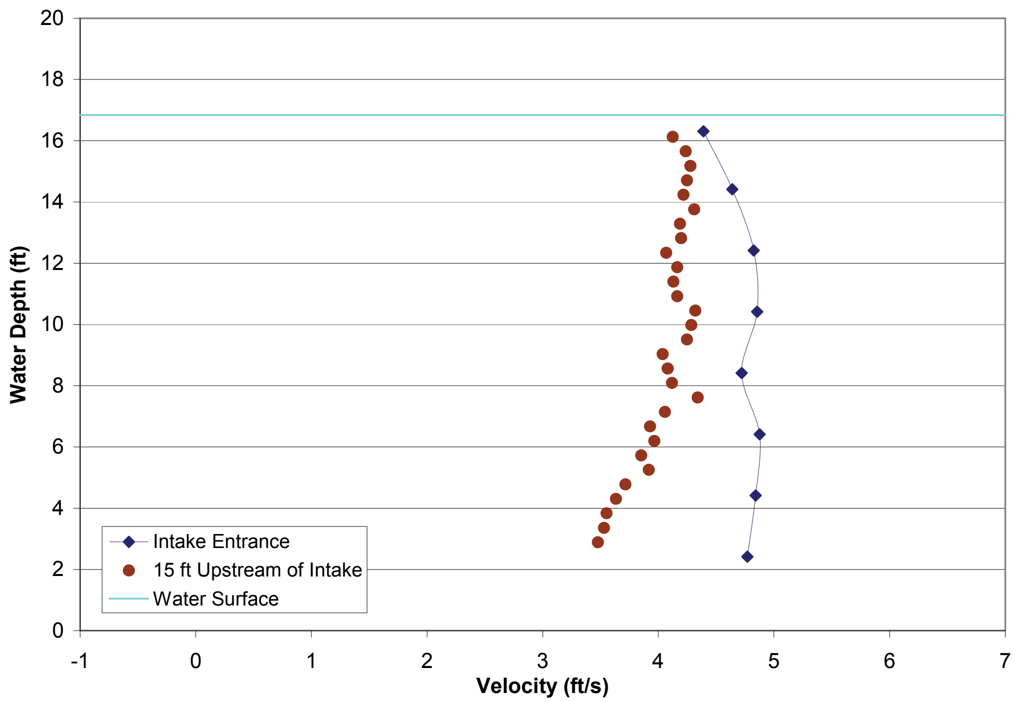

FIGURE A2-34.—Test 5A, bypass 4 approach velocity profiles with bypass 1 and 2 closed, measured bypass ratio = 1.24, bypass ratio with facility instruments = 1.41, outgoing tide, water depth = 16.84 ft, trashrack differential = 1.09 ft, louvers differential = 0.56 ft.

Distance from Channel Bottom (ft)	Average Downstream Velocity Component (ft/s)	Average Lateral Velocity Component (ft/s)	Average Vertical Velocity Component (ft/s)
16.17	4.64	-0.06	-0.48
14.17	5.44	-0.32	-0.90
12.17	5.78	-0.32	-0.85
10.17	5.81	-0.26	-0.65
8.17	5.86	-0.32	-0.73
6.17	6.03	-0.43	-0.56
4.17	6.34	-0.36	-0.56
2.17	6.30	-0.57	-0.26

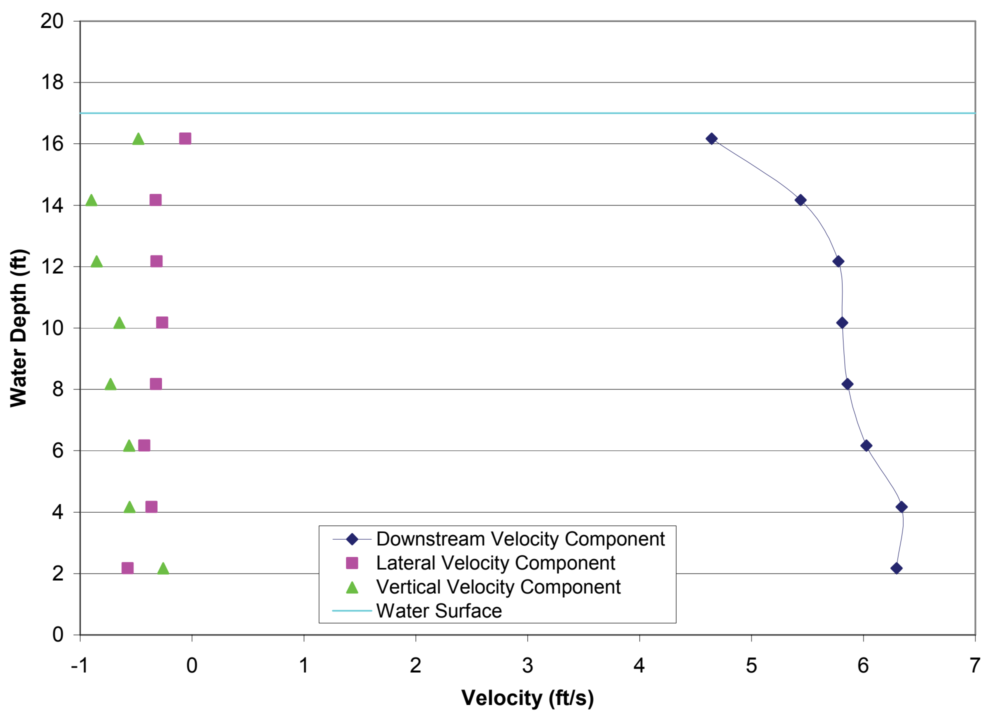

FIGURE A2-35.—Test 5B, bypass 4 intake profile with bypass 1, 2, and 3 closed, measured bypass ratio = 1.63, bypass ratio with facility instruments = 1.86, outgoing tide, water depth = 17.00 ft, trashrack differential = 0.80 ft, louvers differential = 0.59 ft.

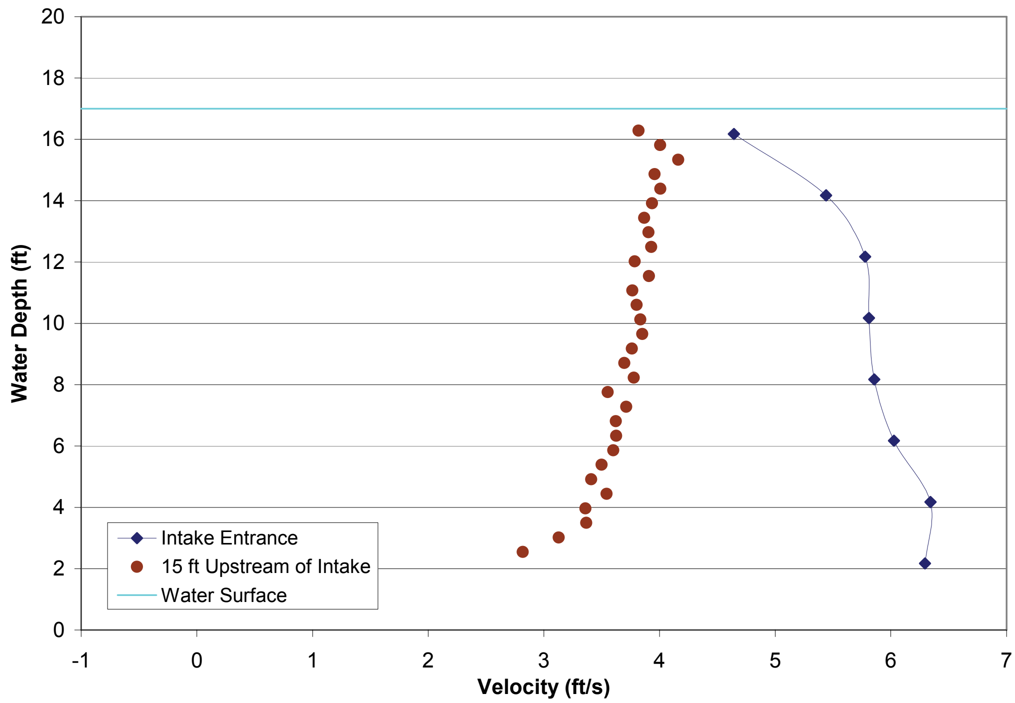

FIGURE A2-36.—Test 5B, bypass 4 approach velocity profiles with bypass 1, 2, and 3 closed, measured bypass ratio = 1.63, bypass ratio with facility instruments = 1.86, outgoing tide, water depth = 17.00 ft, trashrack differential = 0.80 ft, louvers differential = 0.59 ft.