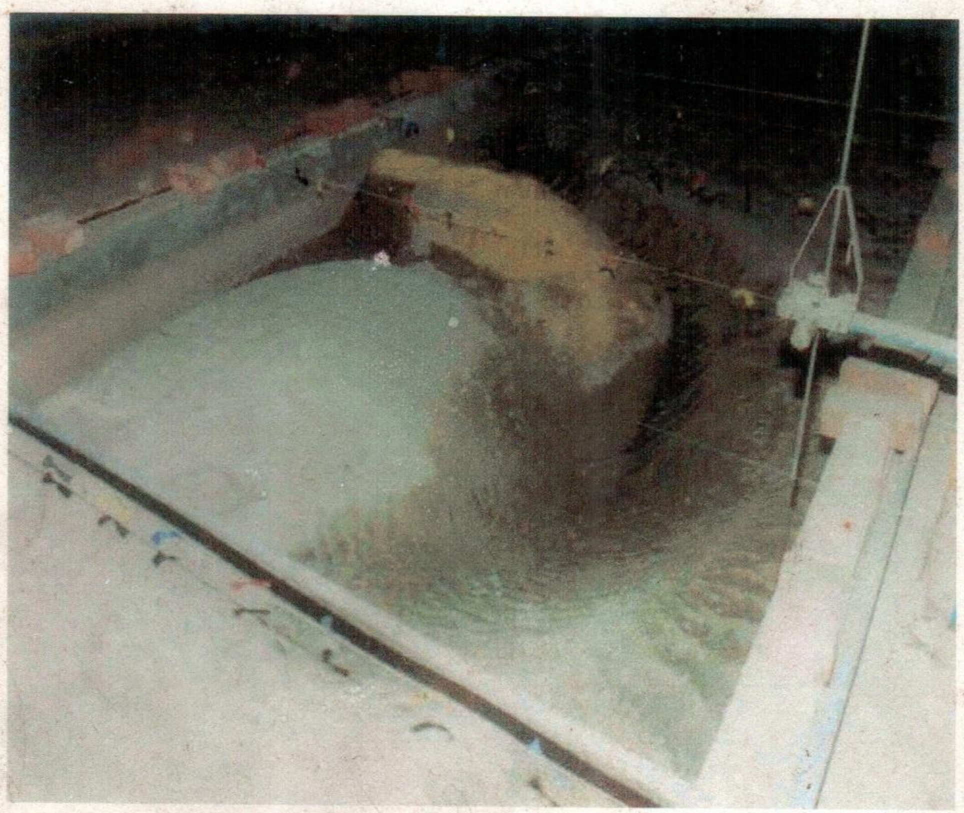
APPLIED RESEARCH
ON
LABORATORY INVESTIGATION OF SCOUR AROUND GROYNE



Report No. RES –5 (2001)

RIVER RESEARCH INSTITUTE, FARIDPUR

JULY 2001

APPLIED RESEARCH ON LABORATORY INVESTIGATION OF SCOUR AROUND GROYNE

Research Report

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RES-06

PREFACE

A detailed knowledge of the scour pattern of different types abutment, groyne etc. are of great value when dealing with the design of river training works, flood control works, channel improvement and so on. The estimation of the scour in a real river situation is very difficult. So far we have little knowledge about the extent of scour, which may occur due to variation of flow, material size, high turbulence etc.

The safe and economical design of a structure requires accurate prediction of the maximum expected scour depth of the streambed around it. An under-estimation of the scour will result in failure, while its over-estimation will increase the cost of the structure. Hence the knowledge of predicting scour depth under various conditions is essential.

In this assessment, the maximum local scour and approach velocity relationship shows that the local scour is increased with the increasing of the velocities. On the other hand, the velocity is increased in the vicinity of the experimental groyne due to increase of blockage ratio.

In this study, an attempt was undertaken to correlate the various parameters such as squire of the discharge per unit width (q^2), silt factor (f) and approach velocity (u), relating to local scour (Hs). For this purpose, regression analysis was done. Three empirical equations were found for three Blockage Ratios. It was observed that there were very good correlation between the local scour (Hs) and q^2/f.

This report will give an idea about the relationship between discharges and scour depth at different situation. I hope it will be helpful for the estimation of scour depth around the hydraulic structures and also will act as a ready reference for the future researchers in this field.

Signed/=

25.11.2001

ENGR. SYED ABDUS SOBHAN
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ACKNOWLEDGEMENT

The authors gratefully acknowledge their the deepest gratitude and indebtedness to Director General Engr. Syed Abdus Sobhan, River Research Institute (RRI), Faridpur, Bangladesh, under whose constant encouragement, inspiration and providing the utmost facilities throughout the investigations, it was possible to complete this research. The researchers' are also grateful to the Director, Hydraulic Research for his valuable suggestions.

The authors extend their deep appreciation to technicians, scientists of RRI for their any helpful co-operation and suggestions.

Gratitude is expressed to all officials and authorities of RRI for providing facilities, cooperation's and financial support to do this research in this regard.

The Authors

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List of Notations

Symbols	Definition	Dimension
B	width of channel	m
BR	blockage ratio	-
B_s	width of scour hole	m
b	projected length of groyne perpendicular to the flow	m
C_D	co-efficient of drag	-
D/D_{50}	ratio of the diameter of sand particle to the median size of the sand	mm
d_{se}	equilibrium scour depth in uniform sediment	-
d_{mm}	diameter of sand particle in millimeter	mm
F_r/F	froude number	-
f	silt factor	-
H_s	Total mean depth	m
h_s	scouring depth	(m)
h_o	water depth before scour/depth of uniform flow	m
h_1	depth of flow at the upper contracted channel	m
Q	discharge	m^3/s
q	discharge per unit width	$m^3/s/m$
U_*	shear velocity	m/s
U_c	critical velocity	m/s
α	opening ratio,[(B-b)/B]	-
PSO	Principal Scientific Officer	-
SO	Scientific Officer	-

CHAPTER –I

INTRODUCTION

1.1 Background of the Study

Scour refers to the removal of material by running water. This usually occurs when the velocity of flow in the waterway exceeds the velocity, which will cause the bed material to move. Scour may occur progressively over the life of a structure or it may occur very quickly as a result of some relatively rare high flow. Many watercourses experience erosion and deposition and consequent changing of bed levels with time as part of their natural life cycle.

Scouring of riverbed in alluvial rivers endangers the riverbank and the structures along the alluvial rivers. Sometimes important township, industries and infrastructures are threatened due to scouring associated with erosion. The mainland of Bangladesh is created by alluvial deposit of the Ganges, the Brahmaputra and the Meghna river system. A number of townships like Sirajgonj, Kazipur, Sariakandi, Chandpur, Bhairab Bazar, Rajshahi, Sylhet (scattered strip of land), Kurigram, etc. are threatened by the riverbank erosion.

A detailed knowledge of the scour pattern of different types abutments, groynes etc. are of great value when dealing with the design of river training works, flood control works, channel improvement and so on. The safe and economical design of retaining wall, floodwall, groyne etc. requires accurate prediction of the maximum scour depth of the streambed around them.

1.2 Problem Identification

Bangladesh is a land of rivers, interlaced by the numerous channels of the three mighty river systems of the world namely the Ganges, the Brahmaputra and the Meghna. Many structures have been constructed across these riverbeds. Methods of estimating scour in sands and gravel subject to a given flow are reasonably well developed. It is still the case that estimation of the likelihood of occurrence of scour in a real river situation is difficult. The effects of variation in flow and material size, and the high turbulence in a real flood situation introduce an area of relative ignorance. Where scour is likely to occur to an extent, which could endanger the foundations of hydraulic structures, adequate prevention and protection must be considered.

At present, different types of groynes are used as river training works. These groynes are normally constructed within the alluvial river. Groyne head is usually subjected to heavy scour. Therefore, provision should be made in the design so that the groyne does not fail due to scour.

The structures such as spur dike, abutment, groyne etc. show that enormous cost have been involved for large length of piles or foundations embedded beyond the scour depth. In future, there is probability of some more new structures across these river systems will be constructed and large sums of money will be involved. If scour depth is correctly predicted, then considerable amount of money can be saved. Therefore, it is felt that there is need to study scour phenomenon around hydraulic structures to obtain reliable data for evaluation of scour depth. In consideration of the fact discussed above, this study has been undertaken to predict local scour depth for abutment or groyne on alluvial bed material. If we get any reliable relations regarding scour depth, it will bear great value to the nation as well as to the world.

1.3 Objectives

The safe and economical design of groyne requires accurate prediction of the maximum expected scour depth of the streambed around it. An under-estimation of the scour will result in failure, while its over-estimation will increase the cost of the structure. Hence the knowledge of predicting scour depth under various conditions is essential. In this context the present study has been planned with the following objectives:

- To find out the effect of approach flow velocity against local scour.
- To find out the effect of blockage ratio on scour depth.
- To find out the correlation among the dominant parameters influencing scour depth.

1.4 Limitations of the study

There are some limitations for these studies are as follows:

- The banks of the channel were fixed.
- Upstream and downstream of the flume was fixed.
- Only one type of material was used (sand, D_{50} = 0.19 mm)
- Only single groyne with fixed slope (1: 1.5) was used for three different blockage ratios (BR).
- Single water depth was maintained (15 cm).
- The orientation of groyne was unchanged (Perpendicular to the flow direction).

CHAPTER-II

REVIEW OF LITERATURE

2.1 Introduction

Spurs are stone, gravel, rock, earth or pile structures built at an angle to a river bank to deflect flowing water away from the critical zones, to prevent erosion of the bank, to establish a more desirable channel for flood control, navigation etc. They are used on wide braided rivers to establish a well-defined channel that neither aggrades nor degrades so that shifts its location from year to year. In this case, the spurs may have long dikes at their outer end to help define the channel and spurs control many miles of a river. Spurs are also used on meandering rivers to control flow into or out of a bend or through a crossing (Richardson, 1975). Spur can be considered as blunt abutment. It also constricts a part of riverbed. For this study, the works of different scientists have been reviewed. The scientific works representative in the case of alluvial river to calculate the local scour for spur or groyne are given below:

2.1.1 Breuser's Study

Breuser (1991) recommends a scour depth as follows:

$$h_0 + h_{sm} = 2.2\left(\frac{Q}{B-b}\right)^{\frac{2}{3}}$$

Where, h_o= Water depth before scouring

h_{sm} = depth of scour below bed level

Q = discharge

B = width of channel

b = projected length of groyne perpendicular to the flow

2.1.2 Grade et al's Study

Garde et al (1961) conducted an extensive study on plate-form spur dikes in a 2 ft width flume and studied the effect of flow, spur dike and sediment characteristics. It was found that the Froude number of the normal channel, the opening ratio, the angle of inclination of the groyne, and the averaged drag coefficient of the sediment particle adequately represent the influence of flow, spur dike and sediment characteristics on the maximum scour depth. They found the equation as follows:

$$\left[\frac{h+\Delta h_1}{h}\right] = k\,\frac{1}{\alpha}\,F_r^{\;n}$$

In which k and n are functions of $C_{D,}$ which can be found as follows:

$$C_D = \frac{4\Delta sD}{3W^2\rho}$$

In which, h = depth of water without scour

Δh_1 = scour depth

Δs = difference of specific weight between sediment and water

W = settling velocities of sediment

α = opening ratio = [(B-b)/B]

$$k, n = \int (C_D)$$

C_D = Co-efficient of drag

D = diameter of particles

ρ =density of particles

2.1.3 Liu et al's Study

Liu et al (1961) proposed the following formula on the basis of dimensional analysis and laboratory test for abutment and spur.

$$\frac{d_{se}}{h_o} = 2.15\left[\frac{B_s}{h_o}\right]^{0.4} F_r^{0.33}$$

where, B_s = width of scour hole

d_{se}= equilibrium scour depth in uniform sediment

h_o=water depth before scouring

F_r= froude number

They recommend 30% increase of h_s/h_o for maximum scour depth, where h_s is the scouring depth. The regime methods of scour depth prediction at the head of a spur or an abutment depend on correlation with the field observations.

2.1.4 Inglis's Study

Inglis (1949) related the total mean depth, $H_s = h_s + h_o$ to the regime depth of Lacey, relying heavily on Indian data

$$H_s = 0.47\left[\frac{Q}{f}\right]^{\frac{1}{3}}$$

Where, H_s= Total mean depth (m)

h_s= scouring depth (m)

h_o = water depth (m)

Q = discharge (m^3/s)

$f = 1.75\langle d_{mm}\rangle^{0.5}$

f = silt factor

d_{mm}= diameter of particle in millimeter

2.1.5 Lacey's Study

Using **Lacey's formula**, the scour depth can be related to the discharge intensity by the following relation:

$$h_o + \Delta h_1 = 0.90\,[q^{2/3}/f^{1/3}]$$

Where, q = the discharge per unit width of main channel
f = silt factor
h_o =water depth before scouring
Δh_1=scoured depth

2.1.6 Gill's Study

Gill (1972) conducted numerous experiments in a 2.5 feet wide flume to study the effect of grain size on bed material, flow depth and also the effect of involving bed load movement of flow on the depth of equilibrium scour around spur dikes. He concluded that the depth of equilibrium scour is affected by the size of bed material and also the depth of uniform flow upstream of the groyne location. The combined effect of both of these have been empirically formulated as:

$$\alpha = 8.375\left[\frac{D}{h_1}\right]^{0.25}$$

Where, α=opening ratio = [(B-b)/B]
h_1 = depth of flow at the upper uncontracted channel
D = diameter of particles

Also he found that the depth of maximum scour occurs when the sand bed upstream of the spur is at threshold of movement. For the purpose of modelling and basic research, it is necessary the distinction between clear water scour while the scour caused by bed load transporting flow should be considered. To determine the maximum depth of scour, Gill introduce the following formula:

$$\frac{h_{s1}}{h_1} = \alpha\left[\frac{B_1}{B_2}\right]^{\frac{6}{7}}\left[\frac{1}{\left(\frac{B_1}{B_2}\right)^{\frac{1}{n}}\left(1-\frac{\pi_c}{\pi_1}\right)+\frac{\pi_c}{\pi_1}}\right]^{\frac{3}{7}}$$

$1 - \pi_c/\pi_1 = 0$ for $\pi_c/\pi_1 \geq 1$

Where, h_{s1}= scoured depth
h_1 = depth of flow at the upper uncontracted channel

α =opening ratio[(B-b)/B]
B_1=water width without blockage
B_2= water width with blockage
π_c/π_1 = ratio of shear stress

2.1.7 Da Cunha's Study

Da Cunha (1971) performed a great number of tests with various vertical-side headed groynes and water depth in the range of 0.04 to 0.14 m with velocities between 1.0 U_c and 1.4U_c. He found the maximum scour depths around the head of the groyne from the following formula:

$$\frac{h_s}{h_o} = 1.65\left[\frac{b}{h_o}\right]^{0.3}\left[\frac{h}{h_o}\right]^{0.95}\left[\frac{w}{U_*}\right]^{0.15}$$

Where, h_s = Maximum scouring depth
h_o = depth of uniform flow
b = projected length of groyne perpendicular to the flow
h = depth of water
w = settling velocity
U. = shear velocity

2.1.8 Ahmed's Study

Ahmed (1953) proposed a formula to predict scour depth at the nose of spur in terms of regime depth of Lacey as follows:

$$H_s = 1.34\left(\frac{q^2}{f}\right)^{\frac{1}{3}}$$

Where, H_s = scour depth
q = the discharge per unit width in the contracted section.
f = silt factor

CHAPTER-III

METHODOLOGY AND DATA ANALYSIS

3.1 Methodology

The experimental set-up consists of a rectangular open channel with suitable inlet stilling pool and adjustable tailgate. The flow rate through this channel can be measured by means of a sharp crested weir. Gate valves in the supply sump control the discharge. The depth of water within the channel is controlled by regulating the tailgates. During test runs, groyne with various projected lengths was constructed and measurements were taken at concerned sections and points. The experimental data were analyzed and conclusion has been drawn with respect to the objectives.

3.2 Experimental Flume

This study was carried out in a rectangular flume with effective mobile bed length of 22.0 meter and 3.0 meter wide. The flume has 6-meter fixed bed at the upstream and 3 meter fixed bed at the downstream. The flume bed was filled with sand of D_{50}= 0.19 mm. The flume was constructed as watertight to avoid water loss due to seepage. The water supply system of the flume at the upstream flume is shown in the Photo plate No. 1.

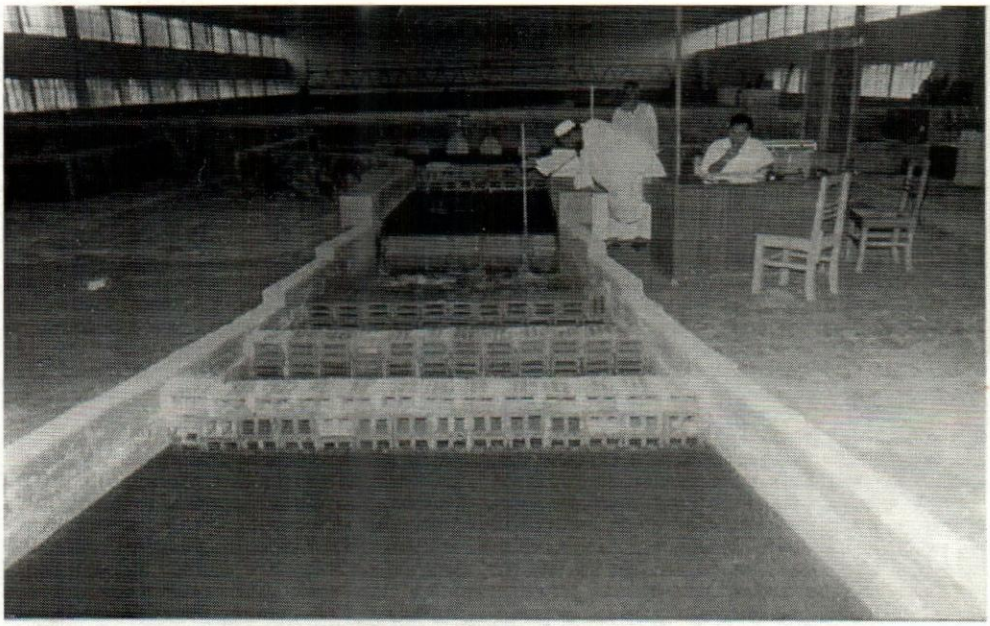

Photo plate No. 1: Experimental Flume with water supply system

3.3 Test Scenario and Data Collection

Total 15 (fifteen) numbers of application tests were conducted considering different test scenarios. The test scenarios are shown in Table –1.

Table –1: Test Scenarios

Test No.	Calculated approach velocity (m/s)	Water depth (m)	Flume width, B (m)	Discharge, Q (m^3/s)	Blockage Ratio (BR)
T1	0.260	0.15	3.00	0.1170	15%
T2	0.325	0.15	3.00	0.1463	
T3	0.390	0.15	3.00	0.1755	
T4	0.455	0.15	3.00	0.2048	
T5	0.520	0.15	3.00	0.2340	
T6	0.260	0.15	3.00	0.1170	25%
T7	0.325	0.15	3.00	0.1463	
T8	0.390	0.15	3.00	0.1755	
T9	0.455	0.15	3.00	0.2048	
T10	0.520	0.15	3.00	0.2340	
T11	0.260	0.15	3.00	0.1170	35%
T12	0.325	0.15	3.00	0.1463	
T13	0.390	0.15	3.00	0.1755	
T14	0.455	0.15	3.00	0.2048	
T15	0.520	0.15	3.00	0.2340	

The following measurements were carried out during the test run:

(a) Discharge: This was measured by sharp crested weir.

(b) Water depth: Water depths were measured at the different location in the flume by graduated sounding rod.

(c) Velocity: The velocities were measured at the different location in the flume by an OTT-current meter.

(d) Flow line: The flow line was determined by float tracking.

(e) Scour: The local scour was measured by graduated sounding rod around the toe of the groyne.

3.4 Data Analysis

The collected data from the experiment of different test scenarios were analyzed. The analyzed data are presented in the tabular form and in the Figures (Table–2 & 3; Figure–2 to 18).

Table –2 : Maximum scour and Velocity around the groyne

Test No:	Measured approach velocity (m/s)	Maximum scour below bed level (m)	Maximum scour from Water Surface (m)	Blockage Ratio
T1	0.30	0.160	0.310	15%
T2	0.35	0.220	0.370	
T3	0.44	0.280	0.430	
T4	0.51	0.345	0.495	
T5	0.56	0.380	0.530	
T6	0.33	0.245	0.395	25%
T7	0.39	0.295	0.445	
T8	0.47	0.340	0.490	
T9	0.56	0.395	0.545	
T10	0.60	0.435	0.585	
T11	0.37	0.320	0.470	35%
T12	0.43	0.380	0.530	
T13	0.53	0.430	0.580	
T14	0.59	0.485	0.635	
T15	0.63	0.555	0.705	

Figure- 2 : Maximum scour and Velocity relationship around the groyne

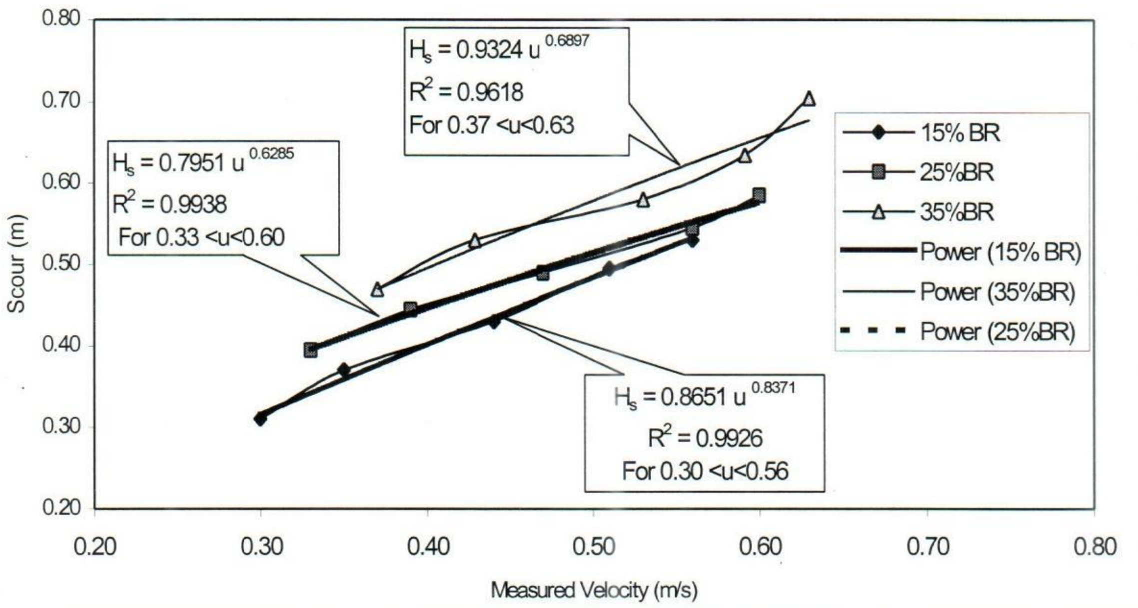

Table- 3: Correlation of various parameters relating to local scour

Test no.	Discharge,Q (m^3/s)	Width of flume,B(m)	q=Q/B (m^2/s)	q^2	Silt factor, f= $1.75\sqrt{d_{50}}$	q^2/f	Max^m scour from water level, Hs (m)	Breakage Ratio(BR)	Correlation
T1	0.1170	3.00	0.0390	0.0015	0.7628	0.0020	0.310	15%	$Hs=3.67(q^2/f)^{0.38}$ $R^2 = 0.996$ ....(1)
T2	0.1463	3.00	0.0488	0.0024	0.7628	0.0031	0.370		
T3	0.1755	3.00	0.0585	0.0034	0.7628	0.0045	0.430		
T4	0.2048	3.00	0.0683	0.0047	0.7628	0.0061	0.495		
T5	0.2340	3.00	0.0780	0.0061	0.7628	0.0080	0.530		
T6	0.1170	3.00	0.0390	0.0015	0.7628	0.0020	0.395	25%	$Hs=2.33(q^2/f)^{0.29}$ $R^2 = 0.998$....(2)
T7	0.1463	3.00	0.0488	0.0024	0.7628	0.0031	0.445		
T8	0.1755	3.00	0.0585	0.0034	0.7628	0.0045	0.490		
T9	0.2048	3.00	0.0683	0.0047	0.7628	0.0061	0.545		
T10	0.2340	3.00	0.0780	0.0061	0.7628	0.0080	0.585		
T11	0.1170	3.00	0.0390	0.0015	0.7628	0.0020	0.470	35%	$Hs=2.76(q^2/f)^{0.29}$ $R^2 = 0.993$....(3)
T12	0.1463	3.00	0.0488	0.0024	0.7628	0.0031	0.530		
T13	0.1755	3.00	0.0585	0.0034	0.7628	0.0045	0.580		
T14	0.2048	3.00	0.0683	0.0047	0.7628	0.0061	0.635		
T15	0.2340	3.00	0.0780	0.0061	0.7628	0.0080	0.705		

CHAPTER –IV

RESULTS AND DISCUSSIONS

The study was performed with a single groyne without changing orientation. A single type of sand particle (D_{50}) was used. In this study, it was observed that the maximum scour and approach velocity relationship that the local scour is increasing with the increasing velocity (Figure-2 and Table-2). The velocity is increased in the vicinity of the experimental groyne due to increase of blockage ratio. It is also evident that the scour depth increases due to decrease of the opening for water flow near the structure.

An attempt was undertaken to correlate the various parameters (such as squire of the discharge per unit width q^2, silt factor f and approach velocity u), relating to local scour. For this purpose the power type regression analysis was done are shown in Table 3 and Figure-2. Three empirical equations were found for three Blockage Ratios (BR) and which are presented in Table-4. It can be observed that there are very good correlation between the local scour (Hs) and q^2/f for equations 1, 2 and 3 (R^2 equal to 0.996, .998 and .993 respectively).

Float tracking was done to observe the flow line which are shown in Figure – 4 to 18. It is also observed that for 15% & 25% blockage ratio (Figure – 4 to 14) that the flow lines near the boundary is parallel. This parallel flow line indicates that there is no effect on the opposite boundary for these blockage ratios. It can be observed from the Figure 15 to 18, the flow line is disturbed or scattered with thė flume boundary that indicate that the blockage ratio of 35% has affected the channel boundary.

CHAPTER-V

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It is concluded from the above result and discussion that the blockage ratio 35% is not acceptable. This blockage will increase the scour depth which indicate the cost of construction increased. The blockage ratio 15% as well as 25% may reasonably accepted.

5.2 Recommendations

The following recommendations can be taken for further improvement of the study:

- For a particular blockage ratio, different dimensions or slope of the groyne can be studied.
- Different depth can be used to get further in-depth scour prediction.
- For a particular blockage ratio different orientation of the groyne will be expected for detail investigation of scour prediction.
- Detail literature survey should be done regarding such scour study.
- Further detail study should be required based on blockage ratio, with respect to velocity, bed load, angle of attack, groyne surface roughness etc.

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Figure-4: Flow line of Test -T1

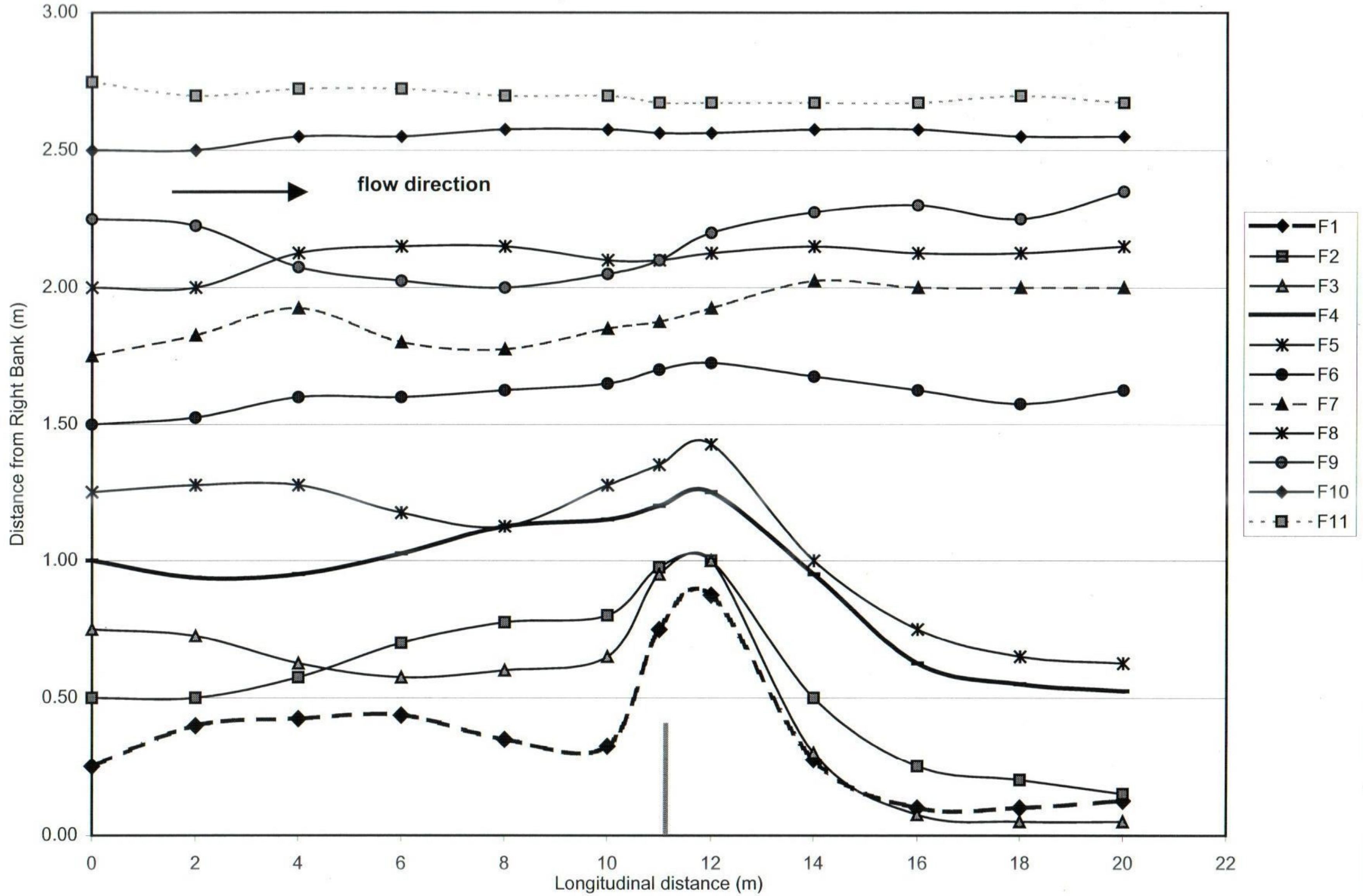


Figure-5 :   Flow line of Test -T2

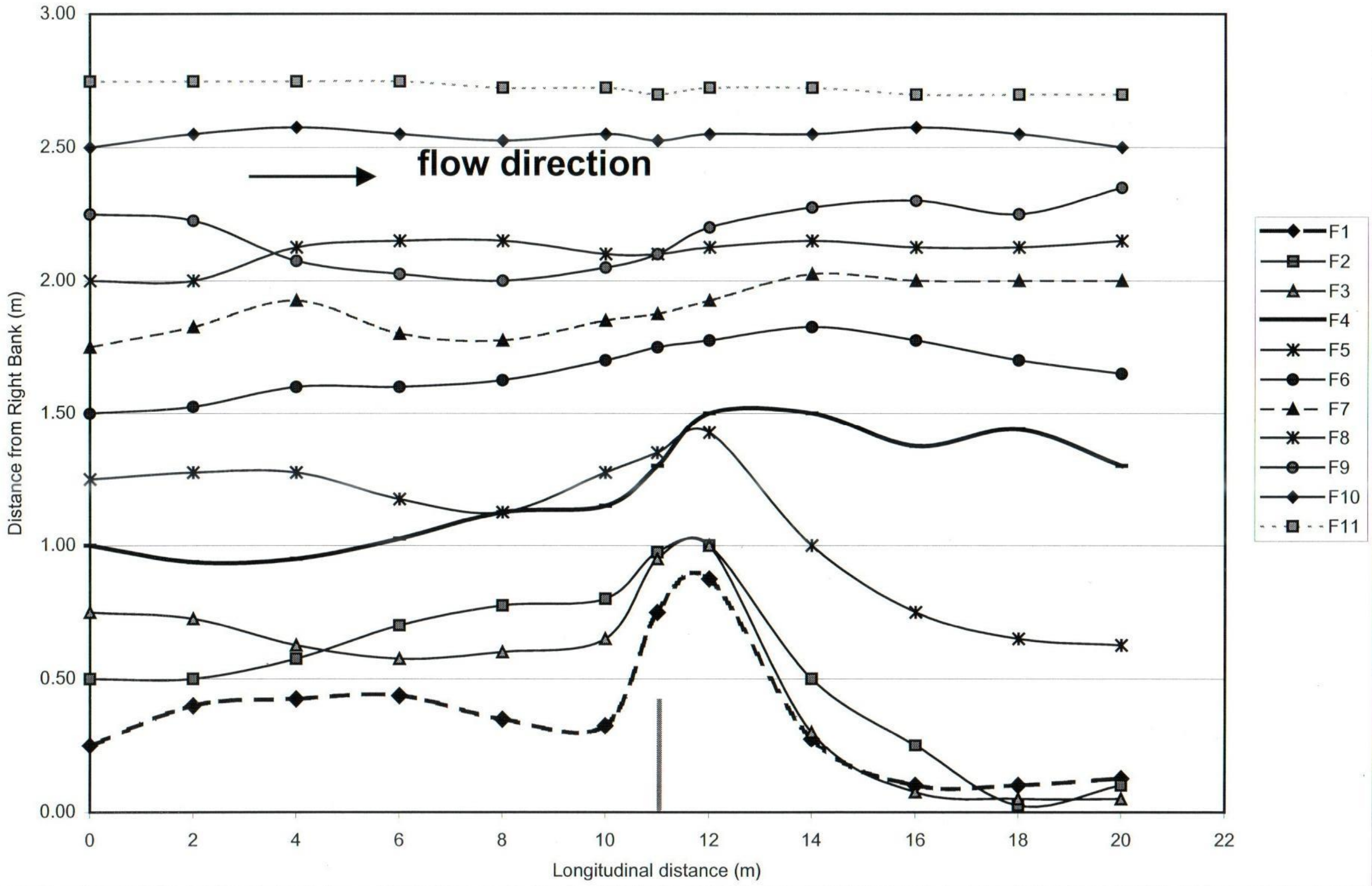


Figure-6: Flow line of Test -T3

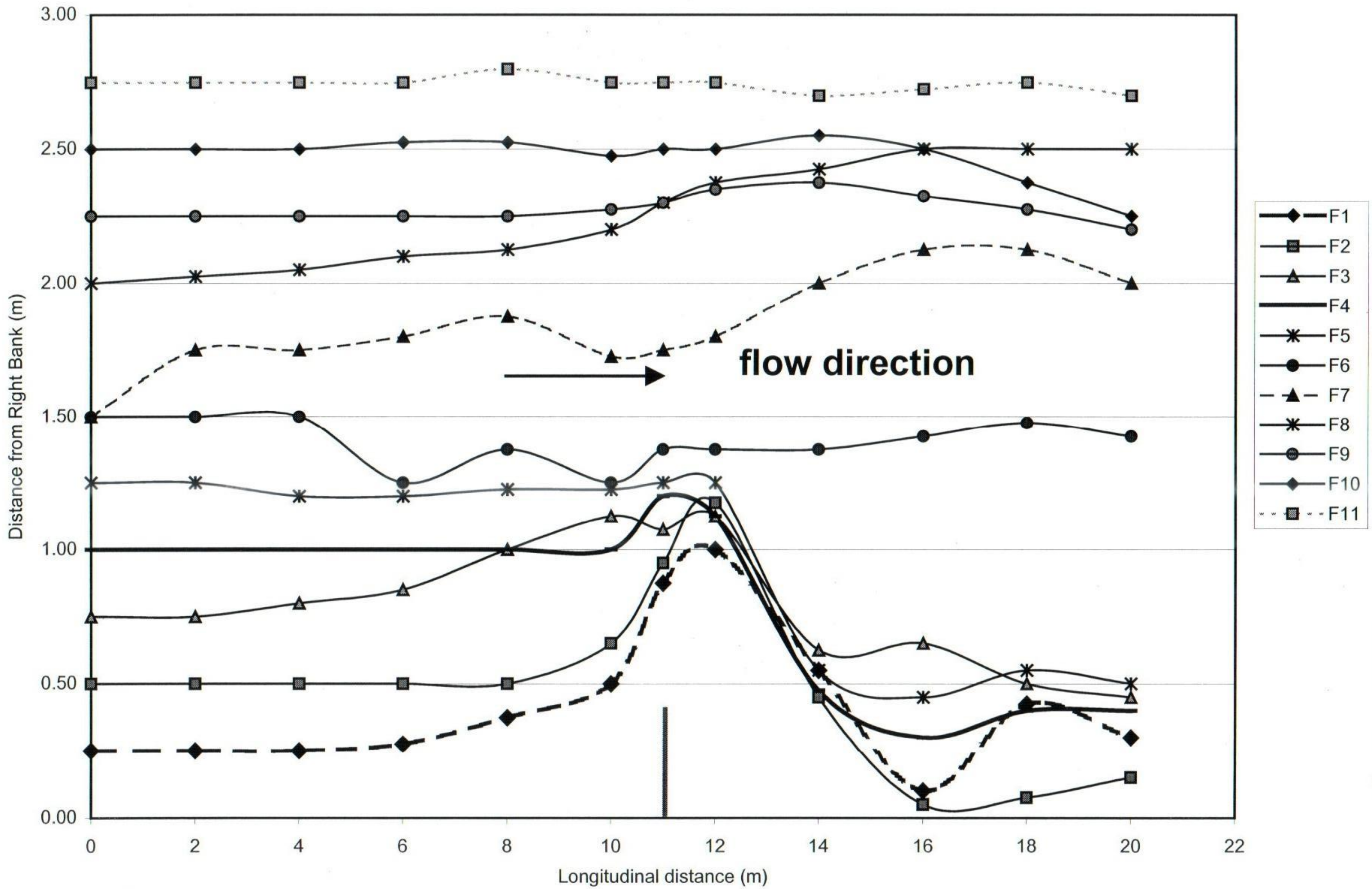


Figure-7: Flow line of Test -T4

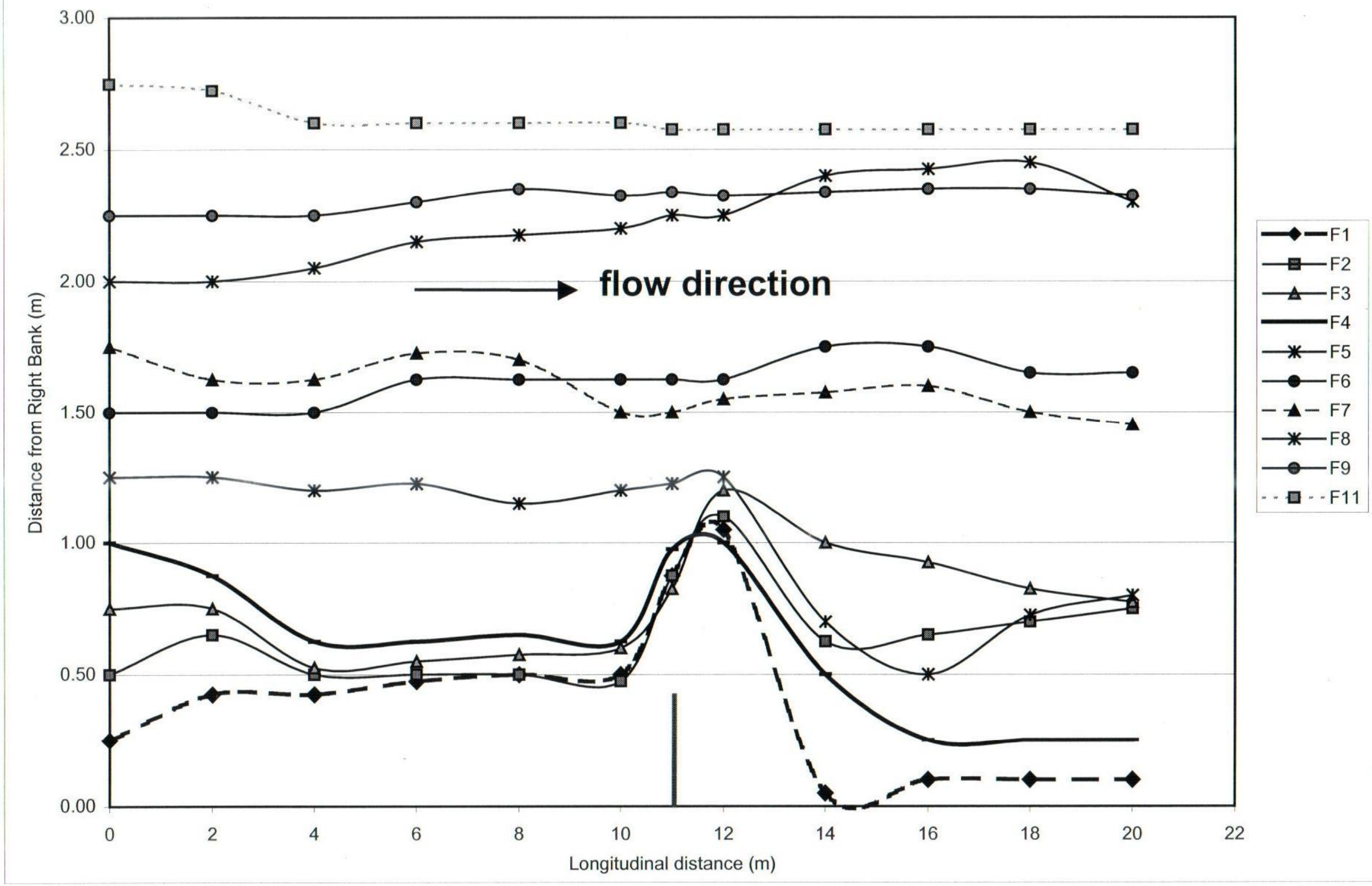


Figure-8: Flow line of Test -T5

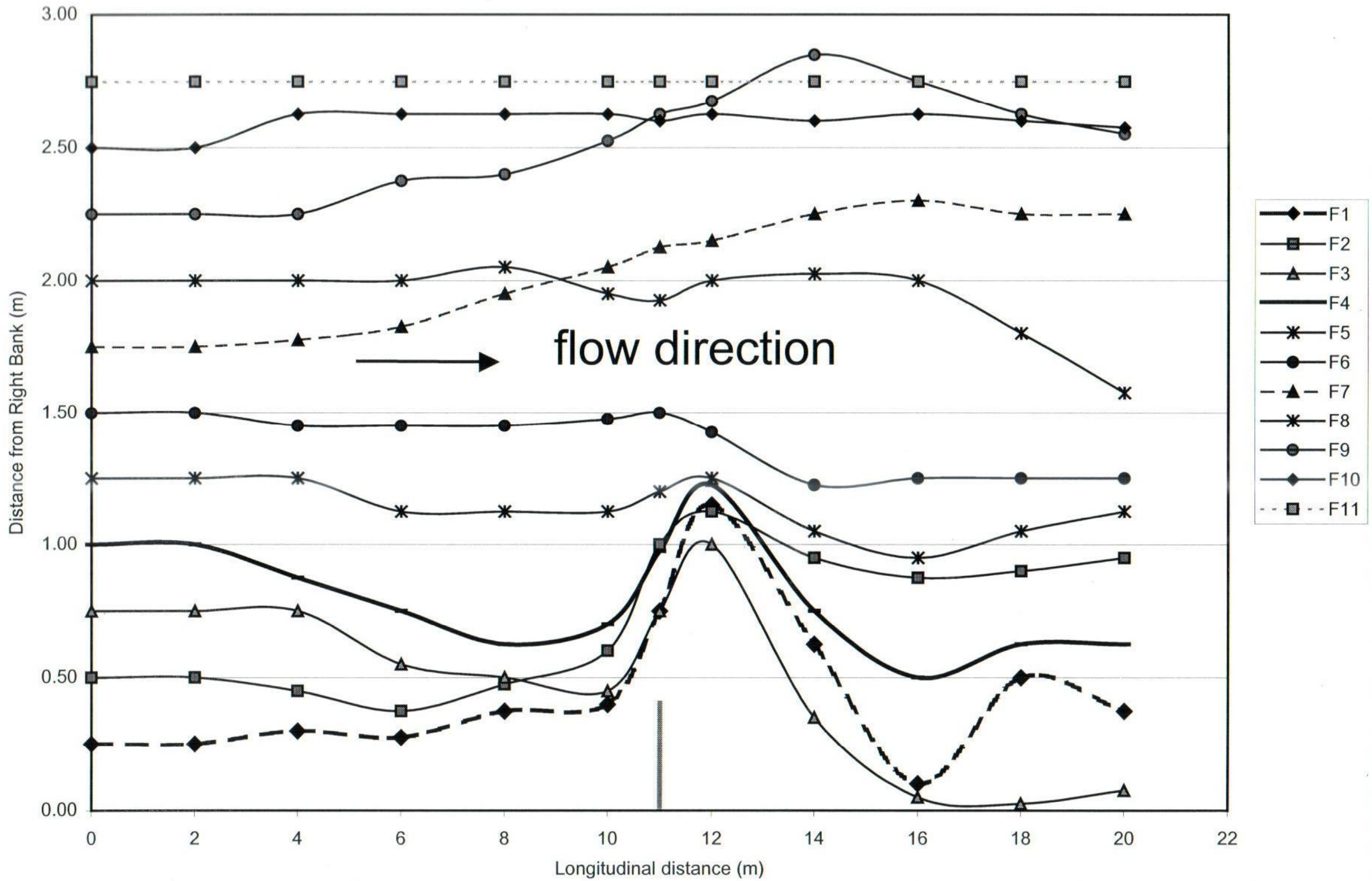


Figure-9: Flow line of Test -T6

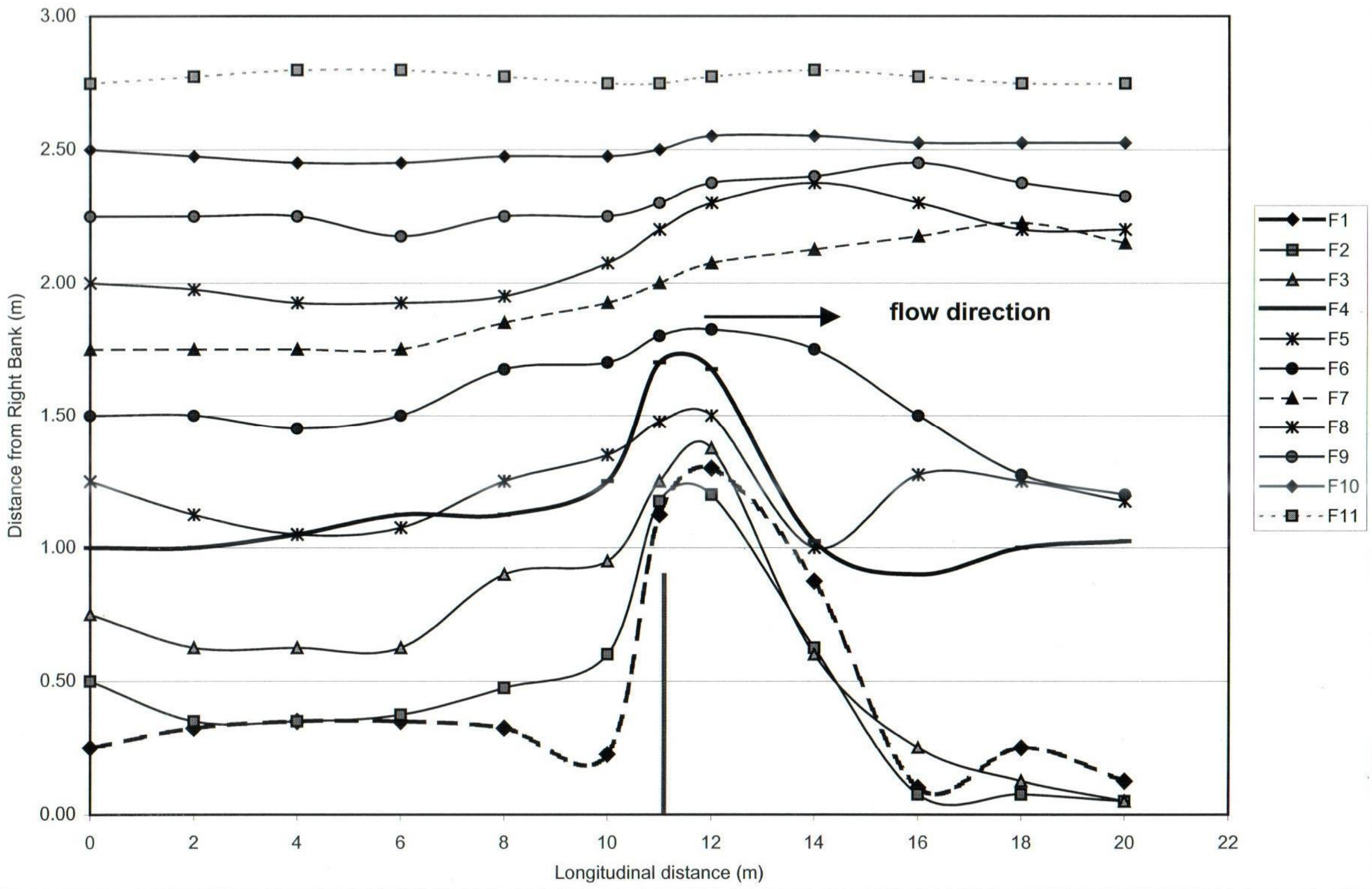


Figure-10: Flow line of Test -T7

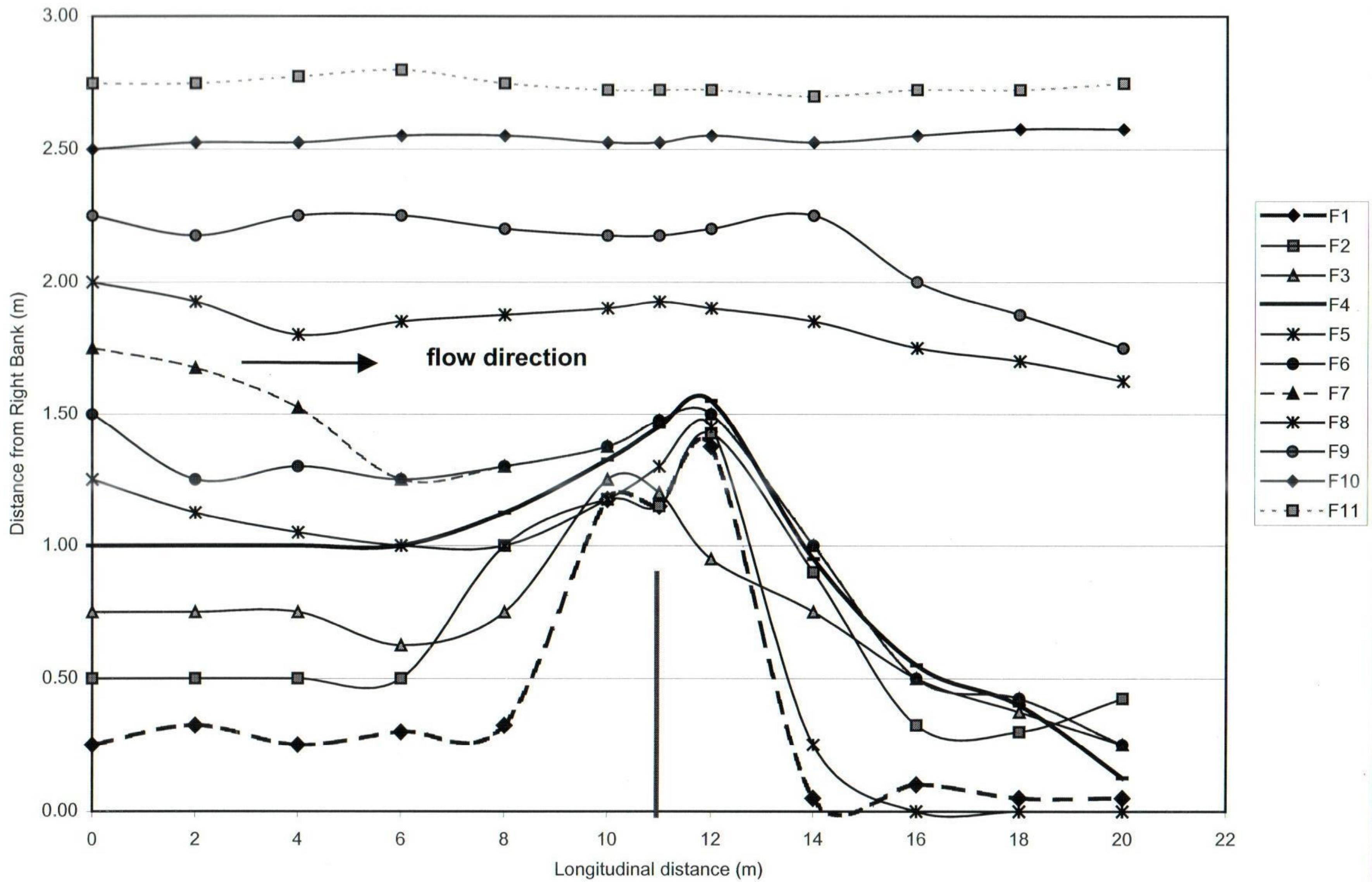


Figure-11: Flow line of Test -T8

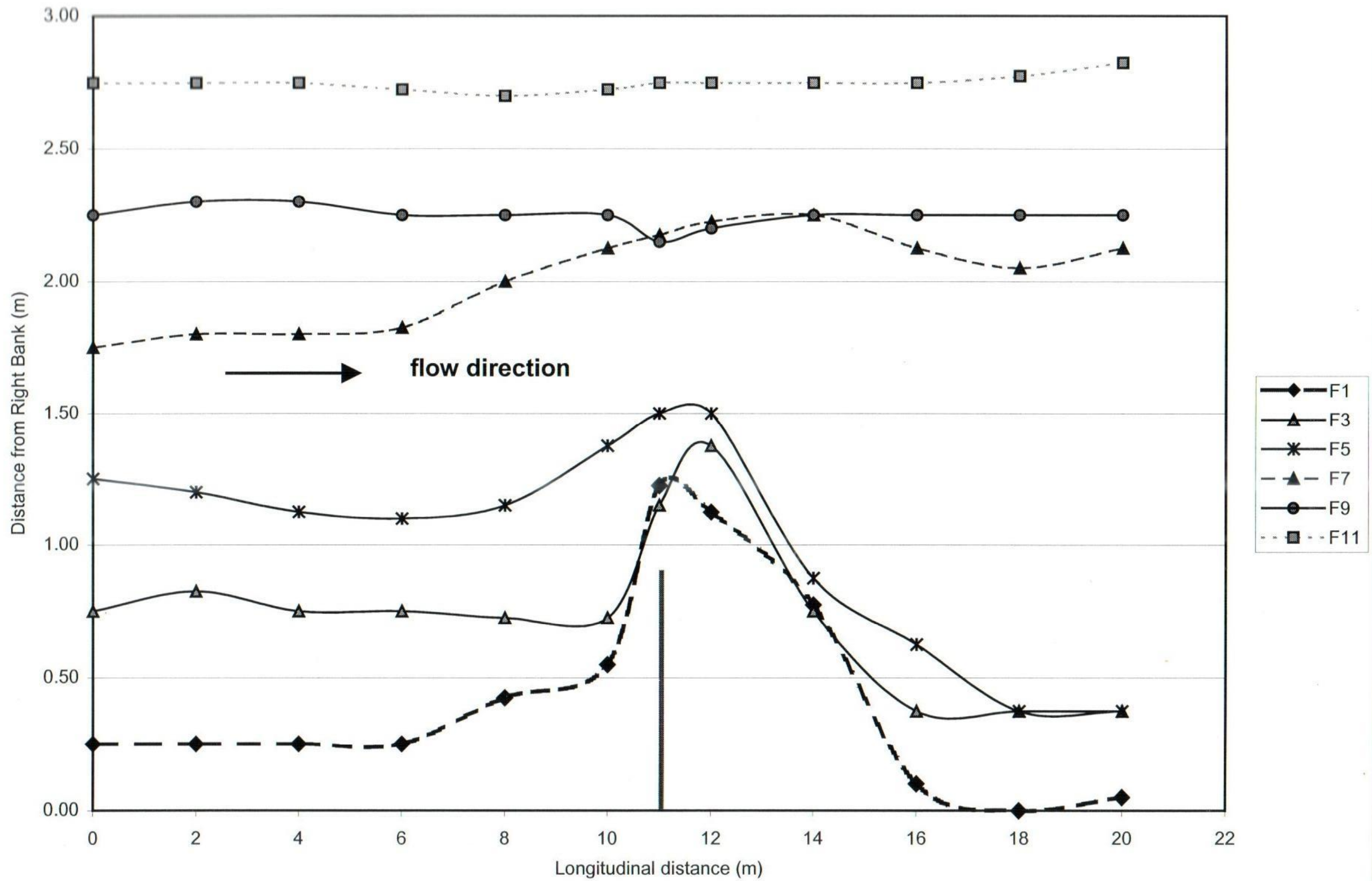


Figure-12: Flow line of Test -T9

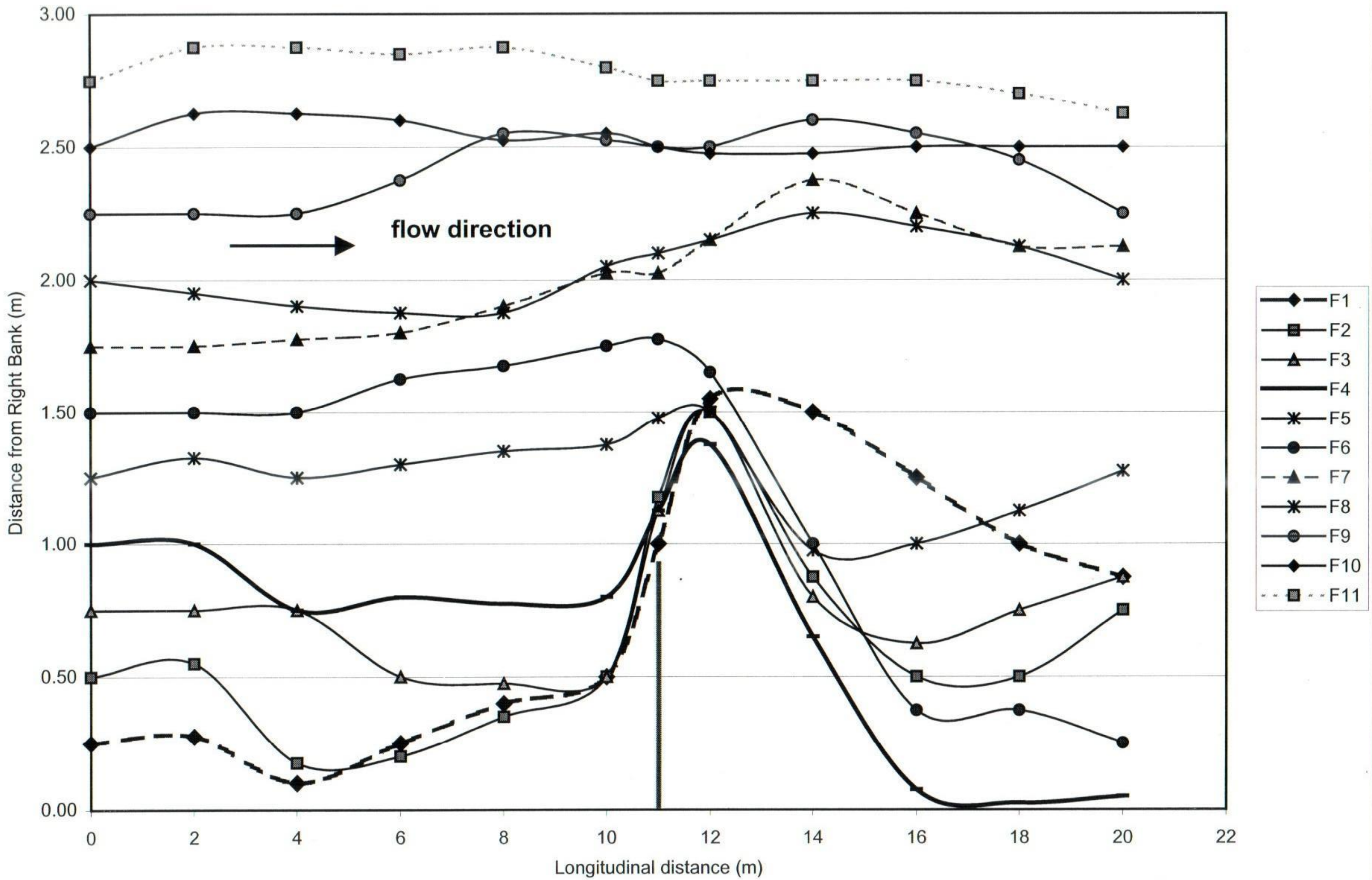


Figure-13: Flow line of Test -T10

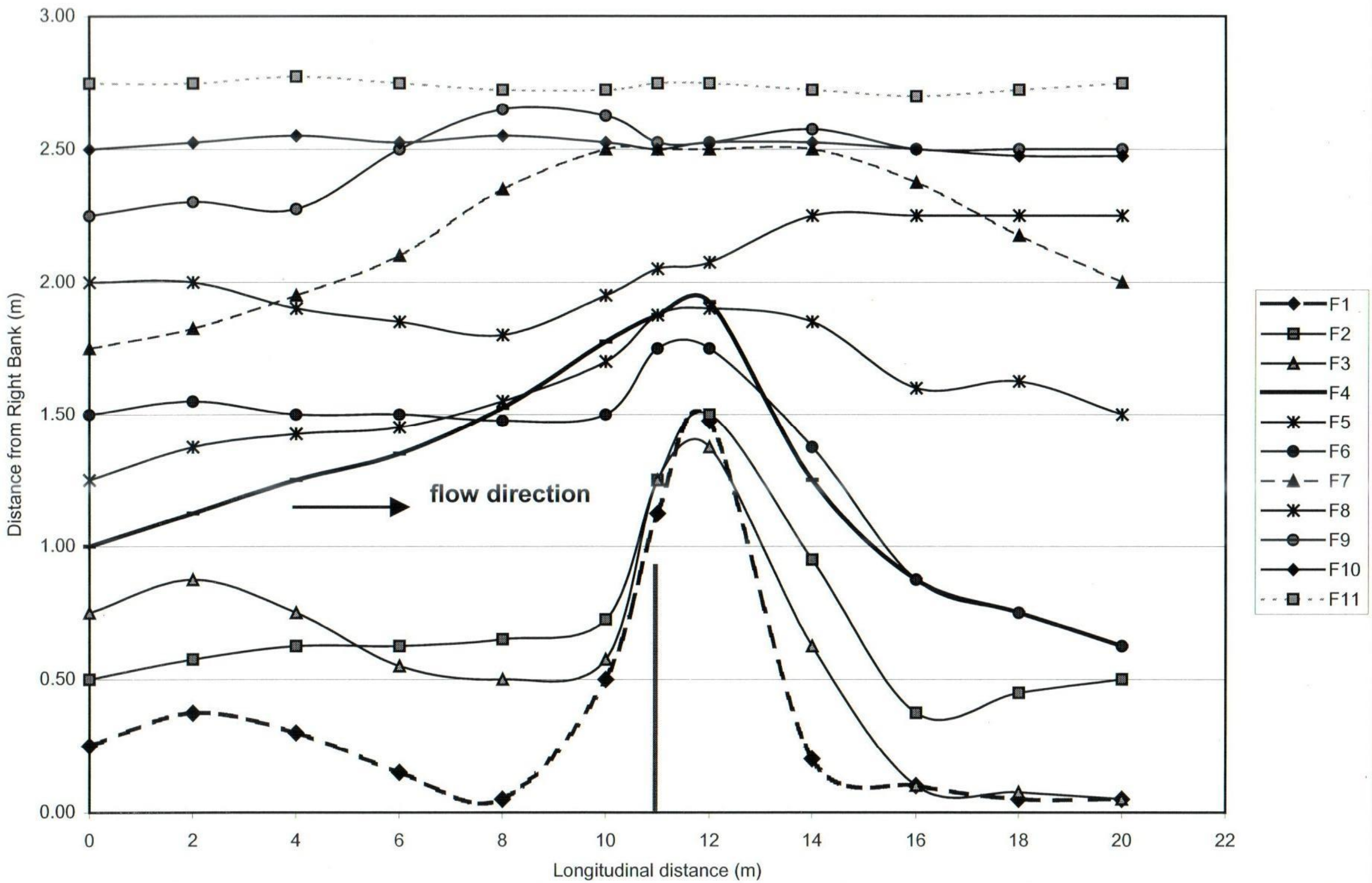


Figure-14: Flow line of Test -T11

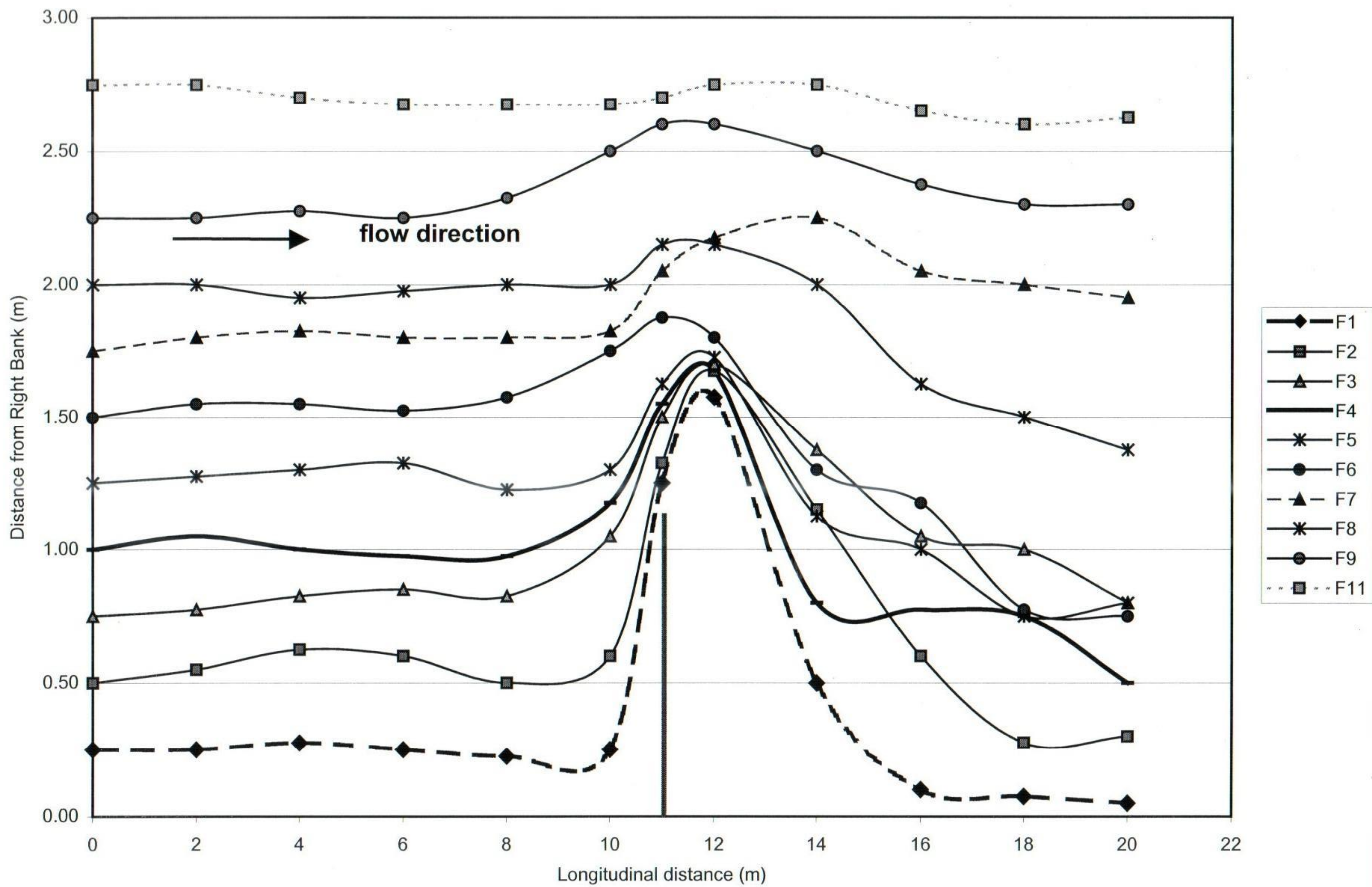


Figure-15: Flow line of Test -T12

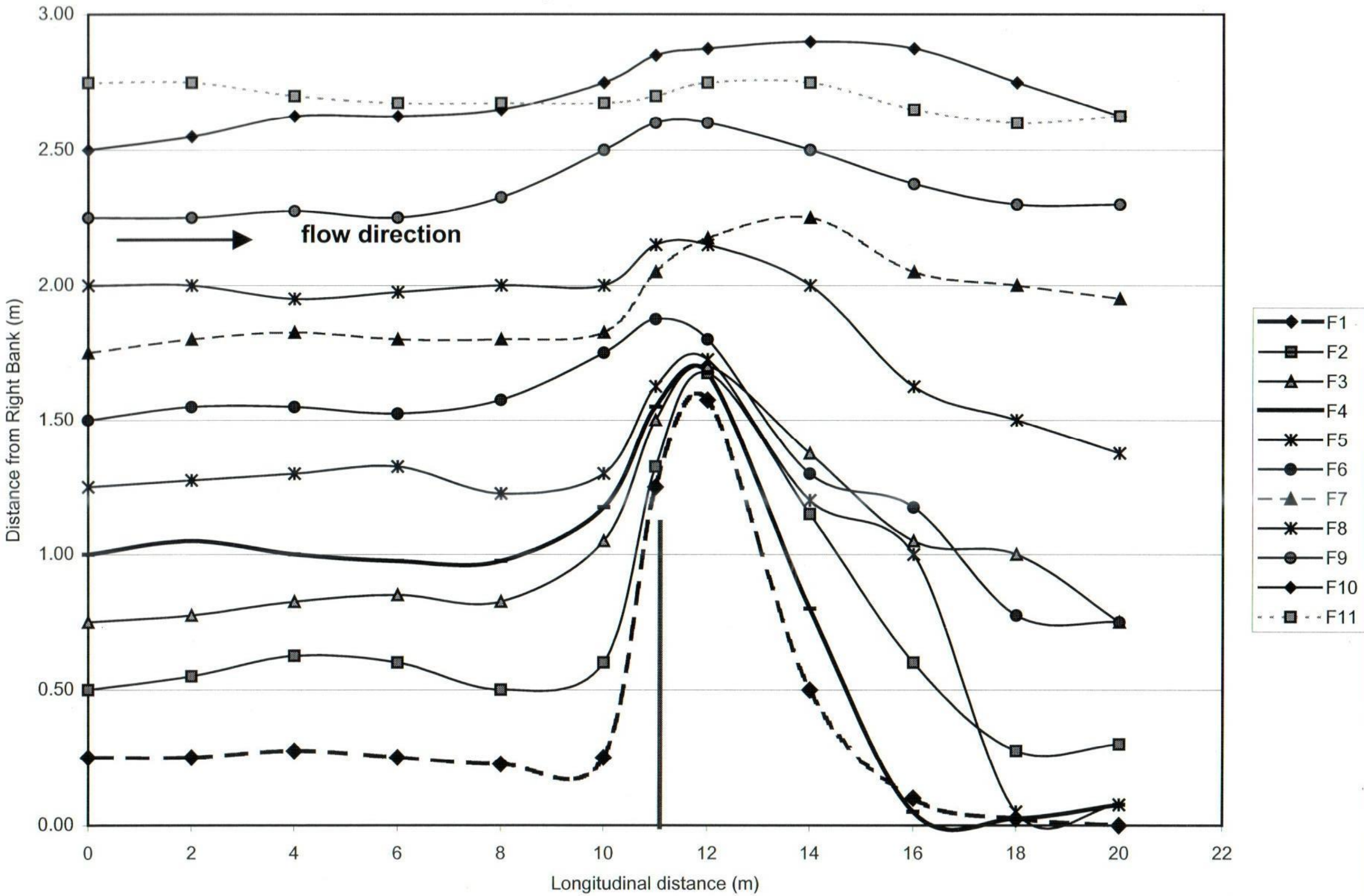


Figure-16: Flow line of Test -T13

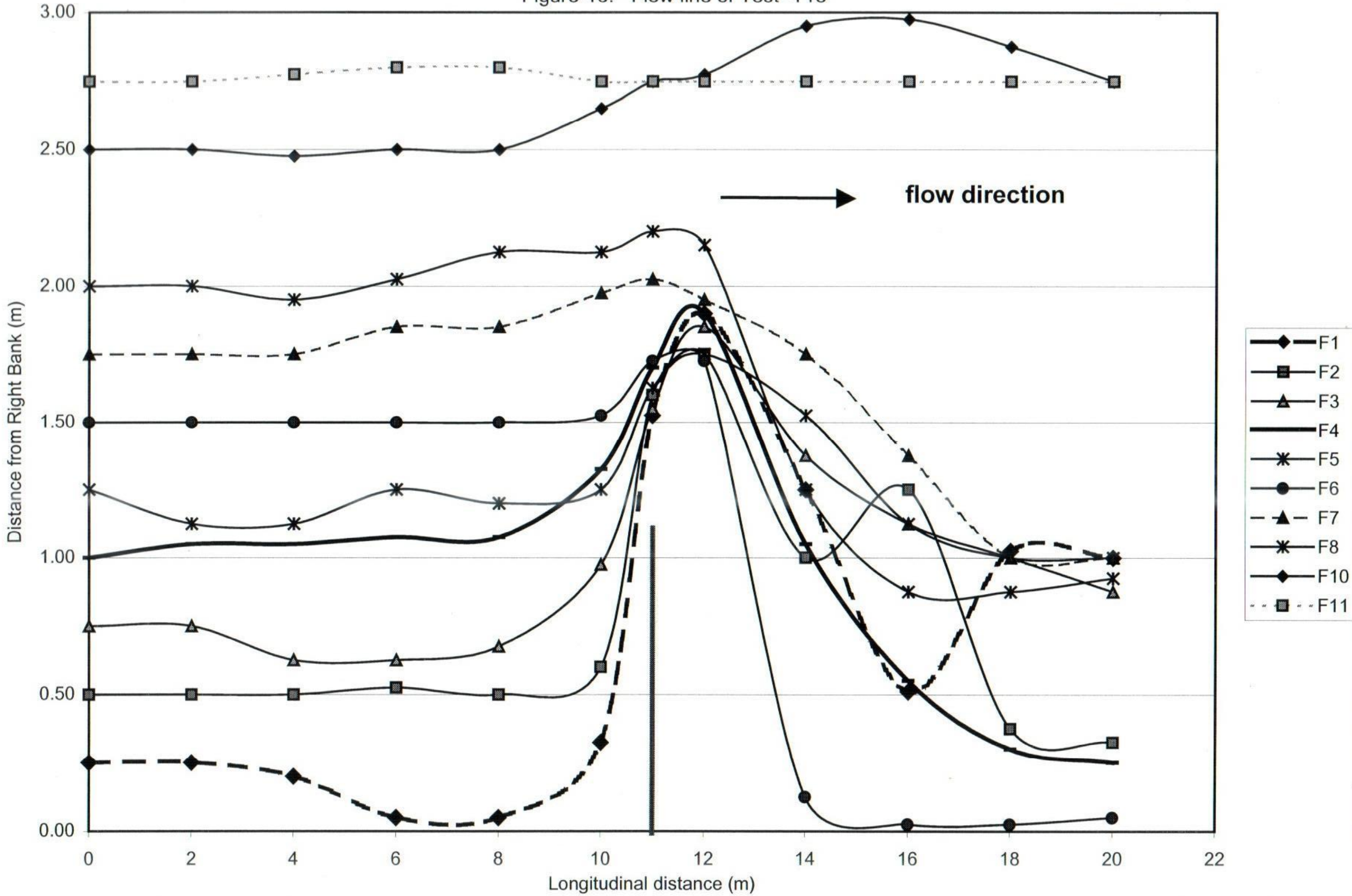
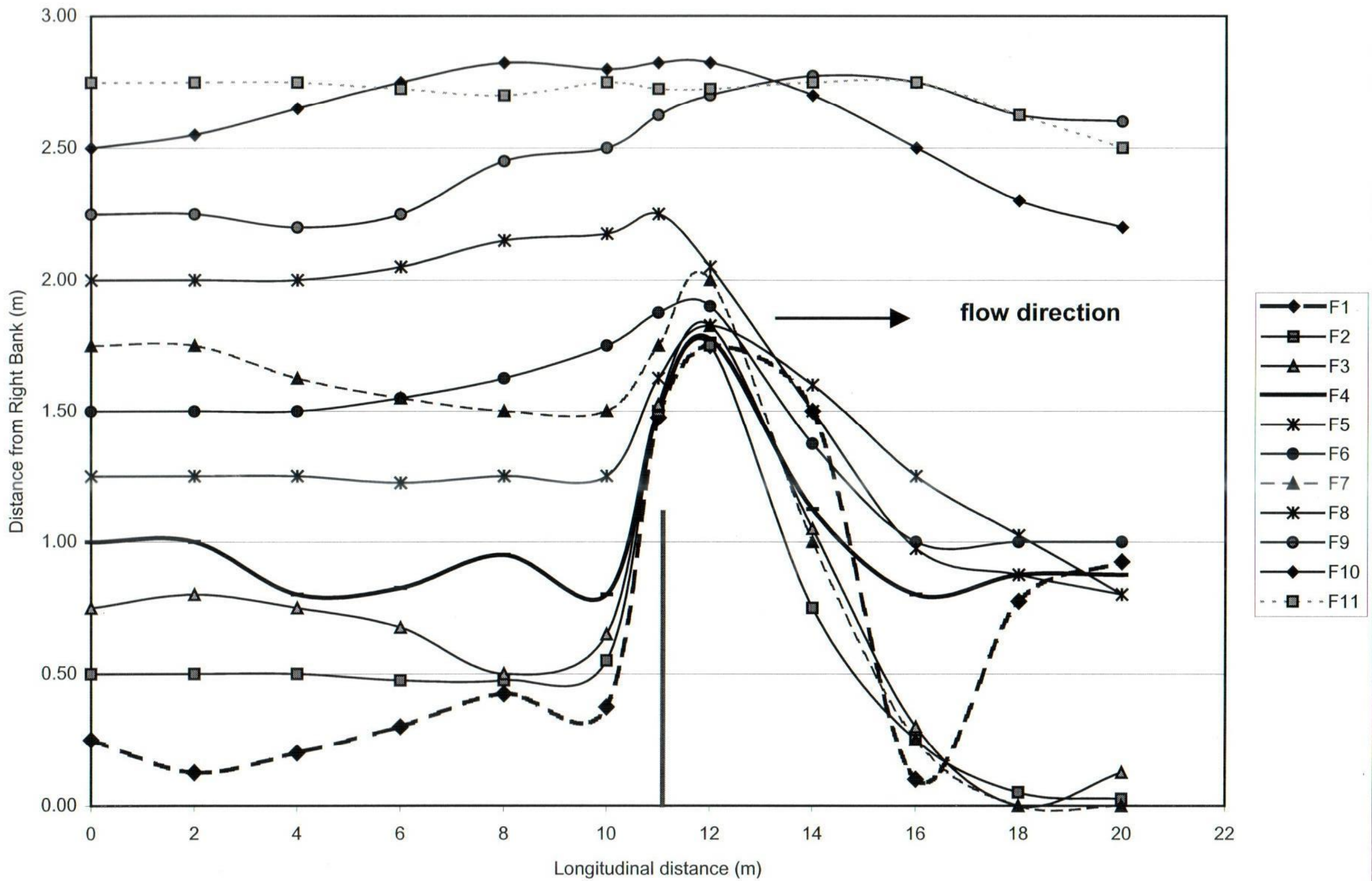


Figure-17: Flow line of Test -T14



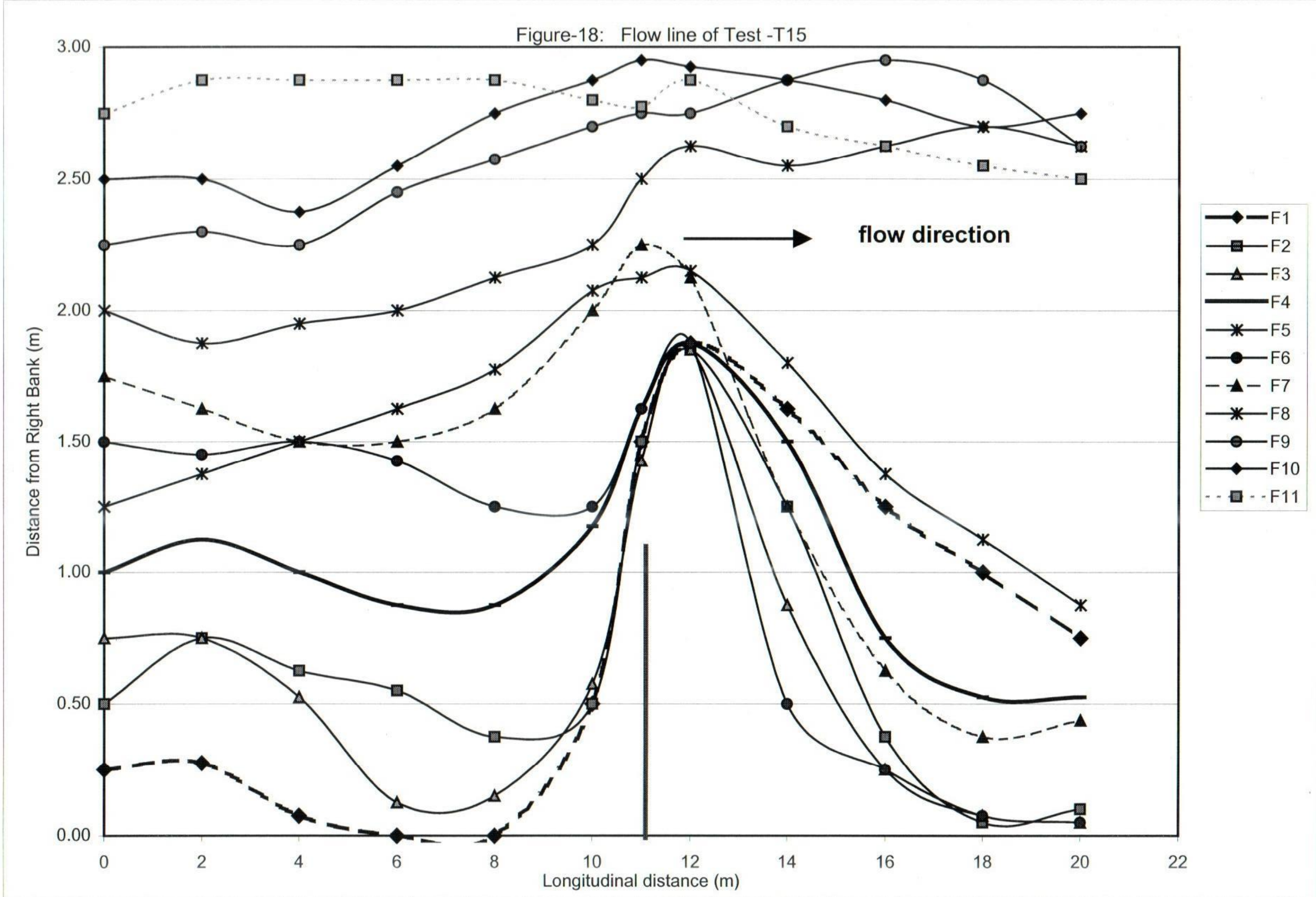


Figure-18: Flow line of Test -T15
flow direction
Distance from Right Bank (m)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
2
4
6
8
10
12
14
16
18
20
22
Longitudinal distance (m)
F1
F2
F3
F4
F5
F6
F7
F8
F9
F10
F11