5. MONITORING RIVER BED MOVEMENT

5. Monitoring River Bed Movement

5.1 Objective

The objective of the monitoring is to examine the actual effects of the test spur dikes, and to transfer the technology of monitoring of the river bed movement by on the job training.

The flow chart of the monitoring river bed movement is listed below :

FLOW CHART OF MONITORING RIVER BED MOVEMENT

DESK PLAN

* Organization
* Monitoring Scope
* Schedule
* Equipment Arrangement

SITE ARRANGEMENT

* Levelling Survey
  (T.B.M , Base Line)

MONITORING

* Cross Section Survey
* Current Measurement
* Float Tracking Survey

DATA PROCESSING

* Water Level
* Water Surface Width
* Bed Level
* Minimum Bed Level
* Average Depth

DATA OUTPUT

* Table of Fluctuation
* Cross Section
* Figure of Fluctuation

MONITORING RESULT

* Flow Regime
* Scour / Sedimentation

5.2 Monitoring Team

The 5 staff for the Team were nominated as below, dated on 08 November 1993.

Seiji Nakayama (SEPLAN)
Tatsuzo Takesita (DER-PI)
Roberto da Silva Foneca (SEPLAN)
Julio Emilio de A.L.R. Costa (SOSP)
Firmino Lopes dos Santos (FUNCPI)

In addition, 4 staff (DNOCS) with experience of a cross-section survey were arranged.

5.3 Monitoring

(1) Monitoring Item

The Monitoring is composed of 3 items as below.

* cross-section survey
* current measurement
* float tracking survey

The Monitoring plan prepared by Portuguese were attached in the Progress Report issued on March, 1994.

(2) Monitoring

The monitoring was carried out seven times during from Jan. 1994 to Jul. 1994 as listed below.

1 : 03/Feb. --- 08/Feb.
2 : 23/Feb. --- 05/Mar.
3 : 14/Mar. --- 19/Mar.
4 : 28/Mar. --- 02/Apr.
5 : 26/Apr. --- 30/Apr.
6 : 17/May --- 20/May
7 : 27/Jun. --- 02/Jul.

(3) Base Line for Cross Section Survey

Based on the Monitoring plan, the bench marks and points necessary for a cross section survey were positions at the sites. The base lines and the point levels for the sites are shown in the Progress Report issued on March, 1994..

(4) Observation Equipment

The observation equipment, including an optical odometer, fiber tape, level, transit, box scale, etc. are to be used to measure the distance and height of the river bed. The measurements of the difference in height are to be made at an interval of less than 20 m based on the elevation of the specified datum points.

In addition, optical sand surface meter will be installed to monitor the fluctuations in the river bed height at the specified points.

5.4 Optical Sand Surface Meter

(1) Introduction

The optical sand surface meter measures and records sand levels underwater, in wave zones, or on beach. Sand surface data are recorded in an internal solid state C memory and can be extracted by a hand held computer on site.

(2) Features

No-moving parts
32 Kbyte solid state IC memory data logger
61 optical sensors installed in a stainless steel rod

(3) General Description

The SPM-III is designed for precision measurement of seabed/riverbed sand surface motion. A standard configuration consists of 61 optical sensors (2.5 cm apart) planted in a groove on a rectangular stainless steel rod, sensor control, main battery and solid state IC memory data logger.

Each optical sensor consists of a pair of infra-red emitting diodes and photo Darligton transistors. Using infra-red emitting diodes eliminates the influence of suspended material. The sensors are calibrated to indicate solids at concentrations over 22,000 ppm of in a test mixture of mud and water.

The data logger features microprocessor based CMOS circuitry and a 32 Kbyte RAM. The logger has 5 modes of data sampling intervals (10, 30, 60, 120, 360 min). With 32K memory, a 60 minutes sampling interval and 61 sensors, the SPM-III can obtain up to 40 days of data. The data logger, sensor control and main battery are housed in a PVC watertight pipe (90x330 mm).

(4) Handling Manual

The English and Portuguese manuals on the operating instructions and data processing were prepared and attached to the Progress Report issued on March, 1994.

(5) Setting

Three optical sand surface meters were set up at each spur dike site during the flood season. The other 3 meters were set up during the low water season. The setting date at the sites are as below,

(Flood season)

Teresina---------- 19/Feb./1994
Uniao ---------- 19/Feb./1994
Buriti dos Lopes---- 20/Feb./1994

(Low water season)

Teresina---------- 21/Jun./1994
Crest Level : El.56.261m

Uniao ---------- 21/Jun./1994
Crest Level : El.44.350m

Buriti dos Lopes---- 20/Jun./1994
Crest Level : El. 7.054m

The sampling interval is 6 hours using the rotary switch in the position 7.

(6) Practice at Buriti dos Lopes Site

The bed level data of the meter installed near the Dike BS-7 were collected on the date of 20th September . The data transfer was attempted using the SEPLAN desk top computer with V486 * 32 MHz . After it was failured , the personal computer can get the data as listed .

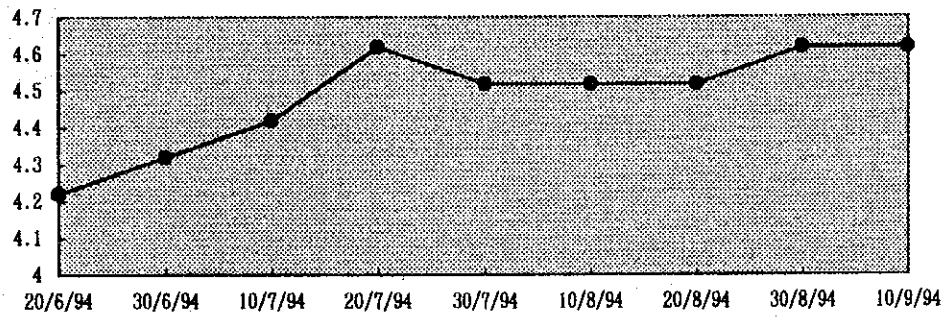
Based on these data , the fluctuation height of the point bed reached to 40 cm within a month as below :

Date	Sensor Position	Sensor's Elevation
1994/6/20	13	4.219
1994/6/30	15	4.319
1994/7/10	17	4.419
1994/7/20	21	4.619
1994/7/30	19	4.519
1994/8/10	19	4.519
1994/8/20	19	4.519
1994/8/30	21	4.619
1994/9/10	21	4.619

No.61 Sensor
Level=(7.054-0.435)=6.619

Crest Level=7.054m
Sensor Interval =5cm

Change of Bed Level measured by the Sand Surface Meter



(7) Service

Through the monitoring at the sites for this Study , the findings on the service of the optical sand surface meter were obtained as follows :

* The meter setting in the river was weak by the flowing logs hunging during the flood.

* For a traverse line in the Parnaiba river with the big channel width , the many number of the meter will be necesarry.

* The battery discharge period during long - time flood season may be improved.

* The desk-top computer with the high processing speed may miss the data transfer from the memory board.

5.5 Monitoring Output

The monitoring output for each cross section survey and current measurement is attached in Annex 1.

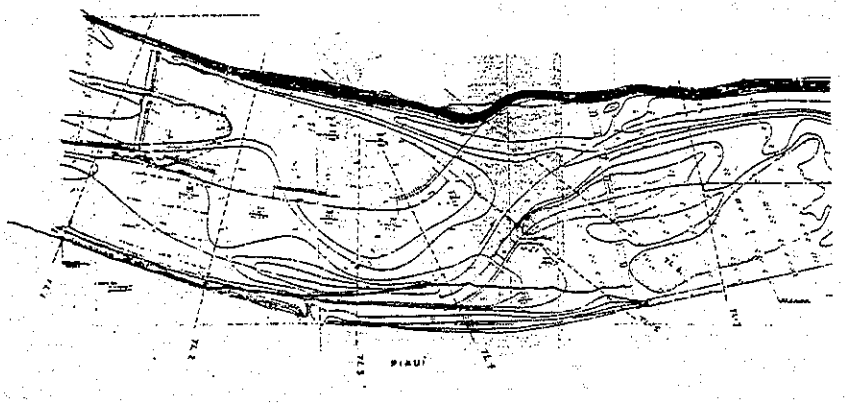
Figs. 5.1 - 5.3 show the cross section drawings illustrating the changes of bed level at the typical lines for 3 spur dikes construction sites.

5.6 Data Processing

A table showing the fluctuations in the river bed height and the magnitude thereof is to be prepared as the cross section survey result. The following items are also to be included as required.

Water level
Water surface width
River bed level at specific points
Minimum height of the river bed
Average depth
Average height of the river bed
Fluctuation in the height of the river bed

Table 5.1 lists the surface width, average and minimum depth of the river bed, and the fluctuation of the river bed at the datum water level for 3 sites. In addition, Fig 5.4 shows the change of average and minimum river bed level.



TERESINA - PI.

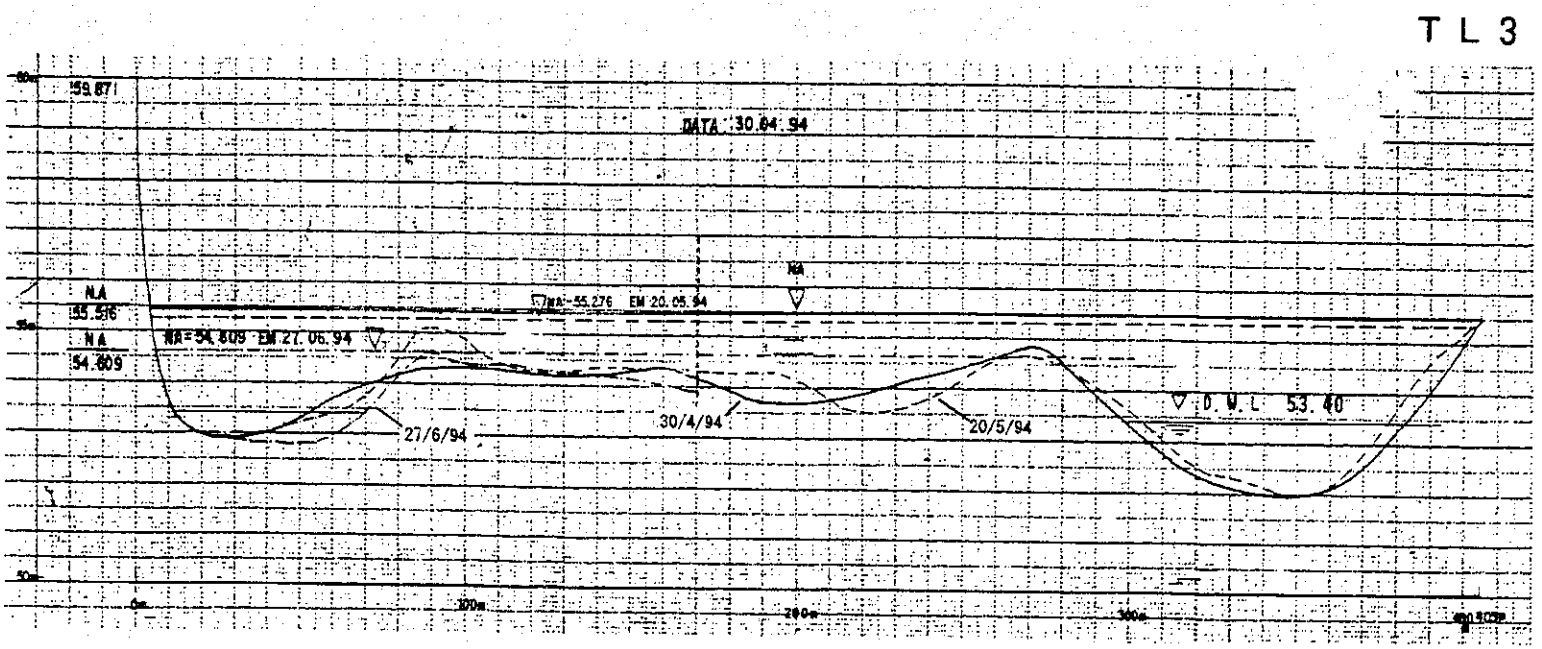
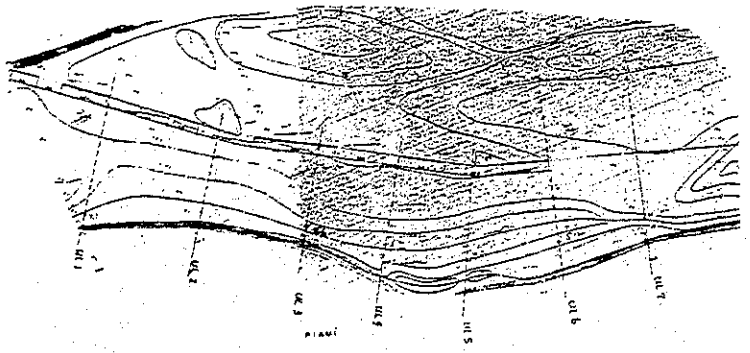


Fig. 5.1 Cross Section Drawing for Teresina



UNIÃO - PI.

U L 6

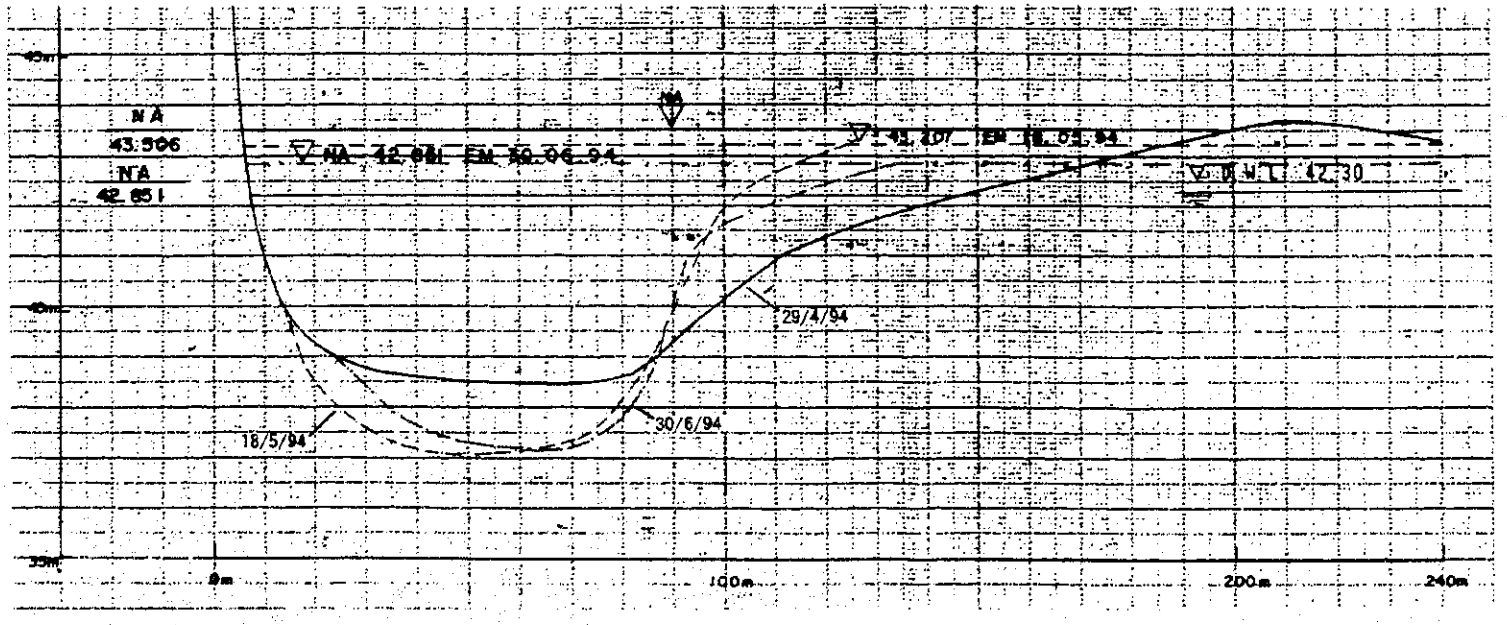
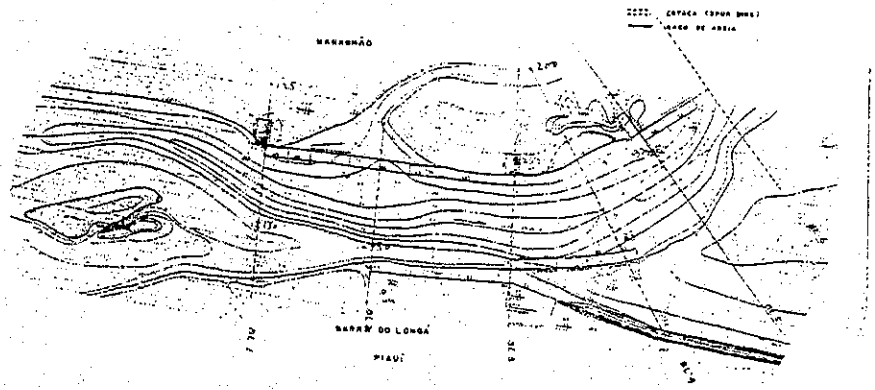


Fig. 5.2 Cross Section Drawing for Uniao



BURITI DOS LOPES - PI.

B L 6

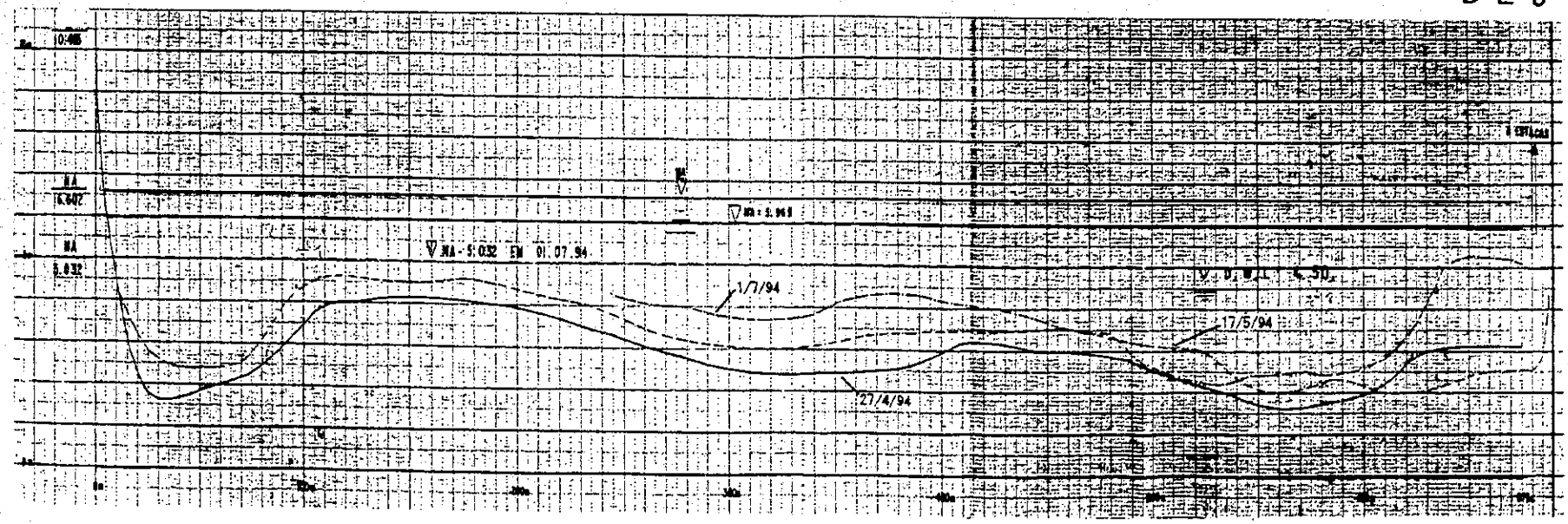


Fig. 5.3 Cross Section Drawing for Buriti dos Lopes

Table 5.1 (1) Fluctuation of River Bed for Teresina

Date	Line Number	Datum W.L. (EL.m)	Width (m)	Minimum Bed Level (EL.m)	Average B.L. (EL.m)	Preceding Width (m)	Preceding Average B.L. (EL.m)	Change (m)
3/2/94	TL1	53.40	158.18	52.00	52.31			
22/2/94			208.41	50.05	51.78	158.18	52.31	-0.53
16/3/94			180.14	52.00	52.30	208.41	51.78	0.52
28/3/94			167.22	51.30	52.03	180.14	52.30	-0.27
30/4/94			156.85	51.20	52.29	167.22	52.03	0.26
20/5/94			98.51	51.00	52.09	156.85	52.29	-0.20
27/6/94			99.31	50.09	51.99	98.51	52.09	-0.10
3/2/94	TL2	53.40	129.44	52.20	53.05			
22/2/94			63.00	53.20	53.33	129.44	53.05	0.28
16/3/94			51.86	53.00	53.20	63.00	53.33	-0.13
28/3/94			83.19	52.60	52.98	51.86	53.20	-0.22
30/4/94			197.98	52.70	53.08	83.19	52.98	0.10
20/5/94			225.62	52.20	52.93	197.98	53.08	-0.15
27/6/94			76.66	52.20	53.09	225.62	52.93	0.16
3/2/94	TL3	53.40	39.07	52.40	52.81			
22/2/94			42.86	52.30	52.73	39.07	52.81	-0.08
15/3/94			136.55	52.30	53.00	42.86	52.73	0.27
28/3/94			104.80	52.10	52.89	136.55	53.00	-0.11
30/4/94			122.54	52.00	52.69	104.80	52.89	-0.20
20/5/94			117.93	52.00	52.78	122.54	52.69	0.09
27/6/94			53.67	52.80	52.95	117.93	52.78	0.17
4/2/94	TL4	53.40	75.68	50.00	51.34			
22/2/94			86.50	51.50	51.98	75.68	51.34	0.64
16/3/94			62.42	51.30	52.25	86.50	51.98	0.27
28/3/94			137.92	51.90	52.68	62.42	52.25	0.43
30/4/94			45.29	52.90	53.13	137.92	52.68	0.45
20/5/94			49.02	52.00	52.55	45.29	53.13	-0.58
27/6/94			60.40	52.70	52.97	49.02	52.55	0.42
4/2/94	TL5	53.40	145.23	52.40	52.74			
23/2/94			122.85	52.00	52.47	145.23	52.74	-0.27
16/3/94			130.29	52.00	52.66	122.85	52.47	0.19
28/3/94			319.49	52.50	52.81	130.29	52.66	0.15
30/4/94			190.87	52.50	52.81	319.49	52.81	0.00
20/5/94			33.52	52.60	53.00	190.87	52.81	0.19
27/6/94	TL6	NO MEASURED				33.52	53.00	-53.00
4/2/94		53.40	56.24	52.00	52.66			
20/2/94			185.29	51.70	52.57	56.24	52.66	-0.09
16/3/94	TL7	53.40	136.20	51.80	52.63			
28/3/94			185.95	51.50	52.57	136.20	52.63	-0.06
30/4/94			154.40	52.00	52.63	185.95	52.57	0.06
20/5/94			155.23	52.10	52.76	154.40	52.63	0.13
27/6/94			145.28	51.20	52.55	155.23	52.76	-0.21

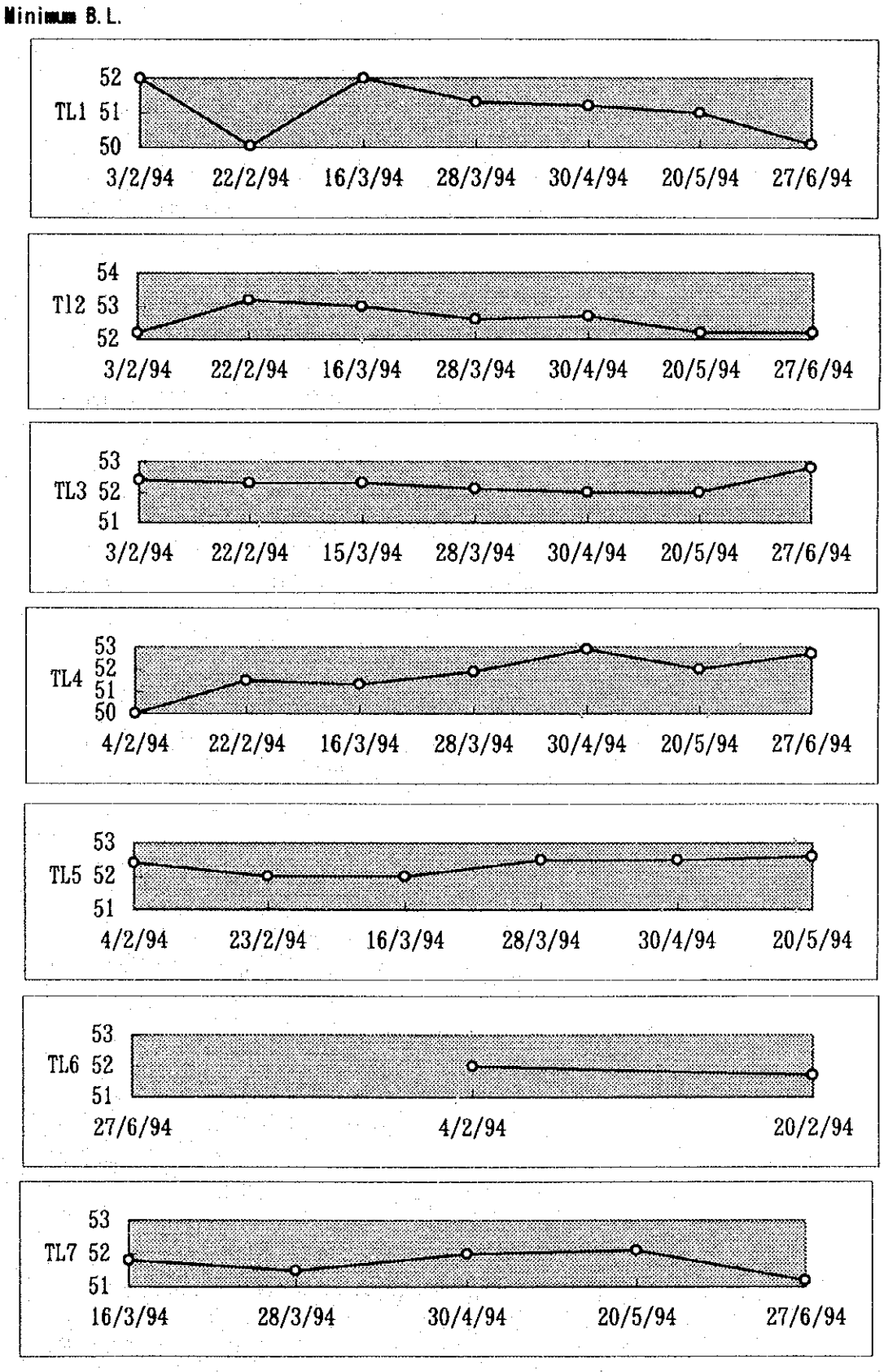


Fig. 5.4 (1) Time Series Changes of Bed Level for Teresina

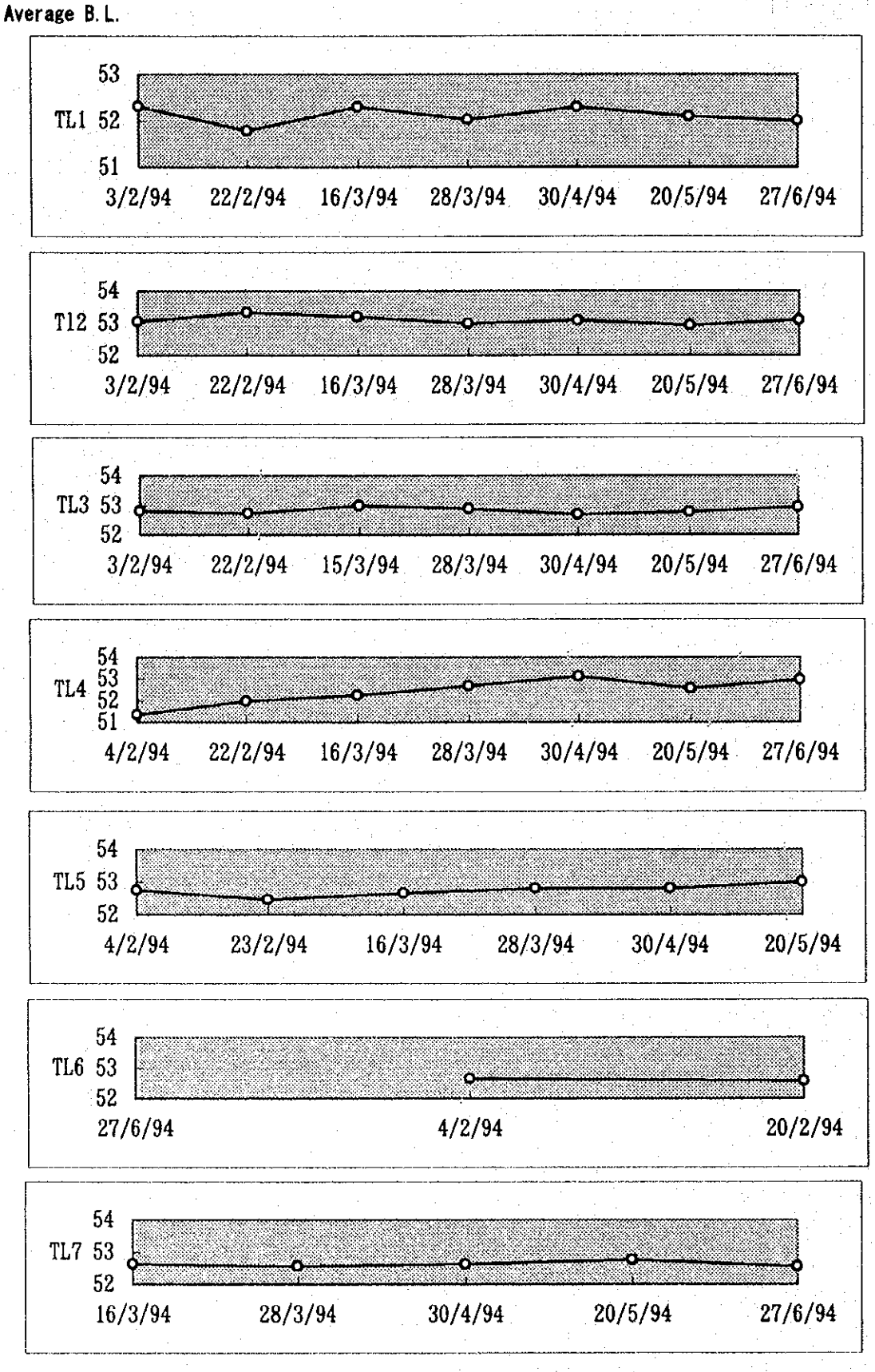


Fig. 5.4 (1) Time Series Changes of Bed Level for Teresina

Table 5.1 (2) Fluctuation of River Bed for Uniao

Date	Line Number	Datum W.L. (EL.m)	Width (m)	Minimum Bed Level (EL.m)	Average B.L. (EL.m)	Preceding Width (m)	Preceding Average B.L. (EL.m)	Change (m)
5/2/94	UL1	42.30	228.54	40.10	41.34			
4/3/94			376.90	39.40	41.19	228.54	41.34	-0.15
17/3/94			357.85	40.10	41.21	376.90	41.19	0.02
26/3/94			265.22	40.30	41.26	357.85	41.21	0.05
28/4/94			341.39	40.00	40.85	265.22	41.26	-0.41
18/5/94			326.04	40.20	40.93	341.39	40.85	0.08
29/6/94			342.11	40.10	41.17	326.04	40.93	0.24
5/2/94	UL2	42.30	227.69	38.80	40.92			
3/4/94			148.36	39.10	41.10	227.69	40.92	0.18
17/3/94			234.77	39.10	40.98	148.36	41.10	-0.12
26/3/94			243.37	39.00	41.06	234.77	40.98	0.08
28/4/94			281.24	39.70	41.18	243.37	41.06	0.12
18/5/94			282.63	39.70	41.01	281.24	41.18	-0.17
29/6/94			264.30	40.10	41.09	282.63	41.01	0.08
5/2/94	UL3	42.30	244.03	38.60	40.72			
4/3/94			123.04	38.70	40.03	244.03	40.72	-0.69
17/3/94			193.05	38.90	40.96	123.04	40.03	0.93
26/3/94			148.48	39.00	40.62	193.05	40.96	-0.34
28/4/94			234.00	39.00	40.92	148.48	40.62	0.30
18/5/94			211.28	39.30	40.89	234.00	40.92	-0.03
29/6/94			194.57	38.90	40.73	211.28	40.89	-0.16
5/2/94	UL4	42.30	212.72	40.60	41.01			
4/3/94			160.66	40.30	41.05	212.72	41.01	0.04
18/3/94			154.39	40.20	41.10	160.66	41.05	0.05
26/3/94			164.99	39.60	40.43	154.39	41.10	-0.67
28/4/94			163.43	39.40	40.63	164.99	40.43	0.20
18/5/94			122.95	37.80	39.04	163.43	40.63	-1.59
30/6/94			305.71	38.60	41.28	122.95	39.04	2.24
6/2/94	UL5	42.30	115.02	40.90	41.80			
4/3/94			277.99	40.90	41.58	115.02	41.80	-0.22
17/3/94			297.29	41.00	41.37	277.99	41.58	-0.21
26/3/94			278.30	39.50	41.03	297.29	41.37	-0.34
28/4/94			133.76	38.60	39.83	278.30	41.03	-1.20
18/5/94			103.75	37.50	39.08	133.76	39.83	-0.75
30/6/94			117.23	37.30	39.92	103.75	39.08	0.84
6/2/94	UL6	42.30	227.86	40.30	41.40			
5/3/94			342.08	40.40	41.59	227.86	41.40	0.19
18/3/94			288.31	40.20	41.36	342.08	41.59	-0.23
26/3/94			288.22	40.50	41.32	288.31	41.36	-0.04
29/4/94			145.91	38.40	39.82	288.22	41.32	-1.50
18/5/94			97.28	37.10	38.73	145.91	39.82	-1.09
30/6/94			114.27	37.20	39.23	97.28	38.73	0.50

Table 5.1 (2) Fluctuation of River Bed for Uniao

6/2/94	UL7	42.30	123.38	38.70	40.70			
6/3/94			182.28	39.40	41.41	123.38	40.70	0.71
18/3/94			286.45	39.70	41.32	182.28	41.41	-0.09
26/3/94			103.19	40.30	41.33	286.45	41.32	0.01
29/4/94			165.66	38.40	40.37	103.19	41.33	-0.96
18/5/94			176.97	38.50	40.47	165.66	40.37	0.10
30/6/94			176.13	38.10	40.40	176.97	40.47	-0.07

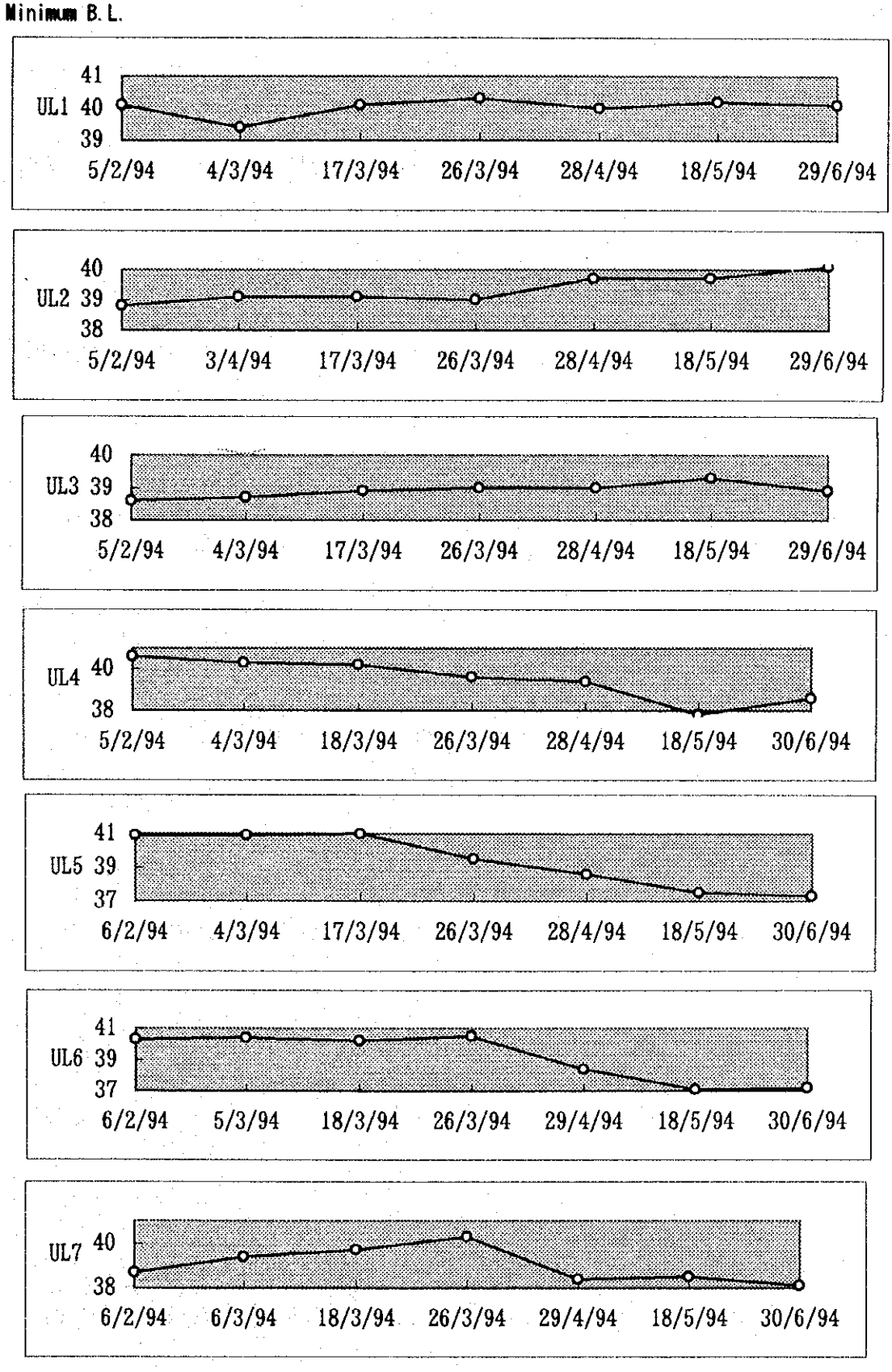


Fig. 5.4 (2) Time Series Changes of Bed Level For Uniao

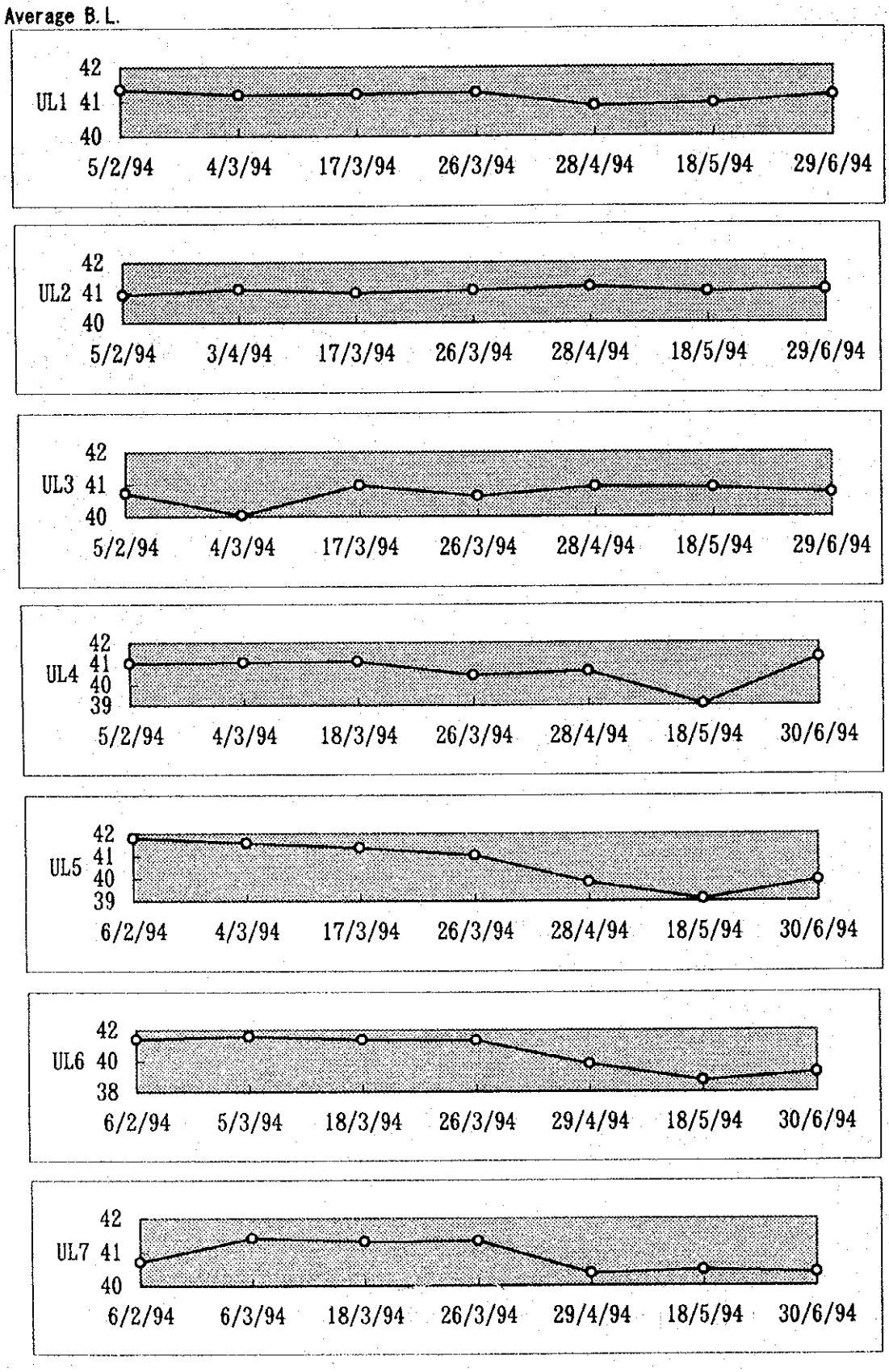


Fig. 5.4 (2) Time Series Changes of Bed Level For Uniao

Table 5.1 (3) Fluctuation of River Bed for Buriti dos Lopes

Date	Line Number	Datum W.L. (EL.m)	Width (m)	Minimum Bed Level (EL.m)	Average B.L. (EL.m)	Preceding Width (m)	Preceding Average B.L. (EL.m)	Change (m)
7/2/94	BL1	4.50	236.04	2.90	3.88	457.45	3.21	0.67
1/3/94			363.27	1.30	3.22	236.04	3.88	-0.66
24/3/94			395.76	1.50	2.77	363.27	3.22	-0.45
26/4/94			390.20	0.40	1.78	395.76	2.77	-0.99
17/5/94			394.73	1.50	2.40	390.20	1.78	0.62
1/7/94			172.13	1.20	2.15	394.73	2.40	-0.25
7/2/94	BL2	4.50	231.50	1.80	2.48	495.22	3.22	-0.74
1/3/94			301.33	1.60	2.69	231.50	2.48	0.21
24/3/94			354.75	1.50	2.48	301.33	2.69	-0.21
26/4/94			387.12	0.20	1.50	354.75	2.48	-0.98
17/5/94			376.59	1.20	1.97	387.12	1.50	0.47
1/7/94			379.10	1.10	2.30	376.59	1.97	0.33
7/2/94	BL3	4.50	212.41	0.50	2.37			
1/3/94			335.49	1.80	3.01	212.41	2.37	0.64
24/3/94			351.83	2.00	2.85	335.49	3.01	-0.16
26/4/94			408.83	0.30	1.42	351.83	2.85	-1.43
17/5/94			397.53	1.40	2.47	408.83	1.42	1.05
1/7/94			397.67	1.90	2.85	397.53	2.47	0.38
7/2/94			348.59	1.70	3.13	397.67	2.85	0.28
1/3/94	BL4	4.50	323.88	2.10	3.36	348.59	3.13	0.23
24/3/94			320.67	2.40	3.11	323.88	3.36	-0.25
26/4/94			613.32	0.70	2.43	320.67	3.11	-0.68
17/5/94			466.31	2.20	3.05	613.32	2.43	0.62
1/7/94			495.22	2.20	3.22	466.31	3.05	0.17
8/2/94	BL5	4.50	215.75	2.90	3.61	379.10	2.30	1.31
2/3/94			187.96	3.00	3.70	215.75	3.61	0.09
25/3/94			498.97	2.70	3.46	187.96	3.70	-0.24
27/4/94			702.00	1.00	2.44	498.97	3.46	-1.02
17/5/94			622.97	2.00	2.95	702.00	2.44	0.51
1/7/94			457.45	2.50	3.21	622.97	2.95	0.26
8/2/94	BL6	4.50	85.36	2.30	3.28	172.13	2.15	1.13
2/3/94			119.17	2.70	3.44	85.36	3.28	0.16
25/3/94			114.57	2.70	3.53	119.17	3.44	0.09
27/4/94			663.36	1.60	2.81	114.57	3.53	-0.72
17/5/94			592.38	2.00	3.10	663.36	2.81	0.29
1/7/94			498.24	2.30	3.54	592.38	3.10	0.44

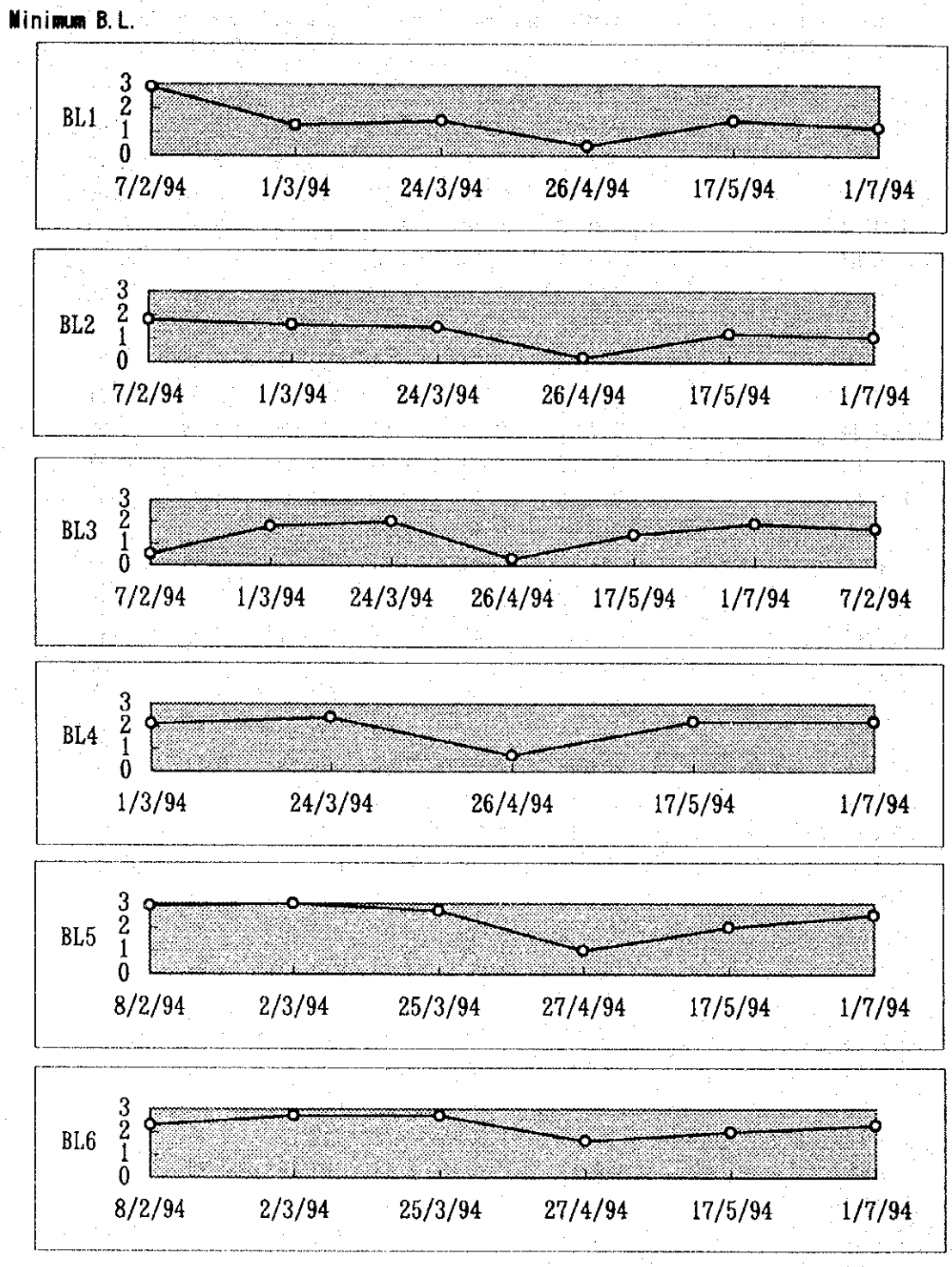


Fig. 5.4 (3) Time Series Changes of Bed Level for Buriti dos Lopes

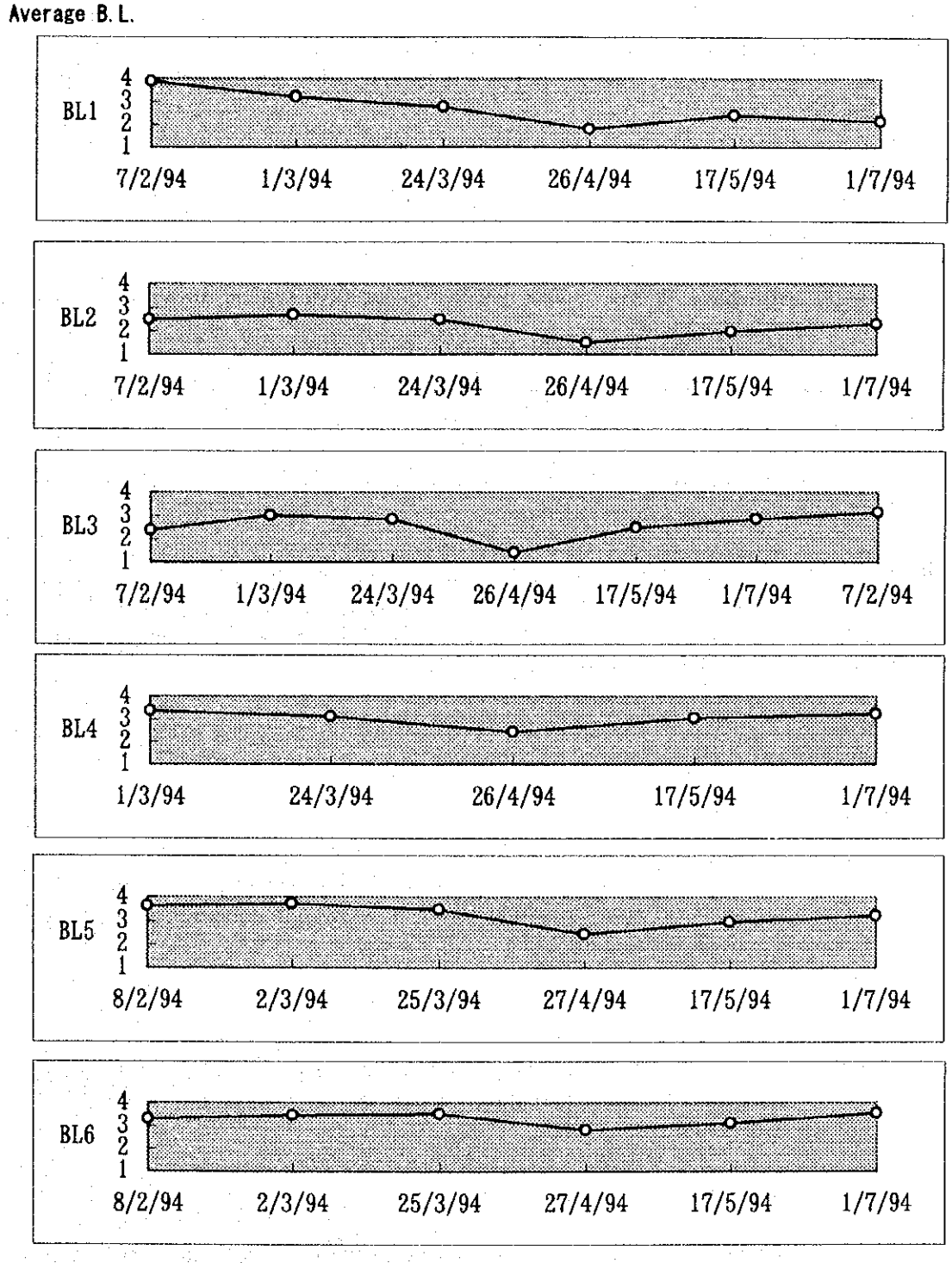


Fig. 5.4 (3) Time Series Changes of Bed Level for Buriti dos Lopes

5.7 Monitoring Result

Based on the monitoring output , data processing and site inspection , the monitoring result as to the flow regime , scouring and sedimentation for the respective dike sites are as below ;

Teresina :

(1) Flow Regime

From the float tracking survey , Annex 4 indicates the flow regime from the Section TL-1 to the new bridge piers .

The observation on 23th Feb. 1994 indicates that the flow was along the right bank side of the channel .

During the observation on 15th March , the flow shifted the left side after the Dike TS-3 with the water level of El. 57.14 m .

On 20th May , the float thrown near the Dike TS-1 moved between the Dikes TS-2 and TS-3 . Another float thrown near the right bank moved between the Dikes TS-3 and TS-4 after the TS-3 . The water level was El. 53.35 m . The level of sand bar formed after the Dike TS-4 was above El. 55.5 m .

On 27th June , the flow was between the Dikes TS-2 and TS-3, and thereafter , was along the left bank side .

(2) Scouring and Sedimentation

Annex 5 shows the time series variation diagrams as to the river bed level along each traverse line on the date of observation and Annex 6 shows the condition of scouring and sedimentation along each traverse line.

* Line TL-2 :

Sedimentation was observed around the right bank of the Dike on 3th Feb. 1994 after the construction of the Dike and, thereafter, the time series changes until the end of June were not remarkable.

* Line Tl-3, TL-4 , Tl-5 :

The bed level changes were not so large on the right bank of traverse lines TL-3 and TL-4.

On the downstream side of Dike TS-4, the river bed rose as can be seen obviously from the variation diagram along the line TL-5, and it is higher than the initial bed level by approx. 2.5 m. The river bed has been stable after the first observation without so large time series changes. During the site survey in June, it was confirmed that sedimentation was ranging to the bridge piers on the downstream side. (Picture 3)

Sedimentation was confirmed on the downstream side of the left bank of Dike TS-3 and a low channel was formed between Dikes TS-2 and TS-3. (Picture 2) As the result of supplementary measurement, the maximum scouring depth was approx. 1.5 m.

* Line TL-7 :

Along traverse line TL-7 on the downstream side of the piers, sedimentation was found during the fourth observation on 28th March but the scouring from the initial river bed was confirmed during the subsequent observation. A large flood had occurred on 18th April before that observation.

Fig. 5.5 shows the contour map of the river bed around the site .

Derived from the current measurement , the discharge at the time of the monitoring date ranged from 600 m3/s to 1,400 m3/s listed in Table 5.2 .

Table 5.2 Discharge Volume

Teresina

Date	Section	Water Level	A(m2)	Average V(m/s)	Q(m3/s)
3-Feb	T1-1	55.00			
23-Feb	T1-3	56.32	1003	0.926	929
16-Mar	T1-2	57.15	1352	1.058	1430
28-Mar	T1-2	56.39	1118		
30-Apr	T1-2	55.58	474		
20-May	T1-2	55.54	893	0.872	779
27-Jun	T1-1	54.60	397	1.572	624

Uniao

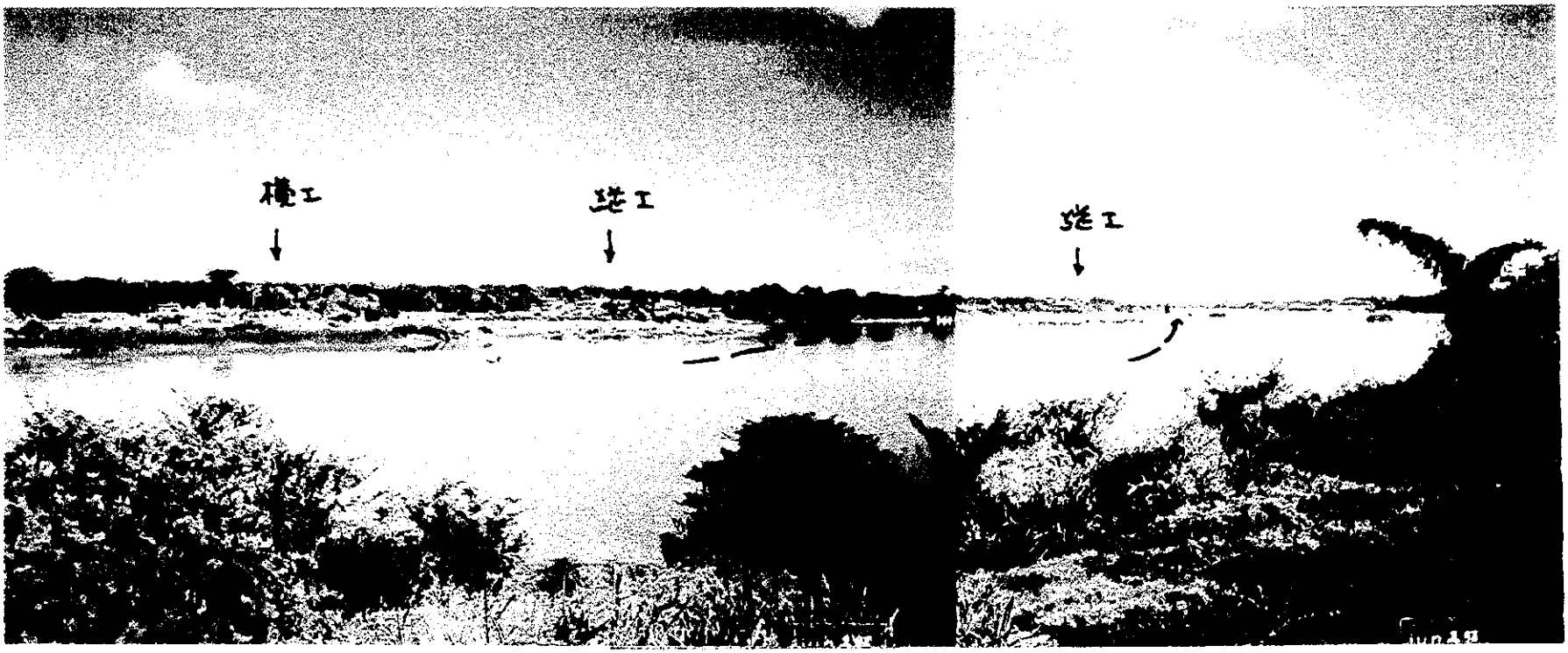
Date	Section	Water Level	A(m2)	Average V(m/s)	Q(m3/s)
6-Feb	U1-5	43.50			
4-Mar	U1-1	44.62	1315		
17-Mar	U1-1	45.24	1541	0.920	1418 *
26-Mar	U1-5	44.20	1017	0.927	943 *
28-Apr	U1-5	43.50	625	1.222	764
18-May	U1-5	43.25	574	1.062	610 *
30-Jun	U1-5	42.88	473	1.448	685

* Velocity assumed Tracking Survey

Buriti dos Lopes

Date	Section	Water Level	A(m2)	Average V(m/s)	Q(m3/s)
7-Feb	B1-1	6.20			
2-Mar	B1-1	6.15	1095	0.784	858
24-Mar	B1-1	7.42	1889	0.987	1864
26-Apr	B1-1	7.39	2233	1.123	2508
17-May	B1-1	6.75	1738	0.783	1361
1-Jul	B1-1	5.10	800	1.295	1036

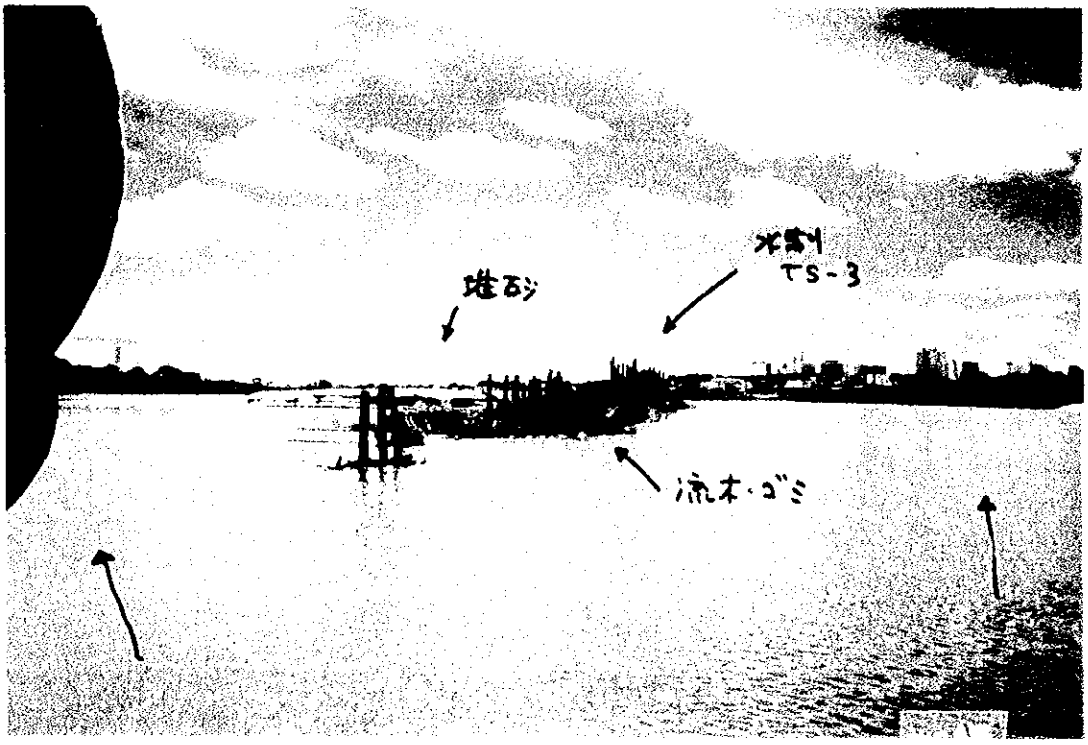
Picture 1



Overview downstream from the right bank at Teresina

Two waterways formed by Dike TS-3

Picture 2



Upstream waterway and the sedimentation around Dike TS-3
(right side : Teresina)

Picture 3

Sedimentation developed Dike TS-4 to the new bridge piers

Sedimentation level : El. 55.5 m

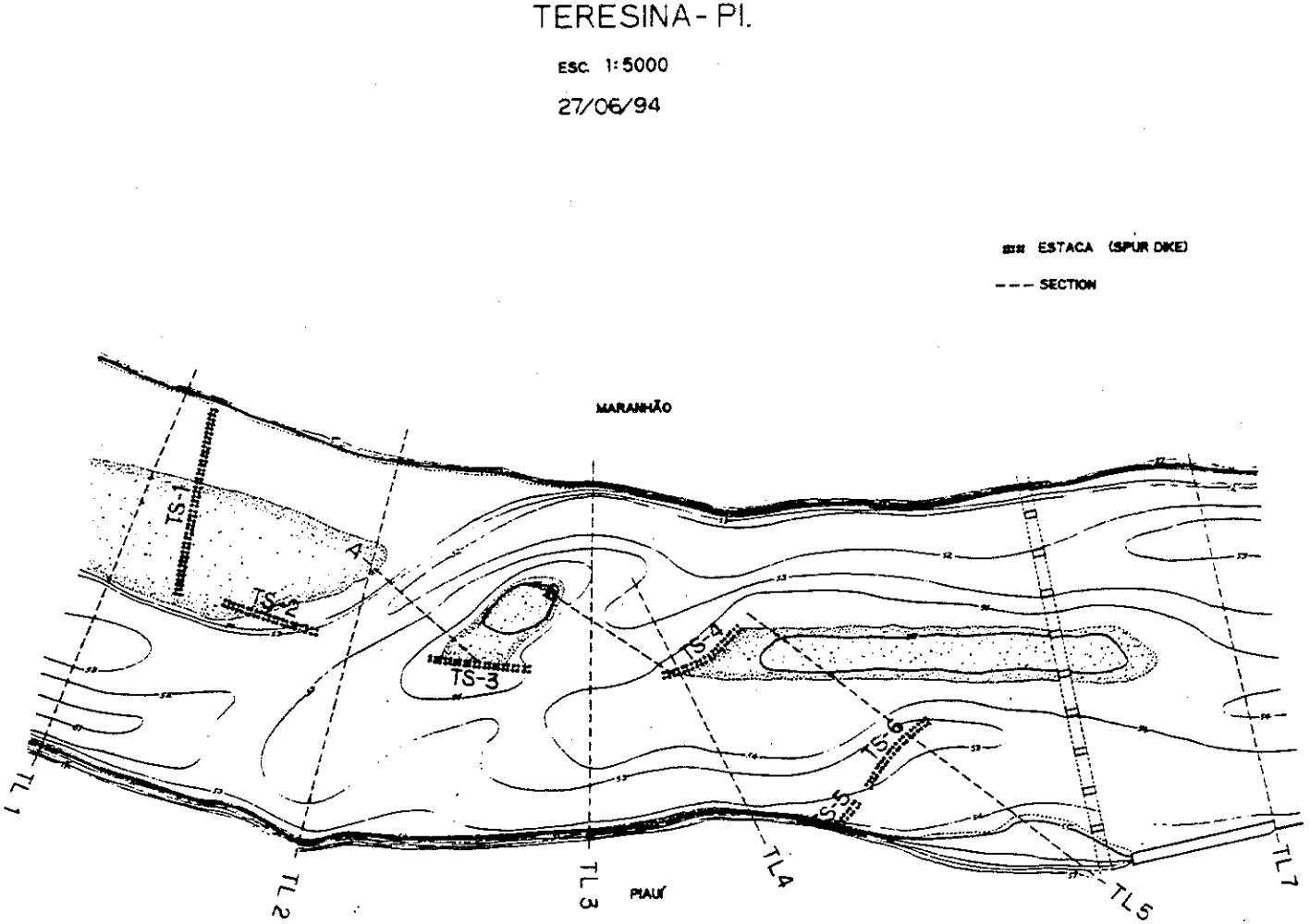


Fig. 5.5 Contour Map of Bed Level (Teresina)

Uniao :

(1) Flow Regime

Annex 4 shows the flow regime from the Sections UL-1 to UL-6 .

As a whole , the float moved nearest the right bank at the Section UL-3 .

On 25th Feb. and 14th Mar. , the float shifted away from the right bank after the Section UL-3 .

During the observations on 29th Apr. , 18th May and 29th Jun., the float moved along the right bank. The float shifted away from the right bank on 29th June .

(2) Scouring and Sedimentation

Annex 5 shows the time series variation diagrams as to the river bed level along each traverse line on the date of observation and Annex 6 shows the condition of scouring and sedimentation along each traverse line.

* Line UL-1 , UL-2 :

Sedimentation of approx. 0.9 - 2.8 m was observed in the main channel (on the right bank side) after the construction of the Dike, and scouring of approx. 1.5 m was seen around the Dike.

The sand bag dikes of US-1 and US-2 were washed away .

Along the left side of Line UL-2 , the scouring had changed into the sedimentation after the observation of 26th March. As for the reason for this phenomenon, it is considered that the sedimentation advanced on the left bank on the downstream side of this traverse line and it became an influence on the upstream side.

* Line UL-3 :

Sedimentation occurred behind Dike US-4 and there was scouring along the front edge of the sand bar . The maximum scouring depth from the initial river bed was approx. 2.1 m .

* Line UL-4 :

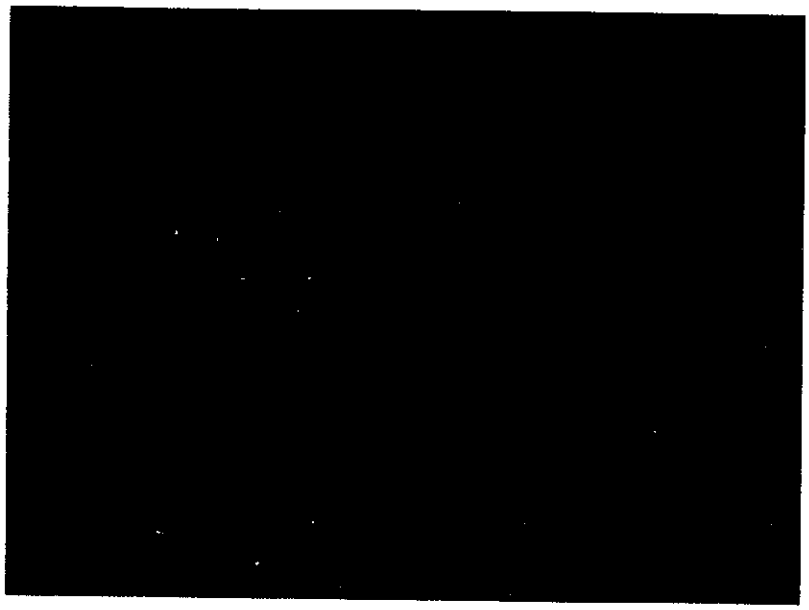
The part of the scouring from the initial river bed level has moved to the right bank side as time elapsed.

* Line UL-5 :

Sedimentation on the initial river bed in the water course can be seen from the variation diagram. In the photos taken during the site survey in June 1993, a sand bar with an elevated river bed was confirmed in the water course . Therefore, it is

considered that such a sand bar has been neglected because the initial river bed was too low due to a mistake in recording of the measurement.

Along the left bank side of the Dike , sedimentation of approx. 1.8 m on the initial riverbed was found.



* Line UL-6 :

The depth of scouring on the right bank side increased after 26th March , it became 2.7 m on 28th April and thereafter it became 3 m on June 30. The area of scouring extended to approx. 70 m from the right bank by 30th June. Conversely, the area of sedimentation has moved toward the Dike US-6 side. The sedimentation behind the Dike had reached a height of 1.3 m by 5th March .

* Line UL-7 :

Sedimentation was seen around the extension line of the Dike US-6 since observations were started on 6th February. The area of scouring is located at a distance of 50 m from the extension line of the Dike toward the Piauí side. The maximum scouring depth from the initial bed level in that area is 2.0 m. Fig. 5.6 shows the contour map of the river bed around Uniao site .

Based on the current measurement , the discharge of the monitoring date ranged from 600 m3/s to 1400 m3/s (Table 5.2). On the date of 30-Jun , the average velocity is recorded 1.448 m/s with maximum 2.174 m/s and minimum 0.714 m/s at the traverse line UL-5 . At the line UL-5 , the discharge is derived about 685 m3/s with an elevation 42.88 m of the water level . At the datum water level (El. 42.30 m) ,the discharge capacity is about 400 m3/s exceeding 250 m3/s of the capacity surveyed in June 1993 .

Picture 4

Maranhao side overview from Uniao slipway

Sedimentation induced by the spur dike on the Maranhao side
Water level : El. 42.99 m

Picture 5

Upstream view from the edge of Uniao spur dike site

Non-visual Dike US-5 ,US-6 under the sands
Sedimentation level : El. 43.5 m

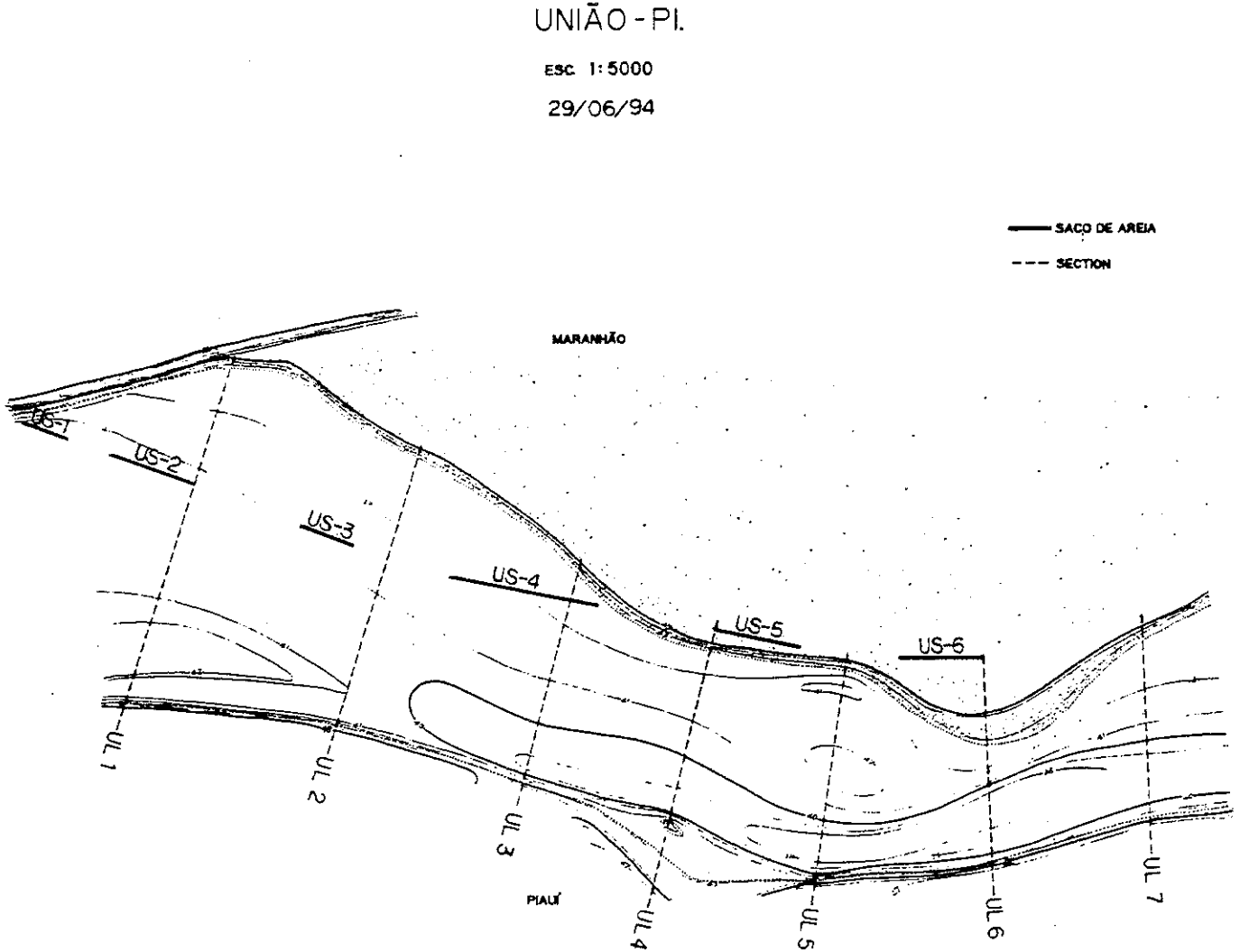


Fig. 5.6 Contour Map of Bed Level (Uniao)

Buriti dos Lopes :

(1) Flow Regime

Annex 4 shows the flow regime based on the float tracking survey .

The float moved along the low water course existed during the survey in 1993 until the Section BL-3 . On 2nd Mar. the float moved into the left side of the waterway after the Section BL-3 .

During the observations on and after 24th Mar. , the float shifted into the center of the waterway .

(2) Scouring and Sedimentation

Annex 5 shows the time series variation diagrams as to the river bed level along each traverse line on the date of observation and Annex 6 shows the condition of scouring and sedimentation along each traverse line.

* Line BL-1 :

Sedimentation on the front side of the Dikes BS-2 and BS-3 as measured between the observations on 7th February and that on 24th March was approx. 2 m as compared with the initial bed level .

At the location of the Dike, scouring had advanced by the time of observation on 26th April , where the maximum scouring depth was approx. 3 m. During the observation on 1st July in the dry season, it was found that the river bed level had recovered to the initial bed level. On the right bank of the Piauí side, scouring of approx. 2 to 3 m from the initial river bed level was found.

* Line BL-2 :

Scouring occurred generally on the left bank side of the Dike BS-4 location with a maximum scouring depth of 3 m.

* Line BL-3 :

Scouring of 3 m or more from the initial river bed level was recorded at the location of the Dike BS-5 .

* Line BL-4 :

Scouring parts concentrated around the left side of the water course , where the maximum scouring depth from the initial river bed level reached 3 m.

* Line BL-5 :

Sedimentation areas concentrated in the location of the Dikes BS-6 and BS-7 , where the maximum sedimentation height on the initial river bed level reached approx. 3 m.

Scouring concentrated on the right bank side of the water course , where the depth was approx. 2 m.

* Line BL-7 :

Sedimentation was found only downstream of the Dike BS-7 with a height of 3 m or more.

Scouring occurred on the right bank side of the water course . The thalweg moved to the center of the river channel as compared with the initial condition . The maximum scouring depth was approx. 3 m.

Fig. 5.7 shows the contour map of the river bed around Buriti dos Lopes site .

The discharge surveyed in the monitoring ranges from 850 m3/s to 2,500 m3/s (Table 5.2). Compared with the discharges dated on 27-Jun at Teresina site and dated on 30-Jun at Uniao site , the discharge value of 1,040 m3/s on 1-Jun is seemed to be reasonable in the veiw of catchment ratio .

Picture 6

Overview of Dike BS-6,BS-7 at Buriti dos Lopes site

Sedimentation induced by the dike

Picture 7

Sedimentation developed downstream from Dike BS-7

Water flow course pushed aside the channel side
Sedimentation level : El. 5.5 m

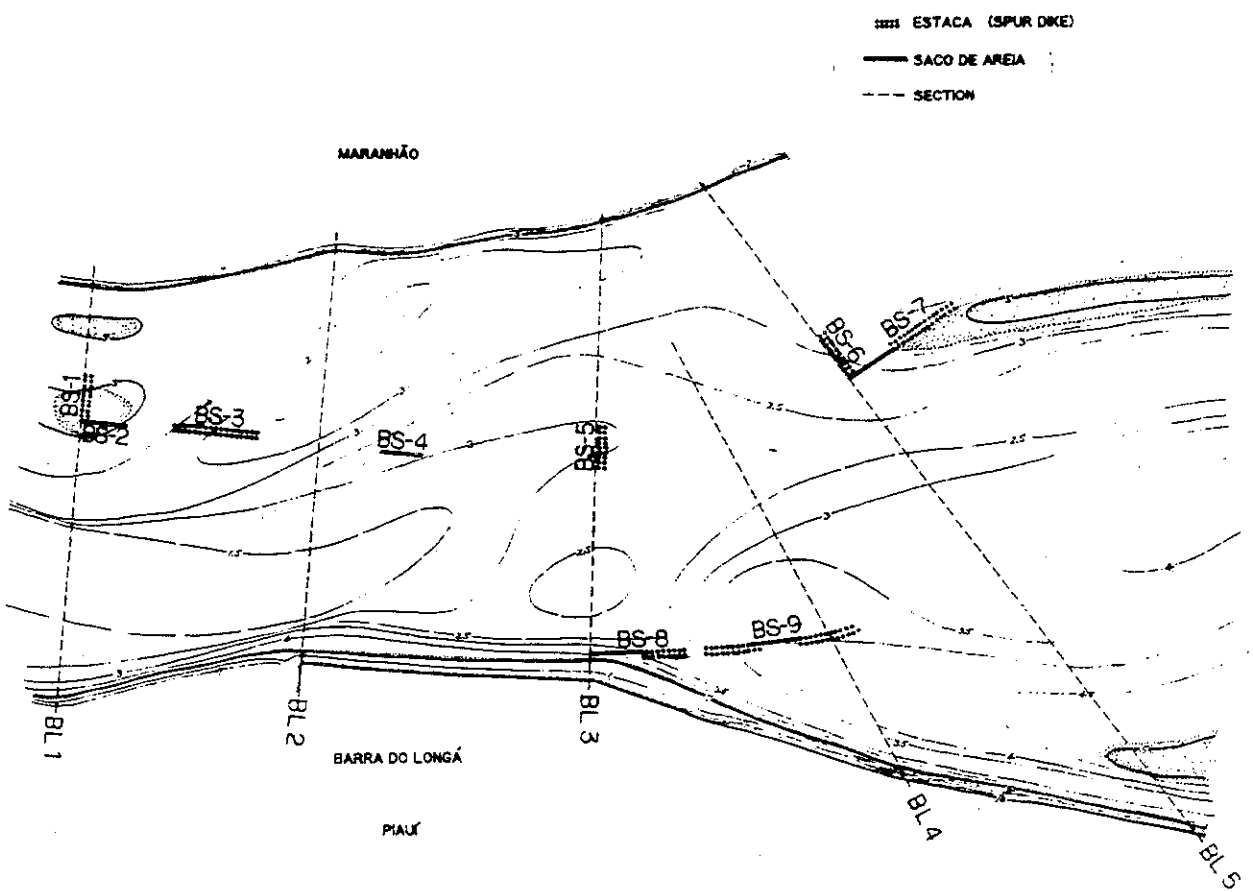


Fig. 5.7 Contour Map of Bed Level (Buriti dos Lopes)

5.8 Summary Result of the Test Spur Dikes Construction

5.8.1 Results

From the monitoring results, the result of the dikes construction is summarized as below;

Teresina :

(1) Sedimentation ,Dike TS-4 to the new bridge piers

The level of sedimentation is above El. 55.5, the height being about 1.6 m. Compared with the river bed condition of June 1993 ,sedimentation from TS-4 connects the piers and caused a 2 to 2.5 m increase in height (Picture 3).

(2) New divided waterway by the sedimentation

By the sedimentation of the left side of Dike TS-3, a waterway with a 100 m surface width upstream the dike and another waterway with 135 m width downstream the dike are formed (Picture 1). For the new waterway between TS-2 and TS-3, a draft depth above 1 m and a 40 m width can be ensured at the datum water level El. 53.4 m.

(3) Change of the water course existing during low water, 1993

The low water course existing in 1993 could not be determined. The interval of Dikes TS-2 to TS-4 was not efficient. The sedimentation downstream of Dike TS-4 was predominant.

(4) Different direction of sand bars formed near Dikes

The direction of sand bars near Dikes TS-2 and TS-3 is different from that after Dike TS-4 .

It can be supposed that the flow regime of the flow direction and discharge scale is different in the forming of sand bars near the Dikes .

Uniao :

(1) The low water course existing in 1993 is still on the same side (Picture 4).

(2) The average river bed level was lower according to the cross sections and the fluctuation of Table 5.1. Especially, the minimum bed level of the section UL-4 to UL-7 is down .

(3) The sand bar near the section UL-5 has disappeared.

(4) Sedimentation on the left side of Dikes US-3 to US-6 is remarkable. The Sedimentation height is above 1.8 m behind the dike , compared with the bed level measured in June 1993.

(5) Dikes US-5 and US-6 are covered by the sand . The remark of Dikes US-1, US-2 is not clear. Dikes US-3, US-4 are still visible.

(6) The degradation is caused by the spur dike construction. At the section UL-5, the fluctuation of bed level between 17/3/94 and 30/6/94 is remarkble. The discharge capacity at the datum level is almost 400 m3/s exceeding 250 m3/s of the capacity surveyed in June 1993. Concentration of the running water in the waterway can ensure the degradation.

Fluctuation at UL-5 , Uniao Site

Date	Channel Width (M)	Area (M2)	A.B. Level (El.m)	Water Depth (M)
17/3/94	297	278	41.37	0.93
26/3/94	278	354	41.03	1.27
28/4/94	134	330	39.83	2.47
18/5/94	104	334	39.08	3.22
30/6/94	117	278	39.92	2.38

Buriti dos Lopes :

(1) Sedimentation behind Dikes BS-8, BS-9 is remarkable. According to the cross section BL-4, the height reaches El. 5.2 m , compared with the bed level El. 4.0 measured in June 1993.

(2) The bed level around the Maranhão side along section BL-1 , BL-2, BL-3 is deeper than the level measured in June 1993. It is considered that the tractive force at the time of the flood scoured the river bed.

(3) Sedimentation downstream of Dike BS-7 is remarkable. The height reaches above 5 m. The result is that the water flow direction around the end of Dike BS-7 has changed toward the center of the channel. The bed level is deeper than that of the 1993 survey due to scouring. The changed waterway is useful for navigation .

(4) Large scale erosion in the sand bar upstream of Dike BS-1 has spread the waterway behind Dikes BS-1 - BS-5 . The Dikes were flown away by scouring .

It should be pointed out that long-term connected monitoring will be conducted to judge the performance of the spur dikes for the waterway improvement . Annex 7 includes the request letter for this connected monitoring .

Caused by the arrangement of transportation ,monitoring instruments, man-power and the budget , the smooth monitoring can be failured .

5.8.2 Findings

Based on the monitoring result, the findings are summarized as below :

* The spur dike should be one of the countermeasures for forming a navigation channel by the sedimentation and scouring arround the dike.

* The position of the thalweg during the flood season is predominant to that during the low water season for forming of the waterway .

* The course of the thalweg during the flood season is predominant to the interval between the dikes for the scouring .

* The dikes of wooden piles structure has the efficiency for the sedimentation behind the dikes in the sandy river .

* The sedimentation occured behind the dikes will be posible to be more developed exceeding the crest of the dikes .

* Based on the evidence that the sedimentation exceeding or similar crest level of the dikes is connected between the dikes , the interval btween the longitudinal structures type can be longer than that of cross structures type .

* Large scale erosion in the sand bar or of the bank upstream of the dike site can change the thalweg course .

* If even a few structure quantity is installed in the suitable position , the efficient for the modification of the low water channel alignment is coming .

* By the dike structure types , it is difficult to estimate these superiority .

* In less than the average annual maximum discharge, the river bed is changeble . It is still unclear that the discharge scale forms the river bed for the sandy river .

For future planning of the dike construction project , the following will be reminded :

* The suffcient study period is necessary for the planning and designing .

* The site observation is very important to grasp a hydraulic condition , especially thalweg during the flood season .

* A bathmetric map and the levelling survey with a suitable accuracy may be conducted .

* The budget for the construction must be suitable ensured .

ANNEX

Annex 1 : Monitoring Plan

MONITORAMENTO

1. Objetivo

Objetiva-se para certificar a conservação da calagem e da largura do rio, para a via navegável, nas localidades onde serão construídas as obras de diques/espigões.

2. Conteúdo do monitoramento

Constituem-se para execução do monitoramento os seguintes ítens:

- vistoria longitudinal e transversal do leito do rio;
- medição da velocidade da correnteza; e,
- pesquisa de tráfego do objeto flutuante.

3. Local do monitoramento

São 03 (três) localidades a seguir mencionadas, onde serão construídas as obras de diques/espigões:

- Teresina;
- União; e,
- Buriti dos Lopes.

4. Época do monitoramento

A época a ser realizada o monitoramento está contida na tabela anexa, totalizando de 09 (nove) vezes.

E, será realizada o treinamento nos dias 03 a 05 de novembro.

Vistoria longitudinal e transversal do leito do rio

[Altura da RN Básica]

São os seguintes a altura e a RN Básica para a vistoria longitudinal e transversal (indicar estas localidaades na fotografia)

- Teresina

TP 1	EL 61,54m
TP 2	EL 59,45m

- União

G 06-3	EL 46,703m

- Buriti dos Lopes

BP 1	EL 10,00m (N 7)

(Obs: estas alturas são provisórias)

[Linha de medição e localização de medição]

A localização da linha transversal consta no desenho.

No entando, observar os locais pré-determinados para a localização da medição. E, estabelecer a distância até a localidade de medição com o uso de equipamento próprio.

[Conteúdo da medição]

- a altura do nível d'agua (com a data da medição);
- a profundidade do leito na localidade da medição;e,
- a distância até a localidade da medição (a distância é a distância entre o marco básico.

No caso de executar a medição através de barco, estacionar o mesmo com o uso de âncora.

[Controle de Dados]

Os conteúdos da medição serão controlados na folha a parte e confeccionado o desenho transversal em papel milimetrado, com cada linha medida.

Medição da velocidade da correnteza

[Equipamento para medição]

Universal digital current meter (UC-2, TAMATA)

[Localização da medição]

A localização da medição está mencionada conforme o desenho. Mas, no caso de executar a medição através de barco,estacionar o mesmo com o uso de âncora.

é o seguinte a profundidade a ser medida:

- 10 cm fundo do nível d'água (NA 10 cm)
- 100 cm fundo do nível d'água (NA 1m)
- 200 cm fundo do nível d'água (NA 2m)

[Conteúdo da medição]

- máxima da velocidade da correnteza,
- média da velocidade da correnteza.

[Controle de dados]

Será feito o controle em papel a parte os valores medidos.

Pesquisa sobre tráfego de objeto flutuante

[Equipamentos para medição]

- bóia (garrafa plástica, contendo 1,5 litro de água).
- cronômetro.

[Seção a ser medida e a linha da medição]

- executar-se nos pontos indicados no desenho.

[Conteúdo da medição]

- tempo da chegada

  a medição do tempo de chegada da boia, da linha da medição determinada do lado montante até a chegada na linha da medição do lado jusante.

- tráfego

  obtenção da localização prévia do objeto flutuante, deixado na na linha da medição determinada do lado montante até a Jusante.

[Controle de dados]

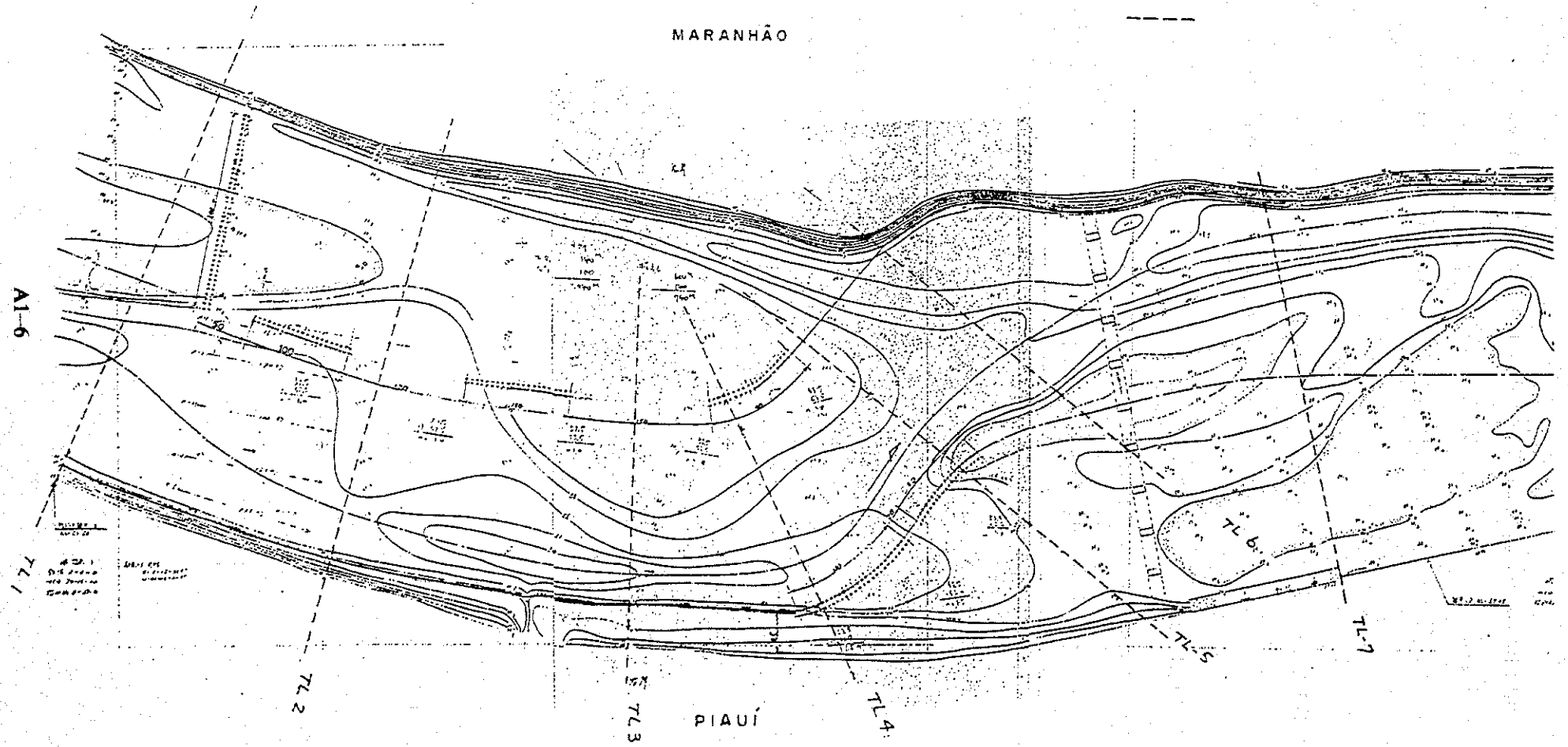
- será feito o controle em papel determinado.

TERESINA - PI.

ESC. 1:4.000

vistoria longitudinal e transversal do leito do rio;

ESTACA (SPUR DIKE)

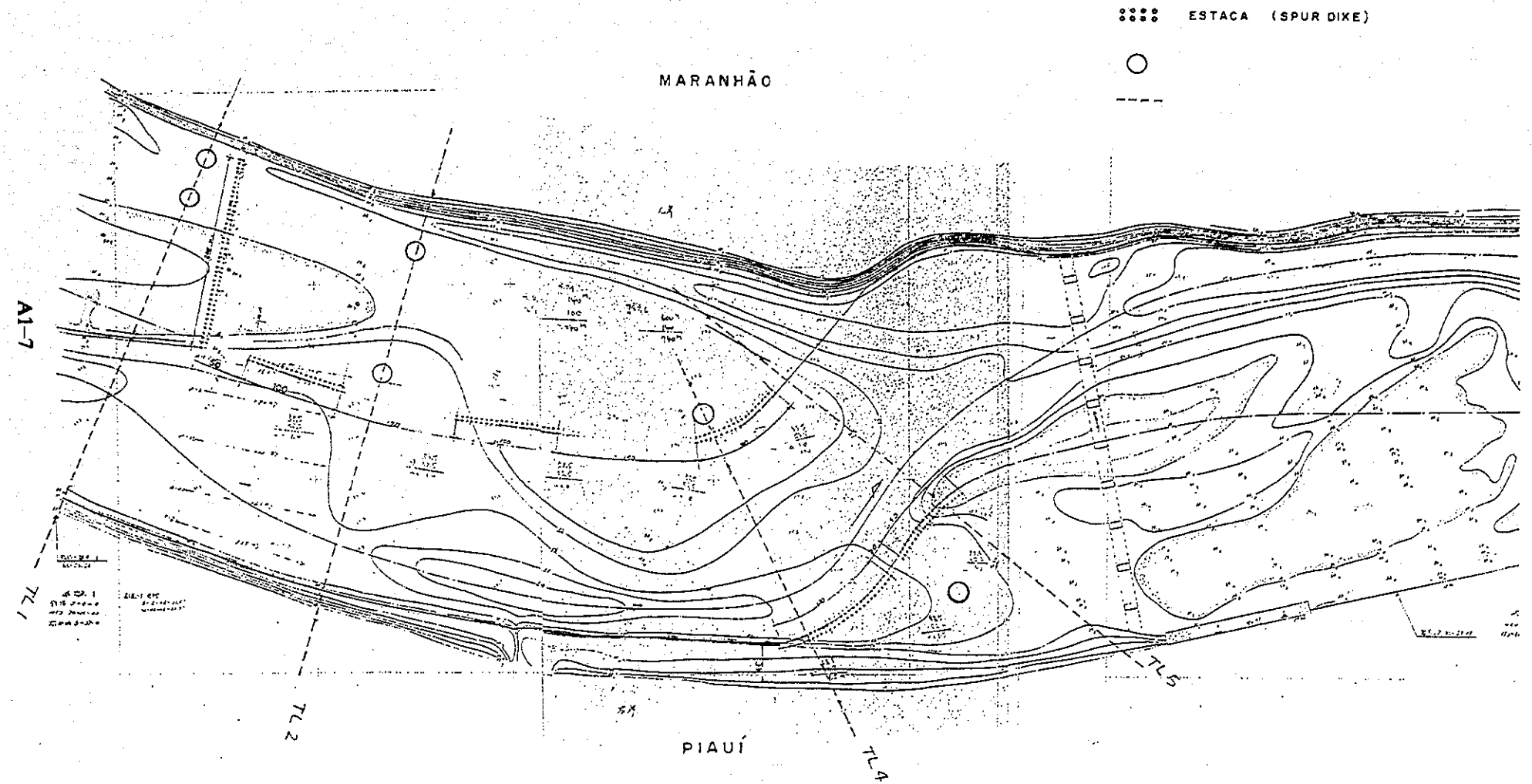


A1-6

TERESINA - PI.

ESC. 1:4.000

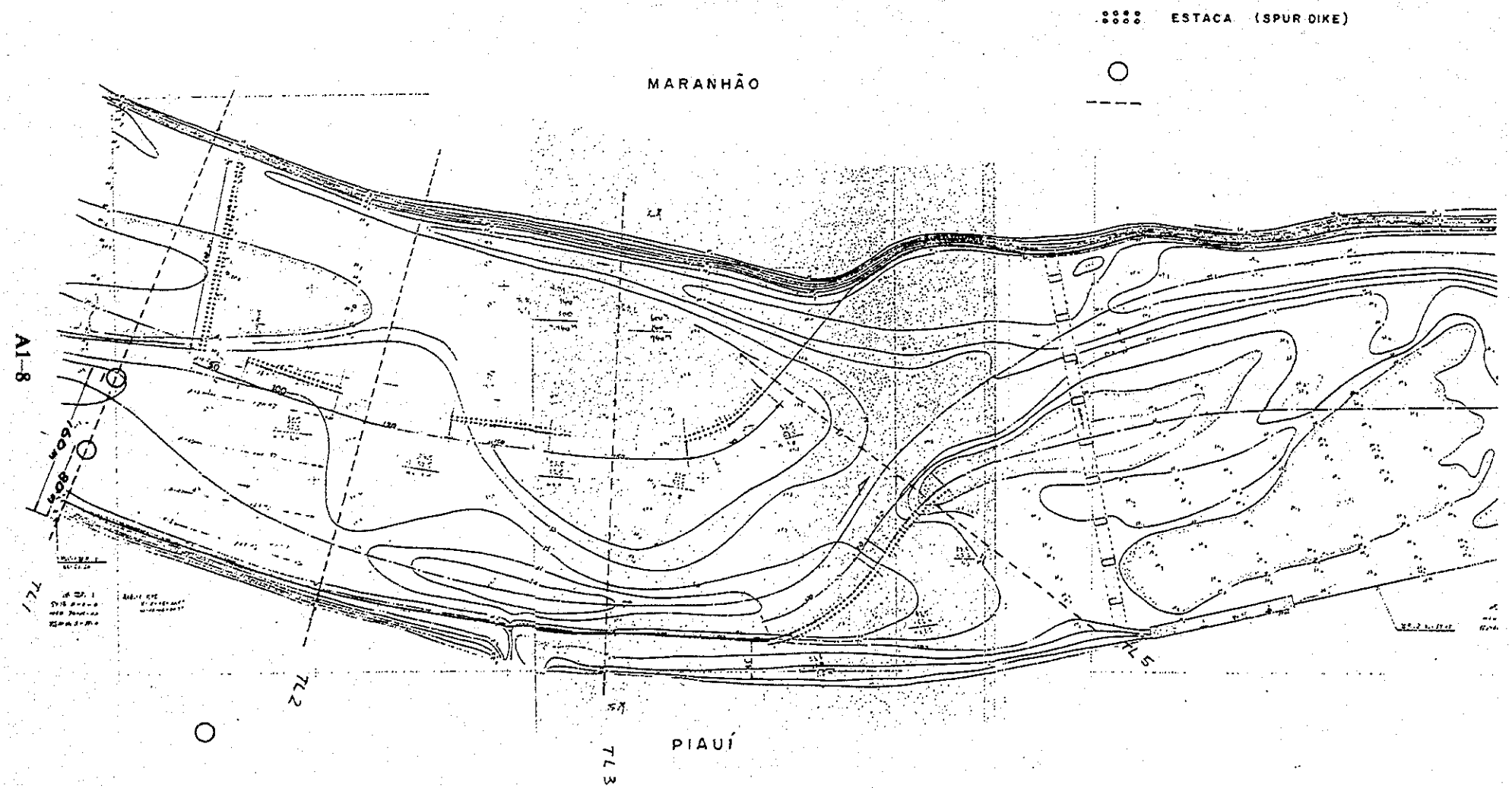
medição da velocidade da correnteza; e,



TERESINA - PI.

ESC. 1:4.000

pesquisa de tráfego do objeto flutuante.



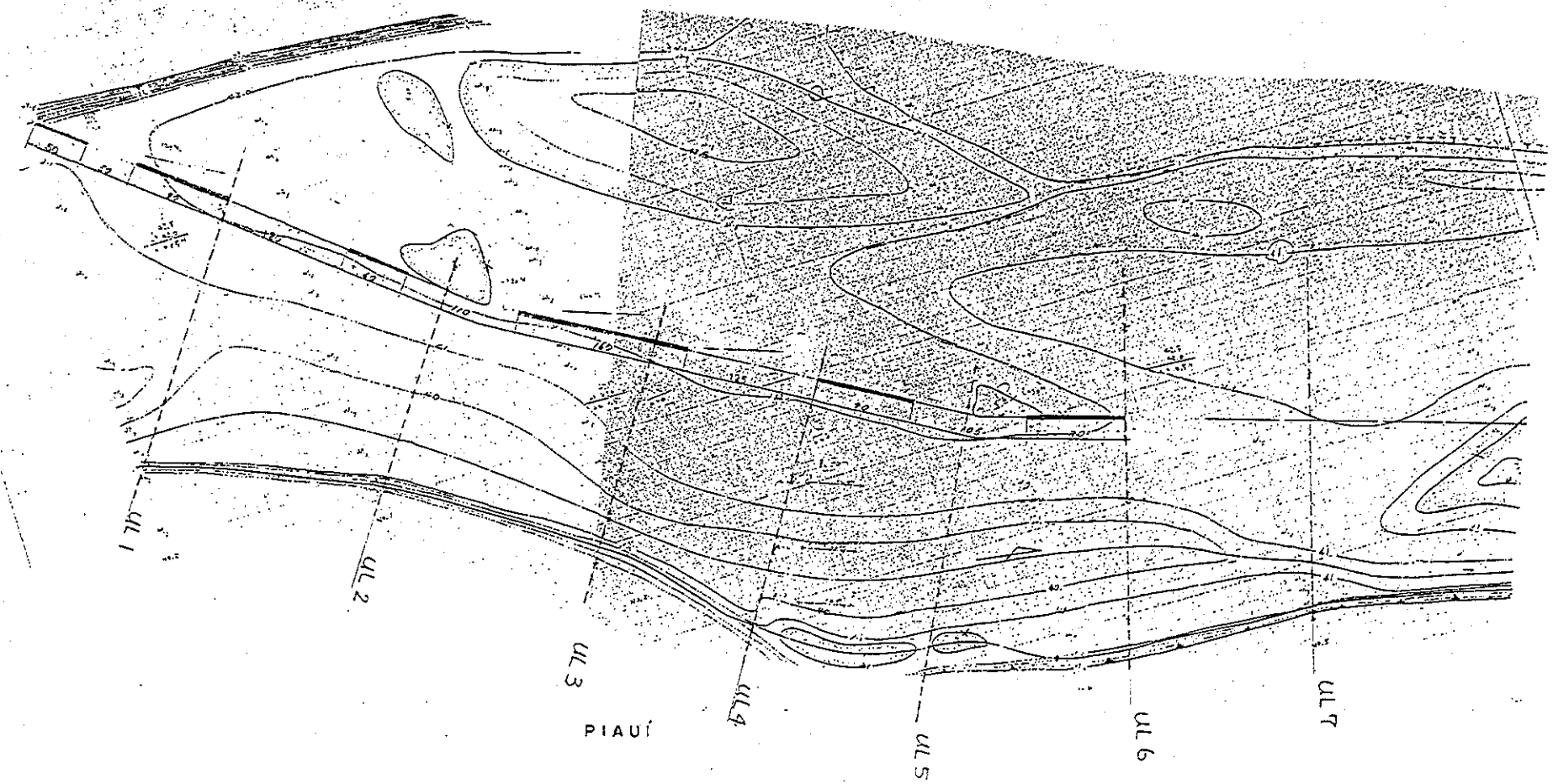
UNIÃO - PI.

ESC. 1:4.000

vistoria longitudinal e transversal do leito do rio;

SACO DE AREIA

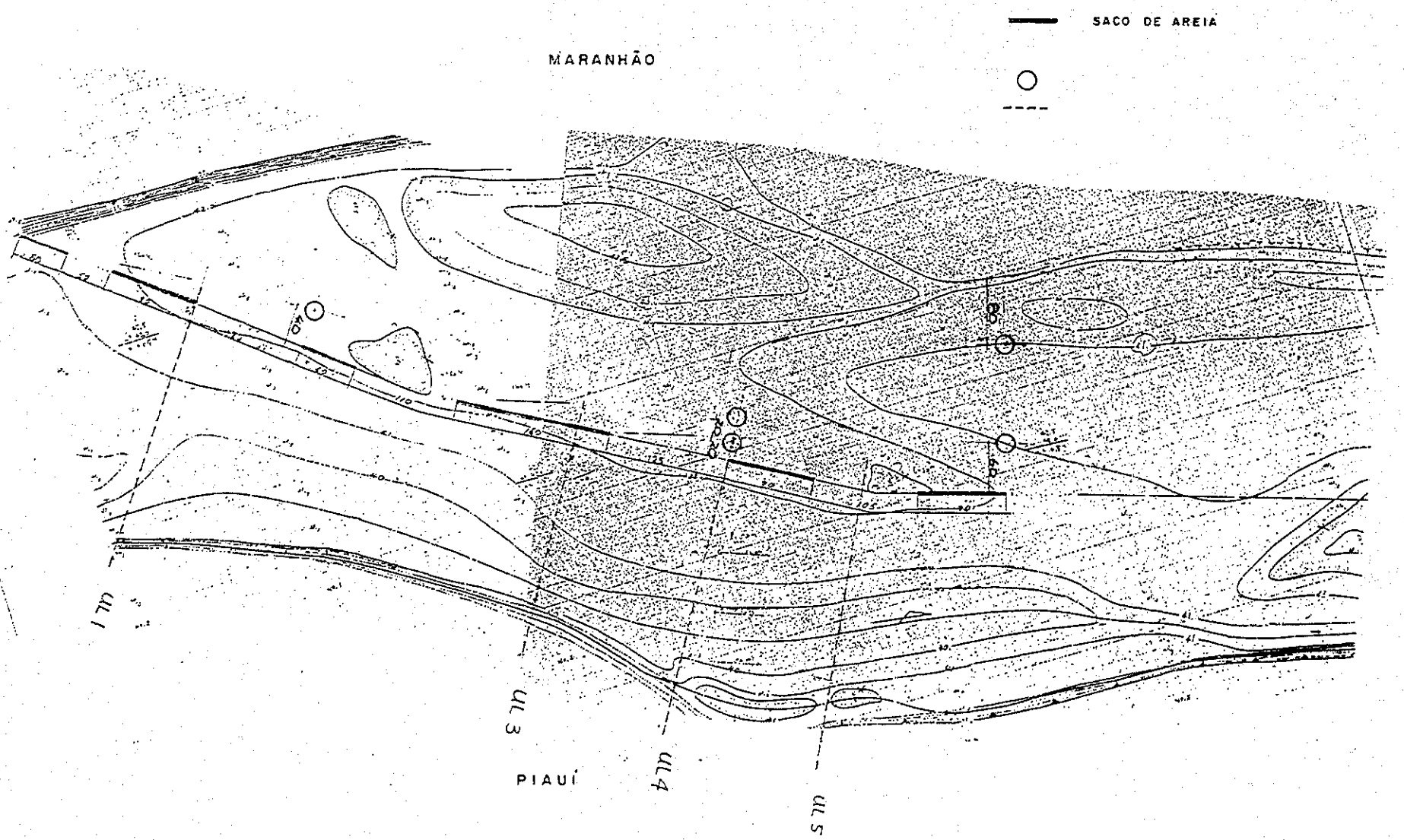
MARANHÃO



UNIÃO - PI.

ESC. 1:4.000

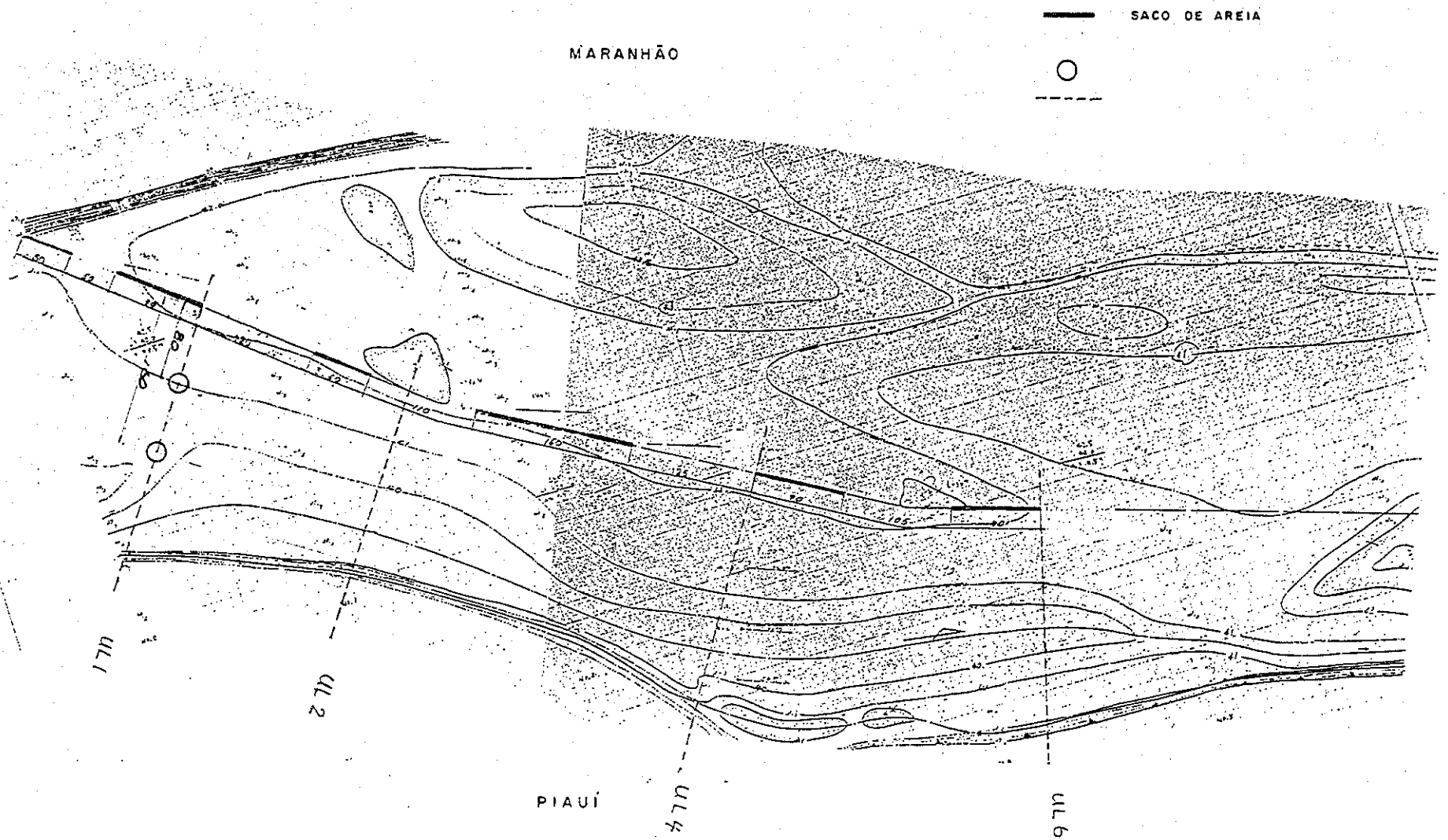
medição da velocidade da correnteza



UNIÃO - PI.

ESC. 1:4.000

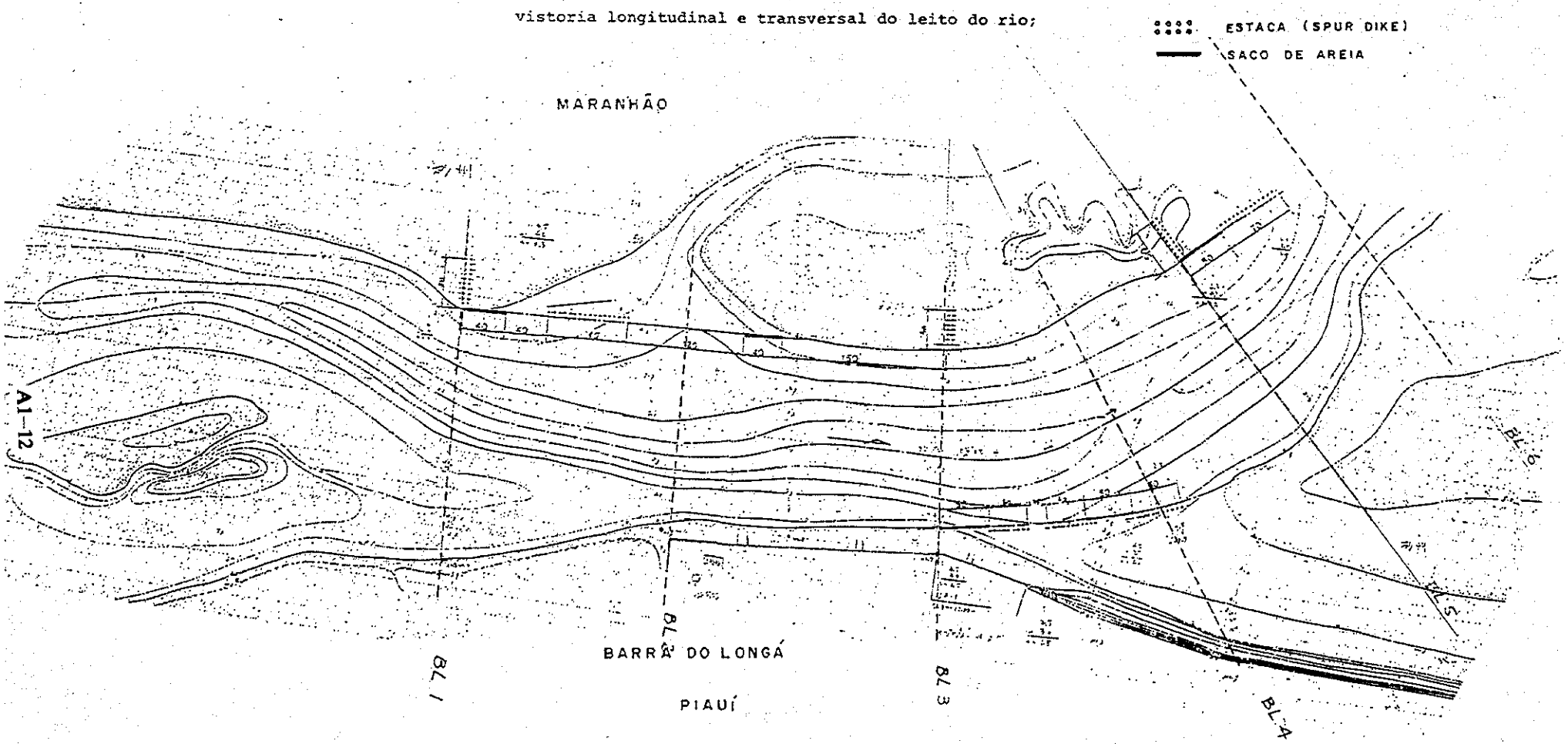
pesquisa de tráfego do objeto flutuante.



BURITI DOS LOPES - PI.

ESC. 1:4.000

vistoria longitudinal e transversal do leito do rio;



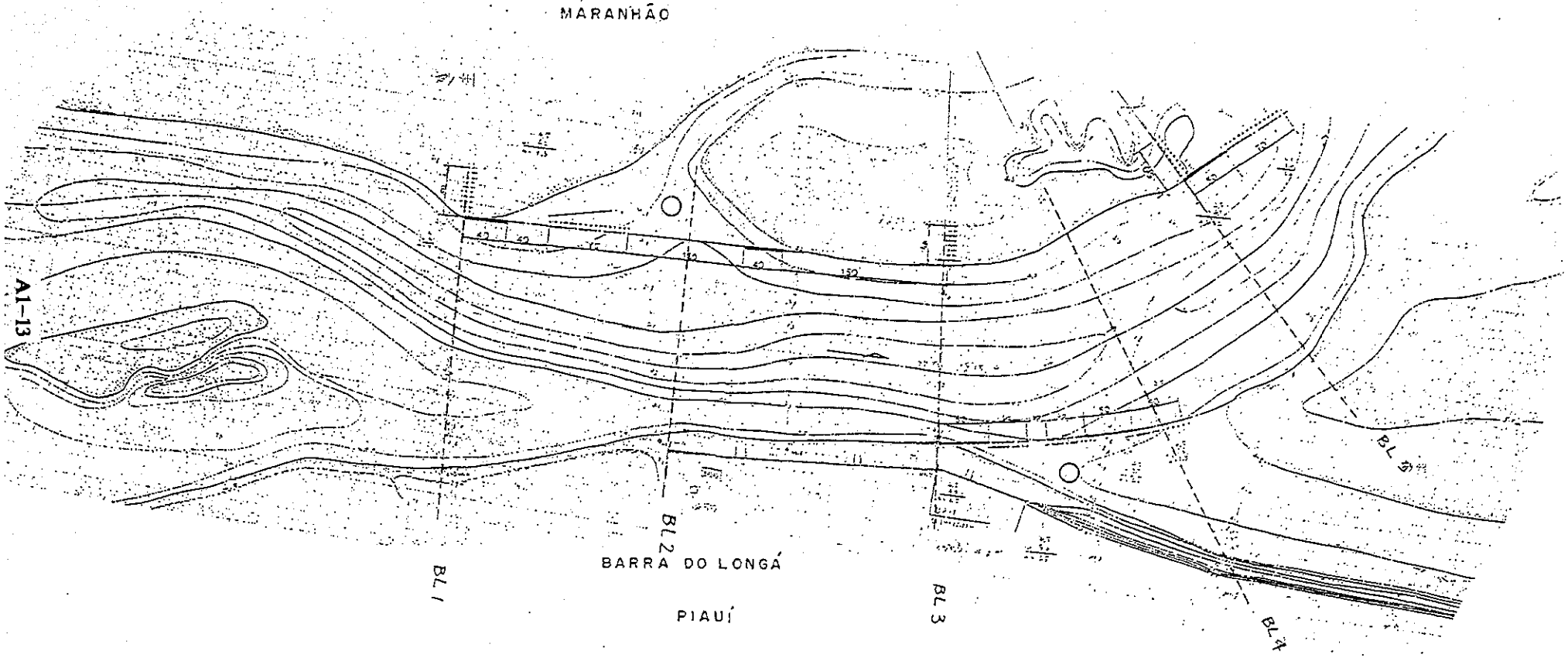
BURITI DOS LOPES - PI.

ESC. 1:4.000

medição da velocidade da correnteza

ESTACA (SPUR DIKE)

SACO DE AREIA



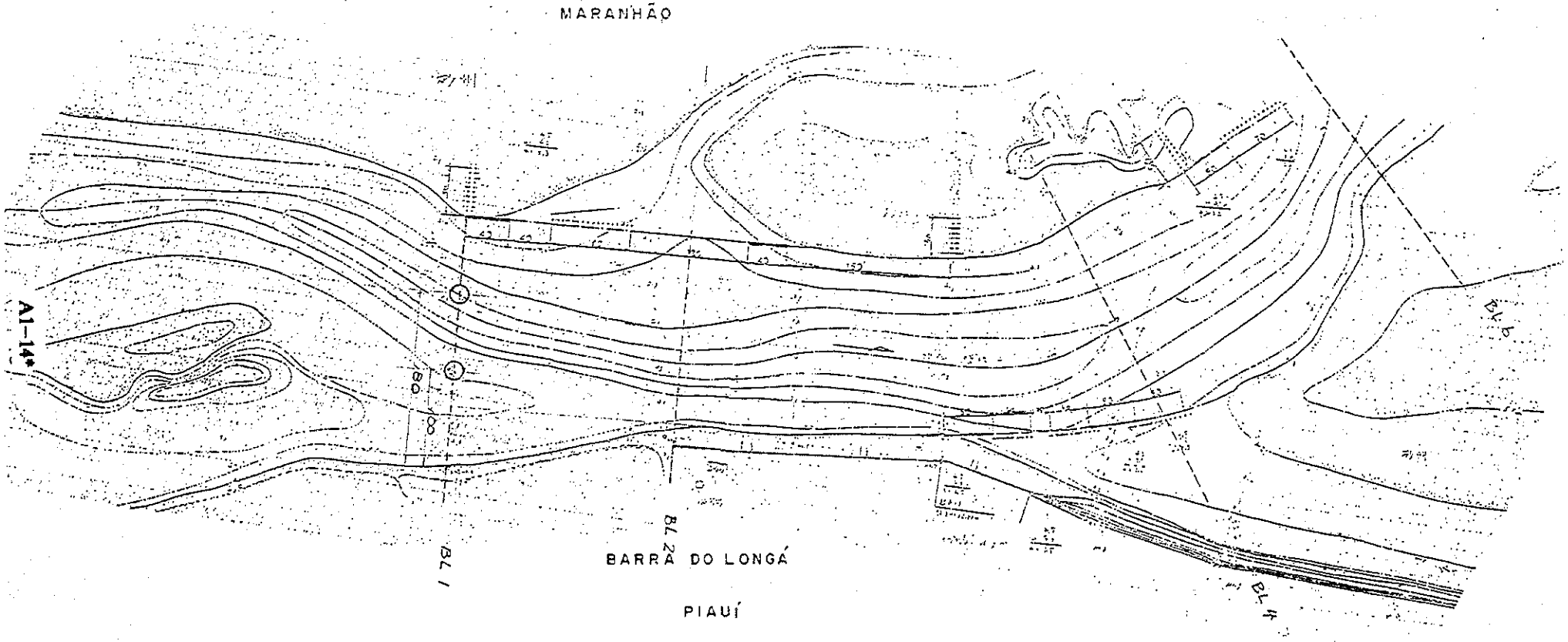
BURITI DOS LOPES - PI.

ESC. 1:4.000

pesquisa de tráfego do objeto flutuante

ESTACA (SPUR DIKE)

SACO DE AREIA



Annex 2 : Operating Instruction

and

Data Processing

1. OPERATING INSTRUCTIONS

1.1. Setting the SPM III

(1) Pushing the white push switch on the battery board, user can check the NiCd battery capacity. If the red led on the battery board be lighted, the battery is full charged. In the case that LED is not lighted, the battery must be charged for 15 hours by the AC adapter.

CAUTION: Once the batteries are fully charged, the led can be lighted for about 3 days after charging, but because of a natural discharge of NiCd battery, the led may not be lighted 2 to 3 days after the charging. When SPM III is not operated for more than one month, the battery must be chrged at least once in every other month, otherwise the NiCd battery would be fully discharged and must replace with new batteries.

(2) Select the sampling interval using rotary switch on the I/O board. The relation of rotary switch position and sampling interval is shown bellow.

POSITION	SAMPLING INTERVAL
0	no operation
1	test mode 1 min.
2	10 min.
3	30 min.
4	1 hr.
5	2 hrs.
6	3 hrs.
7	6 hrs.
8	no operation
9	no operation

(3) Set the new 4 alkaline batteries into the battery and insert the holder in between the alminum frame from the flat cable side.

(4) Connect the 30-P flat cable attached the sensor control circuit board to the I/O board.

(5) Set the data logger according to the guide pins set the SUBFRAME into the data logger using 2 of 20 × 6 mm screws.

(6) Connect the battery cable of the battery holder to the battery board. The SPM III is now ready to operate !.

(7) Push the red switch on the Mother board once according to the preset time. When the red switch is pushed, the LED, on the back of the mother board is lighted for about 4 seconds. User must ensure that the LED is lighted about 4 seconds. In this 4 seconds of operation, the previously stored data are cleared and 32 Kbytes of the memory inicialized, and the data logger is set ay stand-by mode to wait a data acquisition trigger signal. The data measurement begings at the interval of the time after the red switch is pushed; for example, if the sampling interval is 1 hour and the red switch is pushed at 9:00 AM, the measurement begins at 10:00 AM. At the time of sampling, the RED LED blinks for 4 times in 2 seconds interval.
If the RED LED stays to be on longer than 4 seconds, th e logger is mulfunctioned. This occurs when one of the eletric boards of the logger is misplaced slightly at the CARD EDGE connect on the mother board. In the case, remove the data logger from the sensor and turn off the TOGGLE switch attached on the I/O board. Disassemble the logger and clean the CARD EDGE. After the inspection assemble the logger carefully and turn the TOGGLE switch on. After the assembling, set the logger and push the start switch twice.

(8) Set the watertight PVC housing using 4 of 40 x 16 mm stainless steel screws. Apply a small amount the silicon vacuum grase on the inner surface of the watertight pipe.

(9) If necessary, user may attach the extension rod depending on the bottom condition of the measuring station, i.e., if the rough wave condition is predicted, attach the ex-rod and bury the sensor deeper than usual.
User the test the instrument by setting the sampling interval at 1 min., and operate the sensor fro a few minutes. Make it sure that the LED on the back of Mother board blinks at the time of samopling. After the test, disconnect the data logger and the sampling interval must be reset to the desired interval.

1.2. After the Measurement

(1) Remove the watertight hoousing. The waterlightness is ensure by the two 0-rings. Naturally, the water gets into the lower end of the firdt 0-ring.

Therefore, it is recommended that the water must be wiped before the full removal of watertight pipe.

(2) Disconnect the battery cable.

(3) Remove the data logger.

(4) Disconnect the 30-P flat cable from I/O board.

(5) Remove the battery holder.

(6) Remove the memory board the data logger, and read the data by IBM-PC. The data are maintained for 2 weeks by the bacy-up battery on the memory board after the board is removed from the data logger.

CAUTION: (1) Since the memory board has its own back-up battery, putting the memory board on the conductive material such as steel should cause the destruction of stored data. Carefull handling of memory board is recomended

(2) To avoid the data erased by the static eletricity. If the memory board should be transfered, the memory board must be wrapped with the provided anti-static vinyl bag.

(3) If the SPM III is continuingly set at the measuring site. SPM III must be set according to the operating manual and new alkaline batteries should be used.

(4) The battery holder must be inserted from the 30-P flat cable side.

1.3. Maintenance

(1) Since the SPM III is not used has no moving parts, the SPM III is basically free of the maintenance.

(2) There may be some bio-groving such as seaweeda and barnacles on the sensor surface after several weeks in the water. In the case, the bio-growing must be removed by the scraper.

(3) If the SPM III is not used for longer than 6 months, and the NiCd batteries are not charged during the period, the NiCd batteries might be discharged completely. Check the output of the each NiCd batteries and if necessary, replace the NiCd bateries to new one.

2. DATA PROCESSING BY THE IBM-PC

The stored data the SPM III are read and processed by the IBM-PC using the provided softwear. The software handles the basic data process, i.e., readong data and producing the MS-DOS ASCII character data file. For the further analysis using the produced MS-DOS ASCII file, user must create their own softwear.

The providing softwear consists of the two parts, FASTREAD.EXE and SPMDISP.EXE. The FASTREAD is for the reading the stored data and transfered the data to the floppy disk in binary format. The SPMDISP is for the producing the data file for the print-out and the transforming binary data into the MS-DOS ASCII character data file for the further analysis by the user program.

2.1. Reading the stored data

(1) Connect the Memory Reader to the Pc using RS-2320 cable.

(2) Start the Pc using the MS-DOS system.

(3) Insert the program disk into drive A and the data disk into the drive B.

(4) Key in "A:\EXE\FASTREAD", the screen displays the programs discription as shown below:

```
TRANSFER PROGRAM SPM III MEMORY READER ->
Pc ARGUS-OLDENBURG, GER. Version 1.4 e / 10-11-90
Sanyo Sokki Co., Ltd.
Number of com-port (1...4):
```

(5) Key in "1". The PC then requires user to input the data file name as "NAME OF THE DATA FILE:-".

(6) Key in the desired name for data file as "B:*****.DAT". "*****" can be any recognizable name but should be 8 or less characters.

(7) The screen shows "CONECTING TO I/F ...". At this period, Pc send a message to the MEMORY READER to make a proper connection. The MEMORY READER recieves the message and send back the connection completing message to the PC and the 2 LEDs on the front panel of MEMORY READER light on.

(8) When the PC and MEMORY READER connection completes without failure the message below would be displayed on the screen.

```
CONNECTING TO I/F ... SPM3READSN.90007 - Version
0.02  PLEASE INSERT THE MEMORY BOARD!
WAITING FOR A KEY ...
```

(9) Insert the memory board into the MEMORY READER and hit the return key. The data reading starts and the message "RECORD NUMBER: *" would be displayed on the screen. The record number wouldd be counted up until the last record.

(10) When the data reading is completed, the message "PLEASE REMOVE THE MEMORY BOARD!" would be displayed on the screen. Remove the memory board from the MEMORY READER.
Now the stored data in the IC MEMORY hane been transfered to the floppy disk in the drive B.

2.2. Basic Data Process

(1) Start the PC using the MS-DOS system.

(2) Insert the program disk into drive A and the data disk into drive B.

(3) Key in "A:\EXE\SPMDISP". The screen displays the program discription as shown below:

```
"PROCESSING OF SPM DATA FOR IBM-PC ->
ARGUS GmBm - OLDENBURG, GER.   Version 2.23  e  /
10-09-90 [1]
Sanyo Sokki Co., Ltd.
Station Data
Station Name:
Input File:
Type of Output: report
Page Length: 66
Output File:
Start Date: 10-30-1991
Start Time: 11:00:00 AM
Comment: short discription for the station  (com-
mand)
F-10 - Execute Esc-Quit        10-30-1991  11:00:00
```

(4) Key in the required material according to the command which changes as the program proceeds.

"Station Name" is the short description of the station which user can recognize afterwords.

"Input File" is the data file name the user intends to analyze. If the data is in drive B, user must key in as "B:*****.DAT".

For the "Type of Output", 4 options can be selected by just hitting the SPACE key. "Report" is to produce the time series data file for printing out the data as a bar graph. The other options such "List", "Ascii" e "Txt" are all to produce the MS-DOS ASCII character files but the output format is different from each other. User can select the desired format.

"Page Length" is the line number of each output page. Default is 66.

"Output File" is the name of output file and its destination. If user inteds to created the output file on the disk in the drive B, user keys "B:*****.***" in.

"Start Date" and "Start Time" are the starting date and time of the measurement. The displayed date and time are the current date and time.

"Comment" is an additional short comment for the data.

(5) When the all items are keyed in, hit the F-10 key. The program be executed and shows the header record of the data file on the screen as shown below:

```
"PROCESSING OF SPM DATA FOR IBM-PC ->
ARGUS GmBm - OLDENBURG, GER.   Version 2.23  e  /
10-09-90 [23
Sanyo Sokki Co., Ltd.
aFile Information
Data File Name: B:*****.DAT
Type of Sensor: 2
Data Size: 8
Number of Observations: 48
Observation Interval: 0 hours 1 minute
Sampling Interval: 2
Bursts per Interval: 4
Observation Period: 0 days o hours 12 minutes
IF DATA ARE OK PRESS <F10> ELSE QUIT  WITH  <ESC>
<command>
F-10 - Execute Esc-Quit
```

"Data File Name" is the name of the file being processed.

"Type of Sensor" describes the number of opticcal sensor. "2" means the sensor used for the data has 61 sensors. Now, the type of sensor is normally "2".

"Data Size" is the number of byte per data. Since the sensor has 61 sensors, the recorded data on the IC MEMORY uses 64 bits. So the size should be "8".

"Number of Observations" is the total number of observation and is equal to:

Bursts per Interval x Observation Period / Observation Interval

"Observation Interval" is the sampling interval applied.

"Sampling Interval" is always 2 and is actually burst interval.

"Bursts per Interval" is always 4 because the sensor is scanned for 4 times at the sampling.

"Observation Period" is the length of the data measuring period.

(6) f the header record of the data file, press <F10> key to execute as the command says.

(7) When the process is completed without any error, the message "PROGRAM WHITHOUT ANY ERROR TERMINATED" is shown on the screen and the data process is finished.

(8) The data processed can be printed out by the command:

"B:*****.PRN" if the output data file is in drive B.

"*****.***" is a desired file name.