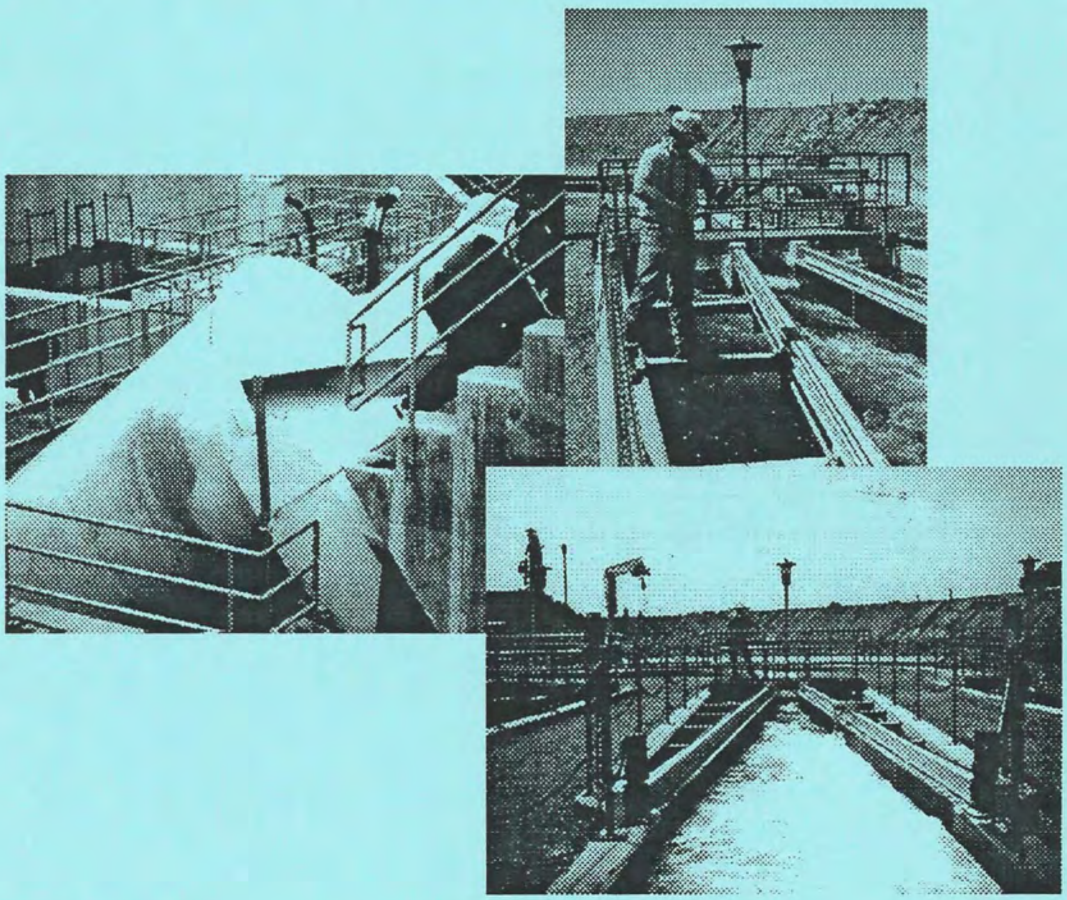
Engineering Shakedown and Evaluations at Red Bluff Research Pumping Plant, 1995



Prepared for
RBRPP Evaluation Team

by
K. Warren Frizell and Stephen P. Atkinson

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U.S. DEPARTMENT OF THE INTERIOR
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WATER RESOURCES MANAGEMENT.....FOR THE FUTURE
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1
Introduction

The Red Bluff Research Pumping Plant (RBRPP) was constructed to evaluate the use of pumps for fish passage. The Archimedes pump and a centrifugal-helical design were chosen for the evaluation. The pumps installed at RBRPP fall into the experimental category due to many unique design features and relatively little experience with passing fish. Initial operation of the plant will be for fisheries and engineering evaluation studies which are scoped out in "Update on Biological and Engineering Evaluations of the Red Bluff Research Pumping Plant, Sacramento River,California," by Liston and Johnson, 1994. At the end of this initial study period, the plant may be used for further related research and to supplement water deliveries to the Tehama-Colusa and Corning Canal systems during the annual gates-out period at the Red Bluff Diversion Dam (May 15-September 15).

This report will describe the progress of the engineering shakedown and evaluations that took place at RBRPP during calendar year 1995.

2

Construction and Plant Features

Construction was completed at RBRPP in May 1995. Figure 1 shows an aerial view of the completed structures.

Figure 1: Aerial view of the Red Bluff Research Pumping Plant.

The plant was designed by Reclamation's Technical Service Center with input from various Resource agencies. The Willows Construction Office monitored the contract. The construction took 18 months and cost about $11,750,000. The resulting pumping plant is a premier research facility for evaluating selected pumps for their fish passage characteristics in a natural setting. The plant will be divided into separate areas for studies and reporting. A plan view of the overall area is shown on figure 2, with specific study areas identified.

The key features of the plant are the three pumps installed for fisheries and engineering evaluations. Two Archimedes pumps or lifts, manufactured by Wheelebrator/CPC were installed in bays No. 1 and 2. These pumps were designed to lift water a maximum of 19.25 ft at a rate

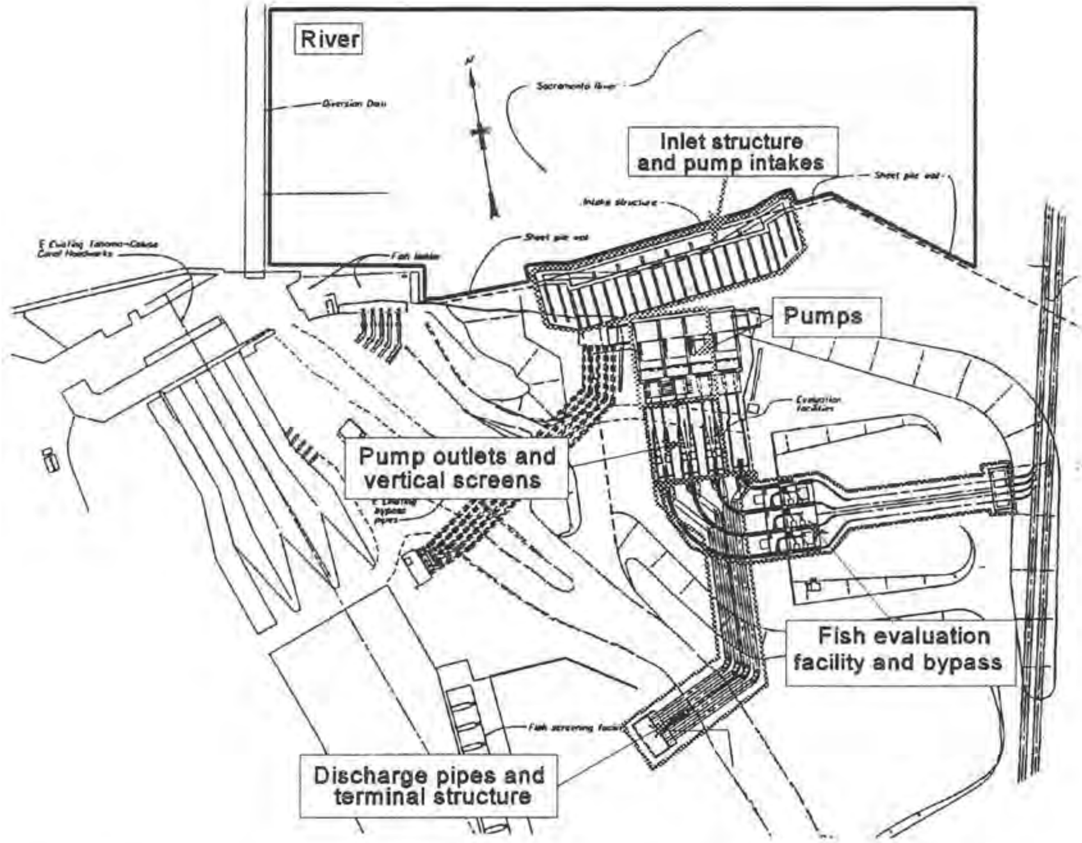


Figure 2: Plan view of the engineering study areas at Red Bluff Research Pumping Plant.

of 100 ft^3/s when operated at 26.5 r/min. These pumps are 10 ft in diameter and have three internal continuously welded flights, figure 3. They are set on a 38° angle and feature a rotating seal at the lower end of the pump that has not previously been tested. Pump No. 1 operates on a direct drive at 26.5 r/min, pump No. 2 can be operated direct or with a variable speed drive, allowing rotational speeds from 1 to 26.5 r/min. Each Archimedes pump features an induction motor and a helical gear reducer.

The centrifugal-helical pump is a variable speed unit manufactured by WEMCO/Hirdrostal. Its speed range is 300-450 rev/min and it will deliver 100 ft^3/s at maximum speed at a total dynamic head of 22.5 ft with 39 ft of available NPSH. The pump has a 48-in inlet and features a single vane-type impeller with a rotating conical shroud, figure 4. The pump is equipped with an induction motor and a helical right angle 4:1 gear reducer. There is an extra pump bay constructed on the premise that an additional pump may be selected for evaluation and installed in bay No. 4.

At the point of the pump outfalls, each bay has an identical channel and chevron screen structure used to separate about 10 percent of the total flow that also is carrying the fish into the bypass and evaluation facilities, figure 5. The bypass is an 18-in-wide sweeping channel that empties into selectable holding tanks where fish are recaptured for identification and further evaluation, figure 6. The bypass flows continue in separate pipes and discharge into the existing bypass pipeline from the Tehama-Coulsa Canal drum screen structure. The bulk of the pump discharge (~90 percent) passes

Figure 3: Archimedes pump being delivered to the construction site on a semi-trailer.

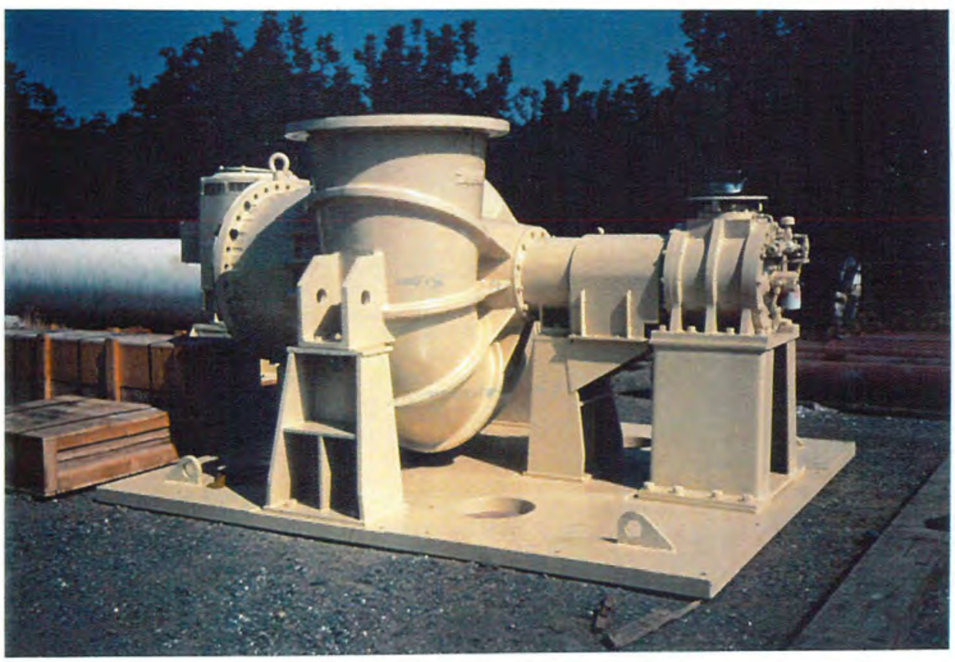


Figure 4: Centrifugal-helical pump onsite prior to installation.

Figure 5: Vertical screen structure and bypass entrance.

Figure 6: Fish evauluation facilities - holding tanks.

through the vertical wedge-wire screens in the chevron screen structure and flows into the headworks of the Tehama-Colusa Canal, figure 7. Many features of the pumping plant were modified and changed during the first few months of operation. This shakedown period is still underway. The plant has operated for preliminary fisheries evaluations. However, much of the operation in 1995 was to correct deficiencies and improve facilities and techniques to allow the planned studies to be done.

Figure 7: Discharge pipes emptying into the Tehama-Colusa Canal headworks.

3

Shakedown

The shakedown period has been longer and more intense than originally anticipated. Many features of the plant did not operate properly and modifications were required. In addition, design and construction of features to help in the study program were completed in this phase of work. As with the evaluations, the shakedown activities will be broken down into the study areas identified in figure 2.

The River

There were no formal shakedown activities associated with the river. The collection of baseline data and any evaluations will be described later.

Inlet Structure and Pump Intakes

No modifications were made to either the inlet structure, trashracks, or the pump intake bells as part of the shakedown activities. Sediment deposits were discovered by divers inspecting the inlet structure. The sediment front extended through the trashracks and the general trend was that the deposit depth increased in the downstream (river) direction. Lifting slings for all the trashracks were purchased and installed.

The Pumps

Initial tests were completed on the three pumps during May 1995. The specifications called for both burn-in tests and performance verification. Operational problems with the variable speed controller prevented complete testing, however, all three pumps were operated for testing over a period of about 1 week. Archimedes pump No. 1 was operated for 8 hours for a burn-in test. The discharge from the installed flowmeters indicated the pump was delivering 86 ft^3/s at a river elevation of 246 ft. Toward the end of this burn-in period, plastic shavings were seen in the pump discharge channel, collecting on the vertical wedge-wire screens. The pump was shut down at this point to eliminate further wear on the UHMW wearing ring (a feature of the rotating seal). Archimedes pump No. 2 was also operated at full speed (26.5 r/min), giving almost identical discharge readings. In a period less than the required 8-hour burn-in, plastic shavings again were observed and the pump was shut down. The lower seal was disassembled and sediments from the river up to 0.125 in had migrated into this area, damaging the UHMW wearing ring and impregnating the compression packing, figure 8. It was decided at this time that a new seal arrangement was needed before further operation of the Archimedes pumps.

Figure 8: Damaged UHMW wearing ring and packing from Archimedes pump.

Reclamation requested that Wheelebrator/CPC provide a new seal design that would handle the expected sediment load. Through many iterations with the manufacturer (over a period of 5-6 months), it became apparent that an acceptable design from the manufacturer was unlikely. The Willows Construction Office decided to approach this problem in two phases: design and install a temporary seal that would allow the pumps to be operated beginning in March 1996, and proceed with the design and installation of a permanent fix by the end of the summer 1996. Engineers at Reclamation's Northern California Area Office (NCAO), RBRPP, and the Technical Service Center began work on achieving this schedule in November 1995.

The centrifugal-helical pump was operated for an 8-hour burn-in test on the variable speed drive at a setting of 45 Hz. This was done as the pump discharge was quite a bit higher than the design value and would have exceeded the downstream channel capacity. The discharge was measured at 115 ft^3/s at a river elevation of 246 ft. The intensive tests indicated in the specifications were bypassed with agreement from the manufacturers. No apparent problems were noted with the centrifugal-helical pump during the burn-in period.

Additional shakedown tasks in support of the pumps included installation of pressure taps on each of the three inlet pipes just upstream from the pumps, figure 9. Three pressure transducers were purchased and will be installed later.

Figure 9: Piezometer tap installation on the intake pipe leading to the pumps.

Pump Outfalls and Vertical Screening Structures

Initial pump tests showed several problem areas with the outfall area and channel leading to the angled vertical screens. Containing all the flow is important to ensure that all the fish carried by the pumps actually remain in the channel and make it to the bypass and evaluation facilities. Splashing at the outfalls was contained by constructing and installing splash guards, figure 10.

The Archimedes pumps exhibited less splashing at the outfall. However, there is quite a bit of splashing and carryover of water at the pump exit at a pump speed of 26.5 r/min, figure 11. Testing at slower rotational speeds indicated that this problem was greatly reduced. Solutions to containing this over-splash are still being considered. The vertical screen structure was an area where many modifications were needed. The brush system used for continuous cleaning of the screens did not operate properly due to high friction of the brush holders on the rail. Teflon strips originally designed for these rails could not be attached adequately in the field. This condition was greatly improved by applying grease to the rail area. Construction of temporary baffles on the screens was also required to prevent large head-drops across the wedge-wire screens. Plywood panels with holes to vary the open area were installed to the back of the screen frames, figure 12. Some additional caulking was required to plug some holes where fish could possibly escape the collection facility.

Fish Evaluation and Bypass Facilities

Several shakedown activities took place to prepare the bypass and fish evaluation facilities for operation. Fish injection containers and crowders were constructed and modified over a period of several months, figure 13. Holes were plugged and offsets smoothed along the bypass channels

Figure 10: Splashguards installed on bay No. 3.

Figure 11: Carryover splashing at the Archimedes pump exit.

Figure 12: Temporary baffles on the vertical screen structures.

Figure 13: Fish injection device.

and all the way into the holding tanks. The jib cranes that are used to lift stoplog gates, the dewatering ramps, and the holding tanks were repaired. The pinch valves and associated level sensors were reset. The holding tanks were modified to allow for easier collection of fish.

Discharge Pipes and Terminal Structure

No shakedown activities were associated with this study area.

The shakedown period is nearly complete except for additional work on the Archimedes pumps since they have operated only sparingly during the year. The Archimedes pumpswere rotated in the dry to see if any other operational problems could be uncovered while waiting for the seal issue to be resolved.

4

Engineering Evaluations

Several preliminary evaluations were conducted throughout 1995. Many of these were the collection of baseline data since there was little operational time during the year.

The River

Initial data were collected in the river during the gates-down period. River transects were collected upstream of the Red Bluff Diversion Dam using a boat-mounted acoustic Doppler current profiler (ADCP). This instrument allows for the simultaneous collection of bottom information and three-dimensional velocities. In addition, several passes in front of the plant's intake structure (without pumps) were made to verify sweeping velocities and look at sediment deposition. These data appears in the appendix.

Sedimentation data were not collected in the river during 1995. There is a large body of previous work concerning sediment transport characteristics and both suspended sediments and bedload behavior at the pumping plant site. Obviously the river morphology can change from year to year depending on flows and storm events. We will continue to monitor and document changes when possible, especially if they influence performance of the pumping plant.

Inlet Structure and Pump Intakes

The basic operation of the inlet structure and pump intakes seemed fine throughout 1995. Almost all observations were made with only the centrifugal-helical pump in operation. The trashrack performance was good, deflecting trash and debris off the racks and downstream. There was considerable deposition of sediments (mostly silt to 0.5 in gravel) in front of and within the inlet structure. The trashrack orientation could be a factor in the amounts and location of sediment deposition. Studies were initiated to look at the velocities within the inlet structure with no pumps operating to study orientation effects. Velocity measurements and suspended sediment measurements were planned. Additional trashrack manipulations are planned in hopes of finding the most effective orientation for excluding sediments while keeping good flow conditions into the pumps and maintaining a strong sweeping velocity component in front of the structure.

The Pumps

Few formal evaluations were performed on the three pumps. As mentioned previously, the two Archimedes pumps only operated for a very short time during 1995 due to seal problems at the lower rotating seal. Operation of the centrifugal-helical pump did continue throughout the summer of 1995 for use in fisheries evaluations; however, little data were collected supporting mechanical and operational features of the pump. Operation of the pump was documented, including hours of operation, maintenance requirements, problems, etc. In September, the centrifugal-helical pump experienced a major problem. During operation, the pump's rotational parts seized and a motor stop was triggered. Upon disassembly of the pump, the impeller appeared to have shifted on the shaft causing it to contact the stationary casing and seize. Upon further inspection, this slippage was deemed to be the result of a complete fracture of the shaft, figure 14. Initial observations showed that the shaft failure indicated a fatigue failure. The manufacturer agreed to fix the problem as it occurred under warranty. The shaft was redesigned and manufactured at its facilities in Peru. The impeller was refurbished at its Salt Lake City plant. Plans are for the pump to return to the site in April and be running by the first of May 1996.

Figure 14: Fracture of shaft in centrifugal-helical pump.

Problems associated with the operation of the pumps during 1995 reinforce the need to have some type of monitoring system to assist the plant operator in pump condition and maintenance needs. Plans were initiated to design a monitoring system that could be installed, using as much of the permanent instrumentation as possible. This system is expected to be finished and working sometime during 1996.

Pump Outfalls and Vertical Screening Structures

No evaluations dealt solely with the pump outfalls other than some general observations. The outfalls from the Archimedes pumps have a pulsing characteristic associated with the dumping of water from each flight of the pump. This pulsing could have effects on wave formation and velocity fluctuations. This will be included in the study plan when the Archimedes pumps are again operational. The outfall of the centrifugal-helical pump is a violent plunge, falling from about 8-10 ft above the channel water surface. However, the main problem associated with the outfall is that it is off-center, which results in a sloshing from side to side as the flow continues downstream. These effects will also be studied further in 1996.

The vertical screen structures feature wedge-wire screens (3/16-in bar width and spacing) in the typical chevron pattern with the bypass centered at the end of the structure. To operate as a fish screen, velocity criteria have to be met. The criteria for this site have been established to be an approach velocity of 0.33 ft/s with a sweeping velocity component of at least twice the approach. First observations and measurements indicated approach velocities far greater than this value. Baffling, or restriction of the available flow area, is a known method used to reduce approach velocities and distribute flow evenly over the entire screen face. Temporary plywood baffles were place in bay No. 3 on the last three screen panels on each side of the structure. The percent open area varied from 50percent, to 25 percent, to 10 percent on the screen panel closest to the bypass entrance.

A set of velocity measurements was taken on the east side of the screen structure. The measurements were made with a three-dimensional acoustic velocity probe manufactured by SONTEK. This probe measures all three components of velocity at a point about 2 in below the probe. Data are fed into a laptop computer for processing and storage. A bracket was constructed to hold the probe at a location 3 in off the screen face and allow for traversing the entire flow depth and length of the screen panels. Velocity profiles were collected at two locations on each screen panel, stations A-M excluding I. Figure 15a&b show velocity profiles for the approach and sweeping velocity components along the east side of bay No. 3 for a flowrate of 110 ft^3/s. Note the reverse flow component of the sweeping velocity near the bypass entrance. This flow condition indicates a submerged eddy caused by poor bypass entrance conditions. An inverted weir was designed to be placed in the bypass channel to accelerate the flow into the bypass. These weirs will be installed in 1996. In addition, these tests pointed to the need to be able to adjust the open area of the baffles easily so a permanent baffle attachment was designed and constructed.

Continued work on the velocity distributions and criteria testing will continue when the pumps become operational in 1996.

Fish Evaluation and Bypass Facilities

Engineering or hydraulic evaluation of the bypass and fish evaluation facilities was limited during 1995. Except discovering that the bypass entrance was well oversized, the remainder of the facilities performed adequately. Spot velocities were taken along the bypass channel leading up to the dewatering ramp. Some experimentation with the operation of adjustable weirs and stoplogs was performed. Additional documentation of the flow fields leading up to the holding tanks will be a priority during 1996.

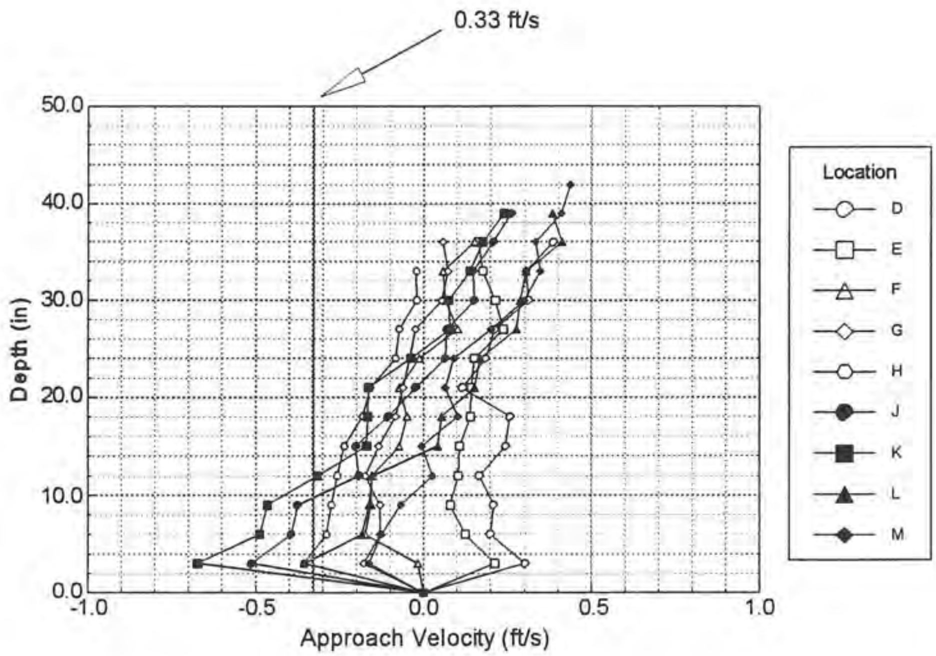


Figure 15a: Approach velocities, 3-in in front of screen face. Negative values are into the screen (velocity in ft/sec).

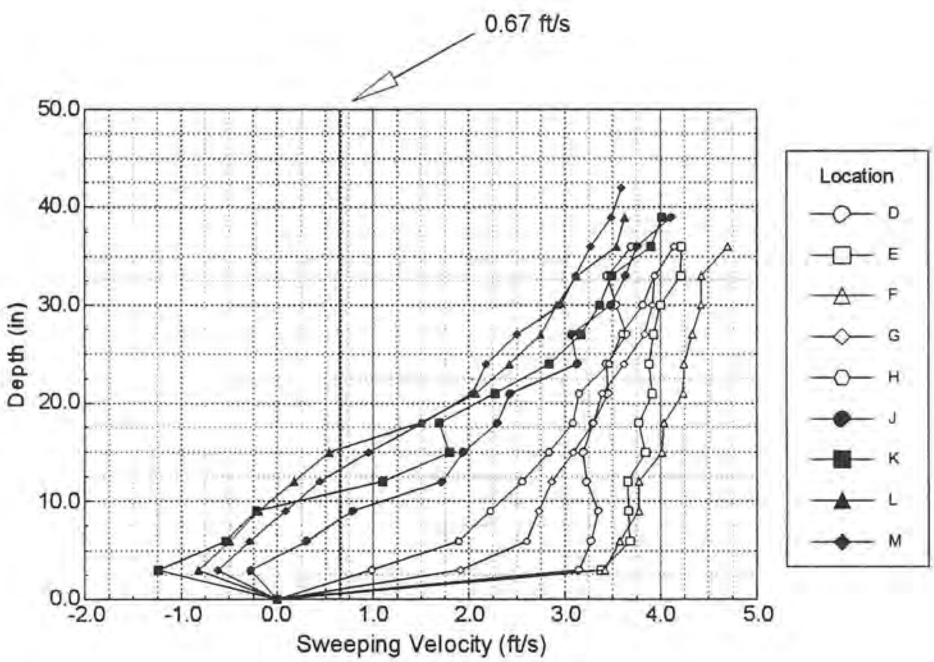


Figure 15b: Sweeping velocities, 3-in in front of screen face. Negative values are in the upstream direction.

Discharge pipes and Terminal Structure

No formal evaluations took place on these facilities during 1995. Verification of proper operation of the propeller-type flowmeters on the discharge pipes leading into the Tehama-Colousa Canal headworks will be attempted in 1996.

5

Closing

The completion of construction and the beginning of the evaluations at Red Bluff Research Pumping Plant took place in 1995. There were several major problems associated with the operation of the pumps that greatly limited both shakedown and evaluation progress. It is anticipated that evaluations will begin again in earnest in March of 1996. The facility promises to be an effective research tool for evaluating the fisheries and engineering features of different types of pumps for fish passage. With the limited evaluations that took place during 1995, the staff remains optimistic and excited about the challenge remaining in completing the planned studies.

APPENDIX

BUREAU OF RECLAMATION
Technical Service Center
Denver, Colorado

TRAVEL REPORT

Code : D-8560 Date: August 14, 1995

To : Manager, Water Resources Research Laboratory

From : Tracy Vermeyen, Hydraulic Engineer

Subject: Travel to Red Bluff, California, for Evaluation of Research Pumping Plant Intake Structure and River Hydraulics

1. Travel period: July 16-19, 1995

2. Places or offices visited: Red Bluff, California, and the Red Bluff Research Pumping Plant

3. Purpose of trip: The purpose of this trip was to take acoustic Doppler current profiler (ADCP) measurements to document the river hydraulics and channel topography near the intake structure of the research pumping plant. This information is needed to evaluate the normal and sweeping velocities near the trashracks. In addition, we also took ADCP measurements at several cross-sections upstream of the Red Bluff Diversion Dam to establish baseline channel topography.

4. Synopsis of trip: I arrived in Redding, California, the evening of July 16 after driving from Sacramento. On July 17 and 18, I collected ADCP data at Shasta and Whiskeytown Lakes for a different project. On July 19, John Martin and I took the NCAO jet boat and ADCP to Red Bluff, California. We met with Hank Harrington and Steve Atkinson. We launched the jet boat upstream of the diversion dam and collected seven transects of ADCP data using a 600 Khz transducer. We started about 800 ft upstream of the dam and worked our way to within 100 ft of the dam. Starting and ending positions along the right and left banks were recorded using a portable global positioning system (GPS) receiver. The latitude and longitude of each bank position, as well as distance moved along each bank, were recorded. GPS data are reported in an attachment to this report. The GPS system worked very well in this application because it allowed rapid identification of our position without having to leave the boat to check survey markers. The GPS data will be archived and will allow us to navigate to the same positions in subsequent data collection surveys.

ADCP transects were used to plot the channel topography and also to measure the velocity field for each transect. Plots of velocity and topography data are attached as figures 1 through 8. The approximate location of each transect is shown in map 1. The channel topography plots were designed to be consistent in their presentation of the left bank (looking downstream) on the left side and the right bank on the right side of the plot. In some cases, transect data were collected from the right bank to left bank so the distance (x-axis) increases from right to left for those data sets. Transects downstream of the dam were attempted but were unsuccessful because of the shallow depths in the center of the river channel (see figure 8). Plots of the bottom topography consist of four lines, where each line represents one of four acoustic beams. The best estimate of the bottom topography would be an average of the four depths. Small discontinuities in the bottom topography for any one beam are probably caused by debris. The distance (x) between the fore and aft beams and the port and starboard beams varies with depth ($x=2*depth*\tan\theta$). For example, for a depth of 22 ft, the distance between beams is 16 ft.

The velocity plots (figures 9-15) for transects collected upstream of the diversion dam show a typical velocity distribution for open channel flow at cross-section No. 1 (furthest upstream) with a maximum velocity of 2.5 ft/sec. However, for transects taken closer to the dam, the velocity distribution becomes skewed by the gate operations. For this data set, most of the flow through the diversion dam was passing through gates near the banks. During this test, flows were routed through gates 1, 2, and 3 near the left bank and through gates 9, 10, and 11 along the right bank. The fish ladders also carry some flow. The river discharge for July 19, 1995 was reported to be about 15,800 ft^3/s at the Bend Bridge upstream of the diversion dam. The average discharge measured by the ADCP was 16,100 ft^3/sec.

Several velocity transects were taken in the vicinity of the pumping plant intake structure. The transects were collected by moving the boat parallel to the trashracks. The first transect (figure 16) was collected moving upstream. The other three transects (figures 17 through 19) were collected moving downstream using a rope to control our speed. The last transect (see figures 19-22) was taken within 10 ft of the trashrack. The other two transects were collected from within 10-20 ft of the trashrack. In summary, the velocity data collected near the diversion structure showed that the sweeping (or eastward) velocity component was the dominant component and was between 3 and 4 ft/sec. The normal (or northward) velocity component was relatively weak and was between 0 and 2 ft/sec. The relatively weak normal velocity was expected because the pumping plant was not operating. The plots of the transect data are presented in figures 16 through 22. Figures 16 through 18 show that the velocity magnitude increases in the downstream direction from 2 ft/sec to 5 ft/sec. Figures 19 through 22 provide a more detailed description of the velocity's magnitude and direction for a transect collected within 10 ft of the trashrack. Figures 19 and 20 show the velocity's magnitude and direction along the trashracks. Figures 21 and 22 show the velocity's north and east components, respectively. Figure 22 shows that the northward or normal velocity increased near the downstream end of the trashrack.

Two stationary ADCP velocity profiles were measured while tied to the intake structure. Plots of the velocity (north, east, and vertical components) are shown in figures 23 and 24. The velocity profile data are the average of about 1000 individual profile measurements. One profile was taken at the upstream edge of the intake structure. The second profile was taken in front of the fourth pump intake bay. In summary, plots of the velocities show that the maximum sweeping velocity (east component) is between 3 and 4 ft/sec and the normal velocity (north component) is about 1 ft/sec.

At the conclusion of testing we packed up our ADCP equipment which was taken back and stored at the NCAO. I drove back to Sacramento and returned to Denver.

5. Conclusions: The 600 Khz ADCP worked very well for this riverine application. We were successful in mapping the bottom topography and in documenting the channel hydraulics upstream of the dam. The ADCP also allowed us to collect data very close to the trashrack structure under difficult flow conditions. The ADCP collects three-dimensional velocity data which allowed for a resolution of the normal and sweeping velocities. The GPS receiver worked very well for this application because it allowed rapid identification of our position without having to leave the boat to check survey markers. The GPS data will be archived and will allow us to navigate to the same positions in subsequent data collection surveys.

6. Action correspondence initiated or required: None.

7. Client feedback received: The personnel at the Red Bluff Research Pumping Plant were appreciative of the use of our instrumentation allowing the collection of data which would have been very difficult and time consuming to obtain otherwise.

Attachments

cc: Mr. Cal McNabb
PO Box 159
Red Bluff CA 96080
(w/att)

bc: D-8220 (Liston), D-8560 (W. Frizell)
(w/att to each)
D-8500, D-8560 (By Lan)

WBR:TVermeyen:rlc:8/10/95:(303)236-2000, x451
H:\HOME\RCASEY\WPFILES\VERMEYEN\REDBLUFF.TRP

SIGNATURES AND SURNAMES FOR:

Travel to: Red Bluff Diversion Dam, Red Bluff, California

Date or Dates of Travel: July 16-19, 1995

Names and Codes of Travelers: Tracy Vermeyen (D-8560)

Traveler	**Date**	**Traveler**	**Date**
[signature]	8/11/95		

Noted and Dated by:

[signature] 8/11/95

DATE	PEER REVIEWER(S)	CODE
8/8/95	[signature] Signature	D-8560
	WARREN FRIZELL Printed Name	
	Signature	
	Printed Name	
Author initials	PEER REVIEW NOT REQUIRED	

Traveler: Vermeyen Date: August 7, 1995

RED BLUFF DIVERSION DAM - TRANSECT DATA

GPS DATA FOR STARTING AND ENDING POSITION OF EACH TRANSECT

TRANSECTS TAKEN UPSTREAM OF RBDD
ADCP FN=RBDD001R.000 TRANSECT FURTHEST UPSTREAM ABOUT 800 FT.
Format- bank, location ID, lat and long in ° ' ", WS El., Datum, Mag. Variation, Mean Sea Level, ??
LB 9,MARK009 ,L/L-dms ,N40°09'19.19",W122°12'19.01" , 238,ft,WGD ,E0016.4,Deg, MSL,47,
RB 10,MARK010 ,L/L-dms ,N40°09'09.33",W122°12'20.86" , 246,ft,WGD ,E0016.4,Deg, MSL,47,
RANGE=1008.8ft, AZIMUTH=171.8° M, ELA=000.6°

ADCP FN=RBDD002R.000 D/S DIST TO NEXT TRANSECT=110.4 FT ON LEFT BANK AND 48.7 FT ON RT BANK
LB 11,MARK011 ,L/L-dms ,N40°09'18.79",W122°12'17.69" , 254,ft,WGD ,E0016.4,Deg, MSL,47,
RB 12,MARK012 ,L/L-dms ,N40°09'09.32",W122°12'21.48" , 248,ft,WGD ,E0016.4,Deg, MSL,47,
RANGE=1002.5ft, AZIMUTH=180.7° M, ELA=-000.2°

ADCP FN=RBDD003R.000 D/S DIST TO NEXT TRANSECT=78.2 FT ON LEFT BANK AND 88.2 FT ON RT BANK
LB 13,MARK013 ,L/L-dms ,N40°09'18.45",W122°12'16.78" , 251,ft,WGD ,E0016.4,Deg, MSL,47,
RB 14,MARK014 ,L/L-dms ,N40°09'09.45",W122°12'20.35" , 247,ft,WGD ,E0016.4,Deg, MSL,47,
RANGE=952.9ft, AZIMUTH=180.5° M, ELA=000.0°

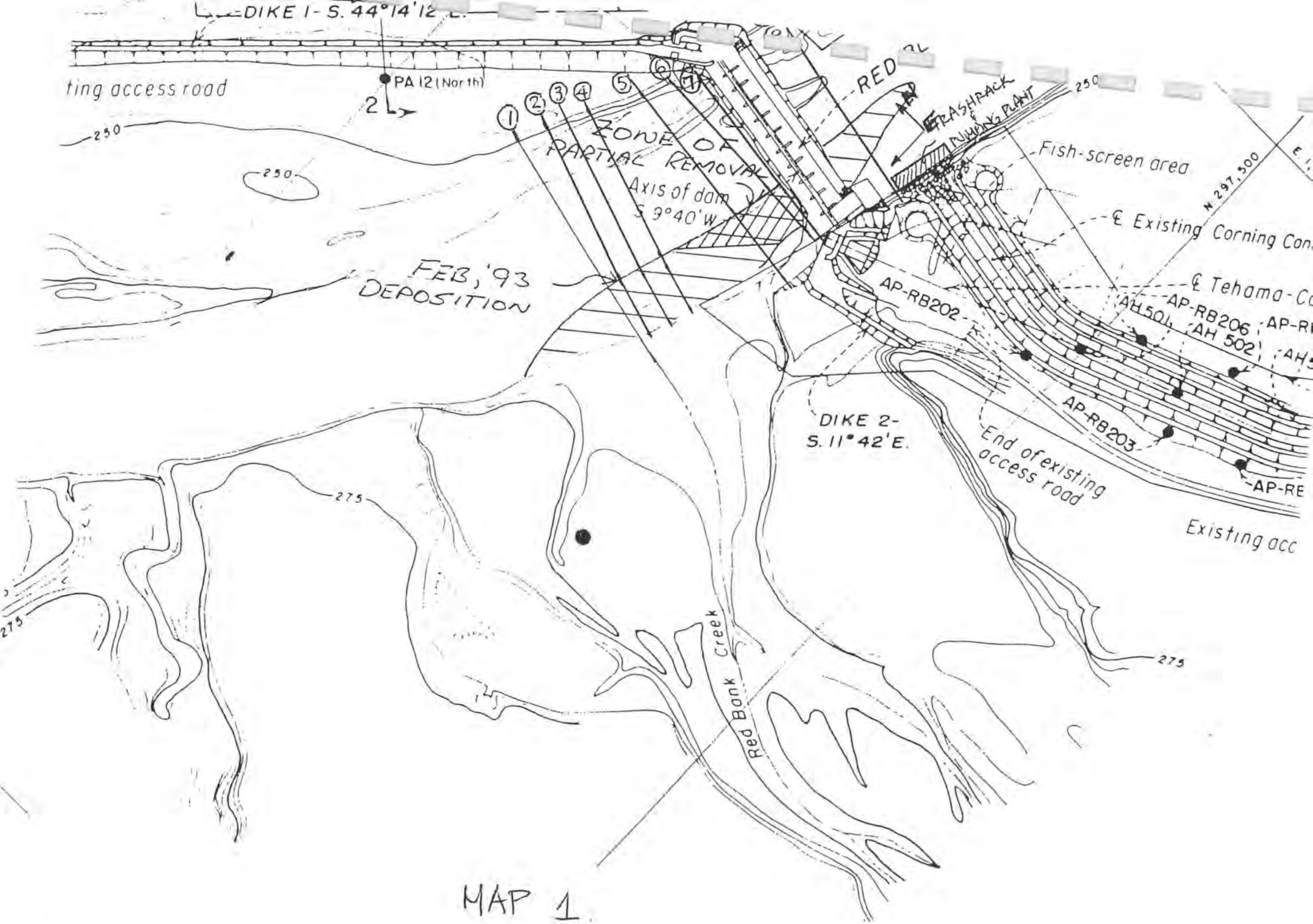
ADCP FN=RBDD004R.000 D/S DIST TO NEXT TRANSECT=92.4 FT ON LEFT BANK AND 78.9 FT ON RT BANK
RB 15,MARK015 ,L/L-dms ,N40°09'08.97",W122°12'19.57" , 240,ft,WGD ,E0016.4,Deg, MSL,47,
LB 16,MARK016 ,L/L-dms ,N40°09'17.84",W122°12'15.87" , 265,ft,WGD ,E0016.4,Deg, MSL,47,
RANGE=943.7ft, AZIMUTH=1.3° M, ELA=001.4°

ADCP FN=RBDD005.000 D/S DIST TO NEXT TRANSECT=217.1 FT ON LEFT BANK AND 316.7 FT ON RT BANK
LB 17,MARK017 ,L/L-dms ,N40°09'16.97",W122°12'13.33" , 251,ft,WGD ,E0016.4,Deg, MSL,47,
RB 18,MARK018 ,L/L-dms ,N40°09'08.89",W122°12'15.50" , 244,ft,WGD ,E0016.4,Deg, MSL,47,
RANGE=934.3ft, AZIMUTH=175.3° M, ELA=-000.3°

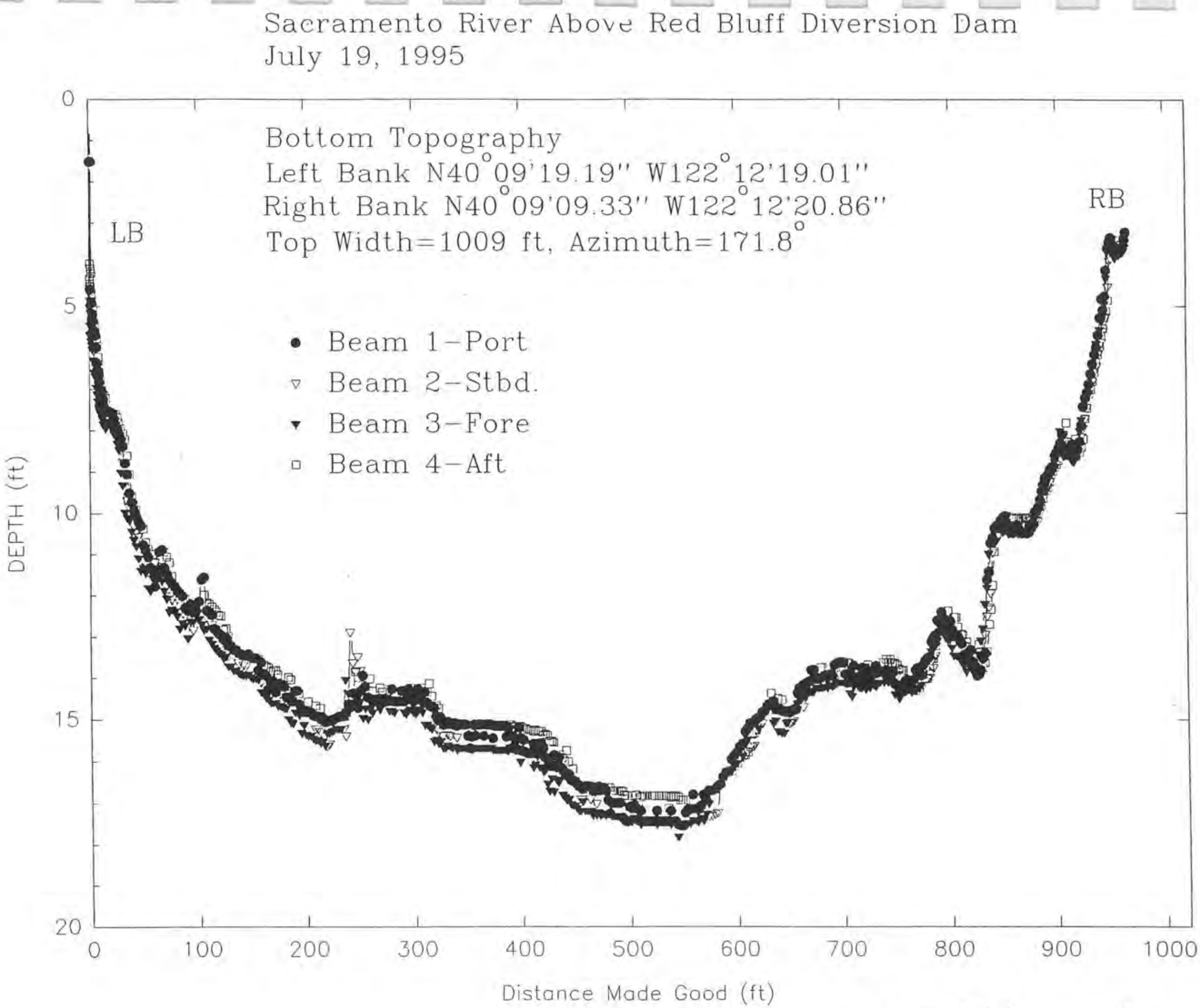
ADCP FN=RBDD006.000 D/S DIST TO NEXT TRANSECT=121.8 FT ON LEFT BANK AND 154.3 FT ON RT BANK
LB 19,MARK019 ,L/L-dms ,N40°09'16.44",W122°12'11.92" , 252,ft,WGD ,E0016.4,Deg, MSL,47,
RB 20,MARK020 ,L/L-dms ,N40°09'08.69",W122°12'13.52" , 255,ft,WGD ,E0016.4,Deg, MSL,47,
RANGE=795.2ft, AZIMUTH=172.7° M, ELA=+000.4°

ADCP FN=RBDD007.000 D/S DIST TO NEXT TRANSECT=195.3 FT ON LEFT BANK AND 225.3 FT ON RT BANK
RB 21,MARK021 ,L/L-dms ,N40°09'08.72",W122°12'10.63" , 264,ft,WGD ,E0016.4,Deg, MSL,47,
LB 22,MARK022 ,L/L-dms ,N40°09'16.31",W122°12'09.41" , 219,ft,WGD ,E0016.4,Deg, MSL,47,
RANGE=774.3ft, AZIMUTH=350.6° M, ELA=-003.5°

TRANSECT TAKEN ABOUT 300 FT DOWNSTREAM OF RBDD
ADCP FN=RBDD007.000 D/S DIST TO NEXT TRANSECT=372.4 FT ON LEFT BANK AND 393.2 FT ON RT BANK
RB 23,MARK023 ,L/L-dms ,N40°09'08.40",W122°12'05.58" , 215,ft,WGD ,E0016.4,Deg, MSL,47,
LB 24,MARK024 ,L/L-dms ,N40°09'15.03",W122°12'04.91" , 210,ft,WGD ,E0016.4,Deg, MSL,47,
RANGE=674.4ft, AZIMUTH=348.0° M, ELA=-000.6°


DIKE I - S. 44°14'12" E.
ting access road
PA 12 (North)
2
250
ZONE OF PARTIAL REMOVAL
Axis of dam S 9°40' W
FEB, '93 DEPOSITION
RED
TRASHRACK & PUMPING PLANT
Fish-screen area
N 297,500
℄ Existing Corning Can
℄ Tehama-Co
AP-RB202
AP-RB206
AP-RB203
AH 504
AH 502
DIKE 2- S. 11° 42' E.
End of existing access road
Existing acc
275
Red Bank Creek

MAP 1



Sacramento River Above Red Bluff Diversion Dam
July 19, 1995
Bottom Topography
Left Bank N40°09'19.19" W122°12'19.01"
Right Bank N40°09'09.33" W122°12'20.86"
Top Width=1009 ft, Azimuth=171.8°
LB
RB
Beam 1-Port
Beam 2-Stbd.
Beam 3-Fore
Beam 4-Aft
DEPTH (ft)
0
5
10
15
20
0
100
200
300
400
500
600
700
800
900
1000
Distance Made Good (ft)
fn=rbddbot1.sp5

FIG. 1

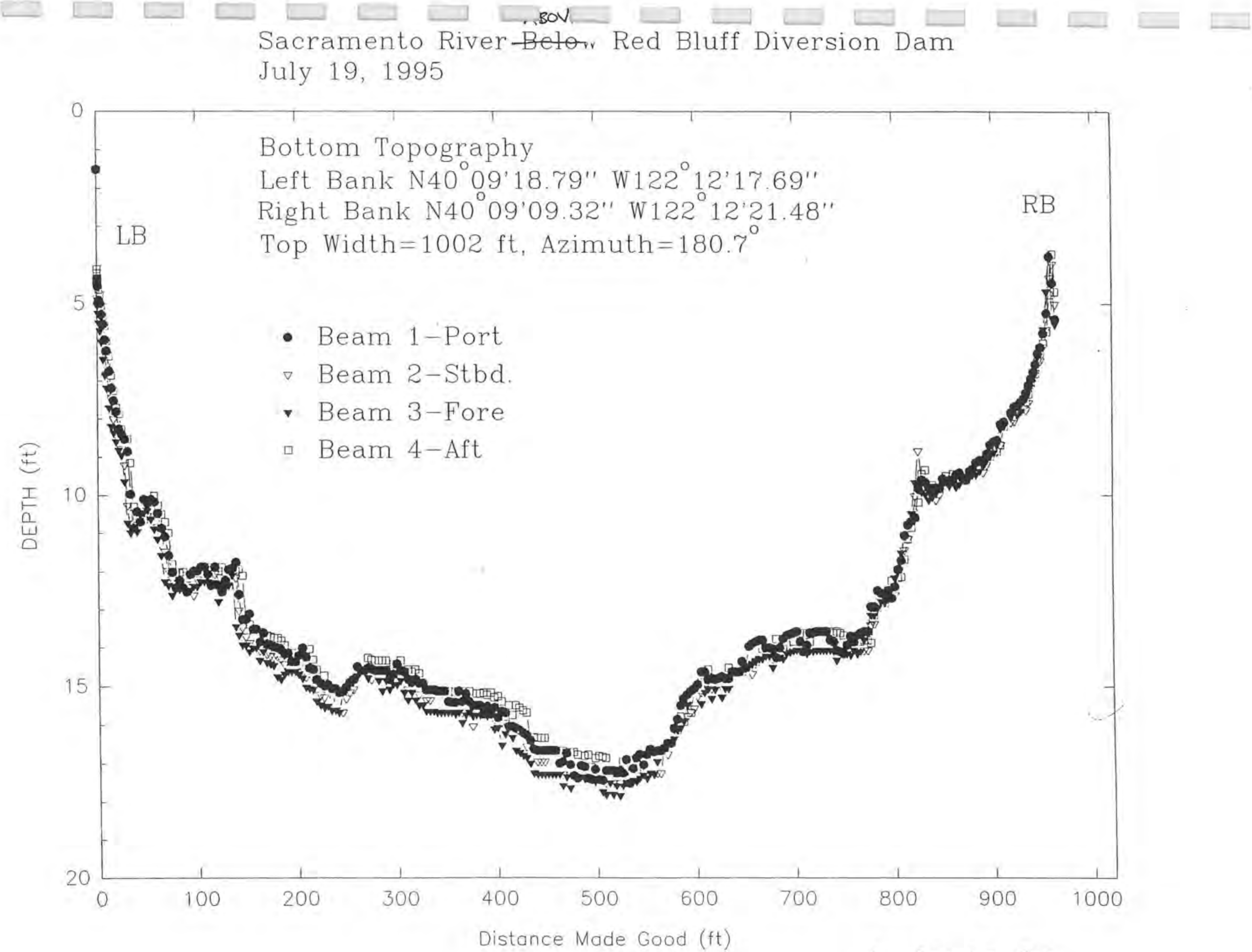

Sacramento River ~~Belo~~ Above Red Bluff Diversion Dam
July 19, 1995
Bottom Topography
Left Bank N40°09'18.79" W122°12'17.69"
Right Bank N40°09'09.32" W122°12'21.48"
Top Width=1002 ft, Azimuth=180.7°
LB
RB
Beam 1-Port
Beam 2-Stbd.
Beam 3-Fore
Beam 4-Aft
DEPTH (ft)
0
5
10
15
20
0
100
200
300
400
500
600
700
800
900
1000
Distance Made Good (ft)
RBDDBEJ2.SPS

FIG. 2

Sacramento River ~~Below~~ Above Red Bluff Diversion Dam
July 19, 1995

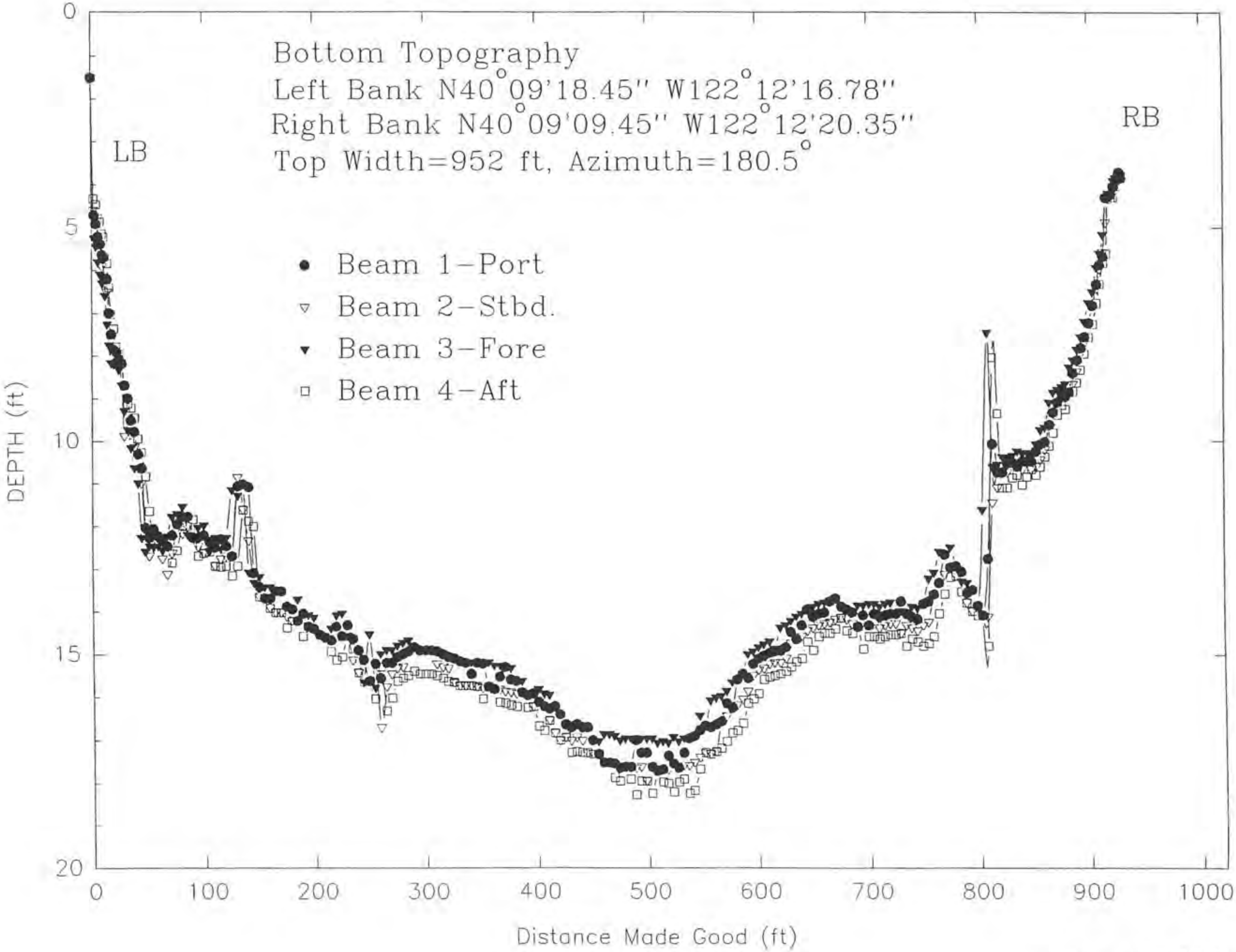
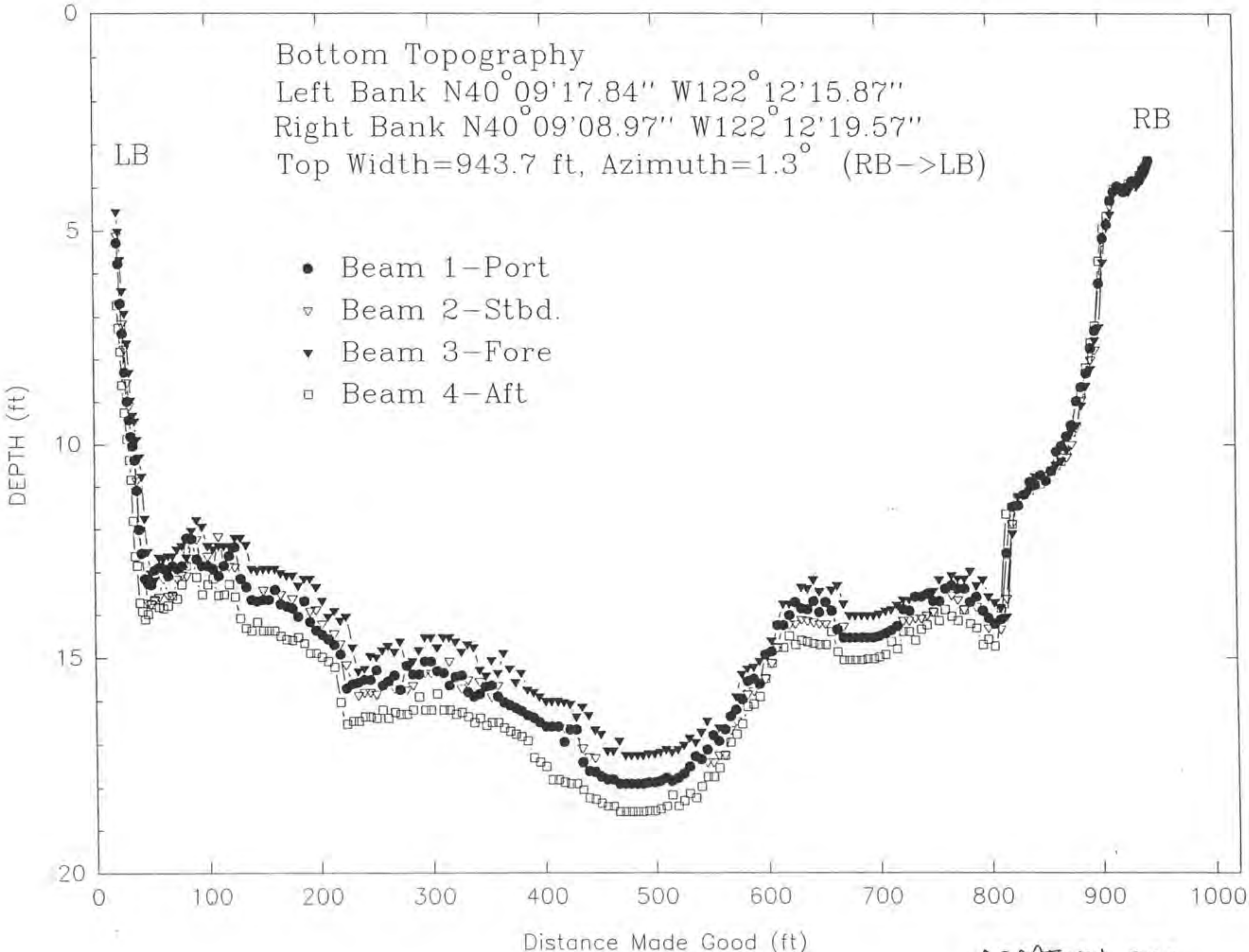


FIG 3.

RBDDBOT3.SP5

Sacramento River ~~Below~~ ABO Red Bluff Diversion Dam
July 19, 1995



RBDDBOT4.SP5

FIG. 4

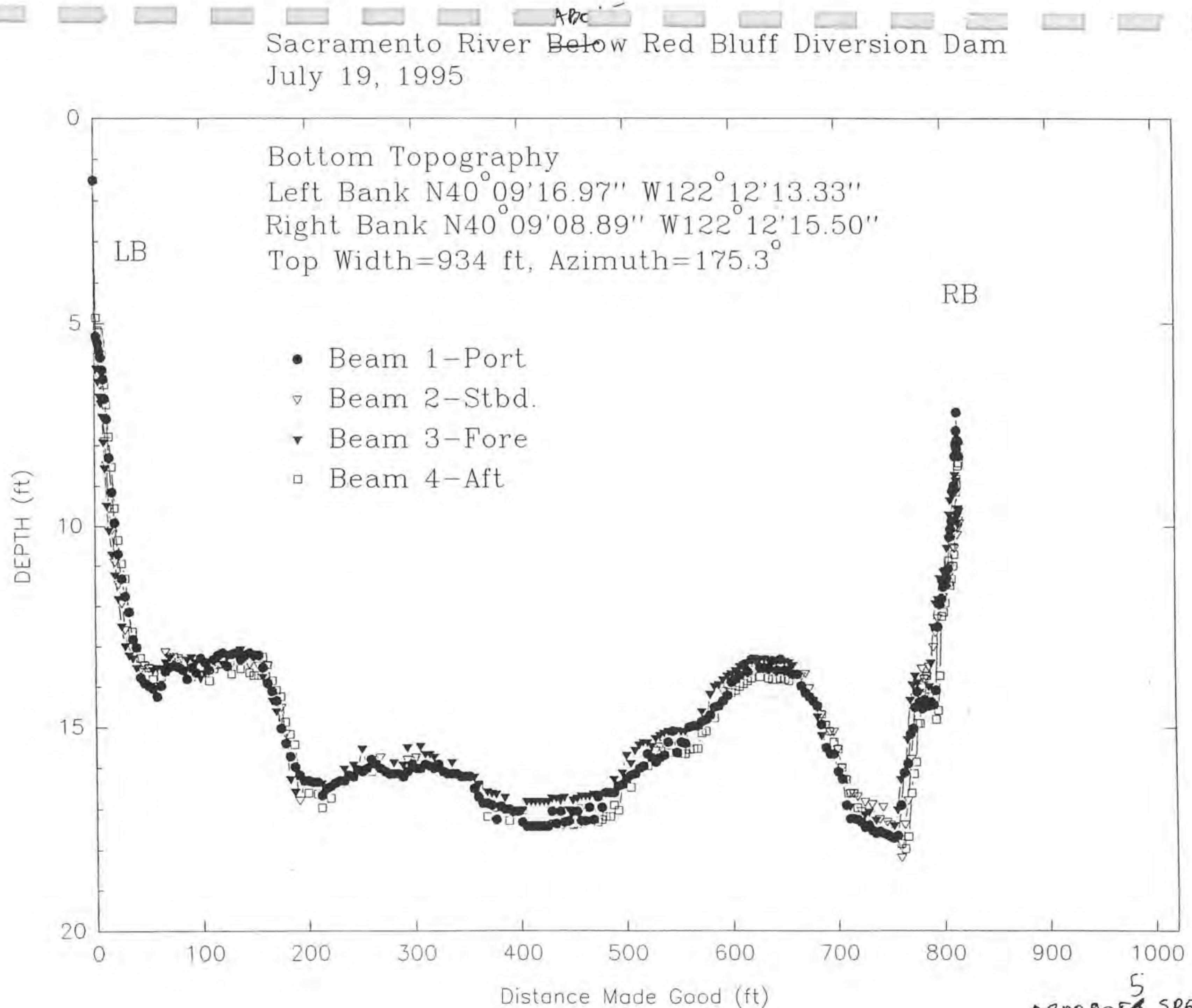

Sacramento River ~~Below~~ Above Red Bluff Diversion Dam
July 19, 1995
Bottom Topography
Left Bank N40°09'16.97" W122°12'13.33"
Right Bank N40°09'08.89" W122°12'15.50"
Top Width=934 ft, Azimuth=175.3°
LB
RB
Beam 1-Port
Beam 2-Stbd.
Beam 3-Fore
Beam 4-Aft
DEPTH (ft)
0
5
10
15
20
0
100
200
300
400
500
600
700
800
900
1000
Distance Made Good (ft)
RBDDBOT5.SP5

FIG 5.

Sacramento River Below Red Bluff Diversion Dam
July 19, 1995

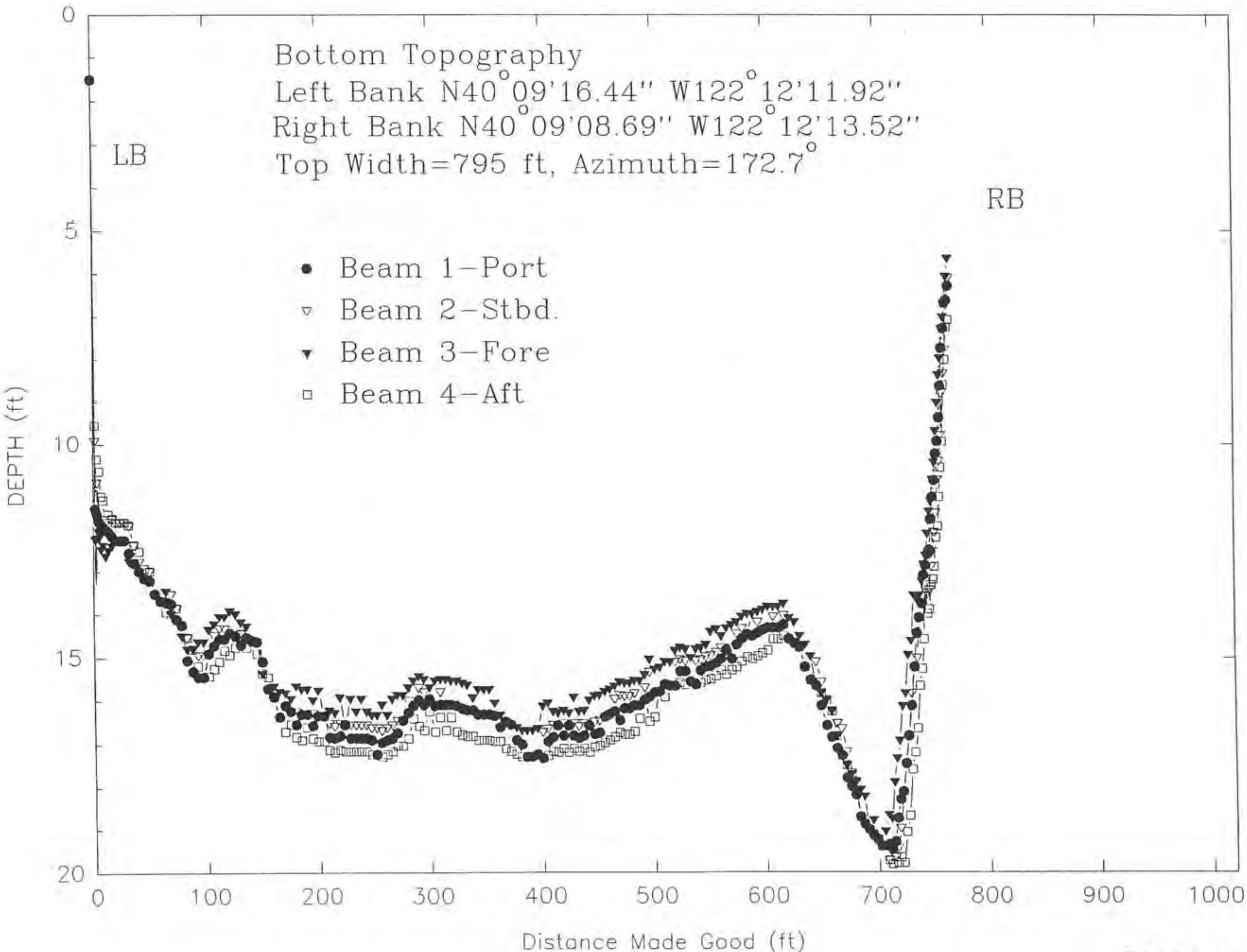


FIG. 6

RBDD BOT6.SPS

Sacramento River Below Red Bluff Diversion Dam
July 19, 1995

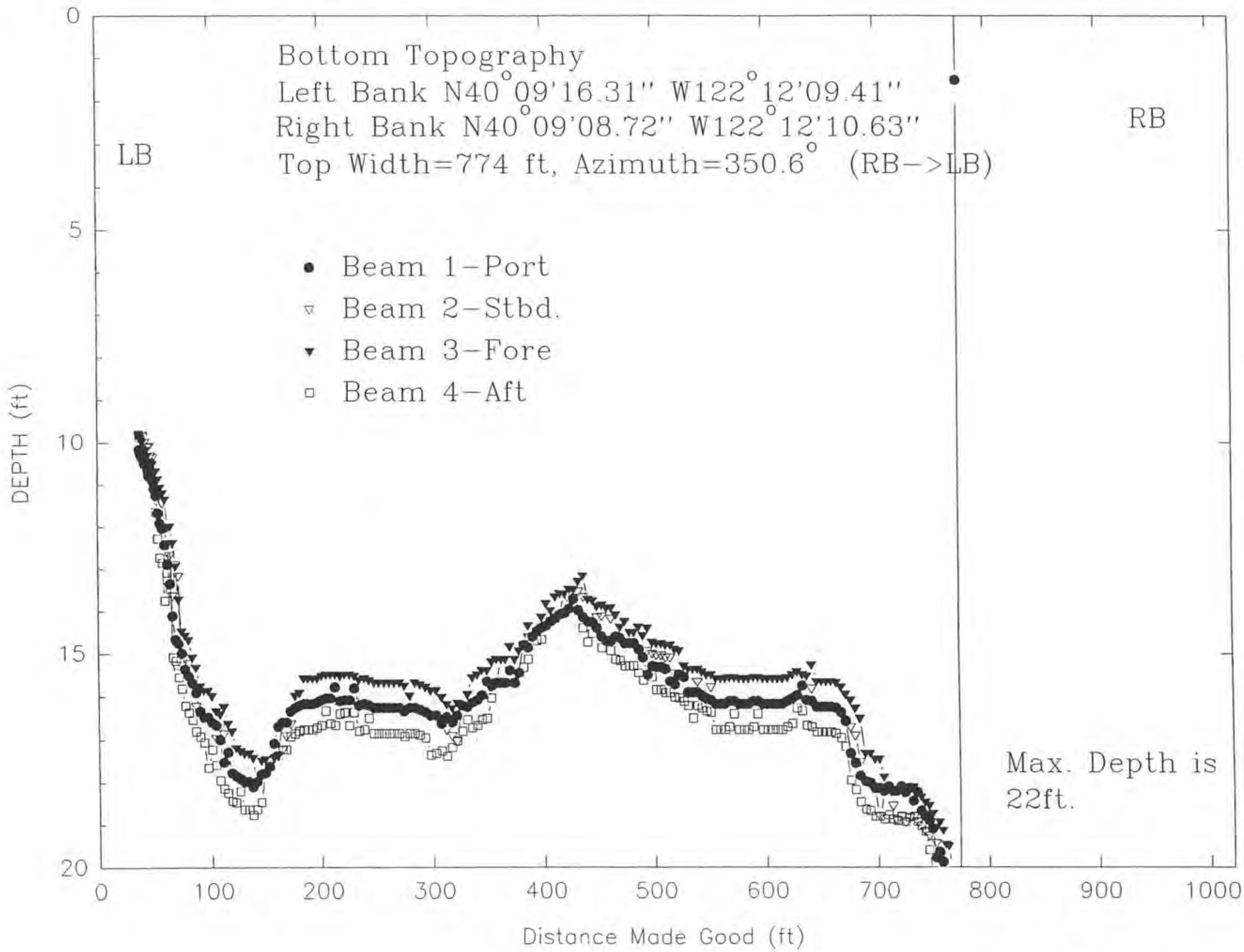


FIG. 7

fn=rbddbot7.sp5

Sacramento River below Red Bluff Diversion Dam
July 19, 1995

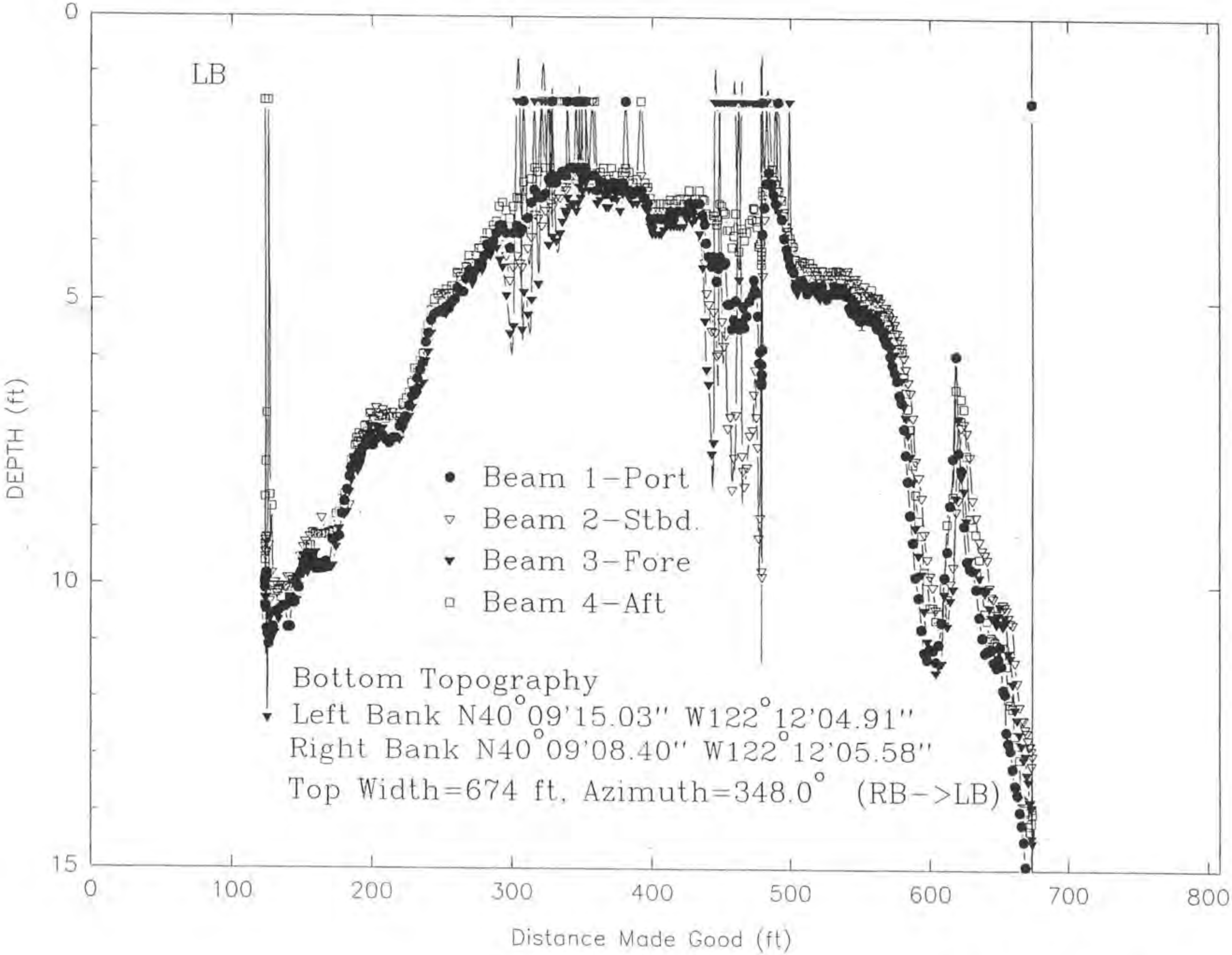


FIG. 8

fn=rbddbt15.sp5

U/S OF DAM ~ 800 ft

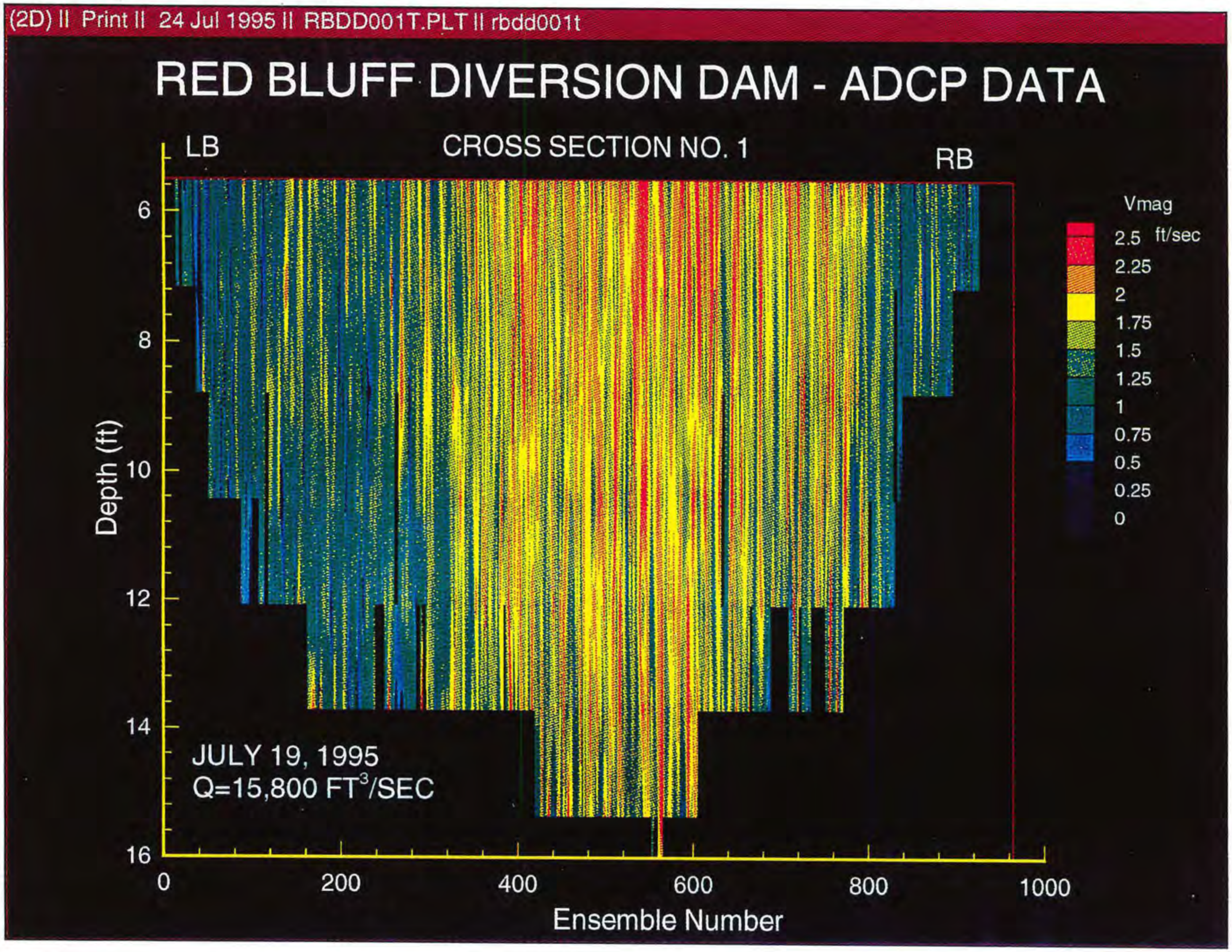


FIG. 9

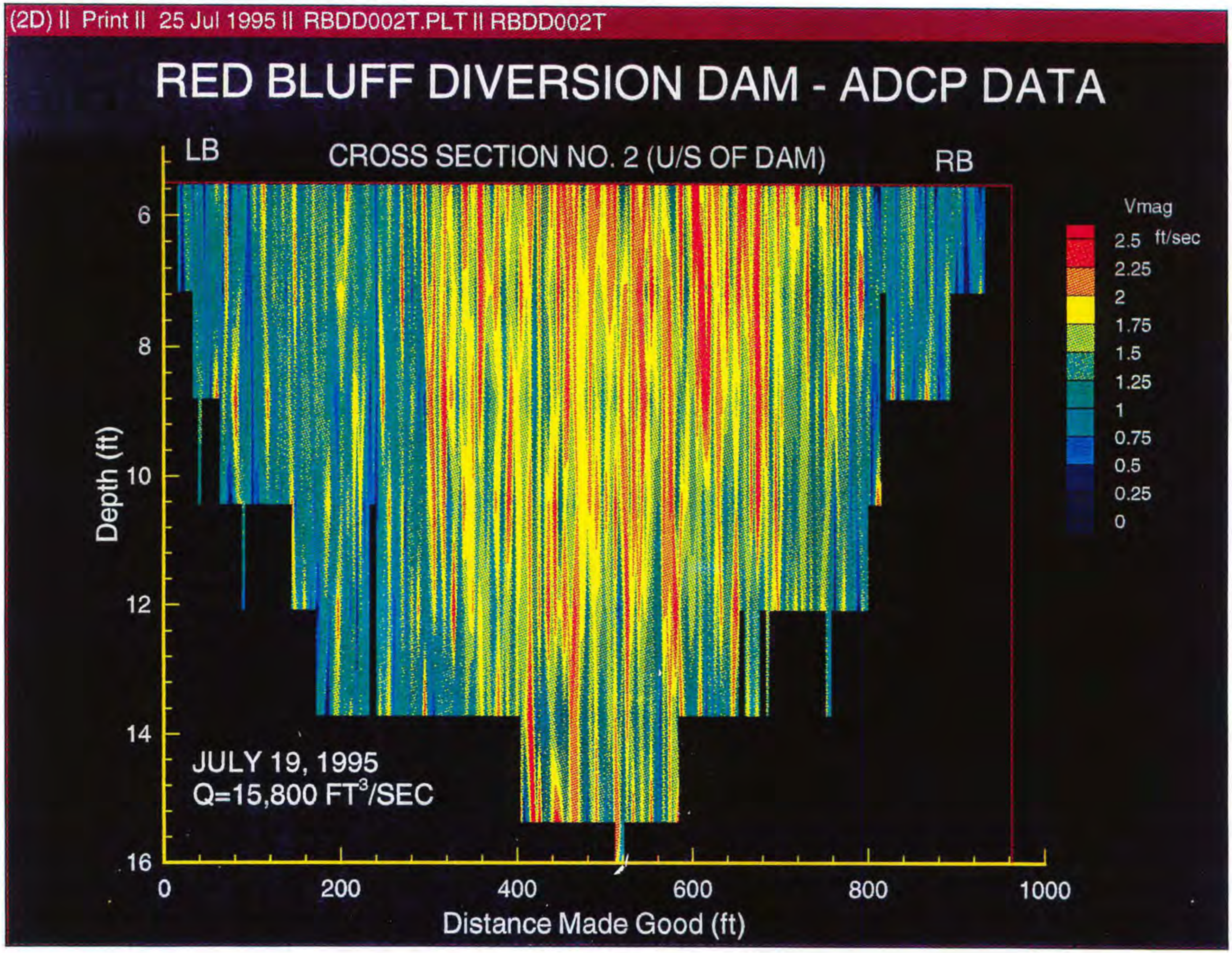

(2D) II Print II 25 Jul 1995 II RBDD002T.PLT II RBDD002T
RED BLUFF DIVERSION DAM - ADCP DATA
LB
CROSS SECTION NO. 2 (U/S OF DAM)
RB
Vmag
2.5 ft/sec
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
Depth (ft)
6
8
10
12
14
16
JULY 19, 1995
Q=15,800 FT³/SEC
0
200
400
600
800
1000
Distance Made Good (ft)

Fig. 10

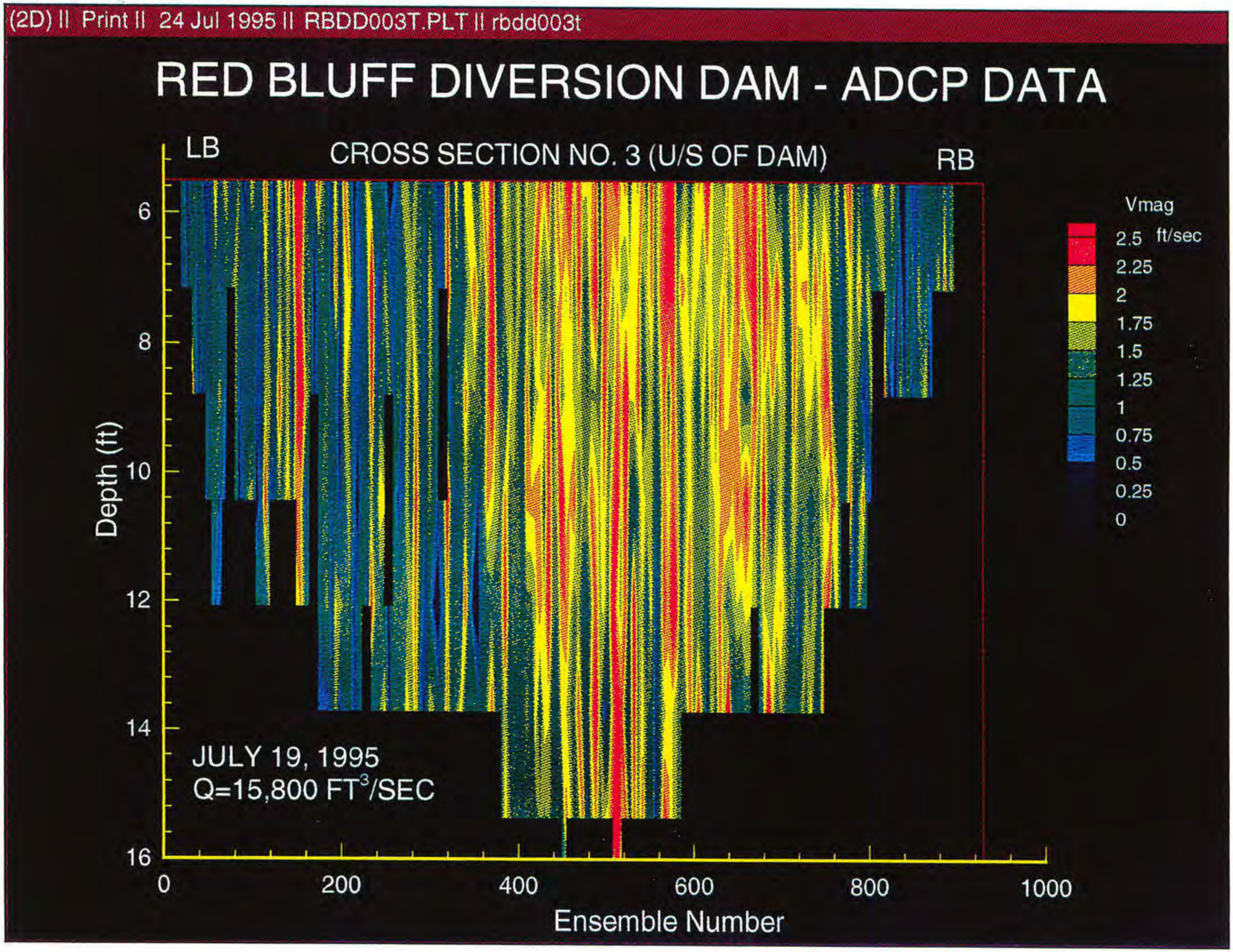

(2D) II Print II 24 Jul 1995 II RBDD003T.PLT II rbdd003t
RED BLUFF DIVERSION DAM - ADCP DATA
LB
CROSS SECTION NO. 3 (U/S OF DAM)
RB
Vmag
ft/sec
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
Depth (ft)
6
8
10
12
14
16
JULY 19, 1995
Q=15,800 FT³/SEC
0
200
400
600
800
1000
Ensemble Number

FIG. 11

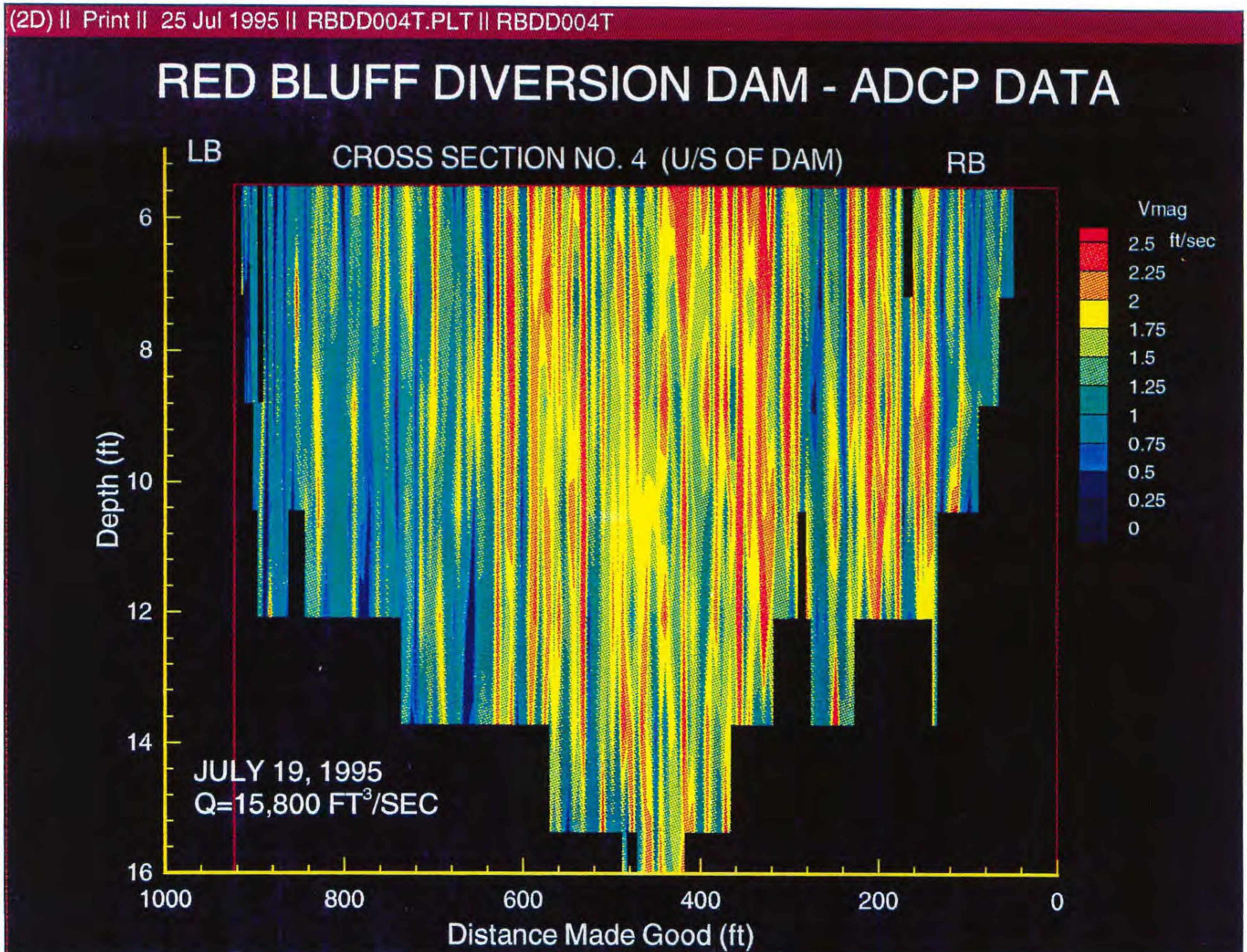

(2D) II Print II 25 Jul 1995 II RBDD004T.PLT II RBDD004T
RED BLUFF DIVERSION DAM - ADCP DATA
LB
CROSS SECTION NO. 4 (U/S OF DAM)
RB
Vmag
ft/sec
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
Depth (ft)
6
8
10
12
14
16
JULY 19, 1995
Q=15,800 FT³/SEC
1000
800
600
400
200
0
Distance Made Good (ft)

FIG. 12

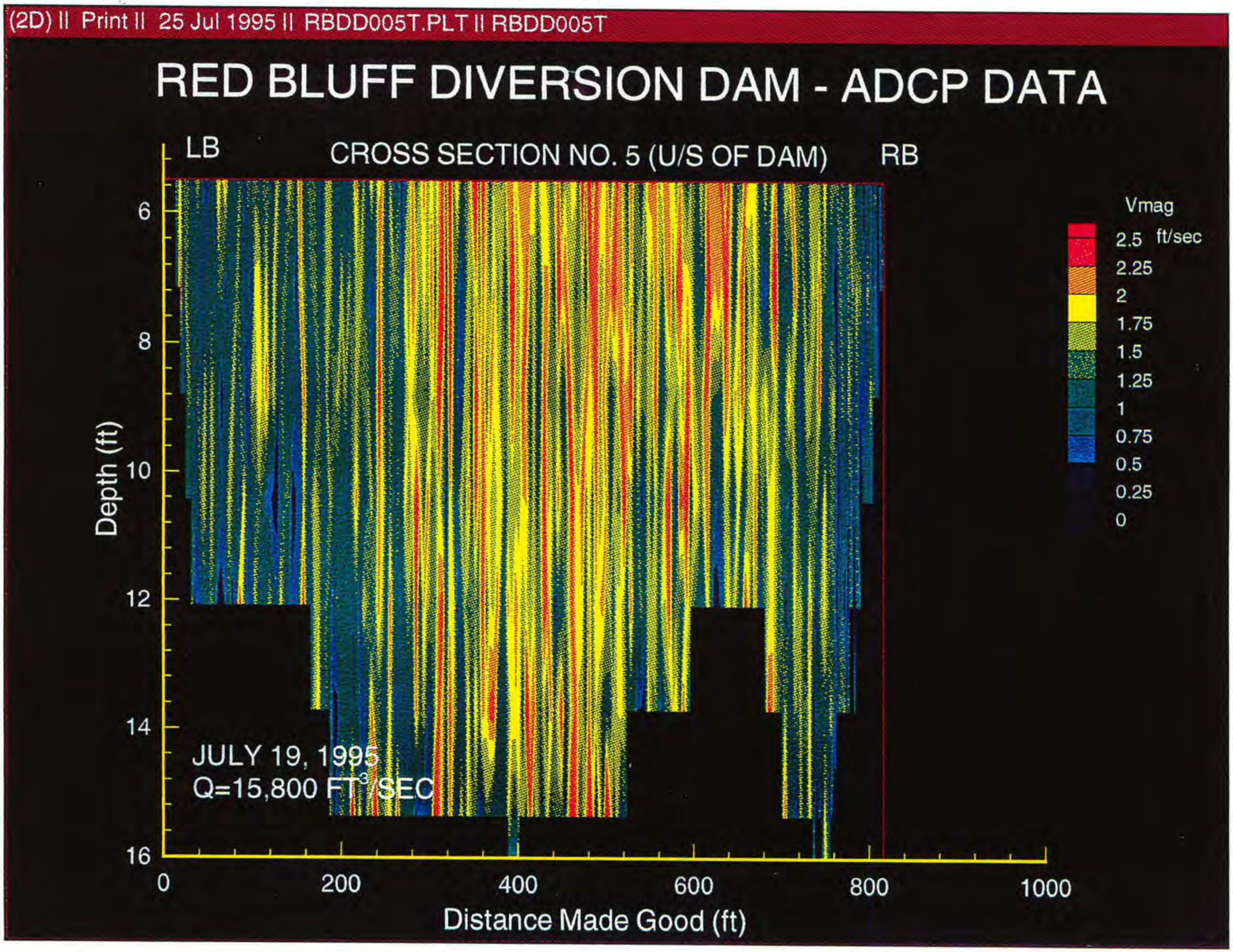

(2D) II Print II 25 Jul 1995 II RBDD005T.PLT II RBDD005T
RED BLUFF DIVERSION DAM - ADCP DATA
LB
CROSS SECTION NO. 5 (U/S OF DAM)
RB
Vmag
2.5 ft/sec
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
Depth (ft)
6
8
10
12
14
16
JULY 19, 1995
Q=15,800 FT³/SEC
0
200
400
600
800
1000
Distance Made Good (ft)

FIG. 13

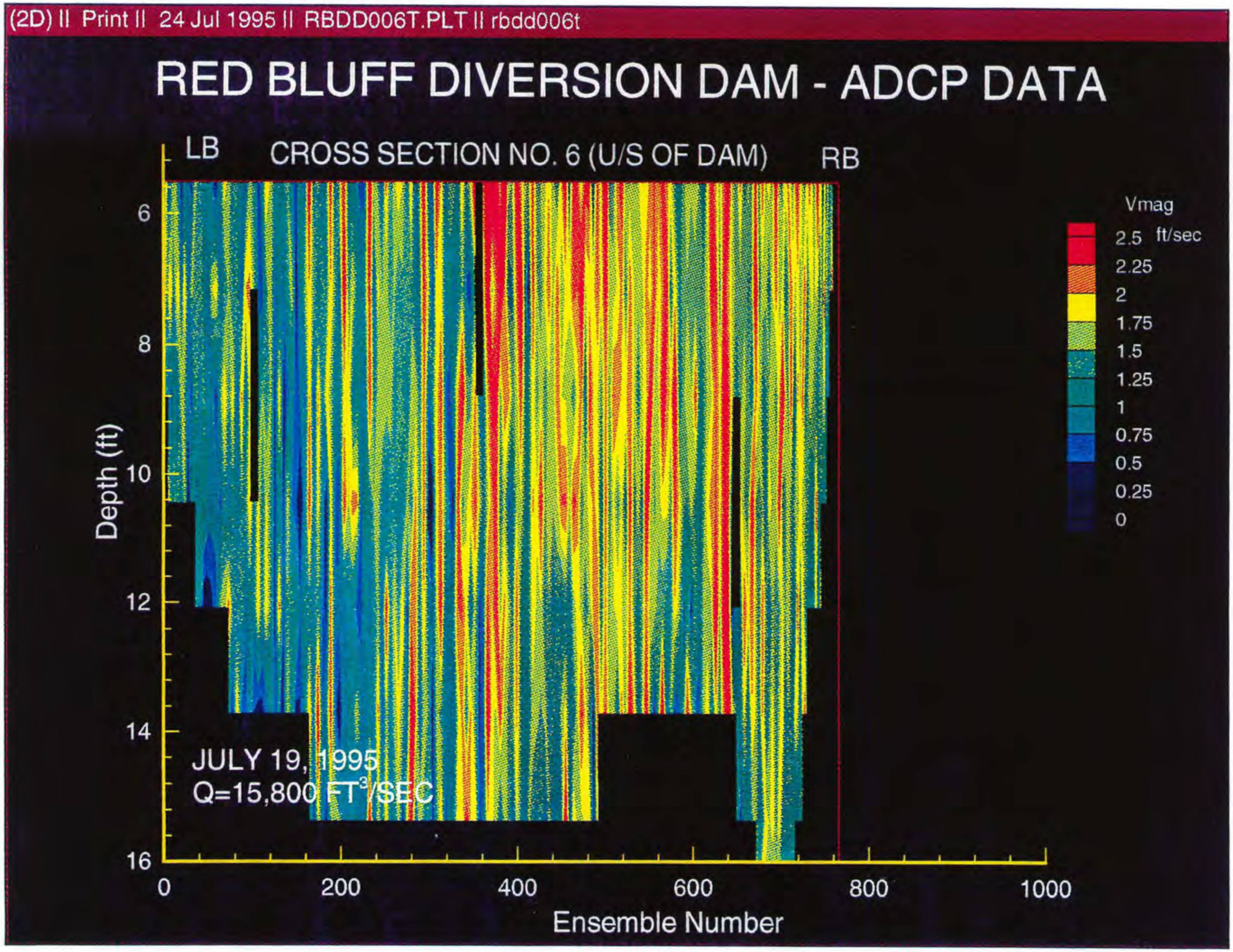
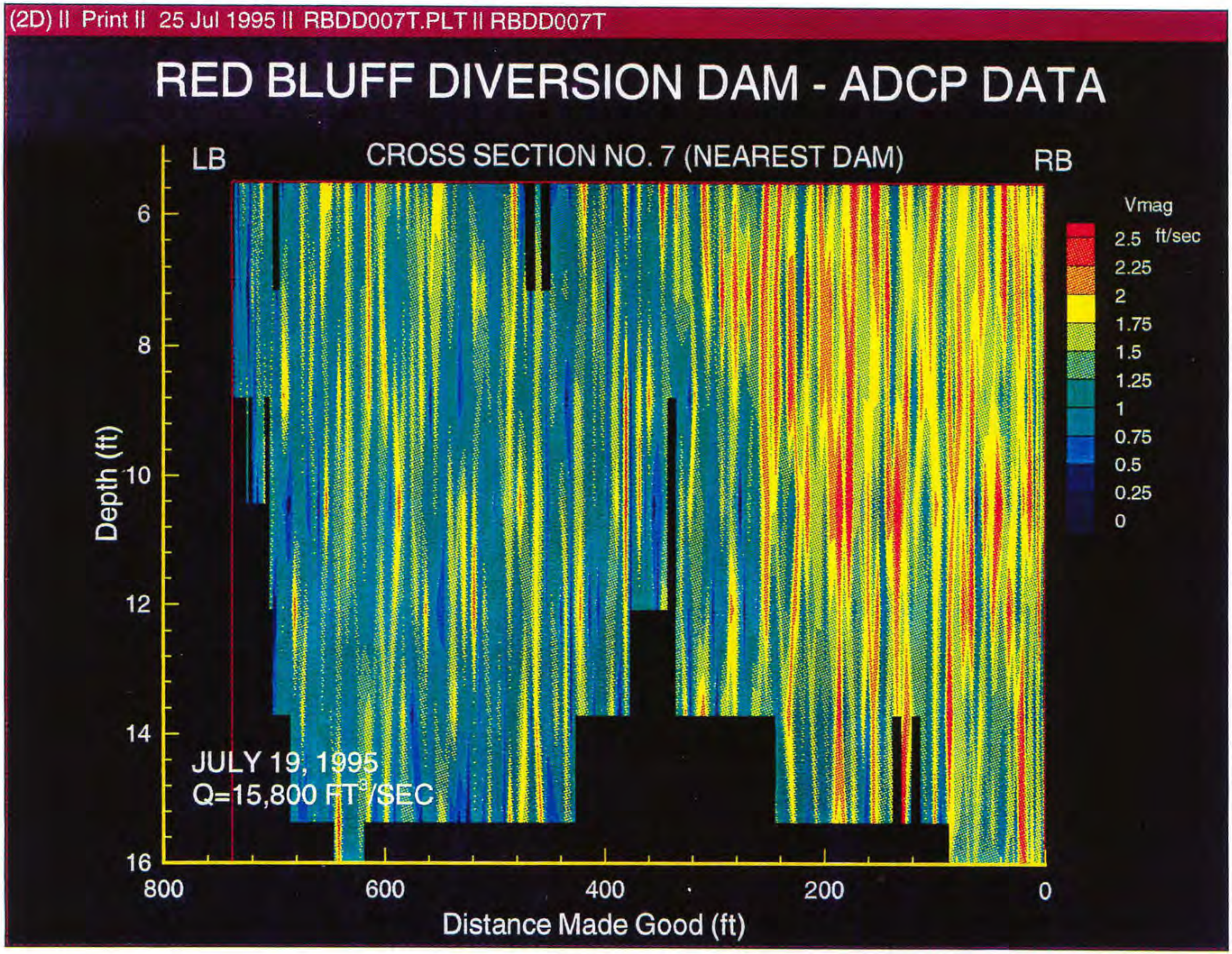

(2D) II Print II 24 Jul 1995 II RBDD006T.PLT II rbdd006t
RED BLUFF DIVERSION DAM - ADCP DATA
LB
CROSS SECTION NO. 6 (U/S OF DAM)
RB
Vmag
ft/sec
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
Depth (ft)
6
8
10
12
14
16
JULY 19, 1995
Q=15,800 FT³/SEC
0
200
400
600
800
1000
Ensemble Number

FIG. 14



(2D) II Print II 25 Jul 1995 II RBDD007T.PLT II RBDD007T
RED BLUFF DIVERSION DAM - ADCP DATA
LB
CROSS SECTION NO. 7 (NEAREST DAM)
RB
Vmag
2.5 ft/sec
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
Depth (ft)
6
8
10
12
14
16
JULY 19, 1995
Q=15,800 FT3/SEC
800
600
400
200
0
Distance Made Good (ft)

FIG. 15

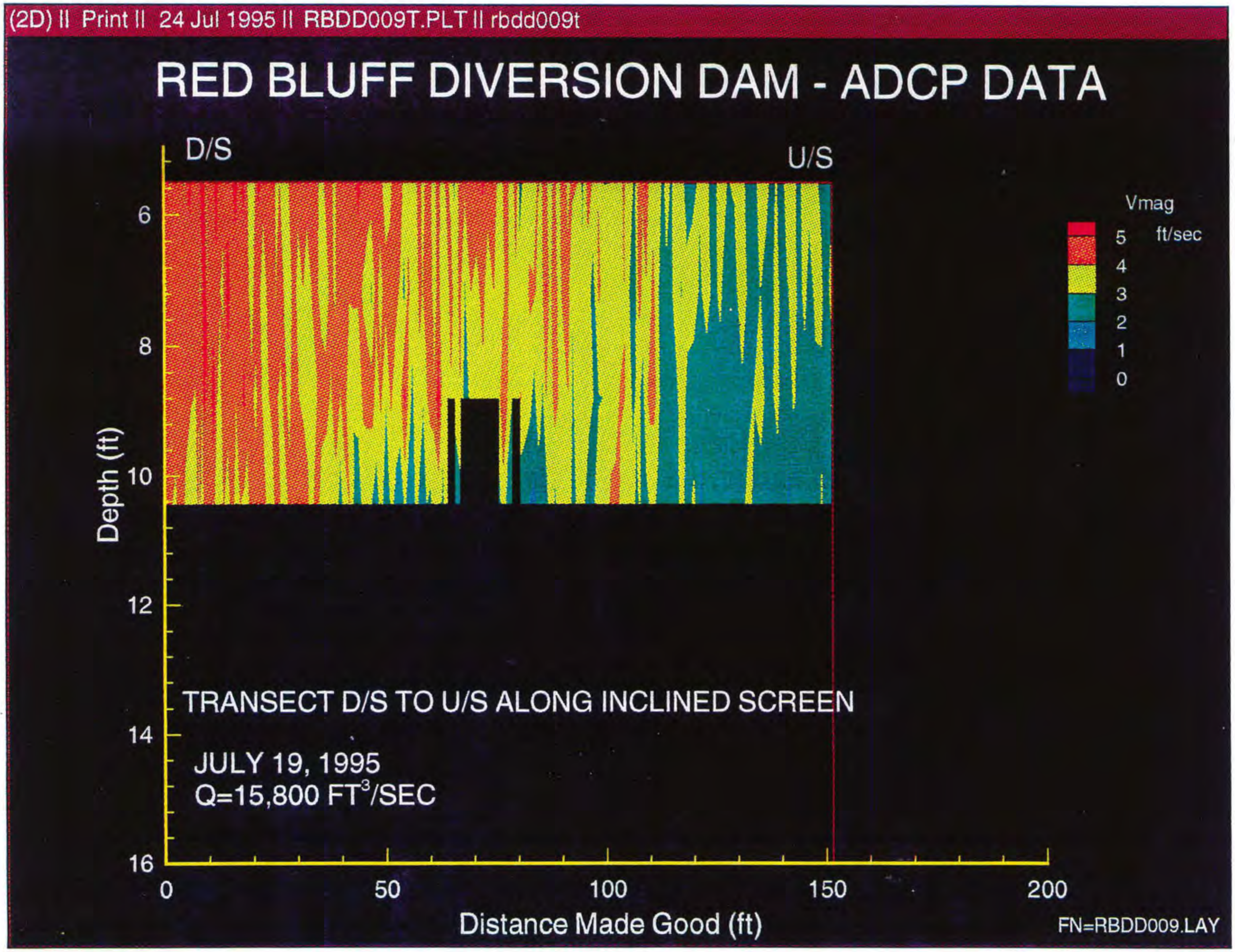

(2D) II Print II 24 Jul 1995 II RBDD009T.PLT II rbdd009t
RED BLUFF DIVERSION DAM - ADCP DATA
D/S
U/S
Vmag
ft/sec
5
4
3
2
1
0
Depth (ft)
6
8
10
12
14
16
TRANSECT D/S TO U/S ALONG INCLINED SCREEN
JULY 19, 1995
Q=15,800 FT³/SEC
0
50
100
150
200
Distance Made Good (ft)
FN=RBDD009.LAY

FIG. 16

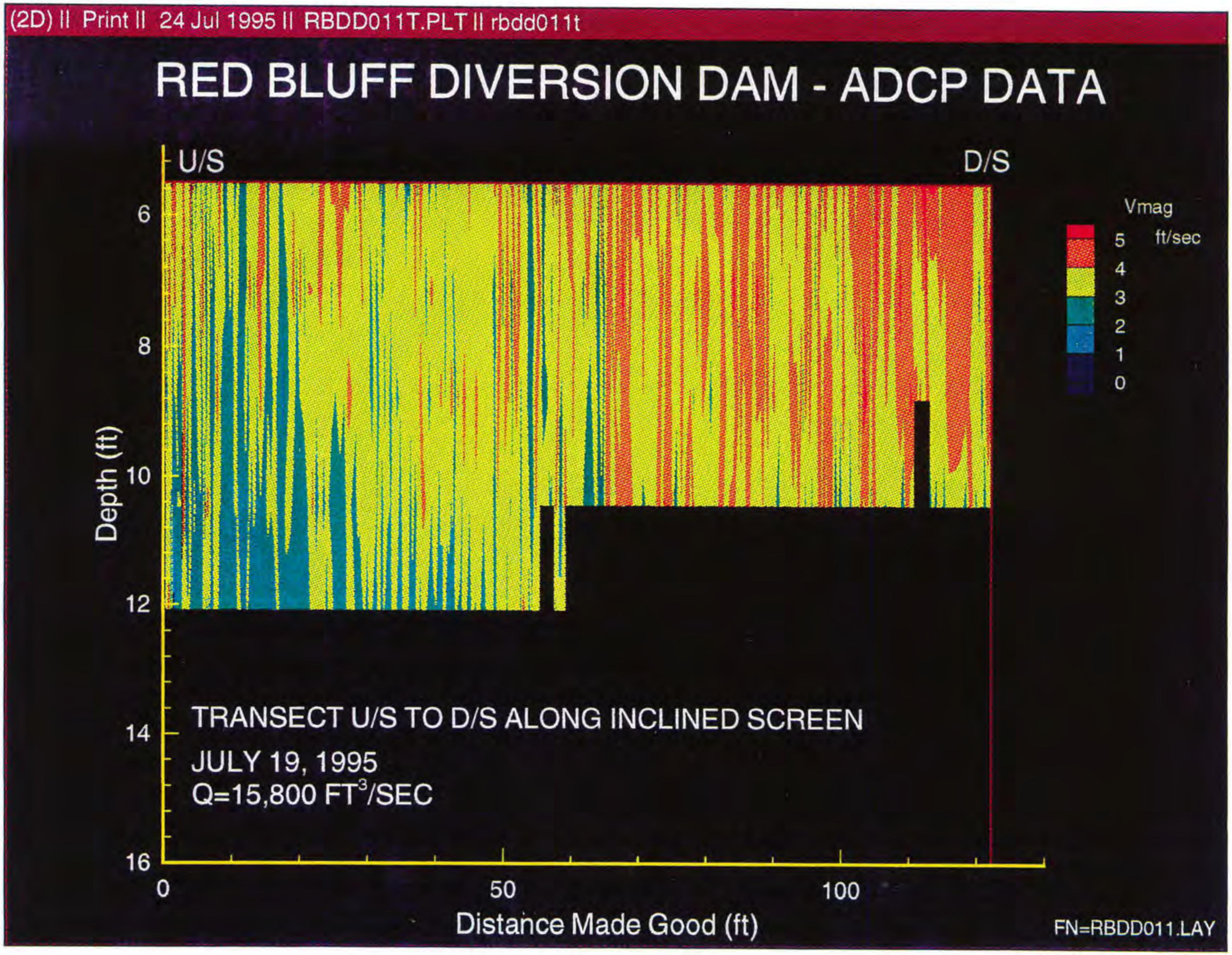

(2D) II Print II 24 Jul 1995 II RBDD011T.PLT II rbdd011t
RED BLUFF DIVERSION DAM - ADCP DATA
U/S
D/S
Vmag
ft/sec
5
4
3
2
1
0
Depth (ft)
6
8
10
12
14
16
0
50
100
Distance Made Good (ft)
TRANSECT U/S TO D/S ALONG INCLINED SCREEN
JULY 19, 1995
Q=15,800 FT3/SEC
FN=RBDD011.LAY

FIG. 17

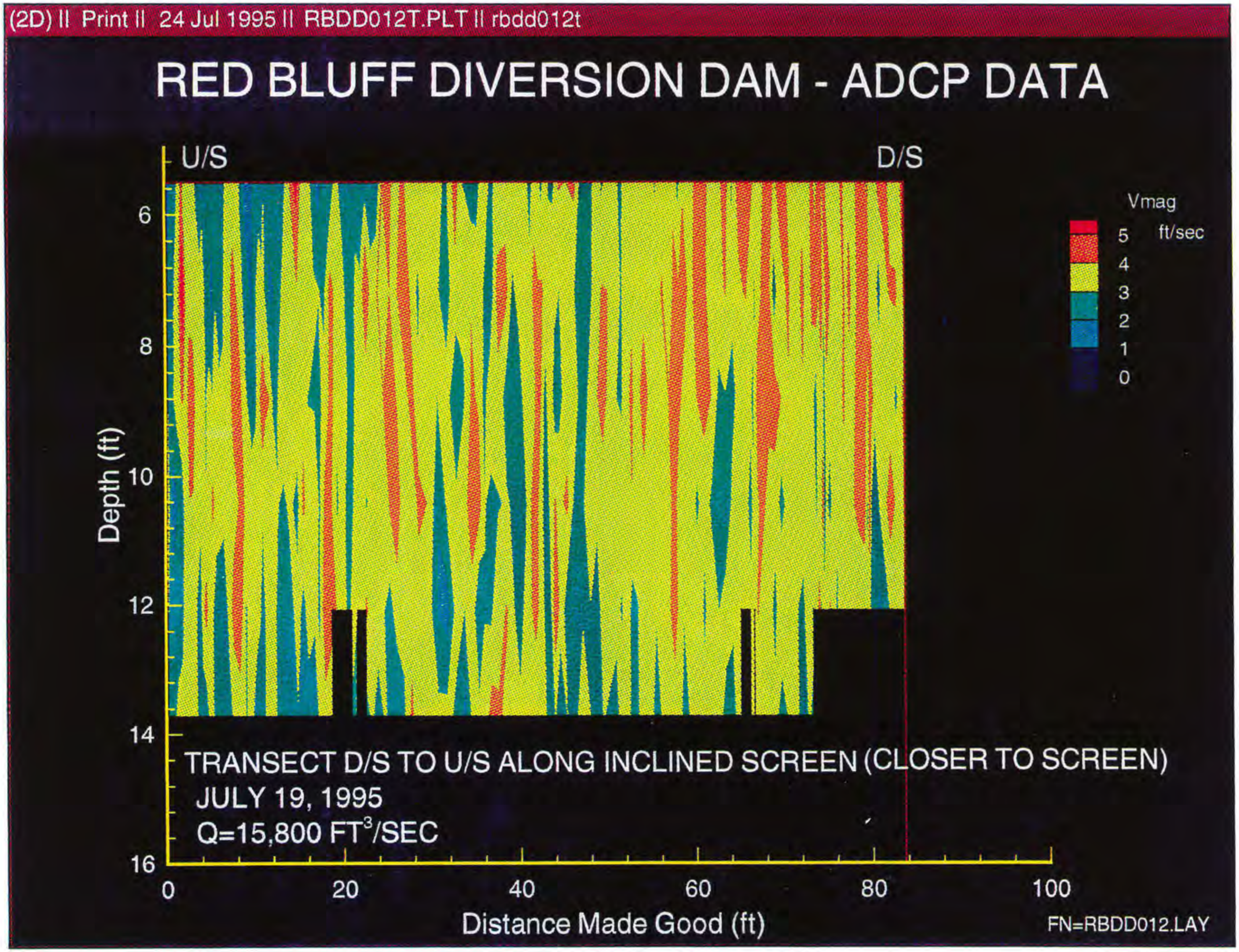
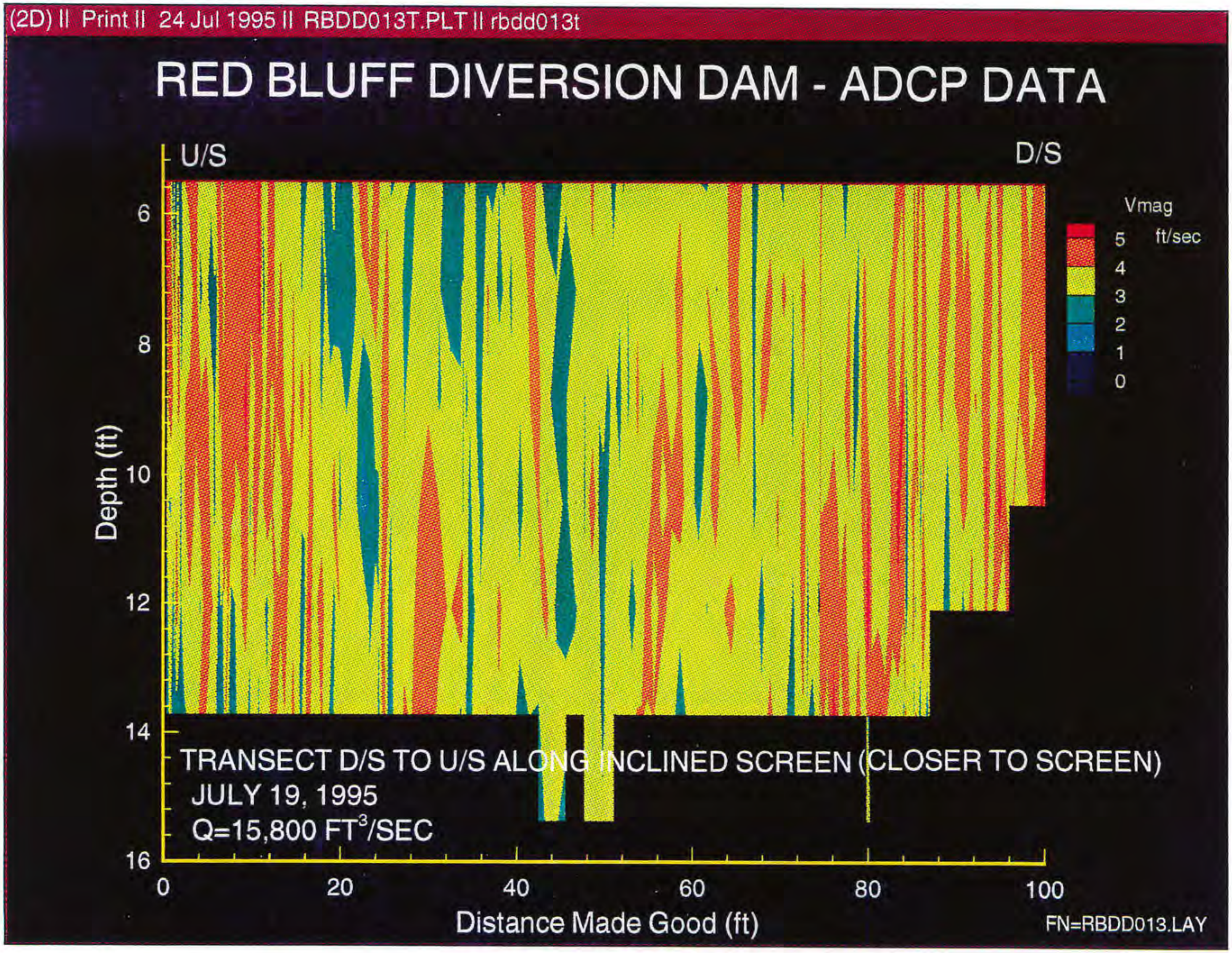

(2D) II Print II 24 Jul 1995 II RBDD012T.PLT II rbdd012t
RED BLUFF DIVERSION DAM - ADCP DATA
U/S
D/S
Vmag
ft/sec
5
4
3
2
1
0
Depth (ft)
6
8
10
12
14
16
TRANSECT D/S TO U/S ALONG INCLINED SCREEN (CLOSER TO SCREEN)
JULY 19, 1995
Q=15,800 FT³/SEC
0
20
40
60
80
100
Distance Made Good (ft)
FN=RBDD012.LAY

FIG. 18



(2D) II Print II 24 Jul 1995 II RBDD013T.PLT II rbdd013t
RED BLUFF DIVERSION DAM - ADCP DATA
U/S
D/S
Vmag
ft/sec
5
4
3
2
1
0
Depth (ft)
6
8
10
12
14
16
TRANSECT D/S TO U/S ALONG INCLINED SCREEN (CLOSER TO SCREEN)
JULY 19, 1995
Q=15,800 FT3/SEC
0
20
40
60
80
100
Distance Made Good (ft)
FN=RBDD013.LAY

FIG. 19

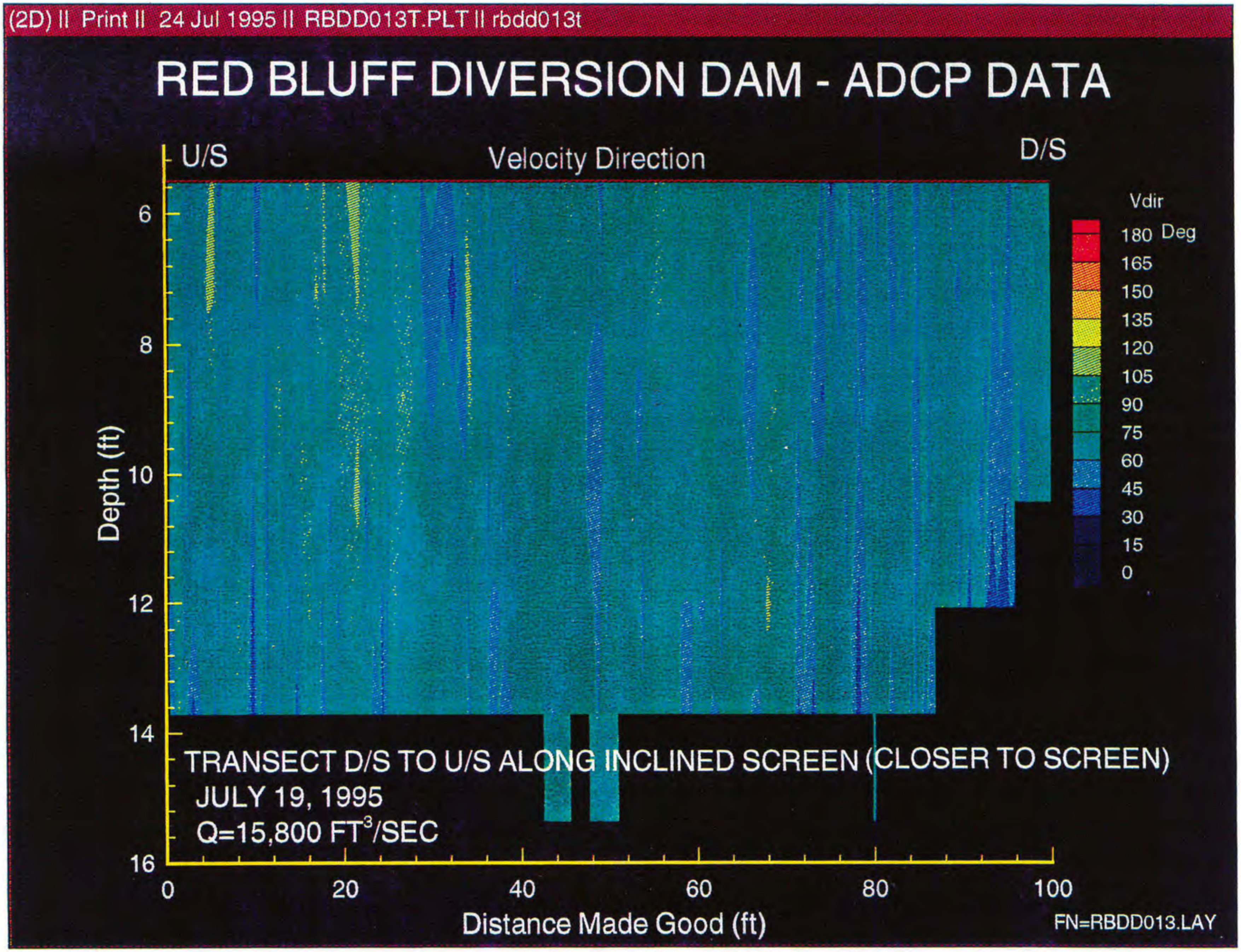

(2D) II Print II 24 Jul 1995 II RBDD013T.PLT II rbdd013t
RED BLUFF DIVERSION DAM - ADCP DATA
U/S
Velocity Direction
D/S
Depth (ft)
6
8
10
12
14
16
Vdir
Deg
180
165
150
135
120
105
90
75
60
45
30
15
0
TRANSECT D/S TO U/S ALONG INCLINED SCREEN (CLOSER TO SCREEN)
JULY 19, 1995
Q=15,800 FT3/SEC
0
20
40
60
80
100
Distance Made Good (ft)
FN=RBDD013.LAY

FIG. 20

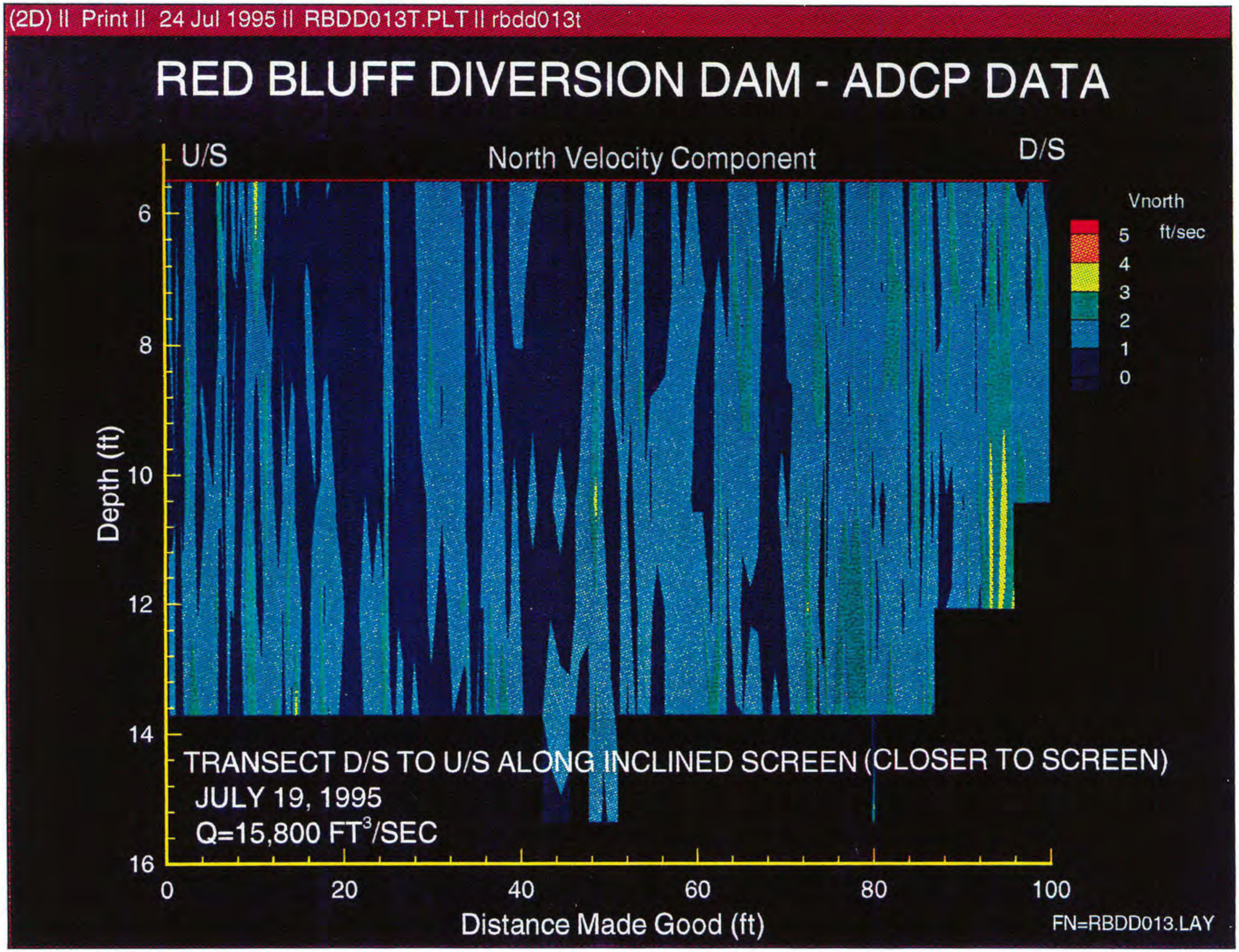

(2D) II Print II 24 Jul 1995 II RBDD013T.PLT II rbdd013t
RED BLUFF DIVERSION DAM - ADCP DATA
U/S
North Velocity Component
D/S
Vnorth
ft/sec
5
4
3
2
1
0
Depth (ft)
6
8
10
12
14
16
0
20
40
60
80
100
Distance Made Good (ft)
TRANSECT D/S TO U/S ALONG INCLINED SCREEN (CLOSER TO SCREEN)
JULY 19, 1995
Q=15,800 FT³/SEC
FN=RBDD013.LAY

FIG. 21

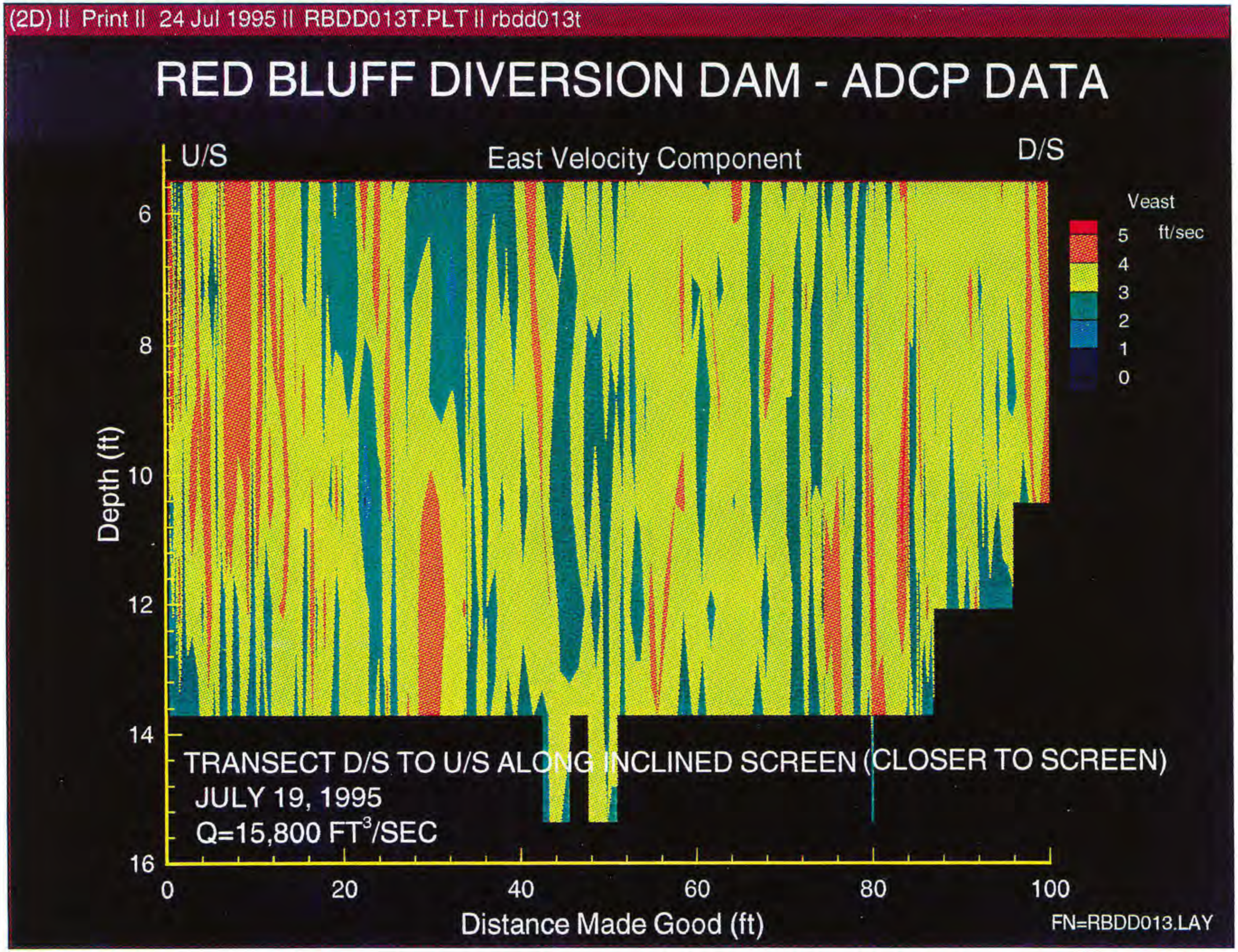

(2D) II Print II 24 Jul 1995 II RBDD013T.PLT II rbdd013t
RED BLUFF DIVERSION DAM - ADCP DATA
U/S
East Velocity Component
D/S
Veast
ft/sec
5
4
3
2
1
0
Depth (ft)
6
8
10
12
14
16
TRANSECT D/S TO U/S ALONG INCLINED SCREEN (CLOSER TO SCREEN)
JULY 19, 1995
Q=15,800 FT³/SEC
0
20
40
60
80
100
Distance Made Good (ft)
FN=RBDD013.LAY

FIG. 22

RED BLUFF DIVERSION DAM
7/19/95
RBDD010T.PRF
VELOCITY PLOTS

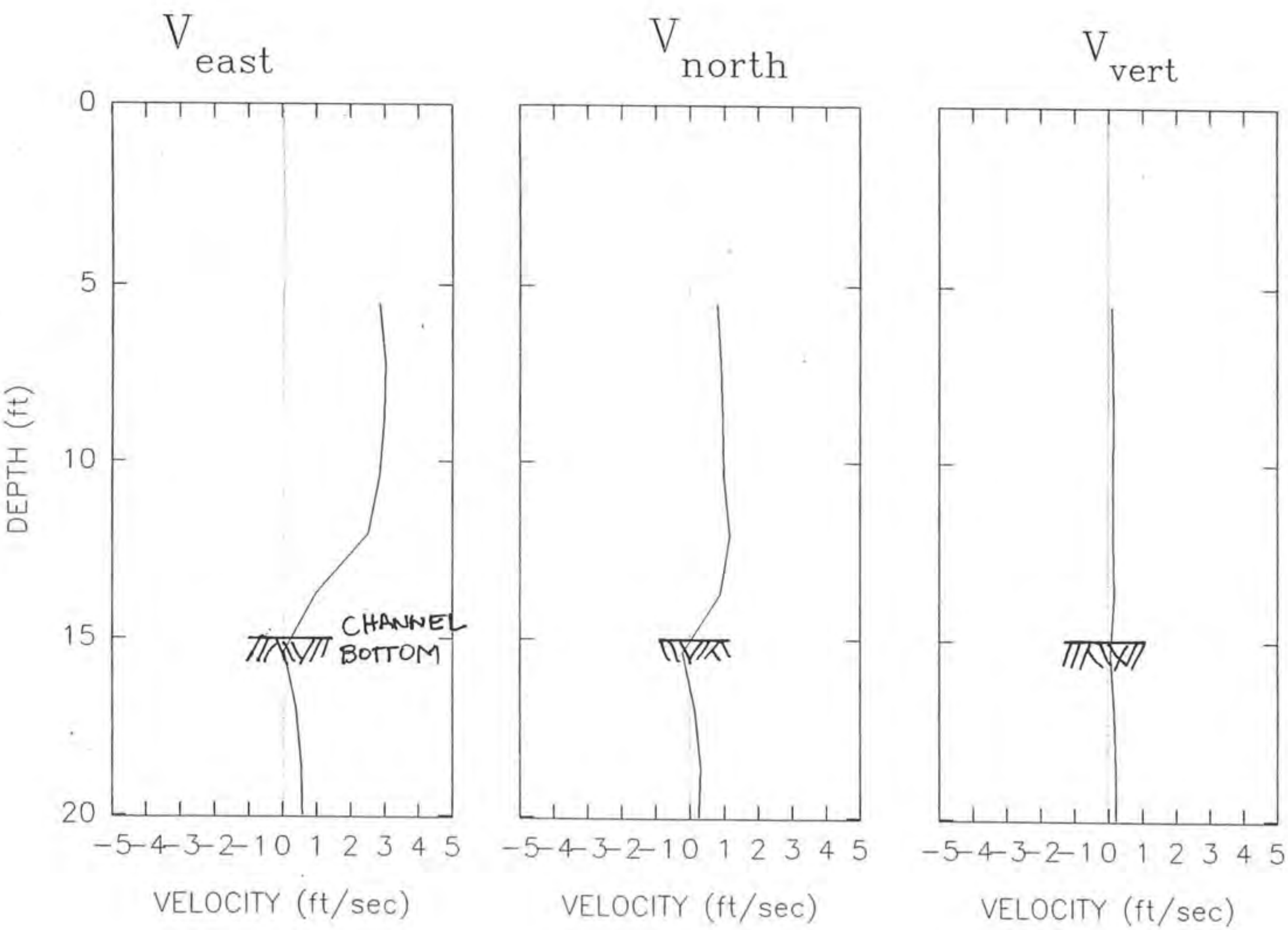


FIG. 23

RED BLUFF DIVERSION DAM

7/19/95

RBDD014T.PRF

VELOCITY PLOTS FOR ℄ OF 4th PUMP INTAKE BAY

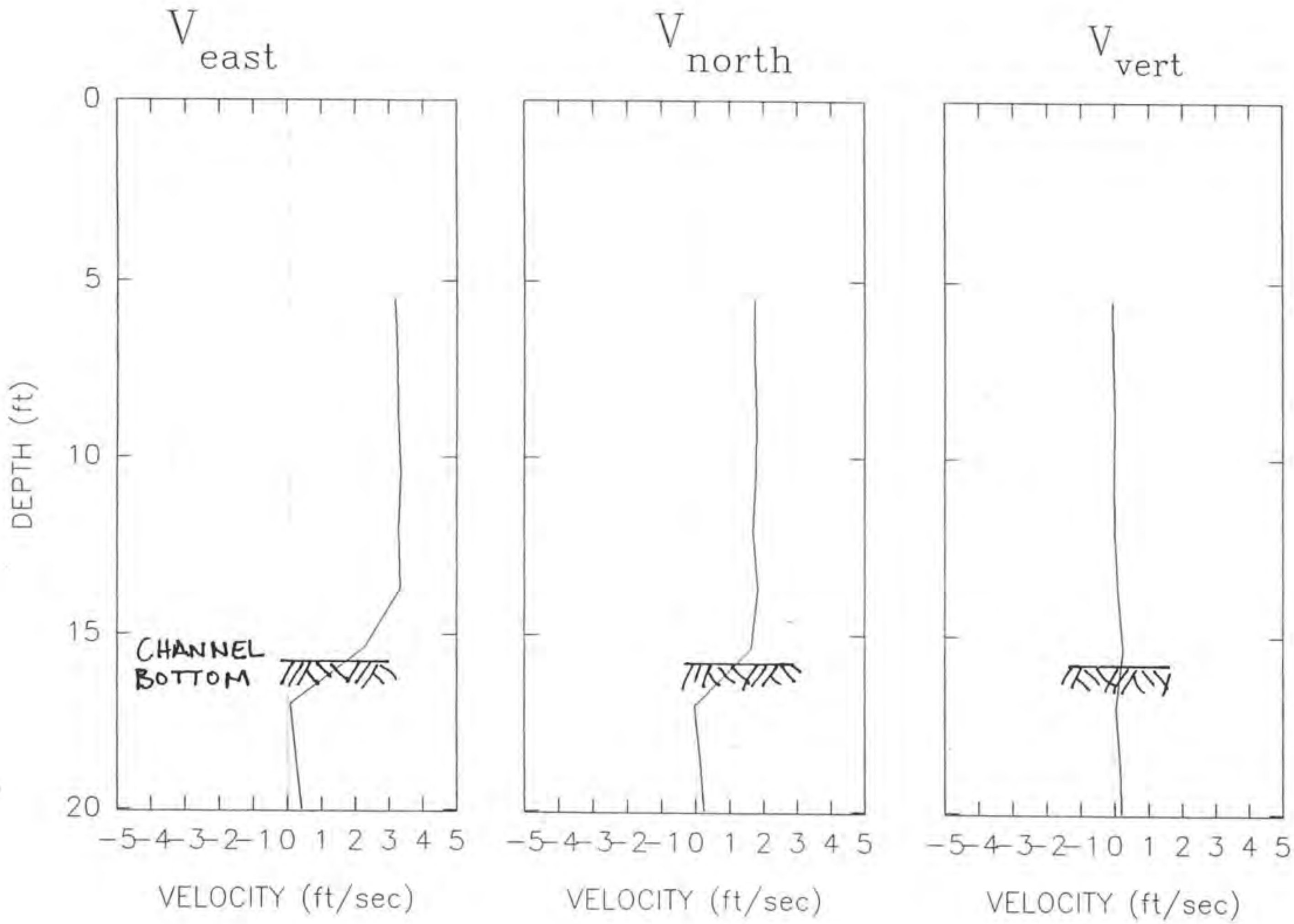


FIG. 24