Monitoring Channel Margin Fine-Grained Sediment Deposits in the Colorado River Ecosystem Downstream of Glen Canyon Dam

Draft Report

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Abstract

A methodology is described for repeatedly measuring topographic changes along cross-sections using total stations for the purpose of monitoring sediment storage along channel margins. We employed this method and measured cross sections at four study sites on four river trips in March, June, August, and September 2000 to assess the effects of the LSSF flow experiment on channel margin sand storage. The LSSF consisted of three flow components; high flows from March through May, low steady flows from June through August, and a high spike flow in September. Using these surveys, we calculated the cross-sectional area between the 255 m^3/s and 878 m^3/s, then determine the difference between surveys as a measure of sediment storage change.

The level of error associated with this technique was limited due to a lack of an estimate of accuracy of the Grand Canyon Monitoring and Research Center (GCMRC) control network. Future surveys should establish local control networks at GCMRC benchmarks until the GCMRC control network is verified. Nonetheless, assuming an accuracy of +/- 0.02m for the GCMRC control points, cross sections can measure changes in excess of 0.2 m^2 to 0.5 m^2. A subset of cross section measurements was used to determine the offset of each data point from the actual cross-section line. Surveyed ground points averaged a mean distance away from the profile line of 0.2m +/- 0.09 m. These results show that the cross section monitoring method developed in this report is a repeatable and relatively accurate way to measure large changes in channel margin sediment storage. Additional sites located in a wider array of geomorphic reaches are recommended if results using this methodology are to be used to imply system-wide responses.

Introduction

Two basic types of bars are deposited along the banks of the Colorado River downstream of Glen Canyon Dam (GCD). The majority of deposition, as much as 75%, occurs as eddy bars within zones of recirculating current, or eddies, in fan-eddy complexes associated with tributary debris fans (Schmidt and Rubin, 1995). Deposits located outside of eddy systems were termed channel margin deposits by Schmidt and Graf (1990). The majority of sand bar monitoring and research conducted during the past decade has focused on eddy bars (Schmidt and Graf, 1990; Beus et al., 1992; Hazel et al., 1993; Kaplinski et al., 1995; Schmidt and Rubin, 1995; Andrews et al., 1999; Hazel et al., 1999; Schmidt et al., 1999; Kaplinski et al., 2000). To date the only studies that have examined channel margin deposits in detail are Schmidt and Leschin (1995), Schmidt and Rubin (1995), and Smith (1999). Graf et al. (1995) surveyed topographic cross-sections in areas dominated by channel margin deposition, but the focus of these measurements was on subaqueous sediment storage changes, not deposition along the higher elevation, subaerial banks. This report documents a method that can be used to detect changes in channel margin fine-sediment storage based on re-surveying monumented cross-sections. Included in this report are descriptions of the cross-section locations, data collection and processing protocols, error analysis, sediment storage changes related to dam releases, and recommendations for future monitoring of channel margin deposits.

Study Design

The purpose of this study is to develop a field-based, repeatable methodology for measuring changes in channel-margin deposits using monumented cross-sections. This technique differs from existing survey protocols established to monitor eddy bars. Eddy bars are monitored either by aerial photographic analysis (Schmidt et al., 1999), or by generating surface models of the entire sand bar from topographic and hydrographic surveys, then calculating volume change from the surface models between different stage elevations (Kaplinski et al., 1995; Hazel et al., 1999). These volumes are then compared to other surveys of the same site to determine storage changes. In contrast, traditional cross-section monitoring in the Colorado River ecosystem determines sediment storage changes by comparing the area beneath the topographic profile, within specific stage elevation ranges (Howard and Dolan, 1981; Beus et al., 1985; Graf et al., 1995).

There are fundamental differences in the data collection effort required for the different techniques. Topographic data points used to develop computer-generated surface models for eddy monitoring need to be somewhat evenly distribution over the bar surface. This requires a rodman (namdor) to physically access the entirety of the bar. Channel margin deposits are usually densely vegetated. The often-impenetrable woody vegetation limits both the ability to physically access areas along the deposit and to see the ground surface with aerial photography. Surveying along a monumented cross-section minimizes the accessibility problem by eliminating the need to survey large areas of the deposit. The initial surveys extend well above the operational parameters of GCD, typically ranging up to the 3,540 m^3/s stage elevation. Subsequent surveys only extended to the 1,274 m^3/s stage elevation.

Study sites were chosen to test the methodology and provide a rough estimation to the magnitude of channel-margin deposition during the Low Steady Summer Flow (LSSF) experiment. Surveying was done in conjunction with several different monitoring projects on an integrated research river trip.

Description of Study Reaches

The four study sites are located in the Colorado River ecosystem downstream from Glen Canyon Dam (Figure 1). The sites are located in straight sections of the river where fan-eddy complexes are absent and channel margin deposits are the dominant bar type. The Badger site extends from approximately river mile 7 to 8 (by convention in the Colorado River ecosystem, site locations are in river miles downstream from Lee's Ferry), directly above Badger rapids. Bedrock at river level is the Permian Hermit Shale and the site lies within the Permian section of upper Marble Canyon as described by Schmidt and Graf (1990). This section is characterized by a wide channel (~108 m) and relatively few tributary debris fans (1.1 per mile; Melis et al., 1997). The U.S. Geological Survey established cross-sections at this site in 1992 (Graf et al., 1995). We retained the U.S. Geological Survey naming conventions and repeated 6 cross-sections (sections p27 through p32) that are spaced about every 60 m along the channel. All of the U.S. Geological Survey cross-sections are monumented with carriage bolts. The Soap Creek site is located between river mile 10 and 11, directly above Soap Creek rapids, and also lies within the Permian section. Ten new cross-sections were added at this study site. The sections are approximately 60 m apart and are named s1 (downstream) through s10 (upstream). New cross sections were monumented with a scribed X. The Anasazi Bridge site is located between river miles 42 and 43, along the north side of point Hansborough and directly above a cultural site known as Anasazi Bridge. This site is located in the Lower Marble Canyon geomorphic reach (Schmidt and Graf, 1990) and characterized by a relatively wide channel (133 m) and numerous tributary debris fans (2.6 per mile; Melis et al., 1997). Bedrock at the river is the Cambrian Muav Limestone. At this site, we established eight new cross-sections and named them AB1 (upstream) through AB8 (downstream) along a 1.25 km stretch of channel. The National site is located from approximately river mile 165 to 166, immediately above National Canyon. Bedrock at the river is Cambrian Muav limestone. This reach has a moderately narrow channel (60 to 80 m wide) and relatively few tributary debris fans (1.2 per mile; Melis et al., 1997). The U.S. Geological Survey established sections at this site and we repeated sections n0 through n2800 (Konieczki et al., 1997).

Streamflow During the Study Period

A Low Steady Summer Flow (LSSF) experiment, designed to benefit endangered native fishes, was conducted during the study period (March-September, 2000). The LSSF experiment consisted of high spring and fall releases, with an intervening period of low steady summer flows (Figure 2). The spring high flow had a four day discharge of 863 m^3/s, followed by steady releases of 490 m^3/s for approximately 25 days. Releases were lowered to a daily average of 234 m^3/s for 96 days following the spring high flows. The LSSF experiment concluded with a fall high flow release. This spike flow was a four day release of 863 m^3/s and began on September 4^{th}. Channel-margin surveys were conducted before and after each of the high flow events (Figure 2).

Channel Margin Deposition

Channel-margin deposits occur along the river banks where debris fans are small or absent. Channel-margin deposits are also present within debris-fan eddy complexes, along the shoreline opposite the eddy bar. These deposits are characterized by discontinuous, linear banks that can stretch for 10's to 1000's of meters (Schmidt and Leschin, 1995). Talus, boulder piles, and irregularities in the bank can separate the deposit along its length. The 1,274 m^3/s, 1996 controlled flood was the most recent large flow event to significantly change the morphology of channel margin deposits. These deposits can extend continuously from the 227 m^3/s level up to the pre-dam terrace zone (>3,537 m^3/s).

Channel margin deposits typically have a steep bank that rises up to a terrace at about the 850 m^3/s stage level. On top of the terrace, channel parallel ridges may be present that slope gently away from the river channel into either higher, older terrace risers or the talus slopes. These channel parallel ridges have been interpreted as levees formed by the same processes that operate on alluvial streams (Nanson, 1986; Schmidt and Rubin, 1995). Excavations of a parallel ridge show that it is composed of a single set of foresets that record the onshore migration and construction of the ridge (Figure 3).

Channel margin deposits often have features similar to eddy bars, but on a smaller scale. This suggests that local topographic irregularities along the shoreline create "micro-eddies" at higher discharges and deposition within these features follow the patterns observed in larger-scale recirculation zones characteristic of fan-eddy complexes.

Smith (1999) measured the topography and water velocity field in the National Canyon reach. These measurements suggest that, at higher discharges, a secondary flow circulation field develops that produces a cross-stream flow. The shoreward component of this cross-stream flow carries sediment towards the bank where it is deposited (Figure 4). Thus, channel margin deposits are constructed by a combination of processes. In places, they have characteristics of levee-style deposits, possibly driven by the processes described by Smith (1999), while in other locations these deposits display characteristics of deposition within small eddy systems created by shoreline irregularities.

Methods

Data Collection

Topographic and bathymetric data were collected during four survey trips in March, June, August and September 2000 (Figure 2). All cross-sections were surveyed during the March and June surveys. However, the National site was not surveyed in August and September and survey errors were encountered during the August Badger surveys that rendered the surveys un-useable.

Ground points at each cross-sectional profile were measured in accordance with standard topographic survey techniques (USACE, 1998). Topcon GS310 total stations outfitted with TDS/Husky data collectors were used for topographic data collection. The control setup and topographic information were downloaded to laptop computers each night.

All surveys were collected from monumented control points in the GCMRC control network using the Arizona State Plane (meters) Coordinate system, with the exception of the National Canyon site. State Plane control coordinates were not available at the time for this area and surveys were collected using a local coordinate system utilizing fixed control points. Survey accuracy in the field was maintained by checking both horizontal and vertical positional error between established control points in the GCMRC control network. Upon the recommendations of the GCMRC survey staff, no corrections were made to the observations for scale factor, sea-level reduction or earth curvature. The location and elevation of each cross-section end reference points were determined during the initial March 2000 survey trip. Each end point was monumented by either a USGS carriage bolt or identifiable by a scribed "X " on a retraceable feature of the talus.

Field procedures were developed to insure proper alignment along the profile for topographic data collection. Field crews consisted of four namdors and at least one instrument operator. Two namdors were assigned to each side of the river. At each profile, a namdor was positioned on the monumented profile end points. The other namdor was visually aligned along the profile using hand and verbal signals from each end point position. Both sides of the river were surveyed in turn and by selecting ground points along the profile at changes in gradient.

Hydrographic data was collected using GCMRC's hydrographic mapping systems. The GCMRC has both a singlebeam and multibeam mapping system and both were used for the cross-section measurements. Both systems consist of a range azimuth navigation system (Geodimeter ATS-TP, or ATS600 robotic total station) and a sonar depth sounder (Marimatech echotrac or Reson 8124) controlled by a laptop computer running HYPACK/HYSWEEP hydrographic mapping software system. Cross-section endpoints were entered in to the HYPACK software and the boat followed the cross-section line for 4-6 passes.

Data Processing and Analysis

Initially, Digital Surface Models (DSM's) were created (using the Triangular Irregular Network method for contouring irregularly spaced data) from the ground based and hydrographic survey points. However, given the linear nature of the ground data and the narrow band of hydrographic data collected, the DSM model produced an unrepresentative profile. In addition, hydrographic data from the August and September trips was not available in time for report preparation. Because the focus of this study is channel margin deposition, it was decided to proceed without the hydrographic data and focus only on subaerial changes using ground topographic data.

Ground Surveys

Ground survey data were edited and processed using Sokkia Mapping Software. For each cross-sectional profile, the left bank reference mark was designated as zero datum. Using this datum the horizontal distance to each measured point was computed and topographic profiles were produced.

Stage-Discharge Relationships

Stage–Discharge relationships were empirically derived for each site by compiling mean water surface elevations and elevations of high water marks using the method of Kaplinski et al. (1995). Discharges measured from the nearest USGS gauging station at the time of the survey (adjusted for the difference in river mileage) were assigned to each of these elevations and a best-fit line was produced. From these relationships an elevation corresponding to a particular discharge was estimated.

Results

Error analysis

Accuracy can be defined as a measurement of exactness or correctness. In terms of spatial information, this can be interpreted as the degree of correctness with which features on the earth's surface can be measured and represented. In this study, an analysis of topographic surveying using total stations depends on the quality of primary positioning (i.e. the GCMRC control network). Primary positioning will affect all subsequent triangulation networks and these in turn will dictate the accuracy of local surveys. An estimate of the GCMRC control network accuracy is not available at this time (M. Gonzales, GCMRC survey department, pers. comm., 2001). Recent GPS observations at some control network points should provide an estimate of the networks accuracy in the near future. In addition, the state plane coordinate system projection scale factor and reference elevation corrections were not applied to our measurements, which further decreases the ability to assess the error of our measurements. An assessment of how well our measurements actually represent real changes on the ground awaits future evaluation of the accuracy of the GCMRC control network.

In the absence of a control network accuracy statement, we made an estimate of the errors contributed by the methodology employed to collect the ground points. Errors inherent in total station surveying are a combined factor of the theodolite, which measures a horizontal and vertical angle, and the Electronic Distance Measurement (EDM), that detects and records the travel time of an infrared pulse reflected from the prism, then converts it to a slope distance. With a properly calibrated instrument, angular errors associated with the Topcon GTS 310 is +/- 3 seconds, and the nominal accuracy of the EDM is +/- (5mm + 5 ppm). For a distance of 150 m these errors account for +/- 0.001 m. Thus, systematic errors are negligible in this application. Gross and random errors introduced by the user account for most of the error associated with total station surveying. Gross errors, such as incorrect rod height elevations are erased during post-processing by editing the data file. Random errors are typically due to the human ability to point the instrument and environmental conditions that limit a clear view of the target, uneven heating of the instrument, drifting of the instrument level, and the ability of the namdor to plumb his rod. Namdors stationed at ground points are equipped with extendable prism poles that adjust the target height 1.837 m, 3.285 m, 4.735, 6.184, and 7.566 m, respectively. Errors introduced by the rod bending and/ or leaning increases with each extension and are estimated to be +/- 0.05m for no extensions, up to +/- 0.4 m at four extensions. We typically do not extend the rods over 3 extensions, but vegetation sometimes requires a higher prism elevation. We estimate the combined error of total station surveying at a distance of 150 m to be +/ 0.05 to 0.30 m, depending on the rod height and distance of the shot.

Cross-Section Repeatability: Horizontal Error

In order to assess the inherent horizontal error in relocating ground survey points along the established cross-section lines, we examined a subset of the observations taken at each study site. This error estimate was developed under the assumption of control network accuracy and may change when the GCRMC survey department evaluates the existing control. For each point along the subset of cross-section, the offset from the section was measured by determining the perpendicular distance from the ground point to the cross-section line (Figure 5). From a sample population of 430 points, the mean offset from the section, or positional error was calculated to be 0.20 m, with a standard error of 0.09 m (Figure 6). This indicates that the visual alignment technique described above provides a practicable method for relocating ground points along profiles.

Sediment Storage Changes

Changes in cross-sectional area between successive measurements were computed to determine the effects of the LSSF experiment on channel-margin sediment storage (Table 1; Figure 7). Cross-sectional area was calculated between the 255 m^3/s and 878 m^3/s stage elevations, then subtracted from subsequent surveys to estimate deposition and/or erosion along the sections. The precision of the area calculations, based on the error of total station surveying are of the order of +/- 0.2 to 0.5 m^2, depending on the horizontal distance over which the areas were calculated.

Comparison of surveys conducted in March and June show that the spring high flow period had only a minor effect on channel margin sediment storage at the four study sites (Table 1; Figure 7a). With the exception of one profile from the National site, the magnitude of change was small, and the area changes were at, or near the detection limits of the method (Figure 7a). The right bank along profile N800 at the National site crosses a small channel margin reattachment bar which aggraded during the spring high flows and resulted in a change of 17 m^2 (Appendix A). The increase along one side of one profile also accounts for the large errors associated with the mean change recorded at the National site during this period (Figure 7a).

Cross section measurements in August show that the low summer flows resulted in minor erosion of the channel margins (Table 1, Figure 7b). All four of the sections measured decreased in area and three out of the four decreases were significant. However, due to logistical constraints and survey errors, only two of the four sites were used in this analysis.

Sections measured in September record the effects of the fall high flow period. The comparison shows that there was only minor amounts of deposition during this time and only two of the six sections increased by a significant amount.

The pattern of deposition and erosion suggests that deposition occurred during the high flows and erosion predominated during the lower flows. Our observations show that the spring and fall high flows produced a small net gain in profile area. This result agrees favorably with results from eddy bar monitoring that shows a slight gain in high-elevation bar volume.

Conclusions/Discussion

This report describes a method for repeat measurements of topographic changes along cross-sections using conventional survey methods. The objective of this study is to develop a monitoring technique that can be applied to channel margin deposits. We employed this method and measured cross sections at four study sites on four river trips in March, June, August, and September 2000 to test the repeatability of this method. We also assessed the effects of the LSSF flow experiment on channel margin sand storage. The LSSF consisted of three flow components; high flows from March through May, low steady flows from June through August, and a high spike flow in September. Using these surveys, we calculated the cross-sectional area that corresponds to the stage elevations reached by flows of 255 m^3/s and 878 m^3/s. Comparison of area changes was used to quantify sediment storage change in the channel margin deposits.

Our results indicate that the level of error associated with this technique was limited due to a lack of an estimate of accuracy of the GCMRC control network. Nonetheless, assuming an accuracy of +/- 0.02 m for the GCMRC control points, cross sections can measure changes in excess of 0.2 m^2 to 0.5 m^2. A subset of cross section measurements was used to determine the offset of each data point from the actual cross-section line. Our ground points averaged a mean distance away from the profile line of 0.2 m +/- 0.09 m. These results show that the cross section monitoring method developed in this report is repeatable and relatively accurate. For example, even though the depositional and erosional response of the channel margin deposits to the LSSF was minor, the changes were still detectable. However, if this method is used to imply system-wide results, the number of sites will need to be expanded.

We recommend that GCMRC place the highest priority on resolving issues surrounding the GCMRC survey control network. The control network is essential to georeferencing spatial data used for monitoring resources in the Colorado River ecosystem and assessing the application of new technologies such as LIDAR. Assessing the amount of error associated with different monitoring techniques cannot be accomplished without a verified control network. For this reason, we could not complete a thorough examination of the errors inherent in the cross-section monitoring methods outlined in this report. We also recommend that scale factors and ellipsoid datum corrections be applied to all data if it is going to be incorporated into the Arizona State Plane Coordinate System. We suggest that, until the GCMRC control network can be verified, future survey parties establish a local grid on the GCMRC network points. This would eliminate any uncertainties associated with the GCMRC network and allow incorporation of these data into the GIS system once the GCMRC network is verified.

We also recommend that new remote sensing technologies should be evaluated for use in channel margin monitoring. New technologies such as LIDAR hold great promise and would expand the amount of terrain evaluated and increase the representativeness of the monitoring. In order to be a useful tool for monitoring, new techniques need to detect vertical surface changes of at least 0.25 m.

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Appendix A: Cross-section plots

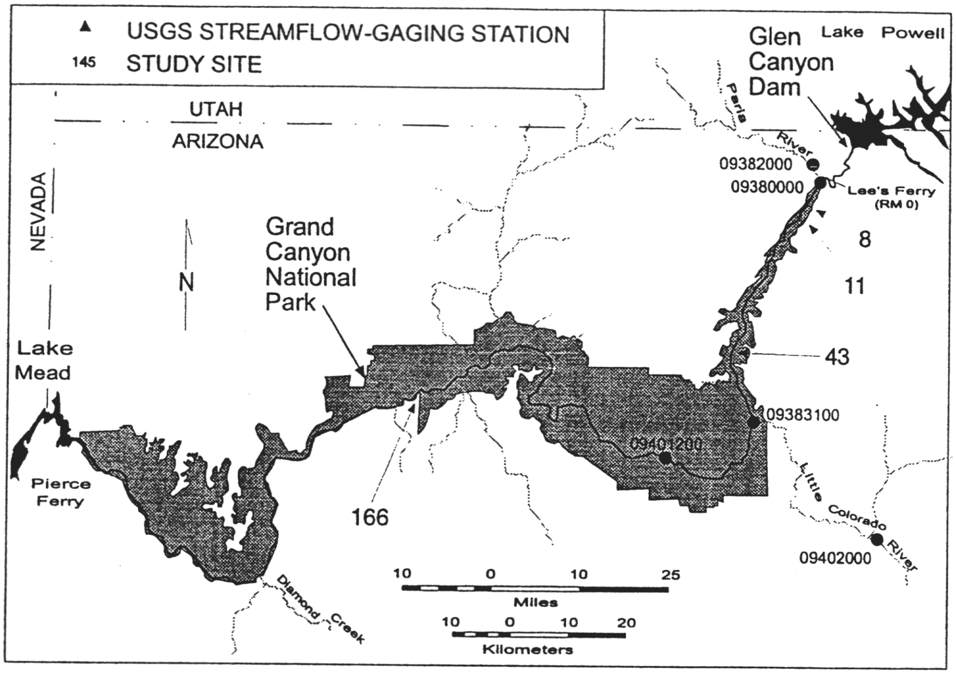


Figure 1. Location map of study areas.

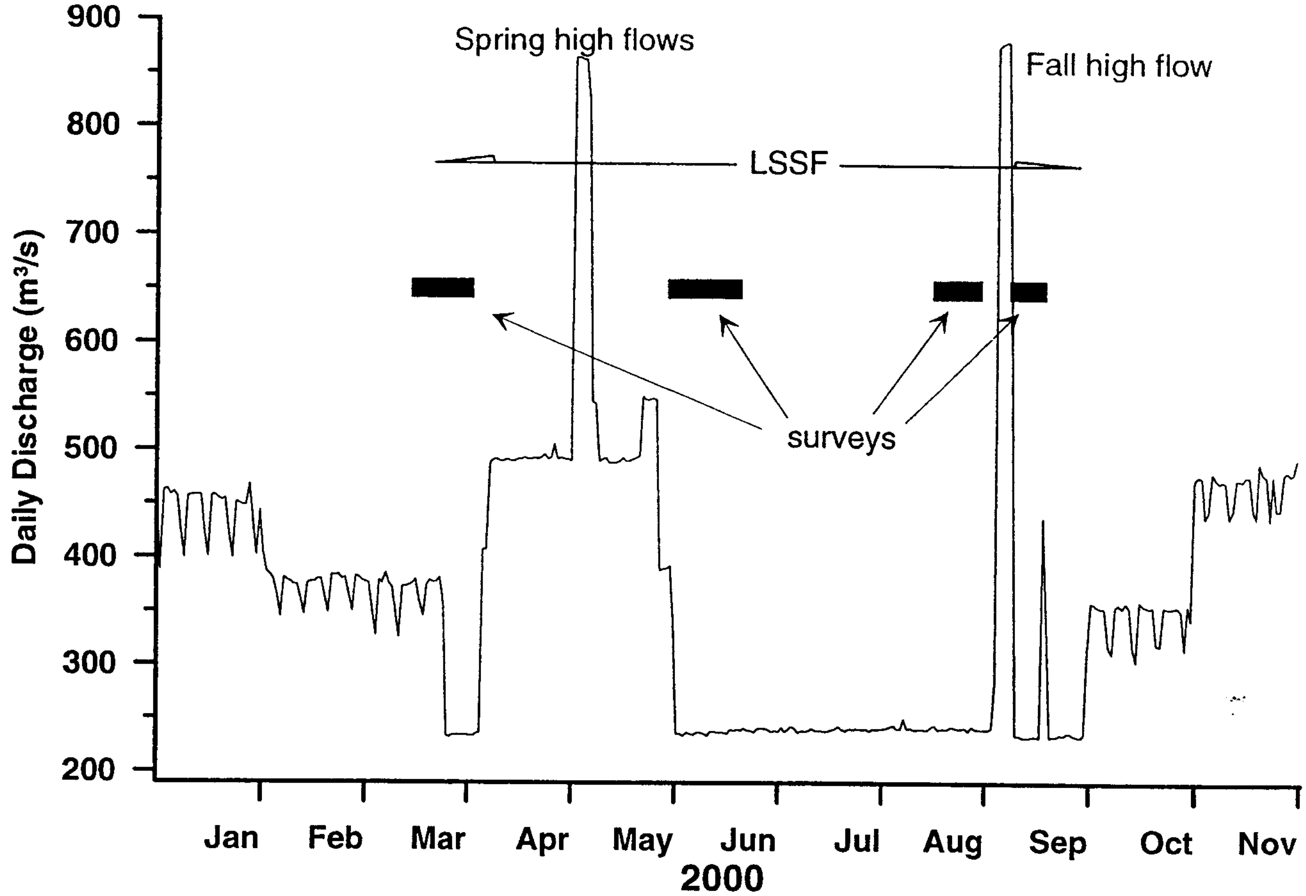


Figure 2. Daily maximum discharge at the USGS streamflow-gaging station, Colorado River at Lee's Ferry, Arizona, January 2000 to November 2000. Blocks show the times when cross-section surveys were conducted.

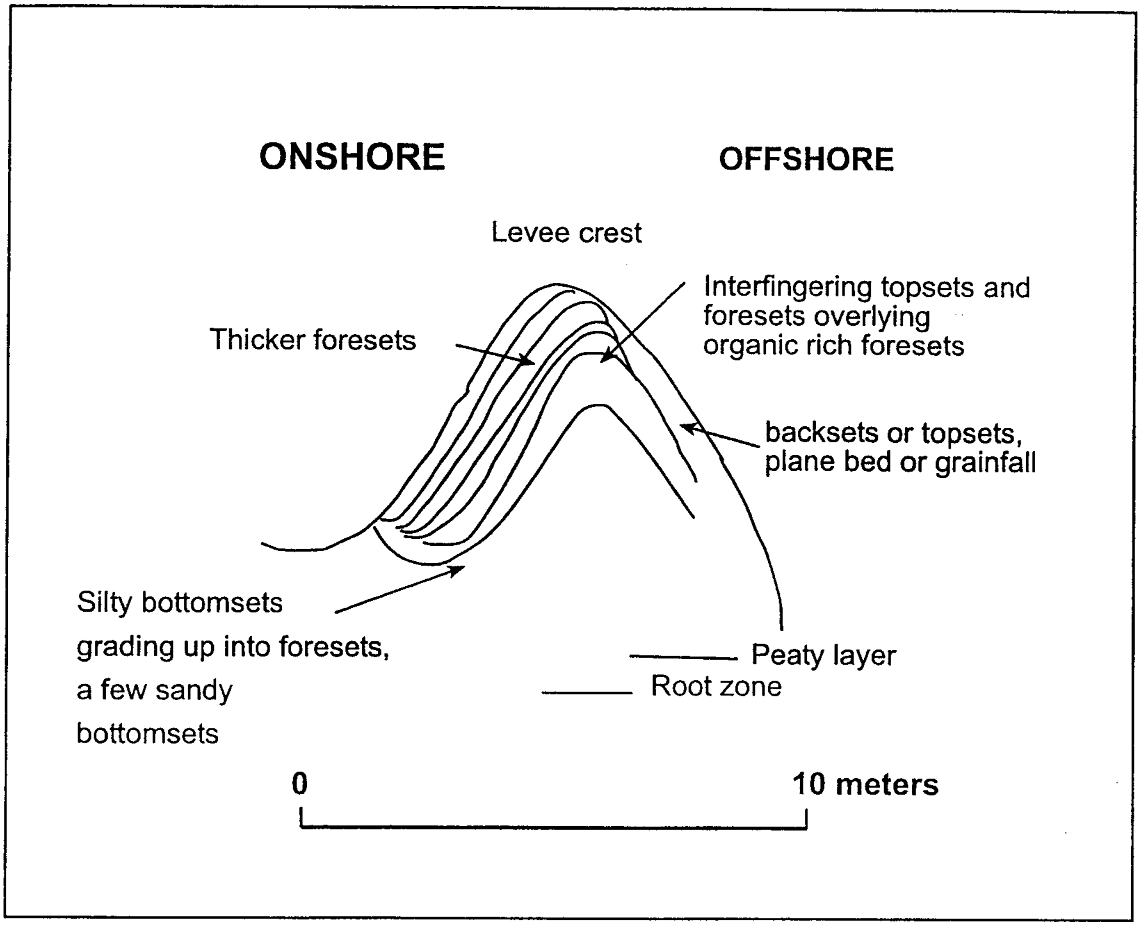


Figure 3. Stratigraphy of a levee-type channel margin deposit at river mile 51. View is downstream, the river channel is to the right side of the levee, and vertical exaggeration is 3 times (from Schmidt and Rubin, 1995).

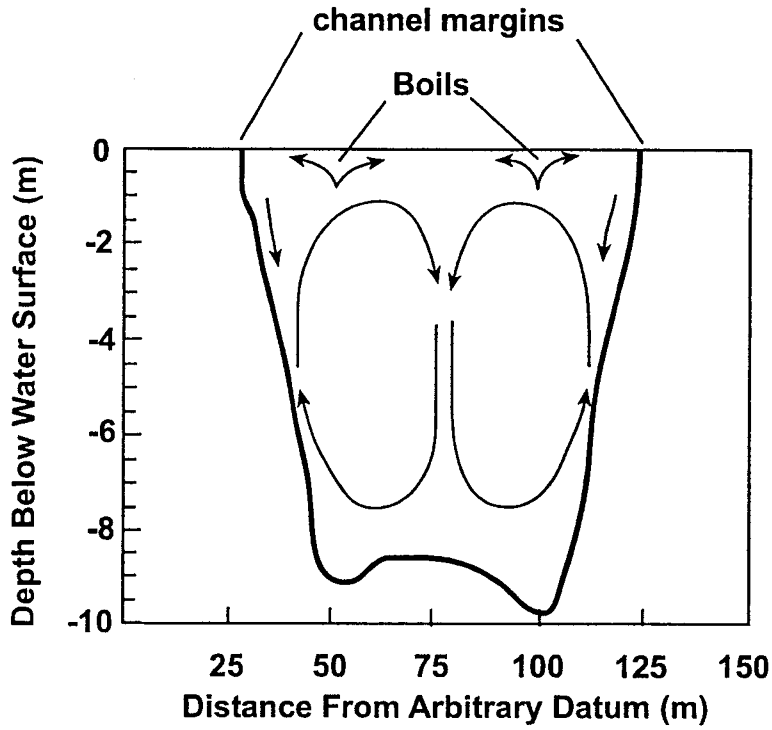


Figure 4. Cross-section of the Colorado River in Grand Canyon, showing direction of secondary circulation, boils, and channel margins (modified from Smith, 1999).

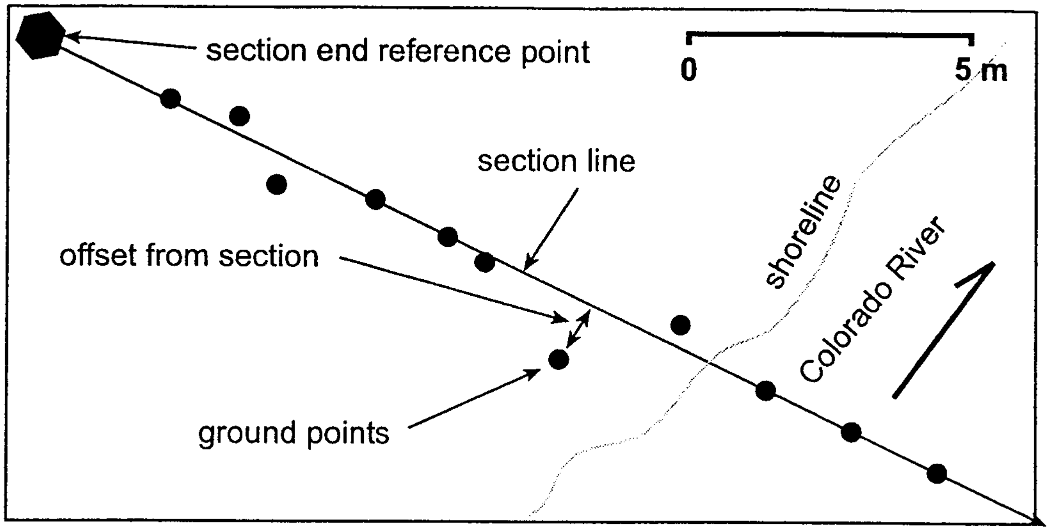


Figure 5. Sketch map of one side of a cross-section across a channel margin deposit showing survey errors, or offset from sections.

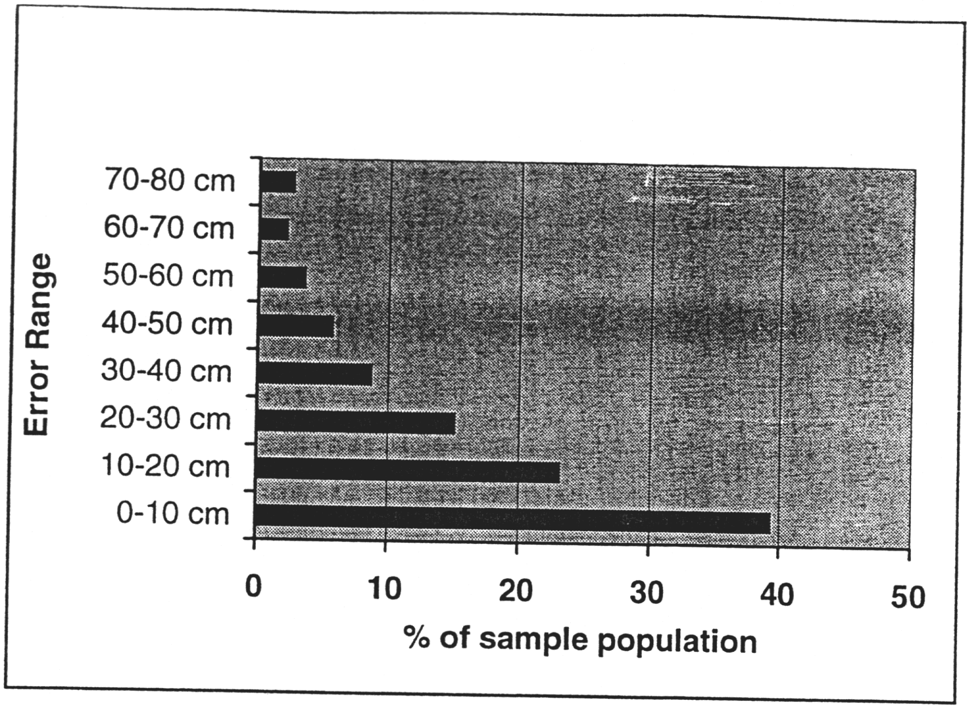


Figure 6. Histogram of offset distance from cross-section line.

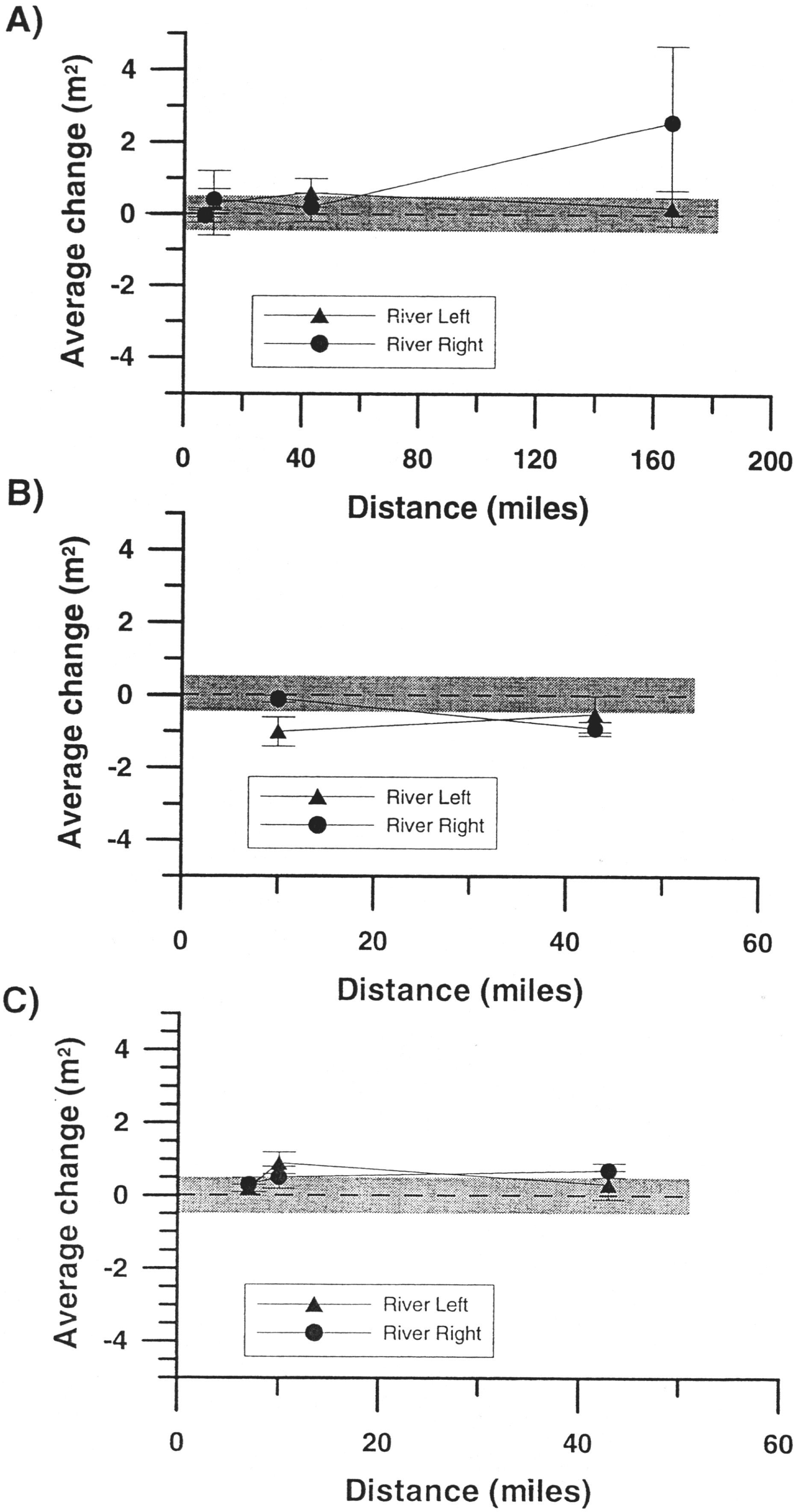


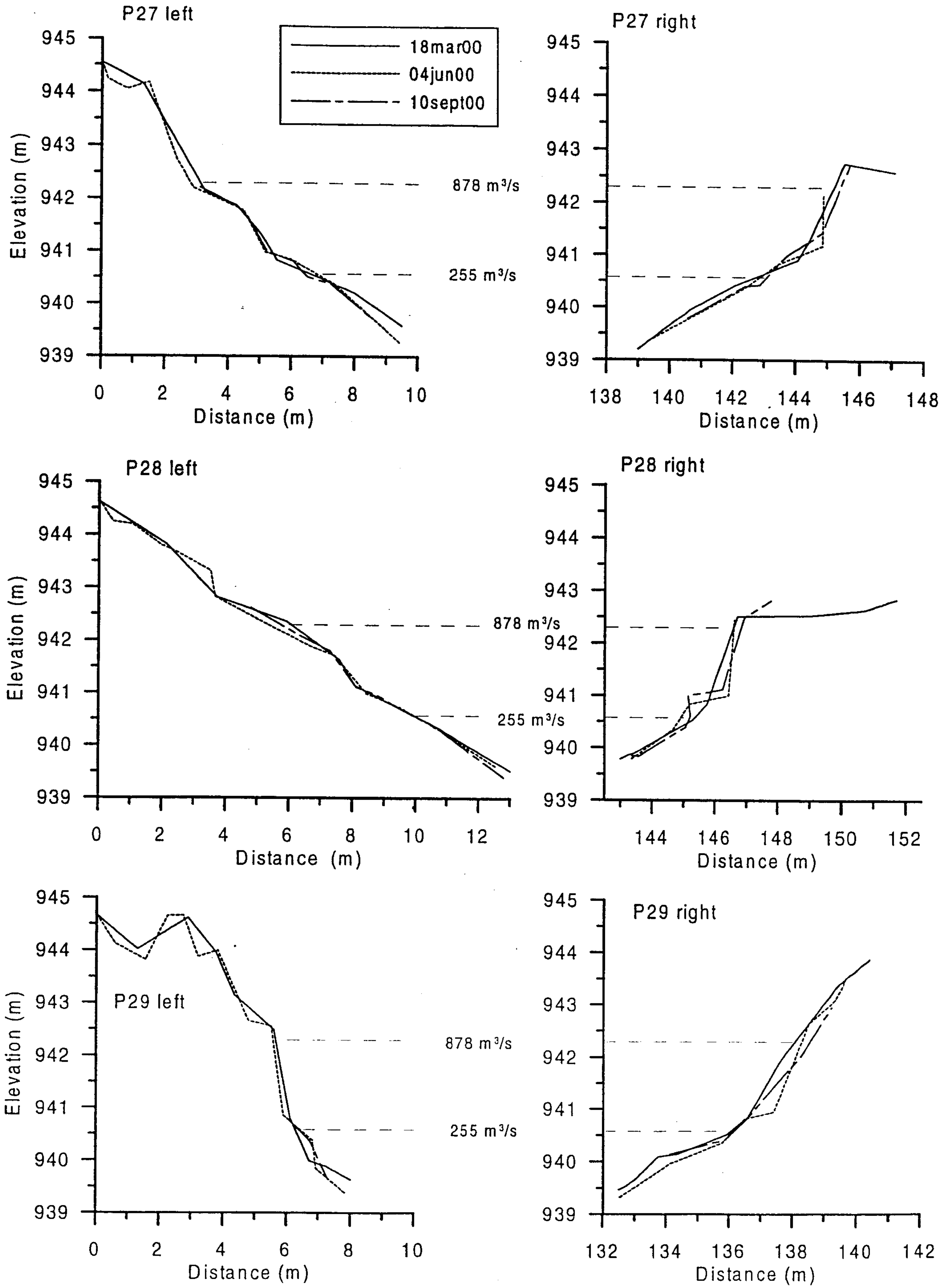
Figure 7. Cross-section area changes for the three comparison periods. A) Spring high flows, B) Low summer flows, C) Fall high flows. Grey area equals the level of significant change, +/- 0.5m2.

Table 1. Area changes at monumented cross-sections

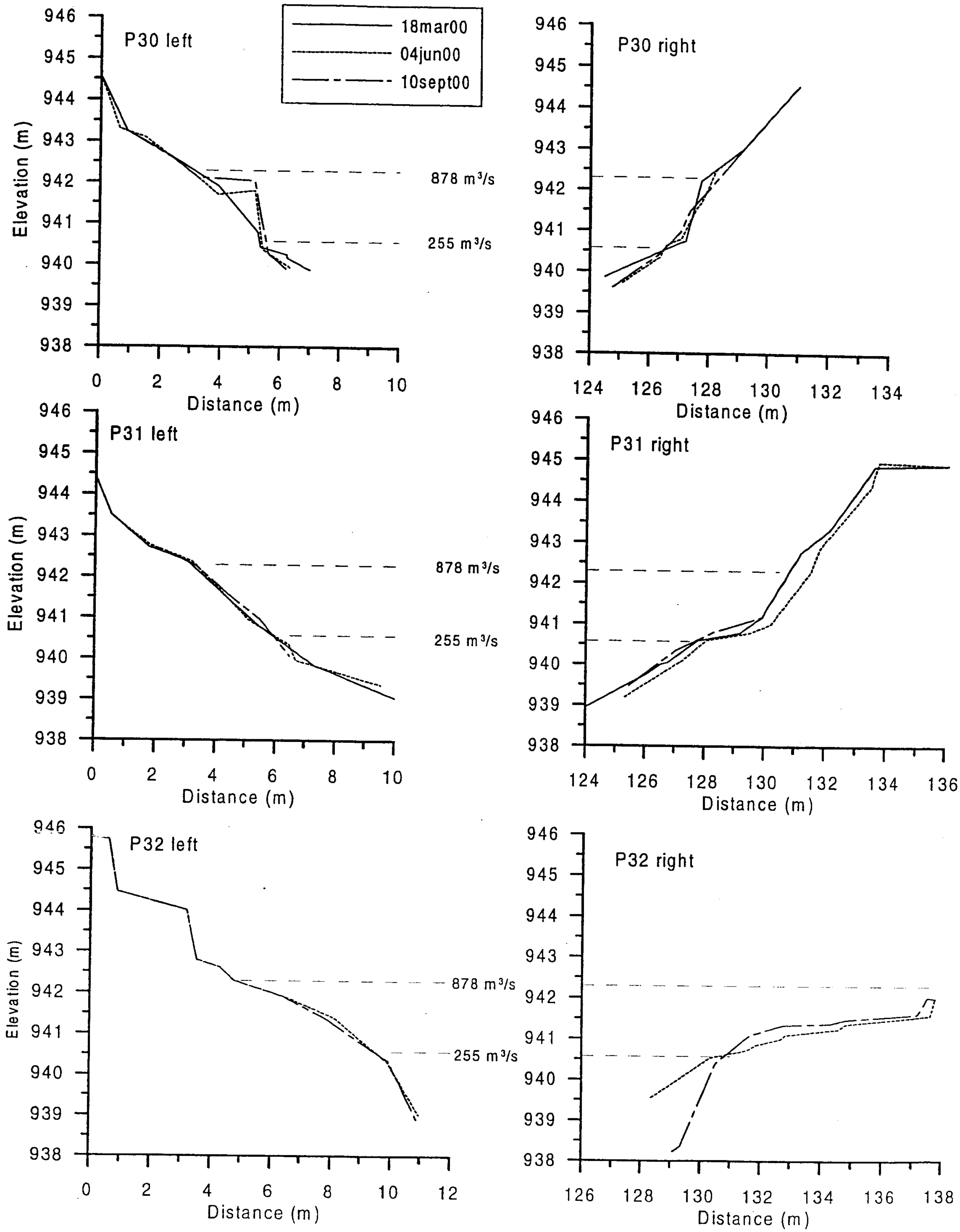
Cross Section Number	Period 1 march 2000 to june 2000		Period 2 june 2000 to august 2000		Period 3 august 2000 to september 2000	
	cross section area change		cross section area change		cross section area change	
	L	R	L	R	L	R
Upstream from Badger						
P27	0.0	-0.1	*** ##	***	0.1 ##	0.0
P28	-0.2	-0.3	***	***	0.1	0.0
P29	-0.2	-0.7	***	***	0.1	0.3
P30	0.4	-0.1	***	***	0.7	0.1
P31	0.0	-0.9	***	***	0.3	1.2
P32	*** ##	***	***	***	-0.2	1.3
Net Change	0.0	-2.1	***	***	1.0	2.8
Mean	0.0	-0.4	***	***	0.2	0.3
std. Error	0.1	0.2	***	***	0.1	0.2
Upstream from Soap Creek						
S1	-1.2	1.1	-1.1	0.1	1.0	1.6
S2	-1.1	0.6	-0.1	0.0	0.3	-0.1
S3	0.1	0.2	-1.0	-0.1	2.3	0.3
S4	-1.0	0.1	-0.3	0.3	0.2	0.9
S5	0.3	1.9	0.0	0.2	-0.3	-0.5
S6	-3.9	1.1	-0.1	-1.1	1.7	2.6
S7	6.6	0.2	-4.4	-0.2	2.5	-0.1
S8	-0.1	0.5	-1.3	0.0	1.6	-0.2
S9	-0.7	-0.3	-0.6	-0.1	0.7	0.2
S10	3.6	-1.9	-0.7	-0.4	-0.5	0.3
Net Change	2.8	3.6	-9.7	-1.5	9.5	5.0
Mean	0.3	0.4	-1.0	-0.1	0.9	0.5
std. Error	0.9	0.3	0.4	0.1	0.3	0.3
Upstream from Anasazi Bridge						
AB1	0.2	-1.9	0.3	-0.8	0.9	0.8
AB2	3.2	2.3	-3.4	-1.4	2.3	0.8
AB3	-0.2	-0.4	-0.4	-0.7	-1.0	0.5
AB4	0.7	0.1	0.0	-0.5	-0.2	0.8
AB5	-0.5	0.0	0.3	-0.7	-0.2	-0.3
AB6	*	*	*	*	*	*
AB7	0.7	0.7	-0.2	-1.0	0.9	0.7
AB8	0.2	0.3	0.2	-1.1	-0.6	1.5
Net Change	4.3	1.1	-3.2	-6.1	2.2	4.8
Mean	0.6	0.2	-0.5	-0.9	0.3	0.7
std. Error	0.4	0.4	0.5	0.2	0.4	0.2
Upstream from National Canyon						
N0	2.1	-0.8	*** ##	***	***	***
N400	-2.2	1.5	***	***	***	***
N800	1.1	17.1	***	***	***	***
N1200	0.1	0.3	***	***	***	***
N1600	0.6	0.0	***	***	***	***
N2000	0.8	0.1	***	***	***	***
N2400	-1.7	1.1	***	***	***	***
N2800	0.5	1.1	***	***	***	***
Net Change	1.3	20.5	***	***	***	***
Mean	0.2	2.6	***	***	***	***
std. Error	0.5	2.1	***	***	***	***

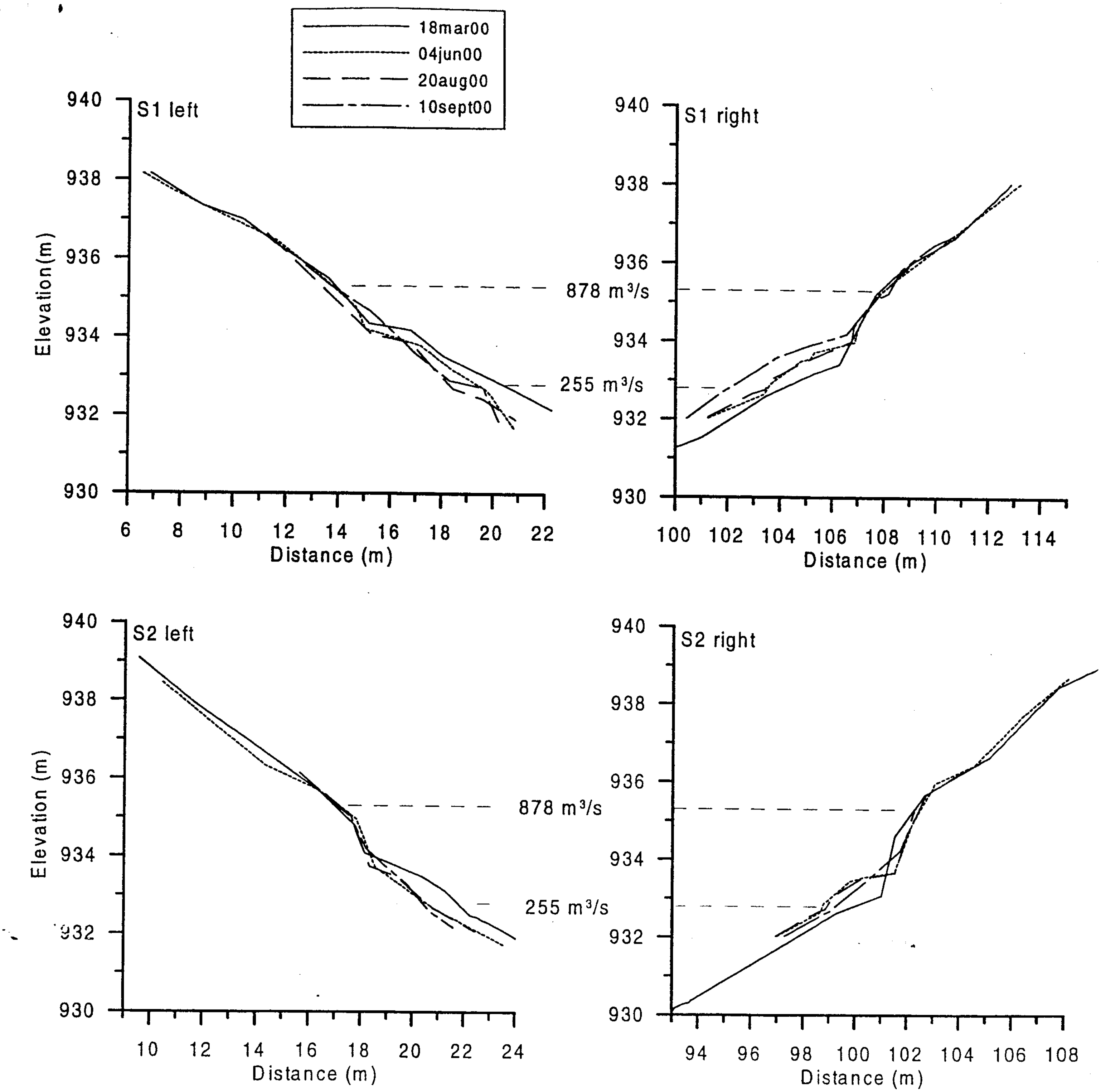
NOTES
(1) Erroneous survey data for P27 to P32, August 2000.
(2) Control station anomalies for cross section P32, March 2000
(3) Results for period 3, cross sections P27 to P32, are for June 2000 to September 2000
(4) Control station anomalies for cross section AB6
(5) National sections were not surveyed in August and September

Appendix A: Cross-Section plots

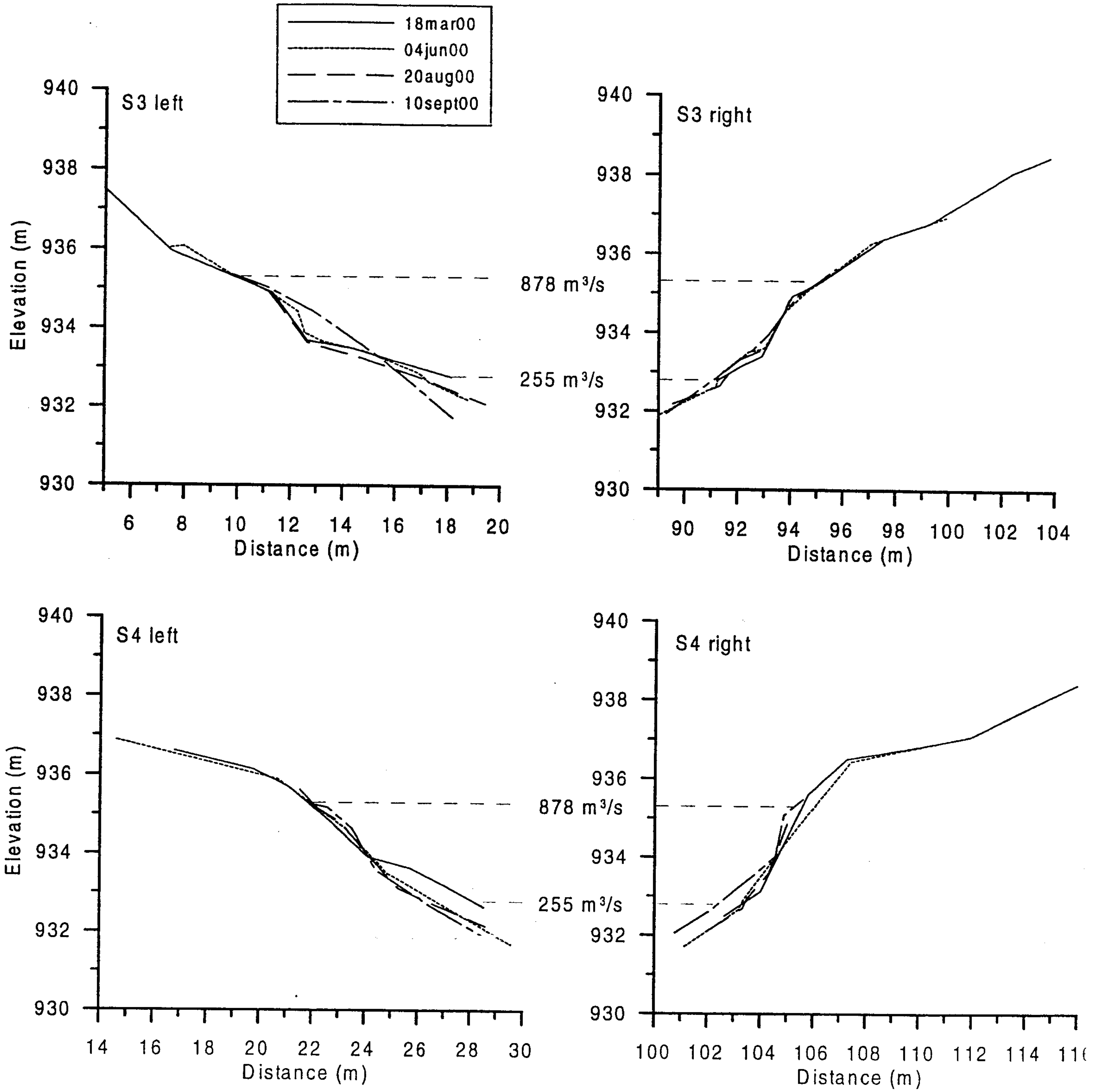


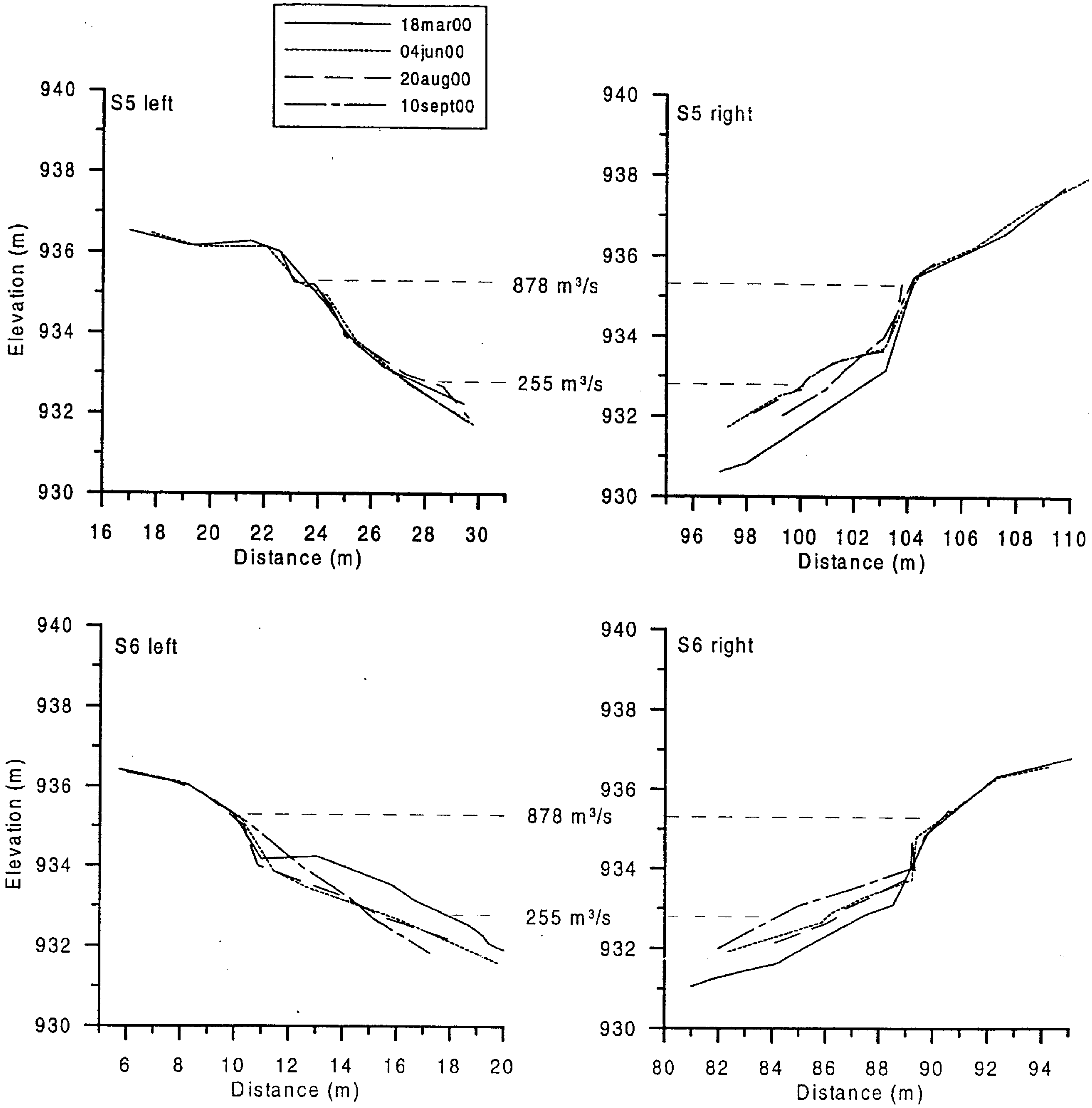
P27 left
18mar00
04jun00
10sept00
878 m³/s
255 m³/s
Elevation (m)
Distance (m)
P27 right
P28 left
P28 right
P29 left
P29 right

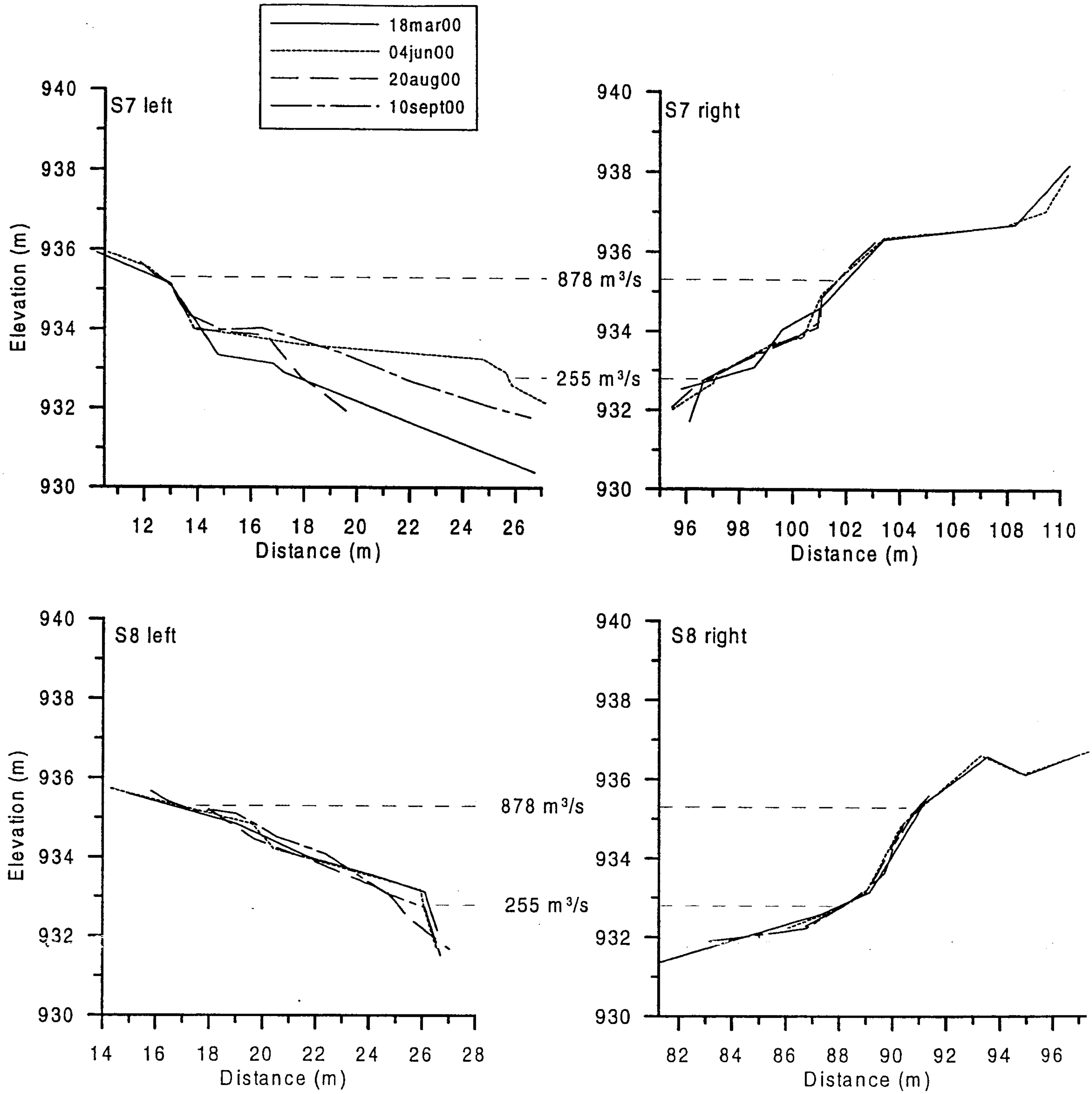

P30 left
18mar00
04jun00
10sept00
878 m³/s
255 m³/s
Elevation (m)
Distance (m)
P30 right
P31 left
P31 right
P32 left
P32 right

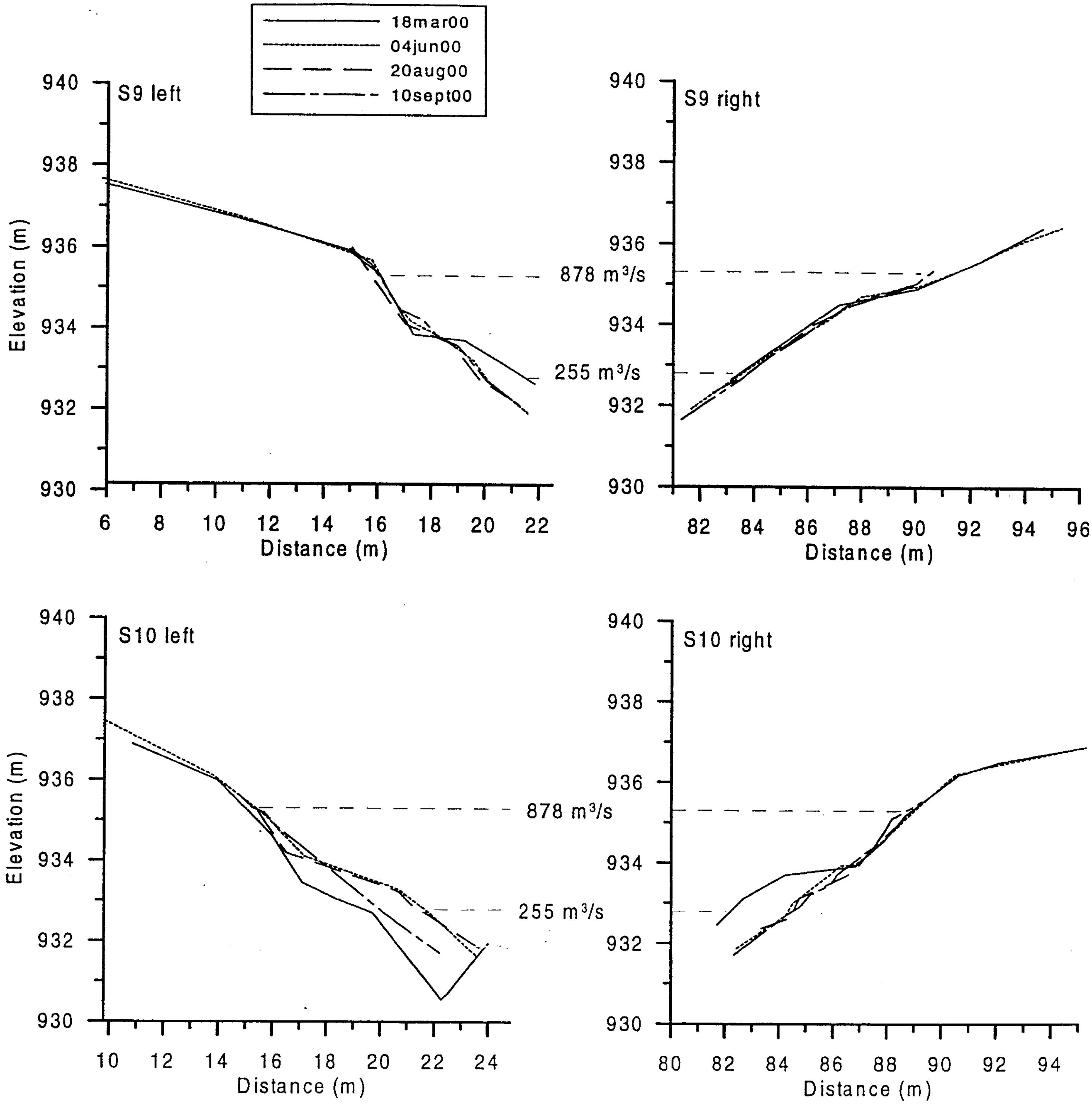


18mar00
04jun00
20aug00
10sept00
S1 left
S1 right
S2 left
S2 right
Elevation(m)
Elevation (m)
Distance (m)
878 m³/s
255 m³/s
940
938
936
934
932
930
6
8
10
12
14
16
18
20
22
100
102
104
106
108
110
112
114
24
94
96
98

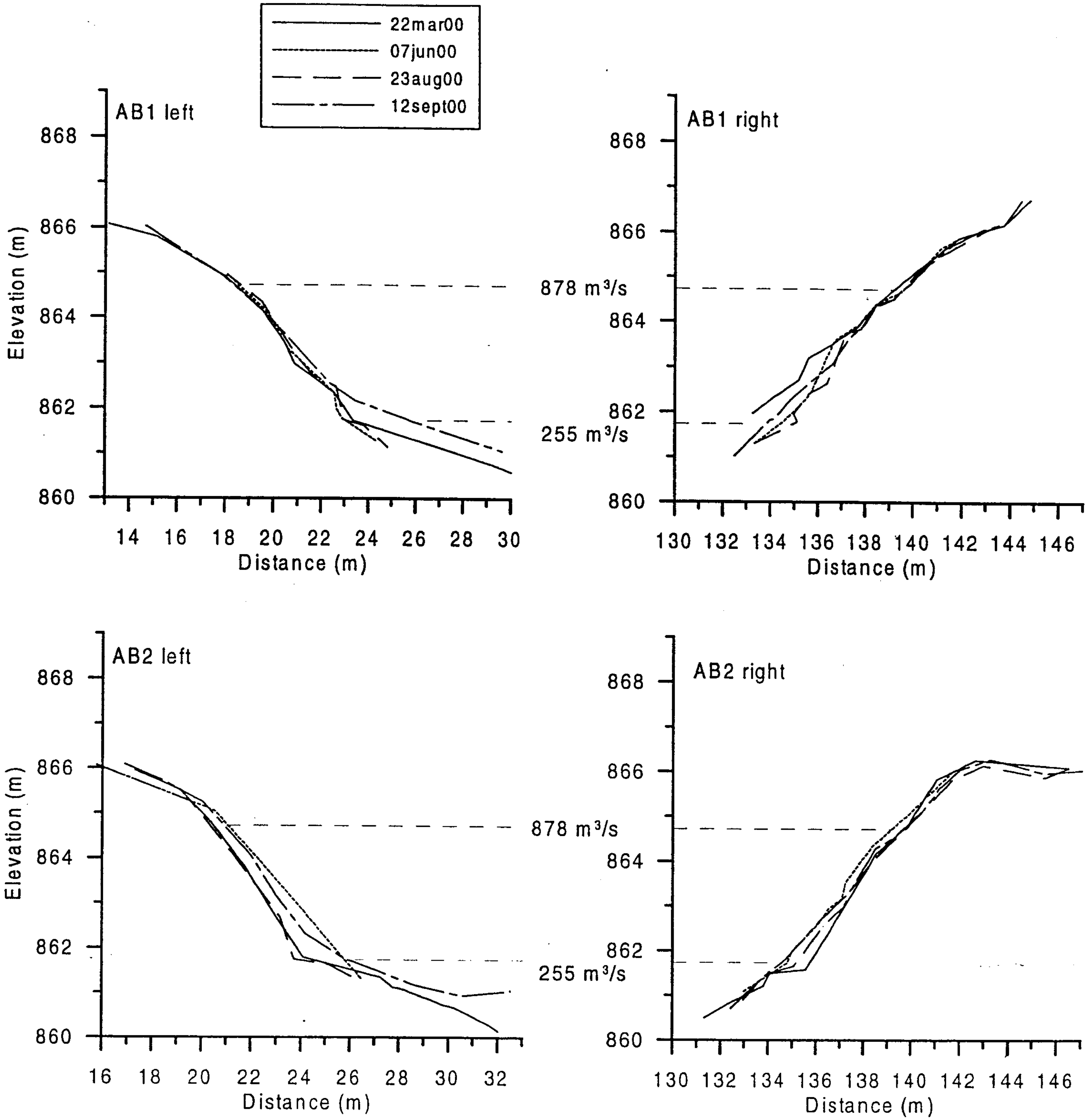

18mar00
04jun00
20aug00
10sept00
S3 left
S3 right
S4 left
S4 right
878 m³/s
255 m³/s
Elevation (m)
Distance (m)
940
938
936
934
932
930
6
8
10
12
14
16
18
20
90
92
94
96
98
100
102
104
14
16
18
20
22
24
26
28
30
100
102
104
106
108
110
112
114


18mar00
04jun00
20aug00
10sept00
S5 left
S5 right
S6 left
S6 right
Elevation (m)
Distance (m)
878 m³/s
255 m³/s
940
938
936
934
932
930
16
18
20
22
24
26
28
30
96
98
100
102
104
106
108
110
6
8
10
12
14
16
18
20
80
82
84
86
88
90
92
94

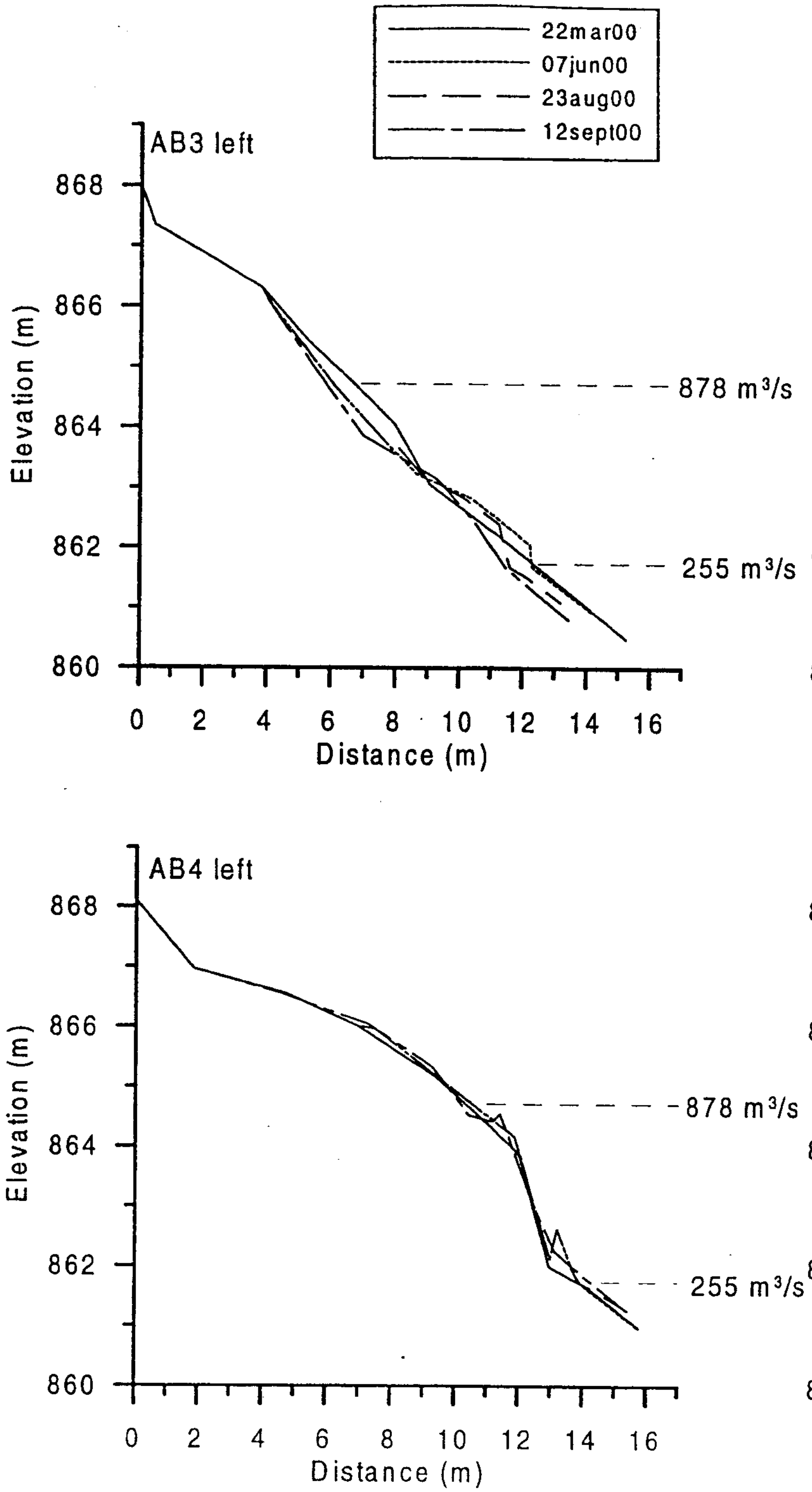

18mar00
04jun00
20aug00
10sept00
S7 left
S7 right
S8 left
S8 right
878 m³/s
255 m³/s
Elevation (m)
Distance (m)
940
938
936
934
932
930
12
14
16
18
20
22
24
26
96
98
100
102
104
106
108
110
28
82
84
86
88
90
92
94



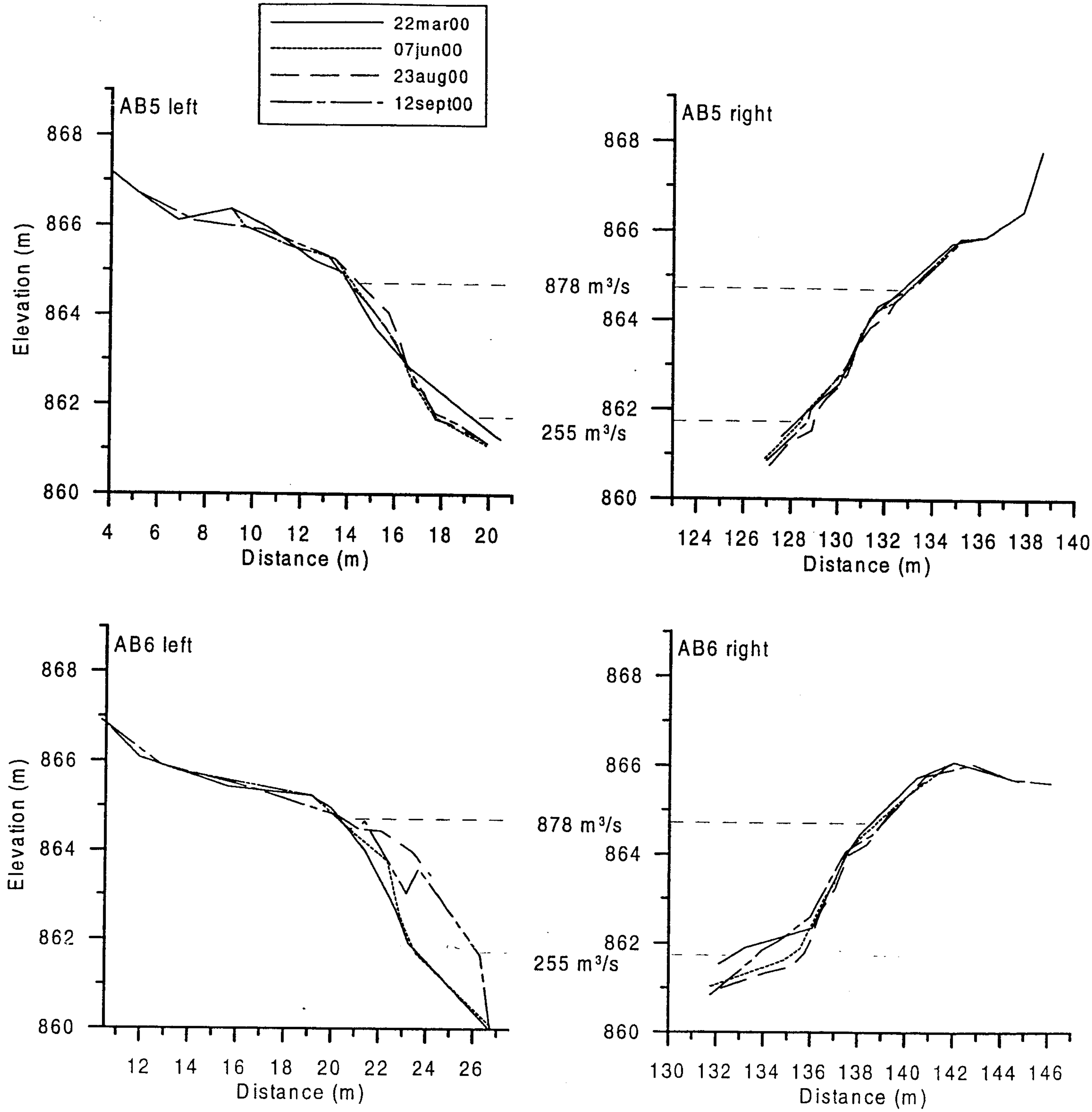
18mar00
04jun00
20aug00
10sept00
S9 left
S9 right
S10 left
S10 right
878 m³/s
255 m³/s
Elevation (m)
Distance (m)

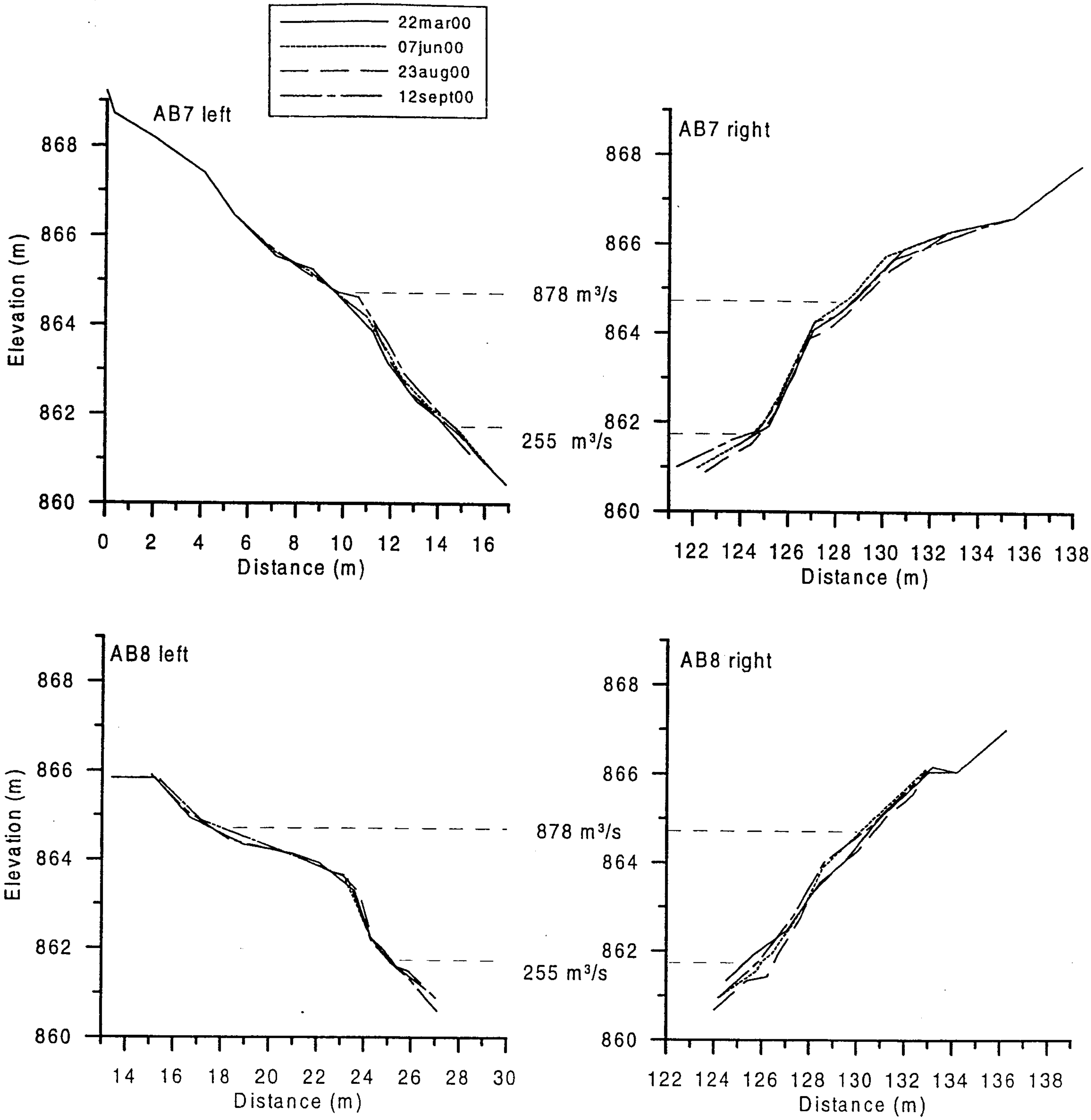


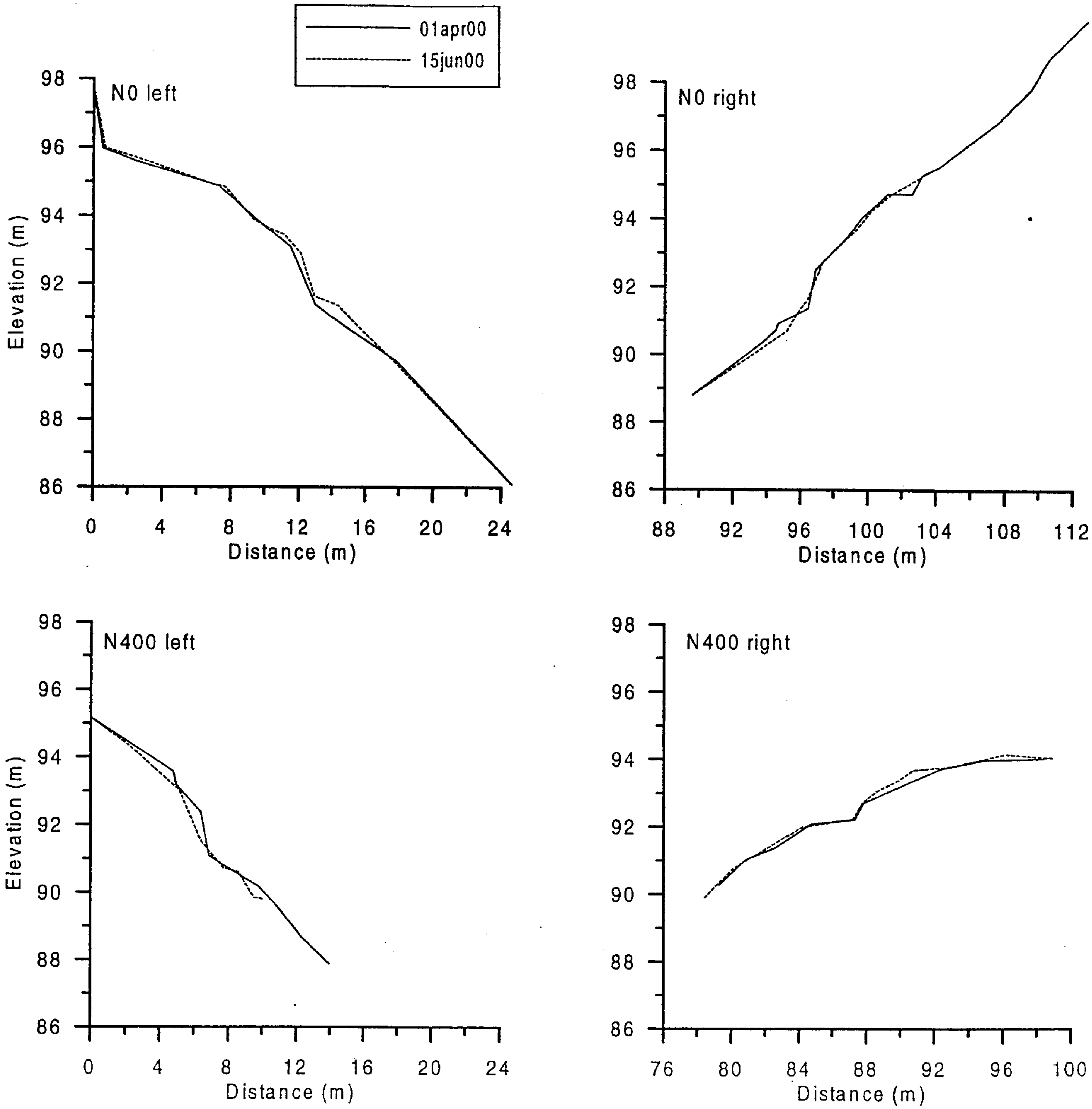
22mar00
07jun00
23aug00
12sept00
AB1 left
AB1 right
AB2 left
AB2 right
878 m³/s
255 m³/s
Elevation (m)
Distance (m)
868
866
864
862
860
14 16 18 20 22 24 26 28 30
130 132 134 136 138 140 142 144 146
16 18 20 22 24 26 28 30 32

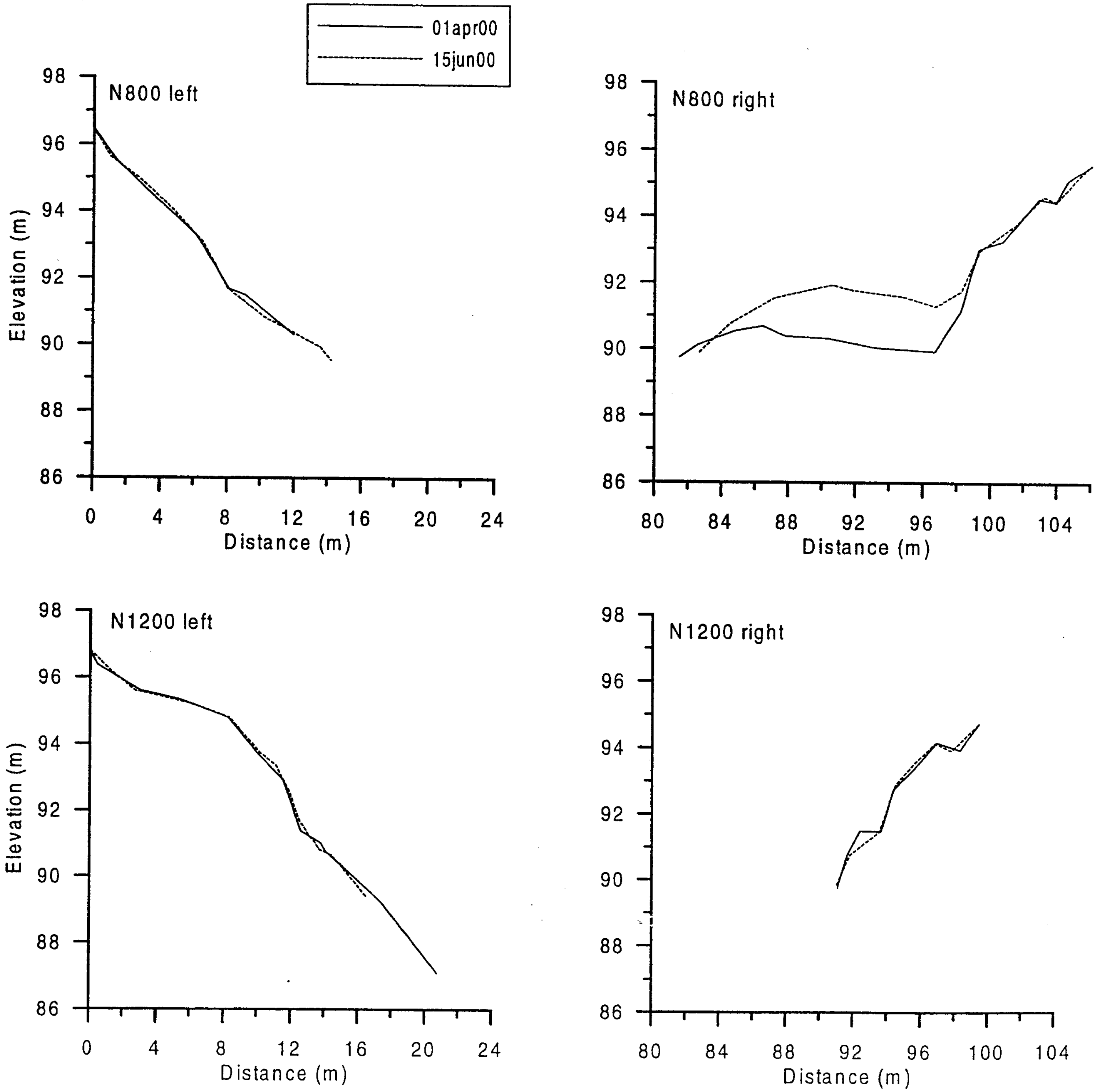


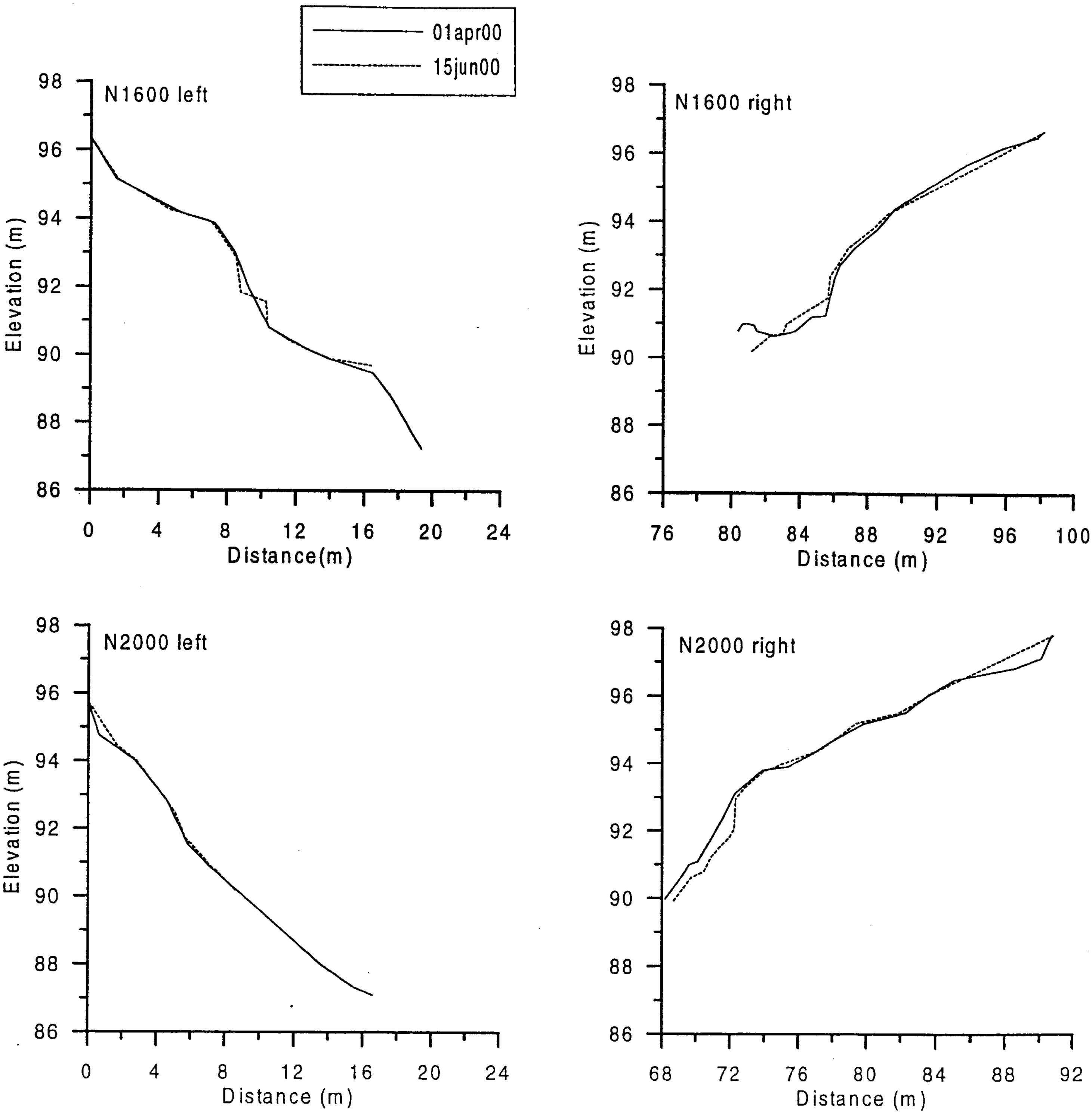
22mar00
07jun00
23aug00
12sept00
AB3 left
AB3 right
AB4 left
AB4 right
Elevation (m)
Distance (m)
878 m³/s
255 m³/s

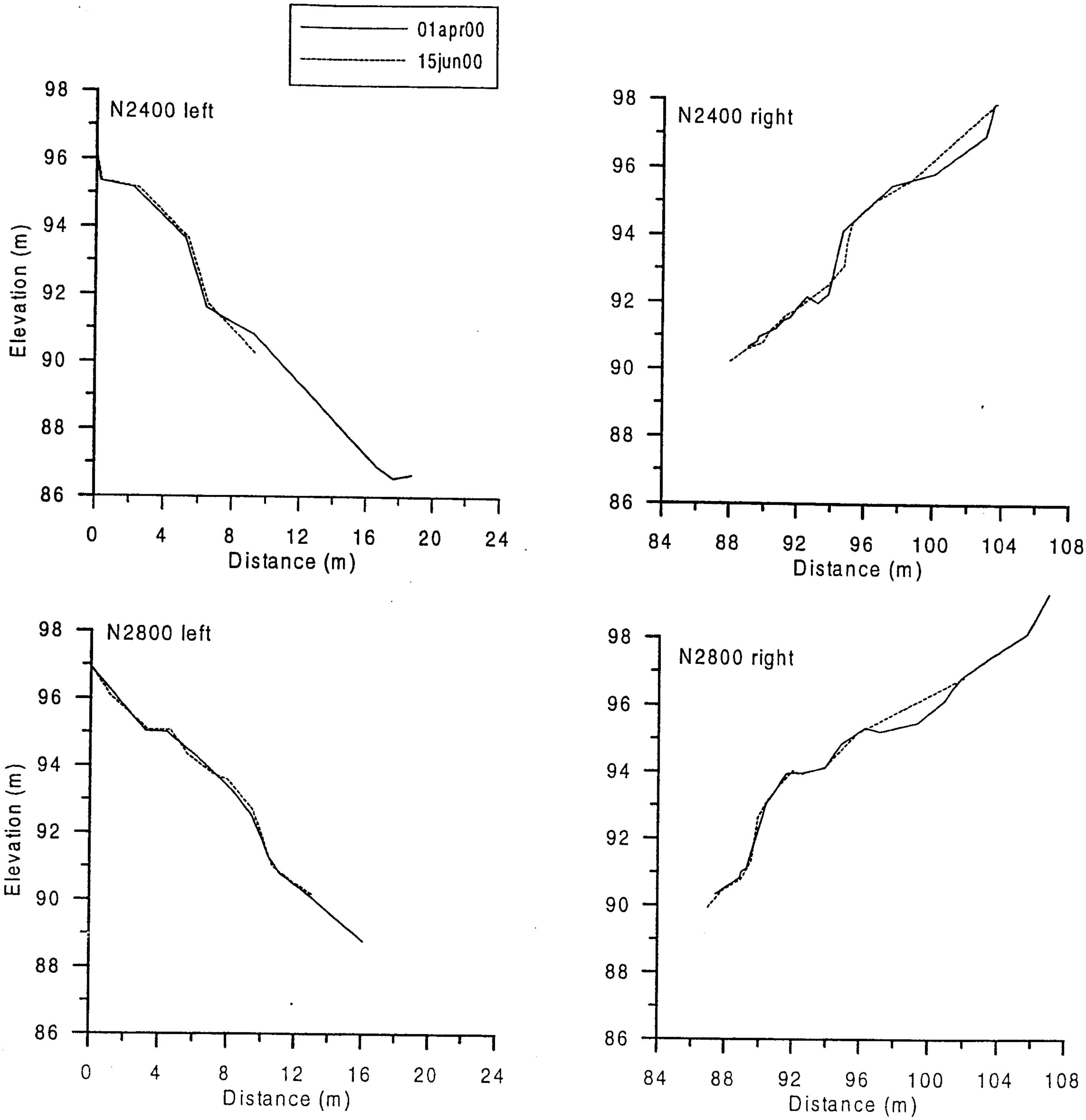

22mar00
07jun00
23aug00
12sept00
AB5 left
AB5 right
AB6 left
AB6 right
Elevation (m)
Distance (m)
878 m³/s
255 m³/s
860
862
864
866
868
4
6
8
10
12
14
16
18
20
124
126
128
130
132
134
136
138
140
22
24
26
142
144
146


22mar00
07jun00
23aug00
12sept00
AB7 left
AB7 right
AB8 left
AB8 right
878 m³/s
255 m³/s
Elevation (m)
Distance (m)
860
862
864
866
868
0 2 4 6 8 10 12 14 16
122 124 126 128 130 132 134 136 138
14 16 18 20 22 24 26 28 30


01apr00
15jun00
N0 left
N0 right
N400 left
N400 right
Elevation (m)
Distance (m)


01apr00
15jun00
N800 left
N800 right
N1200 left
N1200 right
Elevation (m)
Distance (m)
98
96
94
92
90
88
86
0
4
8
12
16
20
24
80
84
88
92
96
100
104


01apr00
15jun00
N1600 left
Elevation (m)
Distance(m)
N1600 right
Elevation (m)
Distance (m)
N2000 left
Elevation (m)
Distance (m)
N2000 right
Distance (m)



01apr00
15jun00
N2400 left
N2400 right
N2800 left
N2800 right
Elevation (m)
Distance (m)
98
96
94
92
90
88
86
0
4
8
12
16
20
24
84
88
92
96
100
104
108