Acoustic Dopper Current Profiler Measurements Collected Near the A-Canal Larval Curtain, Klamath Area Project, Oregon

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Purpose

To conduct a hydraulic evaluation of the flow fields approaching and in the near-field of the existing surface-suspended curtain at the A-Canal intake. These hydraulic data will provide some measure of the effectiveness of reducing larval sucker entrainment and assist with determining the fate of the larval fish as they are guided away from the intake. This study is part of a Larval Sucker Entrainment Reduction Plan (Reclamation 2002)

Background

The Bureau of Reclamation's (Reclamation) Klamath Basin Area Office (KBAO), operates the Klamath Area Project (Project) to deliver water to approximately 200,000 acres of irrigated lands. Project operations are thought to adversely impact Lost River and shortnose suckers currently listed under the Federal Endangered Species Act (ESA). The KBAO is charged with developing and implementing a project entrainment reduction plan for all life stages of suckers, including larvae, juveniles, sub-adults, and adult fish. Reclamation has already prepared and submitted under separate cover a draft plan that focuses on protecting juvenile, sub-adult, and adult suckers through installing traditional fish screens on irrigation diversion structures (Reclamation 2002a). However, it is thought that larval suckers, because of their extremely small early life history stage (i.e., 10-25 mm), are still susceptible to potentially high levels of entrainment even when a traditionally designed fish screen is operating.

ESA Requirement - FWS (2002) concluded that larval entrainment results in the potential loss of millions of sucker larvae annually. As a result, FWS has stipulated a specific Biological Opinion (BO) requirement for Reclamation to investigate possible approaches to reduce the Project's larval entrainment problem. The FWS BO/Reasonable and Prudent Measure 1(a) states that Reclamation is required to assess and implement <u>practical</u> methods to substantially reduce entrainment of larval suckers occurring on the Project. This project is part of a Reclamation program developed to explore options to reduce larval sucker entrainment on the Project (Reclamation 2002b).

Temporary Larval Entrainment Reduction Activities

Reclamation initiated a temporary larval entrainment reduction activity as part of its interim project operating plan from April 2001 to May 2002. Reclamation proposed to help reduce sucker larval entrainment by installing a deflection curtain adjacent to the A-Canal diversion. The FWS BO (2002) on the interim project required Reclamation to implement the deflection curtain, monitor its condition, and repair holes as required. Furthermore, the FWS BO on the 2002-2012 project operating plan required that the curtain remain in place until the permanent A-Canal fish screen is constructed and to continue to monitor its condition. The curtain is Reclamation's first attempt, and currently the only effort underway to implement a larval entrainment reduction device on the Project.

Figure 1. Enhanced photograph of the deflection curtain, A-Canal Intake, and ADCP measurement locations.

Deflection Curtain - In May 2002, Reclamation installed the deflection curtain parallel to the current approaching A-Canal (see Figure 1). The curtain was installed to guide weak swimming, surface-oriented larval suckers away from and downstream of the canal entrance. This approach was based upon the assumption that larval suckers drifting in the near-surface layer can be deflected by re-directing surface velocity vectors moving toward the canal.

The A-Canal curtain was constructed from waterproof canvas material and is about 300 ft long and 3 ft deep. The curtain position is maintained with a float line at the top which is secured at both ends with anchors (see figure 2). The curtain bottom has a weighted line and intermittent anchor lines that forces the curtain to hang vertically in the water.

Reclamation's monitoring efforts to date have been primarily to determine the condition of the curtain in relation to currents flowing into and past A-Canal. Reclamation has not monitored and evaluated its biological effectiveness to reduce larval entrainment. Reclamation has observed that the curtain has a noticeable bow or concave orientation in relation to the A-Canal headworks (figure 2). Curtain deformation appears to be caused by forces associated with flow entering A-Canal.

Figure 2. Photograph of larval curtain and its float line. The accumulated debris is on the upstream side of the curtain. Flow to A-Canal is to the left side of the photo.

Evaluation of the A-Canal Larval Curtain

Reclamation (1998) previously collected velocity data in the vicinity of the A-Canal headworks using an acoustic Doppler current profiler (ADCP). This study, conducted on three different dates under three different operating conditions, produced horizontal velocity fields for May, July, and September 1998. In general, flow enters the A-Canal intake channel primarily from the south and southwest. The flow vectors point almost straight north along the east bank of the Link River arm of the lake. The effect was most pronounced in September, when the canal withdrawal was near maximum and the UKL water surface elevation was 4140.2 ft.

Reclamation's 1998 flow analysis focused on the horizontal velocity field. Velocity data showed there is a very strong current toward the canal entrance as UKL levels drop. This probably explains why the deflection curtain sags noticeably into the canal. This also raises the additional question about what affect the vertical component of flow may be having at the curtain and on drifting sucker larvae. If there is a large vertical velocity component, then sucker larvae could be swept under the 3-ft-deep curtain and entrained into A-Canal. Three dimensional velocity measurements are required to determine if the larval curtain at A-Canal is effective at re-directing larvae downstream past the diversion canal.

Reclamation recently measured three-dimensional velocities near the larval curtain to determine the near-field velocities. Reclamation conducted the velocity measurements on July 24, 2002. During the measurements approximately 850 ft^3/sec was being diverted into A-Canal and about 1000 ft^3/sec was flowing towards Link River Dam. The larval curtain is located about 200 ft upstream of the A-Canal head gate structure and had a substantial load of debris causing the curtain to bow toward the head gates (figure 2). Near the center of the curtain, the bottom was only about 1 to 2 ft below the surface of the water. Based on these field observations, there was not much evidence of surface flow moving along the curtain as indicated by the debris accumulation. The flow appeared to pass mostly under the curtain or around the end suggesting that it is probably not a very effective device to direct larval fish away from the A-Canal.

ADCP Data Collection

Velocity profile data were collected using a 1200 kHz RD Instruments Rio Grande ADCP. The ADCP was operated from a moving boat. ADCPs use the Doppler shift principle to measure velocities along four acoustic beams projected downward below the moving boat (figure 3). The ADCP sends out precise acoustic pulses (called pings) and then receives the backscattered acoustic signals reflected off of particles throughout the water column (e.g. suspended sediment). The Doppler shift of the backscattered signal is proportional to the velocity of the scattering particle. The acoustic beams diverge both longitudinally and laterally as shown in figure 3, so that the velocity reported by the instrument is the average of measurements made along each of four different acoustic beams, rather than a measurement at a single point directly below the instrument. Individual velocity measurements are made within discrete vertical depth cells, or bins, with a height of 25 centimeters

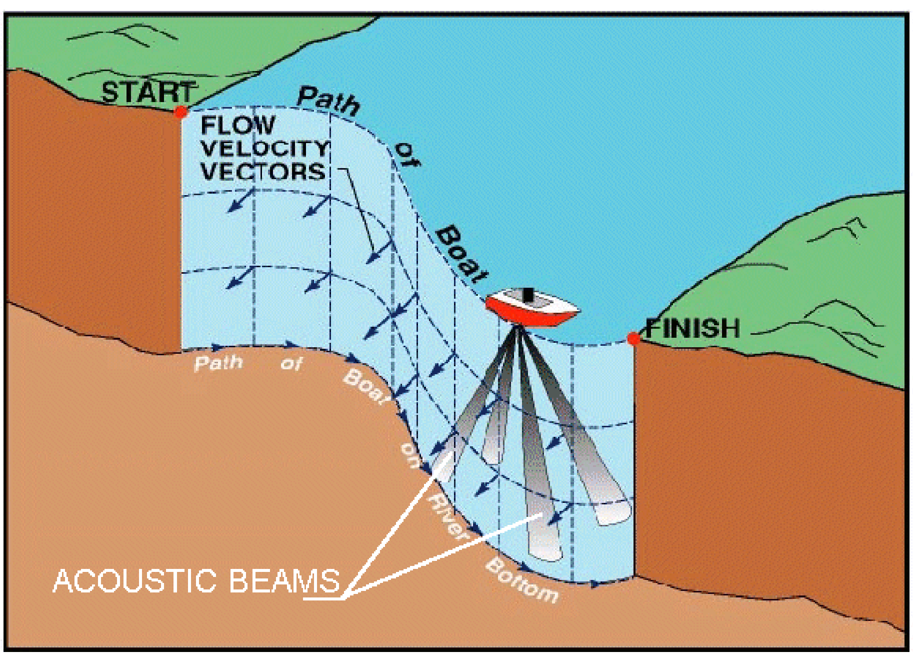

Figure 3. Illustration of an ADCP transect to measure velocity profiles and bathymetry.

each, yielding a velocity profile from near the surface to near the bed. Velocities cannot be measured very near the surface because the transducer must be submerged and because

there is some time delay between the send and receive modes of operation for the instrument. Velocities also cannot be measured very near the bed (approximately the last 10 percent of the depth) due to a phenomenon called side-lobe interference.

ADCPs measure three orthogonal components of velocity; an internal compass is used to transform velocities to an earth coordinate system (east/north/up). Tilt sensors are used to correct for any pitch/roll errors in depth measurements. In addition to the velocity data, the ADCP records the bathymetry along the transect. Dedicated bottom tracking pings are collected to track the boat motion relative to the channel bottom using the same Doppler shift technique used to measure velocity. This measurement allows the water velocity measurements to be corrected for relative boat motion, and permits tracking instrument position along the transect.

A laptop computer was used to configure the ADCP and collect the data. A portable global positioning system (GPS) was connected to the laptop computer so that continuous GPS data were recorded simultaneously with the velocity data. GPS was the only method available for locating the ADCP measurement locations. As a result, the accuracy of positions reported here are ± 10 ft.

Velocity data were collected on July 24, 2002, and the project operating conditions are summarized in Table 1. ADCP measurements were collected along 11 transects and 4 profiling sites. Figure 4 shows a general plan view of the area where ADCP data were collected. Features to note include: the Link River arm of UKL, the orientation of the A-Canal intake channel and headworks, the Fremont Bridge, and the larval curtain.

Table 1. Project operating conditions during ADCP data collection.

Date	Upper Klamath Lake Elevation, ft	A-Canal Diversion Flow, ft^3/s	Flow Over Link River Dam, ft^3/s	Number of Transects
July 24, 2002	4140.5	830	1,000	11

Velocity Data Analysis

Figure 5 shows the horizontal velocity field near the curtain and the A-Canal headworks. This figure was constructed using the depth-averaged velocities at points on each transect; each vector is the average of the east and north velocities measured throughout the depth of the water column. Upstream from the curtain, the velocities are predominantly along the curtain with a minor

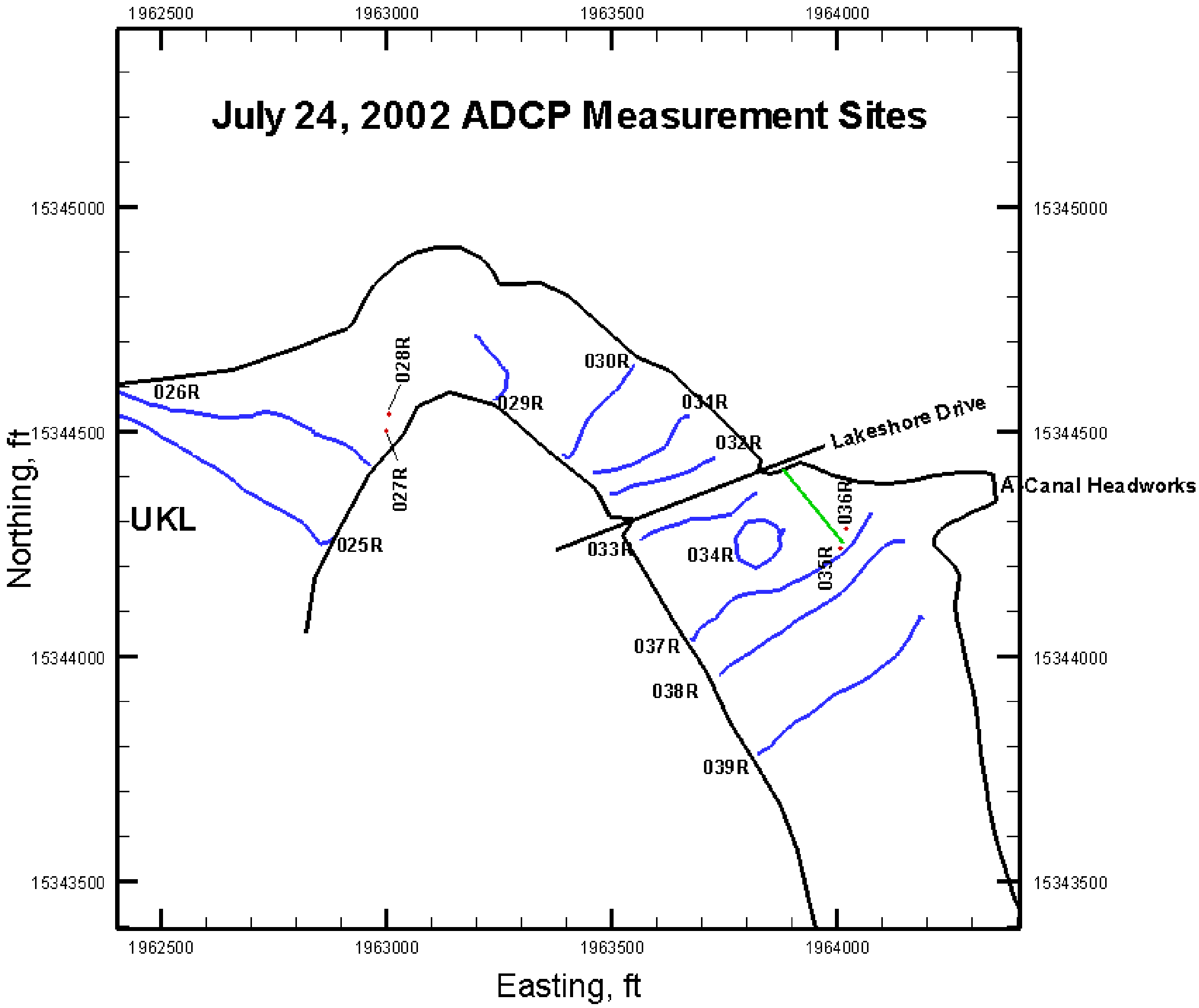

Figure 4. Plan view of UKL near the A-Canal headworks. ADCP transects and profile locations are shown in blue and red, respectively. The larval deflection curtain is represented by a green line.

velocity component toward the curtain. Downstream from the curtain, the velocity vectors indicate an upstream flow into A-Canal. Consequently, larval suckers may be deflected by the curtain, but they are likely entrained into A-Canal once they have drifted past the curtain. It appears that flow enters the A-Canal intake channel primarily from the south and southwest based on transects collected downstream from the larval curtain.

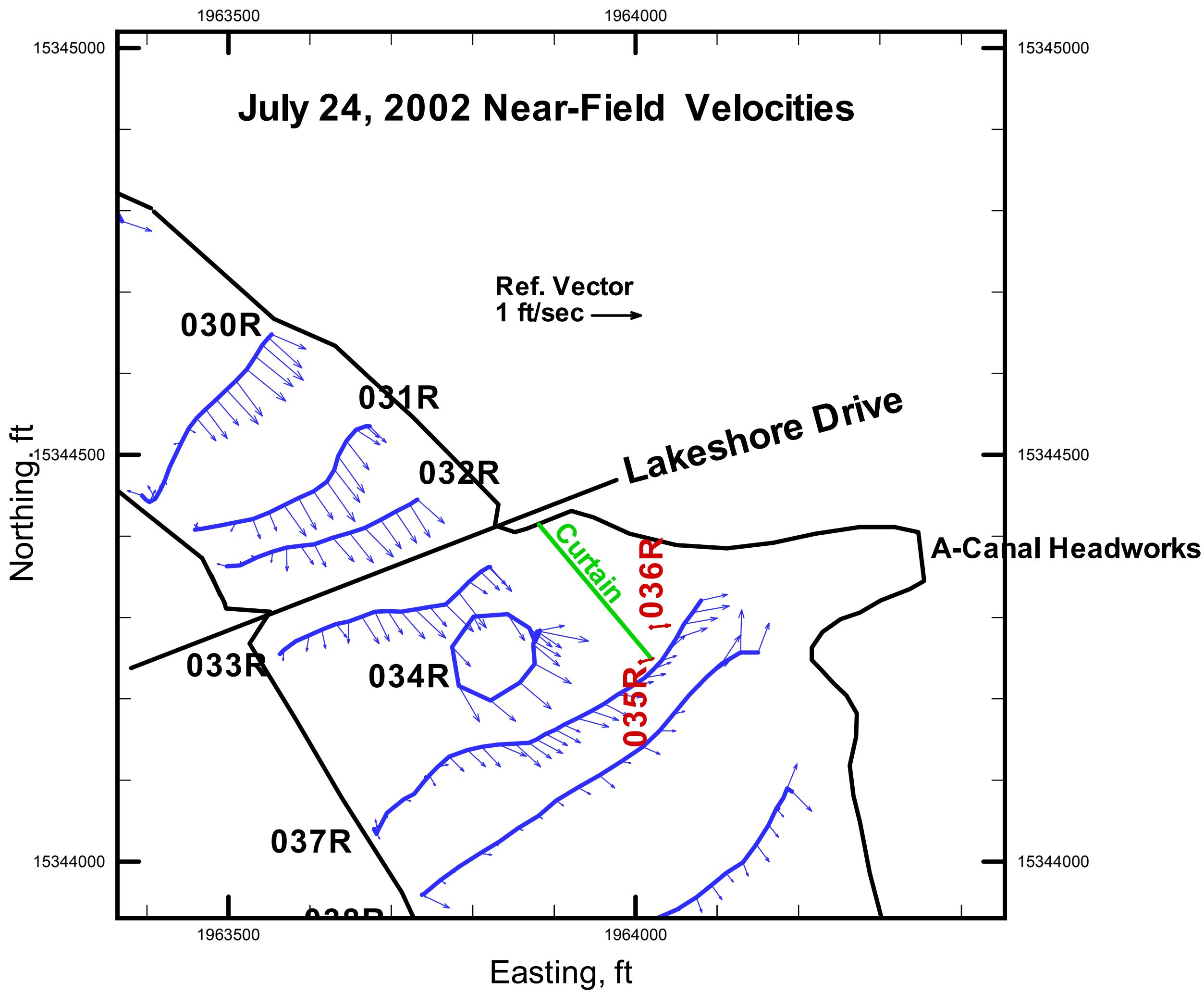

Figure 5. Plot of near-field velocity vectors near the curtain and A-Canal headworks. Depth-averaged velocity vectors indicate an upstream flow into A-Canal downstream from the curtain. This velocity field indicates that larval suckers may be deflected by the curtain, but they are likely entrained into A-Canal once they have drifted past the curtain. The red vectors are profiles collected at fixed points on both sides of the curtain.

Profiles collected at fixed points on the upstream (035R) and downstream (036R) side of the curtain (figure 5) are summarized in Table 2. In general, velocities upstream from the curtain are 0.3 ft/sec in a easterly direction - toward A-Canal. Velocities measured at a depth of 2.34 ft are near the curtain bottom. At a depth of 2.34 ft, the upstream profile (035R) had an average downward velocity of ! 0.03 ± 0.01 ft/sec. This is a relatively small vertical velocity and velocities closer to the surface are likely to have the same magnitude or smaller. Since the ADCP cannot measure surface velocities, surface velocity measurements would have to be collected using a point velocity meter to verify their magnitude and direction. Near-surface velocities measured between the curtain and the A-Canal headworks (036R) are higher in magnitude (0.54 ft/sec) and are in an easterly direction.

Table 2. Velocity Profile Data

035R - Profile upstream from curtain

Depth [ft]	Velocity Mag. [ft/s]	Dir [°from N]	Vvert.[ft/s]
2.34	0.33	77.5	-0.03
3.16	0.35	89.7	0.01
3.98	0.31	77.7	0.02
4.8	0.24	75.6	0.04
5.62	0.33	69.6	0.06
6.44	0.28	70.9	0.08
7.26	0.26	84.7	0.06
8.08	0.32	73.6	0.10
8.9	0.22	73.1	0.08

036R - Profile downstream from curtain

Depth [ft]	Velocity Mag. [ft/s]	Dir [°from N]	Vvert.[ft/s]
2.34	0.54	89.2	0.03
3.16	0.24	73.0	0.00

Additional ADCP Transects

Figure 6 shows the depth-averaged velocity vectors for data collected upstream from the A-Canal headworks. These transects were collected as an initial effort to evaluate alternative curtain locations in Upper Klamath Lake. The vector plots show relatively high velocities along the left bank approaching A-Canal and low velocities along the right bank. This same flow field was observed for similar conditions in September 1998 (USBR 1998).

Velocity contour and vector plots for individual ADCP transects collected upstream from the Fremont Bridge have been included in figures 7-12. Each of the color contour figures show the vertical variation in velocity magnitude across the transect line. The velocity contour plots are oriented so that the left bank is on the left as if looking downstream and are useful for visualizing the channel's cross section. The vector plots are the depth-average velocities measured along the transect. Each vector is a spatial average of 10 consecutive profiles. Vector averaging was done to smooth the data for presentation purposes. Also included in the plots is a summary table of the discharge data and cross section properties, such as top width, area, and average channel velocity.

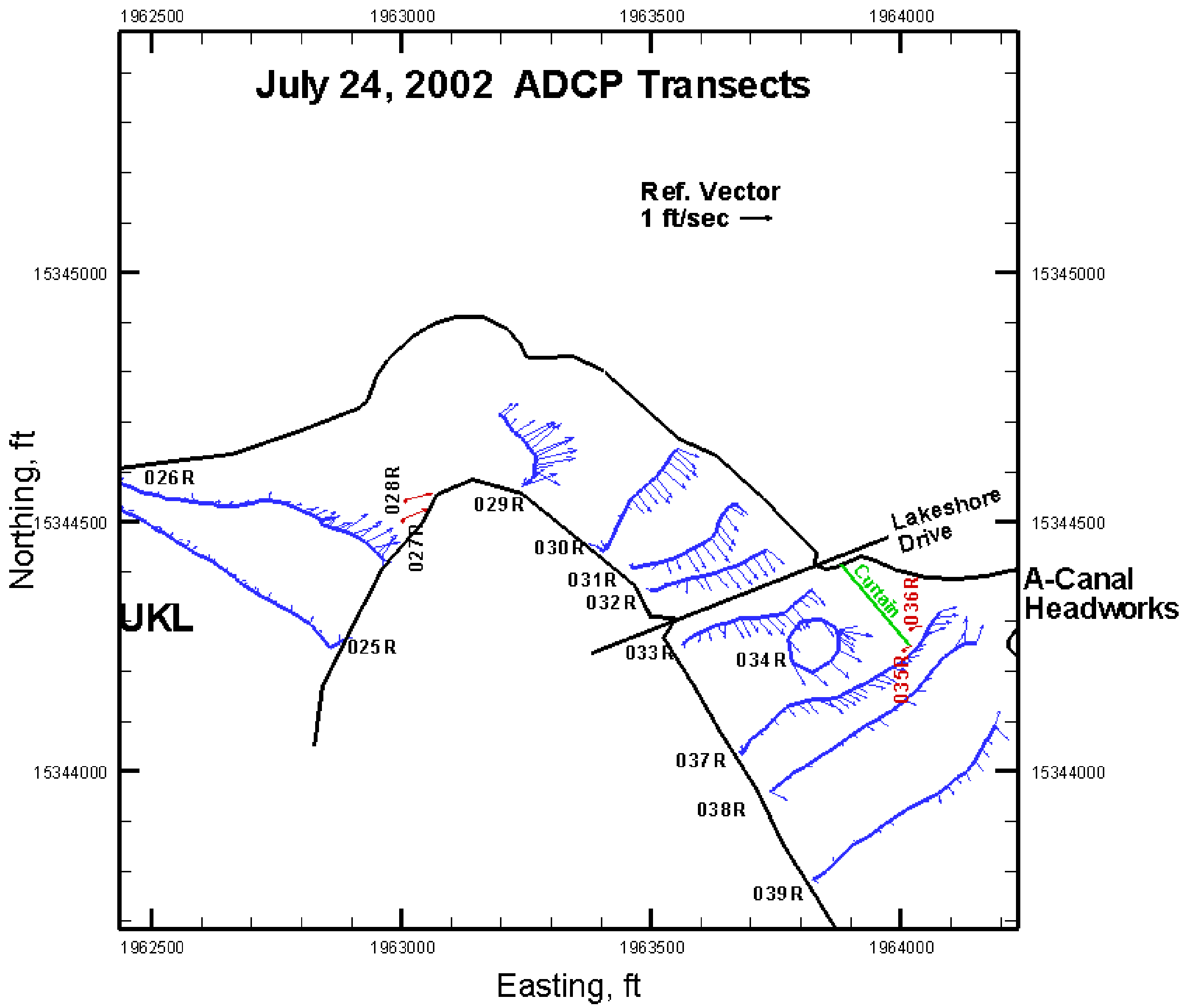

Figure 6. Depth-averaged velocity vectors for ADCP data collected in the Link River Arm of UKL. These vectors show low velocities along the right bank from transect 030R to 039R.

Conclusions

An important curtain design parameter is that there be adequate depth under the curtain to minimize velocity and entrainment of surface water beneath the curtain. Even though floating debris accumulates against the curtain (the buoyancy of aquatic debris will keep it from being entrained), it is possible that the withdrawal zone upstream of the curtain extends to the surface when underflow velocities are high. Detailed velocity profiles collected upstream from the existing curtain showed that vertical velocities near the curtain bottom were small and were directed downward (-0.03 ft/sec at 2.3 ft below the water surface).

The depth-averaged velocity vector plots for ADCP transects collected downstream from the curtain showed an upstream flow into A-Canal. These velocity fields indicate that while larval suckers may be deflected by the curtain they are likely entrained into A-Canal once they move downstream from the curtain.

References

Bureau of Reclamation. 1998. Measurements of Velocity Fields on Upper Klamath Lake Approaching the A-Canal Intake Using an Acoustic Doppler Current Profiler. Memo (November 1988) and Report, prepared by Tony Wahl and Tracy Vermeyen (Technical Service Center, D-8560) for Area Manager, USBR, Klamath Basin Area Office.

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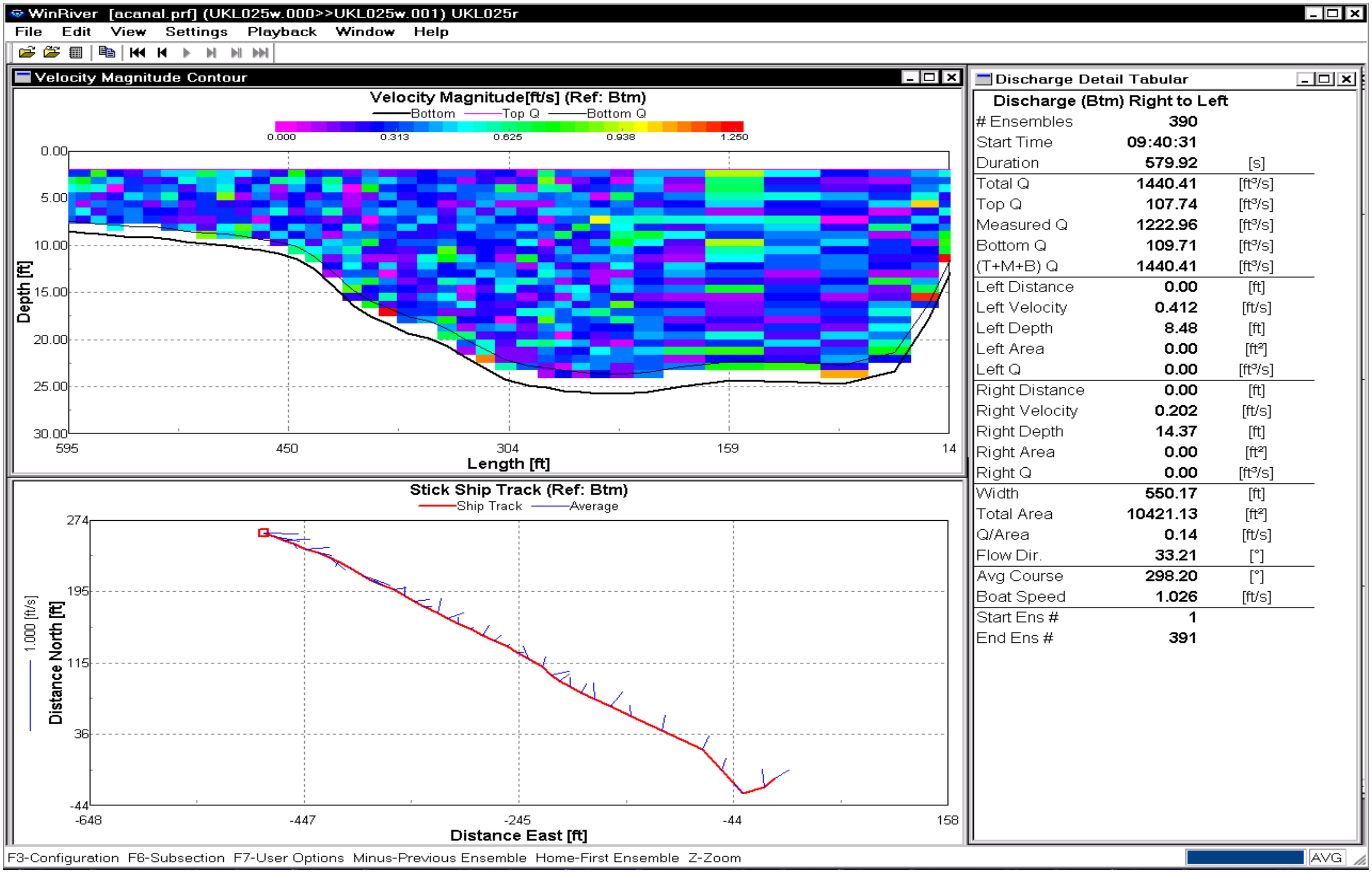

Figure 7. Plots of ADCP transect data (025R) and a summary of the discharge data which provides information on the cross sectional properties.

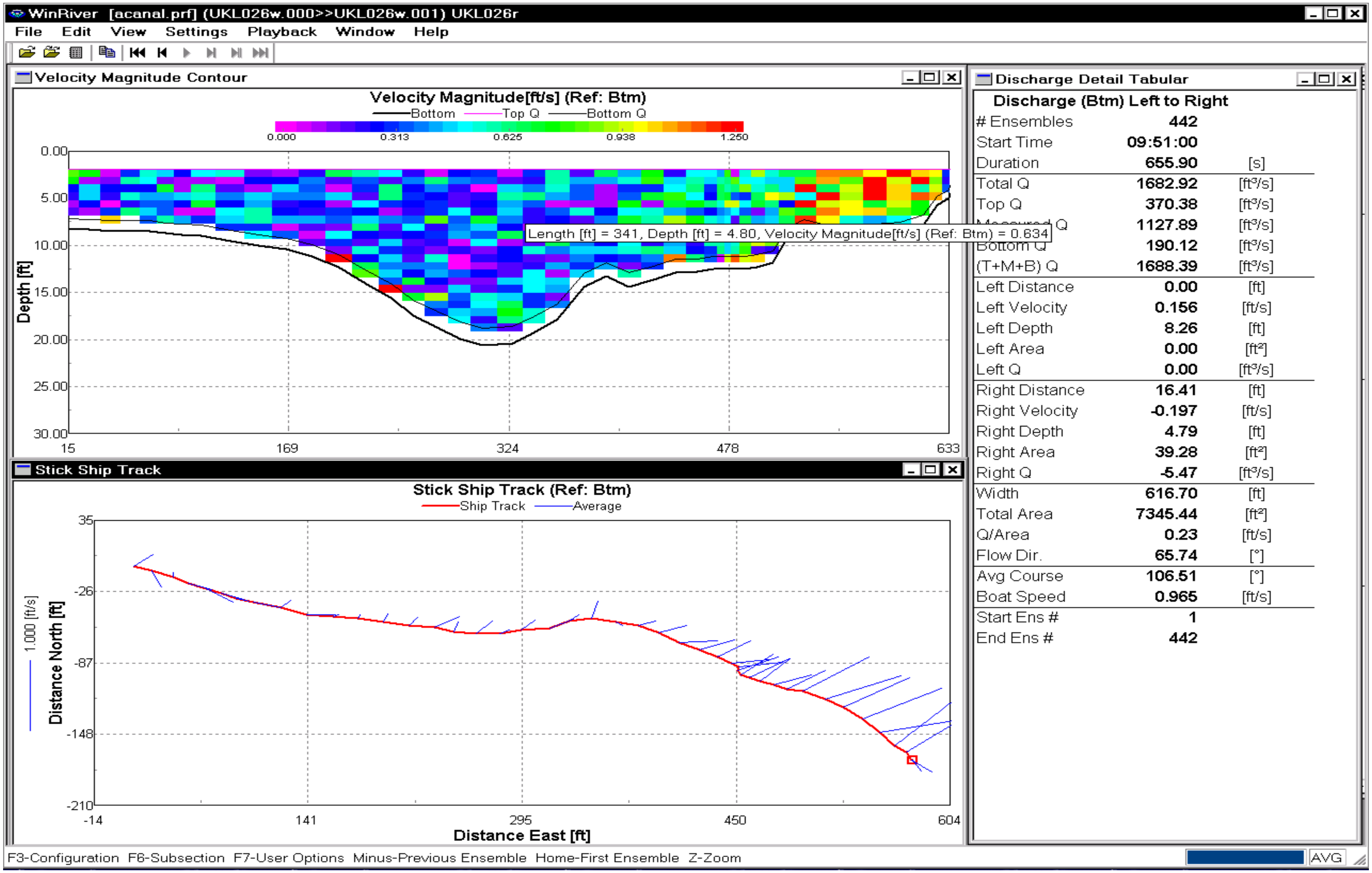

Figure 8. Plots of ADCP transect data (026R) and a summary of the discharge data. Both plots show 1 ft/sec velocities in the shallows near the right bank.

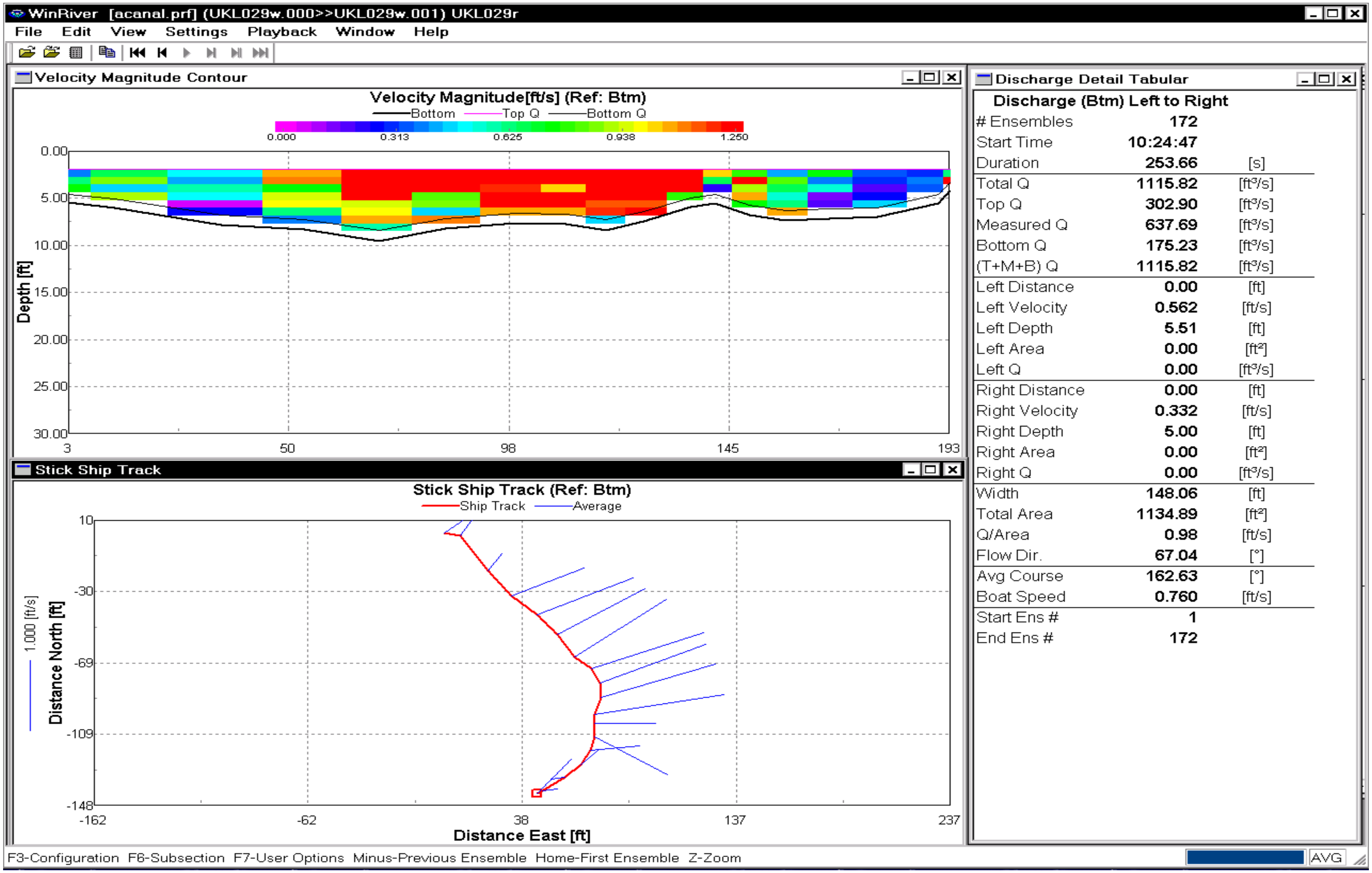

Figure 9. Plots of ADCP transect data (029R) and a summary of the discharge data. The contour plot shows relatively shallow depths and 1 ft/sec velocities in the center of the channel.

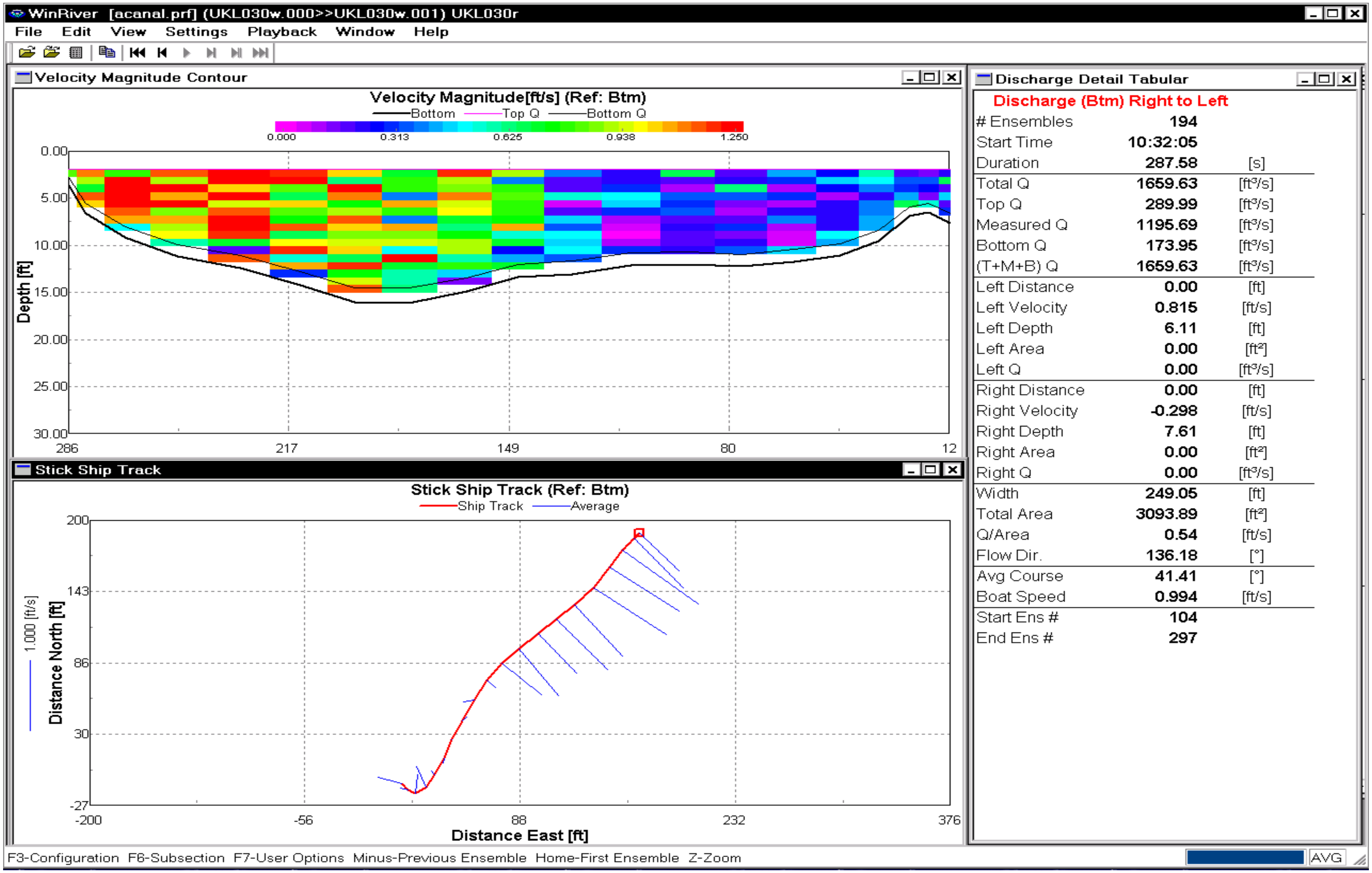

Figure 10. Plots of ADCP transect data (030R) and a summary of the discharge data. The contour plot shows the higher velocities were concentrated along the left side of the channel. This velocity field is typical of flow through a bend.

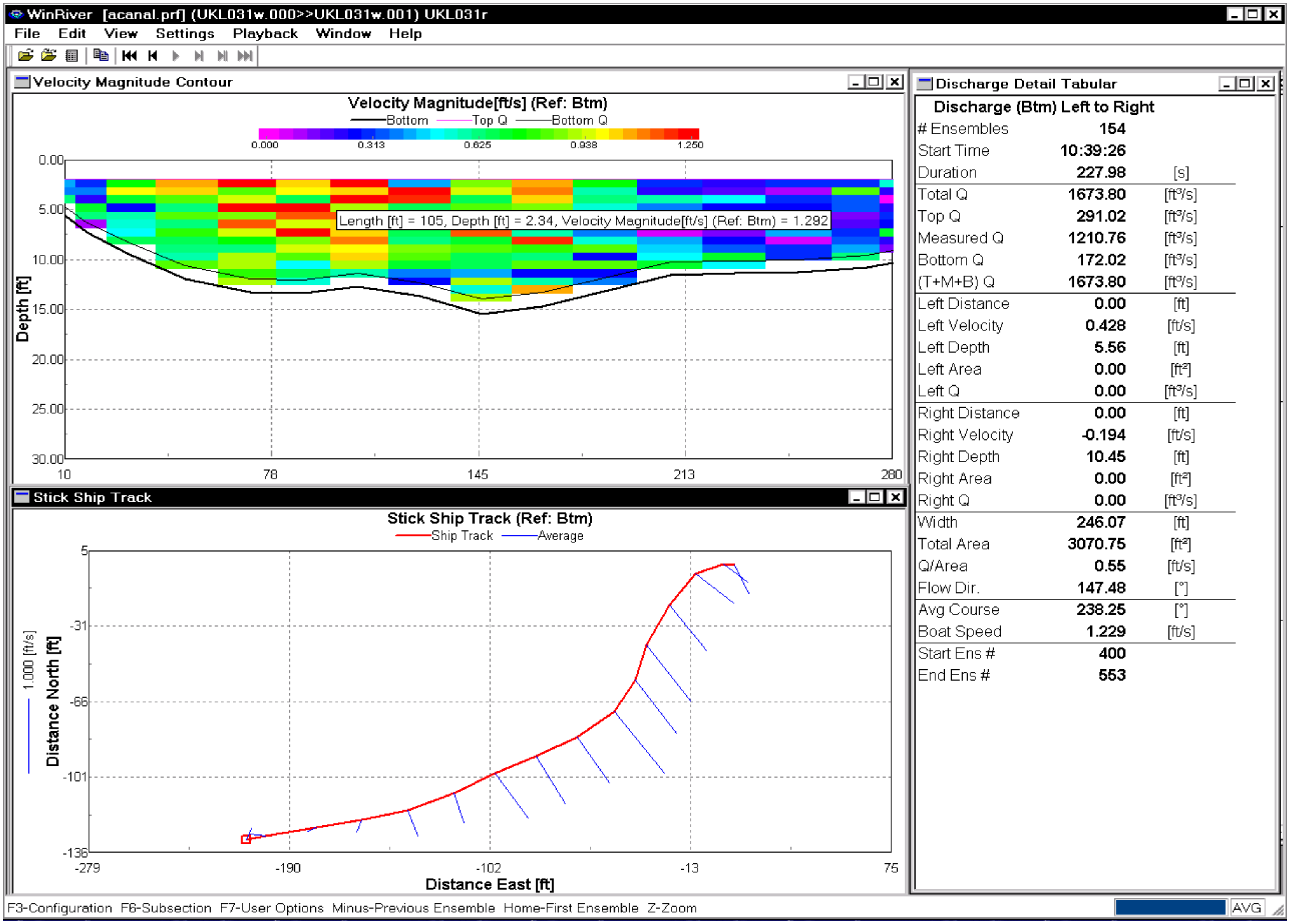

Figure 11. Plots of ADCP transect data (031R) and a summary of the discharge data. The plots show low velocities near the right bank and higher velocities in the center and left side of the channel.

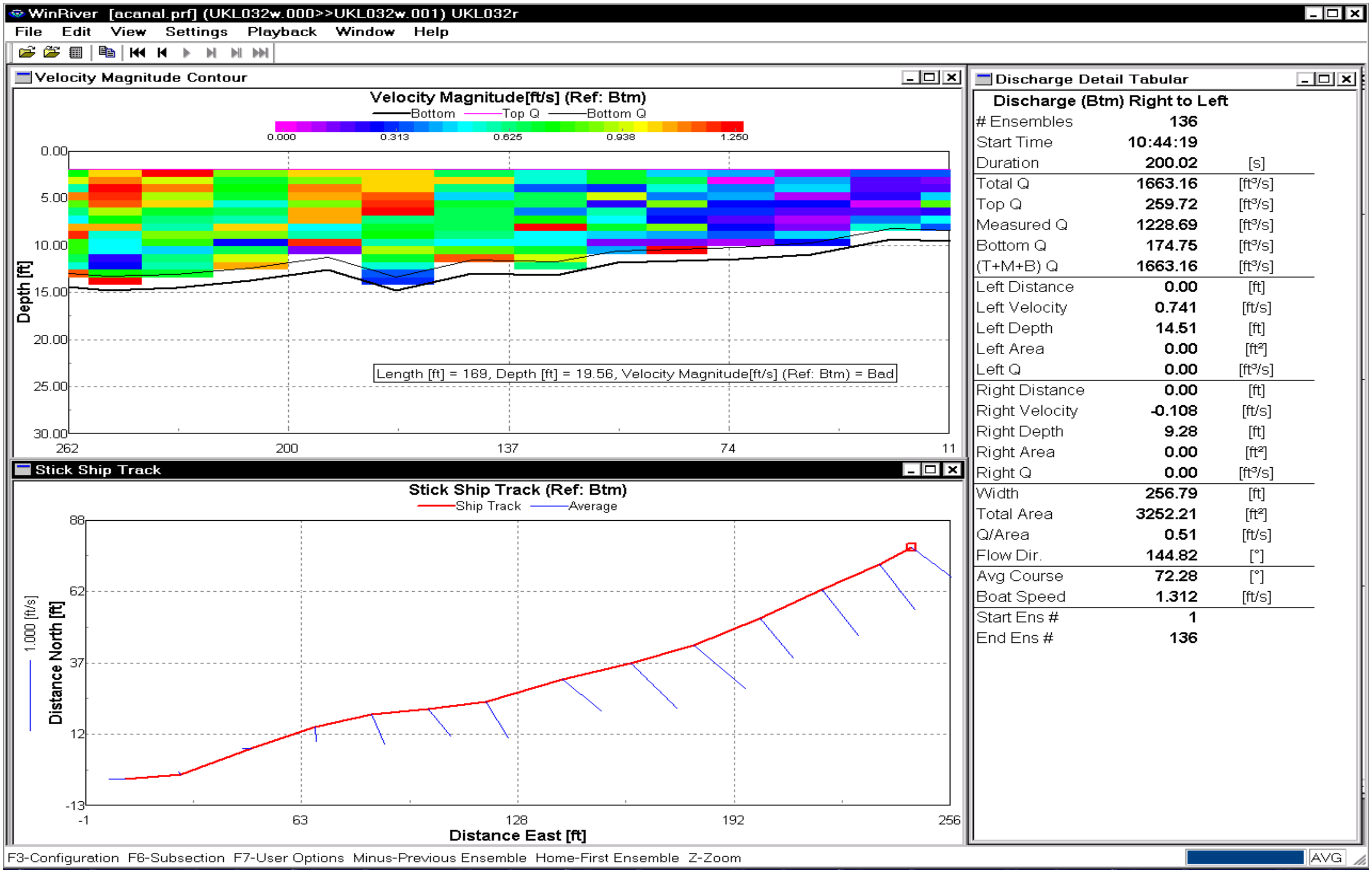

Figure 12. Plots of ADCP transect data (032R) and a summary of the discharge data. The contour plot shows relatively shallow depths and 1 ft/sec velocities across left side of the channel.