

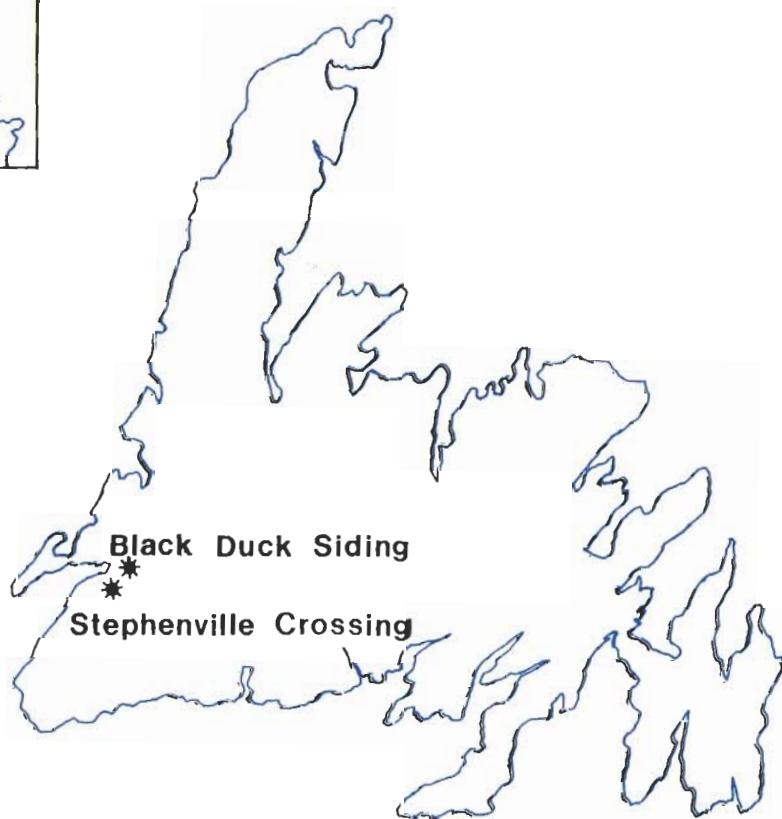
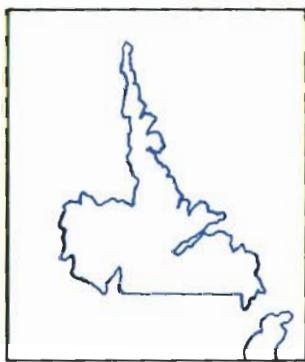


Canada - Newfoundland
**Flood
Damage
Reduction**
Program

Water Resources Division
Hydrologic Modelling
Section

Hydrotechnical Study of the Stephenville Crossing and Black Duck Siding Areas

Technical Appendices



ACRES INTERNATIONAL LIMITED



Department of
Environment



Environment
Canada

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**HYDROTECHNICAL STUDY
STEPHENVILLE CROSSING AND BLACK DUCK SIDING AREAS**

**TECHNICAL APPENDICES
VOLUME II**

FOR

CANADA NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM

MAY 1988

APPENDIX A
FALL FIELD PROGRAM - HARRY'S RIVER

APPENDIX A

HARRY'S RIVER FALL FIELD SURVEY

A.1 - Objectives

The field survey of Harry's River was carried out with the following objectives:

- i) Establish and obtain cross sections at all representative locations throughout the entire channel reach.
- ii) Verify the physical dimensions of Harry's River Bridge as given on plan drawings provided by the Department of Transportation.
- iii) Observe and record the physical and topographical characteristics of the study area, such as overbank properties, size and extent of tree cover, and areas of past and potential erosion by water and ice. These observations will be particularly useful when calibrating the HEC-2 mathematical model.
- iv) Obtain a water surface profile throughout the study reach.

The steps carried out in the field survey of Harry's River are outlined below. All measurements were done using a Weiss Ni2 Automatic level and a Kern Kl-S Theodolite. All distances were obtained by chaining.

A.2 - Cross Section Locations

A walk-over survey of the river reach was completed to identify cross section locations and also to note any special problem areas.

Cross section locations were marked at locations where the river changed in plan (widened or narrowed), locations of islands, locations where changes occurred in river depth, and at locations where tributaries entered the river.

A.3 - Vertical Control System

Once the cross section locations had been identified, a vertical control system was established along the left bank of the river, looking upstream. This system referenced the Geodetic Survey of Canada Benchmark 76F879 (El. 35.414 m), which is a plug in the south corner of the west abutment of Harry's River Bridge on Route 460. Temporary benchmarks (TBM's) were established at each cross section location and the elevations carried up/down from the geodetic benchmark on the bridge. The survey loops were closed at the end of each day with a degree of accuracy of 5-10 mm. Distances and angles between each TBM were measured for the purposes of mapping the section locations with reference to Harry's River Bridge.

A.4 - Cross Sections

With the vertical control system in place, and the section locations tied into the bridge, channel sections were surveyed. In measuring sections, the zero point was taken to be the edge of the natural river channel on the left bank (looking upstream), and elevations were measured to the left and right of this point. This system enables easy visual identification of the width of the natural river channel and the extent of the overbanks, which will be important in calibrating the HEC-2 model for roughness coefficients.

The locations of the cross sections and the cross section plots are given in Appendix A-1. The cross sections were also plotted on 1:2500 scale mapping to ensure that the measured elevations correspond to those on the map and that sections tied in, both

horizontally and vertically. The 1:2500 mapping used are the 1985 Flood Risk Maps for the Black Duck area (Reference maps FR-BD-1 to FR-BD-5).

Most of the cross sections presented in Appendix A-1 have been extended by about one contour interval (1 m) using the FR-BD 1:2500 scale mapping, after careful checking to ensure that the elevations from the survey and the mapping corresponded. These extensions were done to provide upper boundaries at higher elevations for the HEC-2 and ICESIM models. It also meant that in certain areas, such as steep, heavily wooded banks, extensive cutting could be avoided. Cutting is considered a change in vegetation along a river bank and requires the approval of the Department of Fisheries. Where the extension of a cross section covered areas considered more important, usually a long distance across a relatively flat field, spot elevations were taken and cross sections were tied into buildings.

A description of the measured cross sections is presented in the following section.

A.5 - Cross Section Descriptions

When measuring the cross sections, a careful record was kept of the nature of the cross sections such as the overbank conditions, vegetation, and tree cover, and locations of past or potential erosion. A brief description of the cross sections is presented here, starting upstream, with photographic references.

In the following descriptions, the left bank (L/B) is taken as looking upstream.

Section 5+742 - deep and narrow. L/B is very steep and heavily wooded with dense brush at bank edge. R/B is low sloping with dense brush.

Photo reference: 68

Sections 5+562 - 5+419 - narrow, not as deep as previous section. Gradual sloping L/B with dense brush at bank edge and flat grassy field beyond. Right bank is low sloping with dense brush/trees. Average slope of riverbed = 0.002.

Photo reference: 65 - 67

Sections 5+382 - 5+329 - shallow, fast moving water with steep heavily wooded R/B. Island has medium tree growth (mostly birch) with some brush undergrowth. L/B has gradual slope with dense brush at bank edge and flat field beyond. Average slope of riverbed = 0.007

Photo reference: 64 - 65

Section 5+190 - deep and narrow section with steep, densely wooded R/B. L/B gradually sloping with flat grassy field beyond.

Photo reference: 63

Sections 5+060 - 4+773 - sections taken through two large islands just upstream of bridge. Region is very wide with deeper channel near R/B. There is a smaller channel between Dhoon Lodge field and island on L/B with main channel between two islands. L/B is fairly flat with medium trees and brush at bank edge and flat grassy field beyond. R/B is fairly steep with dense trees and brush at bank. The islands are densely wooded with thick undergrowth. Average slope of riverbed = 0.005.

Photo reference: 60- 63

Section 4+712 - section just upstream of bridge. Fairly narrow with fast moving flow. Steep L/B with light to medium brush. R/B fairly steep with light brush and trees.

Photo reference: 58 - 60

Sections 4+627 - 4+367 - starting just below the bridge, sections widen and get shallower towards downstream. L/B has fairly flat slope with flat grassy field beyond medium dense trees/brush. R/B has gradual steep slope and is very heavily wooded from bank inland. Average slope of riverbed = 0.001.

Photo reference: 52, 54 - 57

Sections 4+323 - 4+011 - River wide and shallow at 4+323, gradually narrowing and deeper to end. L/B is fairly steep with brush/small alders near bank and heavily wooded beyond. R/B has flatter slope and is heavily wooded. Evidence of erosion at Section 4+085. Average slope of riverbed = 0.005.

Photo reference: 49 - 53

Sections 3+907 - 3+645 - River starting to widen. L/B is very steep and heavily wooded. R/B has flatter slope with medium to dense tree cover. Average slope of riverbed = 0.001.

Photo reference: 44 - 48

Section 3+448 - at transmission line, 15 m wide clearing at bank. Flat and grassy field extends back 55 m beyond bank edge with a 1 m rise to level land. R/B is fairly steep and heavily wooded.

Photo reference: 41, 43

Sections 3+373 - 2+917 - shallow and wide, gets deeper and narrow downstream. Steep L/B with thick to medium brush at bank edge, and very thickly wooded beyond. R/B has gradual slope with medium/dense trees/brush. Average slope of riverbed = 0.005.

Photo reference: 36 - 40, 42

Sections 2+802 - 2+332 - at Hickey's farm. Sections 2+702 to 2+492 are taken through the large island. All sections have very steep R/B with dense woods. L/B has medium to dense brush with flat grassy field beyond. Section 2+332 also includes the natural channel that runs from Hickey's farm into Harry's River. Average slope of riverbed = 0.002.

Photo reference: 24 - 35

Sections 2+177 - 1+591 - generally narrow, deeper sections with a very steep, densely wooded R/B. L/B has a gradual slope and is heavily treed with a grassy field beyond. These sections include the intermittent side channel that runs almost parallel to the river down to Section 1+591. At Section 1+756, there is a 20 m wide opening with flat field beyond. Average slope of riverbed = 0.003.

Photo reference: 14 - 23

Sections 1+401 - 1+347 - very shallow with rapids. River wide at Section 1+401, narrows downstream of Section 1+347. Steep L/B with dense woods. R/B has lower slope with very dense woods. Section 1+401 contains an inflow and flooding section that indicates an "island" at cross section 1+347 during flooding. Average slope of riverbed = 0.009.

Photo reference: 10 - 13

Section 1+254 - Narrow and deeper. L/B is flat with grass/brush. R/B gradual slope with very dense woods.

Photo reference: 8 - 9

Sections 1+152 - 0+679 - Narrow with fast moving water. Section 1+152 taken just below entrance of Black Duck Brook into Harry's River. L/B is fairly steep with medium brush/grass at bank,

dense woods beyond. R/B is gradually sloped with brush/grass at bank edge, medium to thick woods beyond. Average slope of riverbed = 0.002.

Photo reference: 6 - 7

Section 0+471 - Narrow with fast moving flow. Very steep L/B bank, rising to flat area where there is evidence of substantial clearing of trees caused by nature or man. The R/B is fairly steep with medium to dense trees.

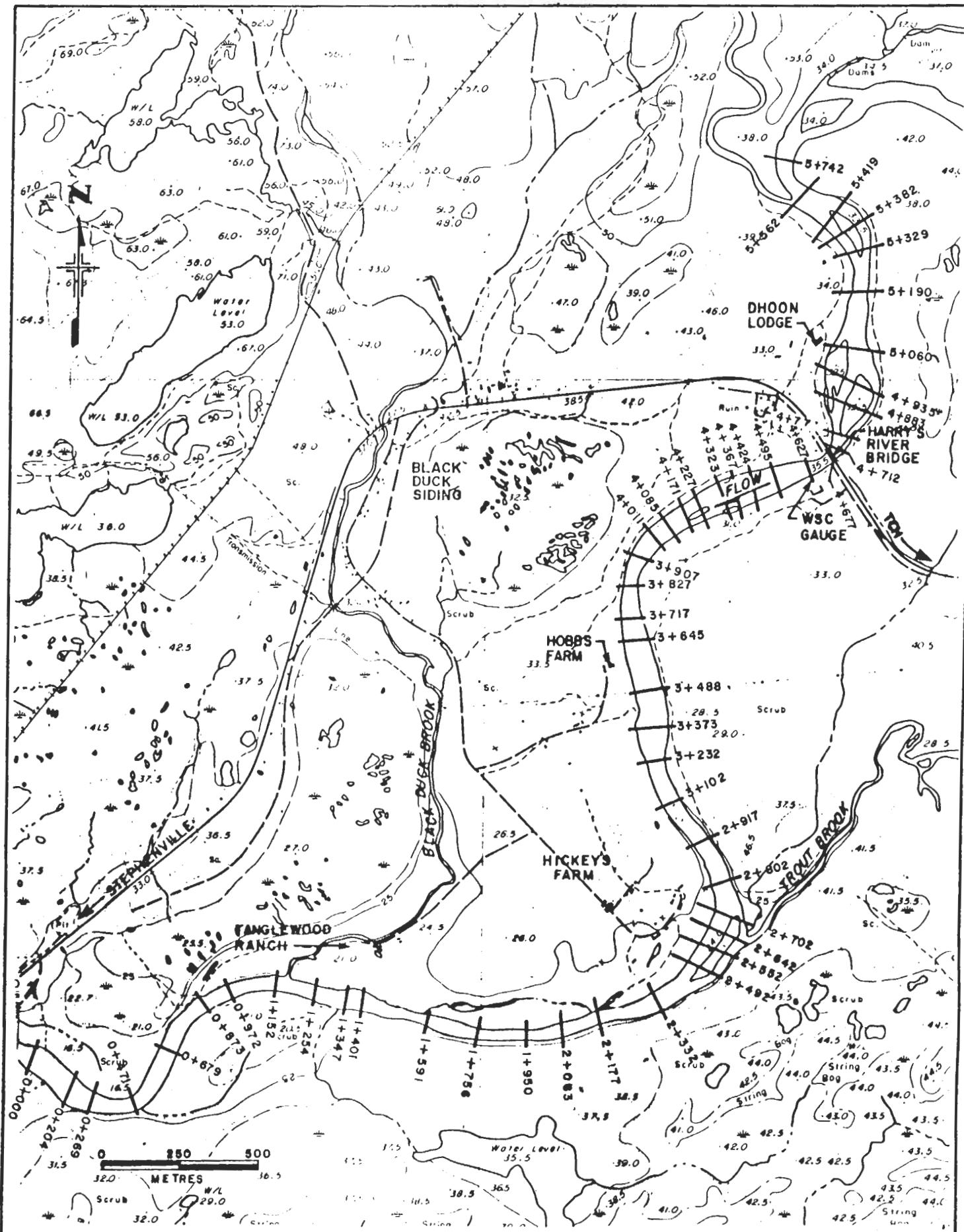
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Sections 0+269 - 0+204 - narrow with fast moving flow/rapids. R/B fairly steep with dense woods. Low sloping L/B with tall grass/brush. Average slope of riverbed = -0.01.

Photo reference: 1, 4

Section 0+00 - Last section in reach. Deep with fast moving water. L/B and R/B similar with initially low slopes with grass/brush at the banks and steeper, heavily wooded slopes starting inland.

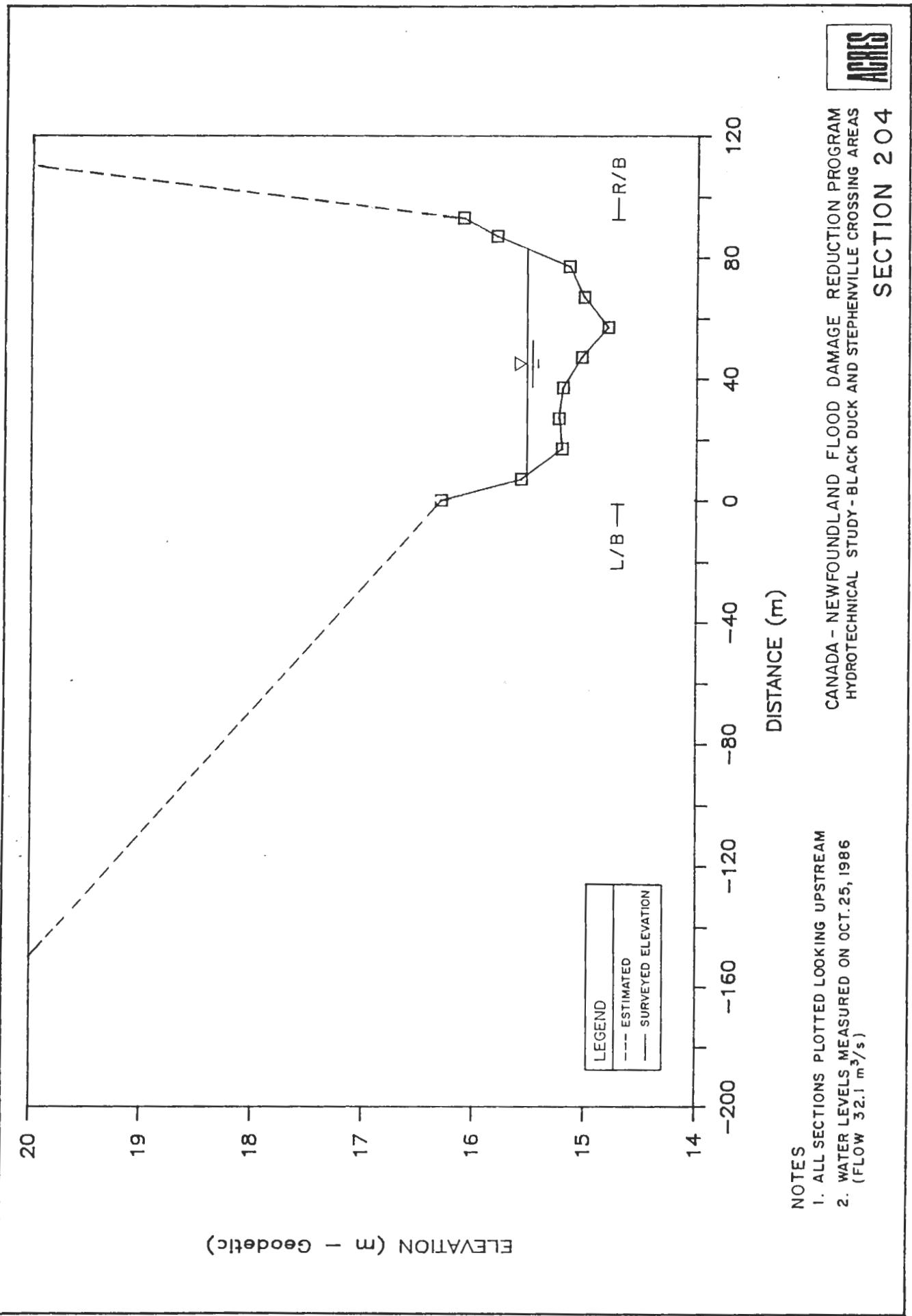
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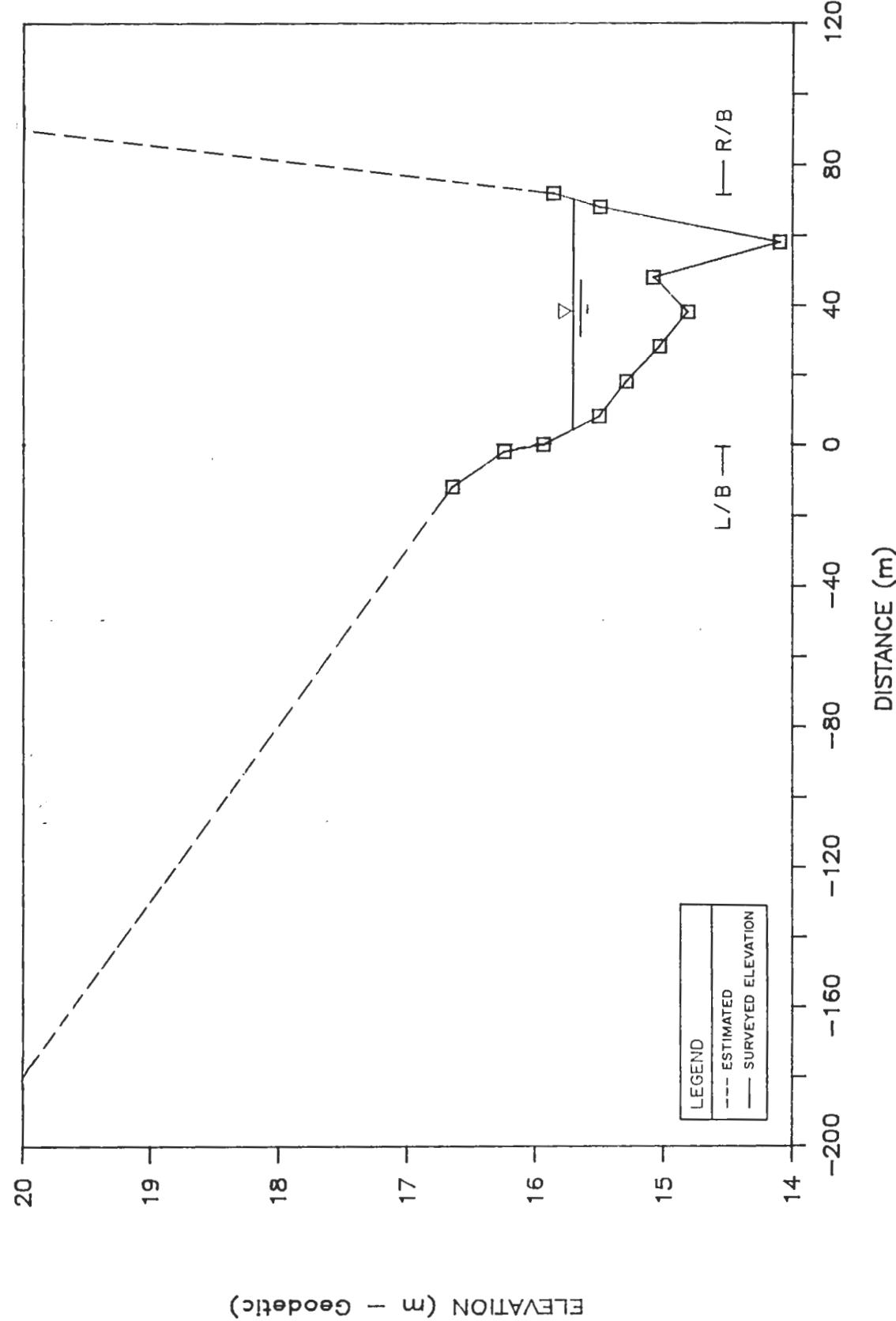


CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - STEPHENVILLE CROSSING AND BLACK DUCK SIDING AREAS

SURVEYED CROSS SECTION LOCATIONS- HARRY'S RIVER

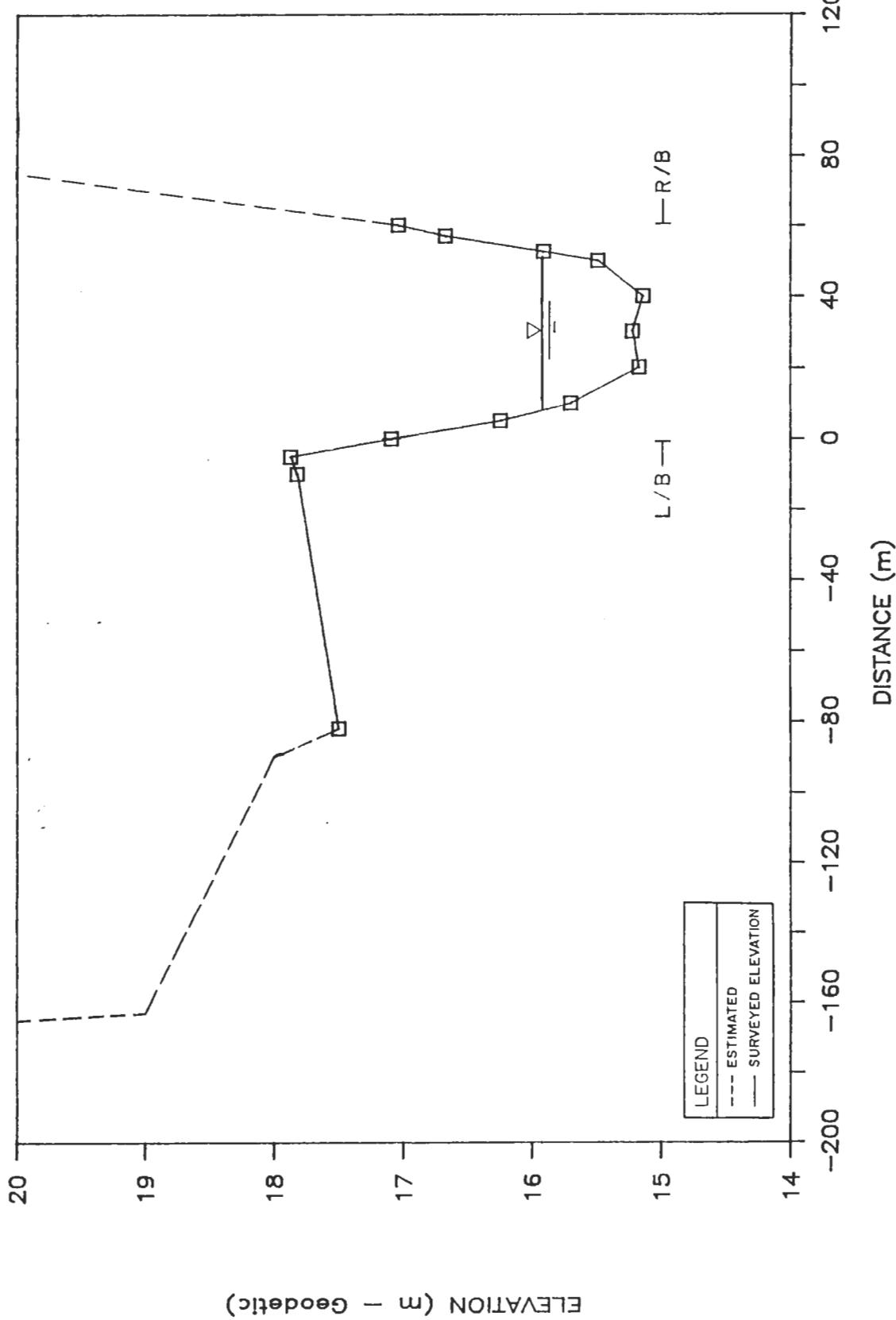
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NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)



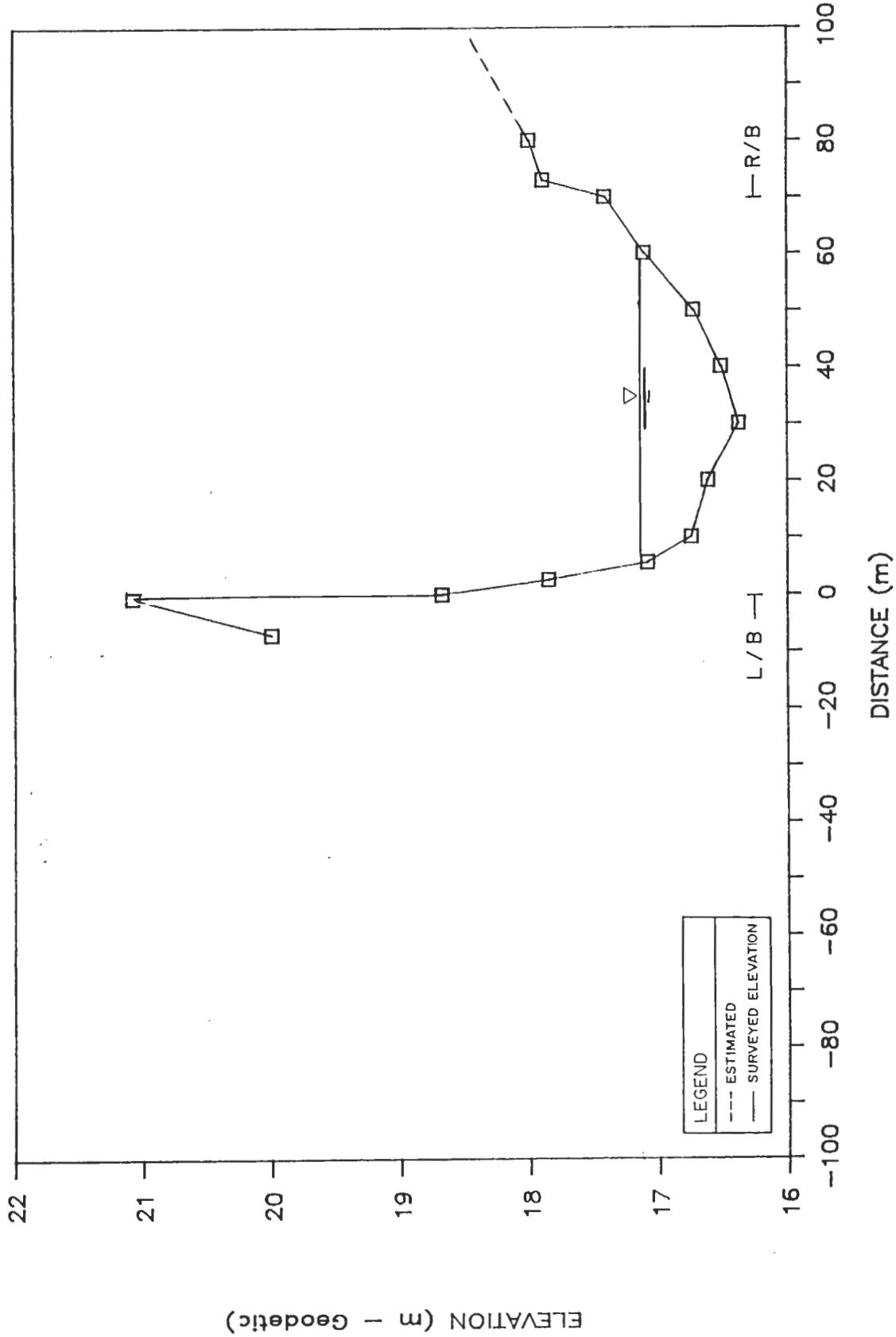
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HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS

SECTION 471

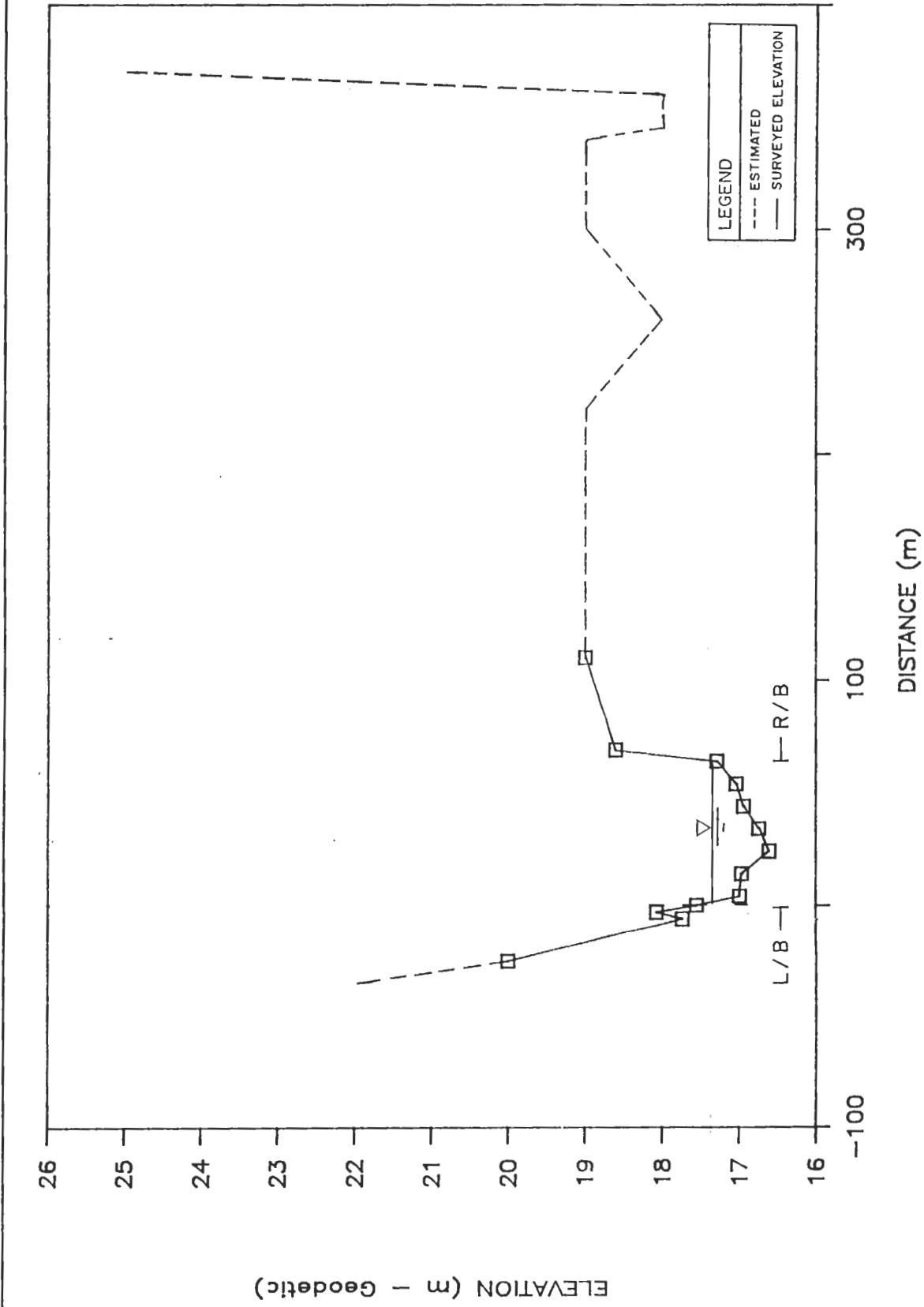


NOTES

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CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 679





NOTES

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HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS

ACRS
SECTION 873

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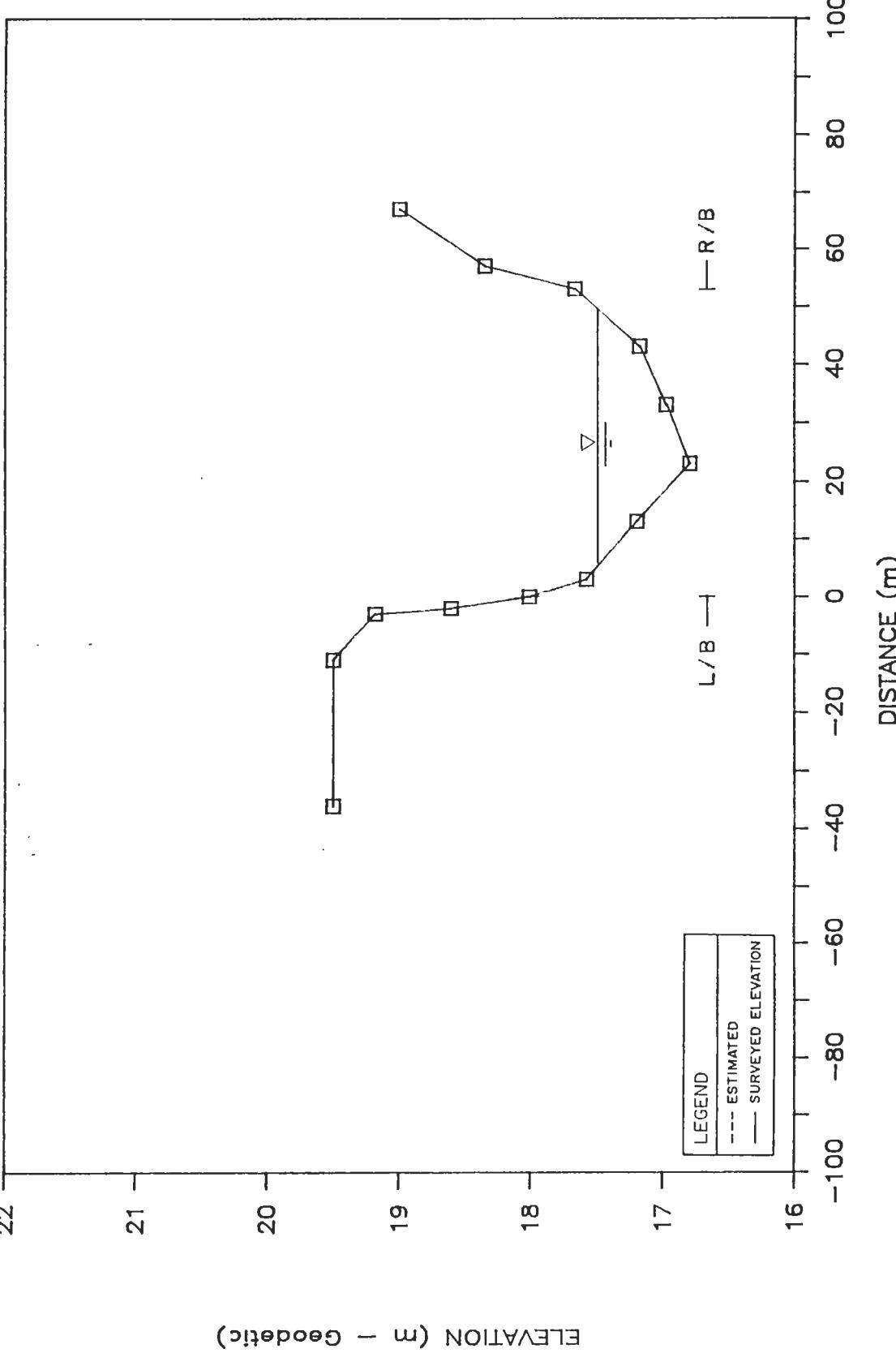
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ELEVATION (m - Geodetic)

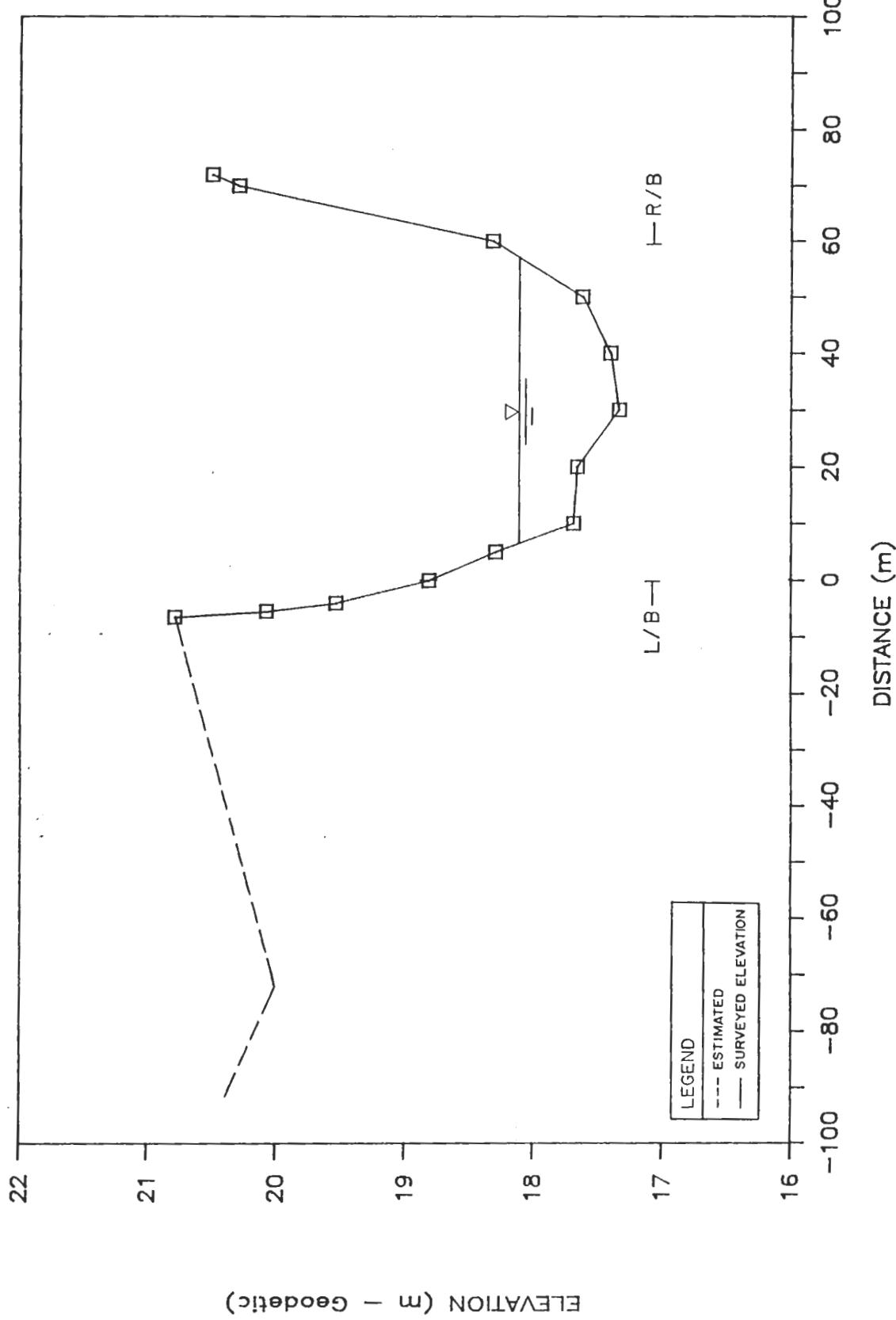


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(FLOW 32.1 m³/s)



SECTION 972

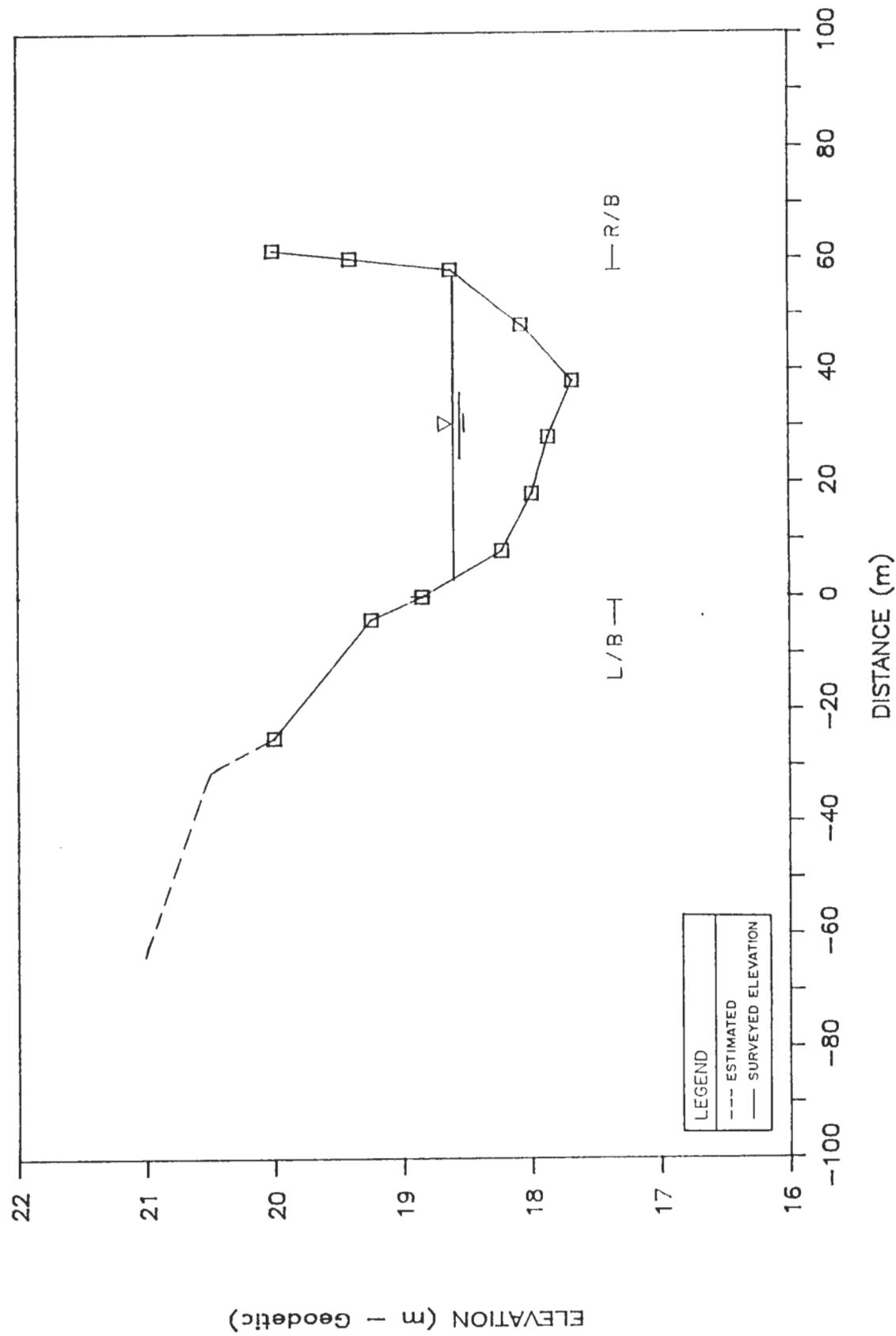


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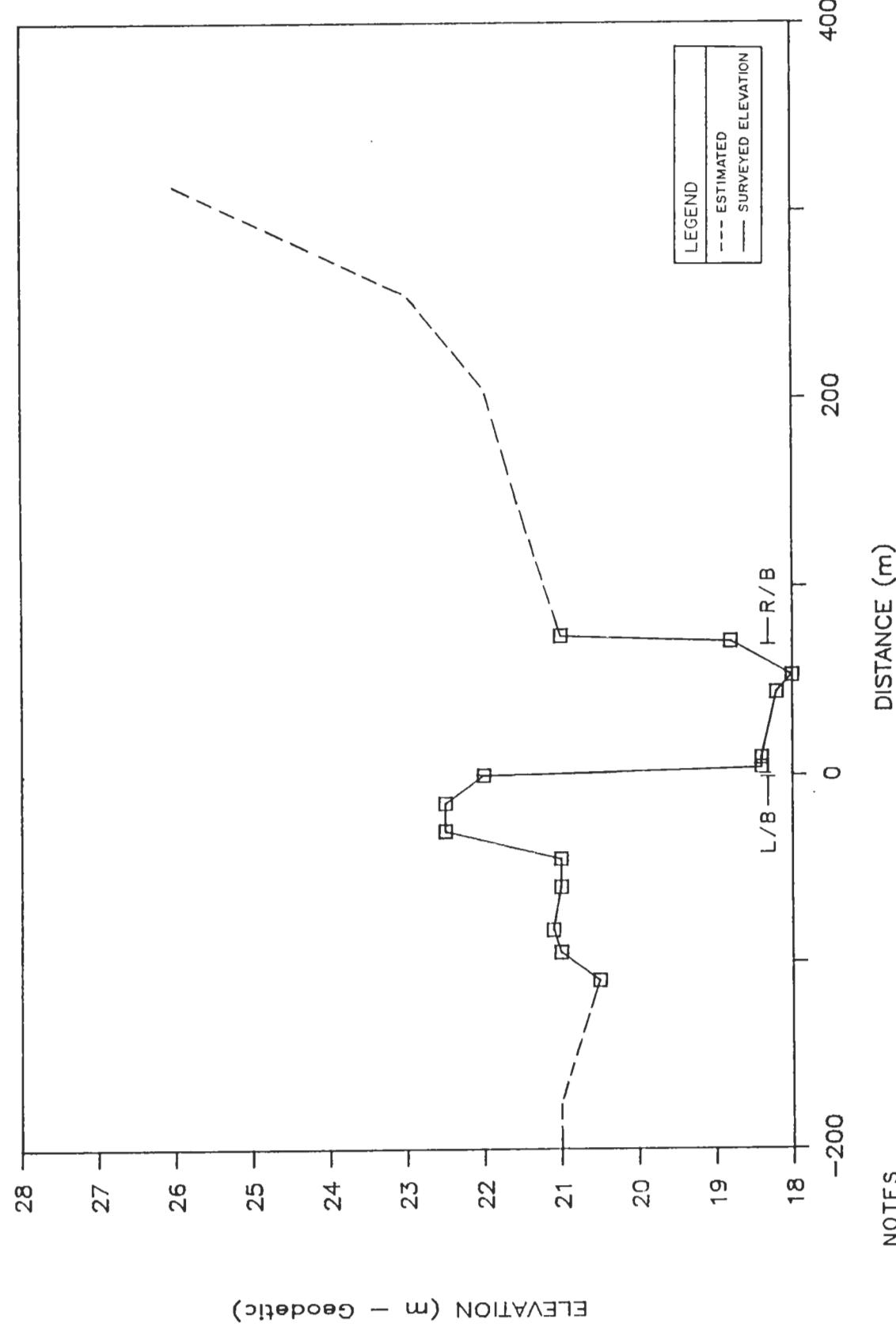
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CANADA - NEWFOUNDLAND AND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 1152



NOTES
 1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
 2. WATER LEVELS MEASURED ON OCT. 25, 1986
 (FLOW 32.1 m³/s)



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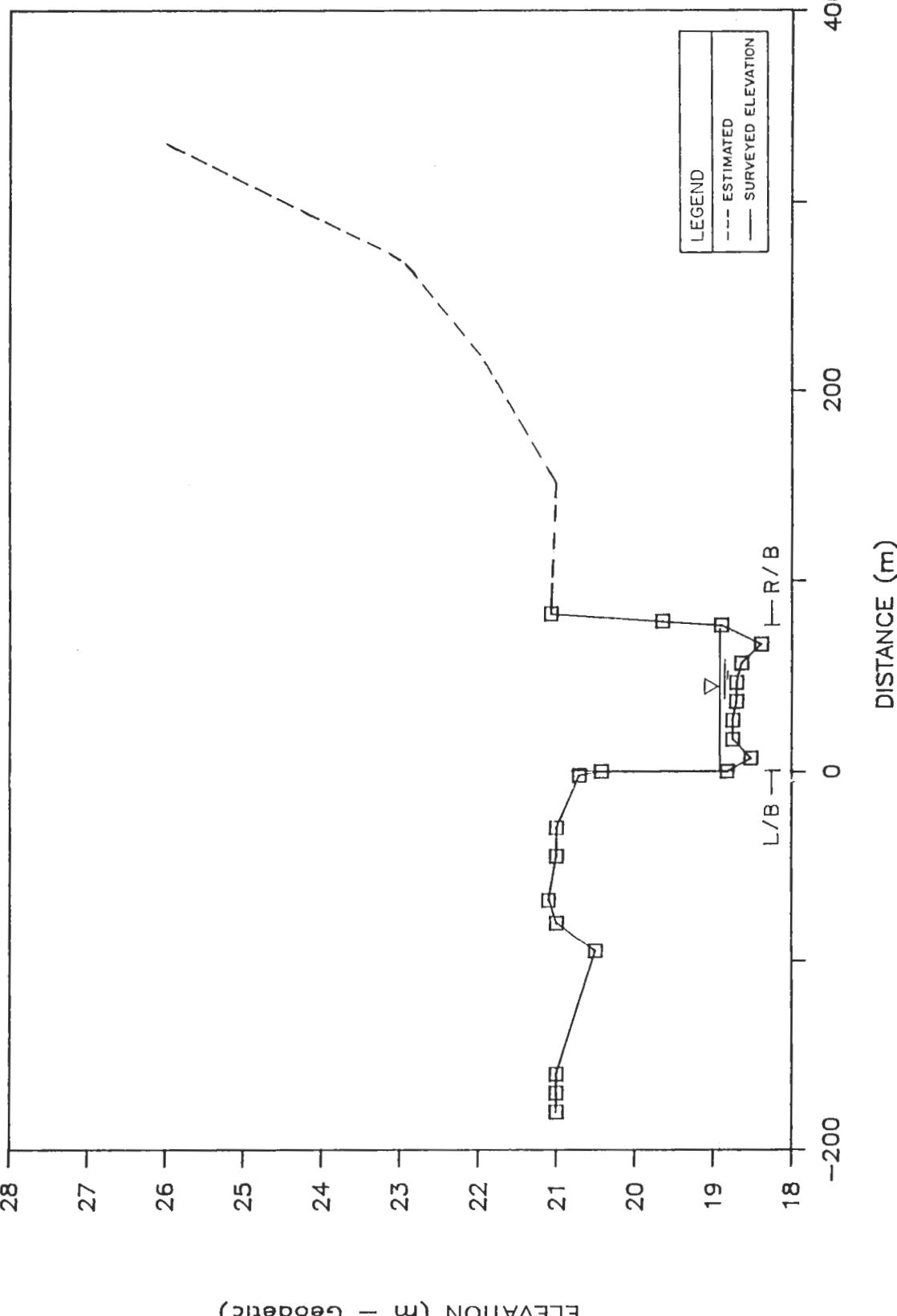
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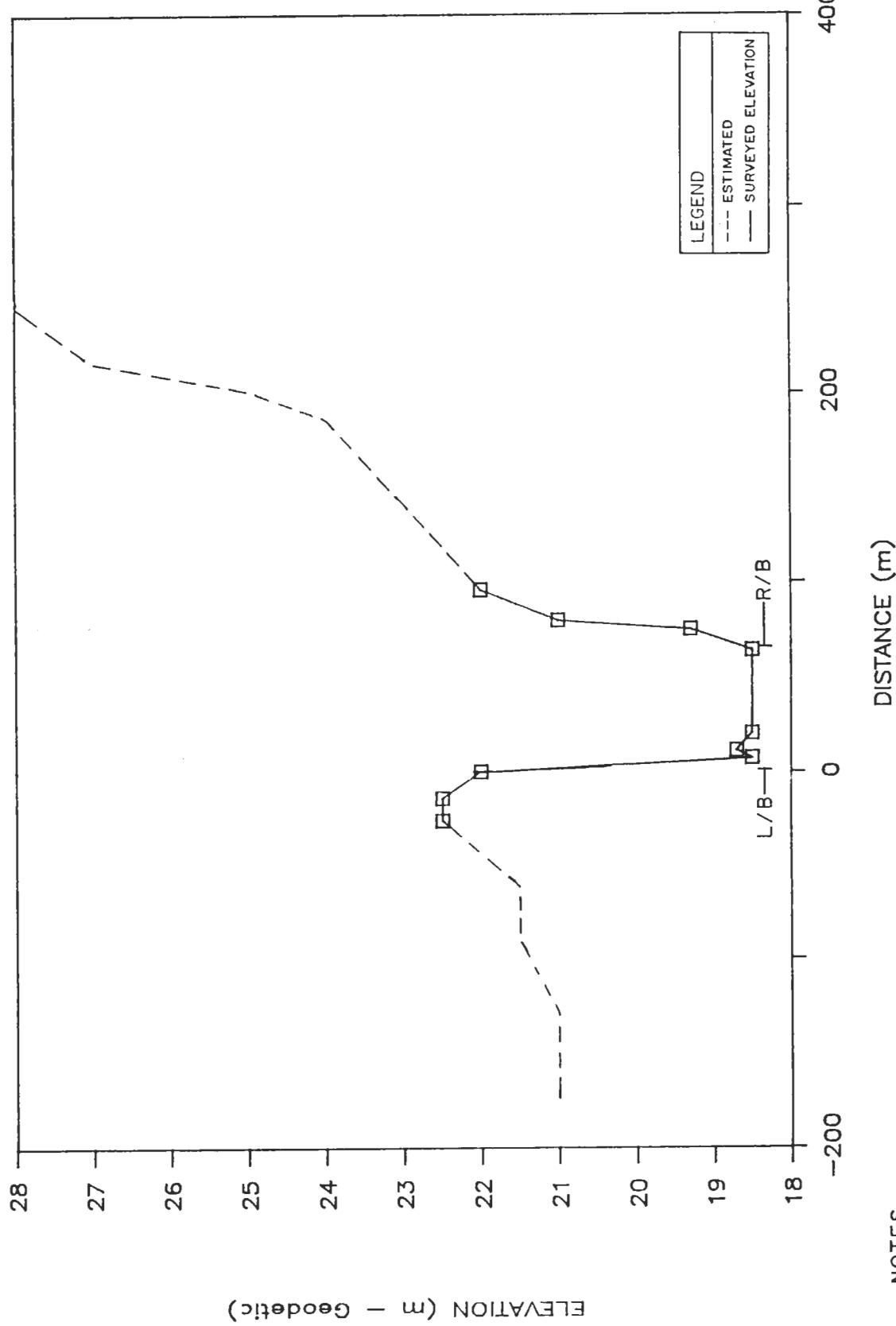


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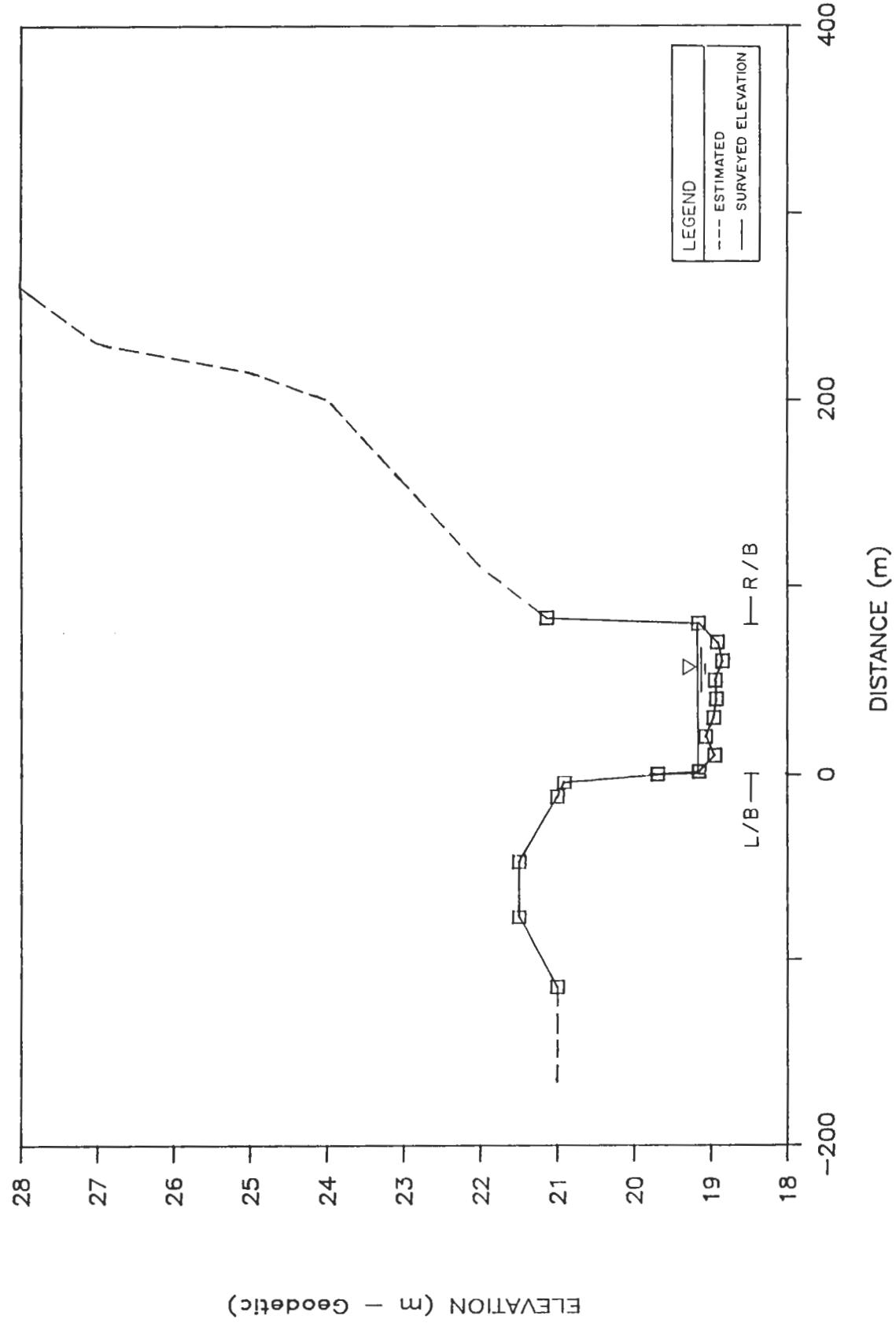
CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 1347



**NOTES**

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2. POST EXCAVATION SECTION TAKEN
FROM NOLAN DAVIS' AS BUILT SURVEY

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HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 1401 (POST EXCAVATION)



NOTES

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(FLOW $32.1 \text{ m}^3/\text{s}$)

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ELEVATION (m - Geodetic)

NOTES

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FROM NOLAN DAVIS' AS BUILT SURVEY

DISTANCE (m)

LEGEND

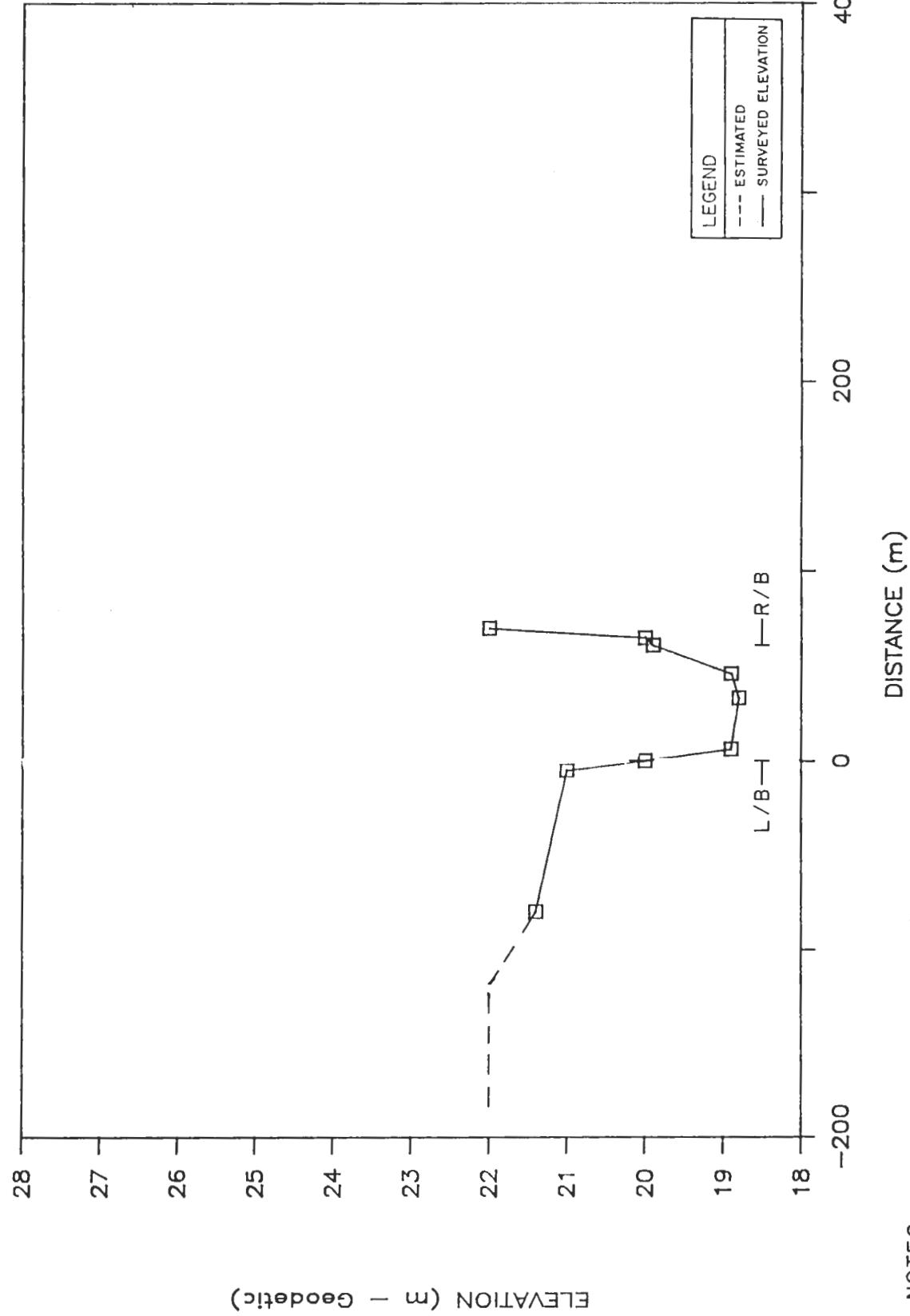
--- ESTIMATED
— SURVEYED ELEVATION

L / B — R / B

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HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS

SECTION 1466 (POST EXCAVATION)





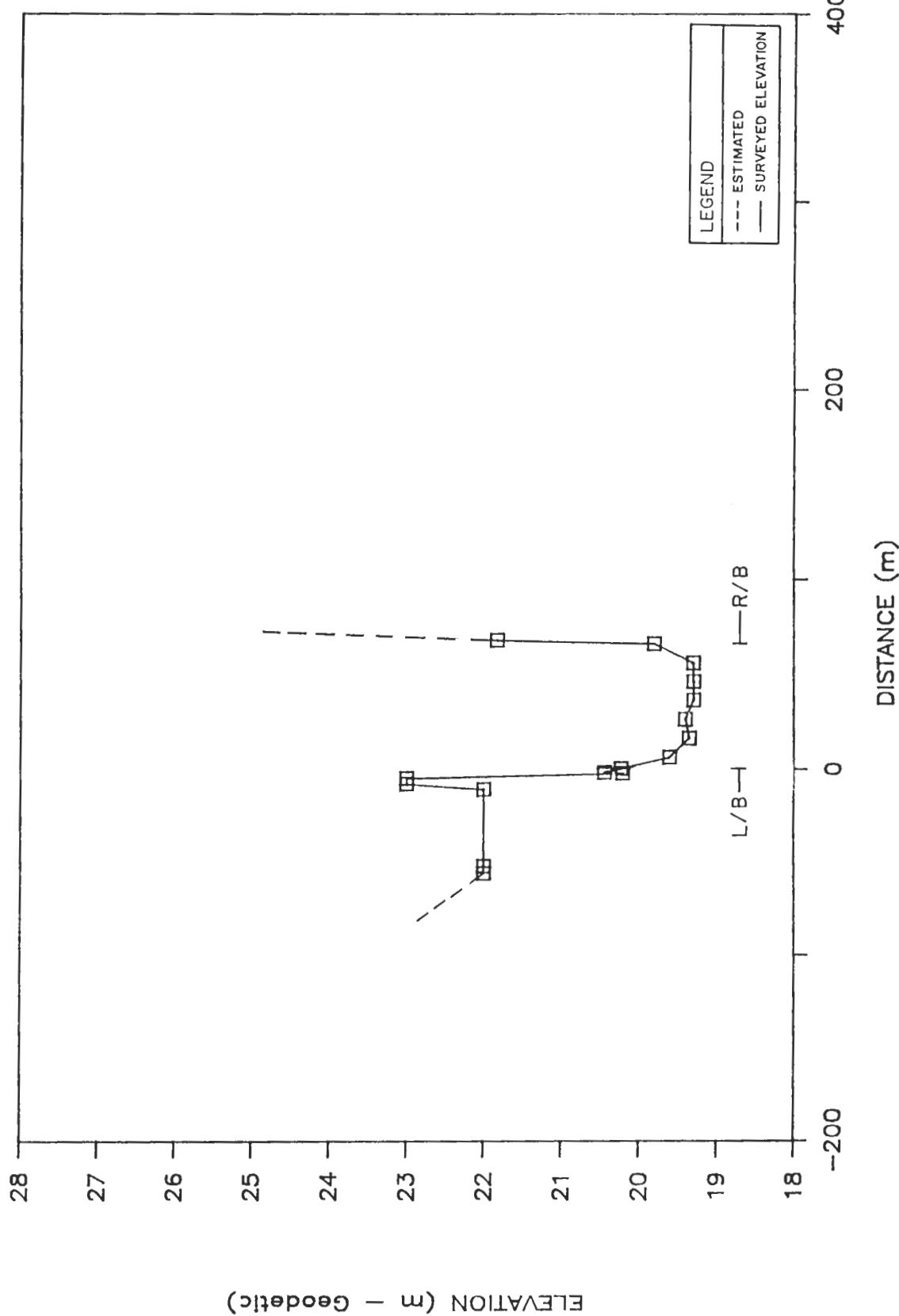
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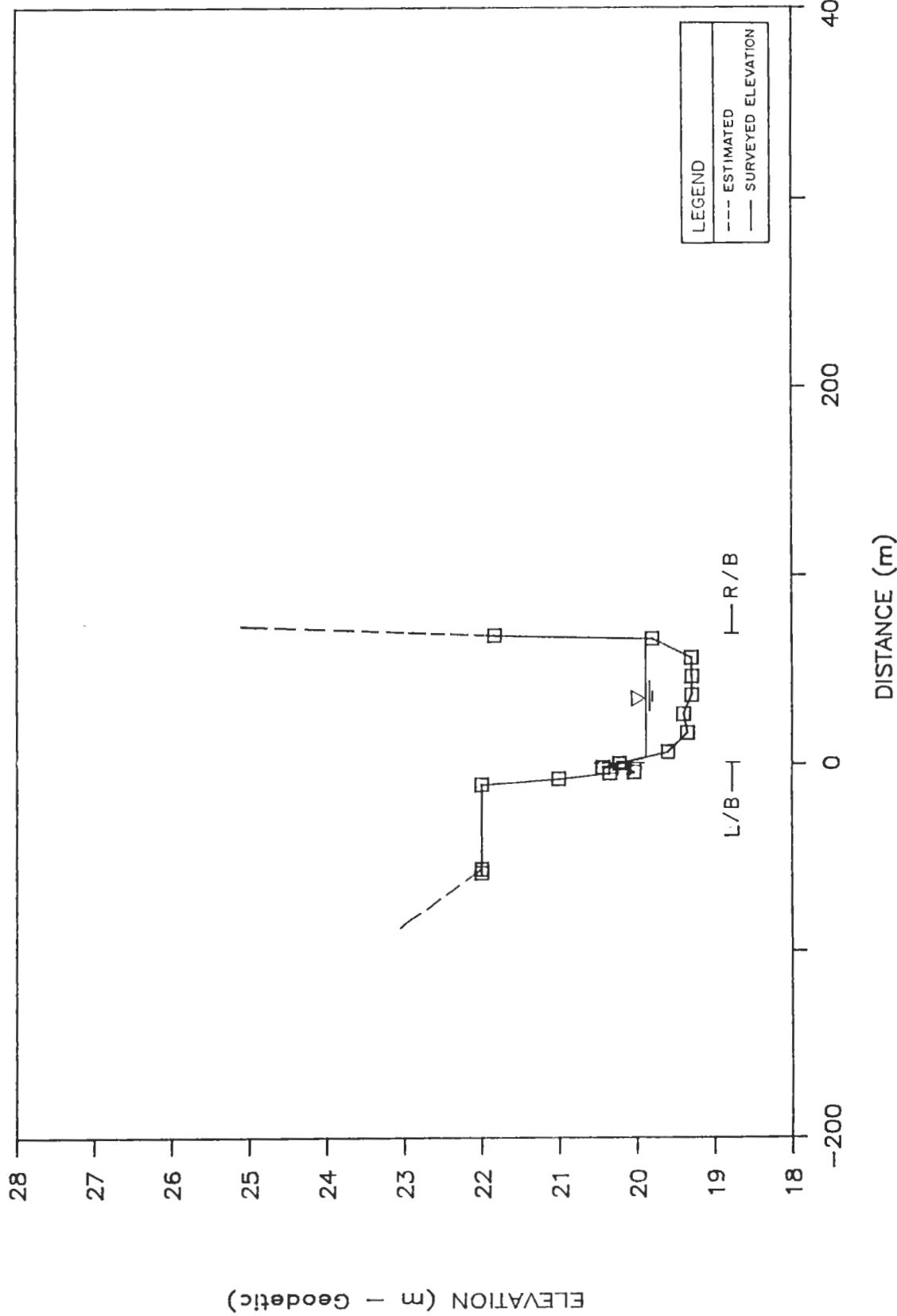
CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS

SECTION 1491 (POST EXCAVATION)

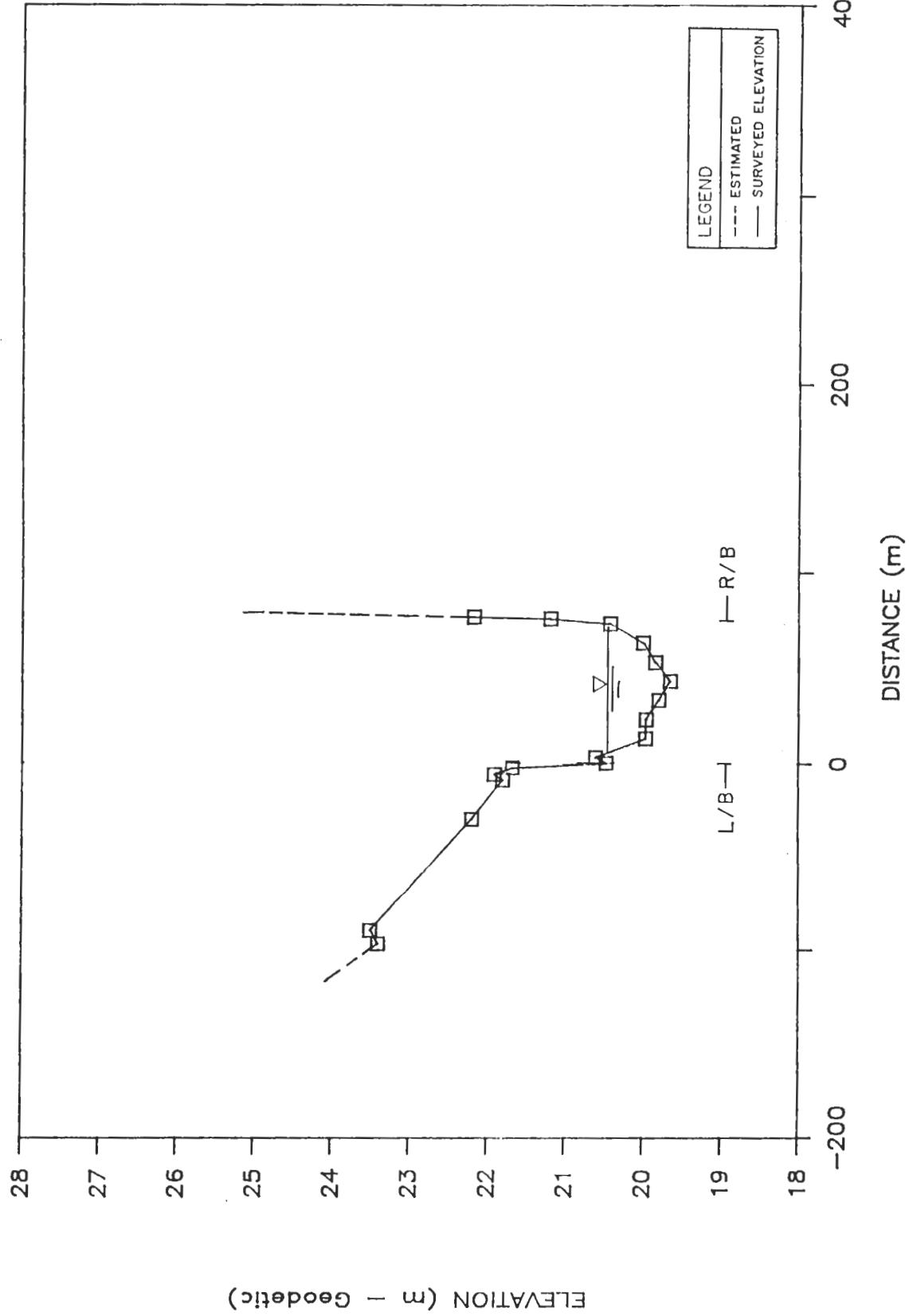




CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS



- NOTES
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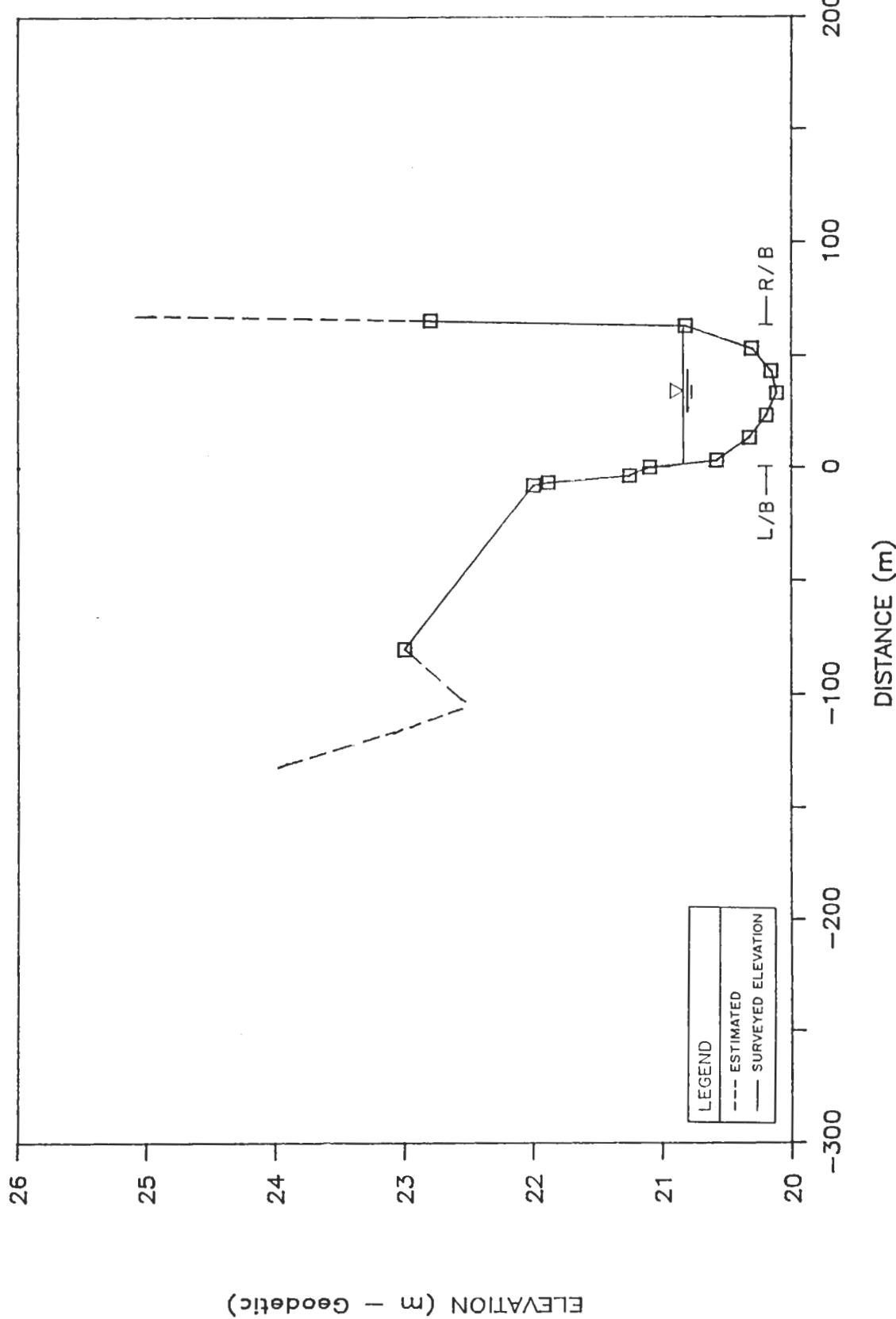


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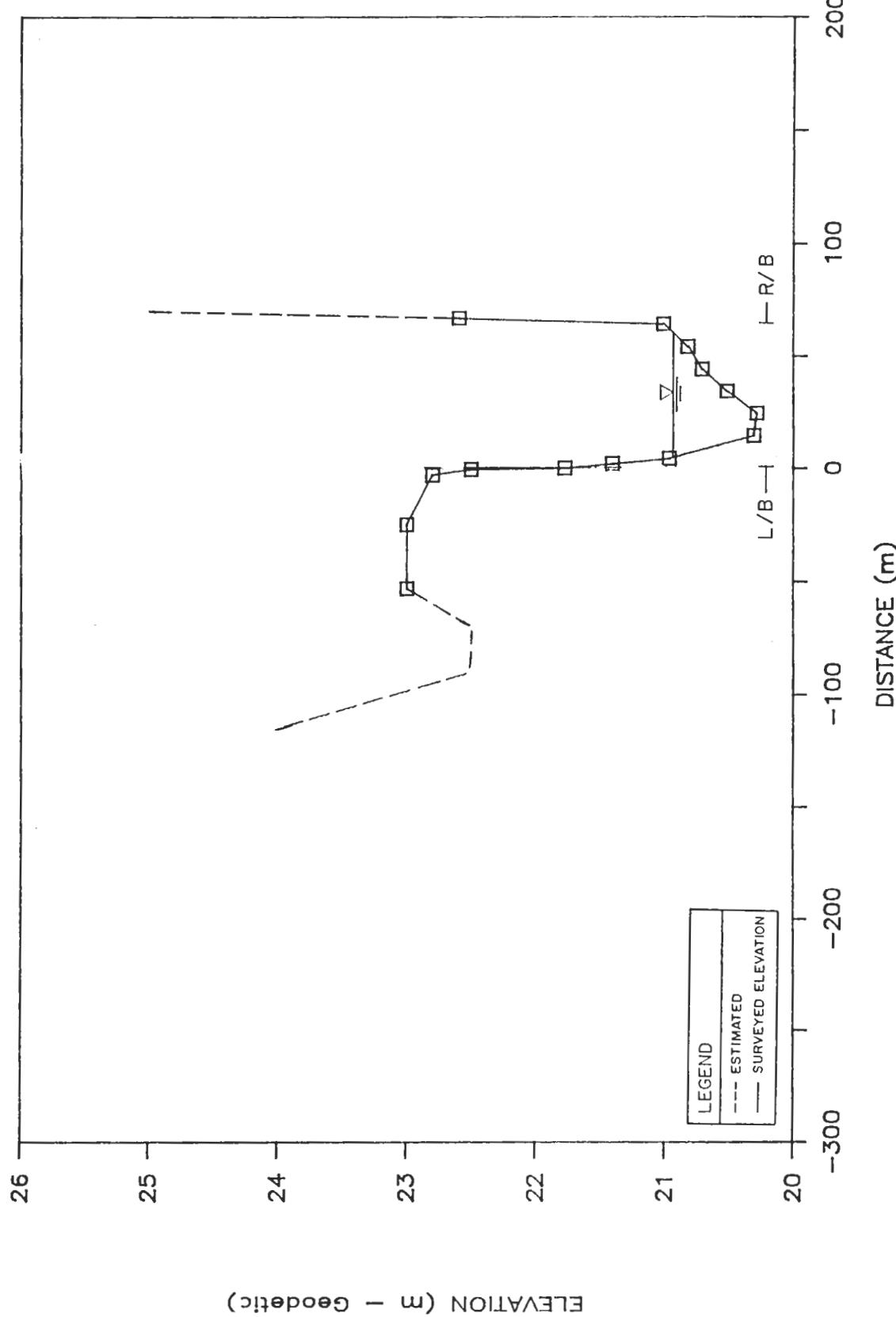


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HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 1756

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 1950

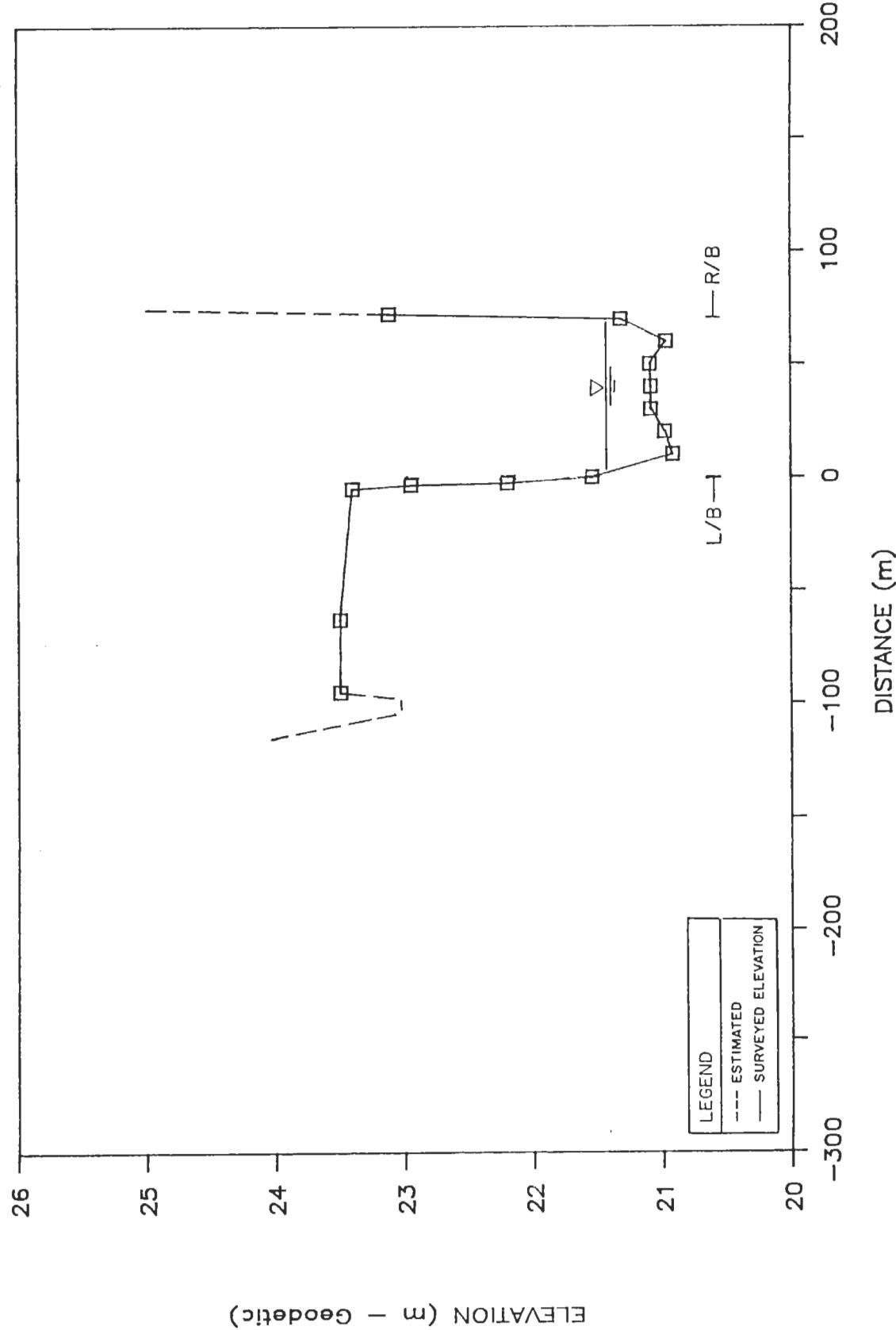


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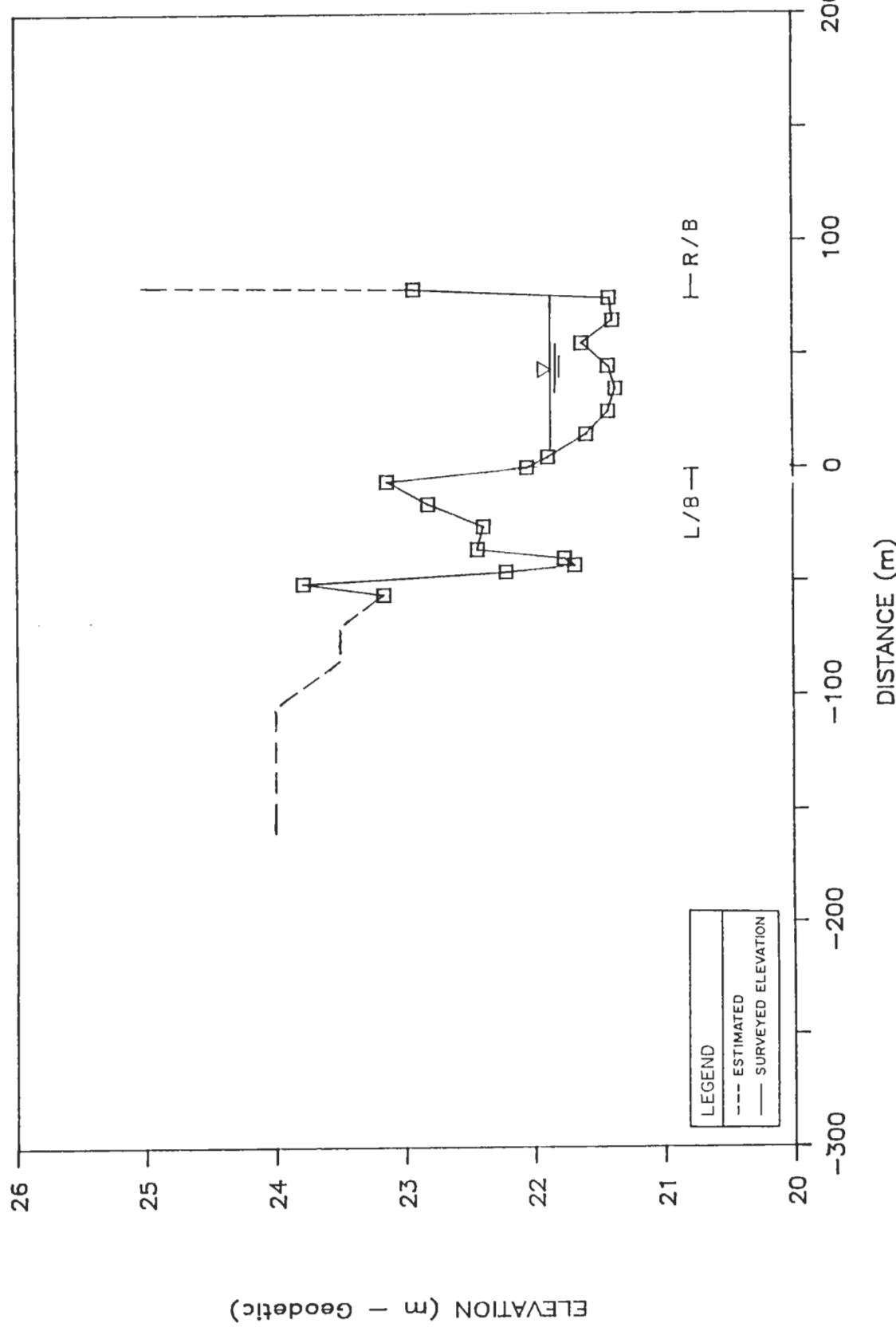


NOTES

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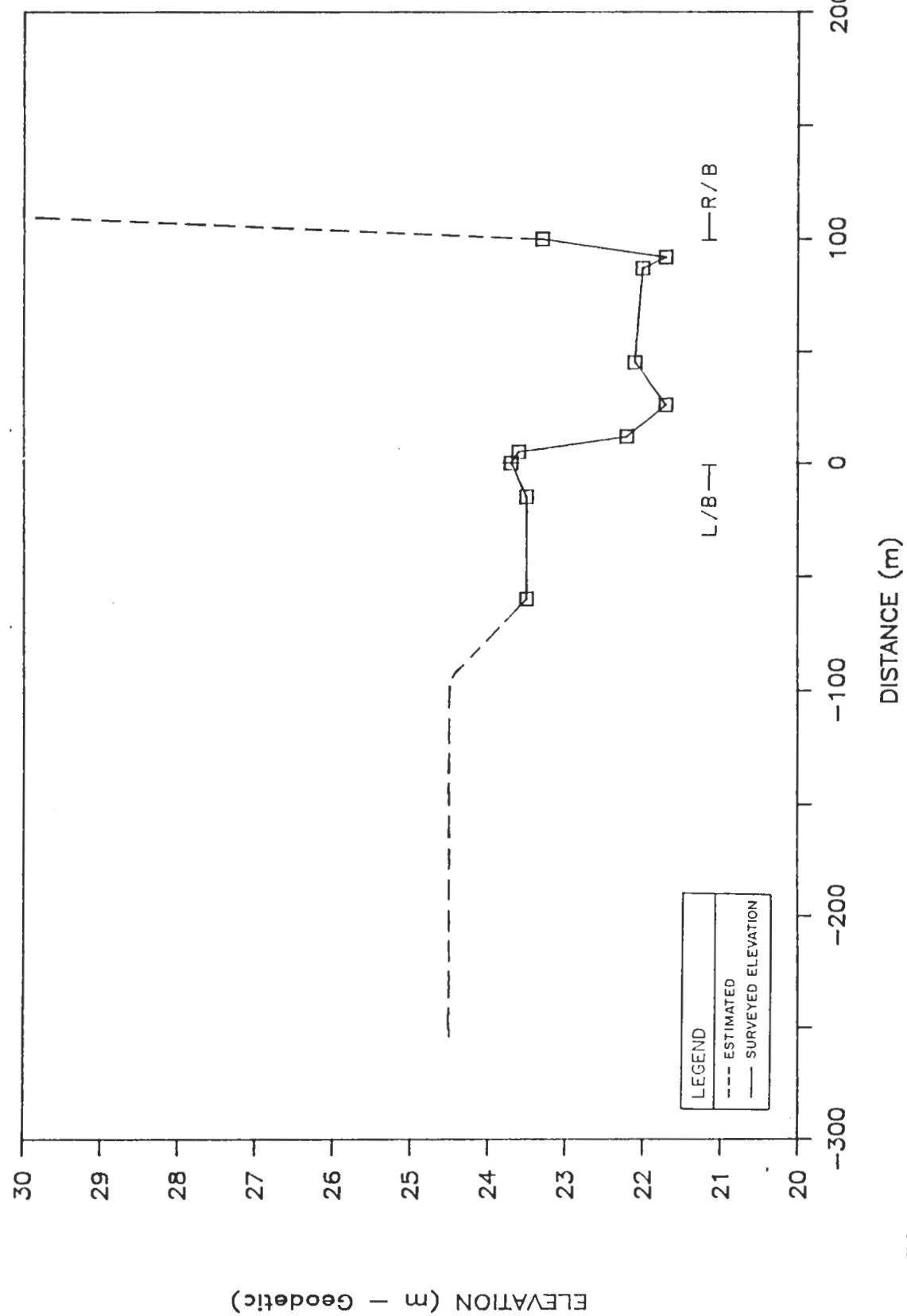


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CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 2332



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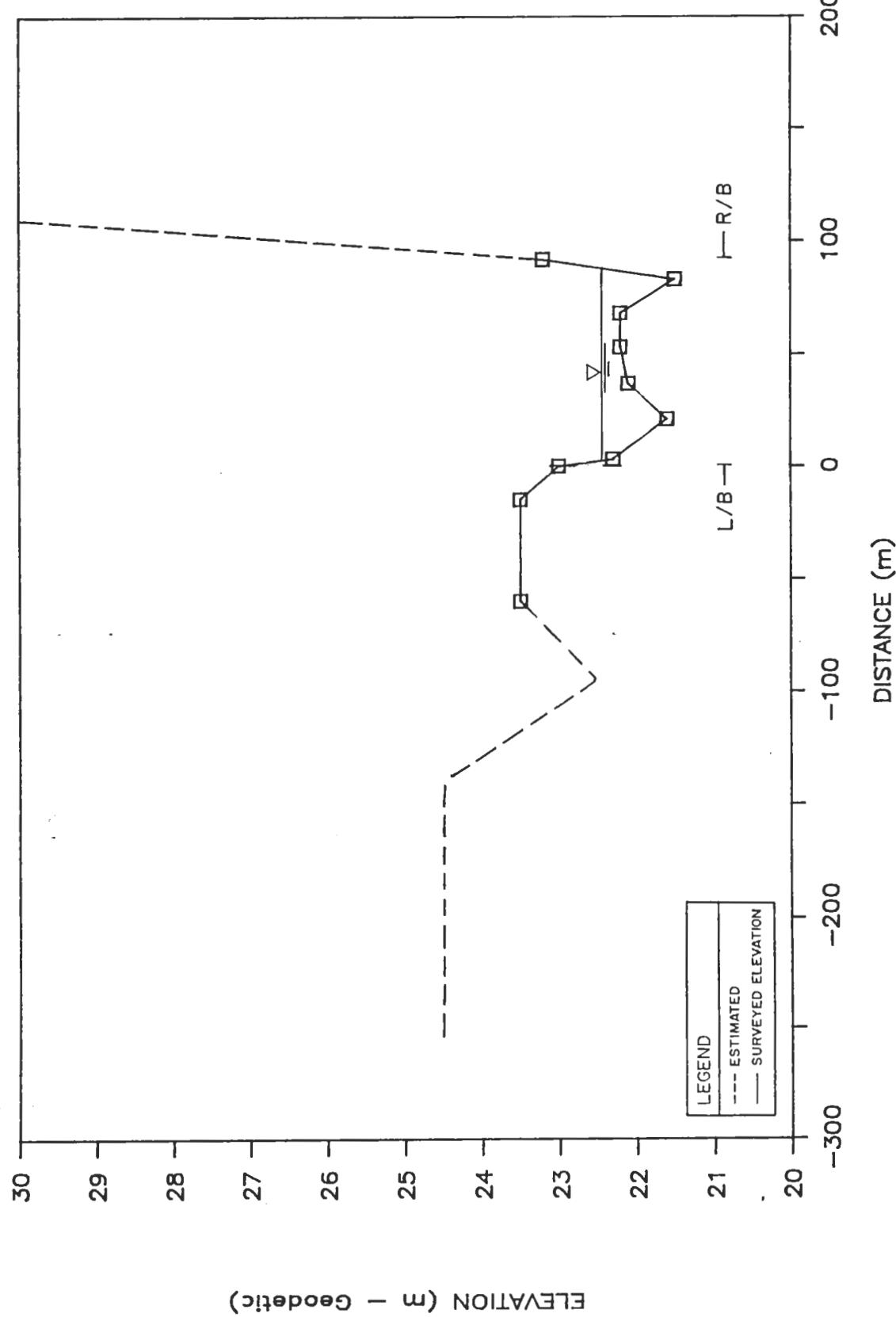
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FROM NOLAN DAVIS' AS BUILT SURVEY

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
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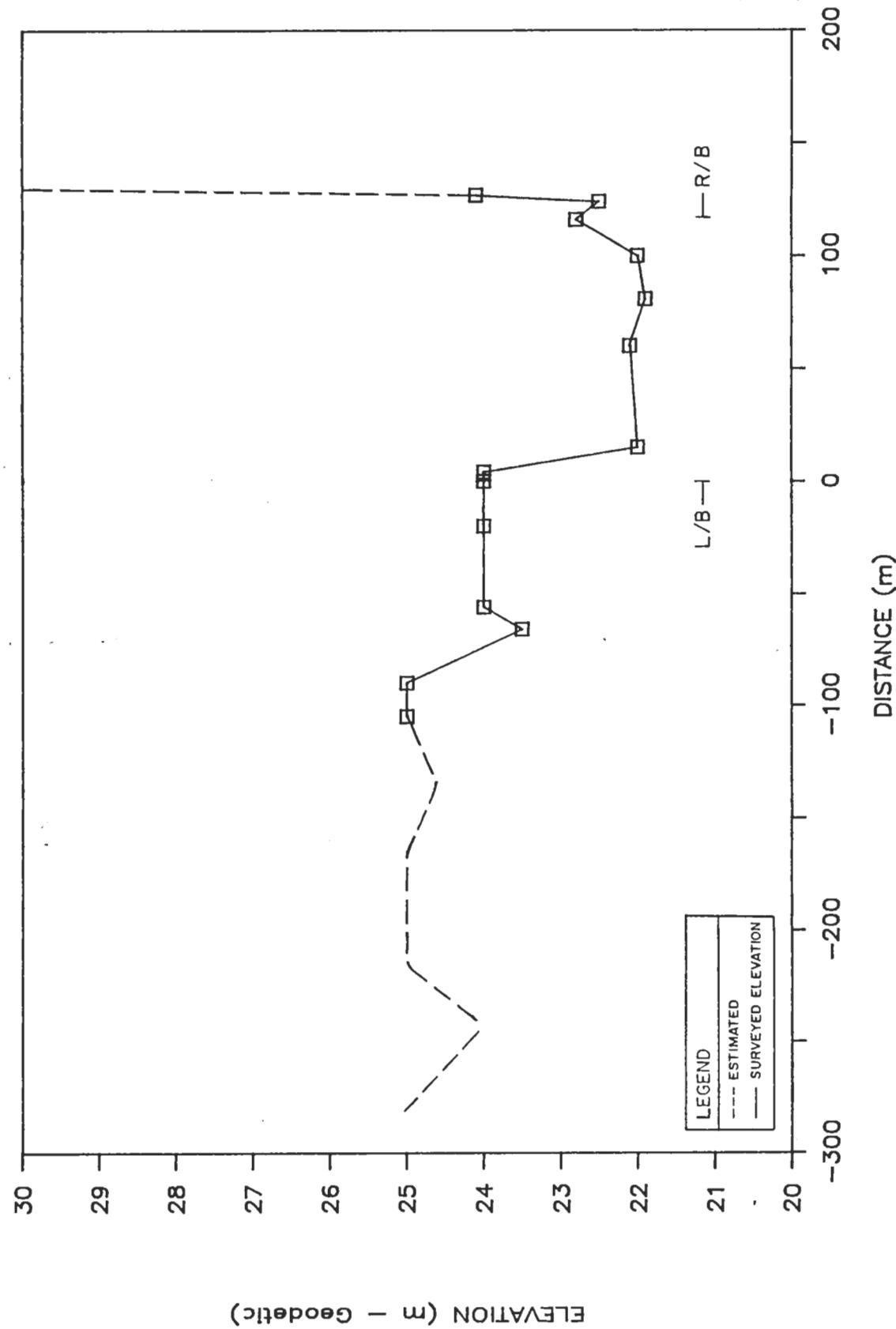




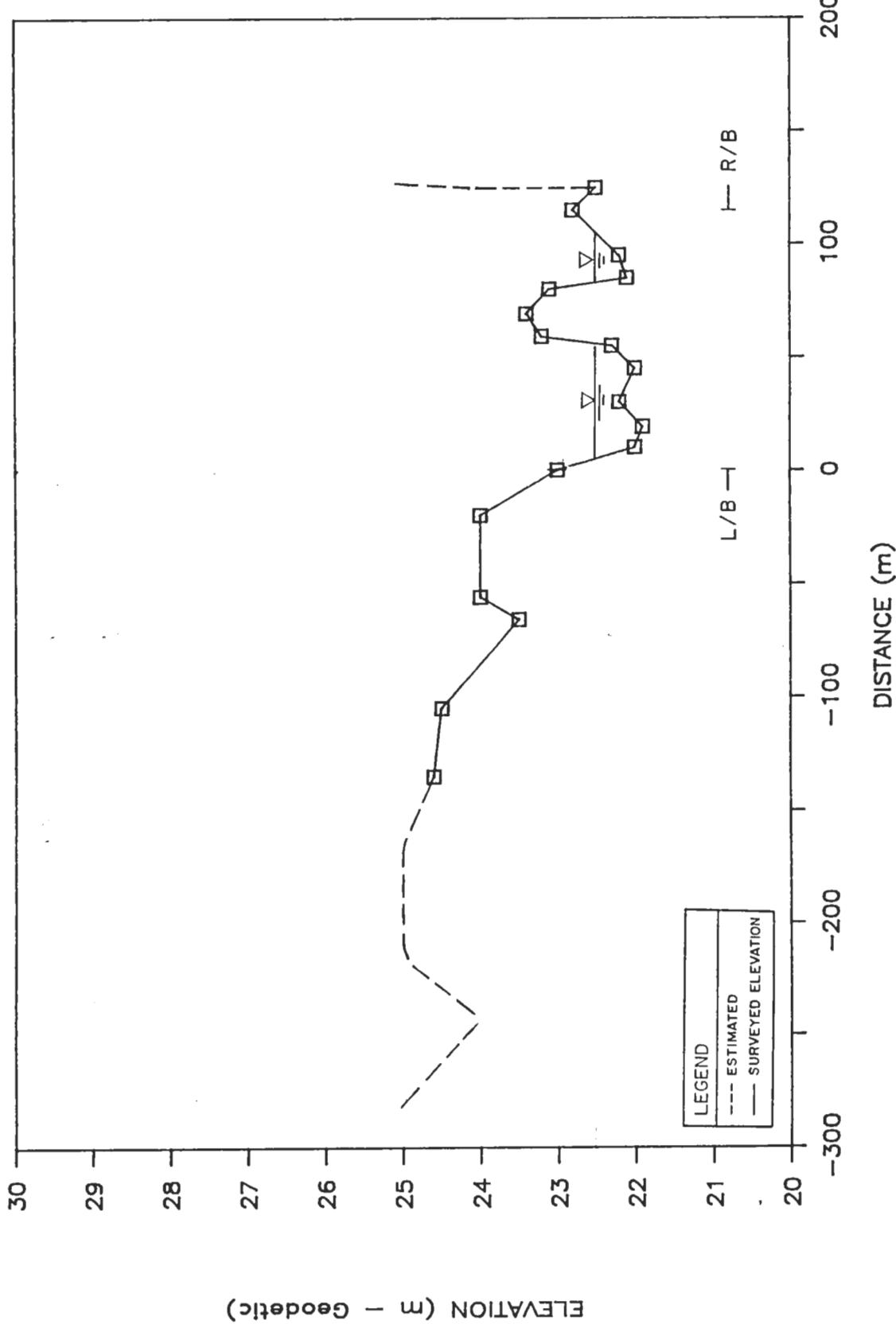
CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 2492



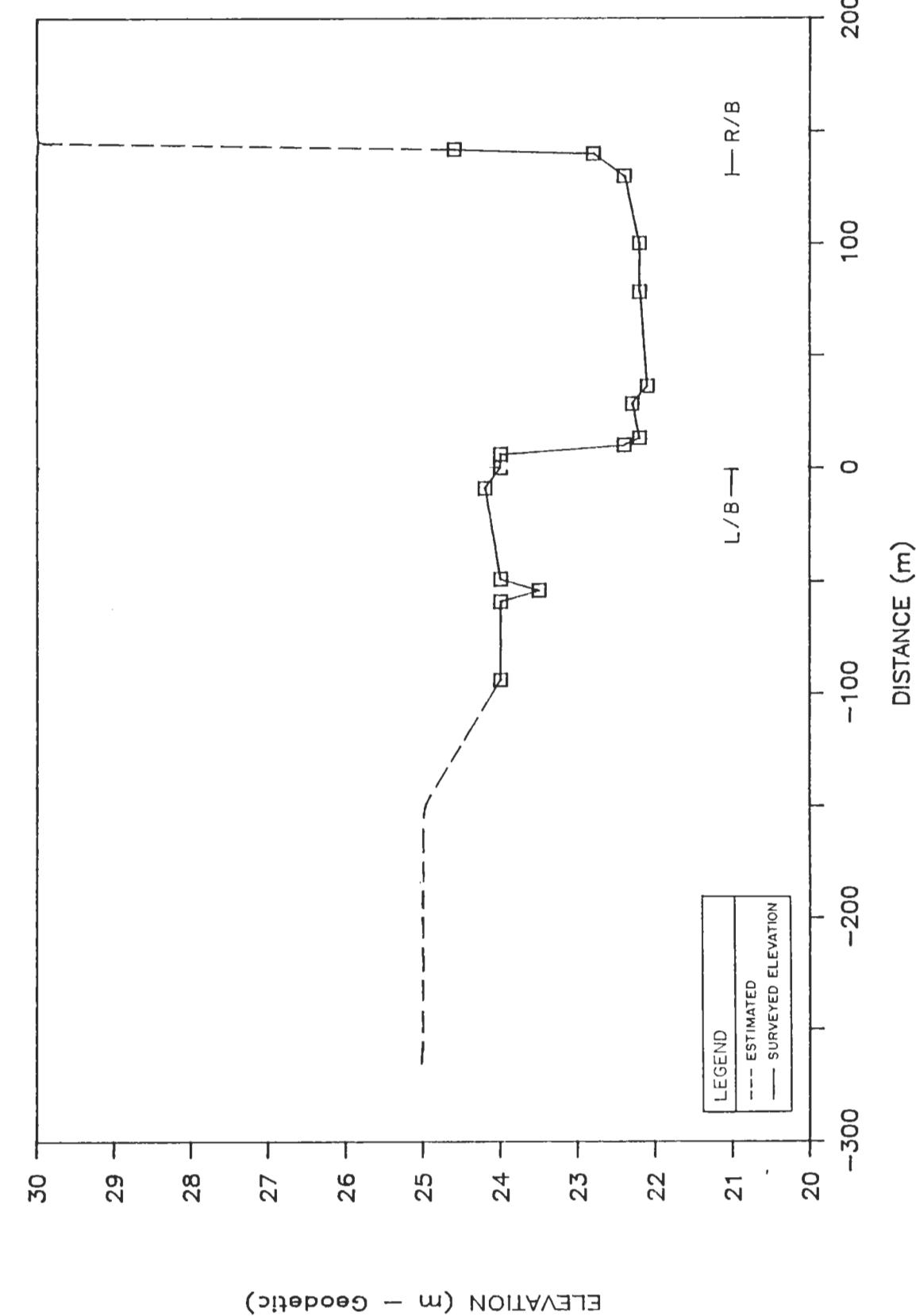
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- NOTES**
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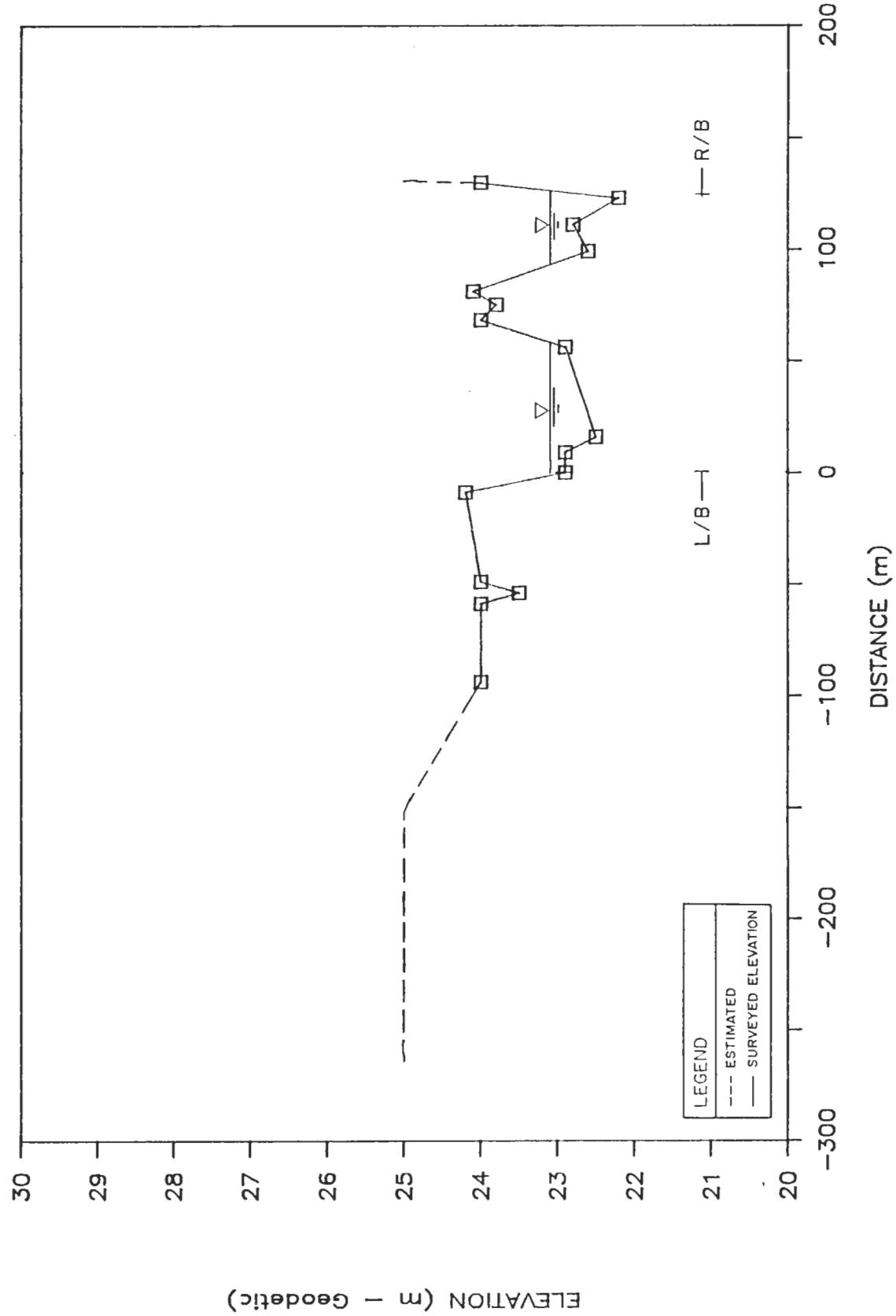


- NOTES
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CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS

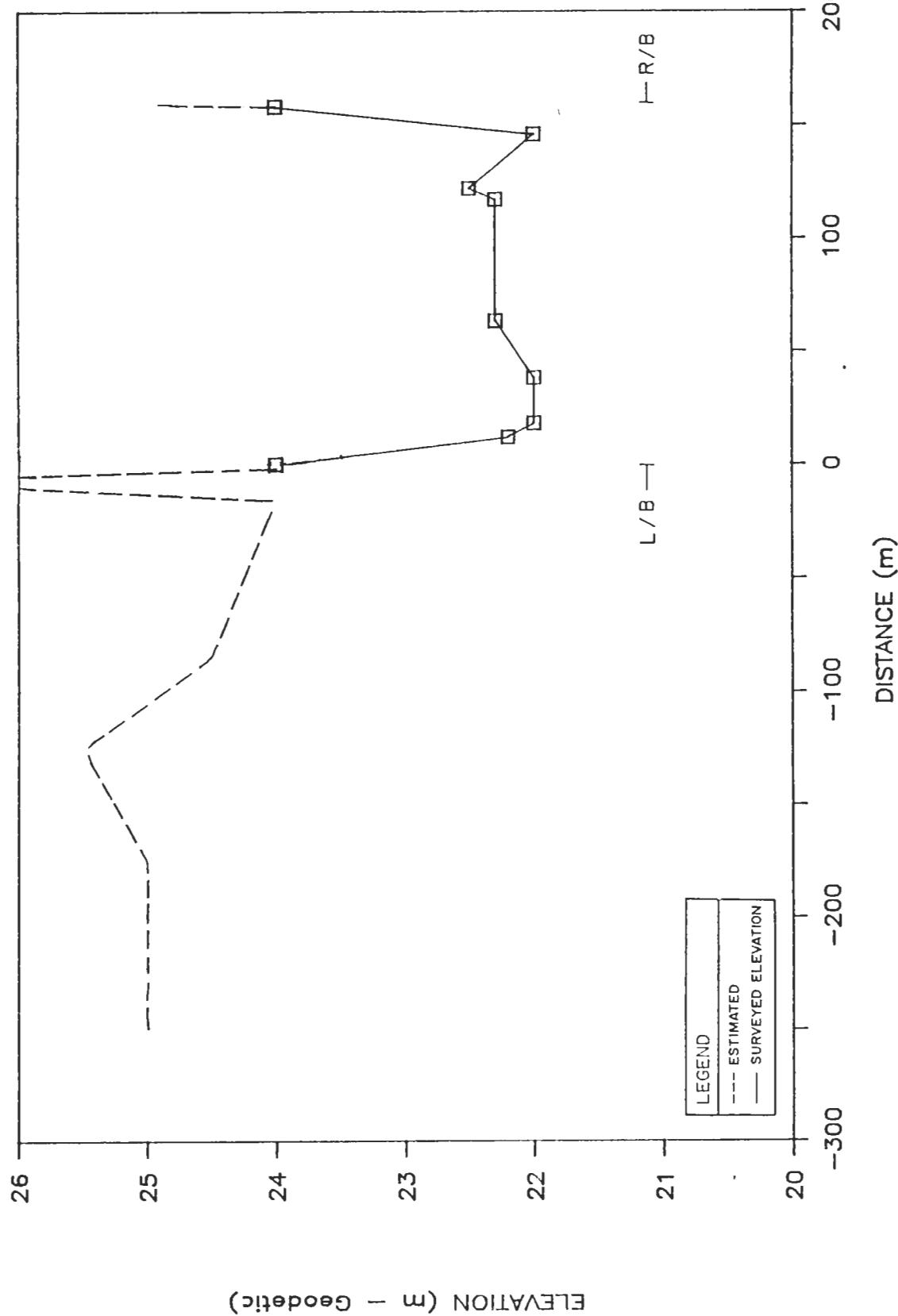


NOTES

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(FLOW 32.1 m³/s)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 2642

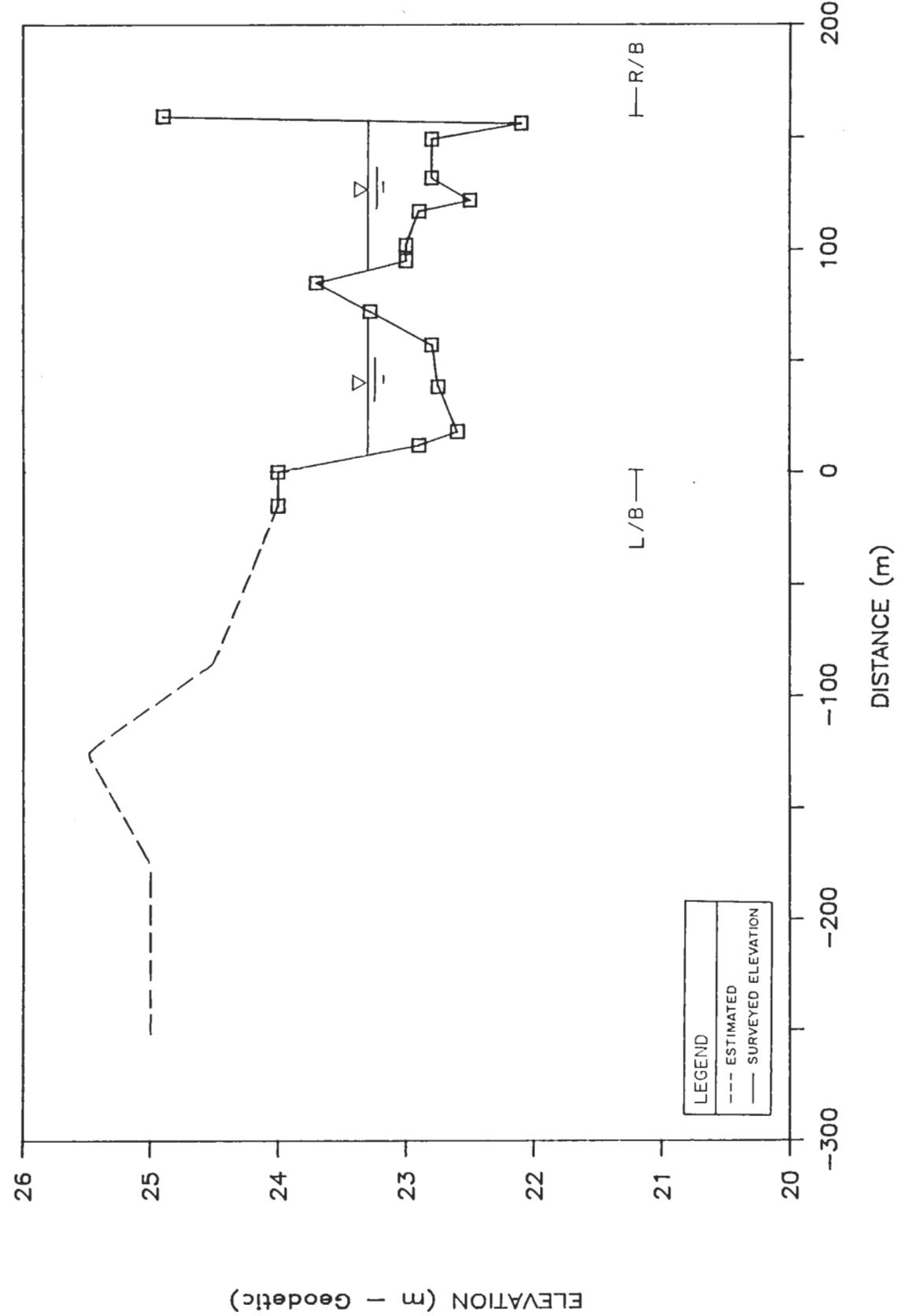




- NOTES**
1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
 2. POST EXCAVATION SECTION TAKEN
FROM NOLAN DAVIS' AS BUILT SURVEY

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 2702 (POST EXCAVATION)





NOTES

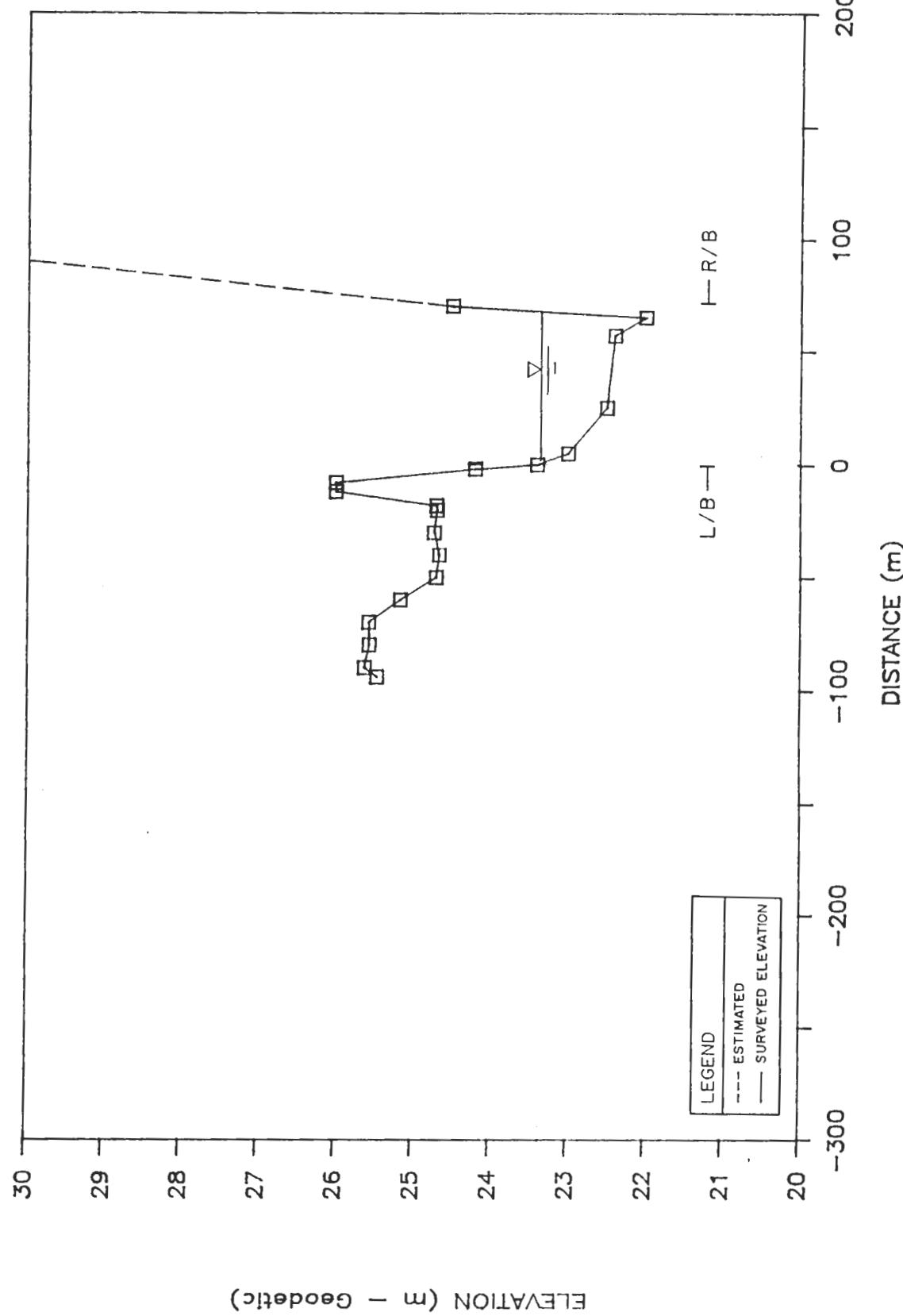
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(FLOW 32.1 m³/s)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 2702

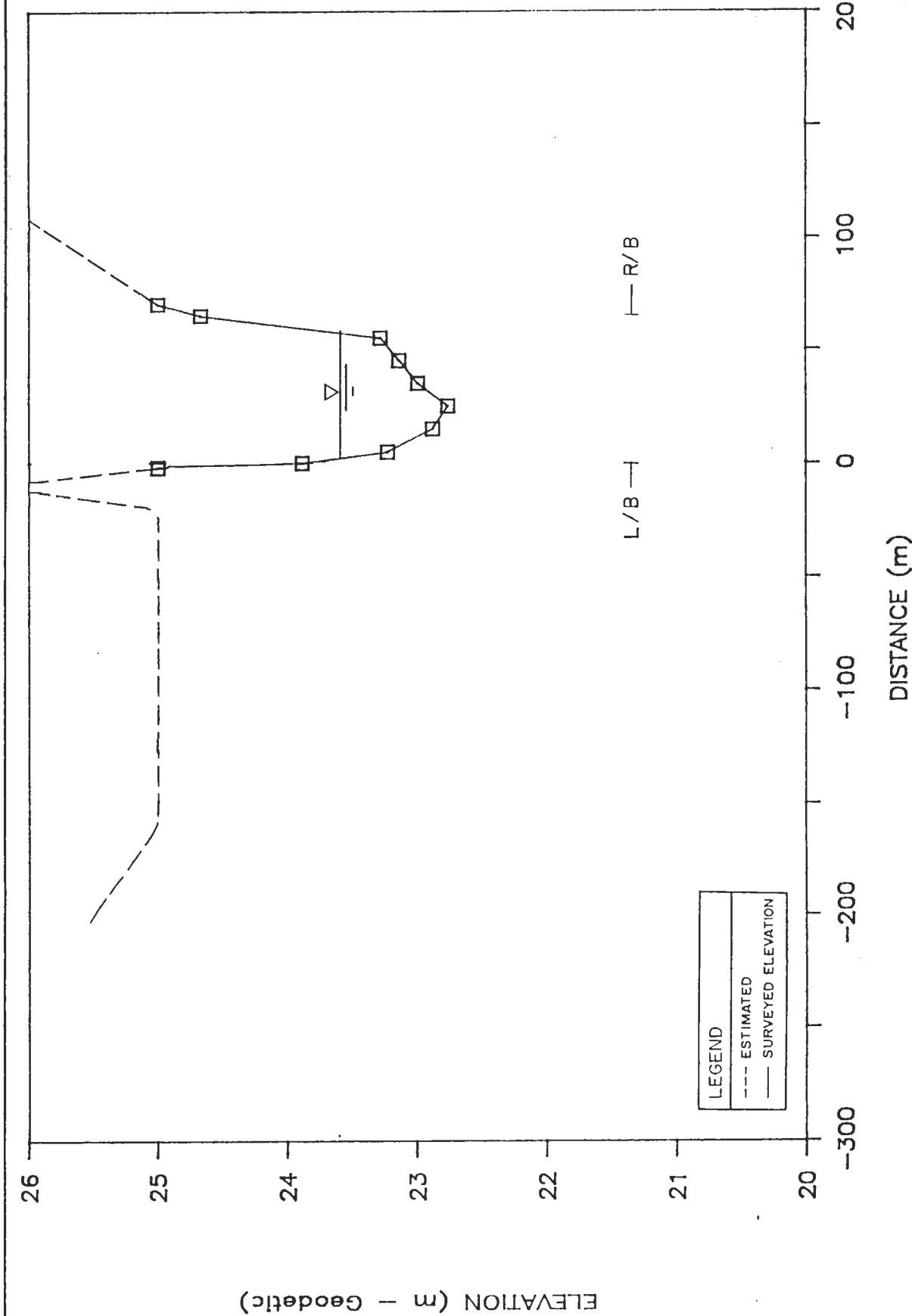


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CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 2802



- NOTES
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(FLOW $32.1 \text{ m}^3/\text{s}$)



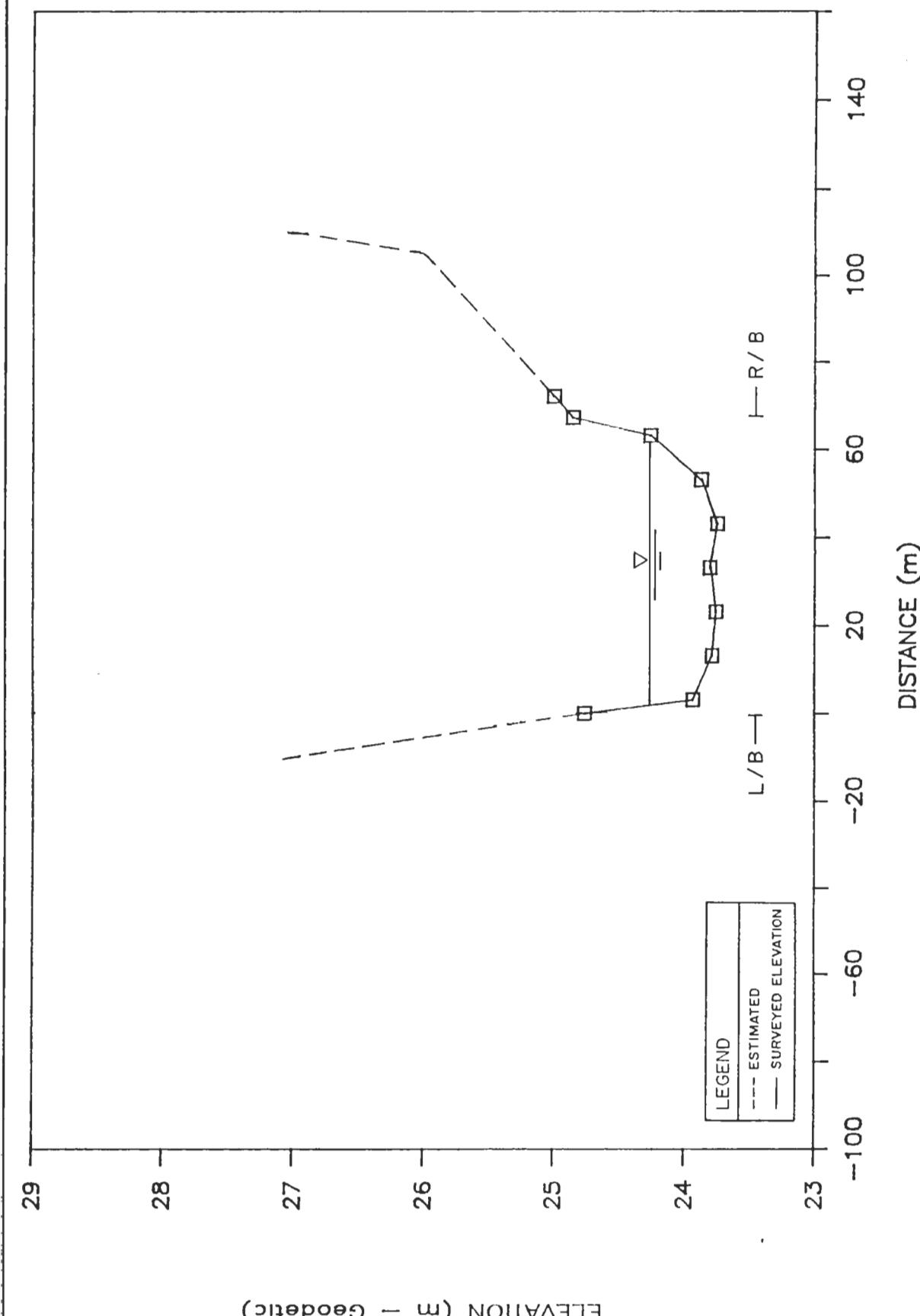
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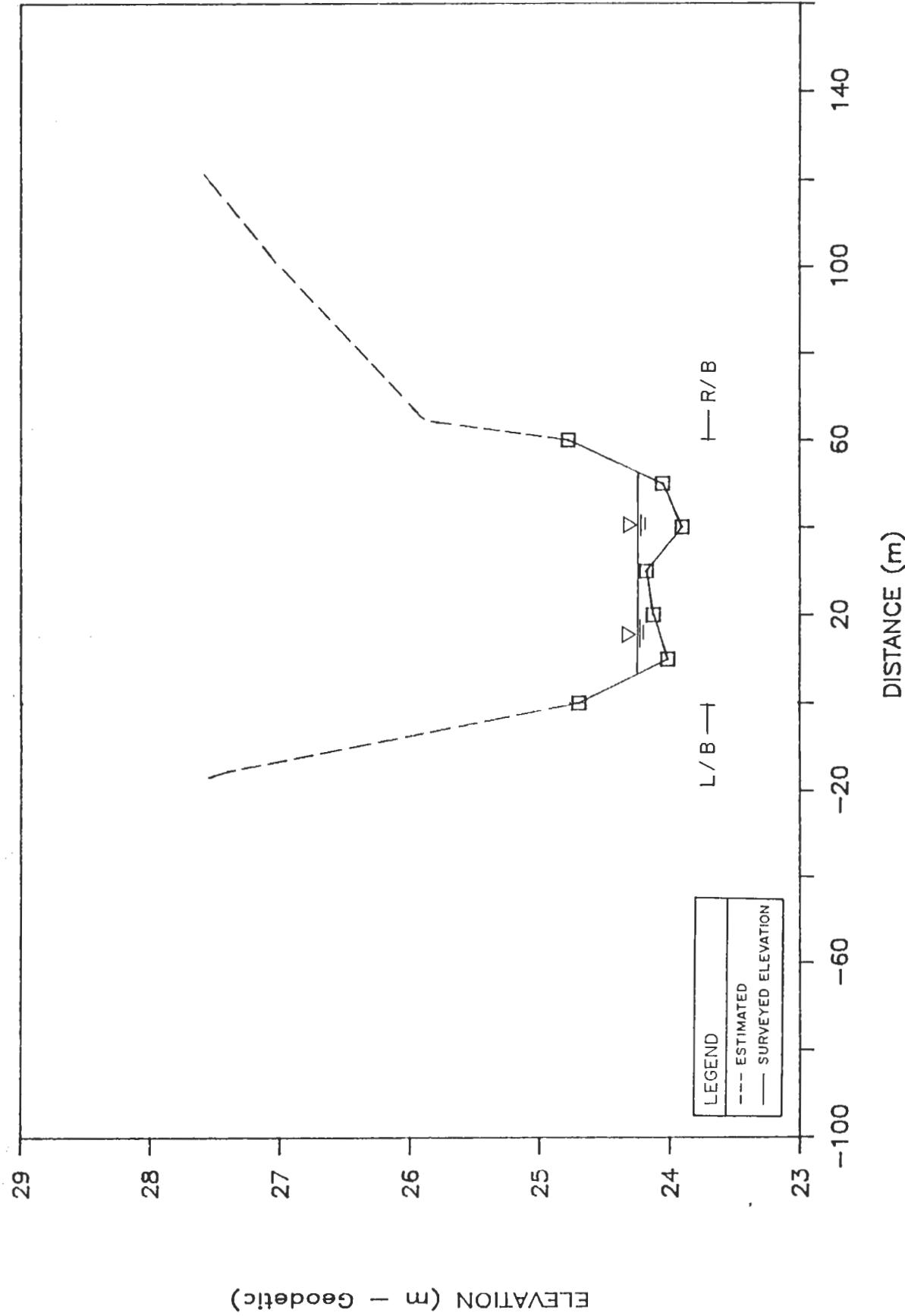
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2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND AND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS

- NOTES
1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW 32.1 m³/s)

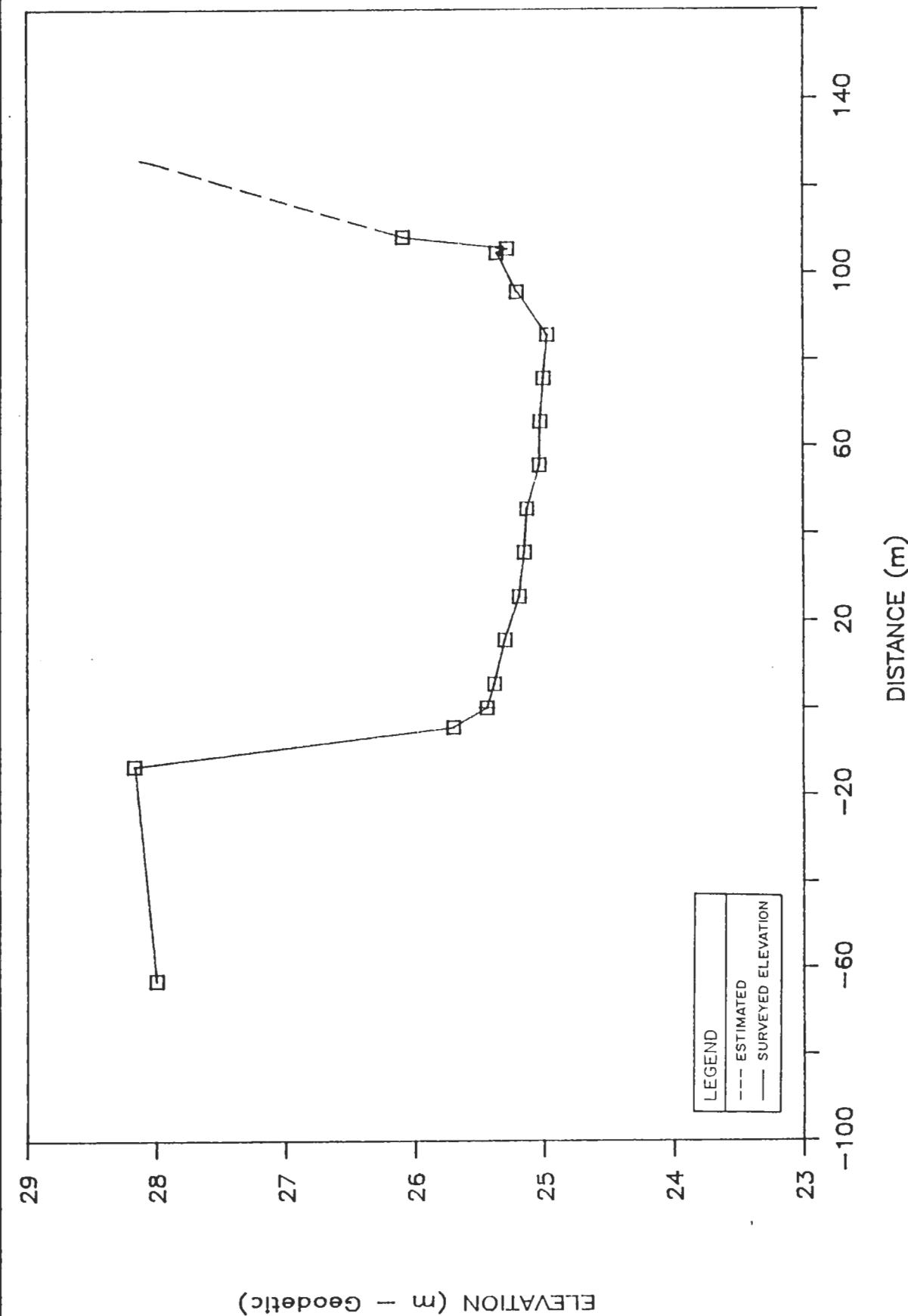




- NOTES
1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
 2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 3232

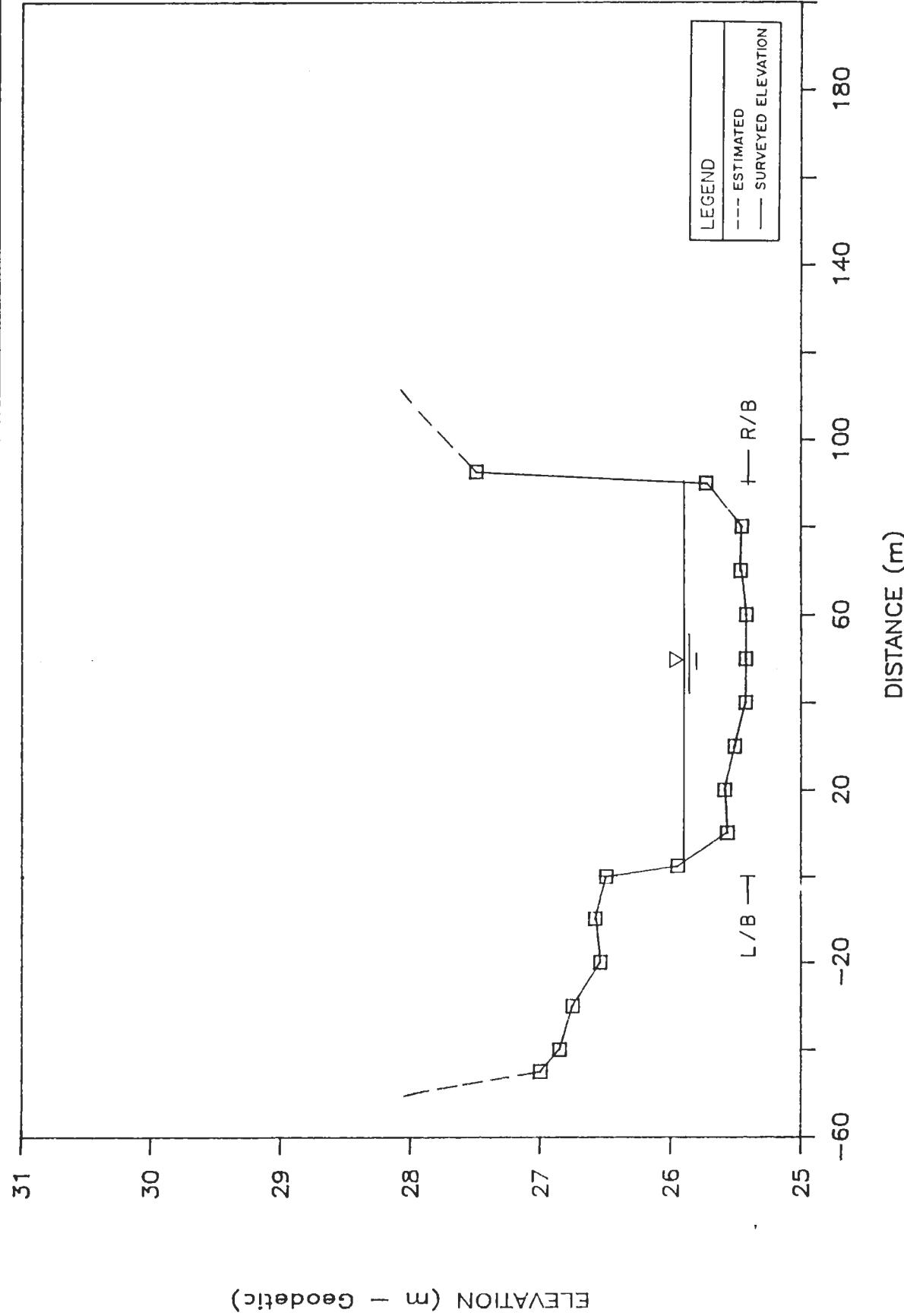




- NOTES
1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
 2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW 32.1 m³/s)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS





NOTES

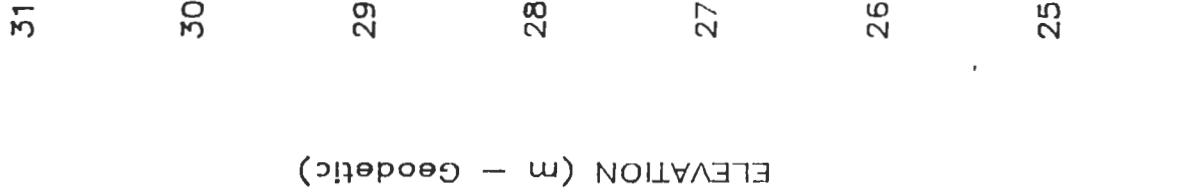
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2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND AND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS

ACROS

SECTION 3488

31

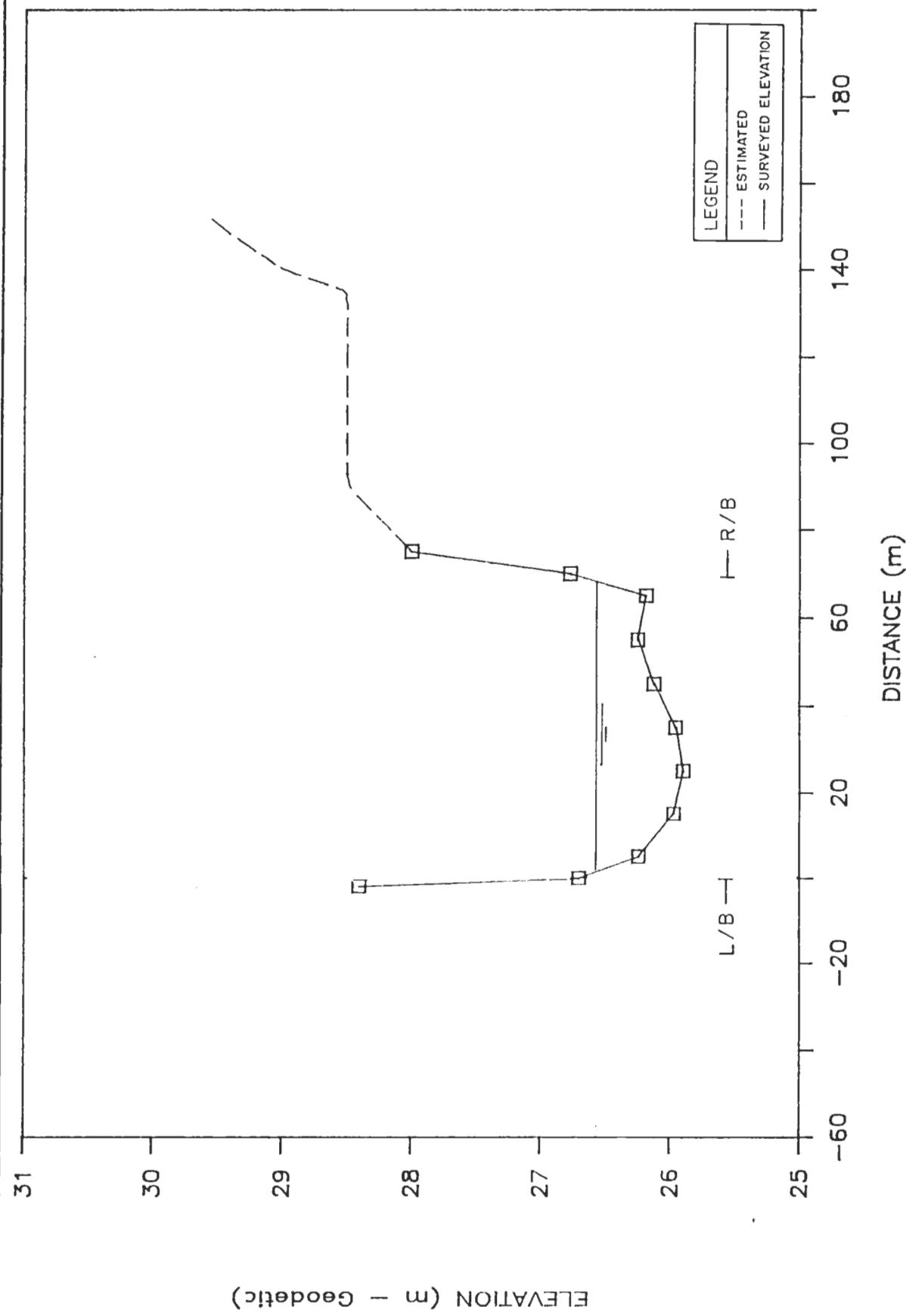


NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW 32.1 m³/s)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 3645



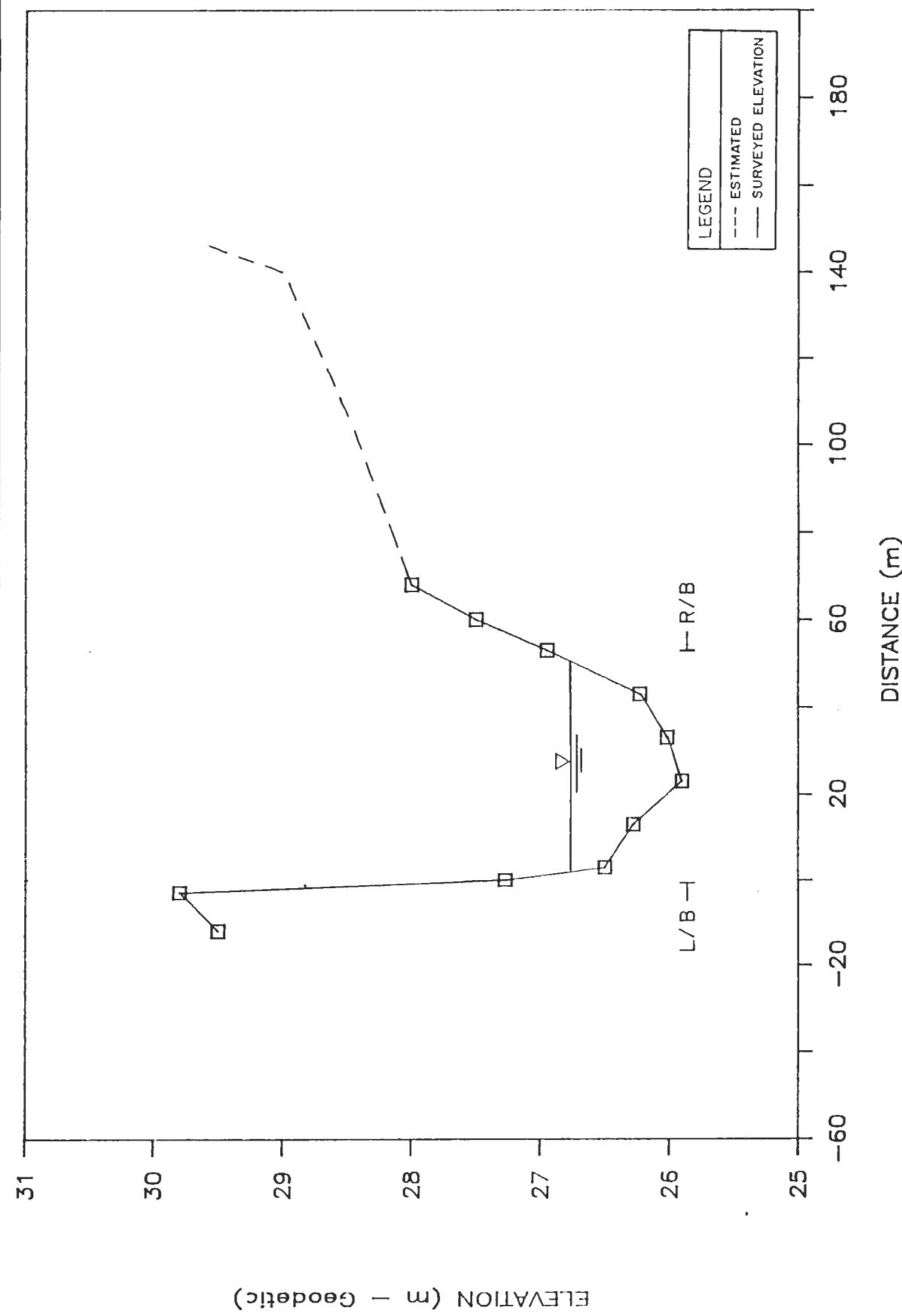


- NOTES
1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
 2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS

SECTION 3717



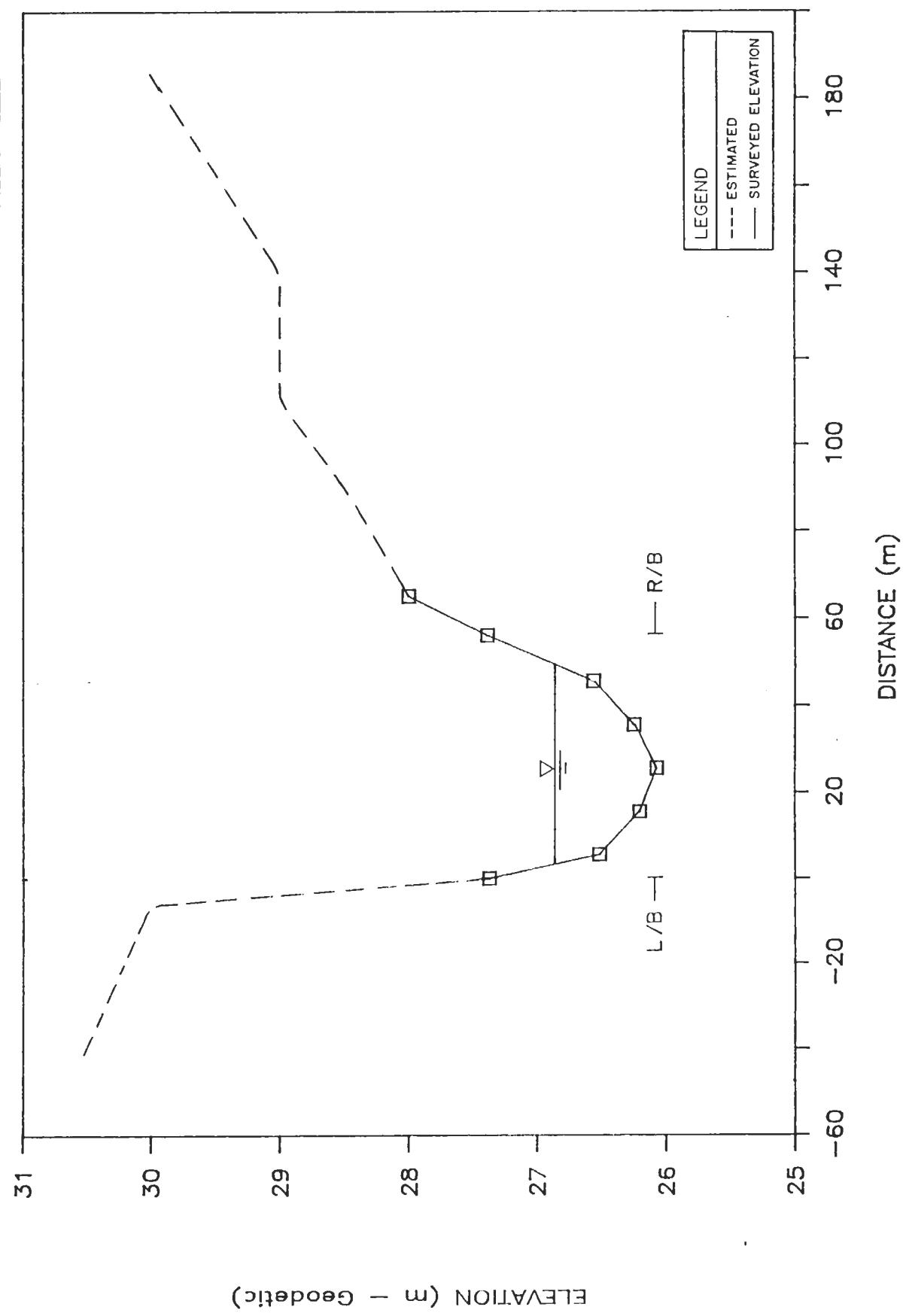


NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 3827

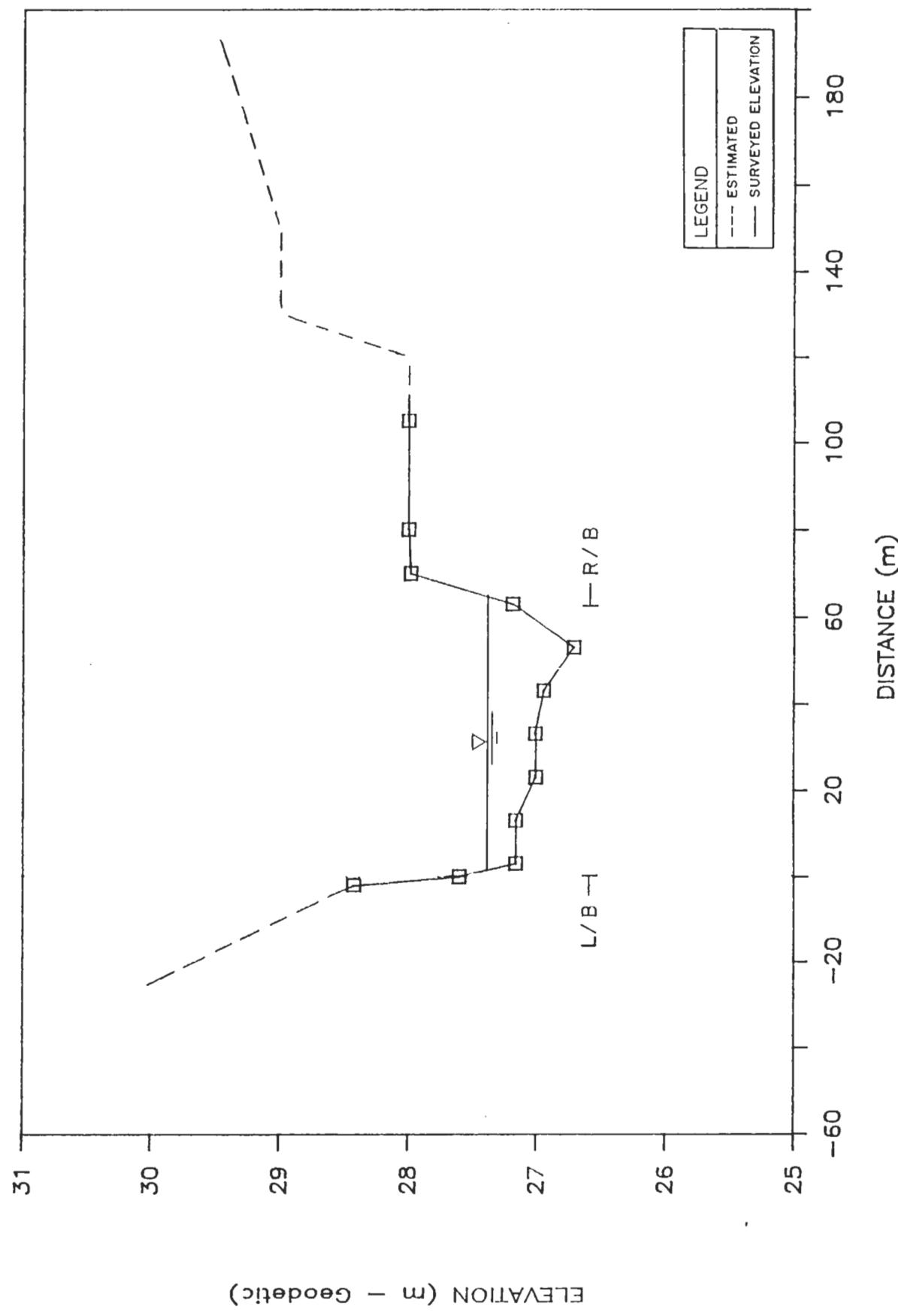




- NOTES
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 2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 3907





NOTES
 1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
 2. WATER LEVELS MEASURED ON OCT. 25, 1986
 (FLOW 32.1 m³/s)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
 SECTION 401 |



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ELEVATION (m - Geodetic)

L / B — R / B

NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

DISTANCE (m)

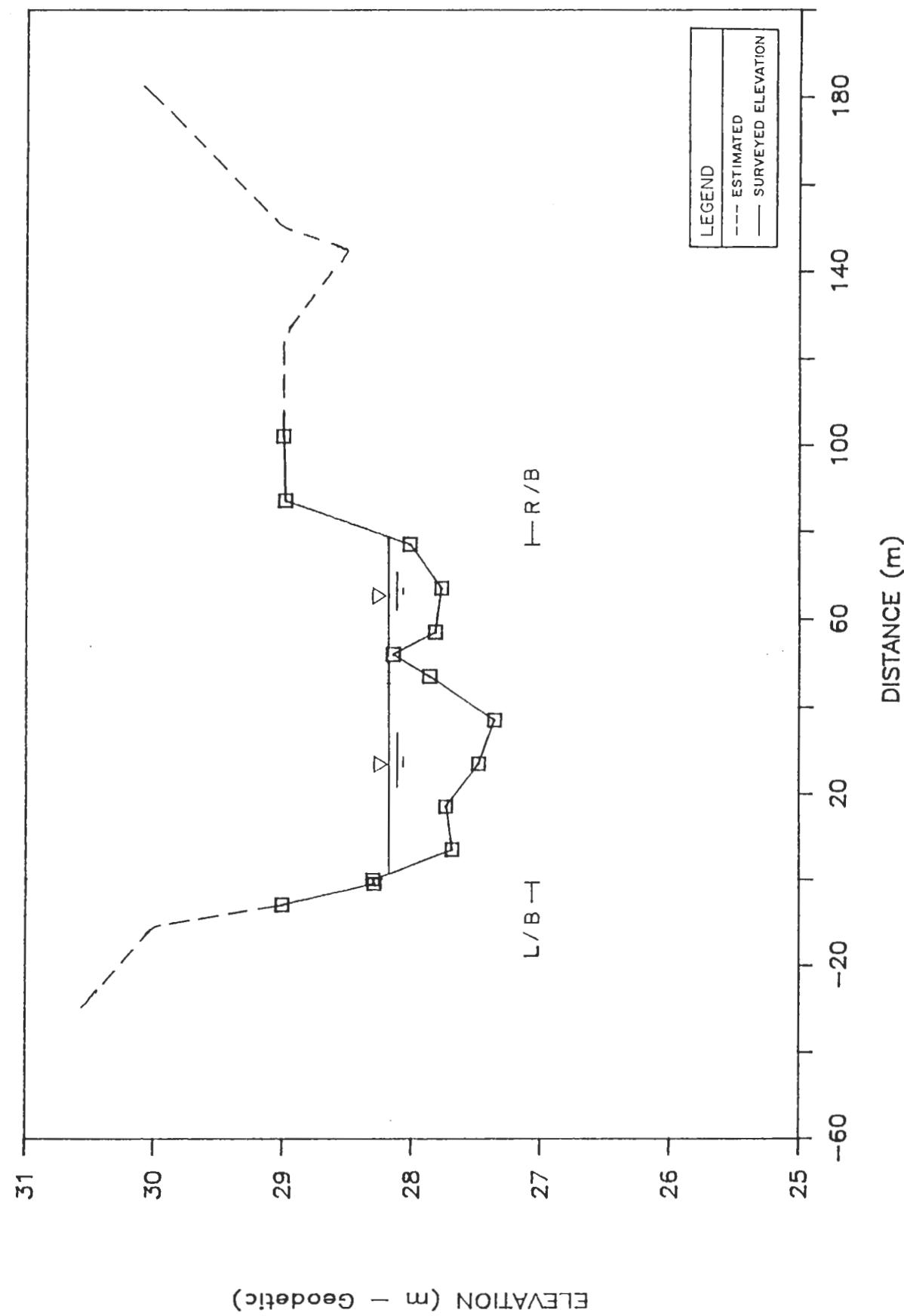
180
140
100
60
20
-20
-60

LEGEND

—	ESTIMATED
—	SURVEYED ELEVATION

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 4085



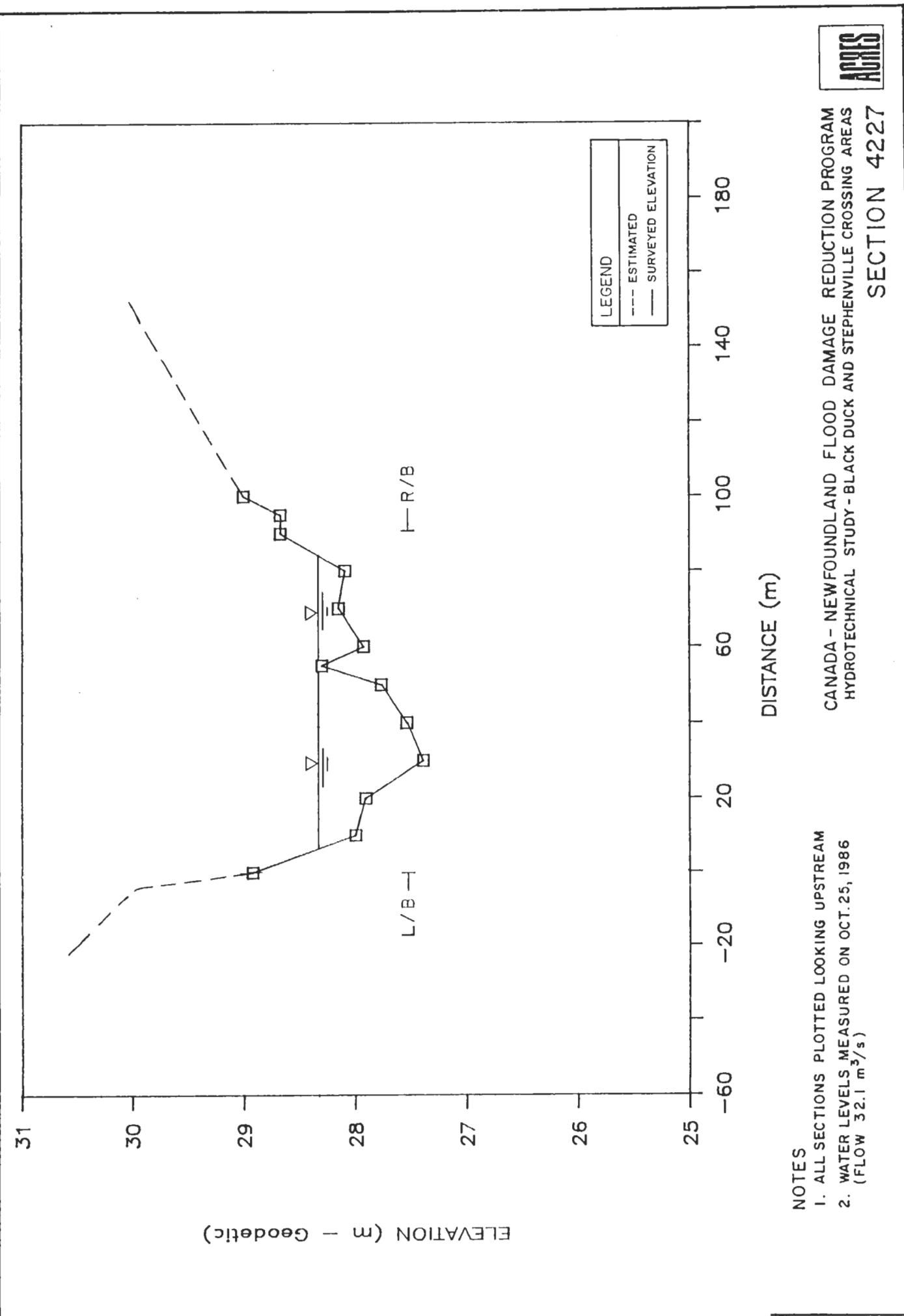


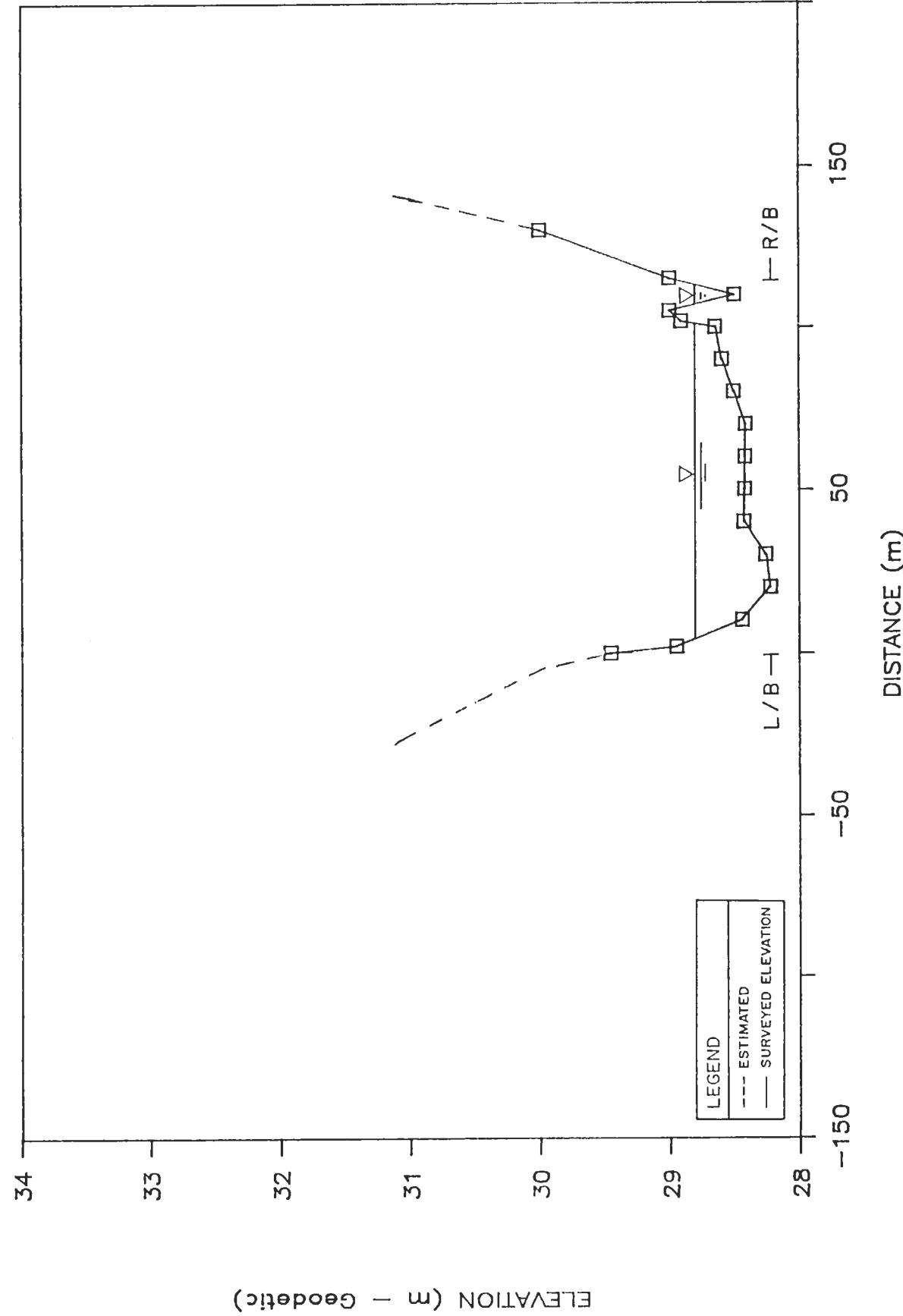
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1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 4171







NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 4323



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-150

-50

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150

DISTANCE (m)

ELEVATION (m - Geodetic)

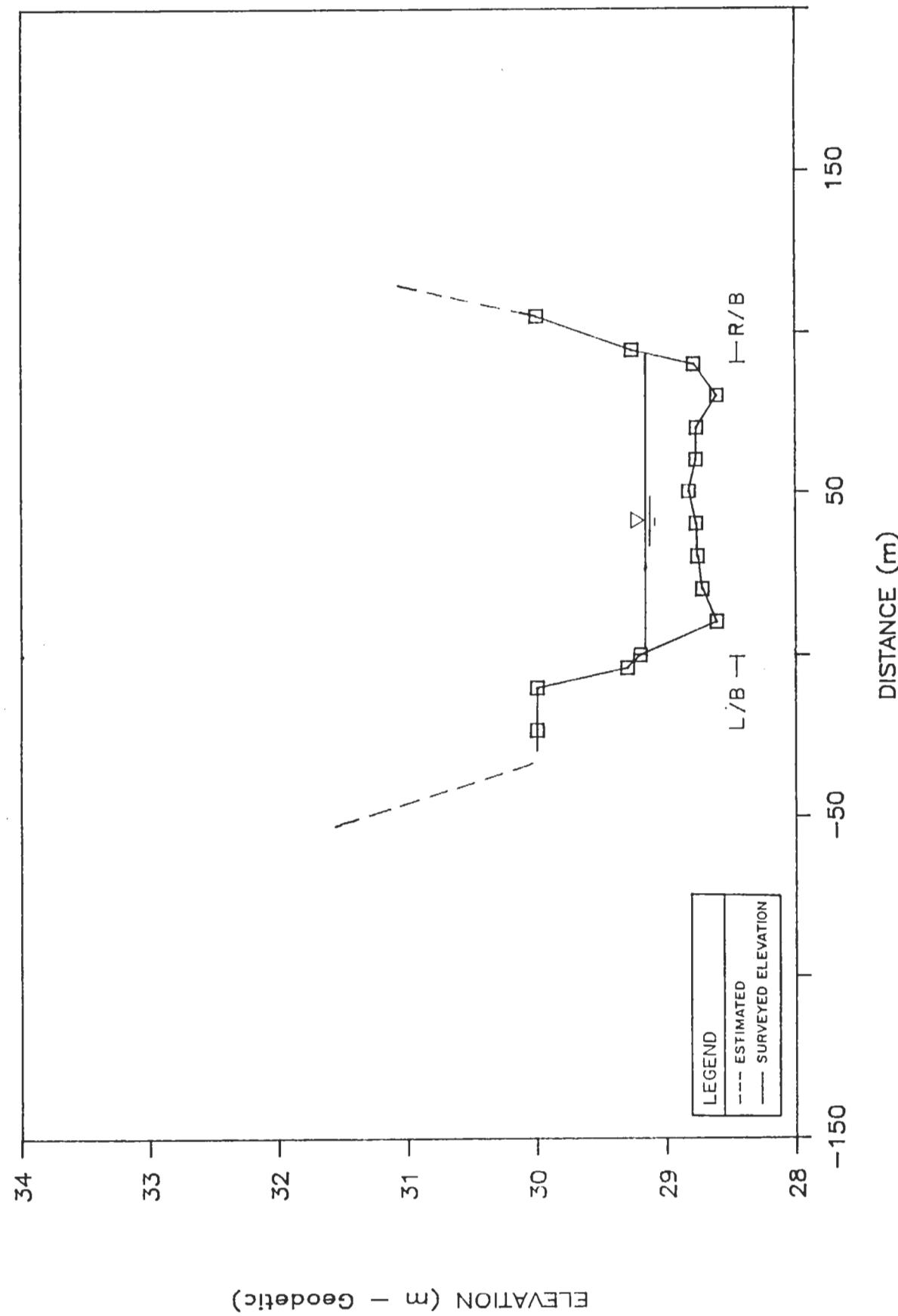
LEGEND
- - - ESTIMATED
— SURVEYED ELEVATION

NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 4367





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-150

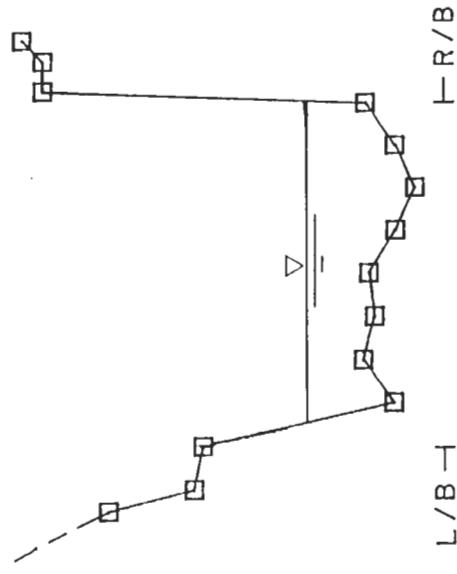
-50

150

DISTANCE (m)

ELEVATION (m - Geodetic)

LEGEND
--- ESTIMATED
— SURVEYED ELEVATION



NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 4495



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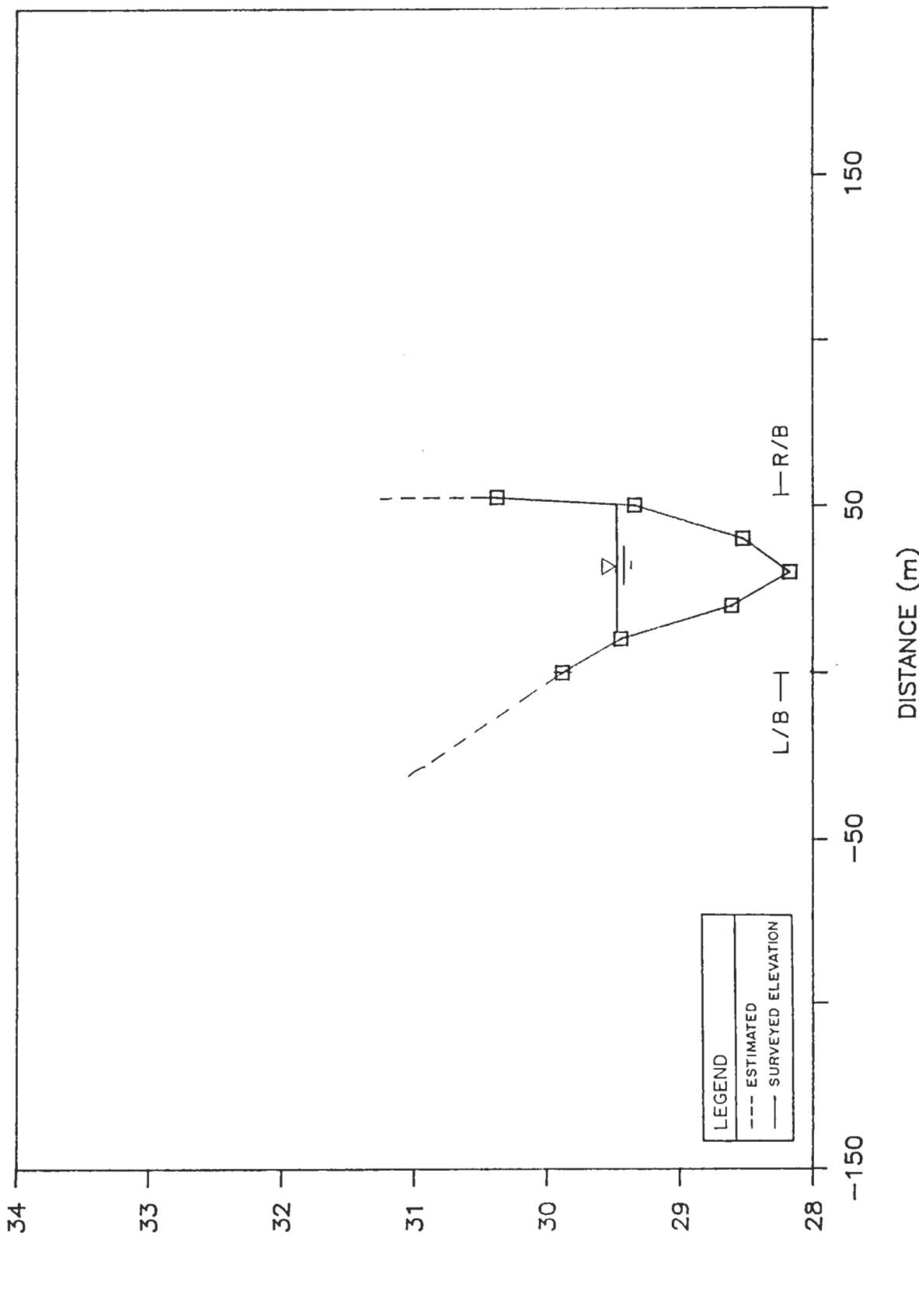
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ELEVATION (m - Geodetic)

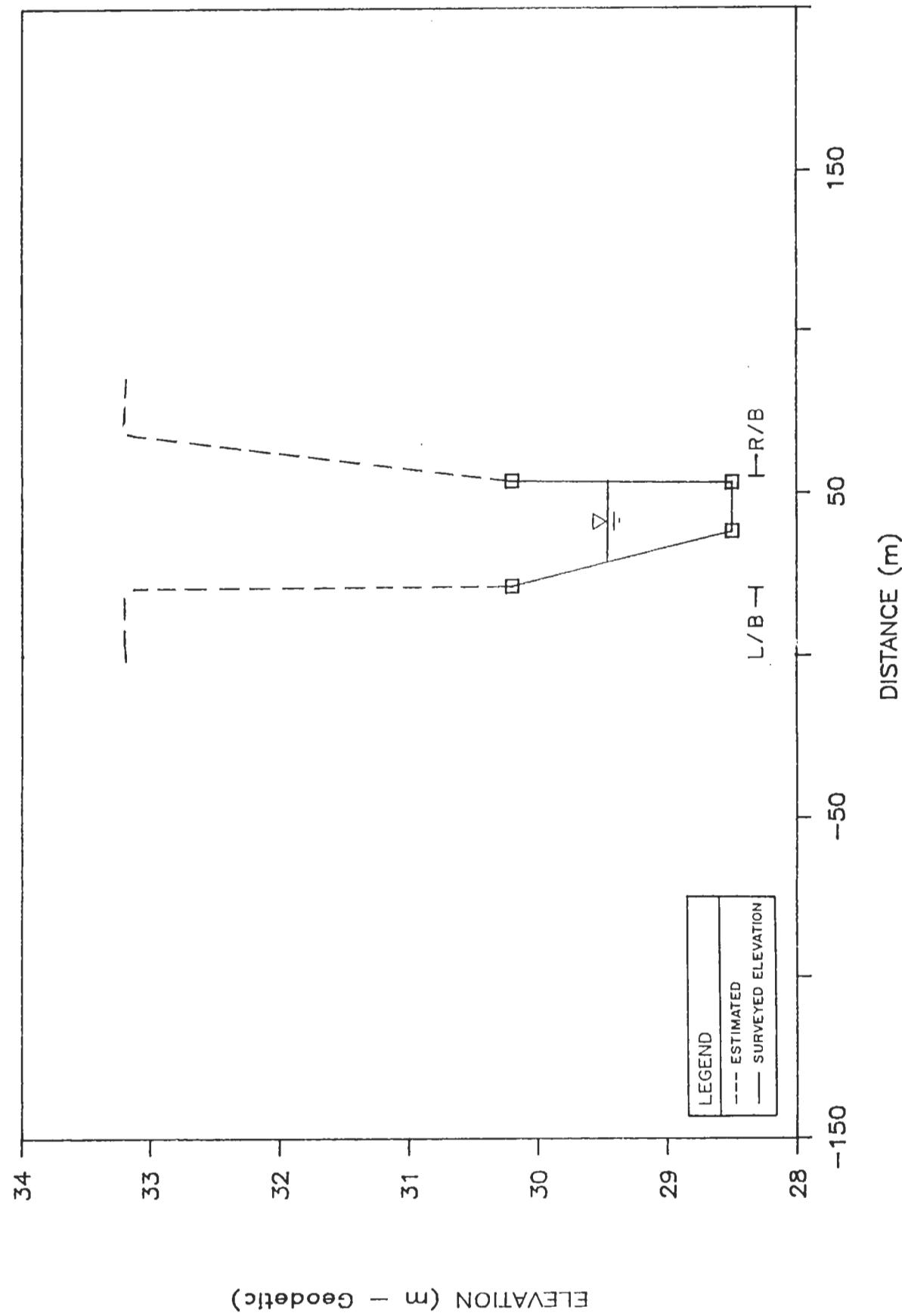


NOTES

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2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

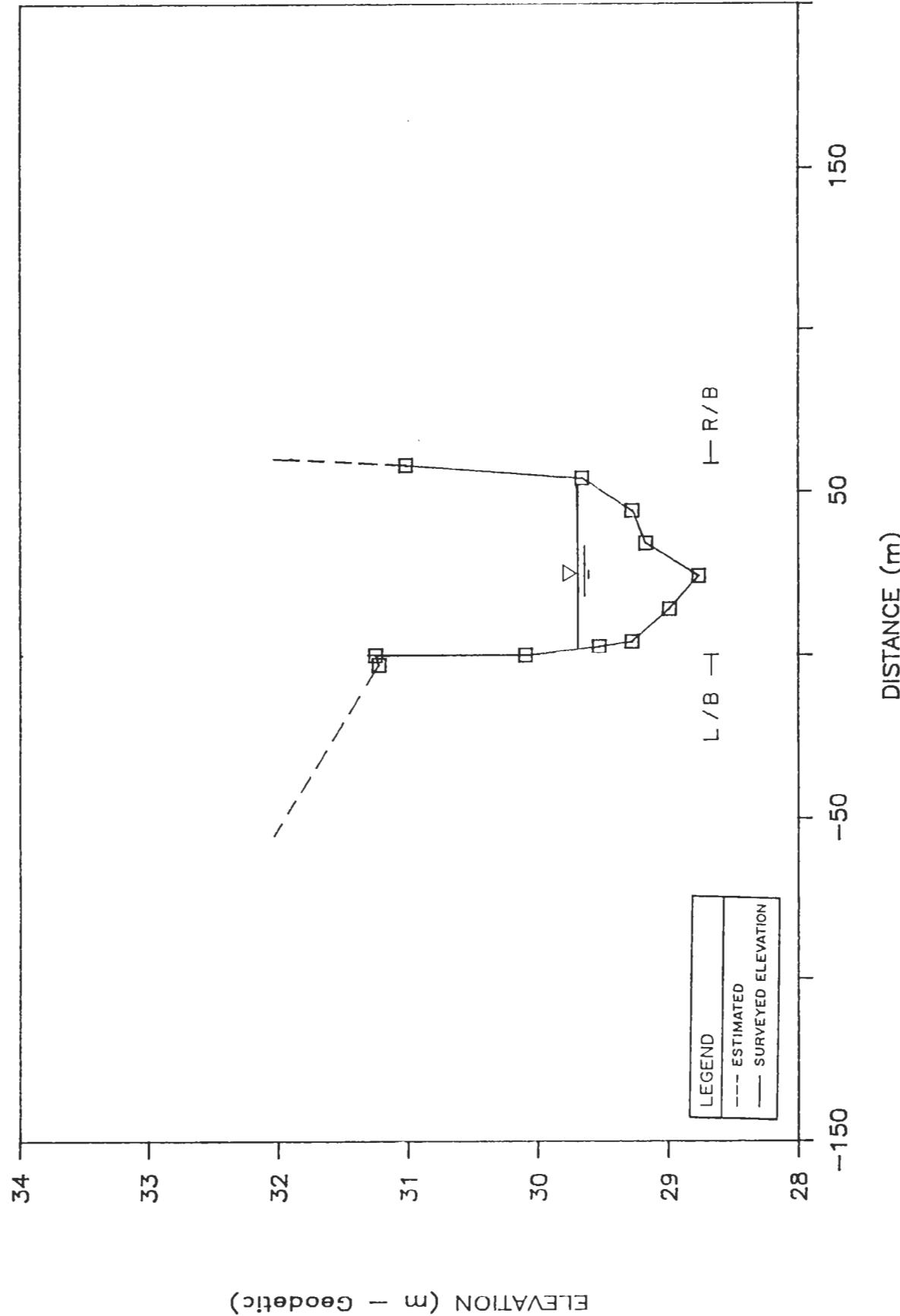
CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 4627





CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 4677





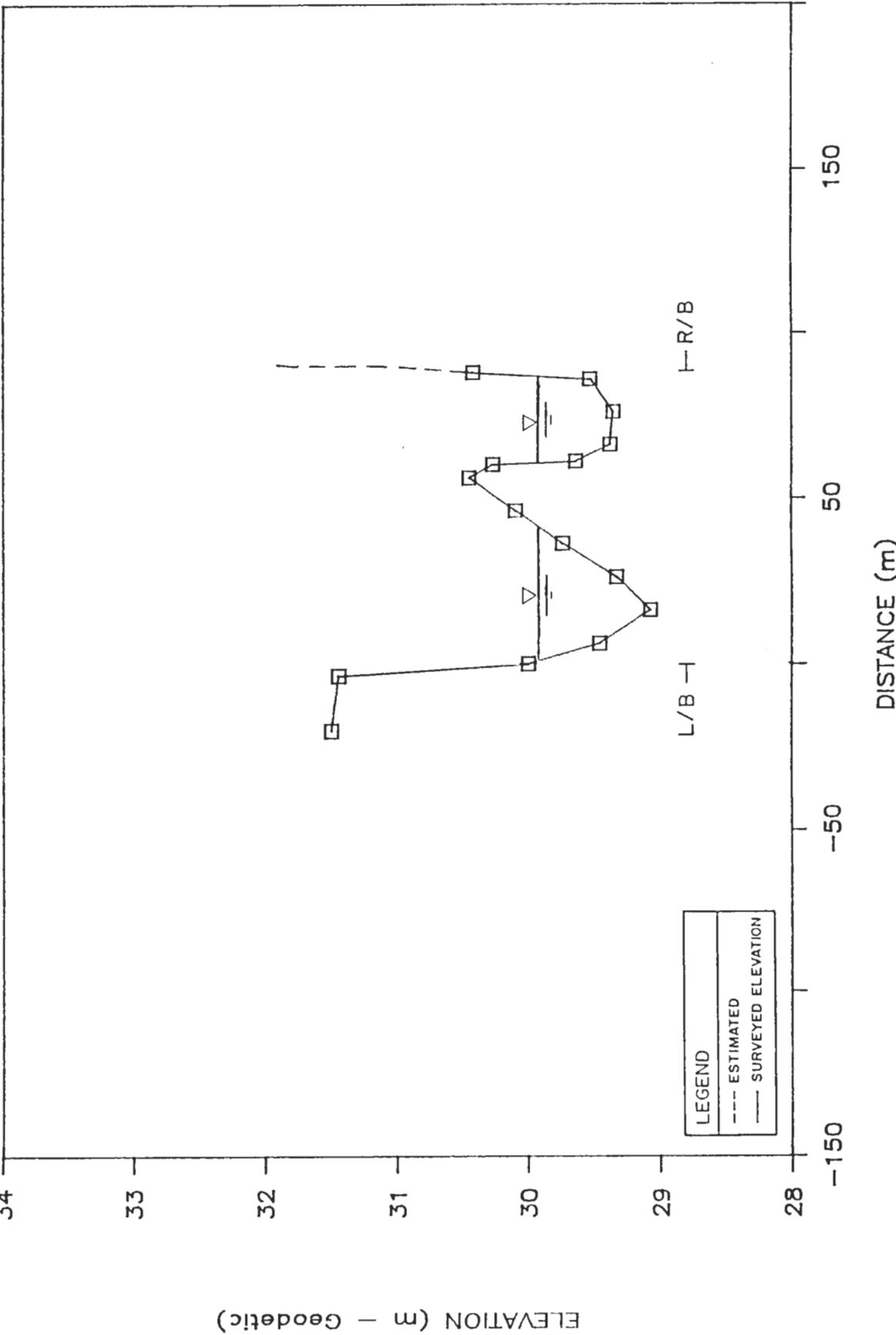
NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 4712



34

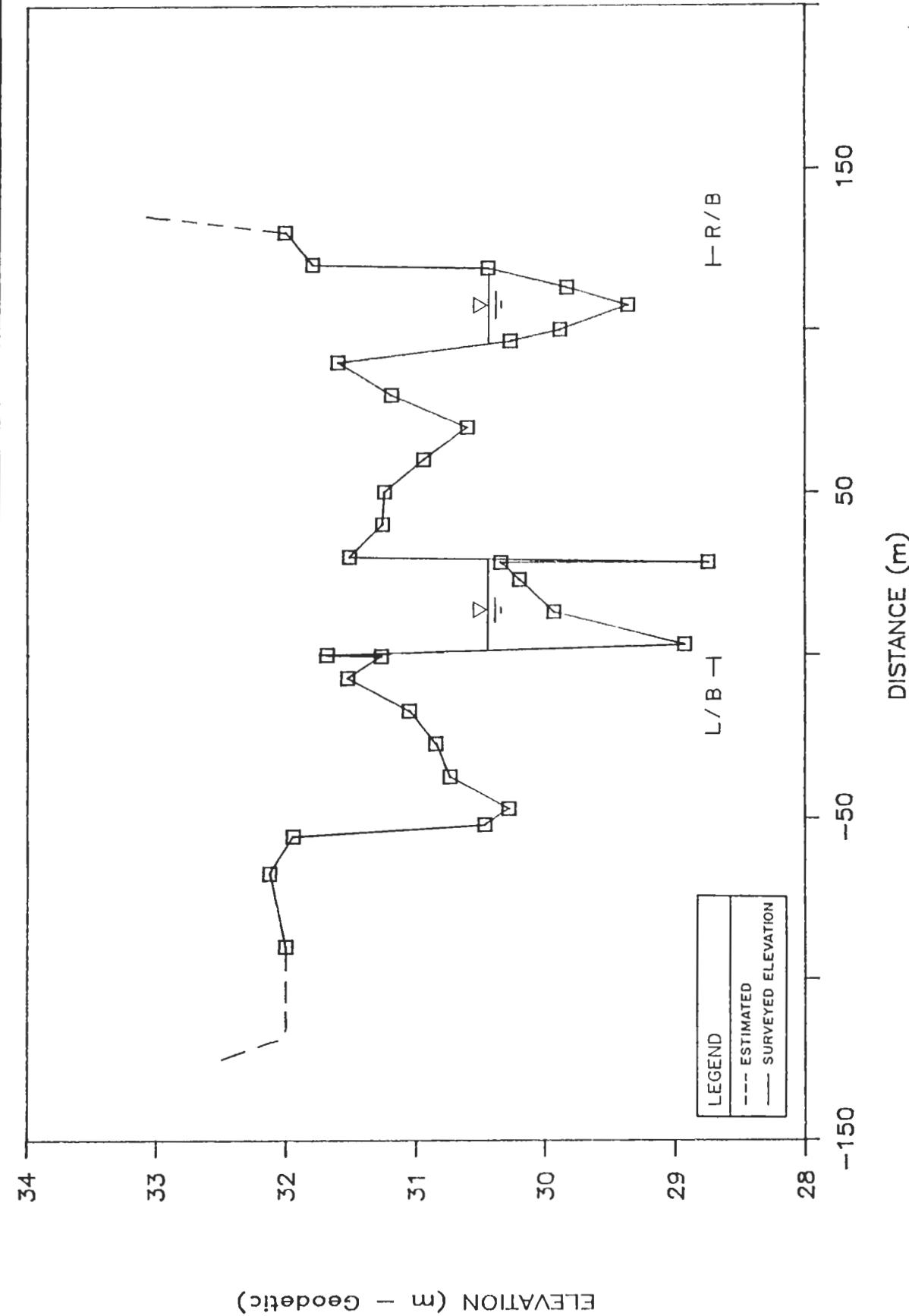


NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 4773

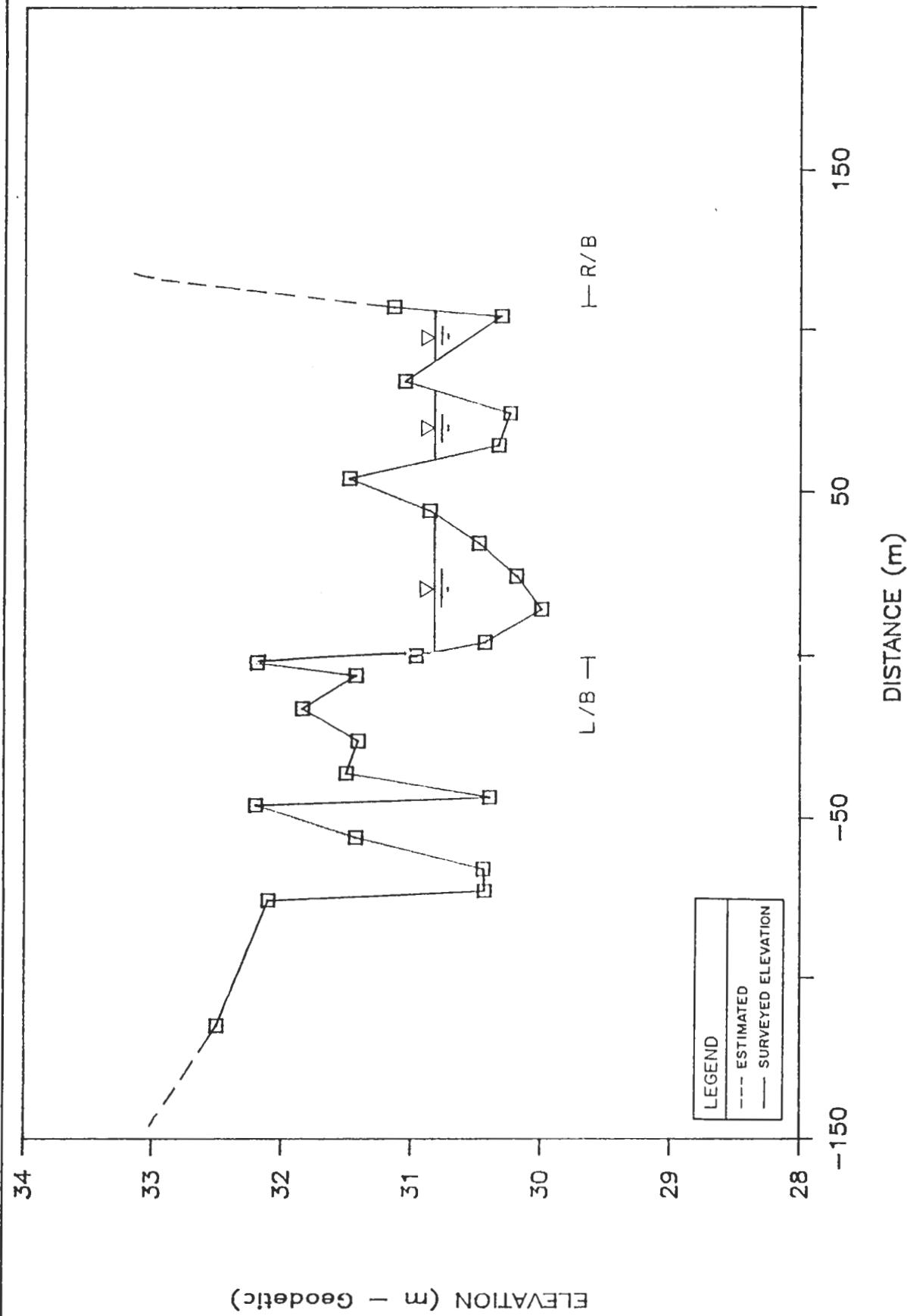




NOTES
 1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
 2. WATER LEVELS MEASURED ON OCT. 25, 1986
 (FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
 SECTION 4883





NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW 32.1 m³/s)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 4935



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-120

-80

0

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80

120

160

DISTANCE (m)

ELEVATION (m - Geodetic)

LEGEND
--- ESTIMATED
— SURVEYED ELEVATION

L / B — R / B

NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 5060



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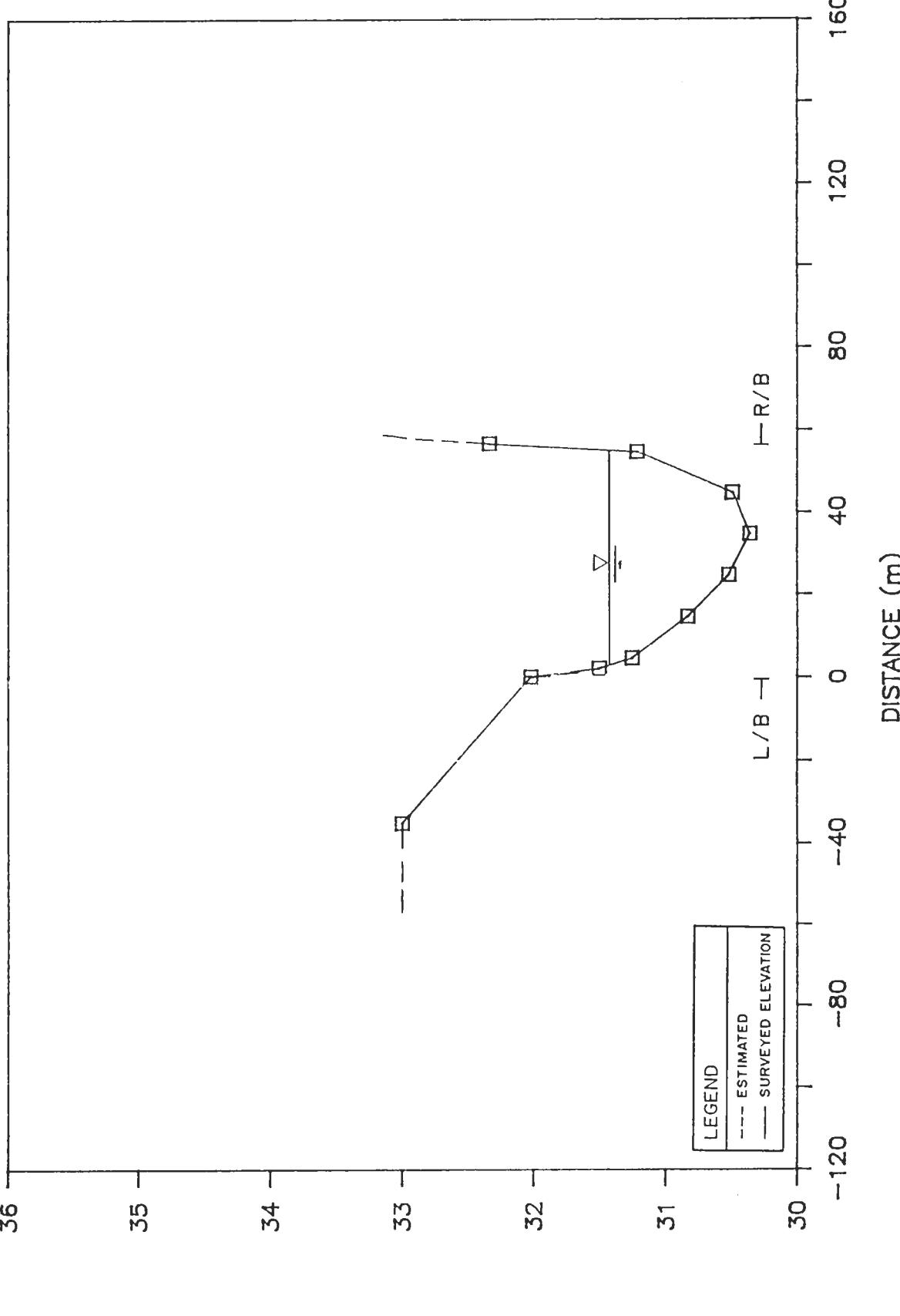
33

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ELEVATION (m - Geodetic)

**NOTES**

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW 32.1 m³/s)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 5190



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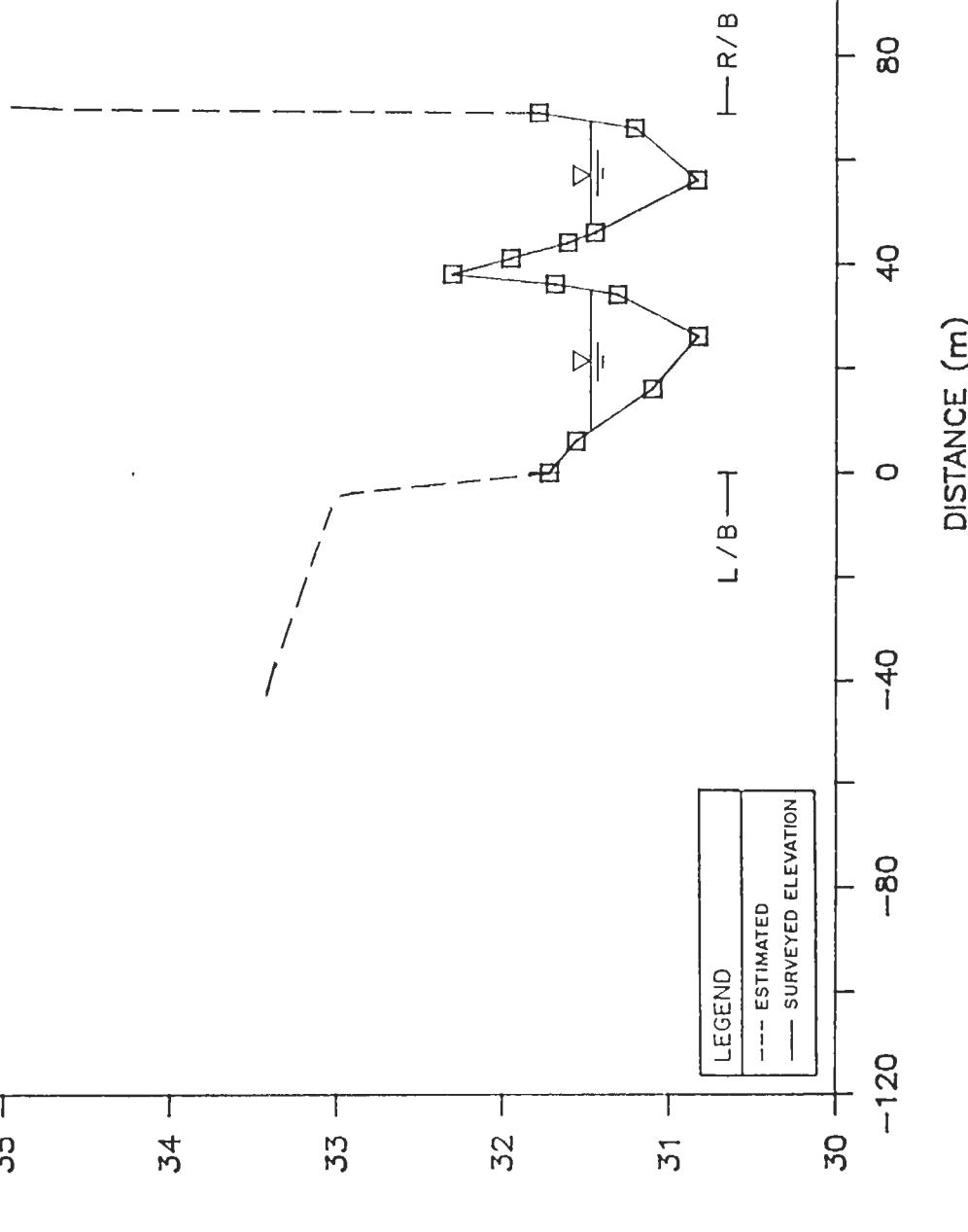
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32

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ELEVATION (m - Geodetic)

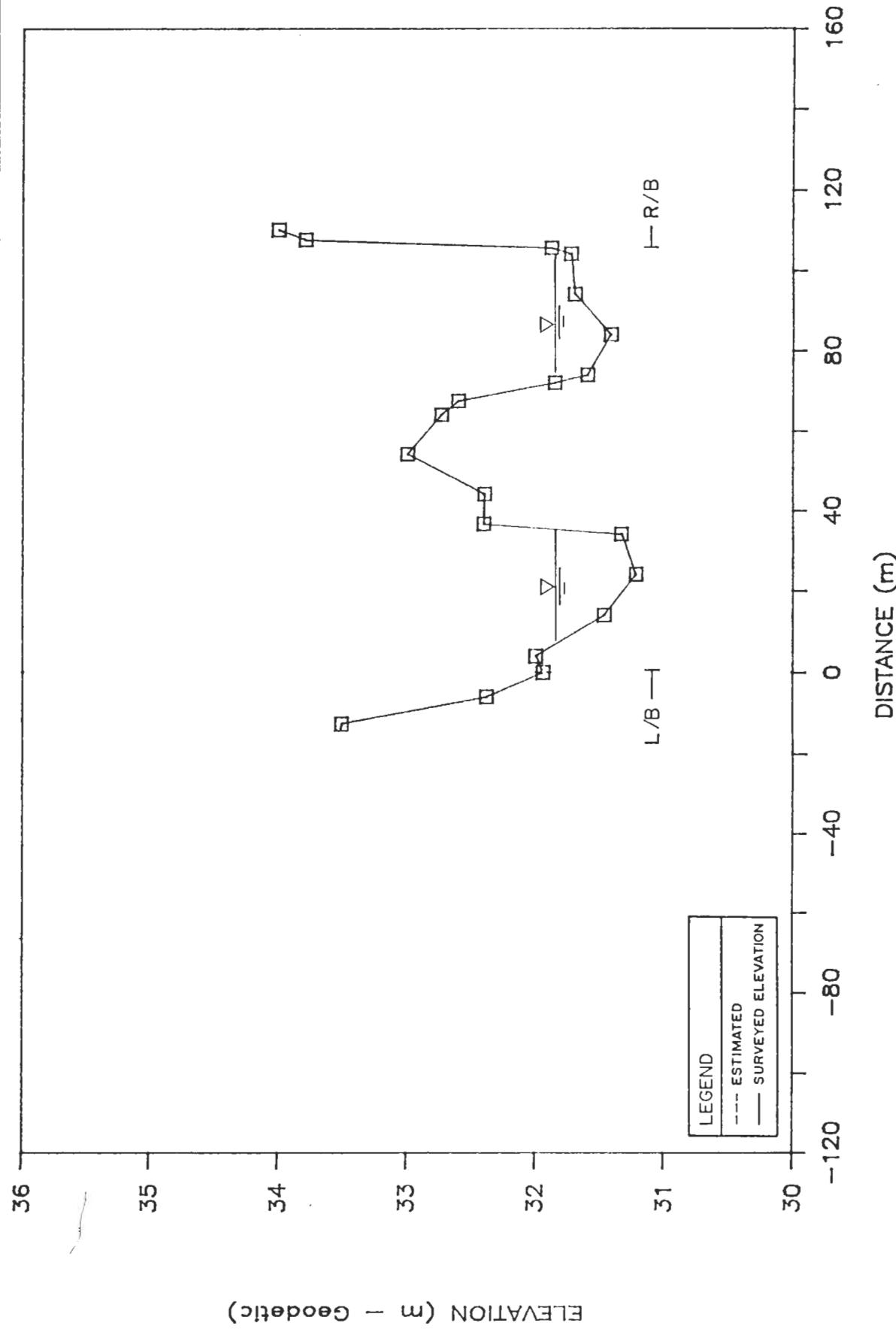


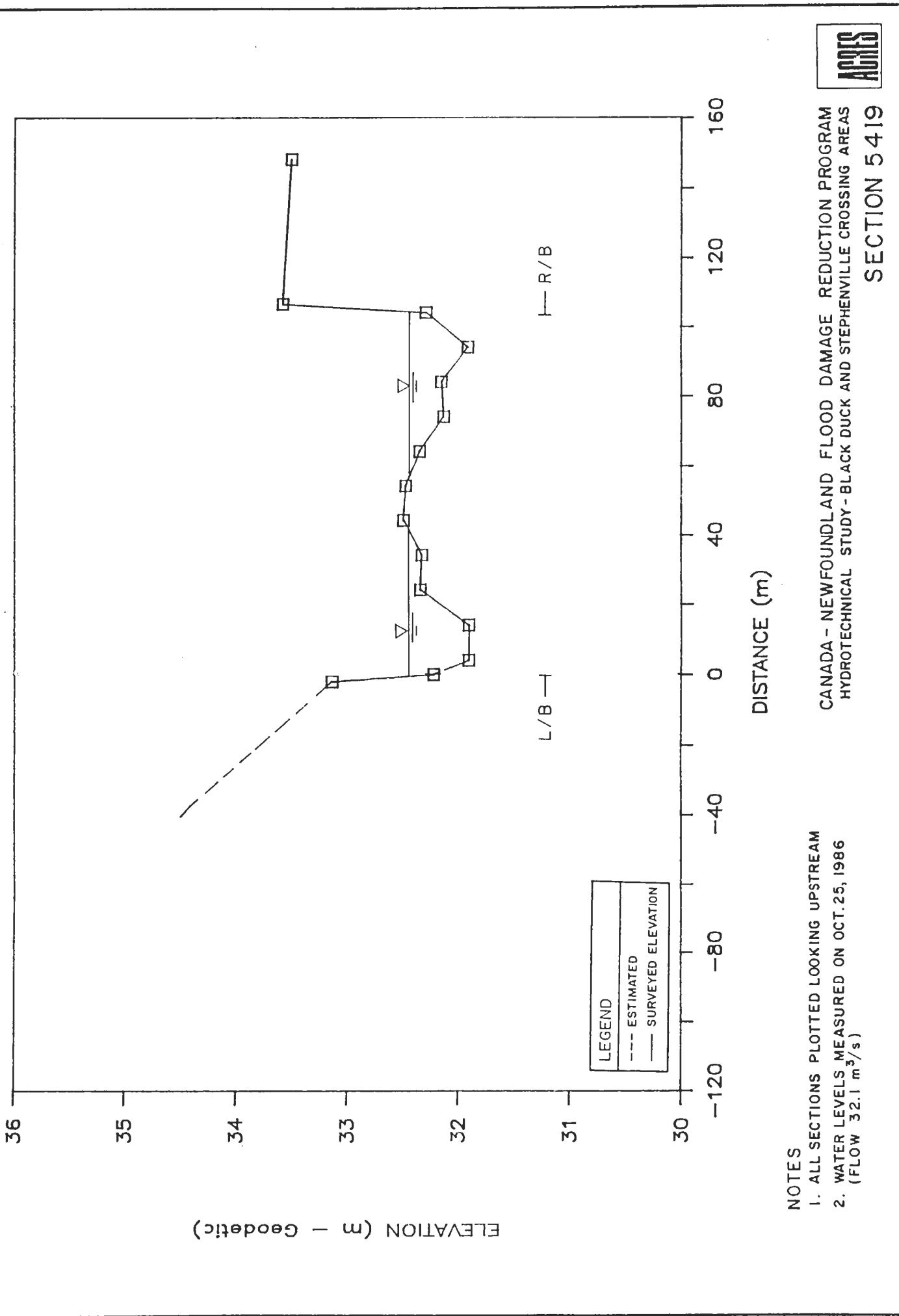
NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW 32.1 m³/s)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 5329







NOTES

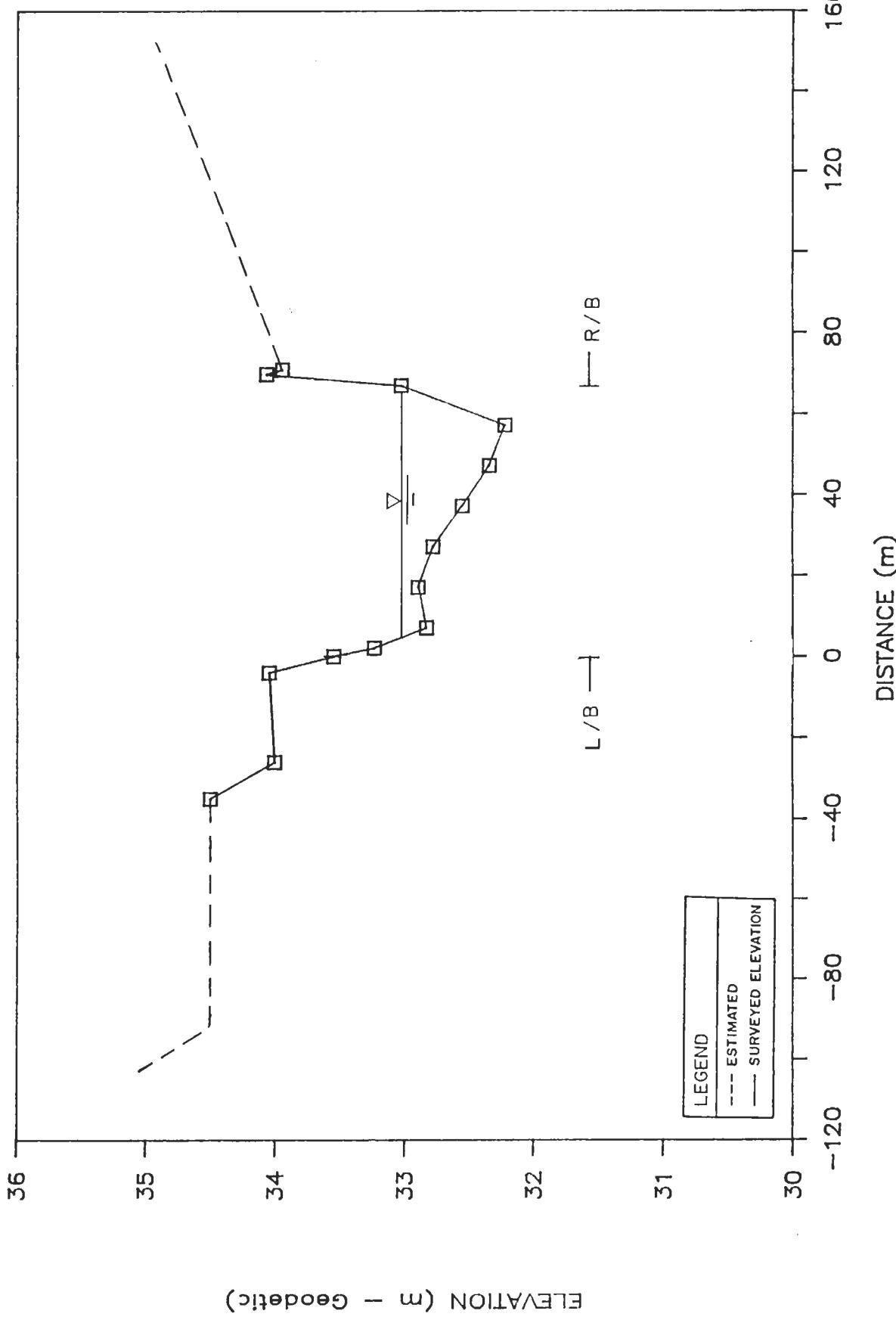
- 1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW 32.1 m³/s)**

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS MEASURED ON OCT-25, 1986

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CAV

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SECTION 5419



CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS



SECTION 5562

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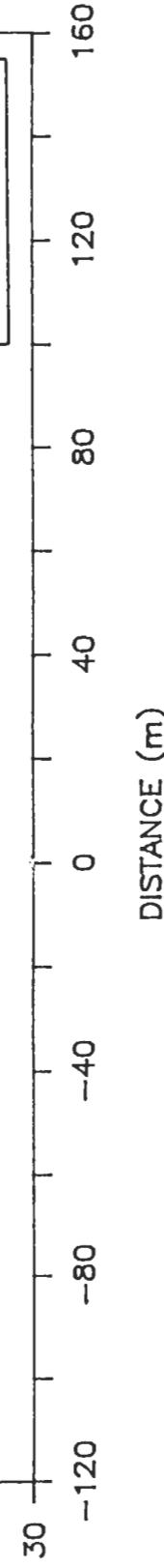
34

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ELEVATION (m - Geodetic)



LEGEND	
---	ESTIMATED
—	SURVEYED ELEVATION

- NOTES
1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
 2. WATER LEVELS MEASURED ON OCT. 25, 1986
(FLOW $32.1 \text{ m}^3/\text{s}$)

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 5742



APPENDIX B
WINTER FIELD PROGRAM - HARRY'S RIVER

APPENDIX B

HARRY'S RIVER WINTER FIELD SURVEY

B.1 - Freeze-Up Reconnaissance

During the period of December 23 to December 31, a walkover survey of Harvey's River was completed by Acres. The purpose of this survey was to

- observe the mechanisms and characteristics of ice formation
- identify possible control sections within the river reach
- identify locations for measurement of high water levels should a flood occur.

Very deep snow made access to some locations difficult. Observations were made where possible along the river reach from Roberts Brook upstream of Dhoon Lodge, to Black Duck Brook in the lower study reach.

B.1.1 - Observations

Figures B.1 and B.2 show ice conditions on Harry's River during mid-December 1986.

For the purposes of description, the river reach is divided into three sections:

1. upstream of bridge to Roberts Brook.
2. downstream of bridge to Hickey's farm.
3. Hickey's farm to White's farm.

The observations noted for each of these sections on December 13, 23 and 21, 1986 are briefly described in the following notes.

Bridge to Roberts Brook Upstream (Looking Upstream)

December 13 - Area along right bank, including channel to right of large island has frozen and is snow covered. Main channel is free of ice, except for some border ice growth along left bank of large island. Channel to the left of the smaller island (at Dhoon Lodge) has some ice growth at banks, and wide open water lead. No ice upstream of island.

Reference photos: 76

Refer also to Figure B.1

December 19 - Main channel around island has frozen and water is flowing over the ice. In some areas this water has frozen to form a second ice layer. There is still a small open water lead close to the left bank of the main channel. No observations were made further upstream.

Reference photos: 78

December 23 - Main channel has completely frozen over. There is an open lead in the small channel closest to the left bank at Dhoon Lodge. Stationary ice cover has also formed upstream of islands to Robert's Brook.

Reference photos: 88

Refer also to Figure B.2

December 31 - Ice covered with 15-20 cm of snow. Small lead that was present on December 23 has widened and extends back into main channel. There is also an open lead in smaller left bank channel at Dhoon Lodge. In both channels the water is fast flowing and frazil ice is being generated. There is also a small shore lead near the right bank, opposite Robert's Brook.

Reference photos: 90, 92 - 95

Bridge to Hickey's Farm (Looking Downstream)

December 13 - Extensive ice cover has formed from the right bank to the center of the river. There is a shore lead about 7 m wide along the left bank which extends down almost to the first bend. A shore lead is also present about 100 m downstream of the bridge on the right bank. These leads occur where the water is very deep. There are also some partially frozen transverse leads across the ice cover, which could be the result of water flowing over the ice.

Underneath the bridge, there is some water flowing over the ice near both abutments. At E. Hobb's property, there is open water in the main channel with extensive frazil/slush being formed. Ice cover (as border ice) has formed at both banks. This ice is very thin and, in some places there is water on the top of the ice. These ice conditions prevail down to Hickey's farm.

Reference photos: 69, 76

Refer also to Figure B.1

December 19 - Open water lead at left bank contains a lot of frazil ice and the upper part is freezing. The lead at the right bank is also generating frazil ice. The water that was flowing over the ice underneath the bridge has frozen. No observations were made further downstream.

Reference photos: 77

December 23 - There is some water flowing on top of the ice at the right abutment underneath the bridge. Towards d/s, more ice cover has formed in the center of the channel and shore leads are still present, though not wide. At E.

Hobb's property and downstream, ice conditions are essentially the same as December 13, with slightly more ice cover advancing from the banks outward.

Reference photos: 89

Refer also to Figure B.2

December 31 - Conditions essentially the same as December 23, with the shore leads being gradually frozen in. There is still considerable frazil ice being generated in the open water leads. Underneath the bridge, the river is completely frozen over. No further observations were taken d/s.

Reference photos: 91

Hickey's Farm to White's Farm (Tanglewood)

December 13 - Some border ice present on both banks of the river (2-3 m wide, very thin). In the area where the island was, ice has formed as an extension of the border ice at the mouth of Trout Brook. The main channel however is open with considerable frazil ice being generated and some slush pans present. The shoal area at the lower end of Hickey's farm is also ice covered with water flowing freely around it.

Reference photos: 70 - 74

Refer also to Figure B.1

December 23 - At Hickey's farm, border ice has advanced from both banks and more slush pans have formed. Just below where the island was, the water is flowing through and over the ice cover that has formed. The ice here is very wet and is mostly slush in some places. Towards White's farm, the channel is practically free of ice except for some anchor ice that has formed around the rocks in the shallower sections and some small slush pans. There is no border ice

on the right bank in front of the farm. Black Duck Brook is frozen over and, downstream of White's farm, the river appears to be ice free. The water levels are lower than those observed during the fall field program.

Reference photos: 79 - 87

Refer also to Figure B.2

B.1.2 - Identification of Control Sections

During the freeze-up reconnaissance, note was made of possible control sections in the river. These observations were made keeping in mind the locations of past ice problems such as White's farm during the freeze-up event of 1985 and the flood of 1984.

Four sections were noted that may cause problems during a freeze-up or break-up event.

1. Just upstream of Tanglewood Ranch there is a natural constriction in the channel and the area immediately downstream is very shallow. During a freeze-up event there will be ice formation here since the velocity of flow decreases considerably. There are also many rocks around which anchor ice can form. This was noted in the freeze-up reconnaissance on December 23, 1986. A substantial amount of ice had formed in the wider section of the channel up to the constriction. This may have caused a slight backwater effect and, as the water level rose, it began to flow over the ice, creating open channels through the ice cover. This can be seen in photos 84 to 87.

2. Another location of concern is the area just below E. Hobb's property where the same situation as at Tanglewood Ranch occurs. The river widens just below

the transmission line and then narrows very quickly around the bend. This is an area of potential ice jamming during an ice break-up event.

3. At the bridge there is also the possibility of ice jamming because of the constriction of the river's width beneath the bridge. Ice jamming here was also recorded during the February 1984 break-up event.
4. Previous events have been reported to be associated with the island in front of Hickey's farm. However, the island was removed by the Nfld. Department of Environment in an attempt to prevent an event such as occurred in 1984. The dredged material was used to build up the river bank in front of Hickey's farm as a remedial measure. The Department of Environment has also deepened the river bed immediately upstream of White's farm and an embankment was built up along the river bank.

The effects of both these measures on future events will be closely monitored.

B.2 - January 1987 Field Reconnaissance

The January, 1987 field reconnaissance included a helicopter fly-over of the river, followed by walkovers of particular areas of interest. The fly-over was documented in a video recording, as well as in photographs 97 - 138, presented in a separate volume.

A major jam was observed near White's farm, about 1.5 km downstream of the study reach. Considerable shoving appeared to have occurred in this jam. The cover had not progressed very far. Numerous open leads were observed upstream of the jam. Between this area and the bridge, the river was approximately 50 percent ice covered, primarily with border ice, with some ice apparently

grounded in shallower sections. Upstream of the bridge the ice cover varied from nearly complete cover to over 90 percent open near George's Lake.

B.3 - February 1987 Mid-Winter Field Survey

During the period of February 24-25, a field survey was completed to determine the average ice cover thickness and water levels along the river reach. Ice and snow thickness measurements were made at five cross sections. Since no ice events occurred in 1987, this information was not used directly for calibration. The ice thicknesses were typical of those expected during pre-freeze up conditions, i.e. with no thickening due to shoving or deposition. Profiles of the ice and snow thicknesses in these areas are included at the end of this Appendix (see also photographs 139-143).

B.4 - Ongoing Monitoring

During the winter of 1986-1987, constant contact was also maintained with local residents of Black Duck Siding to monitor the ice conditions. A record of the monitoring results is provided in Table B.1, at the end of this Appendix.

TABLE B.1

HARRY'S RIVER OBSERVED WINTER ICE CONDITIONS - 1986-1987

Date	Observed Ice Conditions	Comments
November 25/86	No ice in river	Island being removed d/s @ Hickey's property
December 13/86	Some ice (border ice mostly) has formed in the river. U/S to right of large island frozen. Lots of slush ice and frazil being generated but there are large open water leads along entire reach.	See photos
December 19/86	No real change d/s of bridge. U/S of bridge large open water lead has frozen over and water is flowing over the ice.	See photos
December 23/86	River has almost frozen over u/s of bridge with small open water lead. Open water at White's property up to Hickey's with slush pans and frazil present.	See photos
December 31/86	Still not much change. A lot of snow has fallen hence most of ice snow covered. Walked up to Dhoon Lodge and beyond and river is totally frozen over. Still open water mostly at Hickey's and White's with border ice growth. Water levels seem to be very low.	See photos
January 12/87	Talked to E. Hobbs. River same as December 31, with bridge to u/s totally frozen over. Open water at Hickey's and White's, except border ice. 500 yds d/s of White's frozen to mouth of river. Flows still low.	

TABLE B.1 (continued)

HARRY'S RIVER OBSERVED WINTER ICE CONDITIONS - 1986-1987

Date	Observed Ice Conditions	Comments
January 15/87	Field survey completed by Acres and D.O.E. personnel. River essentially same as January 12.	Photos and observations noted. Also aerial photos taken during fly-over from mouth to headwaters
January 19/87	River has filled in a little more but doesn't appear to be backing up. Expecting temperatures of -15 C tonight so expect river to freeze-up even more. Open channel that was present at Hobbs during last week's field trip may freeze-in. (Talked to E. Hobbs).	E. Hobbs keeping close watch on river.
January 26/87	Talked with E. Hobbs. The river has just about froze across. About 3 ft left to freeze up. Same water levels as when mid-winter survey was done. No slob formed. He expects open lead to freeze over tonight as temperatures have been getting lower.	E. Hobbs thinks river looks better than it has for past few years.
January 28/87	Talked with M. Hickey. Some open water around island and as far down as he can see. Some open channels d/s bridge 10-15 ft wide. River is frozen over at Hobbs. Water flowing freely under ice.	
February 6/87	u/s of transmission line is totally frozen over. d/s to Black Duck there still exists open water leads. Mr. Hobbs does not think ice is safe enough to walk on d/s of bridge.	E. Hobbs provided information.

TABLE B.1 (continued)

HARRY'S RIVER OBSERVED WINTER ICE CONDITIONS - 1986-1987

Date	Observed Ice Conditions	Comments
February 18/87	River not frozen d/s of Hobbs. Open water lead has closed in to 5-10 ft. Could get thickness measurements if extra care was taken. If cold temperatures persist, whole river will freeze in.	E. Hobbs provided information. Water levels still low.
February 23/87	Surveyor looked at river. River still volatile and open in places. Local residents still won't go out on it. Snow covered but not ice covered.	Mid winter. The survey completed February 24-25. Only possible to do 4 cross sections. (See report).
March 18/87	Past 3 days have been fairly mild but no rain. River completely frozen over and ice has softened. No ice moving. Ice thicker than usual. As long as no rain should be O.K.	
March 20/87	E. Hobbs called to report that water levels have risen about 8 in. Raining very heavy at times. Water rose 8 in. in 6 hours. No ice moving but there is a trench opened up with water flowing in center. If it keeps raining, E. Hobbs expects river to break up by Sunday. He will call back tonight.	Called transport Canada for forecast for March 21. Calls for mild temperatures 20% probability of precipitation tonight. 10% tomorrow.
March 21/87	Weather mild but not raining. He will watch and call surveyors to measure high water levels if jam occurs.	W. Dyke provided information.

TABLE B.1 (continued)

HARRY'S RIVER OBSERVED WINTER ICE CONDITIONS - 1986-1987

Date	Observed Ice Conditions	Comments
March 21/87	Levels have gone down a little and weather is cooler. He thinks that river will go own now by melting. information will monitor and call if develops.	E. Hobbs provided out on its a n y t h i n g
March 22/87	d/s of bridge, ice from shore to shore with water flowing under ice. u/s of bridge, 3 ft. wide channel on Dhoon Lodge side of large island. Weather has been cold at night and mild during the days.	E. Hobbs provided infor-mation.
April 6/87	Ice started to melt out and by April 4, was all gone. Disappeared by melting. Ice melted first in the middle where small trench had been forming prior to March 23. Ice gradually melted and weakened, breaking off in small pans and carried down river. No jamming or high levels observed.	

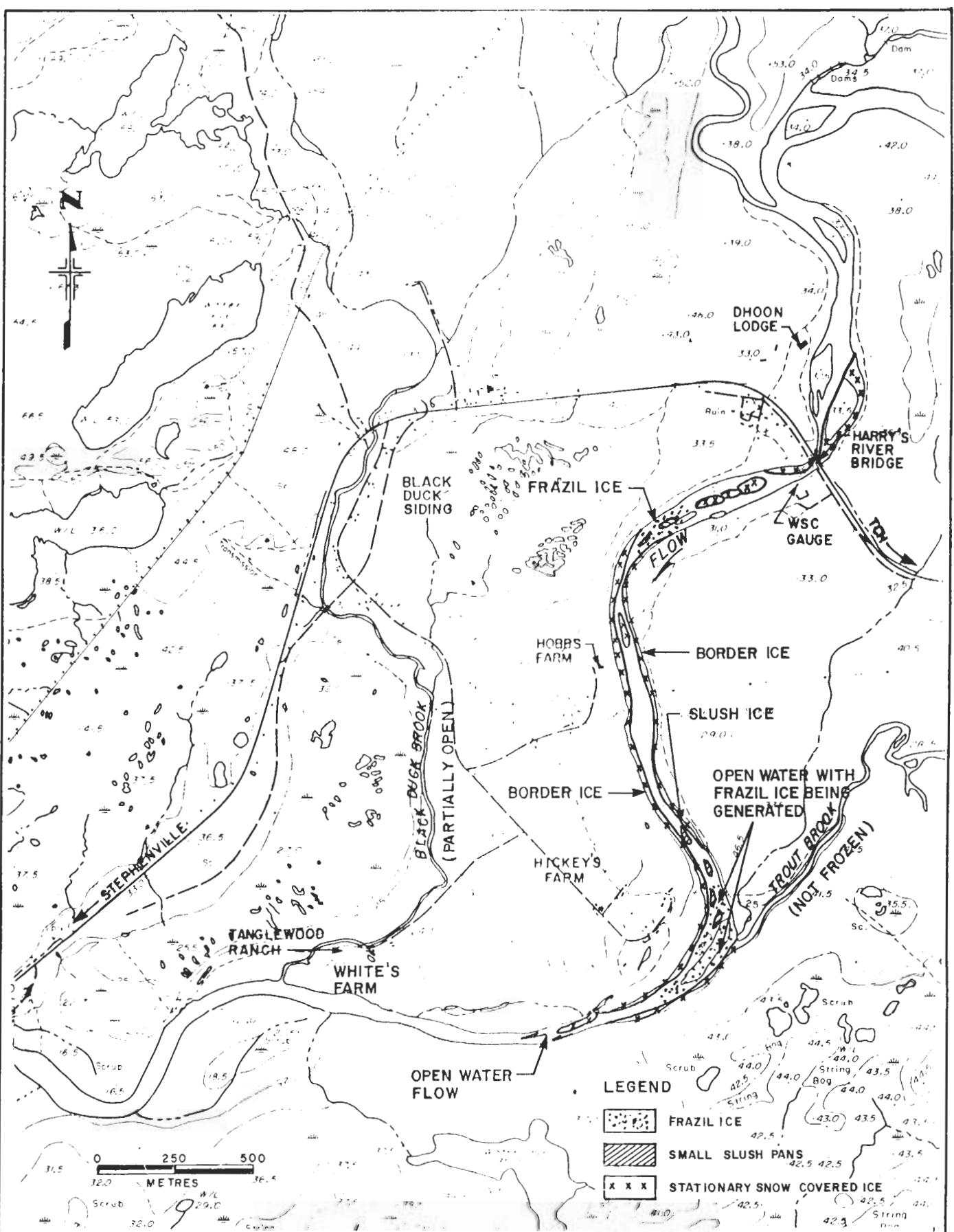


FIG .B.1

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - STEPHENVILLE CROSSING AND BLACK DUCK SIDING AREAS

HARRY'S RIVER ICE CONDITIONS-DEC.13,1986



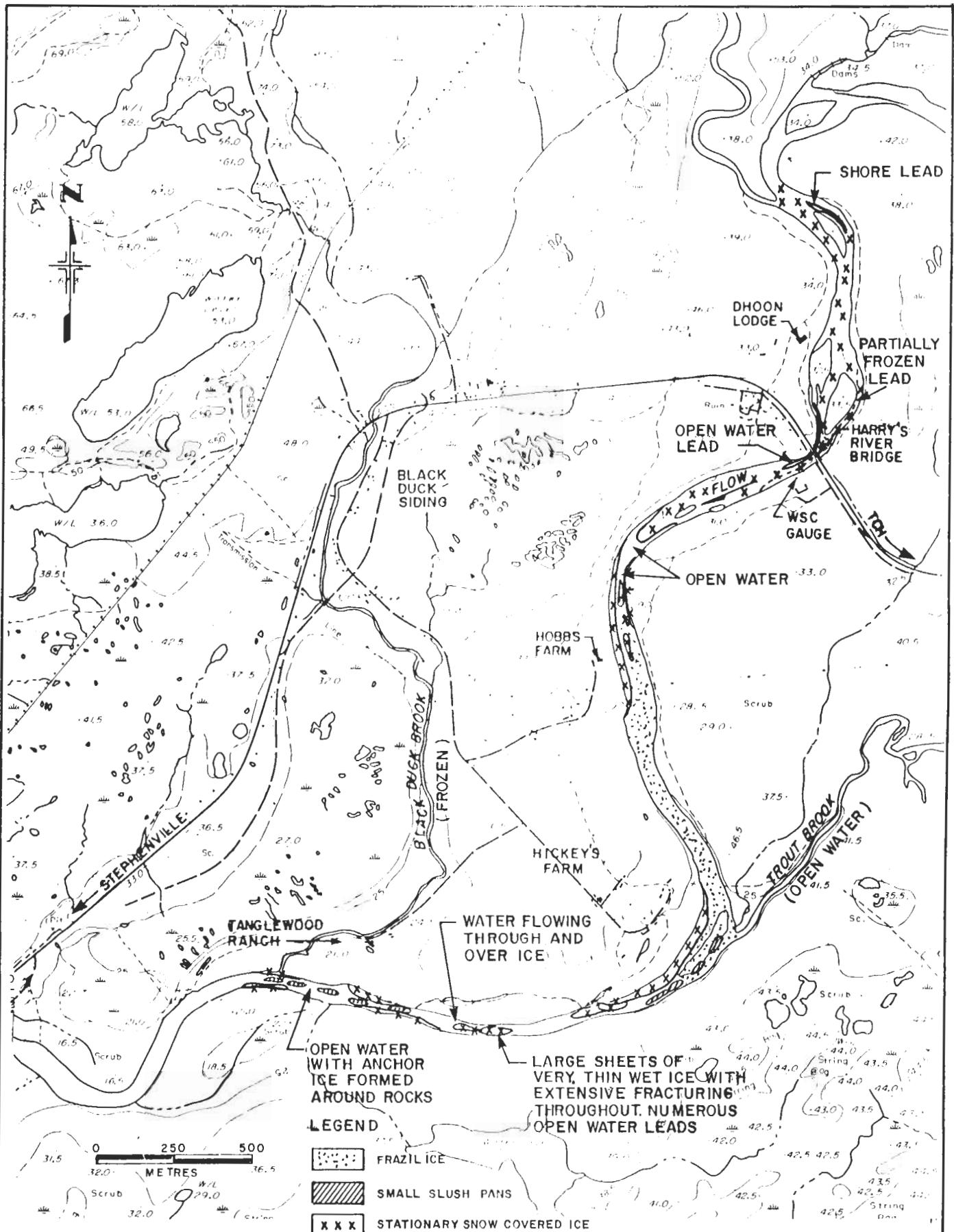


FIG. B.2

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - STEPHENVILLE CROSSING AND BLACK DUCK SIDING AREAS
HARRY'S RIVER ICE CONDITIONS- DEC. 23, 1986

36

MIDWINTER ICE SURVEY

35

34

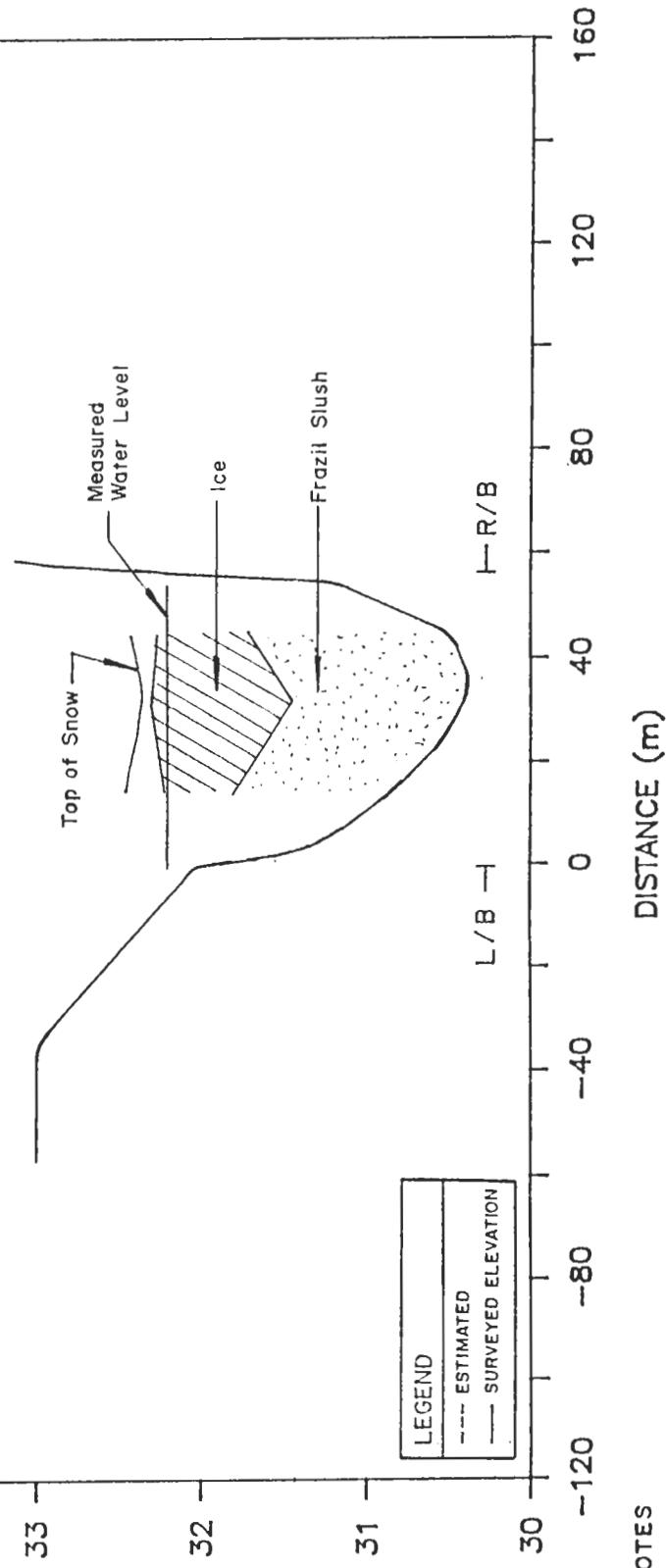
33

32

31

30

ELEVATION (m - Geodetic)



NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS AND ICE THICKNESSES
MEASURED ON FEB 24 - 25, 1987

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 5190



34

MIDWINTER ICE SURVEY

33

32

31

30

29

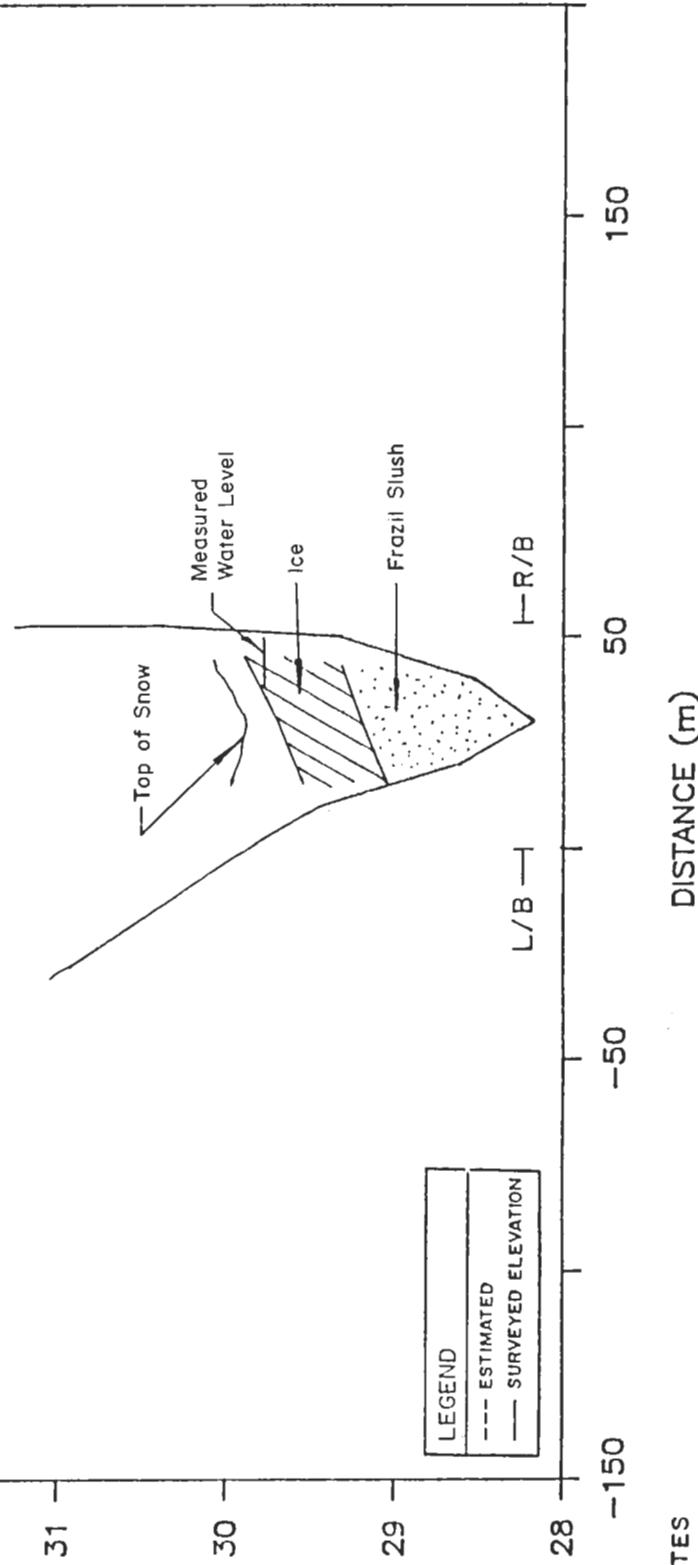
28

-150

50
-50

150

ELEVATION (m - Geodetic)



CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 4627



30

MIDWINTER ICE SURVEY

29

28

27

26

25

24

23

22

21

20

-300

-200

0

100

200

NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS AND ICE THICKNESSES
MEASURED ON FEB 24 - 25, 1987

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 2642 (POST EXCAVATION)

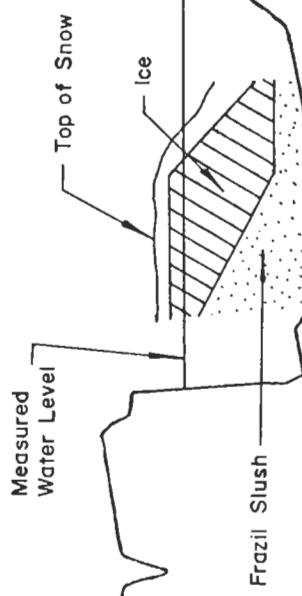


ELEVATION (m - Geodetic)

LEGEND	
---	ESTIMATED
—	SURVEYED ELEVATION

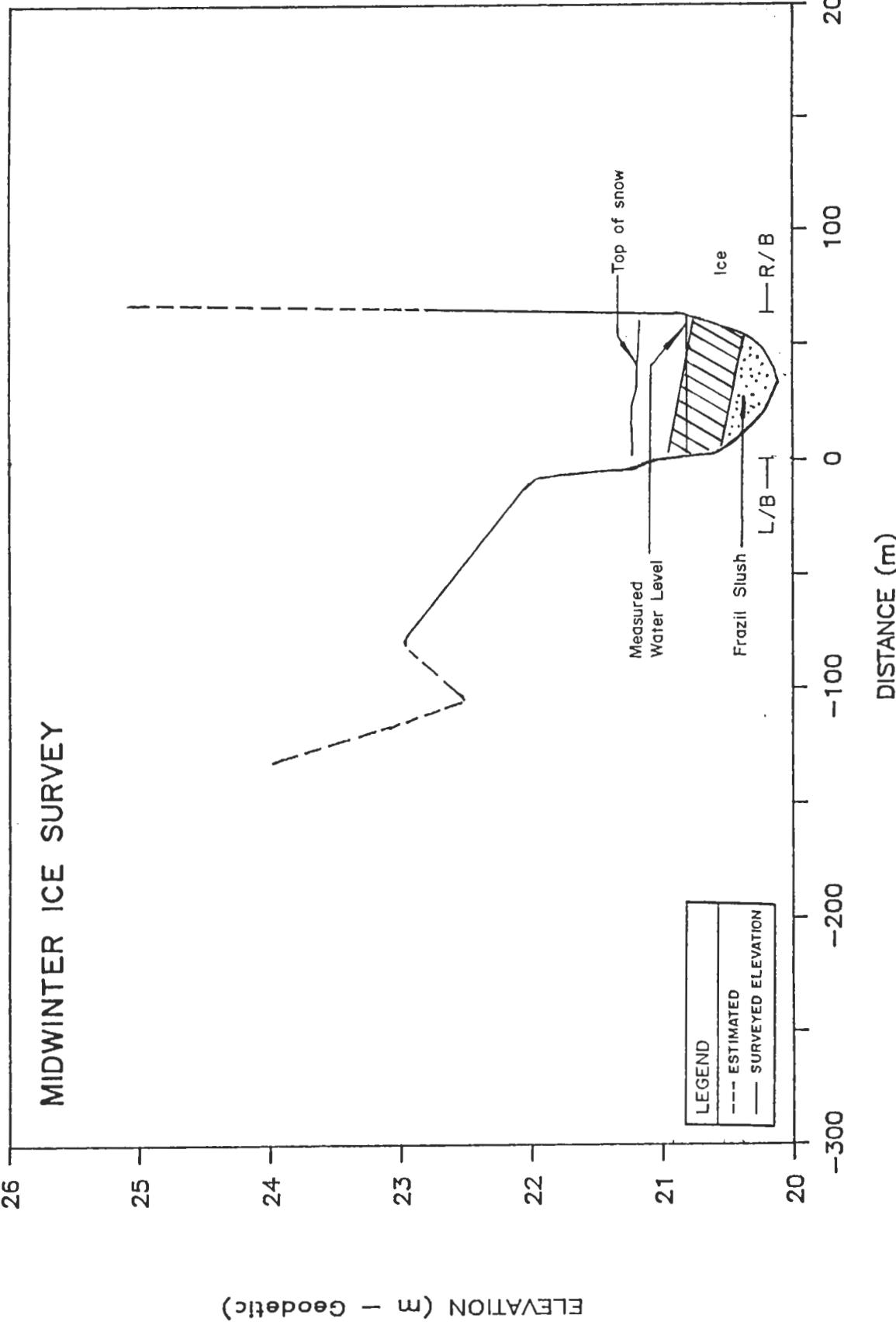
L/B — R/B

DISTANCE (m)



26

MIDWINTER ICE SURVEY



NOTES

1. ALL SECTIONS PLOTTED LOOKING UPSTREAM
2. WATER LEVELS AND ICE THICKNESSES
MEASURED ON FEB 24 - 25, 1987

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
SECTION 1950



APPENDIX C
HARRY'S RIVER SINGLE STATION FREQUENCY
ANALYSIS RESULTS

APPENDIX C

HARRY'S RIVER SINGLE STATION FREQUENCY ANALYSIS RESULTS

This appendix presents the results of the single station frequency analysis of the open water flows on Harry's River. The analysis was completed for both the annual maximum instantaneous flows and the annual maximum mean daily flows using the FDRPFFA computer program. The output results are reproduced in the following pages.

HARRY'S RIVER MAX DAILY FLOWS D.W.

YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
1969	333.	333.	1	.056	18.000
1970	184.	279.	2	.111	9.000
1971	121.	267.	3	.167	6.000
1972	228.	261.	4	.222	4.500
1973	260.	260.	5	.278	3.600
1974	121.	228.	6	.333	3.000
1975	261.	219.	7	.389	2.571
1976	166.	186.	8	.444	2.250
1977	152.	184.	9	.500	2.000
1978	186.	166.	10	.556	1.800
1979	156.	156.	11	.611	1.636
1980	219.	152.	12	.667	1.500
1981	131.	137.	13	.722	1.385
1982	267.	131.	14	.778	1.286
1983	116.	121.	15	.833	1.200
1984	137.	121.	16	.889	1.125
1985	279.	116.	17	.944	1.059

HARRY'S RIVER MAX DAILY FLOWS 0.W.

SAMPLE STATISTICS

MEAN = 195. S.D. = 66.4 C.S. = .5450 C.K. = 2.8540

SAMPLE STATISTICS (LOGS)

MEAN = 5.2198 S.D. = .3375 C.S. = .1512 C.K. = 2.3413

SAMPLE MIN = 116. SAMPLE MAX = 333. N = 17

PARAMETERS FOR GUMBEL I A = .019673 U = 165.

PARAMETERS FOR LOGNORMAL M = 5.2198 S = .3375

PARAMETERS FOR THREE PARAMETER LOGNORMAL A = 101. M = 4.2481 S = .8608

STATISTICS OF LOG(X-A)

MEAN = 4.2481 S.D. = .8608 C.S. = -.4074 C.K. = 2.5673

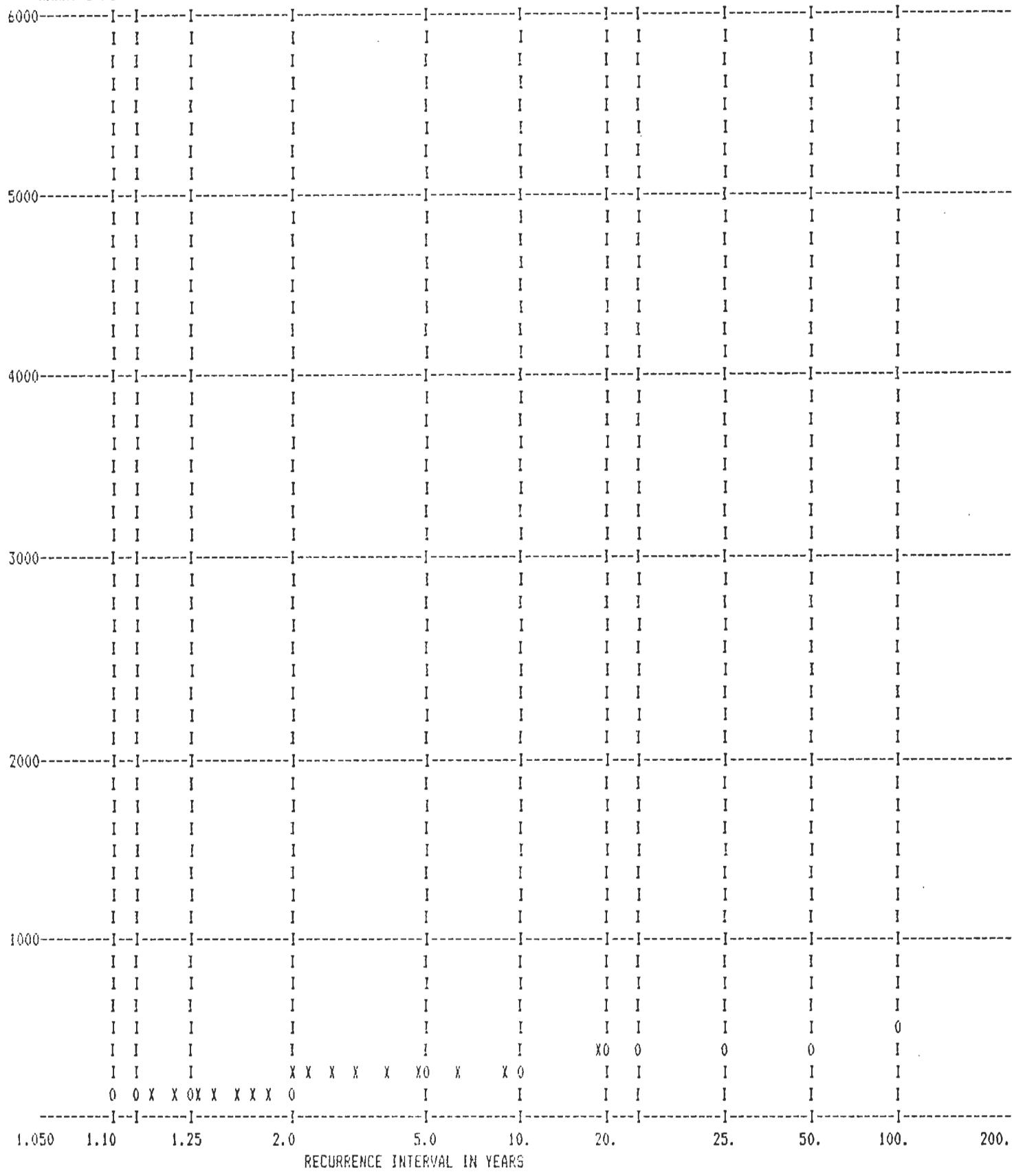
PARAMETERS FOR LOG PEARSON III BY MOMENTS A = .0255 B = .1750E+03 LOG(M) = .7553 M = .2128E+01

NO MAXIMUM LIKELIHOOD SOLUTION FOR LOG PEARSON III

RETURN PERIOD	GUMBEL I			LOGNORMAL			THREE PARAMETER LOGNORMAL			LOG PEARSON III MAX. LIKELIHOOD			MOMENTS	
	FLOOD ESTIMATE	S.E. PERCENT	UCL	FLOOD ESTIMATE	LCL	S.E. PERCENT	UCL	FLOOD ESTIMATE	LCL	S.E. PERCENT	FLOOD ESTIMATE	S.E. PERCENT	FLOOD ESTIMATE	S.E. PERCENT
1.050	108.1			105.3				117.5			.0		106.9	
1.100	120.3			117.8				123.0			.0		118.7	
1.250	140.5			139.2				134.7			.0		138.9	
2.000	183.3	7.9	219.9	184.9	155.4	8.2	206.3	170.8	141.4	8.9	.0	.0	183.3	8.8
5.000	241.0	9.2	300.6	245.6	200.7	9.5	332.2	245.2	181.0	14.3	.0	.0	244.9	9.9
10.000	279.1	10.2	360.2	285.0	225.5	11.0	471.8	311.7	206.0	19.6	.0	.0	286.4	12.0
20.000	315.7	11.0	420.4	322.2	246.9	12.6	663.5	389.2	228.3	25.2	.0	.0	326.8	15.0
25.000	327.3	11.3	440.1	333.9	253.3	13.0	738.3	416.7	235.2	27.0	.0	.0	339.7	16.1
50.000	363.1	11.9	502.3	369.9	272.4	14.4	1019.4	510.9	256.1	32.6	.0	.0	380.0	19.8
100.000	398.5	12.5	566.4	405.5	290.3	15.8	1387.0	619.4	276.6	38.0	.0	.0	421.0	23.9
200.000	433.9	13.0	632.7	441.1	307.6	17.0	1860.5	743.6	297.2	43.3	.0	.0	462.8	28.2
500.000	480.6	13.5	724.1	488.5	329.6	18.6	2688.0	934.6	325.0	49.8	.0	.0	519.9	34.1
1000.000	515.8	13.9	796.3	524.7	345.8	19.7	3500.9	1101.6	346.6	54.5	.0	.0	564.7	38.7

GUMBEL I DISTRIBUTION

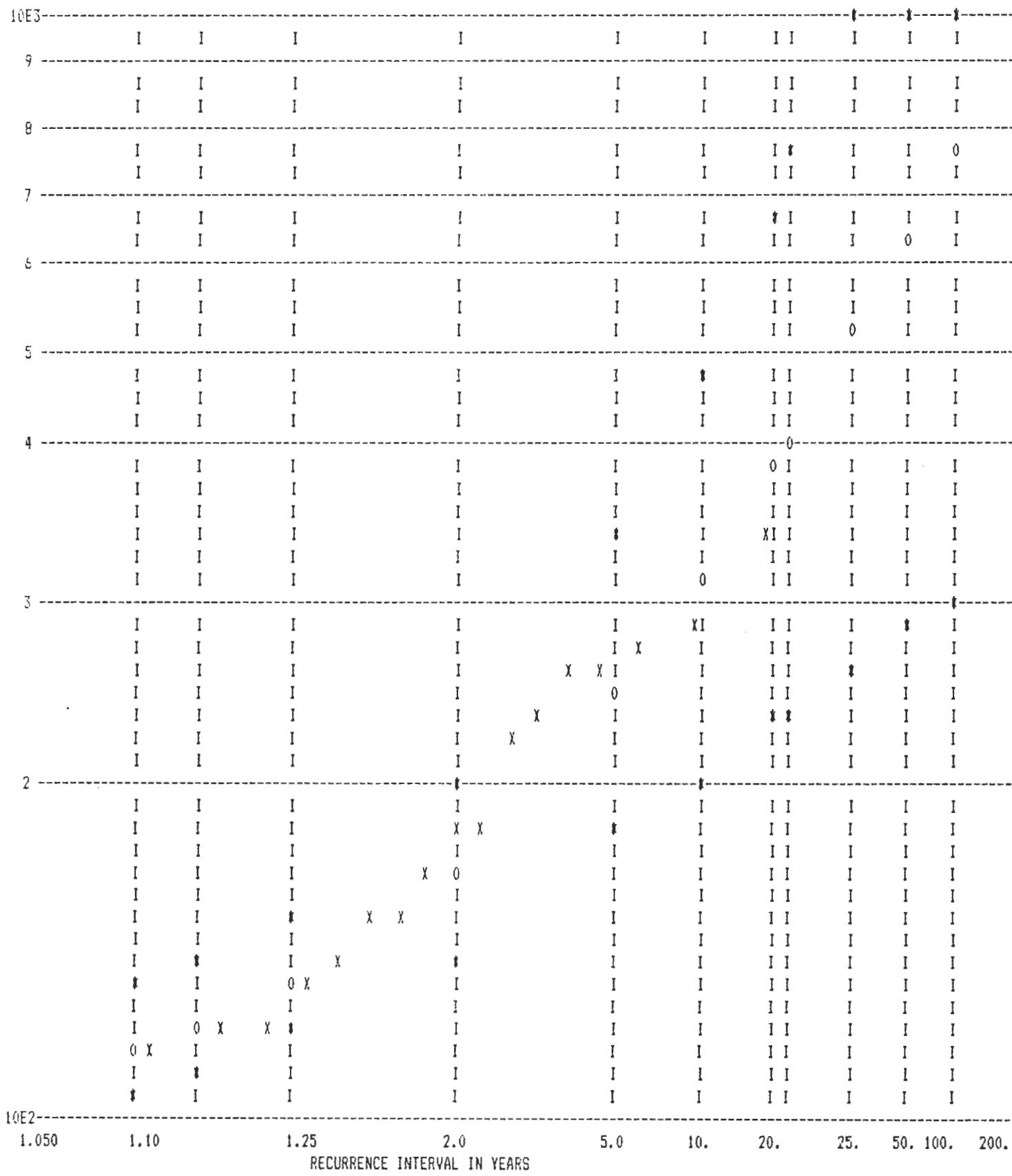
HARRY'S RIVER MAX DAILY FLOWS O.W.



X--OBSERVED DATA

0--ESTIMATED DATA

HARRY'S RIVER MAX DAILY FLOWS Q.W.
 3 PARAMETER LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL
 PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD



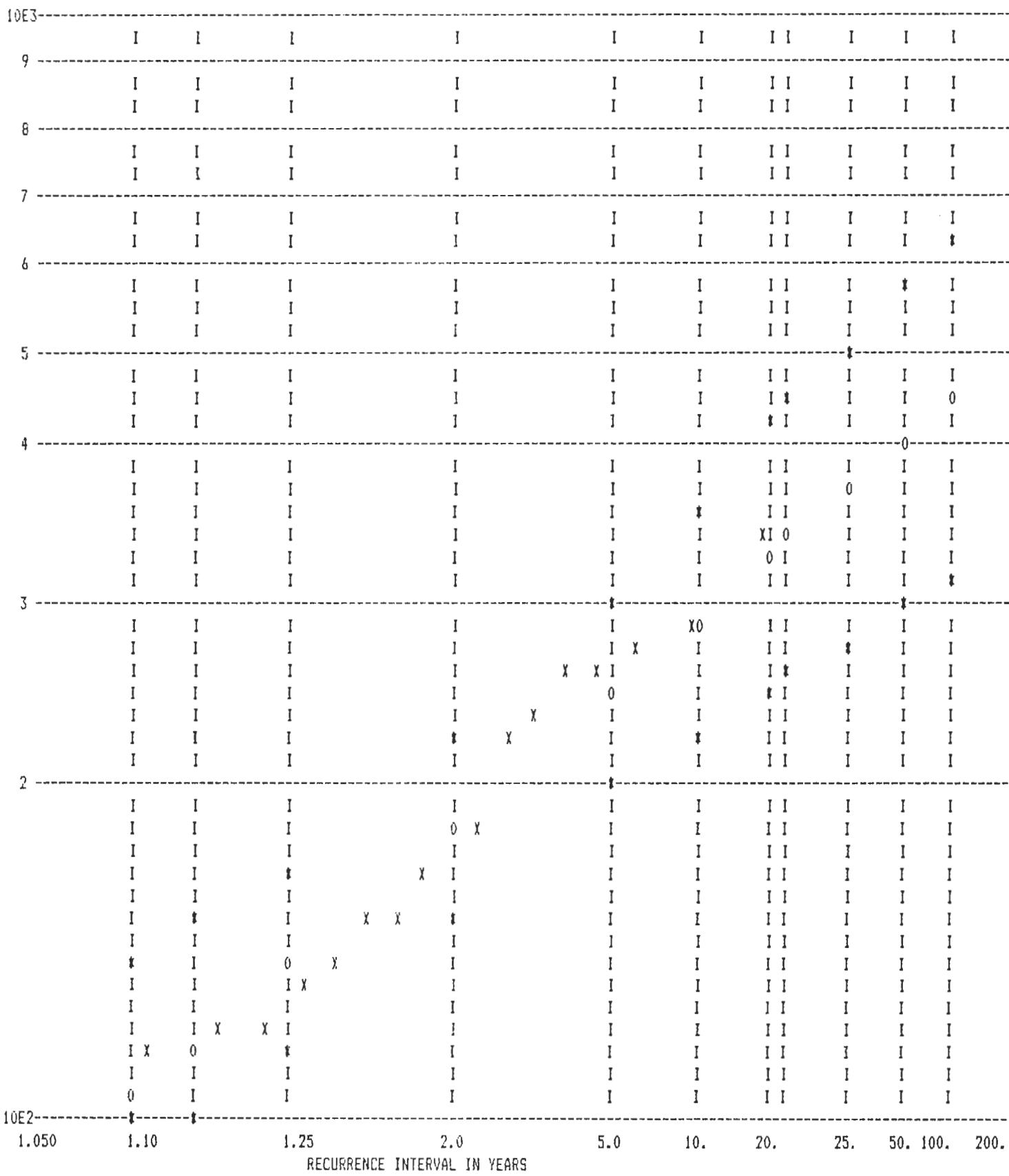
X--OBSERVED DATA

I--ESTIMATED DATA

\$-- 95% CONFIDENCE LIMITS

RECURRENCE INTERVAL IN YEARS

HARRY'S RIVER MAX DAILY FLOWS Q.W.
LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL



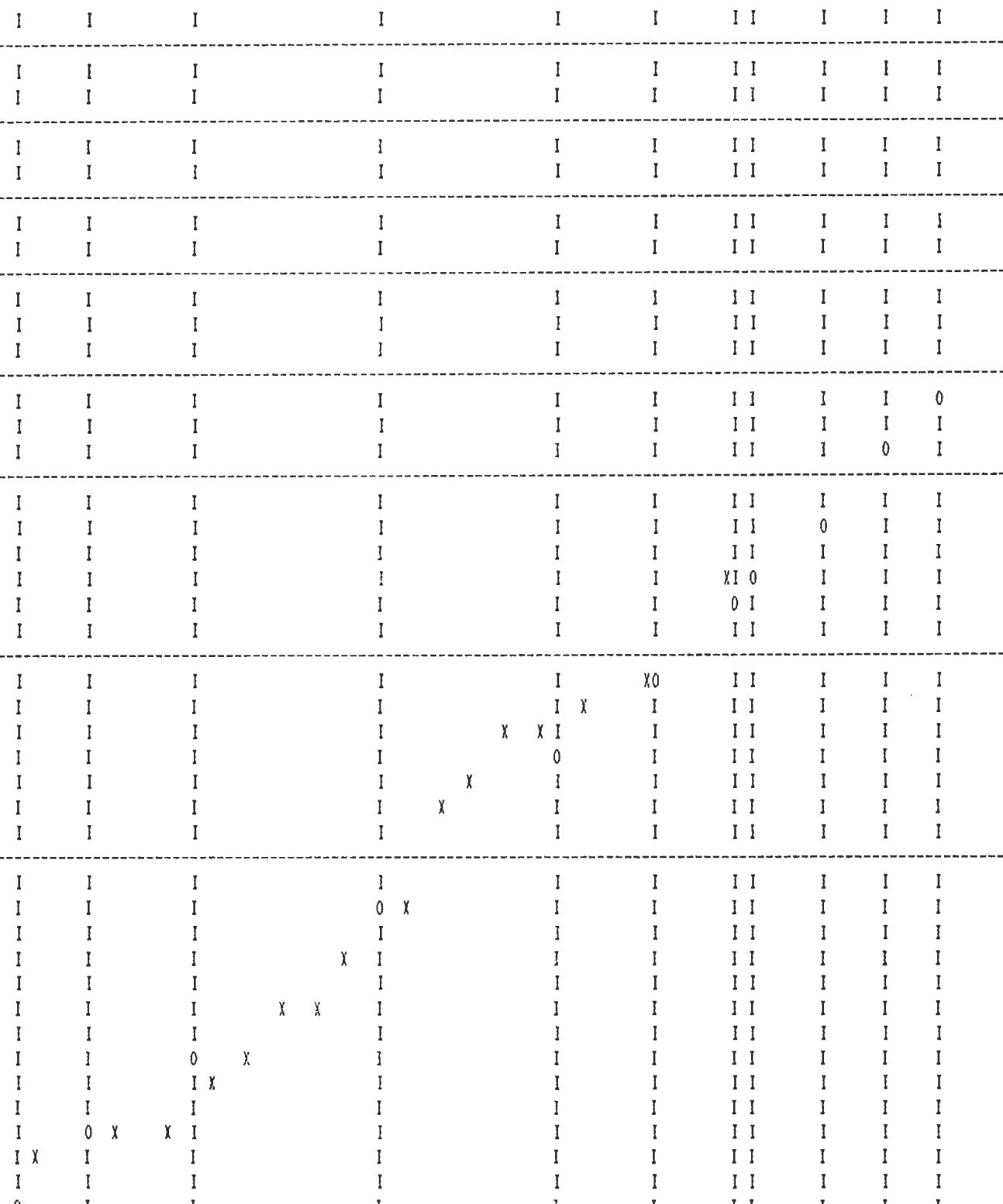
X--OBSERVED DATA

O--ESTIMATED DATA

*-- 95% CONFIDENCE LIMITS

HARRY'S RIVER MAX DAILY FLOWS D.W.
 PARAMETERS ESTIMATED BY MOMENTS
 LOG PEARSON TYPE III DISTRIBUTION

10E3



X--OBSERVED DATA

O--ESTIMATED DATA

I-- 95% CONFIDENCE LIMITS

HARRY'S RIVER MAX INST FLOWS D.W.

YEAR	DATA	ORDERED	RANK	PROB.	RET. PERIOD
1969	436.	688.	1	.057	15.000
1970	281.	442.	2	.133	7.500
1971	183.	436.	3	.200	5.000
1973	688.	430.	4	.267	3.750
1974	326.	402.	5	.333	3.000
1975	430.	379.	6	.400	2.500
1976	379.	340.	7	.467	2.143
1978	340.	326.	8	.533	1.875
1979	244.	281.	9	.600	1.667
1980	442.	281.	10	.667	1.500
1981	187.	244.	11	.733	1.364
1982	281.	208.	12	.800	1.250
1984	208.	187.	13	.867	1.154
1985	402.	183.	14	.933	1.071

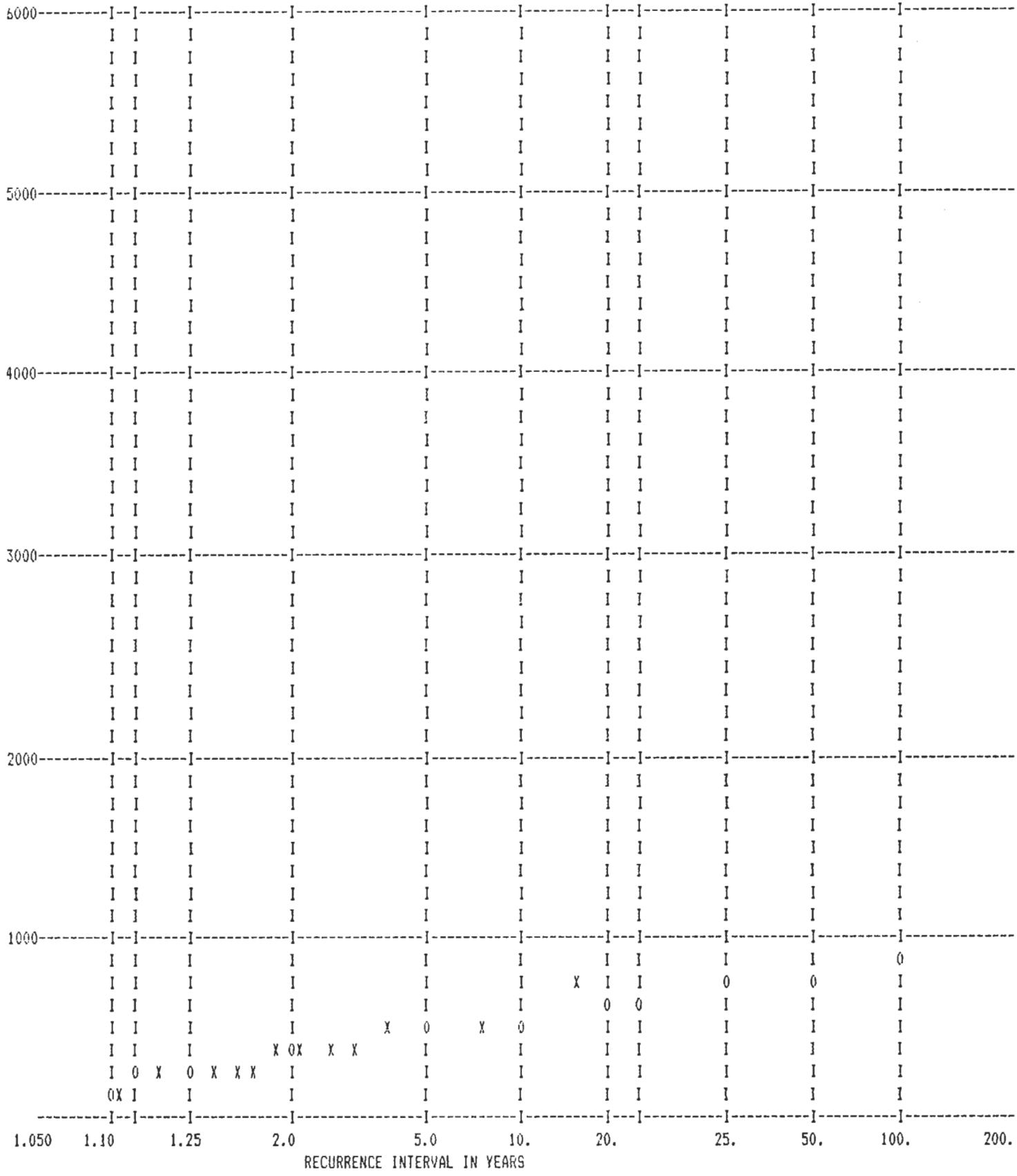
HARRY'S RIVER MAX INST FLOWS D.W.

SAMPLE STATISTICS
 MEAN = 345. S.D. = 134.7 C.S. = 1.1277 C.K. = 5.9146
 SAMPLE STATISTICS (LOGS)
 MEAN = 5.7763 S.D. = .3773 C.S. = .1275 C.K. = 3.5779
 SAMPLE MIN = 183. SAMPLE MAX = 688. N = 14
 PARAMETERS FOR GUMBEL I A = .010066 U = 286.
 PARAMETERS FOR LOGNORMAL M = 5.7763 S = .3773
 PARAMETERS FOR THREE PARAMETER LOGNORMAL A = B6. M = 5.4317 S = .5291
 STATISTICS OF LOG(X-A)
 MEAN = 5.4317 S.D. = .5291 C.S. = -.1663 C.K. = 3.3500
 PARAMETERS FOR LOG PEARSON III BY MOMENTS A = .0241 B = .2459E+03 LOG(M) = -.1405 M = .8689E+00
 NO MAXIMUM LIKELIHOOD SOLUTION FOR LOG PEARSON III

RETURN PERIOD	GUMBEL I			LOGNORMAL			THREE PARAMETER LOGNORMAL			LOG PEARSON III					
	FLOOD ESTIMATE	S.E. PERCENT	UCL ESTIMATE	FLOOD ESTIMATE	LCL	S.E. PERCENT	UCL	FLOOD ESTIMATE	LCL	S.E. PERCENT	FLOOD ESTIMATE	S.E. PERCENT	LOG(M)	M	MOMENTS
1.050	175.5			171.9				180.3			.0			174.4	
1.100	199.2			194.9				198.6			.0			196.2	
1.250	238.8			234.8				232.2			.0			234.3	
2.000	322.5	9.7	401.1	322.6	259.4	10.1	397.9	314.3	248.3	10.9	.0	.0		320.0	10.9
5.000	435.1	11.0	570.9	443.1	343.9	11.7	589.3	442.5	332.3	13.3	.0	.0		442.0	12.2
10.000	509.7	12.0	702.0	523.2	389.9	13.6	765.4	536.0	375.4	16.5	.0	.0		525.7	14.7
20.000	581.2	12.9	838.2	600.1	429.6	15.5	979.4	631.5	407.2	20.3	.0	.0		608.2	18.2
25.000	603.9	13.2	883.3	624.5	441.6	16.0	1057.3	662.9	415.7	21.6	.0	.0		634.8	19.6
50.000	673.8	13.9	1028.2	700.2	476.9	17.8	1329.7	763.3	438.2	25.7	.0	.0		718.4	24.1
100.000	743.1	14.4	1180.4	776.1	510.2	19.4	1652.9	868.4	456.3	29.8	.0	.0		804.0	29.0
200.000	812.2	14.9	1340.8	852.7	542.2	21.0	2033.6	978.9	471.2	33.9	.0	.0		892.2	34.1
500.000	903.4	15.5	1566.2	955.7	583.2	22.9	2637.5	1133.7	487.3	39.1	.0	.0		1013.6	41.3
1000.000	972.3	15.8	1747.4	1035.3	613.4	24.2	3181.0	1258.1	497.6	42.9	.0	.0		1109.4	46.8

GUMBEL I DISTRIBUTION

HARRY'S RIVER MAX INST FLOWS D.W.

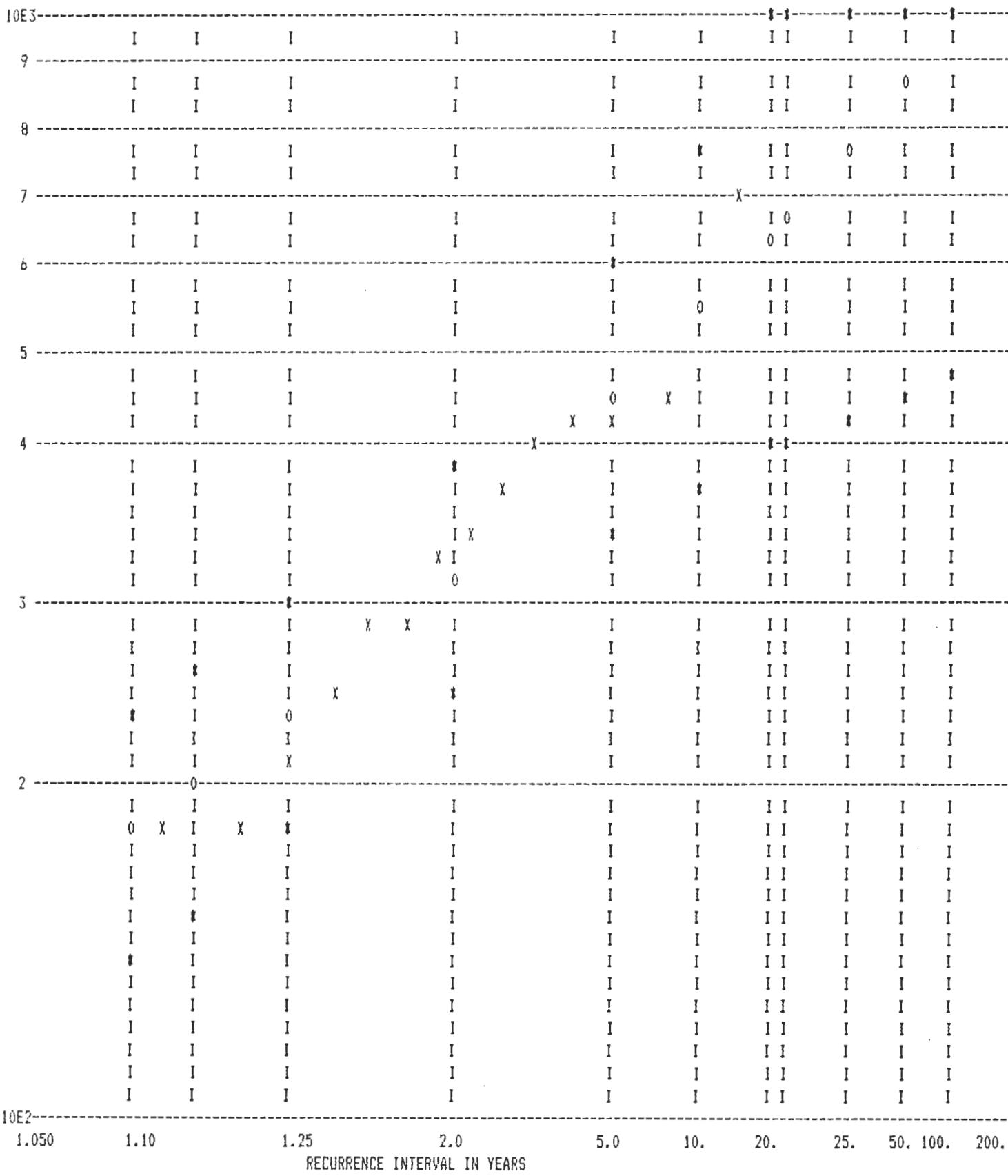


X--OBSERVED DATA

0--ESTIMATED DATA

HARRY'S RIVER MAX INST FLOWS Q.W.

3 PARAMETER LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL
 PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD



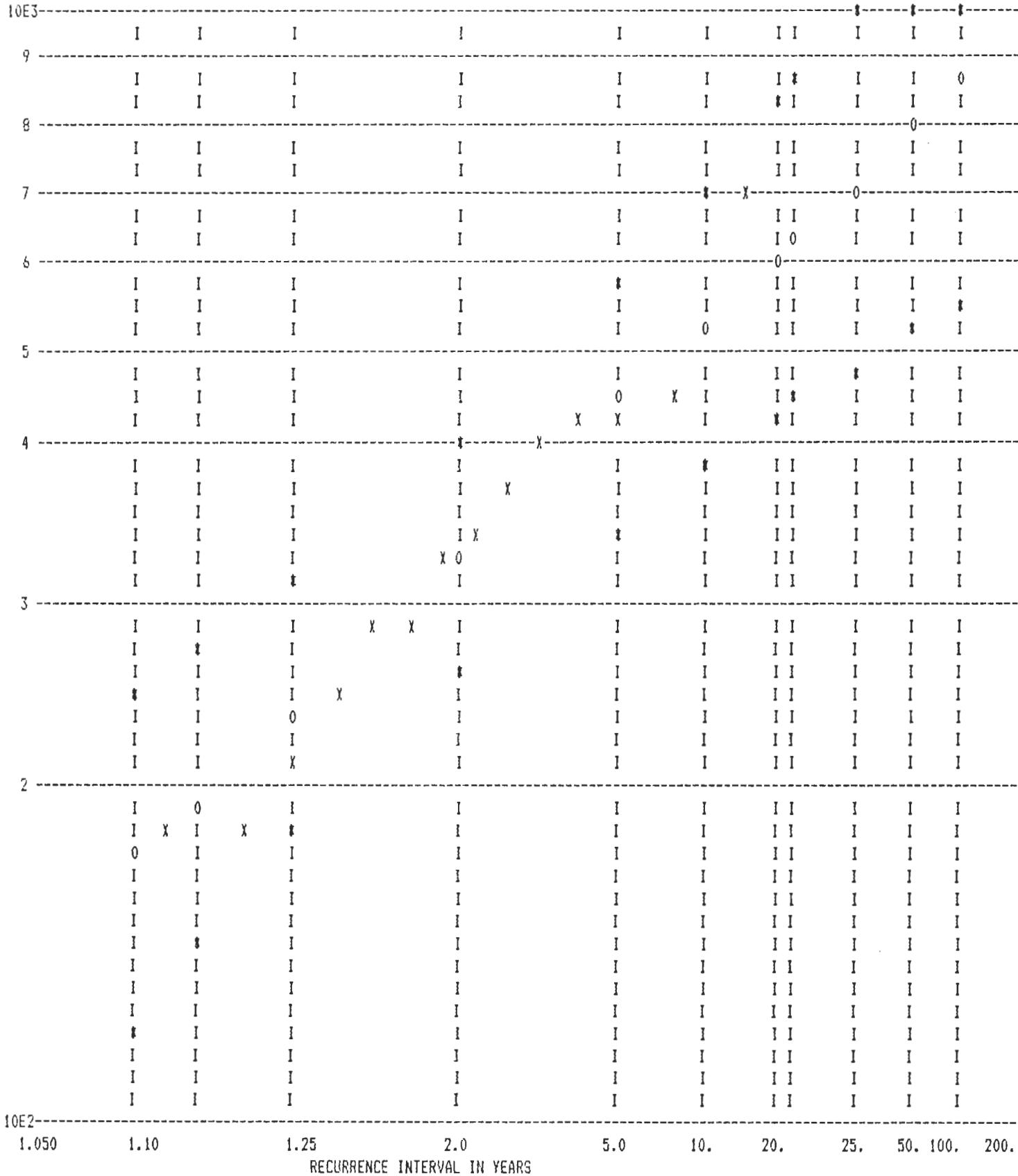
X--OBSERVED DATA

0--ESTIMATED DATA

\$-- 95% CONFIDENCE LIMITS

RECURRENCE INTERVAL IN YEARS

HARRY'S RIVER MAX INST FLOWS Q.W.
LOG-NORMAL DISTRIBUTION-WITH 95 PCT CL

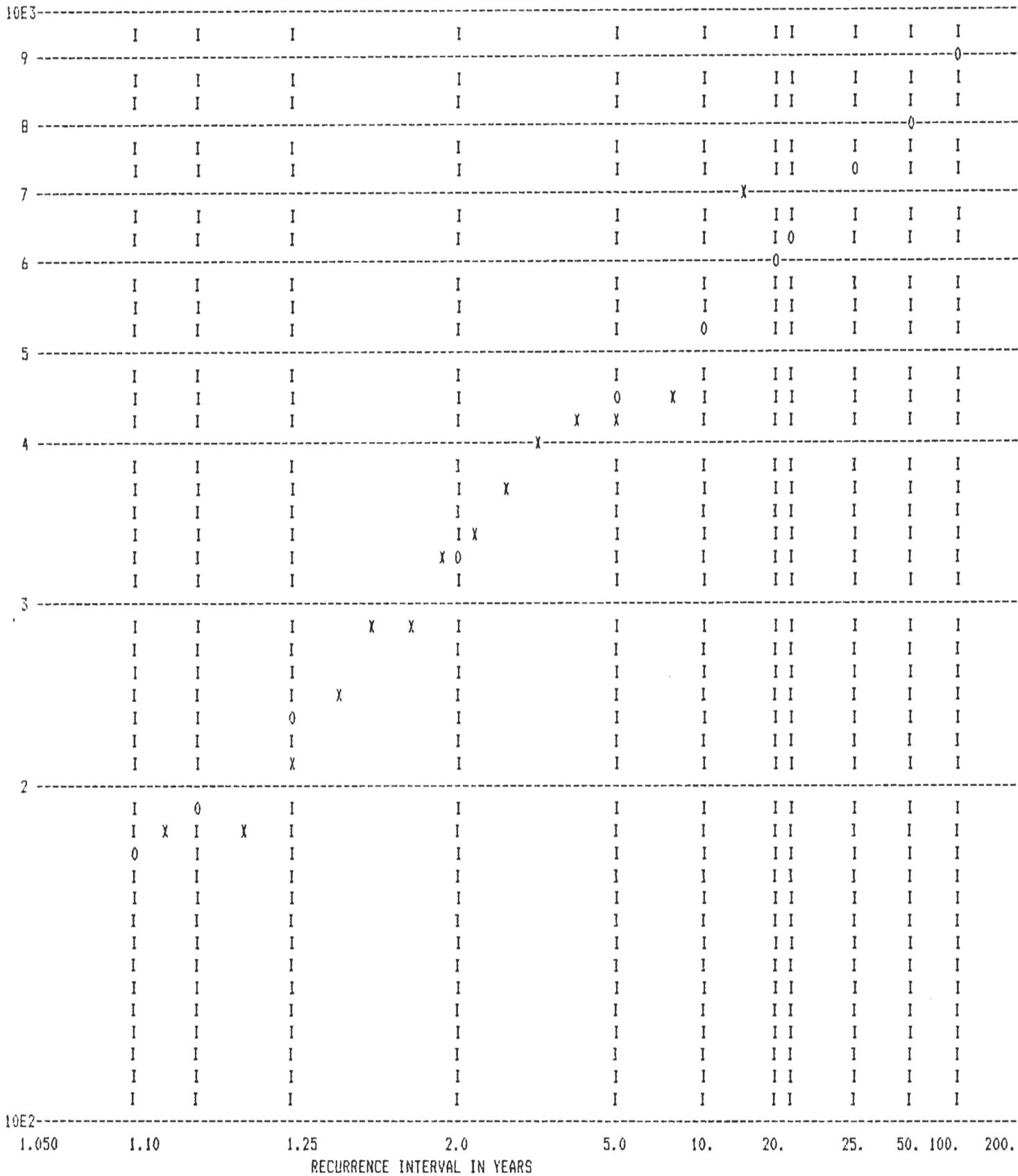


X--OBSERVED DATA

0--ESTIMATED DATA

I-- 95% CONFIDENCE LIMITS

HARRY'S RIVER MAX INST FLOWS D.W.
 PARAMETERS ESTIMATED BY MOMENTS
 LOG PEARSON TYPE III DISTRIBUTION



X--OBSERVED DATA

O--ESTIMATED DATA

*-- 95% CONFIDENCE LIMITS

RECCURENCE INTERVAL IN YEARS

APPENDIX D
HEC-2 MODEL SENSITIVITY TESTING

APPENDIX D

SENSITIVITY TESTING OF HEC-2 BACKWATER MODEL

D.1 - Introduction

In order to assess the effect of variations in the magnitude of various input parameters for HEC-2 on flood profiles for Harry's River, a sensitivity analysis was undertaken.

The following parameters were tested in the sensitivity analysis of the HEC-2 model:

- channel and floodplain roughness coefficients;
- peak discharges calculated;
- distance between surveyed cross sections;
- expansion and contraction coefficients

The following sections outline the methodology and results of the sensitivity testing of the HEC-2 model.

D.2 - Sensitivity to Variations in Channel and Floodplain Roughness Coefficients

The sensitivity of the HEC-2 model to variations in the channel and floodplain roughness coefficients (Manning's n) was tested to evaluate the accuracy of the calibrated HEC-2 model.

A 20% range of Manning's n values about the calibrated value was applied in the sensitivity analysis. This range corresponds to the range of potential values as described by Chow (7) for a channel with similar characteristics as Harry's River. The sensitivity analysis was completed for +20% and -20% changes in the roughness coefficients for both the calibrated flow of 32.1 m^3/s at the gauge and the computed 1:100 year flow of 868 m^3/s at the gauge. In the high flow case, the floodplain roughness

coefficients were also varied along with the channel coefficients since there is flow in the overbanks.

The results of the sensitivity analysis are found in Tables D.1 and D.2. It was found that, for average flows, a -20% and +20% change in the roughness coefficients along the study reach resulted in an average difference in water levels along the study reach of -0.06 m and +0.05 m respectively. The corresponding range of differences were found to be 0.0 m to 0.10 m and 0.0 m to 0.09 m respectively. For very high flows, the average difference in water levels for a -20% and +20% change in the channel and floodplain roughness coefficients was -0.04 m and +0.03 m respectively. The corresponding range of differences were found to be +0.13 m to -0.29 m and -0.24 m to +0.17 m.

On the basis of these tests it was concluded that there is some variation in water levels along the study reach with changes in the roughness coefficients. These variations are more pronounced at higher flows where there is inundation of water over the floodplains. In the high flow case, the range of variation in water levels was found to be greater, although the average differences in water levels was found to be comparable with the differences observed for lower flows. However, it was concluded that the calibrated model is sufficiently accurate for this application and that variations in the roughness coefficients would not significantly affect final results.

D.3 - Sensitivity to Computed Peak Discharge

A sensitivity analysis was conducted using the computed 1:20 and 1:100 year flood flows estimated in Section 6 (from Single Station Frequency Analysis) and the corresponding flows at the -95% and +95% confidence levels. The results are presented in Tables D.3 and D.4.

As can be seen the peak discharge does affect the water levels.

For the 1:20 year flood flow ($632 \text{ m}^3/\text{s}$ at the gauge), the calculated water levels for the -95% confidence level flow ($407 \text{ m}^3/\text{s}$) averaged about 0.7 m lower. The peak flow at the +95% confidence level ($979 \text{ m}^3/\text{s}$) resulted in an increase of about 1 m in water levels compared with those calculated for the 1:20 year flood flow. For the 1:100 year flood peak ($868 \text{ m}^3/\text{s}$ at the gauge), the average differences were found to be -1.2 m for the -95% confidence level flow ($457 \text{ m}^3/\text{s}$) and +2.0 m for the +95% confidence level flow ($1653 \text{ m}^3/\text{s}$). In both cases the largest differences were found to be in the area upstream of the bridge while the smaller differences were noted in the steeper reaches.

D.4 - Sensitivity to Interpolated Sections

The sensitivity of the HEC-2 model to the distance between modeled sections was tested using the provision for the HEC-2 model to compute internally interpolated sections, depending on the maximum allowable velocity head calculated.

The maximum allowable velocity head was chosen on the basis of a review of preliminary runs at both average and high flows. The change in velocity head between consecutive sections was noted for each case, with the smallest value chosen for the sensitivity testing to ensure that interpolated sections were inserted by the HEC-2 model. Based on these reviews, the maximum allowable change in velocity head was set at 0.01 m. The HEC-2 model was then run for both the calibration flow ($32.1 \text{ m}^3/\text{s}$ at the gauge) and the computed 1:100 year flood flow.

The results of these runs are given in Tables D.5 and D.6. As can be seen in Tables D.5 and D.6, the use of interpolated sections makes minimal difference to the water levels at the calibrated flow. Differences are noted in the order of 0.0 m to 0.05 m. At high flows, the differences are greater in some cases (0.36 m) but overall the water surface profile is approximately the same. It is concluded that the cross sections

as input to the model are accurate and interpolated sections do not have to be used.

D.5 - Sensitivity to Variations in Expansion and Contraction Coefficients

The sensitivity of the model to variations in changes in the expansion and contraction coefficients was also tested. A range of 0.1 to 0.6 for the contraction coefficient and 0.3 to 1.0 for the expansion coefficient was tested. In all cases, the results showed no change in the calculated water levels for both low and high flows. From these results it was concluded that the HEC-2 model is insensitive to changes in the contraction and expansion coefficients for this application. Final values of 0.1 and 0.3 were chosen for the contraction and expansion coefficients respectively, which are the values recommended for a river with gradual changes in cross section geometry.

TABLE D.1

MANNING'S n SENSITIVITY
CALIBRATION FLOW (32.1 m³/s AT GAUGE)

<u>Sta</u>	<u>n</u>	<u>Water elev (m)</u>	<u>Sensitivity Testing</u>		
			Water elev (m) (-20% n)	Water elev (m) (+20% n)	
5742 - 5382	.025	33.23 - 31.82	33.18 - 31.85	33.28 - 31.81	
5329 - 5060	.025	31.58 - 31.31	31.50 - 31.27	31.64 - 31.35	
4935 - 4883	.050	30.80 - 30.49	30.75 - 30.45	30.84 - 30.52	
4773	.040	29.94	29.90	29.96	
4712	.040	29.74	29.66	29.80	
4677 - 4367	.030	29.50 - 28.99	29.40 - 28.94	29.59 - 29.03	
4323 - 4227	.045	28.79 - 28.34	28.74 - 28.29	28.84 - 28.39	
4171 - 3232	.025	28.16 - 24.63	28.13 - 24.58	28.19 - 24.68	
3102	.030	24.20	24.15	24.26	
2917 - 2492	.030	23.57 - 22.43	23.49 - 22.36	23.64 - 22.47	
2332 - 1756	.025	21.97 - 20.36	21.92 - 20.33	22.01 - 20.40	
1591 - 1347	.025	19.86 - 19.00	19.78 - 18.95	19.93 - 19.05	
1254	.030	18.53	18.44	18.60	
1152	.025	18.16	18.10	18.22	
972 - 204	.025	17.66 - 15.42	17.56 - 15.42	17.73 - 15.42	

TABLE D.2

MANNING'S n SENSITIVITY
1:100 YEAR FLOOD FLOW (868.0 m³/S AT GAUGE)

<u>Sta</u>	<u>Calibration</u>				<u>Sensitivity Testing</u>		
	<u>CHn</u>	<u>LOBn</u>	<u>ROBn</u>	<u>Water el (m)</u>	<u>Water elev (m)</u> (-20% n)	<u>(+20% n)</u>	
5742 - 5382	.025	.10	.10	35.47 - 35.54	35.46 - 35.62	35.46 - 35.72	
5329 - 5060	.025	.08	.10	35.30 - 35.36	35.47 - 35.44	35.53 - 35.50	
4935 - 4883	.050	.08	.10	35.39 - 35.38	35.48 - 35.47	35.56 - 35.53	
4773	.040	.08	.10	35.30	35.40	35.47	
4712	.040	.10	.10	35.18	35.21	35.25	
4677 - 4367	.030	.10	.10	33.27 - 31.38	35.40 - 31.20	35.35 - 31.30	
4323 - 4227	.045	.10	.10	31.31 - 31.05	31.17 - 30.88	31.27 - 30.97	
4171 - 3232	.025	.10	.10	30.75 - 26.97	30.64 - 27.04	30.68 - 27.03	
3102	.030	.10	.10	26.48	26.34	26.54	
2917 - 2492	.030	.05	.10	26.33 - 25.39	26.63 - 25.25	26.63 - 25.33	
2332 - 1756	.025	.08	.10	24.90 - 23.34	24.79 - 23.16	24.72 - 23.16	
1591 - 1347	.025	.07	.10	22.51 - 21.09	22.34 - 21.45	22.32 - 21.39	
1254	.030	.07	.10	21.22	21.03	21.20	
1152	.025	.07	.10	20.78	20.61	20.82	
972 - 204	.025	.10	.10	20.38 - 17.56	20.06 - 17.57	20.18 - 17.56	

Note: CHn - Channel "n"
 LOBn - Left Overbank "n"
 ROBn - Right Overbank "n"

TABLE D,3

**SENSITIVITY TO COMPUTED PEAK DISCHARGES
AT WSC GAUGE - 1:20 YR FLOOD PEAK**

HEC-2 WATER LEVELS (m GEODETIC)

STA	-95% C.L. Gauge Flow (407 m ³ /s)	Calculated Gauge Flow (632 m ³ /s)	+95% C.L. Gauge Flow (979 m ³ /s)
5742 - 5382	34.95 - 33.68	35.28 - 34.59	35.64 - 35.95
5329 - 5060	33.41 - 33.11	34.36 - 34.27	35.80 - 35.79
4935 - 4883	33.70 - 33.06	34.29 - 34.27	35.82 - 35.82
4773	32.93	34.18	35.75
4712	32.77	34.03	35.62
4677 - 4367	31.50 - 30.37	32.38 - 30.91	33.67 - 31.59
4323 - 4227	30.29 - 29.87	30.83 - 30.46	31.53 - 31.31
4171 - 3232	29.60 - 26.07	30.19 - 26.50	31.01 - 27.20
3102	25.80	26.02	26.68
2917 - 2492	24.89 - 24.05	25.65 - 24.76	26.58 - 25.67
2332 - 1756	23.64 - 22.03	24.34 - 22.74	25.14 - 23.65
1591 - 1347	21.30 - 20.59	21.88 - 20.56	22.61 - 21.35
1254	20.72	20.80	21.39
1152	19.71	20.40	20.96
972 - 204	19.28 - 16.65	19.81 - 17.13	20.60 - 17.74

TABLE D.4
**SENSITIVITY TO COMPUTED PEAK
DISCHARGES AT WSC GAUGE - 1:100 YR FLOOD PEAK**
HEC-2 WATER LEVELS (m GEODETIC)

STA	-95% C.L. Gauge Flow (456 m ³ /s)	Calculated Gauge Flow (868 m ³ /s)	+95% C.L. Gauge Flow (1653 m ³ /s)
5742 - 5382	35.06 - 33.88	35.50 - 35.57	38.09 - 38.13
5329 - 5060	33.61 - 33.37	35.40 - 35.37	38.00 - 38.03
4935 - 4883	33.37 - 33.34	35.40 - 35.39	38.08 - 38.07
4773	33.22	35.30	38.01
4712	33.06	35.12	37.89
4677 - 4367	31.70 - 30.50	33.27 - 31.40	35.29 - 34.85
4323 - 4227	30.42 - 30.0	31.34 - 30.99	32.79 - 32.73
4171 - 3232	29.73 - 26.16	30.74 - 26.97	32.43 - 28.36
3102	25.83	26.48	27.72
2917 - 2492	25.16 - 24.21	26.60 - 25.44	27.72 - 27.00
2332 - 1956	23.81 - 22.20	24.91 - 23.40	26.37 - 24.95
1591 - 1347	21.43 - 20.76	22.33 - 21.45	23.79 - 22.55
1254	20.93	21.17	22.50
1152	19.79	20.77	22.15
972 - 204	19.40 - 16.76	20.35 - 17.58	21.89 - 18.74

TABLE D.5

**SENSITIVITY TO INTERPOLATED SECTIONS AT
LOW FLOWS (32.1 m³/S AT GAUGE)**

STA	CALIBRATED FLOW (m ³ /s)	CALCULATED FLOW (m ³ /s)	STA	CALIBRATED FLOW (m ³ /s)	CALCULATED FLOW (m ³ /s)
204	15.42	15.42	3645	26.42	26.46
269	15.70	15.65	3717	26.62	26.62
471	15.93	15.88	3827	26.67	26.78
679	17.01	17.08	3904	26.89	26.89
873	17.54	17.49	4011	27.31	27.34
972	17.66	17.68	4085	27.90	27.87
1152	18.16	18.14	4171	28.16	28.13
1254	18.58	18.58	4277	28.34	28.41
1347	19.00	18.99	4323	28.79	28.77
1401	19.30	19.27	4367	28.99	28.96
1521	19.56	19.55	4421	29.16	29.16
1591	19.86	19.89	4495	29.33	29.33
1756	20.36	20.37	4627	29.45	29.45
1950	20.86	20.82	4677	29.50	29.50
2063	21.10	21.11	4712	29.74	29.76
2177	21.47	21.46	4773	29.94	29.94
2332	21.97	21.94	4883	30.49	30.35
2492	22.43	22.42	5935	30.80	30.68
2552	22.63	22.62	5060	31.31	31.24
2642	23.01	23.05	5190	31.47	31.45
2702	23.24	23.24	5329	31.58	31.59
2802	23.38	23.35	5382	31.82	31.84
2917	23.57	23.57	5419	31.99	31.99
3102	24.20	24.22	5562	32.92	32.94
3232	24.60	24.63	5742	33.23	33.23
3373	25.36	25.38			
3488	25.87	25.81			

TABLE D.6**SENSITIVITY TO INTERPOLATED SECTIONS AT
HIGH FLOWS (868 M³/S AT GAUGE)**

STA	CALIBRATED FLOW (m ³ /s)	CALCULATED FLOW (m ³ /s)	STA	CALIBRATED FLOW (m ³ /s)	CALCULATED FLOW (m ³ /s)
204	17.57	17.57	3645	28.37	28.47
269	17.81	17.93	3717	28.69	28.69
471	18.77	18.76	3827	29.30	29.30
679	20.07	19.90	3904	29.93	29.93
873	20.22	20.09	4011	30.42	30.40
972	20.35	20.35	4085	30.41	30.39
1152	20.77	20.76	4171	30.74	30.74
1254	21.17	21.15	4277	31.99	31.14
1347	21.45	21.81	4323	31.34	31.44
1401	21.66	21.67	4367	31.40	31.46
1521	22.39	22.39	4421	31.91	31.47
1591	22.33	22.34	4495	31.40	31.49
1756	23.40	23.26	4627	31.91	31.90
1950	23.63	23.53	4677	33.27	33.25
2063	23.88	23.99	4712	35.12	35.12
2177	24.29	24.27	4773	35.30	35.32
2332	24.91	24.85	4883	35.39	35.40
2492	25.44	25.39	5935	35.40	35.41
2552	25.48	25.46	5060	35.37	35.37
2642	25.55	25.54	5190	35.29	35.29
2702	25.71	25.76	5329	35.40	35.46
2802	25.56	25.56	5382	35.57	35.61
2917	26.60	26.51	5419	35.68	35.74
3102	26.48	26.54	5562	35.24	35.25
3232	26.97	26.97	5742	35.50	35.83
3373	28.19	28.15			
3488	28.16	28.11			

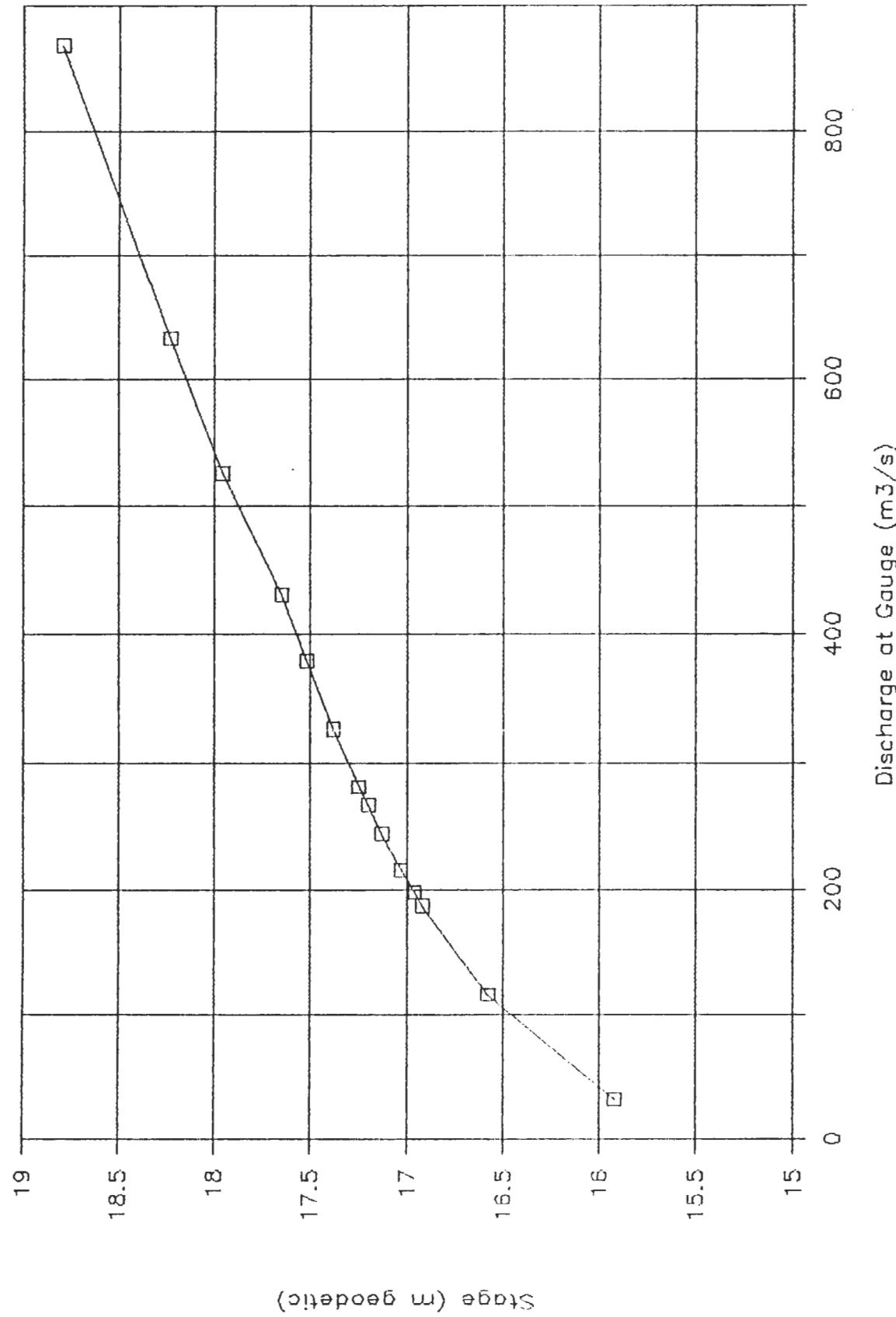
**APPENDIX E
OPEN WATER STAGE DISCHARGE CURVES
HARRY'S RIVER**

APPENDIX E

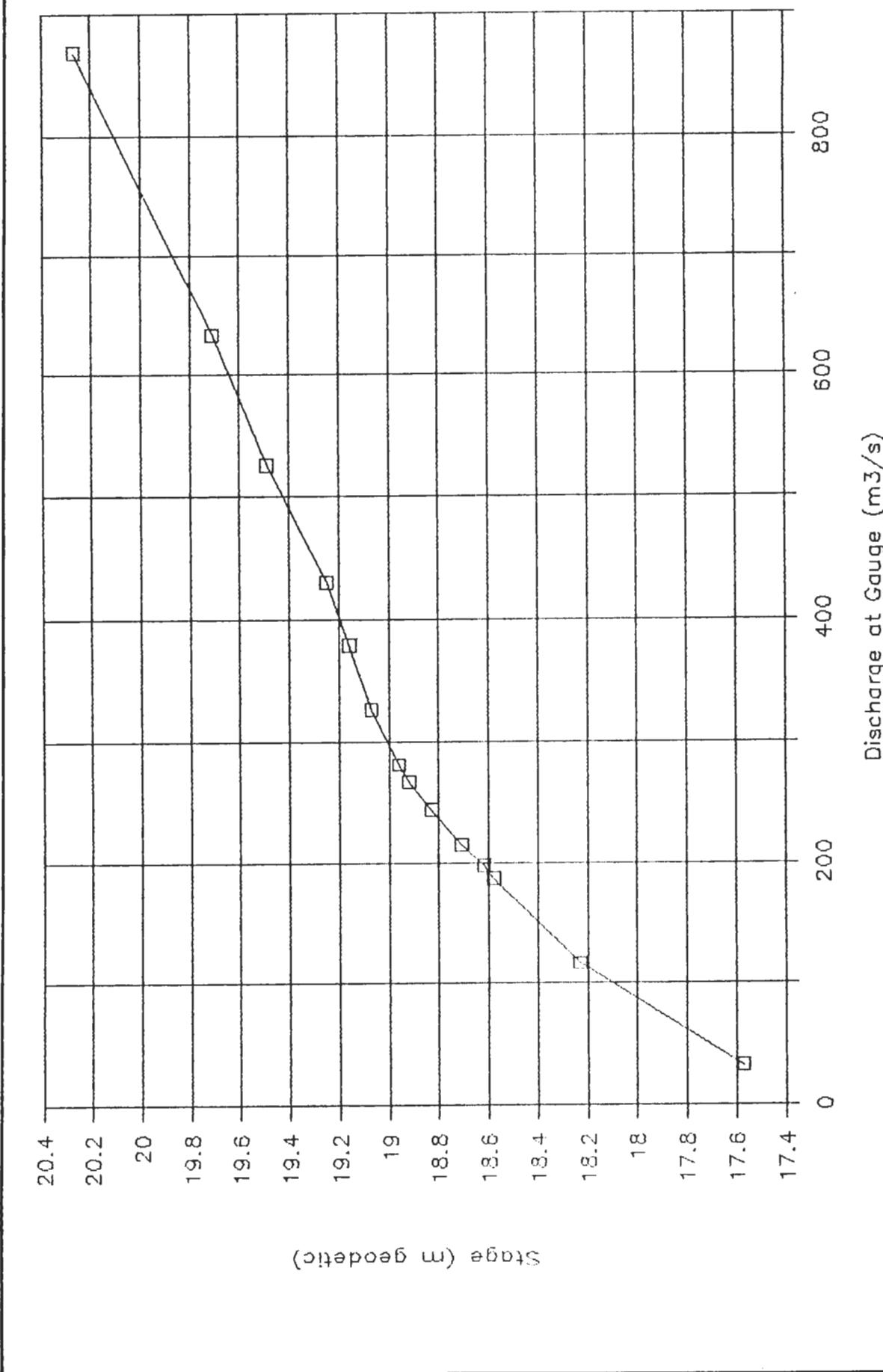
OPEN WATER STAGE DISCHARGE CURVES - HARRY'S RIVER

This appendix presents the open water stage discharge curves for each of the sections used in the frequency analysis. These curves were prepared from the results of the HEC-2 modelling and are used to determine the levels at each section for the maximum annual flows.

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
 STAGE - DISCHARGE CURVE - STA. O + 471

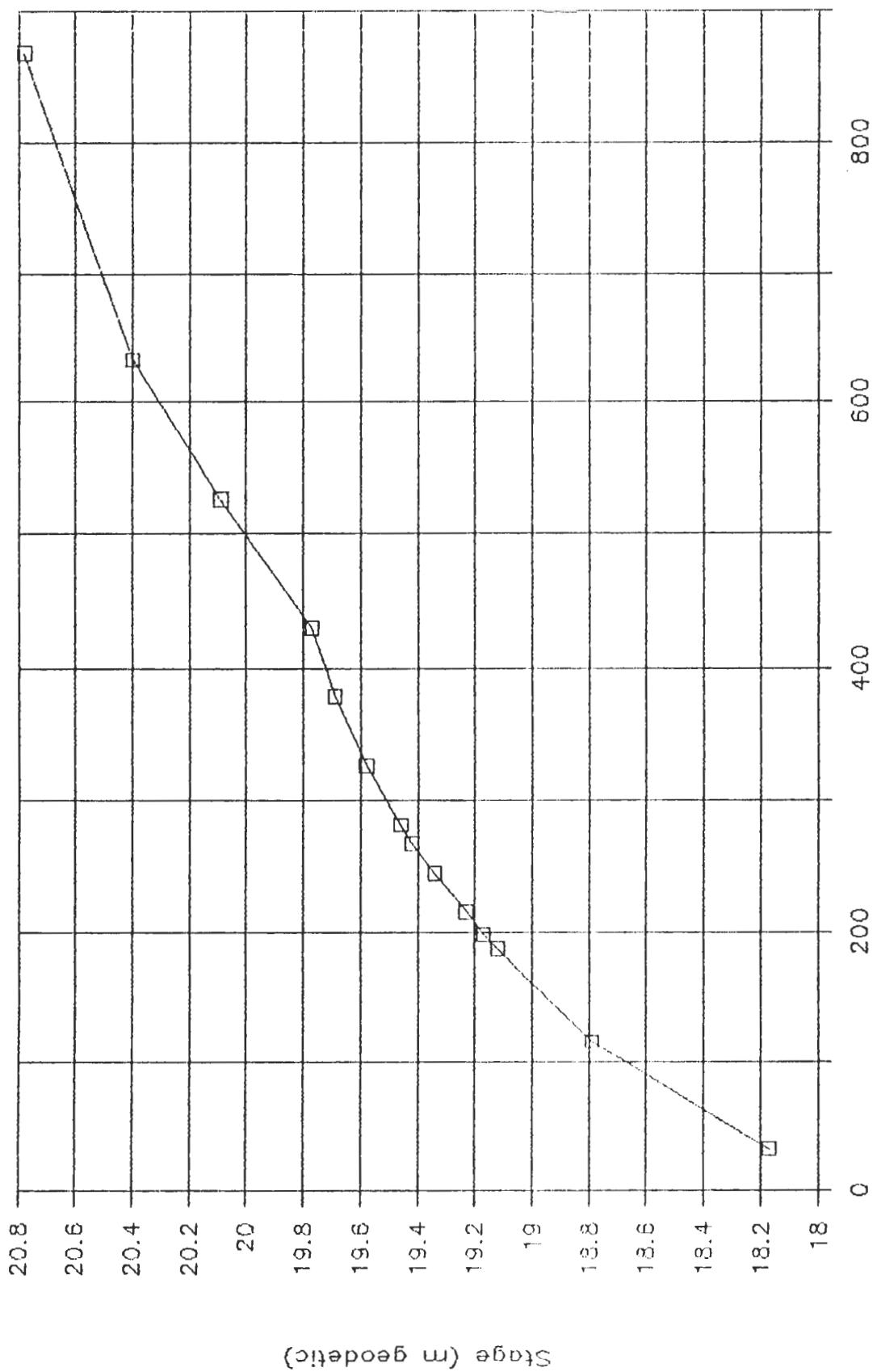


CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
STAGE - DISCHARGE CURVE - STA. O + 873

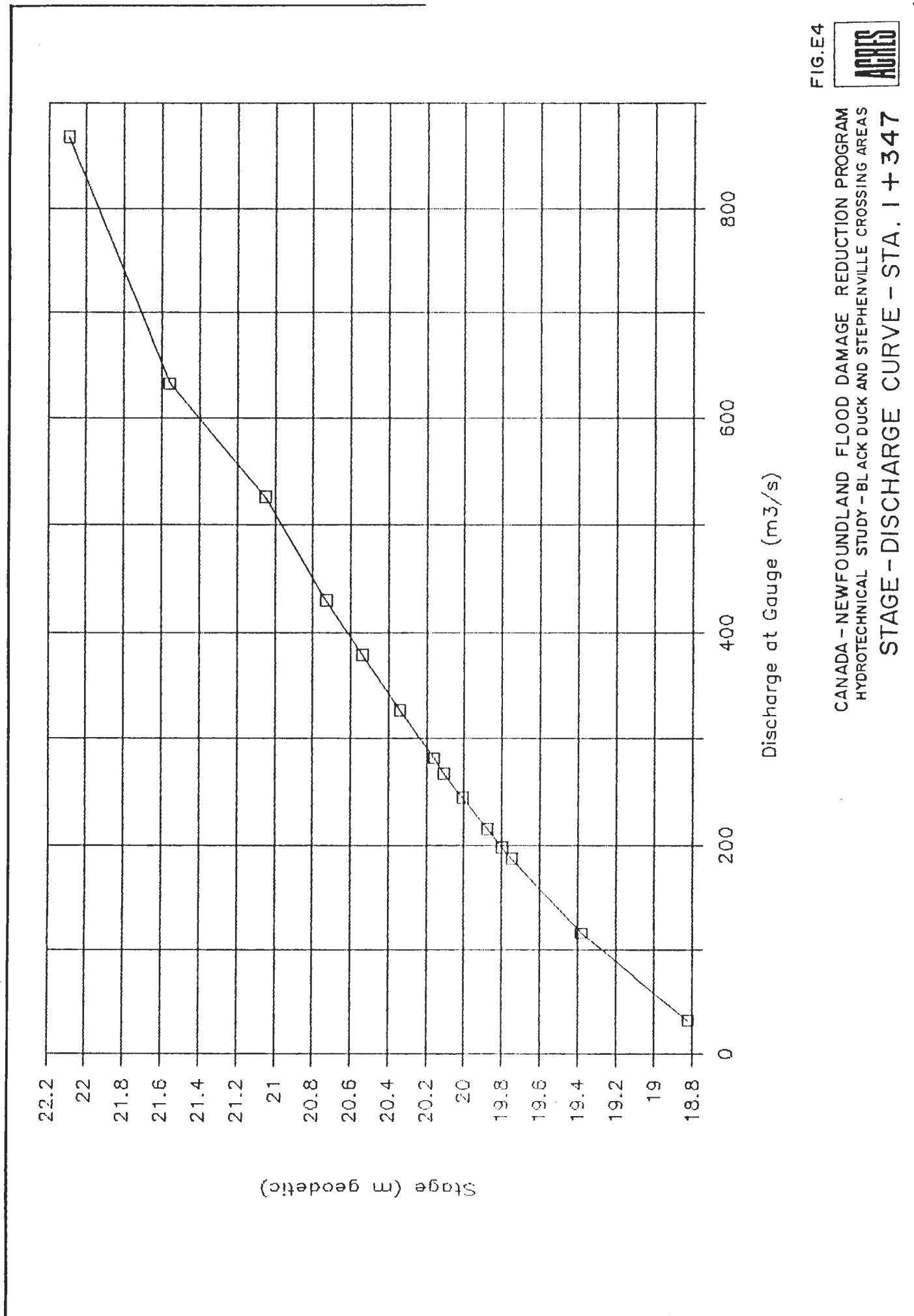


CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
 STAGE - DISCHARGE CURVE - STA. 1 + 152

Discharge at Gauge (m^3/s)



CANADA-NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
 STAGE - DISCHARGE CURVE - STA. I + 347



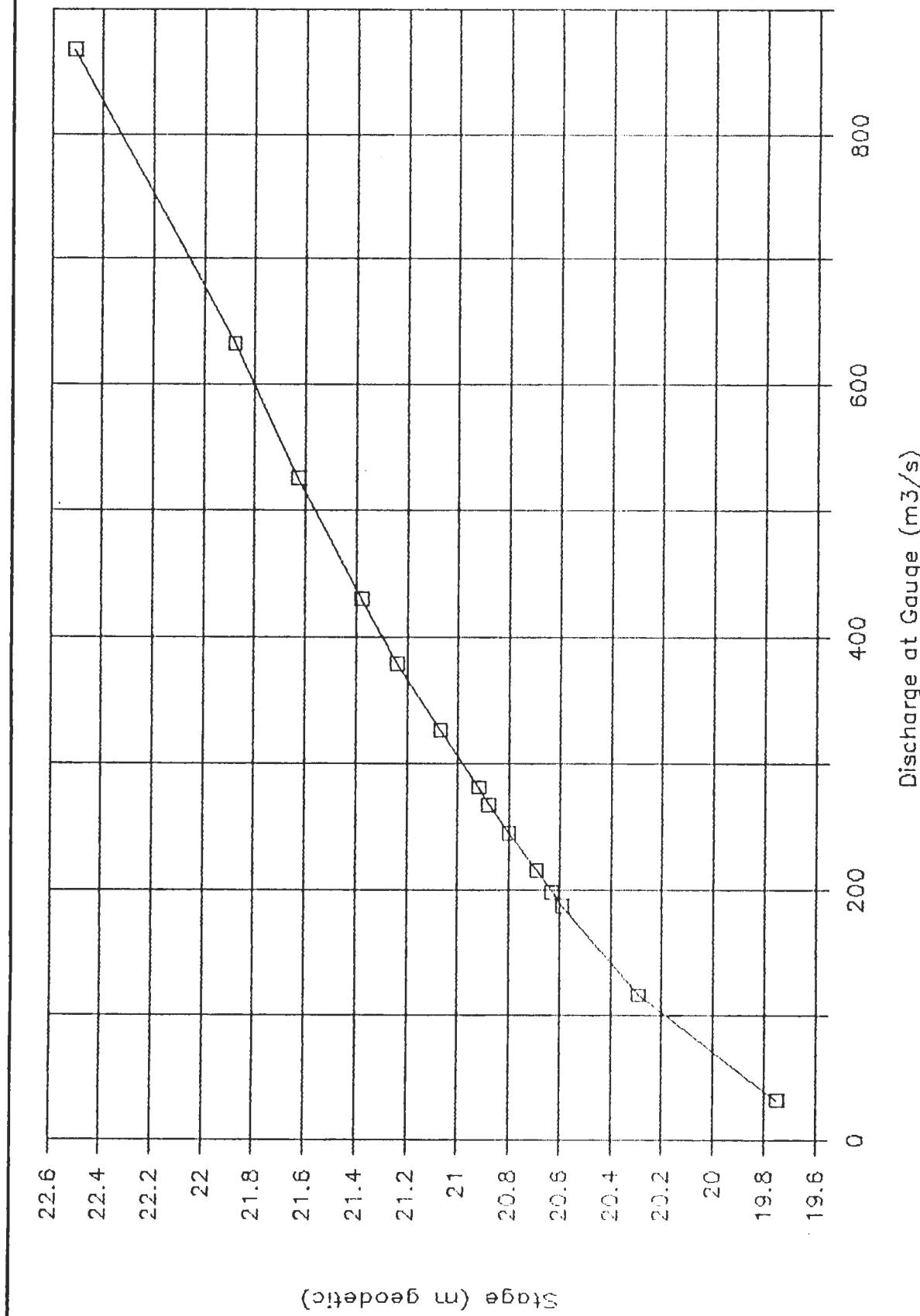
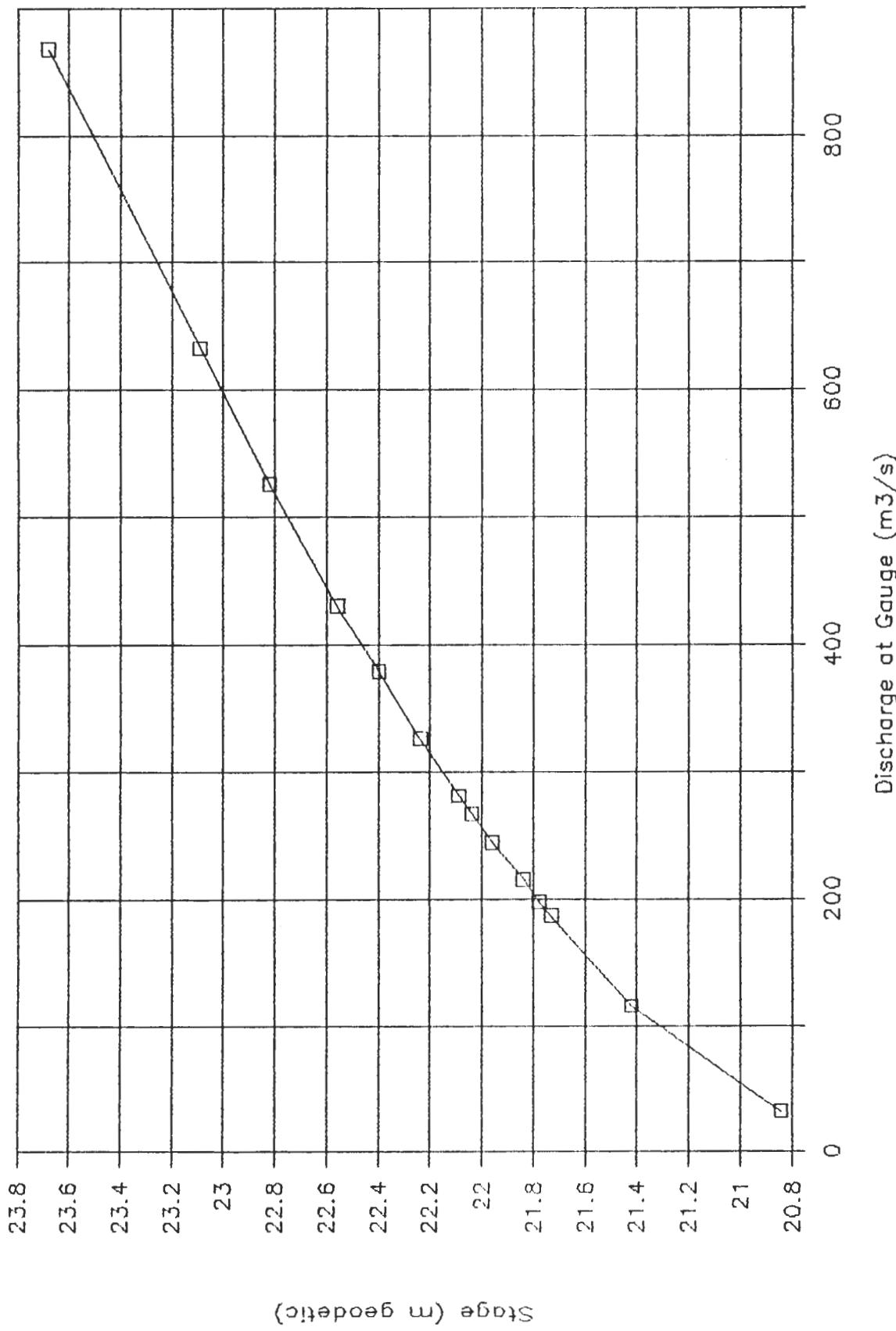


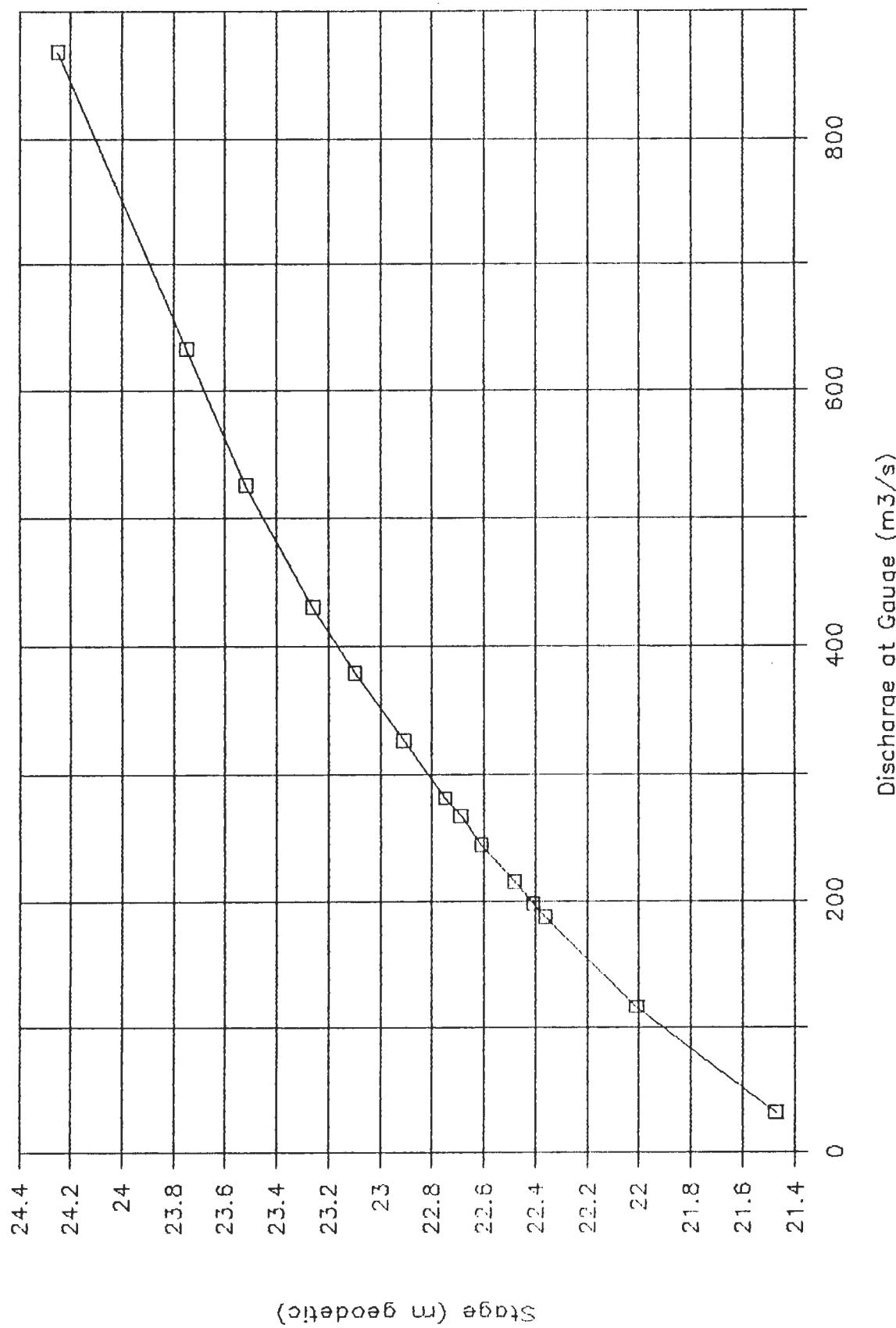
FIG. E5
ACRES

CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
STAGE - DISCHARGE CURVE - STA. I + 591

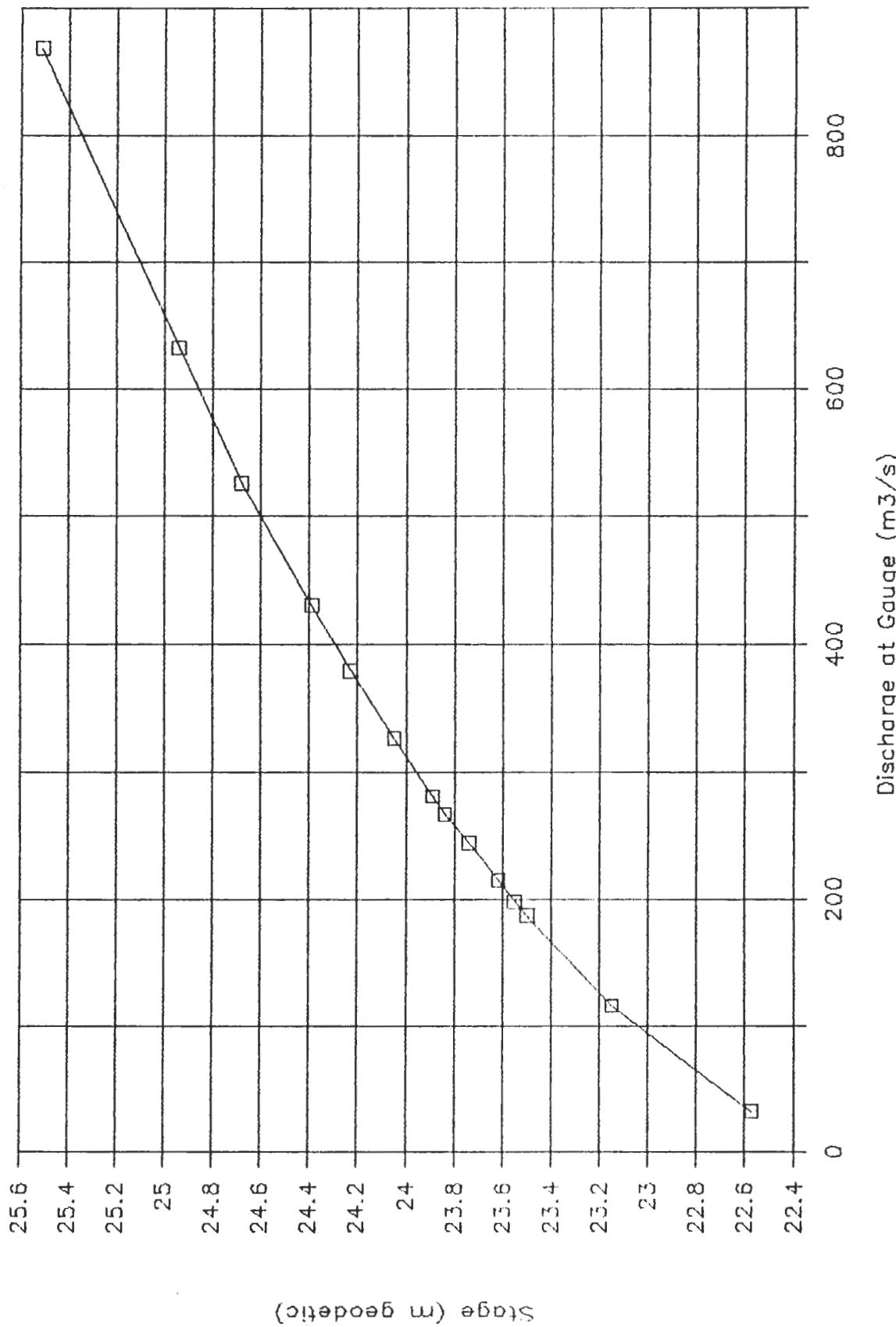
CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
STAGE - DISCHARGE CURVE - STA. 1 + 950



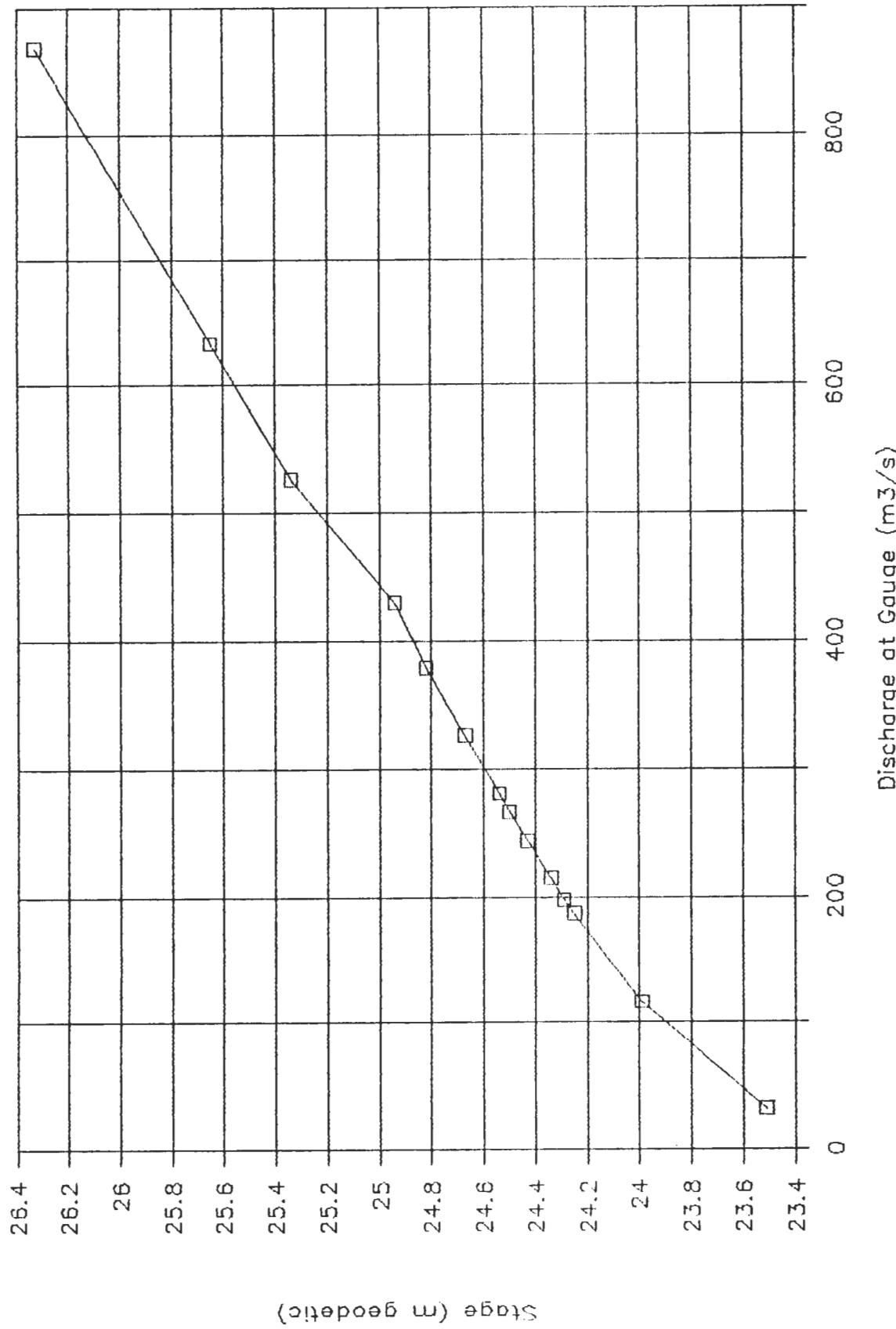
CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
 STAGE - DISCHARGE CURVE - STA. 2 + 177



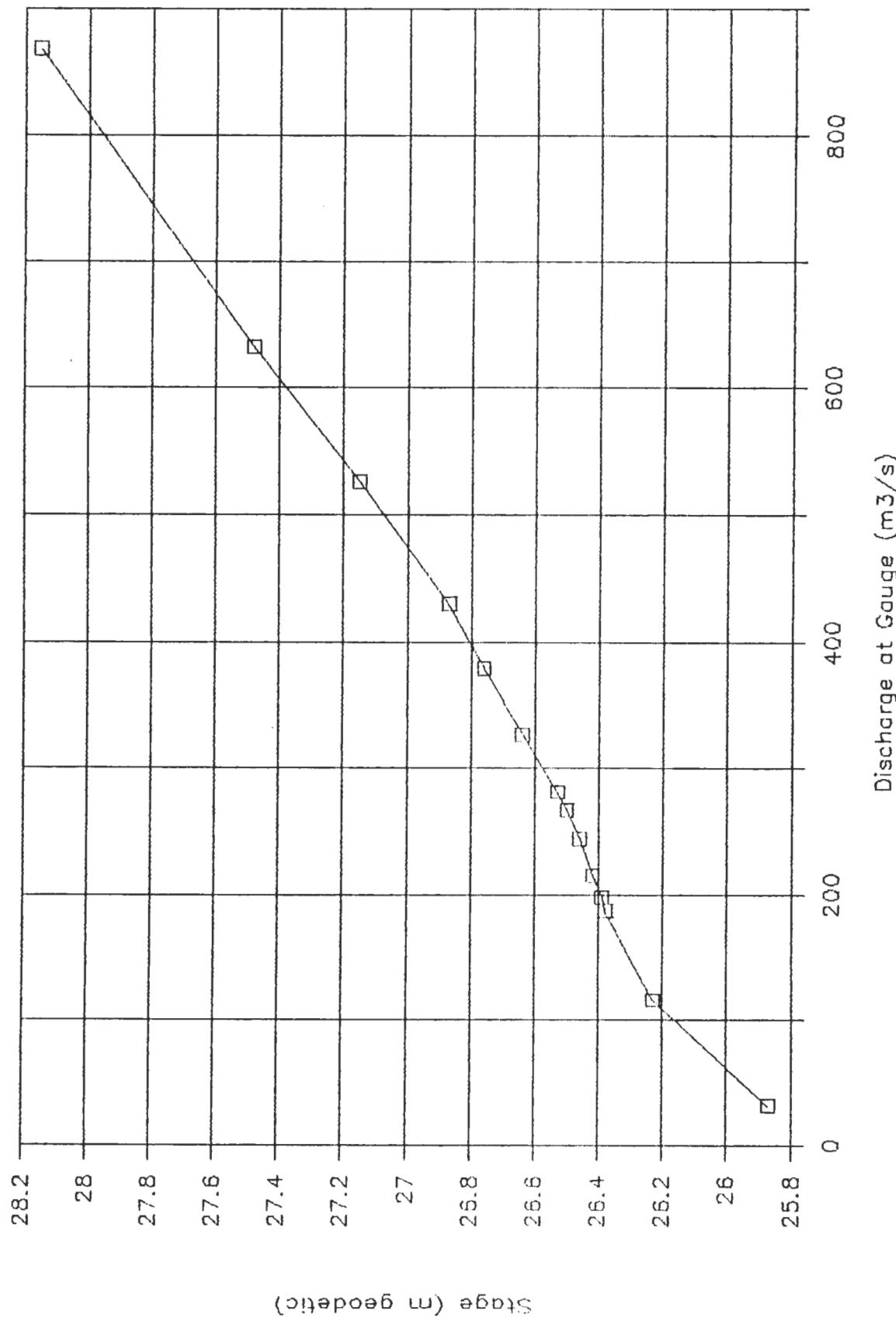
CANADA-NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
STAGE - DISCHARGE CURVE - STA. 2 + 552



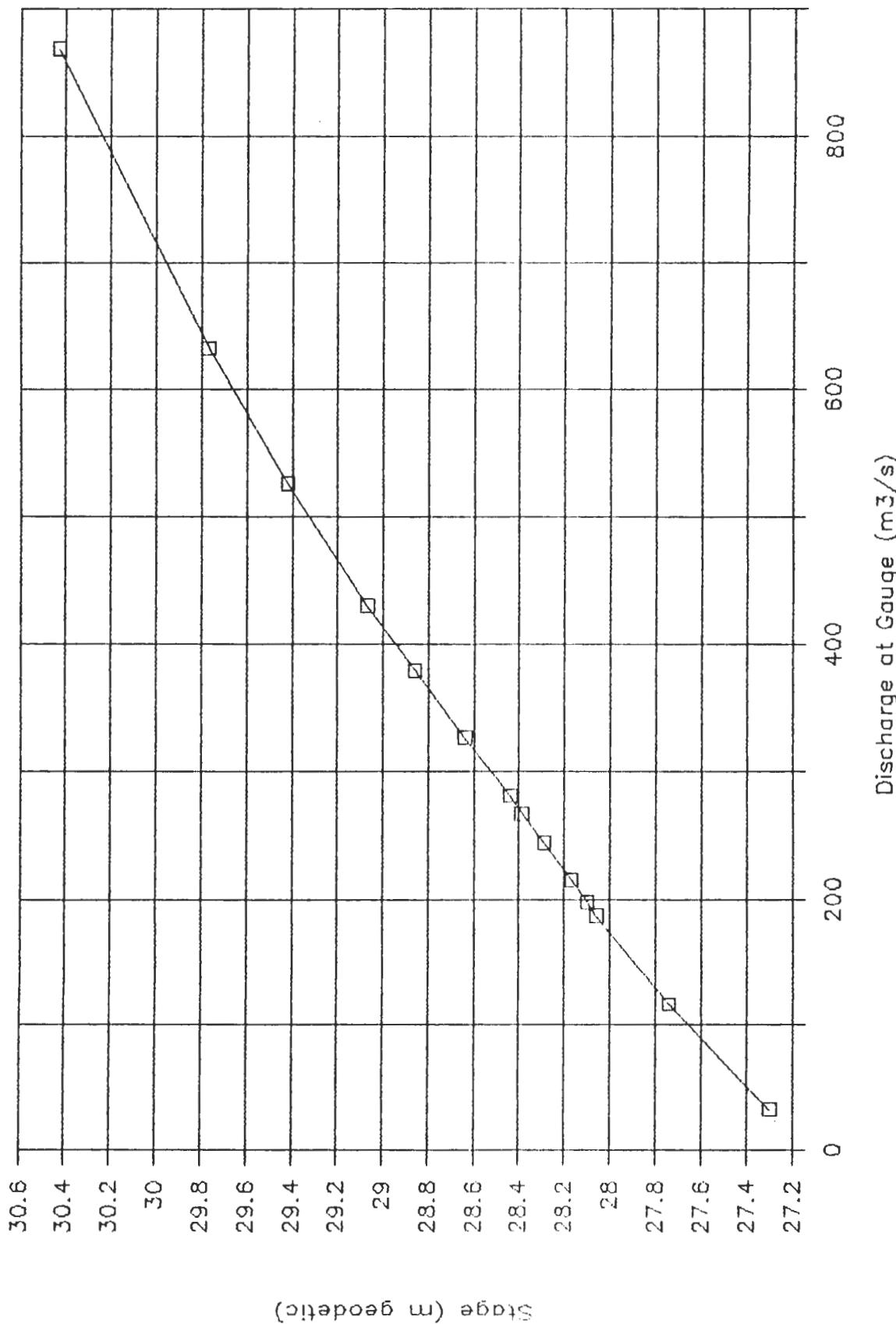
CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
STAGE - DISCHARGE CURVE - STA. 2 + 917



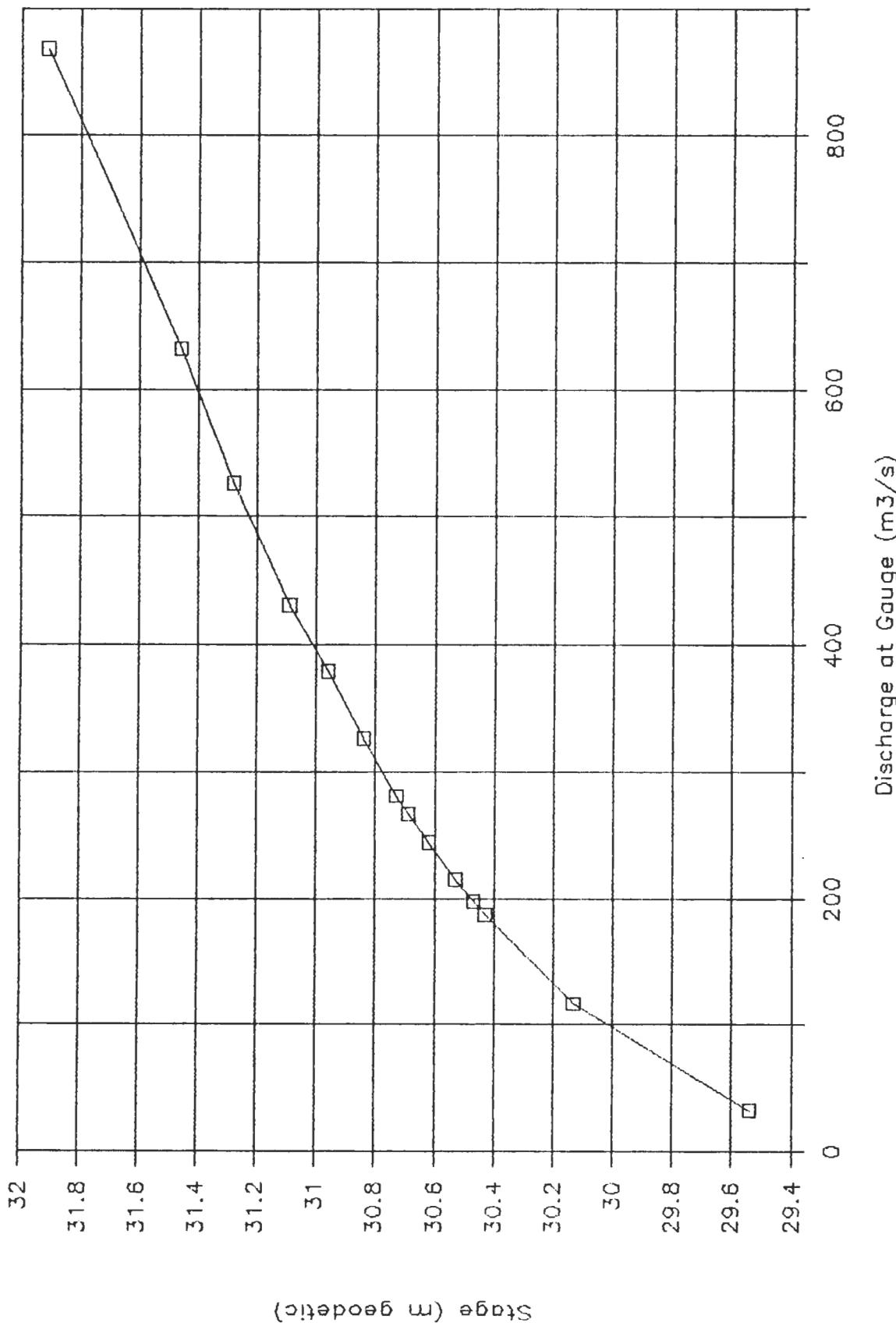
CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
STAGE - DISCHARGE CURVE - STA. 3 + 488



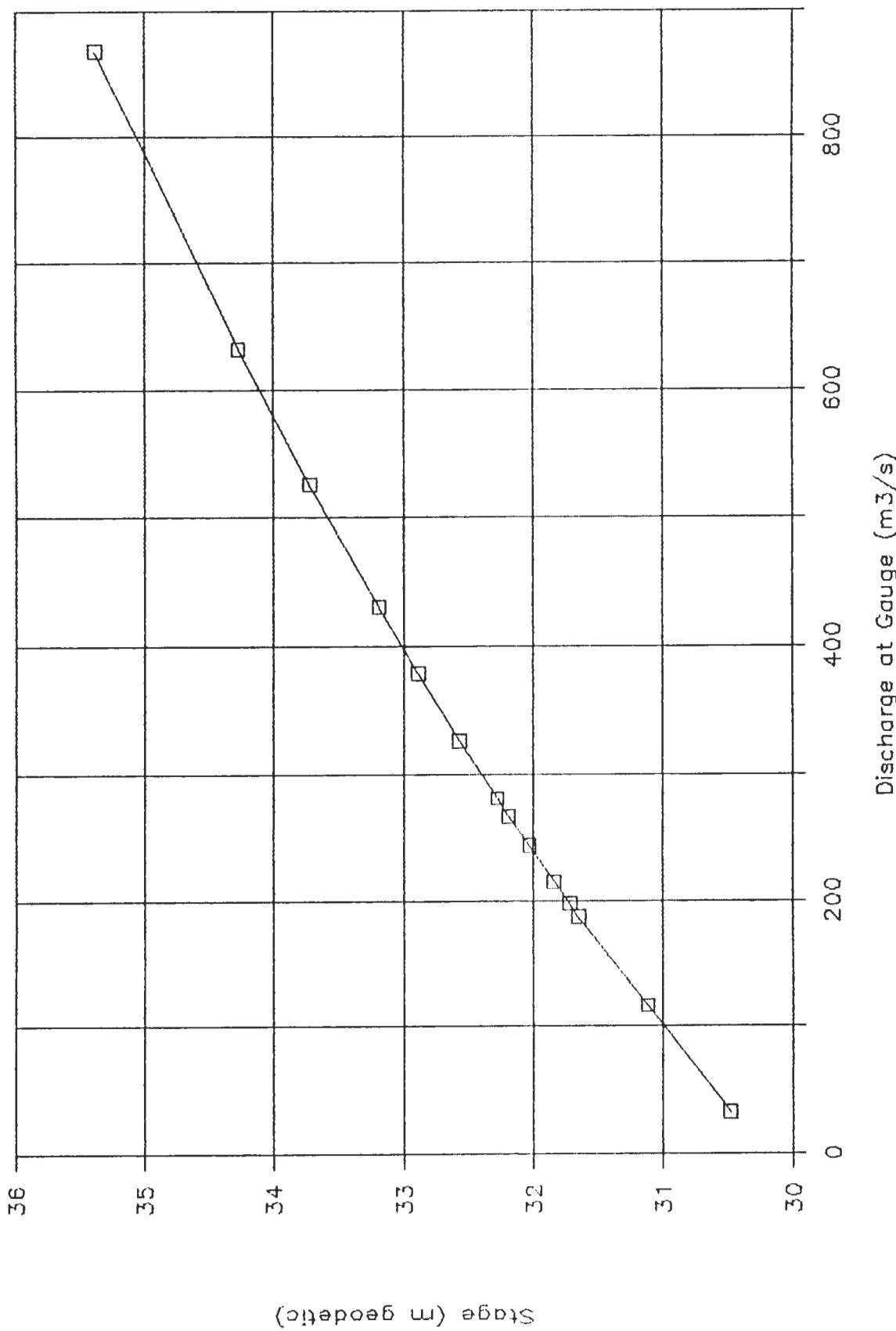
CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
 STAGE - DISCHARGE CURVE - STA. 4 + 011



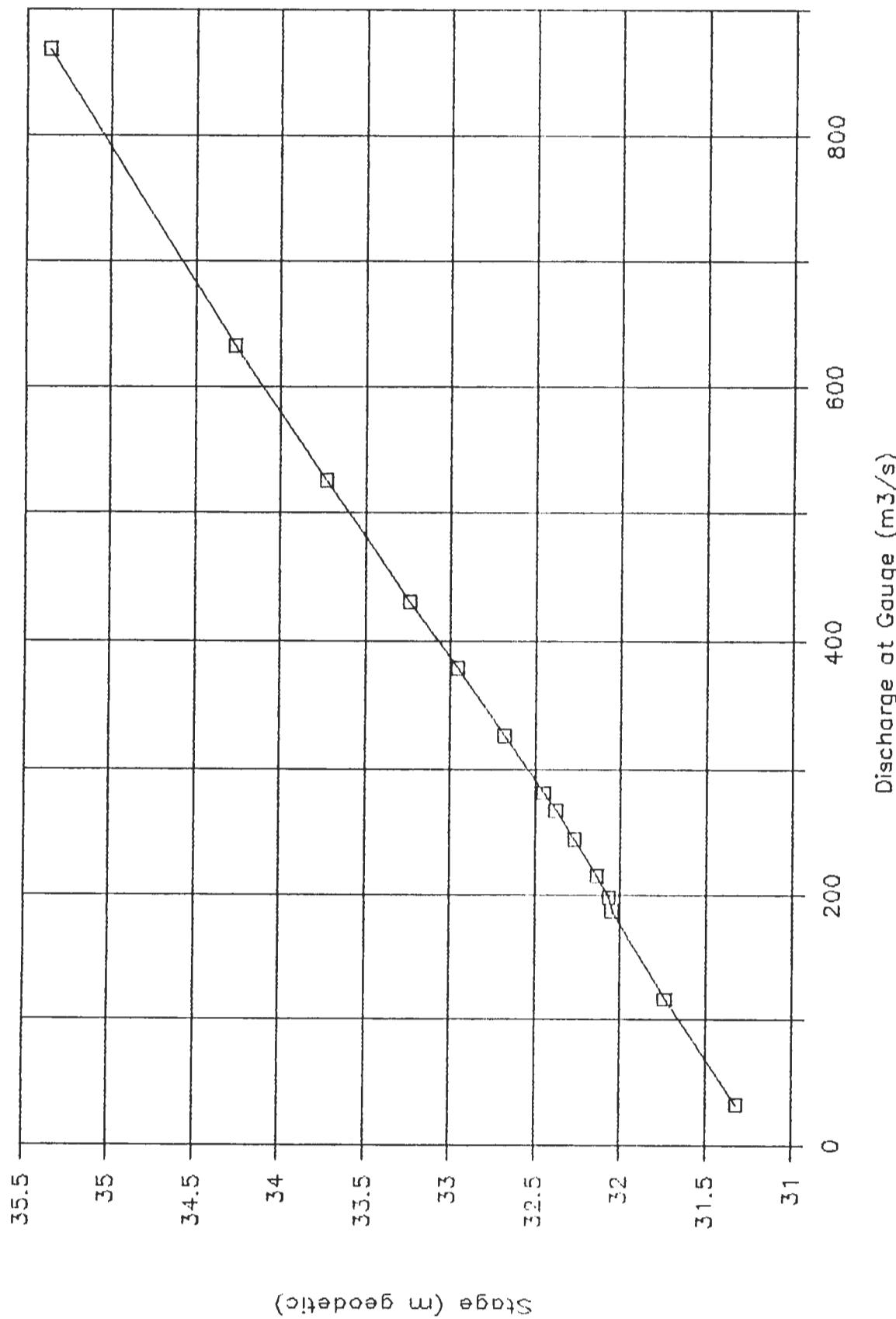
CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
 STAGE - DISCHARGE CURVE - STA. 4 + 627

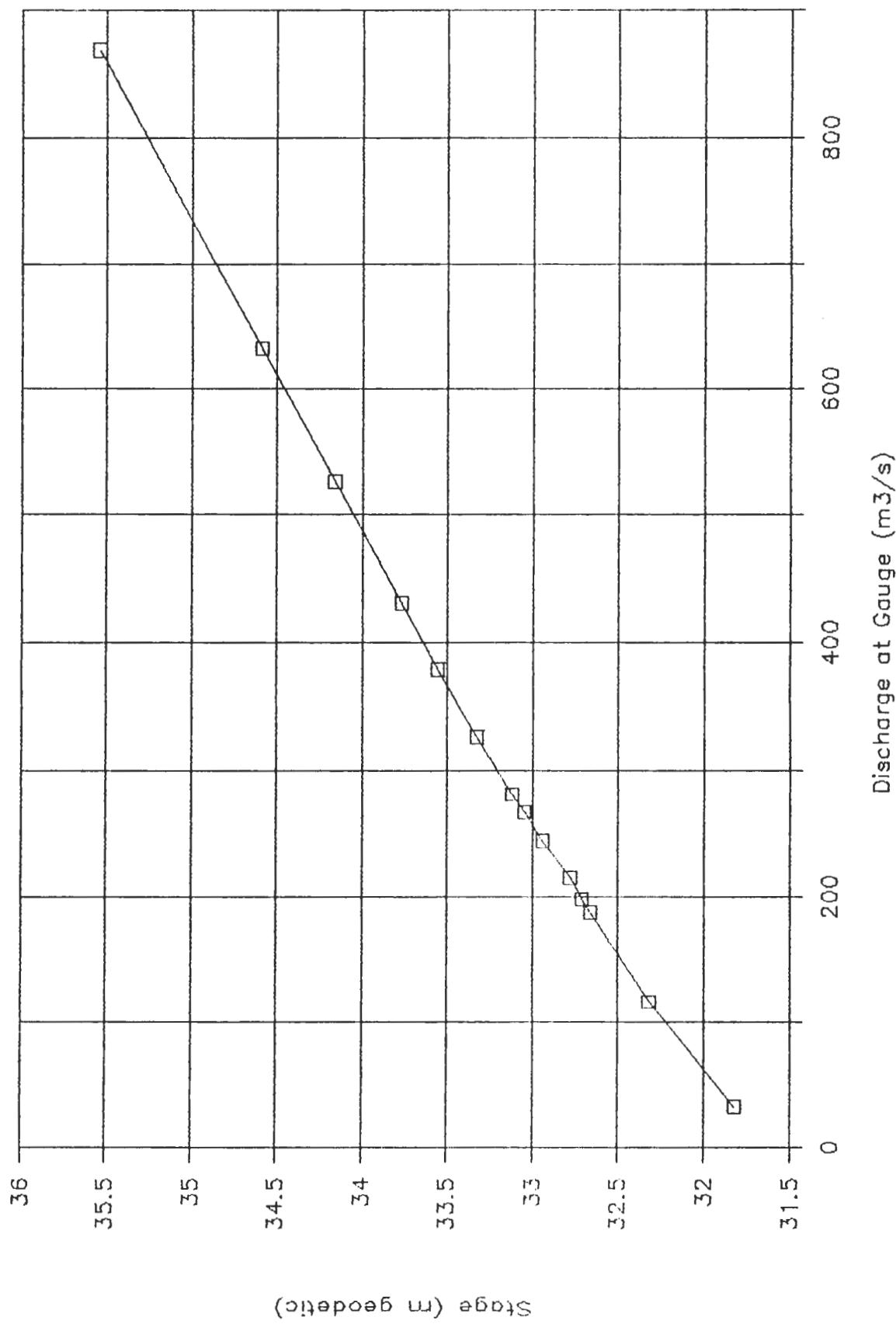


CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
STAGE - DISCHARGE CURVE - STA. 4 + 883



CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
 HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
STAGE - DISCHARGE CURVE - STA. 5 + 060





CANADA - NEWFOUNDLAND FLOOD DAMAGE REDUCTION PROGRAM
HYDROTECHNICAL STUDY - BLACK DUCK AND STEPHENVILLE CROSSING AREAS
STAGE - DISCHARGE CURVE - STA. 5 + 382

APPENDIX F
ICESIM SENSITIVITY TESTING

APPENDIX F

ICESIM SENSITIVITY TESTING

Sensitivity testing of significant parameters input to ICESIM was undertaken to assess the effect of variations in these parameters on the ice cover thicknesses and observed water levels.

The following parameters were varied during these sensitivity tests

- Froude number
- Deposition velocity
- Ice erosion velocity
- Ice cohesion
- Ice roughness.

The calibration results for the January 1985 freeze-up event were used as the basis for the sensitivity testing. Each parameter was varied individually, keeping all other parameters constant. Table F.1 presents the range of the parameters tested and the results of the sensitivity tests.

TABLE F.1

RESULTS OF ICESIM SENSITIVITY ANALYSIS

Parameter	Calibrated Value	Sensitivity Value	Effect of Change in Parameter
Froude number	0.10	0.08	Higher ice thicknesses (1.3 - 2.0 m) and higher water levels near Tanglewood Ranch than observed (0.8 - 1 m). Localized shoving in area of Tanglewood but little shoving along remainder of reach.
	0.12		Water levels unchanged but higher ice thicknesses (1.2 to 2.1 m) than observed from Tanglewood to Hickey's farm. (0.8 to 1 m). Shoving much more extensive than observed through study reach.
Deposition velocity	0.9	0.8	No effect on water levels, ice thicknesses or processes.
	1.2		Water levels remained constant. Higher ice thicknesses (1 to 1.3 m) than observed (0.8 to 1 m) in area of island at Hickey's farm.
	1.5		Water levels remained constant. Higher ice thicknesses (1.5 to 2 m) than observed (0.8 to 1 m) in area of Tanglewood ranch. Considerably more shoving.

TABLE F.1 (continued)

RESULTS OF ICESIM SENSITIVITY ANALYSIS

Parameter	Calibrated Value	Sensitivity Value	Effect of Change in Parameter
Erosion velocity	1.5	1.3	No change in water levels or ice processes
		1.7	No change in water levels or ice processes
		2.0	No change in water levels or ice processes
Ice Cohesion (Freeze-Up)	1000	1500	Water levels and ice thicknesses unchanged. No shoving observed through entire reach.
		2000	Water levels and ice thicknesses slightly lower (0.6 to 0.8 m) in area of Tanglewood ranch. No shoving.
Ice Roughness	0.045	0.03	Ice thicknesses and water levels lower than calibrated. Processes not affected.
		0.06	Ice thicknesses much too high compared to observed. Processes not affected.

APPENDIX G
RESULTS OF SCREENING FOR BREAKUP EVENTS

APPENDIX G

RESULTS OF SCREENING FOR BREAK-UP EVENTS

This appendix contains the results of the preliminary screening for historical break-up events. Table G.1 shows the dates of the possible historical break-up events, selected on the basis of the meteorological data and streamflow records. The recorded rainfall, snowcover and melting degree days are given, as well as the recorded flow at the WSC gauge. A "B" given along with the recorded flow indicates that ice effects were present. The total rainfall and melting degree days as well as the total snowpack melted is also presented.

These results were used along with the data available for freeze-up in each year to determine the historical break-up events for use in ICESIM modeling.

TABLE G.1

RESULTS OF SCREENING FOR BREAK-UP EVENTS

YEAR	DATE	RAINFALL (mm)	SNOWCOVER (cm)	MELTING TEMP (°C-d)	FLOW (m³/s)
1970	Feb 2	6.4	48	-	18.6B
	Feb 3	-	46	3.6	32.6B
	Feb 4	1.3	13	8.9	46.7B
	Feb 5	-	3	1.7	88.7R
Total*		7.7	45	14.2	
1970	Mar 3	0.3	33	1.1	11.0B
	Mar 4	0.3	20	0.6	7.6
	Mar 5	-	20	-	7.2
	Mar 6	-	20	0.9	6.8
	Mar 7	-	18	1.4	6.6
	Mar 8	1.3	30	0.3	7.7
	Total	1.9	3	4.3	
1971	Feb 12	0.3	36	-	9.9B
	Feb 13	5.6	33	2.8	19.5B
	Feb 14	54.1	23	6.4	29.6B
	Feb 15	0.0	15	-	26.2B
Total		60.0	21	9.2	
1972	Mar 24	-	56	-	43.0B
	Mar 25	8.9	48	6.4	29.7B
	Mar 26	-	36	1.1	59.2B
	Mar 27	-	36	1.4	52.7B
	Mar 28	0.8	33	3.4	46.2B
	Total	9.7	23	12.3	
1975	Mar 20	-	66	3.4	4.7B
	Mar 21	1.5	48	5.3	5.1B
	Mar 22	16.3	38	2.3	5.6B
	Mar 23	7.4	33	1.1	7.3B
	Mar 24	5.1	25	0.6	11.3B
	Mar 25	-	28	1.4	19.8B
	Mar 26	8.9	23	1.9	26.9B
Total		39.2	43	16.0	

* Total rainfall and melting degree-days summed over period given. Total snowcover refers to total melted and is given by the difference in final and initial snowcover.

TABLE G.1**RESULTS OF SCREENING FOR BREAK-UP EVENTS (continued)**

YEAR	DATE	RAINFALL (mm)	SNOWCOVER (cm)	MELTING TEMP (°C - d)	FLOW (m ³ /s)
1976	Jan 26	-	38	-	19B
	Jan 27	34.0	33	2.8	28.3B
	Jan 28	7.6	33	4.5	73.6B
	Jan 29	2.3	33	2	60.9B
	Jan 30	-	-	-	49.6B
Total		43.9	5	9.3	
1978	Jan 25	-	-	-	19.8B
	Jan 26	35.0	74	1.0	23.8
	Jan 27	0.3	25	1.7	30.7
	Total	35.3	49	2.7	
1979	Jan 8	52.8	29	3.4	26.6B
	Jan 9	8.0	10	0.1	135
	Total	60.8	9	3.5	
1979	Mar 5	3.8	28	2.2	11.3B
	Mar 6	5.0	10	6.1	34.0B
	Mar 7	14.9	4	5.4	113B
	Mar 8	33.1	2	5.3	165
	Mar 9	1.0	1	0.6	130
	Total	57.8	27	19.6	
1981	Feb 17	0.6	7	0.6	25B
	Feb 18	0	3	2.1	24.5B
	Feb 19	0	3	2.7	23.0B
	Feb 20	0	2	2.9	21.6B
	Feb 21	0	0	2.4	20.4B
	Feb 22	0	0	0	19.2B
	Feb 23	0	0	1.2	18.3B
	Feb 24	0	1	3.6	17.3
	Total	0.6	7	15.5	
1984	Jan 5	0.2	16	9.0	13.0B
	Jan 6	11.4	10	4.3	30.0
	Jan 7	4.2	4	3.0	59.2
	Total	15.8	12	16.3	

TABLE G.1

RESULTS OF SCREENING FOR BREAK-UP EVENTS (continued)

YEAR	DATE	RAINFALL (mm)	SNOWCOVER (cm)	MELTING TEMP (°C - d)	FLOW (m³/s)
1984	Feb 4	16.4	44	3.7	8.9B
	Feb 5	41.9	18	3.3	32B
	Feb 6	0	0	1.0	88.5
Total		58.3	22		7.0

APPENDIX II
FREQUENCY ANALYSIS RESULTS
SECTION 2552 - OPEN WATER
FREEZE-UP
BREAK-UP

Note on Use of CFA88

The CFA88 frequency analysis package (20) was used to estimate the water levels at each cross-section for the required return periods. CFA88 is a convenient, well tested, and well accepted program for fitting data from an annual series to several common frequency distributions. CFA88 was developed for flow analysis and in the analysis of flows, it has been found that the logarithms of the variate exhibit less skew than the untransformed data points. However, variables other than flow do not necessarily require logarithmic transformation unless there is a high degree of skewness in the data.

In the case of Harry's River, the maximum water levels are governed by the hydraulics of the river as well as by flows. There was thus no reason to automatically assume that the logarithms of water levels would provide a better fit than the untransformed levels. Water level-frequency plots for several cross-sections in different reaches of the river were examined, and based on this examination, it was decided to use untransformed data in the analysis.

Since CFA88 was the frequency analysis package of choice, the input data were adjusted to compensate for the logarithmic transformation automatically carried out by the program. The data shown in the sample files in this Appendix are thus adjusted depths. The result of the adjustment is that the frequency analysis using CFA88 was carried out on the untransformed levels.

WSC STATION NO=2552 FREEZ
 WSC STATION NAME=LN

MONTH (1)	YEAR (2)	DATA (3) (CMS)	ORDERED (4) (CMS)	RANK (5)	PROB. (6) (%)	RET. PERIOD (7) (YEARS)
1	1970	1.280	4.810	1	3.70	27.000
1	1971	1.170	4.220	2	9.88	10.125
1	1972	1.380	3.530	3	16.05	6.231
1	1973	1.310	1.510	4	22.22	4.500
1	1974	1.280	1.510	5	28.40	3.522
1	1975	1.020	1.380	6	34.57	2.893
1	1976	4.220	1.310	7	40.74	2.455
1	1977	1.510	1.310	8	46.91	2.132
1	1978	1.270	1.300	9	53.09	1.884
1	1979	1.310	1.300	10	59.26	1.687
1	1980	1.300	1.280	11	65.43	1.528
1	1981	1.510	1.280	12	71.60	1.397
1	1982	1.200	1.270	13	77.78	1.286
1	1984	3.530	1.200	14	83.95	1.191
1	1985	1.300	1.170	15	90.12	1.110
1	1986	4.810	1.020	16	96.30	1.038

FREQUENCY ANALYSIS -- GENERALIZED EXTREME VALUE DISTRIBUTION
2552 FREEZ LN

SAMPLE STATISTICS

X (MIN)= 1.020 TOTAL SAMPLE SIZE= 16
 X (MAX)= 4.810 NO. OF LOW OUTLIERS= 0
 LOWER OUTLIER LIMIT OF X= 0.533 NO. OF ZERO FLOWS= 0

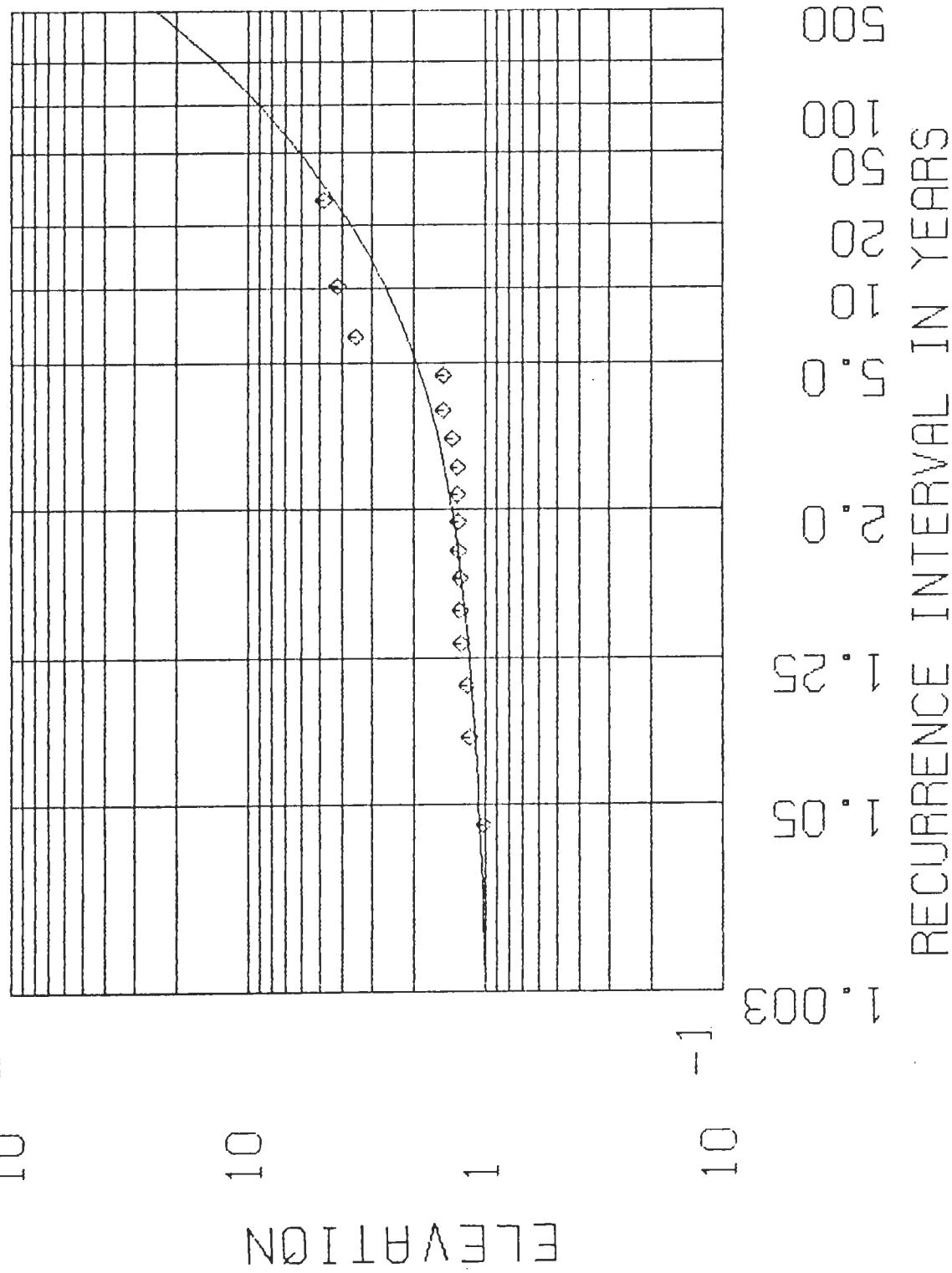
SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

GEV PARAMETERS: U= 1.28 A= 0.264 K= -0.653

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	ELEVATION
1.003	0.997	1.00
1.050	0.952	1.07
1.250	0.800	1.17
2.000	0.500	1.38
5.000	0.200	1.95
10.000	0.100	2.63
20.000	0.050	3.68
50.000	0.020	6.04
100.000	0.010	9.02
200.000	0.005	13.70
500.000	0.002	24.20

FREQUENCY ANALYSIS - 2552 FRE
GENERALIZED EXTREME VALUE-MAX LIKELIHOOD



FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
2552 FREEZ LN

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	1.837	1.194	0.650	1.889	5.874
LN X SERIES	0.473	0.484	1.022	1.675	5.066
LN(X-A) SERIES	-0.865	1.183	-1.368	0.298	4.942

X (MIN) = 1.020 TOTAL SAMPLE SIZE = 16
 X (MAX) = 4.810 NO. OF LOW OUTLIERS = 0
 LOWER OUTLIER LIMIT OF X = 0.533 NO. OF ZERO FLOWS = 0

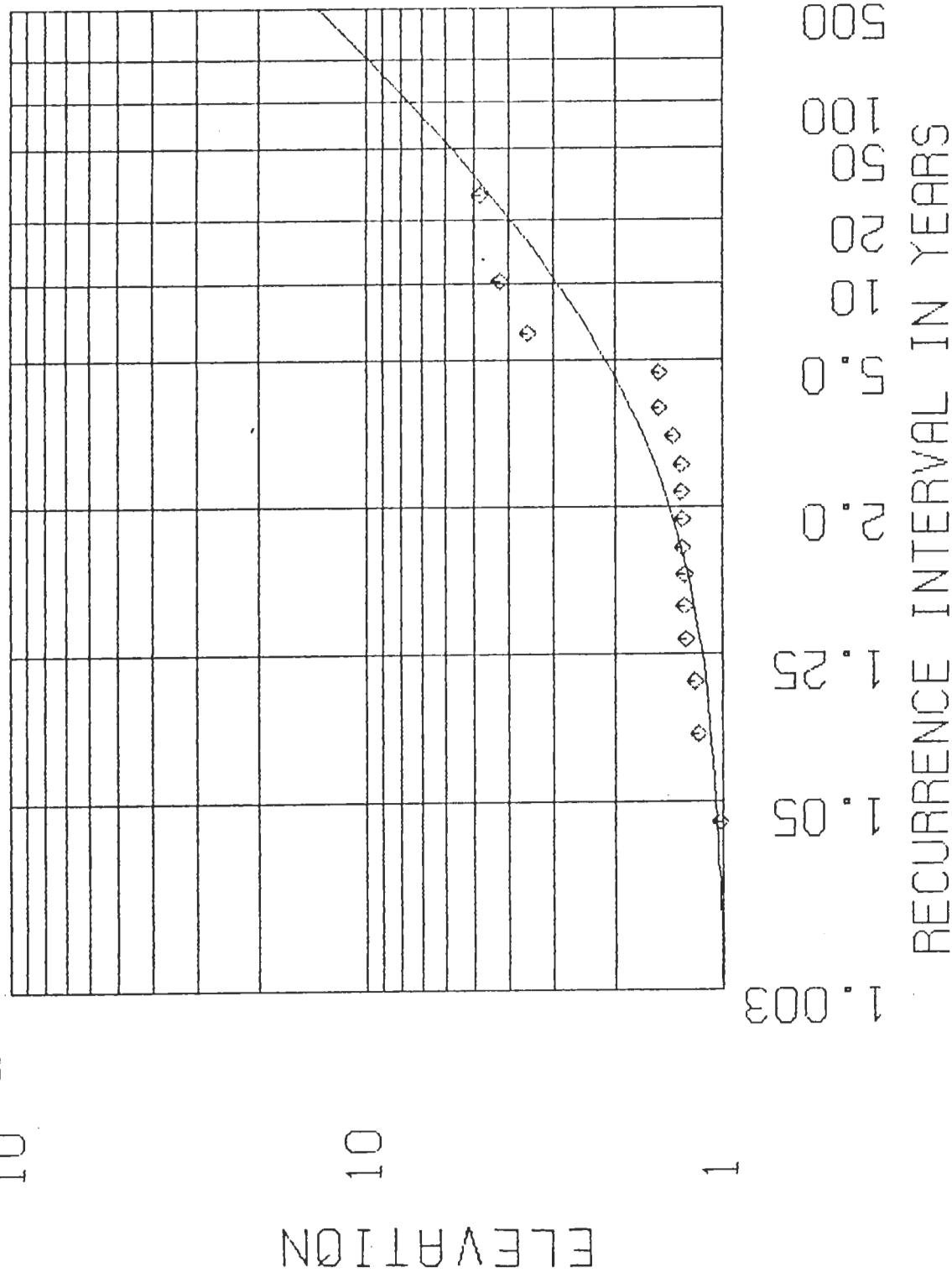
SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= -0.988 B=-0.865 C= 1.183

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	ELEVATION
1.003	0.997	1.00
1.050	0.952	1.05
1.250	0.800	1.14
2.000	0.500	1.41
5.000	0.200	2.13
10.000	0.100	2.91
20.000	0.050	3.94
50.000	0.020	5.77
100.000	0.010	7.59
200.000	0.005	9.86
500.000	0.002	13.70

FREQUENCY ANALYSIS - 2552 FRE
THREE PARAMETER LOGNORMAL-MAX LIKELIHOOD



FREQUENCY ANALYSIS -- LOG PEARSON TYPE III DISTRIBUTION
2552 FREEZ LN

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	1.837	1.194	0.650	1.889	5.874
LN X SERIES	0.473	0.484	1.022	1.675	5.066

X (MIN)= 1.020 TOTAL SAMPLE SIZE= 16
 X (MAX)= 4.810 NO. OF LOW OUTLIERS= 0
 LOWER OUTLIER LIMIT OF X= 0.533 NO. OF ZERO FLOWS= 0

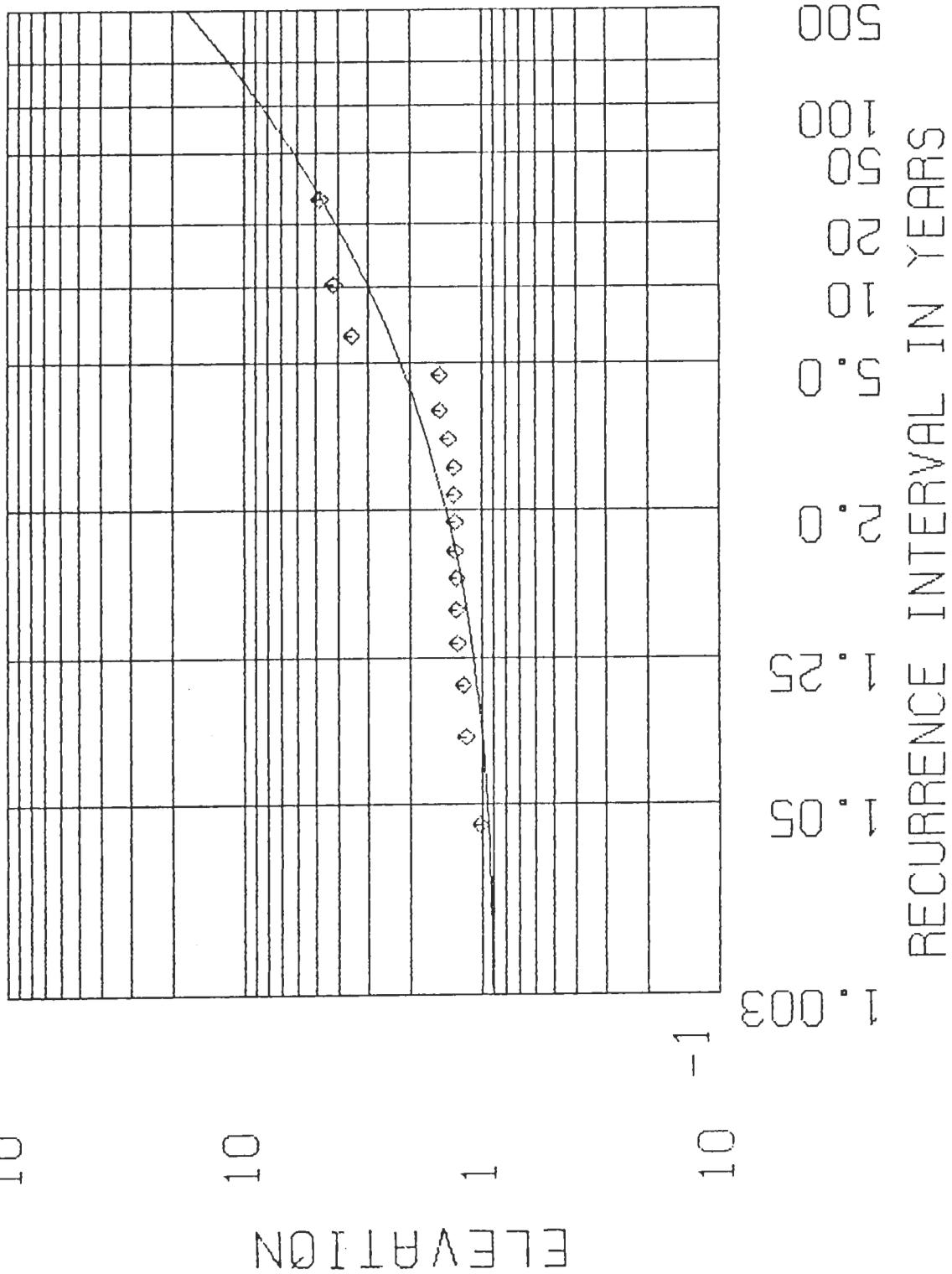
SOLUTION OBTAINED VIA MOMENTS

LPS PARAMETERS: A= 0.4050 B= 1.426 LOG(M)=-0.1042
M = 0.9011

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	ELEVATION
1.003	0.997	0.90
1.050	0.952	0.95
1.250	0.800	1.09
2.000	0.500	1.42
5.000	0.200	2.20
10.000	0.100	3.02
20.000	0.050	4.13
50.000	0.020	6.22
100.000	0.010	8.48
200.000	0.005	11.60
500.000	0.002	17.50

FREQUENCY ANALYSIS - 2552 FRE
LOG PEARSON TYPE III-MOMENT



FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
2552 FREEZ LN

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	1.837	1.194	0.650	1.889	5.874
LN X SERIES	0.473	0.484	1.022	1.675	5.066

X (MIN)= 1.020 TOTAL SAMPLE SIZE= 16
 X (MAX)= 4.810 NO. OF LOW OUTLIERS= 0
 LOWER OUTLIER LIMIT OF X= 0.533 NO. OF ZERO FLOWS= 0

THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED VIA ITERATION FOR
PARAMETER B, ASSUMING M TO BE NON-ZERO.

M= -1.045 A= -2.107 B= 0.30 C= 3.427 D= 0.272

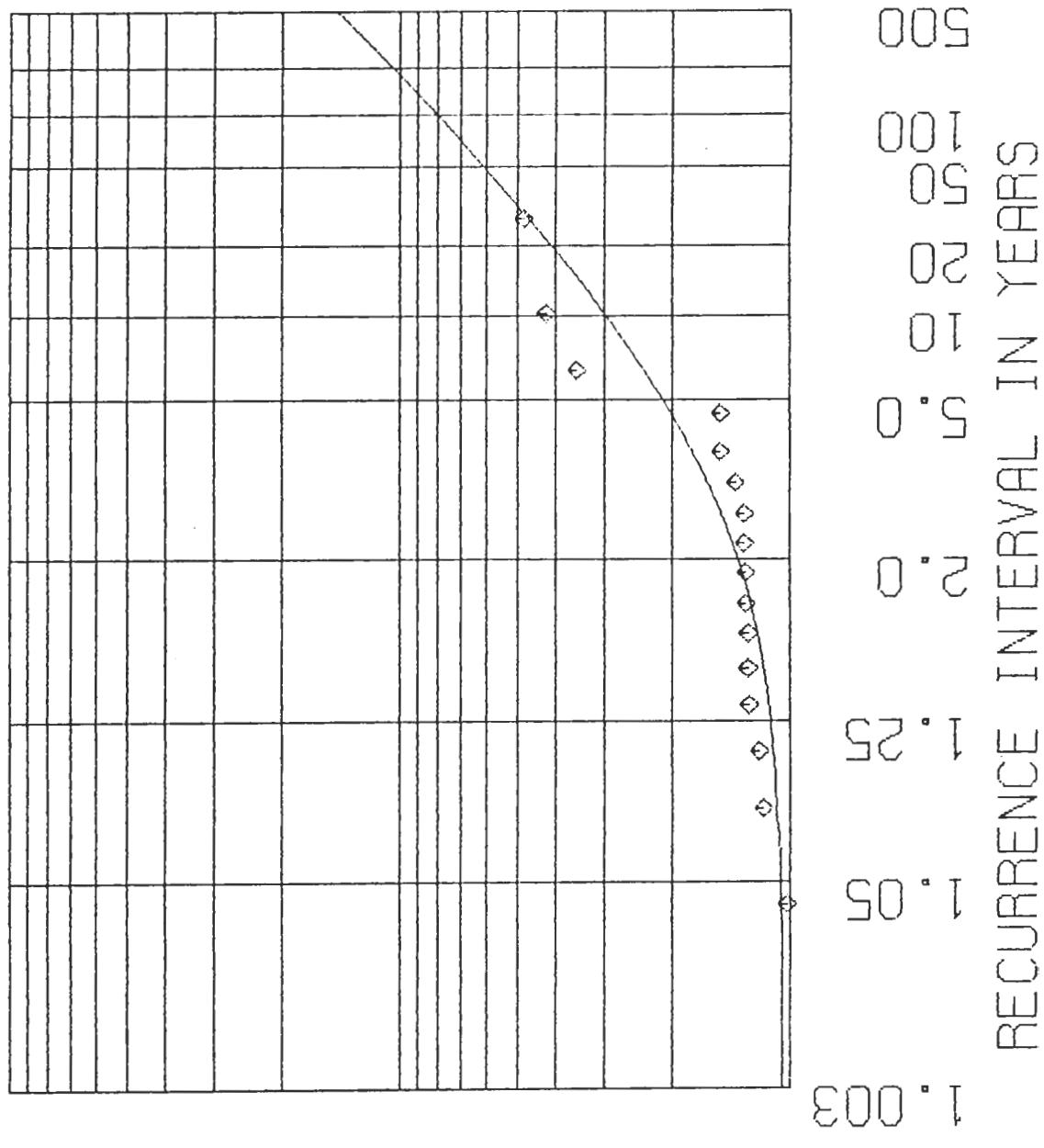
FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	ELEVATION
1.003	0.997	1.05
1.050	0.952	1.06
1.250	0.800	1.12
2.000	0.500	1.36
5.000	0.200	2.12
10.000	0.100	2.97
20.000	0.050	4.10
50.000	0.020	6.08
100.000	0.010	8.02
200.000	0.005	10.40
500.000	0.002	14.40

FREQUENCY ANALYSIS - 2552 FRE

WAKEBY₂
10⁻²

10
ELEVATION



WSC STATION NO=2552 OPEN
WSC STATION NAME=LN

MONTH (1)	YEAR (2)	DATA (3) (CMS)	ORDERED (4) (CMS)	RANK (5)	PROB. (6) (%)	RET. PERIOD (7) (YEARS)
1	1969	4.100	8.250*	1	3.49	28.667
1	1970	2.440	4.180	2	9.30	10.750
1	1971	1.600	4.100	3	15.12	6.615
1	1972	3.560	4.010	4	20.93	4.778
1	1973	8.250	3.670	5	26.74	3.739
1	1974	2.860	3.560	6	32.56	3.071
1	1975	4.010	3.420	7	38.37	2.606
1	1976	3.420	3.000	8	44.19	2.263
1	1977	2.250	2.860	9	50.00	2.000
1	1978	3.000	2.440	10	55.81	1.792
1	1979	2.100	2.440	11	61.63	1.623
1	1980	4.180	2.250	12	67.44	1.483
1	1981	1.650	2.100	13	73.26	1.365
1	1982	2.440	1.790	14	79.07	1.265
1	1983	1.730	1.730	15	84.88	1.178
1	1984	1.790	1.650	16	90.70	1.103
1	1985	3.670	1.600	17	96.51	1.036

FREQUENCY ANALYSIS -- GENERALIZED EXTREME VALUE DISTRIBUTION
2552 OPEN LN

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	3.121	1.596	0.511	2.160	10.025
LN X SERIES	1.043	0.431	0.413	0.699	4.424

X(MIN)= 1.600 TOTAL SAMPLE SIZE= 17
X(MAX)= 8.250 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 1.050 NO. OF ZERO FLOWS= 0

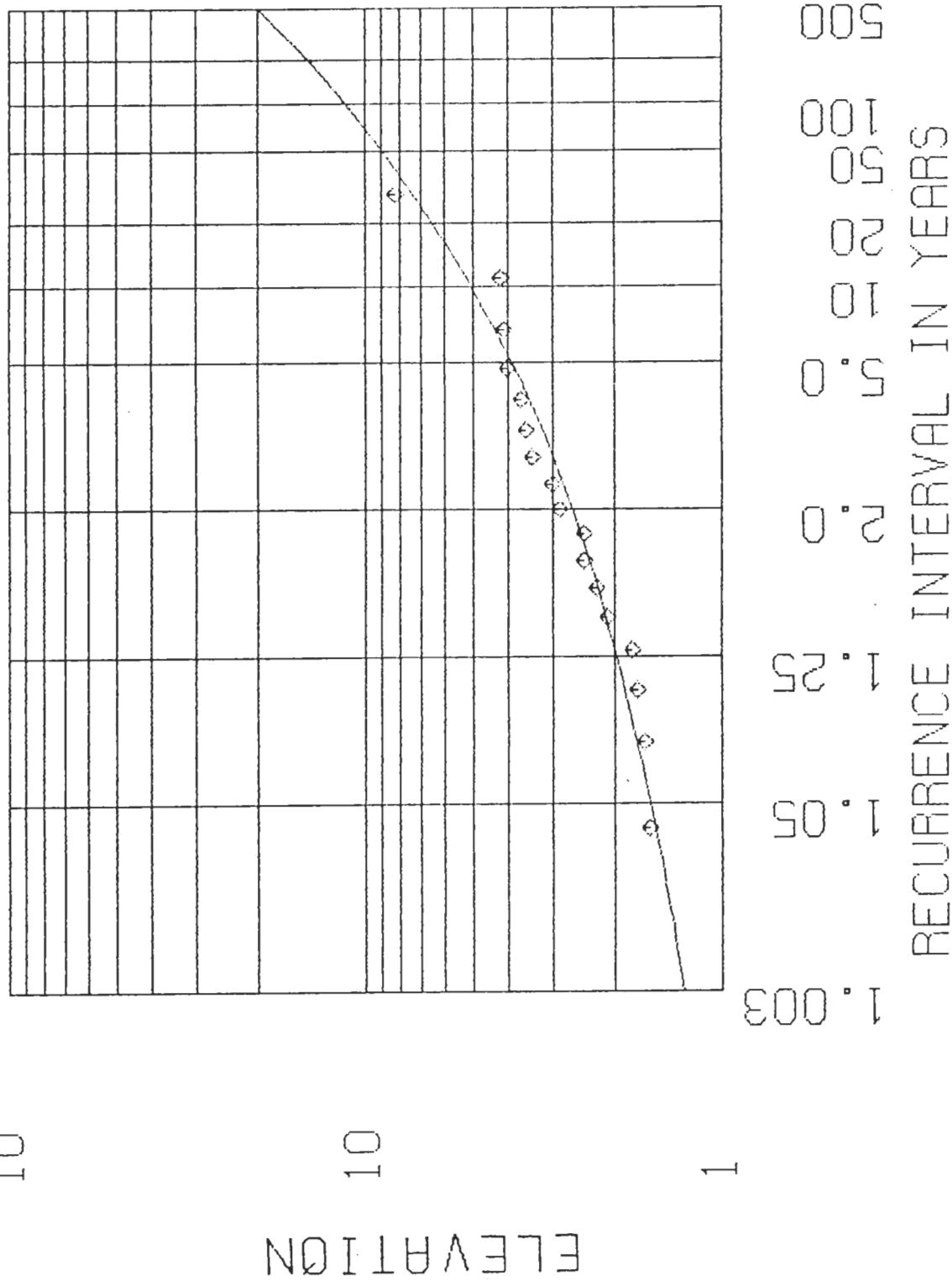
SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

GEV PARAMETERS: U= 2.33 A= 0.798 K= -0.348

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	ELEVATION
1.003	0.997	1.28
1.050	0.952	1.59
1.250	0.800	1.98
2.000	0.500	2.64
5.000	0.200	3.90
10.000	0.100	5.05
20.000	0.050	6.48
50.000	0.020	8.96
100.000	0.010	11.40
200.000	0.005	14.50
500.000	0.002	20.00

FREQUENCY ANALYSIS - 2552 OPE
GENERALIZED EXTREME VALUE-MAX LIKELIHOOD



FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
2552 OPEN LN

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	3.121	1.596	0.511	2.160	10.025
LN X SERIES	1.043	0.431	0.413	0.699	4.424
LN(X-A) SERIES	0.126	0.998	7.901	-0.373	3.155

X (MIN) = 1.600 TOTAL SAMPLE SIZE = 17
X (MAX) = 8.250 NO. OF LOW OUTLIERS = 0
LOWER OUTLIER LIMIT OF X = 1.050 NO. OF ZERO FLOWS = 0

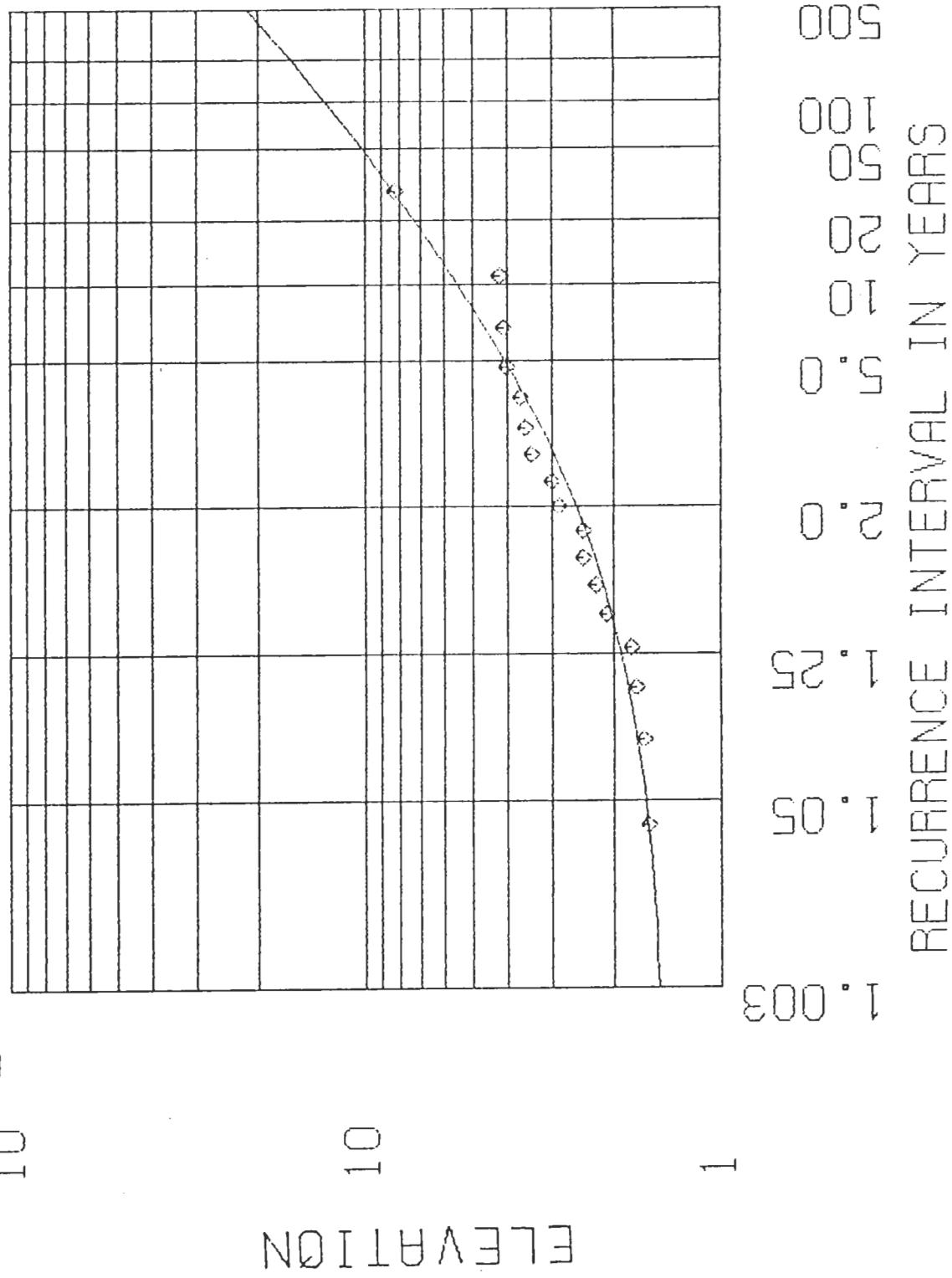
SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

SLN PARAMETERS: A= 1.417 N= 0.126 S= 0.998

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	ELEVATION
1.003	0.997	1.49
1.050	0.952	1.63
1.250	0.800	1.91
2.000	0.500	2.55
5.000	0.200	4.04
10.000	0.100	5.49
20.000	0.050	7.27
50.000	0.020	10.20
100.000	0.010	13.00
200.000	0.005	16.20
500.000	0.002	21.50

FREQUENCY ANALYSIS - 2552 OPE
THREE PARAMETER LOGNORMAL-MAX LIKELIHOOD



FREQUENCY ANALYSIS - LOG PEARSON TYPE III DISTRIBUTION
2552 OPEN LN

SAMPLE STATISTICS

X SERIES	MEAN 3.121	S.D. 1.596	C.V. 0.511	C.S. 2.160	C.K. 10.025
LN X SERIES		0.431	0.413	0.699	4.424

X(MIN)= X(MAX)= LOWER OUTLIER LIMIT OF X=	1.600 8.250 1.050	TOTAL SAMPLE SIZE= NO. OF LOW OUTLIERS= NO. OF ZERO FLOWS=	17 0 0
-------------------------------------------------	-------------------------	------------------------------------------------------------------	--------------

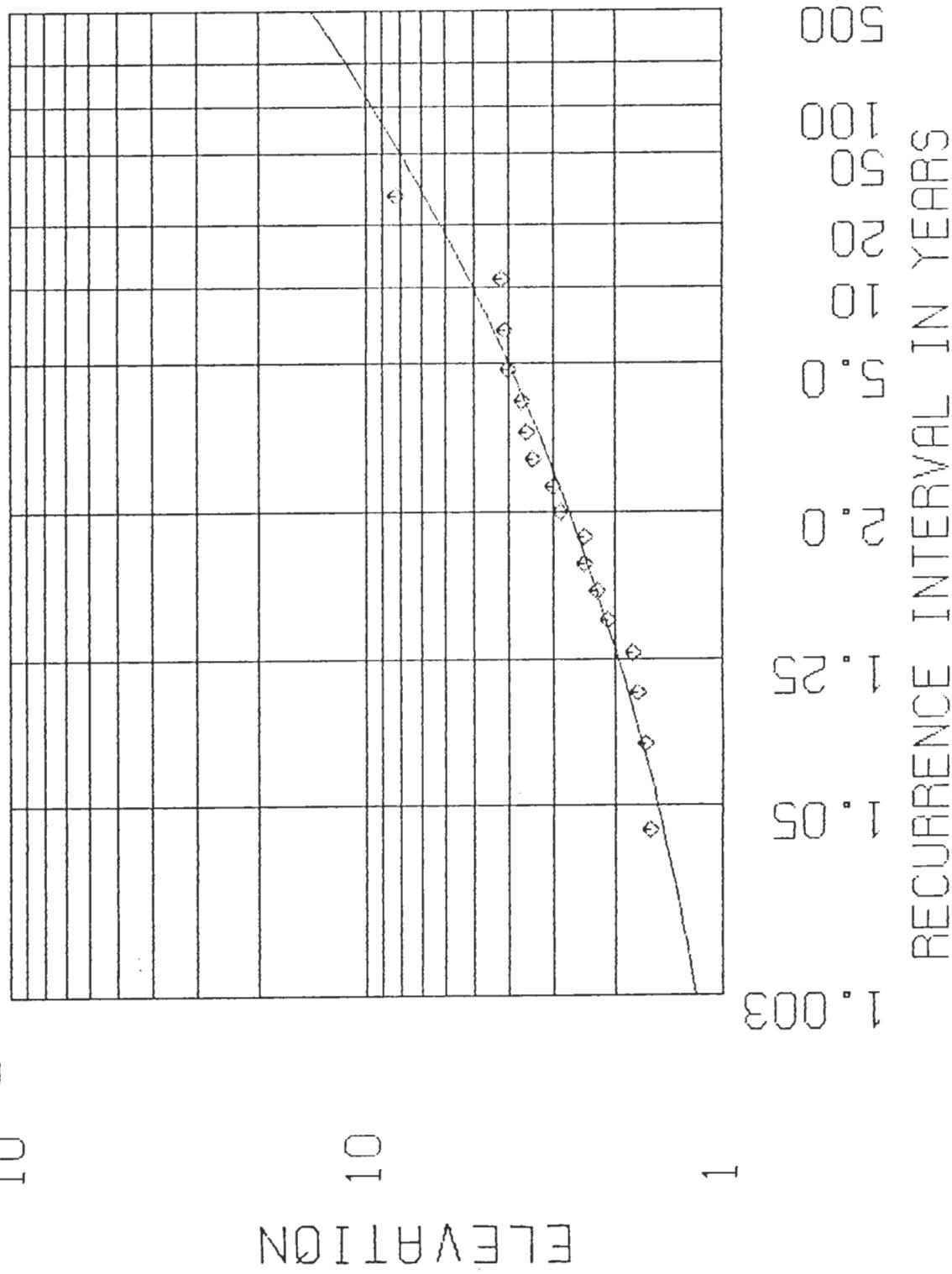
SOLUTION OBTAINED VIA MOMENTS

LP3 PARAMETERS: A= 0.1505 B= 8.188 LOG(M)=-0.1899
M = 0.8270

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	ELEVATION
1.003	0.997	1.19
1.050	0.952	1.53
1.250	0.800	1.96
2.000	0.500	2.70
5.000	0.200	3.98
10.000	0.100	5.03
20.000	0.050	6.21
50.000	0.020	8.01
100.000	0.010	9.59
200.000	0.005	11.40
500.000	0.002	14.20

FREQUENCY ANALYSIS - 2552 GPE
LOG PEARSON TYPE III-MOMENT



FREQUENCY ANALYSIS - WAKEBY DISTRIBUTION
2552 OPEN LN

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	3.121	1.596	0.511	2.160	10.025
LN X SERIES	1.043	0.431	0.413	0.699	4.424

X (MIN)= 1.600 TOTAL SAMPLE SIZE= 17
X (MAX)= 8.250 NO. OF LOW OUTLIERS= 0
LOWER OUTLIER LIMIT OF X= 1.050 NO. OF ZERO FLOWS= 0

THE FOLLOWING WAKEBY PARAMETERS WERE OBTAINED BY ASSUMING M TO BE NON-ZERO. THE ITERATION ALGORITHM WAS NOT REQUIRED.

M= 1.263 A= 2.214 B= 1.23 C= 0.571 D= 0.527

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	ELEVATION
1.003	0.997	1.27
1.050	0.952	1.41
1.250	0.800	1.87
2.000	0.500	2.79
5.000	0.200	3.93
10.000	0.100	4.70
20.000	0.050	5.62
50.000	0.020	7.37
100.000	0.010	7.35
200.000	0.005	12.20
500.000	0.002	18.00

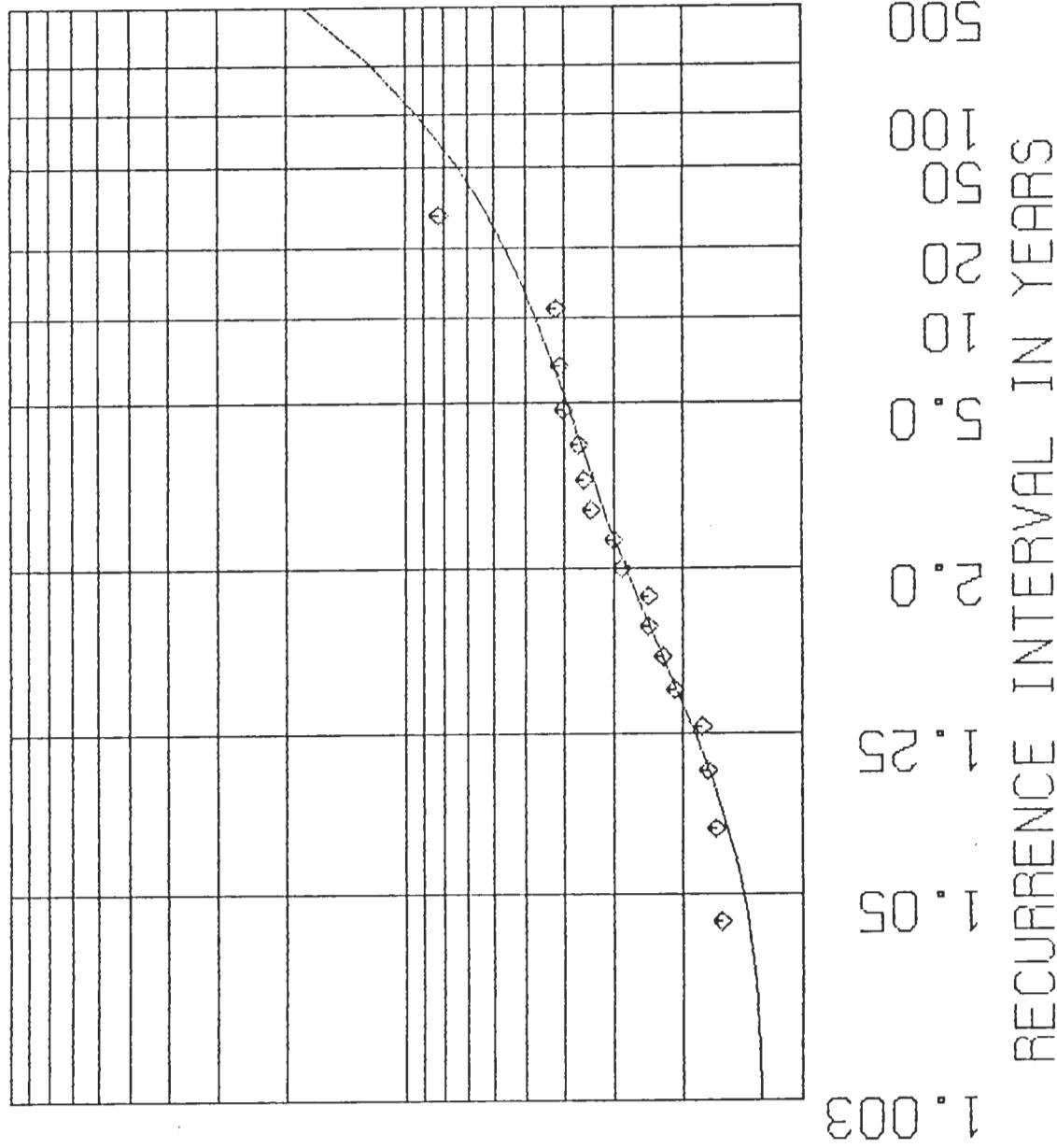
FREQUENCY ANALYSIS - 2552 OPE

WAKEBY²
10⁻²

ELEVATION

10

1



Section # 2552

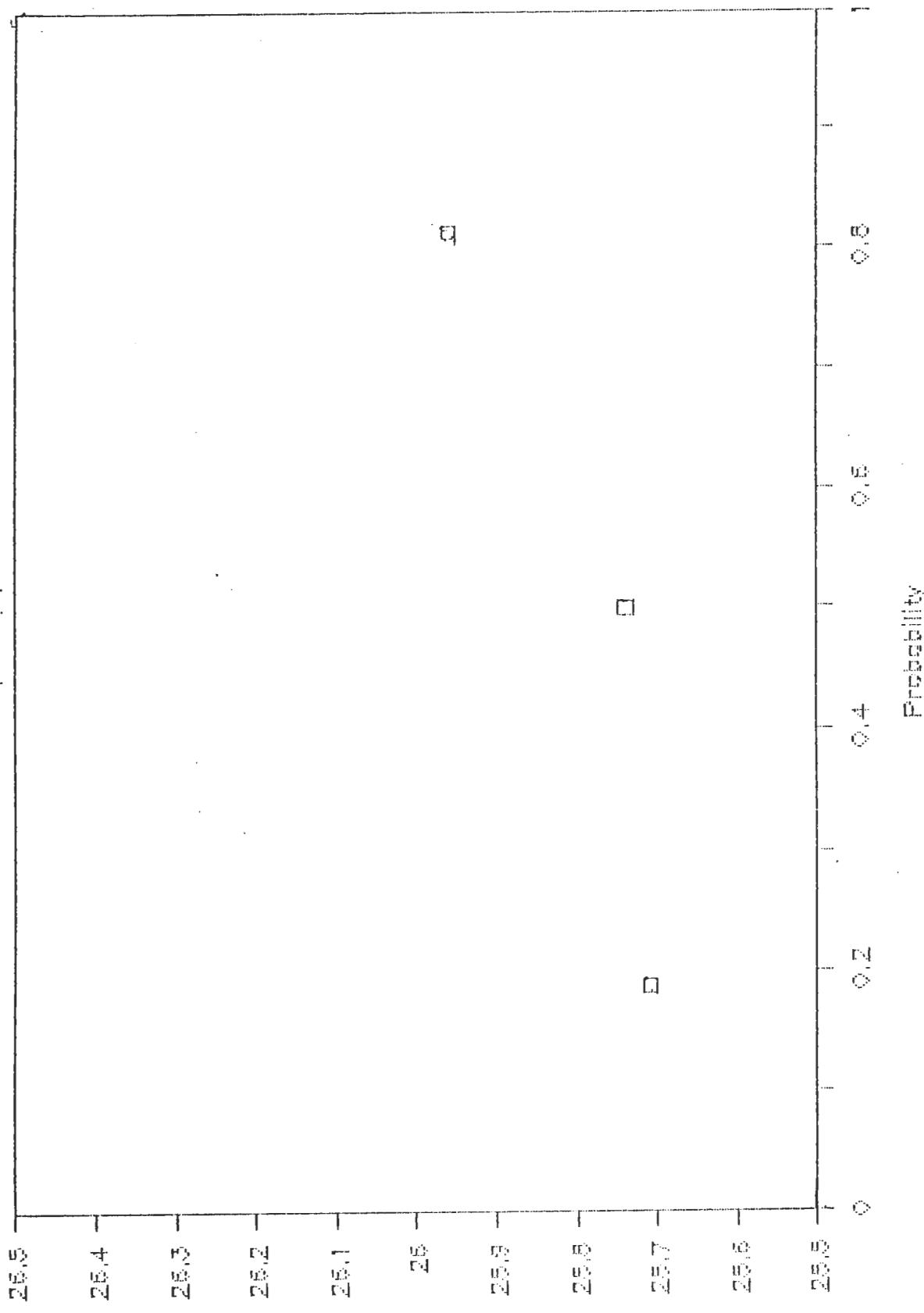
Year	Breakup Elev (m)	Ranked	m=rank	Prob	Rtn Period
1970	25.96	25.96	1	0.1875	5.33
1979	25.71	25.74	2	0.5	2.00
1984	25.74	25.71	3	0.8125	1.23

Cunnane Plotting Position formula

$$P = (m-0.4)/(n+0.2)$$

Section 2552

Breakup freq plot



**APPENDIX I
STEPHENVILLE CROSSING
FIELD PROGRAM**

APPENDIX I

STEPHENVILLE CROSSING FIELD PROGRAM

1 - RECORDED PRESSURES

Table I.1 presents the pressures recorded and the corresponding water levels obtained from the field program at Stephenville Crossing.

TABLE I.1**ST. GEORGE'S RIVER WATER LEVELS, DEC. 1986**

<u>HOUR</u>	<u>DATE</u>	<u>GAUGE PRESSURE (mb)</u>	<u>AIR PRESSURE (mb)</u>	<u>WATER LEVEL (m)</u>
0	21286	1187	1025.6	1.61
1	21286	1183	1025.3	1.58
2		1180	1025.7	1.54
3		1179	1025.7	1.53
4		1178	1026.9	1.51
5		1181	1026.9	1.54
6		1185	1026.8	1.58
7		1187	1026.8	1.60
8	31286	1188	1026.8	1.61
9	31286	1187	1027.3	1.60
10		1184	1027.3	1.57
11		1183	1027.2	1.56
12		1183	1027.6	1.55
13		1182	1027.9	1.54
14		1191	1028.1	1.63
15		1213	1028.2	1.85
16		1212	1028.4	1.84
17		1213	1028.4	1.85
18		1218	1029.0	1.89
19		1229	1028.8	2.00
20		1241	1029.0	2.12
21		1246	1028.8	2.17
22		1243	1027.6	2.15
23		1237	1026.3	2.11
24		1227	1025.8	2.01
25		1218	1025.0	1.93
26		1211	1024.1	1.87
27		1206	1024.0	1.82
28		1202	1023.1	1.79
29		1203	1022.1	1.81
30		1206	1019.8	1.86
31		1211	1018.0	1.93
32	41286	1216	1015.9	2.00
33	41286	1212	1013.6	1.98
34		1216	1009.8	2.06
35		1218	1006.7	2.11
36		1207	1003.8	2.03
37		1200	1001.8	1.98
38		1188	998.9	1.89
39		1181	998.2	1.83
40		1179	996.1	1.83
41		1186	995.9	1.90
42		1200	996.3	2.04
43		1215	996.7	2.18
44		1231	997.6	2.33
45		1241	997.8	2.43

TABLE I.1**ST. GEORGE'S RIVER WATER LEVELS, DEC. 1986 (continued)**

HOUR	DATE	GAUGE PRESSURE (mb)	AIR PRESSURE (mb)	WATER LEVEL (m)
46		1240	997.5	2.43
47		1233	996.8	2.36
48		1223	996.2	2.27
49		1215	995.7	2.19
50		1204	995.3	2.09
51		1197	995.4	2.02
52		1192	995.4	1.97
53		1191	995.3	1.96
54		1195	995.0	2.00
55		1201	994.9	2.06
56	51286	1210	994.6	2.15
57	51286	1216	994.6	2.21
58		1213	995.0	2.18
59		1205	994.6	2.10
60		1198	994.6	2.03
61		1192	994.7	1.97
62		1187	994.7	1.92
63		1183	994.9	1.88
64		1181	995.1	1.86
65		1183	995.6	1.87
66		1192	996.2	1.96
67		1210	997.0	2.13
68		1231	998.2	2.33
69		1248	998.9	2.49
70		1260	999.3	2.61
71		1262	999.7	2.62
72		1256	999.7	2.56
73		1247	1000.4	2.47
74		1237	1001.2	2.36
75		1227	1002.1	2.25
76		1218	1003.0	2.15
77		1212	1004.3	2.08
78		1210	1005.1	2.05
79		1211	1005.3	2.06
80	61286	1214	1005.8	2.08
81	61286	1219	1006.3	2.13
82		1221	1006.5	2.15
83		1215	1006.4	2.09
84		1208	1006.4	2.02
85		1201	1006.8	1.94
86		1196	1007.1	1.89
87		1192	1007.2	1.85
88		1191	1007.5	1.84
89		1191	1008.4	1.83
90		1191	1008.6	1.82

TABLE I.1**ST. GEORGE'S RIVER WATER LEVELS, DEC. 1986 (continued)**

HOUR	DATE	GAUGE PRESSURE (mb)	AIR PRESSURE (mb)	WATER LEVEL (m)
91		1192	1010.0	1.82
92		1198	1010.5	1.88
93		1210	1011.7	1.98
94		1222	1012.6	2.09
95		1228	1013.2	2.15
96		1226	1013.9	2.12
97		1221	1014.9	2.06
98		1214	1015.3	1.99
99		1207	1016.3	1.91
100		1202	1016.6	1.85
101		1198	1016.4	1.82
102		1196	1016.2	1.80
103		1195	1015.4	1.80
104	71286	1196	1014.5	1.82
105	71286	1201	1014.1	1.87
106		1207	1012.9	1.94
107		1210	1011.0	1.99
108		1209	1009.8	1.99
109		1204	1008.7	1.95
110		1198	1007.5	1.91
111		1193	1006.6	1.86
112		1190	1006.8	1.83
113		1189	1006.2	1.83
114		1190	1008.6	1.81
115		1193	1009.5	1.84
116		1196	1010.9	1.85
117		1199	1012.0	1.87
118		1205	1012.5	1.93
119		1212	1013.3	1.99
120		1218	1013.8	2.04
121		1219	1014.0	2.05
122		1217	1015.3	2.02
123		1215	1015.9	1.99
124		1214	1015.5	1.99
125		1213	1015.3	1.98
126		1212	1014.8	1.97
127		1210	1014.4	1.96
128	81286	1209	1013.7	1.95
129	81286	1207	1013.2	1.94
130		1207	1010.7	1.96
131		1212	1010.0	2.02
132		1218	1008.2	2.10
133		1220	1006.5	2.14
134		1219	1004.3	2.15
135		1214	1001.9	2.12

TABLE I.1

ST. GEORGE'S RIVER WATER LEVELS, DEC. 1986 (continued)

HOUR	DATE	GAUGE PRESSURE (mb)	AIR PRESSURE (mb)	WATER LEVEL (m)
136		1208	999.4	2.09
137		1203	997.4	2.06
138		1200	995.3	2.05
139		1199	992.6	2.06
140		1202	992.0	2.10
141		1202	995.4	2.07
142		1207	997.2	2.10
143		1214	999.6	2.14
144		1220	1001.2	2.19
145		1221	1002.6	2.18
146		1214	1004.4	2.10
147		1209	1005.6	2.03
148		1204	1007.0	1.97
149		1201	1008.2	1.93
150		1200	1009.4	1.91
151		1200	1009.6	1.90
152	91286	1201	1009.6	1.91
153	91286	1202	1010.2	1.92
154		1205	1011.3	1.94
155		1206	1011.9	1.94
156		1207	1013.4	1.94
157		1210	1015.8	1.94
158		1212	1017.4	1.95
159		1213	1018.4	1.95
160		1215	1020.1	1.95
161		1216	1022.1	1.94
162		1216	1024.2	1.92
163		1216	1025.6	1.90
164		1218	1026.6	1.91
165		1219	1027.0	1.92
166		1218	1027.2	1.91
167		1221	1027.0	1.94
168		1228	1027.1	2.01
169		1237	1027.2	2.10
170		1245	1027.4	2.18
171		1250	1027.8	2.22
172		1247	1027.7	2.19
173		1242	1027.6	2.14
174		1234	1027.7	2.06
175		1228	1027.5	2.01
176	101286	1223	1027.1	1.96
177	101286	1218	1026.4	1.92
178		1216	1026.1	1.90
179		1214	1024.8	1.89
180		1211	1024.0	1.87

TABLE I.1**ST. GEORGE'S RIVER WATER LEVELS, DEC. 1986 (continued)**

HOUR	DATE	GAUGE PRESSURE (mb)	AIR PRESSURE (mb)	WATER LEVEL (m)
181		1208	1023.3	1.85
182		1207	1022.3	1.85
183		1204	1020.3	1.84
184		1203	1016.7	1.86
185		1202	1015.3	1.87
186		1199	1012.7	1.86
187		1196	1010.8	1.85
188		1193	1010.4	1.83
189		1192	1008.4	1.84
190		1191	1006.0	1.85
191		1191	1003.4	1.88
192		1190	1001.9	1.88
193		1192	1001.0	1.91
194		1195	1001.0	1.94
195		1201	999.9	2.01
196		1202	999.2	2.03
197		1203	998.8	2.04
198		1200	998.1	2.02
199		1195	996.8	1.98
200	111286	1191	996.3	1.95
201	111286	1190	995.8	1.94
202		1191	995.8	1.95
203		1194	995.2	1.99
204		1200	995.0	2.05
205		1212	995.0	2.17
206		1219	995.9	2.23
207		1225	996.4	2.29
208		1229	997.8	2.31
209		1224	999.8	2.24
210		1221	1001.5	2.20
211		1215	1003.1	2.12
212		1210	1005.9	2.04
213		1207	1007.6	1.99
214		1206	1008.4	1.98
215		1206	1009.4	1.97
216		1207	1009.9	1.97
217		1210	1011.8	1.98
218		1213	1013.5	2.00
219		1218	1014.7	2.03
220		1222	1016.6	2.05
221		1221	1018.1	2.03
222		1217	1018.7	1.98
223		1214	1019.4	1.95
224	121286	1211	1019.4	1.92
225	121286	1210	1018.9	1.91

TABLE I.1**ST. GEORGE'S RIVER WATER LEVELS, DEC. 1986 (continued)**

<u>HOUR</u>	<u>DATE</u>	<u>GAUGE PRESSURE (mb)</u>	<u>AIR PRESSURE (mb)</u>	<u>WATER LEVEL (m)</u>
226		1209	1019.3	1.90
227		1209	1019.1	1.90
228		1208	1019.4	1.89
229		1207	1019.5	1.88
230		1208	1019.5	1.89
231		1215	1018.9	1.96
232		1222	1017.7	2.04
233		1228	1016.4	2.12
234		1227	1016.0	2.11
235		1221	1015.1	2.06
236		1213	1014.7	1.98
237		1207	1014.7	1.92
238		1202	1013.3	1.89
239		1199	1011.5	1.88
240		1198	1009.8	1.88
241		1195	1008.5	1.87
242		1194	1007.7	1.86
243		1193	1006.3	1.87
244		1194	1005.0	1.89
245		1195	1004.0	1.91
246		1193	1002.2	1.91
247		1190	1000.8	1.89
248	131286	1189	1000.0	1.89
249	131286	1188	998.8	1.89
250		1187	998.0	1.89
251		1186	997.7	1.88
252		1185	997.5	1.88
253		1185	997.0	1.88
254		1185	996.3	1.89
255		1190	995.7	1.94
256		1201	995.3	2.06
257		1214	994.9	2.19
258		1221	994.4	2.27
259		1221	994.2	2.27
260		1216	994.3	2.22
261		1209	994.4	2.15
262		1203	993.8	2.09
263		1198	993.7	2.04
264		1195	993.6	2.01
265		1194	994.3	2.00
266		1195	995.1	2.00
267		1199	995.8	2.03
268		1206	997.6	2.08
269		1211	998.6	2.12
270		1211	1000.8	2.10

TABLE I.1**ST. GEORGE'S RIVER WATER LEVELS, DEC. 1986 (continued)**

<u>HOUR</u>	<u>DATE</u>	<u>GAUGE PRESSURE (mb)</u>	<u>AIR PRESSURE (mb)</u>	<u>WATER LEVEL (m)</u>
271		1209	1002.4	2.07
272	141286	1206	1004.3	2.02
273	141286	1202	1005.1	1.97
274		1200	1006.1	1.94
275		1199	1007.6	1.91
276		1199	1007.9	1.91
277		1198	1008.2	1.90
278		1199	1008.4	1.91
279		1204	1008.7	1.95
280		1216	1008.9	2.07
281		1231	1009.7	2.21
282		1243	1010.2	2.33
283		1248	1010.3	2.38
284		1244	1011.0	2.33
285		1237	1011.9	2.25
286		1230	1013.0	2.17
287		1223	1013.3	2.10
288		1218	1014.2	2.04
289		1213	1014.3	1.99
290		1211	1014.9	1.96
291		1213	1014.7	1.98
292		1218	1014.6	2.03
293		1224	1014.6	2.09
294		1227	1014.4	2.13
295		1224	1014.0	2.10
296	151286	1219	1013.9	2.05
297	151286	1214	1013.1	2.01
298		1209	1013.0	1.96
299		1205	1012.6	1.92
300		1203	1011.9	1.91
301		1201	1011.0	1.90
302		1201	1010.6	1.90
303		1199	1009.6	1.89
304		1199	1008.7	1.90
305		1200	1008.6	1.91
306		1206	1007.8	1.98
307		1215	1007.1	2.08
308		1223	1006.5	2.17
309		1225	1005.8	2.19
310		1221	1005.3	2.16
311		1216	1005.3	2.11
312		1211	1004.9	2.06
313		1207	1005.2	2.02
314		1205	1006.1	1.99
315		1205	1006.7	1.98

TABLE I.1**ST. GEORGE'S RIVER WATER LEVELS, DEC. 1986 (continued)**

HOUR	DATE	GAUGE PRESSURE (mb)	AIR PRESSURE (mb)	WATER LEVEL (m)
316		1206	1007.2	1.99
317		1209	1007.8	2.01
318		1211	1008.7	2.02
319		1212	1009.0	2.03
320	161286	1211	1009.3	2.02
321	161286	1208	1009.5	1.99
322		1206	1009.7	1.96
323		1205	1009.8	1.95
324		1205	1009.6	1.95
325		1206	1009.8	1.96
326		1206	1010.9	1.95
327		1206	1012.7	1.93
328		1207	1013.9	1.93
329		1209	1014.4	1.95
330		1215	1015.0	2.00
331		1223	1015.8	2.07
332		1232	1016.6	2.15
333		1235	1017.5	2.18
334		1231	1018.0	2.13
335		1227	1018.0	2.09
336		1223	1018.4	2.05
337		1220	1019.1	2.01
338		1219	1019.7	1.99
339		1218	1020.2	1.98
340		1217	1021.2	1.96
341		1217	1021.8	1.95
342		1217	1022.4	1.95
343		1218	1023.1	1.95
344	171286	1218	1023.9	1.94
345	171286	1218	1024.3	1.94
346		1218	1024.6	1.93
347		1218	1024.8	1.93
348		1218	1025.1	1.93
349		1218	1025.7	1.92
350		1219	1026.1	1.93
351		1219	1026.5	1.93
352		1219	1026.9	1.92
353		1219	1027.8	1.91
354		1220	1028.0	1.92
355		1223	1028.4	1.95
356		1227	1029.1	1.98
357		1230	1029.4	2.01
358		1229	1029.2	2.00
359		1228	1029.1	1.99
360		1225	1029.0	1.96

TABLE I.1**ST. GEORGE'S RIVER WATER LEVELS, DEC. 1986 (continued)**

<u>HOUR</u>	<u>DATE</u>	<u>GAUGE PRESSURE (mb)</u>	<u>AIR PRESSURE (mb)</u>	<u>WATER LEVEL (m)</u>
361		1224	1028.8	1.95
362		1223	1029.1	1.94
363		1223	1029.3	1.94
364		1222	1029.5	1.93
365		1222	1029.7	1.92
366		1222	1030.1	1.92
367		1222	1030.1	1.92
368	181286	1221	1030.0	1.91
369	181286	1221	1030.1	1.91
370		1220	1030.1	1.90
371		1220	1029.6	1.90
372		1220	1029.2	1.91
373		1220	1028.7	1.91
374		1220	1028.6	1.91
375		1220	1028.5	1.92
376		1220	1028.7	1.91
377		1220	1028.7	1.91
378		1220	1028.8	1.91
379		1220	1029.4	1.91
380		1221	1029.4	1.92
381		1222	1029.2	1.93
382		1224	1029.2	1.95
383		1225	1028.8	1.96
384		1223	1028.1	1.95
385		1222	1027.9	1.94
386		1221	1028.3	1.93
387		1221	1028.9	1.92
388		1220	1028.1	1.92
389		1220	1027.7	1.92
390		1219	1027.7	1.91
391		1219	1027.9	1.91
392	191286	1220	1027.2	1.93
393	191286	1219	1026.4	1.93
394		1219	1025.9	1.93
395		1216	1025.4	1.91
396		1215	1025.1	1.90
397		1215	1024.9	1.90
398		1214	1024.1	1.90
399		1213	1023.4	1.90
400		1213	1023.5	1.90
401		1212	1023.1	1.89
402		1211	1022.4	1.89
403		1215	1022.4	1.93
404		1220	1021.4	1.99
405		1227	1021.4	2.06

TABLE I.1**ST. GEORGE'S RIVER WATER LEVELS, DEC. 1986 (continued)**

<u>HOUR</u>	<u>DATE</u>	<u>GAUGE PRESSURE (mb)</u>	<u>AIR PRESSURE (mb)</u>	<u>WATER LEVEL (m)</u>
406		1227	1020.7	2.06
407		1221	1019.4	2.02
408		1218	1017.9	2.00
409		1214	1017.1	1.97
410		1211	1016.2	1.95
411		1210	1015.6	1.94
412		1209	1015.4	1.94
413		1208	1015.4	1.93
414		1207	1014.9	1.92
415		1211	1014.1	1.97
416	201286	1215	1013.3	2.02
417	201286	1213	1012.8	2.00
418		1210	1012.0	1.98
419		1207	1012.1	1.95
420		1204	1011.4	1.93
421		1202	1011.0	1.91
422		1201	1010.2	1.91
423		1200	1008.3	1.92
424		1200	1008.1	1.92
425		1199	1007.8	1.91
426		1200	1007.6	1.92
427		1204	1007.5	1.97
428			1178	

2 - POTENTIAL INACCURACIES IN PRESSURE MEASUREMENTS

(a) Water Column Density Gradients

Changes in the water column density due to the formation of thermoclines, the action of internal waves and the mixing of sea and fresh water in tidal surges may affect the accuracy of the measured pressure.

Variations in water density due to thermoclines or the action of internal waves are only applicable to deep water measurement over extended deployment periods and are, therefore, not applicable to the St. George's River study. On the other hand, the Aanderra recorder, being located near the mouth of the St. George's River, will be affected by any variation in density of the overlying fluid. While the pressure measured by the instrument would be correct, the actual depth interpreted could vary depending on the salinity. The variation in salinity is expected to have an insignificant effect on the measurement.

(b) Wave Effects

Wave effects can be neglected because of the location of the instrument and the averaging effect over the sampling interval.

(c) Water Movement

An error could result if there is a significant current flow in the vicinity of the gauge, and it is incident on the pressure port. The acceleration of the fluid as it flows around the port could produce a local pressure decrease.

The fresh water flow was estimated for Harry's River for December 1986 to determine if flow could be a factor in the

accuracy of the water level measurements. The average flow for December 1986 was 15 m^3/s , less than half the mean annual average flow. Using an approximation of the cross sectional area of Harry's River at the gauge and a flow of 20 m^3/s , water velocity was calculated to be 0.04 m/s . A flow of this magnitude would not have a significant effect on pressure regardless of port orientation.

