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Site: New Bedford
Break: 4.4
Other: 49000

REPLY TO ATTENTION OF

SDMS DocID 49000

WESHE-P

6 May 1987

MEMORANDUM FOR RECORD

SUBJECT: Numerical Modeling of Sediment Migration From Pilot Dredging and Disposal, New Bedford Harbor, Massachusetts

Introduction

1. The USAE Waterways Experiment Station (WES), Hydraulics Laboratory is investigating the potential for sediment-associated contaminant migration as part of a dredging and disposal cleanup feasibility study of New Bedford Harbor, The major objective of Task 4, Element 5 of the study is to predict movements of sediments within and out of the upper harbor during dredging using schematic two-dimensional (2-D) numerical modeling.

2. This MFR summarizes results obtained for numerical hydrodynamic and sediment transport modeling of the proposed pilot dredging. Emphasis will be on the migration of various sediments out of the upper harbor. The association between sediments and contaminants will not be made here.

3. Computer codes RMA-2V and RMA-4 of the TABS-2 numerical modeling system developed at WES* were used to model vertically-averaged hydrodynamics and sediment transport, respectively. These models are implicit finite element solvers for the 2-D shallow-water Reynolds form of the Navier-Stokes equations, and the advection-diffusion transport equation. Sediment migration modeling was a two-step process, with hydrodynamic model calculations performed first and used to drive sediment transport calculations. Analyses of the sediment transport runs were then made to estimate the escape of resuspended sediments from the upper harbor.

Numerical-Hydrodynamic Modeling of New Bedford Harbor

4. Hydrodynamic modeling was performed to characterize hydraulic conditions and to generate data required for sediment transport modeling. The area of interest is above the Coggeshall Street Bridge. (See Figure 1) However, to properly describe boundary conditions, the model domain was extended downstream to the hurricane barrier. A numerical mesh of 219 elements was set up to cover the study area for use by both RMA-2V and RMA-4. (See Figure 2)

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* Thomas, W. A. and W. H. McAnally, Jr., "Open-Channel Flow and Sedimentation, TABS-2", Instruction Report HL-85-1, U.S. Army Eng. Waterways Experiment Station, Vicksburg, Miss., 1985.

HYDRAULICS LABORATORY | GEOTECHNICAL LABORATORY | STRUCTURES LABORATORY | ENVIRONMENTAL LABORATORY | COASTAL ENGINEERING RESEARCH CENTER | INFORMATION TECHNOLOGY LABORATORY

Encl 4

5. The numerical hydrodynamic modeling required specification of the seaward boundary as a time-varying water surface elevation and the upstream boundary as a time-varying inflow velocity. A mean-tide water level sequence observed during WES's 5-7 March 1986 survey at the tide gage on the end of Clark's Point was applied to the seaward boundary of the model. At the upper boundary of the model, velocities were specified which changed with the tide to correspond to a constant freshwater inflow of 30 cfs at all time steps.

6. The hydrodynamic model was adjusted to field data. Two element types were specified over the mesh, one type along the main channel, the other type covering areas close to the banks. Manning coefficients of 0.015 and 0.02, respectively, were specified for the two element types to obtain the best agreement with field data. A turbulent exchange coefficient of 50 sq lb-ft/sq sec was used.

7. Field versus model water surface elevation comparison at tide gage #3, and velocity comparisons at boat stations 5, 7, 8, and 9 are given in Figures 4 to 8. Figure 1 shows station locations and Figure 3 shows node locations used for the comparisons. Figures 9.a and 9.b are computed vector plots representative of the velocity field above the Coggeshall Street Bridge during flood and ebb tidal phases, respectively.

8. Hydrodynamic computations were performed by "spinning up" the model from a steady, flat water-surface condition. Results from model-time hour 7 to hour 29 were repeated four times to generate an 8 tidal cycle input file for sediment transport modeling.

9. The original mesh geometry was modified for sensitivity testing by lowering bed elevations by 3 ft in two areas, one in the lower and one in the upper portion of upper New Bedford Harbor (above Coggeshall Street Bridge). These two modified geometry conditions tested the effects on hydrodynamics of lowered bed elevations due to dredging.

Sediment Transport Modeling

10. Sediment transport modeling was performed to estimate escape probabilities from the upper harbor for various sediment materials which might be resuspended as a result of pilot dredging. Transport of resuspended sediment was modeled as a steady mass loading at specified points. Boundary concentrations were set to zero at the upper and lower boundaries of the mesh at all times when inflow occurred. Initial concentrations were set to zero at all mesh locations. Therefore, only sediments released at the mass-loading point were included in computations.

11. An arbitrary mass loading (in g/sec) was specified at node 66 in the vicinity of proposed pilot dredging. Additional transport computations were performed for resuspended sediment sources areas upstream from the pilot area at nodes 54 and 19. (See Figure 3.b) A dispersion coefficient of 5.0 sq m/sec was selected after some sensitivity tests, and used in all computations.

12. Deposition of sediments from suspension was included in sediment modeling as a sink term in the advection-diffusion transport equation. Five settling components or fractions were used to characterize a range of sediments (1) resuspended at the dredge head, (2) released with effluent from the proposed confined disposal area, and (3) which escape from confined aquatic disposal sites. The settling characteristics of resuspended sediments from each of these sources are expected to vary and must be independently evaluated. Settling velocity (W_s) was conservatively assumed to range from 0.01 to 0.2 mm/sec, and the depth (H) changed roughly 1 to 5 m over the area of interest. The effective sediment deposition coefficient used in the sink term of the transport equation is

$$\alpha = \frac{W_s P}{H}$$

where P is the probability of remaining on the bed after settling, assumed to range from 0.25 to 1.0. The five components were specified over the range:

$$0.10 < \alpha < 25.6,$$

where α has the units of 1/day. The sediment deposition coefficient of a sixth component was set to zero to represent a conservative substance and to normalize results from other deposition coefficients. Normalization of results was necessary to accurately define mass loading because, in the RMA-4 computer code, mass loading magnitude was found to be somewhat sensitive to release location, dispersion coefficient, and other conditions. Mass loading magnitude was also tested separately using steady-state RMA-4 solutions.

13. Contour plots of the concentration field with zero deposition coefficient during flood and ebb (Figures 10.a and 10.b) show that maximum concentration around the source area was about 3 mg/ℓ for a release rate of 17 g/sec. However, numerical model results overestimated spreading (and under estimated peak concentrations) near the source. Refer to WESHE MFR entitled "Plume Modeling of Proposed Pilot Dredging, New Bedford, MA" dated 29 January 1987 for near-field predictions. Concentrations were proportional to release rates. For instance, a release of 34 g/sec would have doubled the concentrations shown in Figure 10.

14. Representative values of W_s and $W_s P$ can be estimated from (1) settling rate measurements on field samples of resuspended sediments (presented in the WESHE MFR entitled "Sediment and Contaminant Release During Composite Sampling, New Bedford Harbor, MA" dated 28 January 1987), and (2) from deposition rates of naturally occurring sediments measured for the upper harbor (see WESHE MFR entitled "Baseline Conditions for Contaminant and Sediment Migration, New Bedford Harbor, MA" dated 26 January 1987).

Sediment Migration Analysis

15. Analysis of sediment transport model results was made to determine the escape probabilities of resuspended sediments released in the upper harbor permanently leaving the upper harbor. Average transport rates under Coggeshall Street Bridge during flood and ebb were computed after a spin-up time of from four to seven tidal cycles. The smaller the deposition coefficient, the longer the spin-up time to reach repeating tidal-averaged sediment transport rate. Mean sediment transport rate (in g/sec) during flood (L_f) was calculated by averaging over the flood portion of the tidal period, and over the cross section area under the bridge:

$$L_f = W \left[< \overline{CVH} > \right]$$

where

W = width
C = sediment concentration
V = current velocity
H = water depth

and where the overbar indicates area averaging, and angle brackets indicate averaging over a flood tidal phase. The ebb transport rate, L_e, was calculated similarly.

The escape probability as a percent of the mass loading was calculated as:

$$\frac{|L_e| - |L_f|}{\text{mass loading}} \times 100\%$$

Escape probabilities were calculated for each settling fraction, for the three resuspension source locations, and for the three geometries tested.

Results and Discussion

16. A plot of escape probabilities versus sediment deposition coefficient for mass loadings at the three different source locations is shown in Figure 11. Given mean tidal conditions, geometry, and the pilot dredging scenario, the most important factor determining sediment escape probability from the upper harbor is the sediment deposition coefficient, α. The escape probability decreased appreciably when the source area was moved upstream away from the bridge as shown in Figure 11. Results for lowered bed elevation showed only a very slight decrease in escape probabilities, and will not be presented here.

17. No field data exist to directly compare to sediment model results, but sediment transport results can be qualitatively compared to observed naturally-occurring deposition rates. Suspended sediments are tidally-pumped upstream into the upper harbor, where they deposit. The average α for

natural suspended sediments was estimated to be 1.0 from field data on suspended material concentrations and deposition rates taken during the three WES surveys and the 1983 three-tidal-cycle EPA survey. According to Figure 11, about 50 percent of sediment released near the pilot site with $\alpha = 1$ would escape from the upper harbor. The average ratio of deposition to flood tide flux of suspended material was 0.26 for the surveys, suggesting that the escape probability for $\alpha = 1$ was 74 percent for one tidal cycle. Of course natural sediments flushed from the upper harbor can return on the next flood tide, and possibly deposit. The probability of natural sediment escaping the upper harbor is not known but most probably much smaller than 74 percent, in general agreement with model results.

18. Results shown in Figure 11 can be used to estimate the escape of specific sediments from various sources for proposed pilot dredging.

BUFU YU
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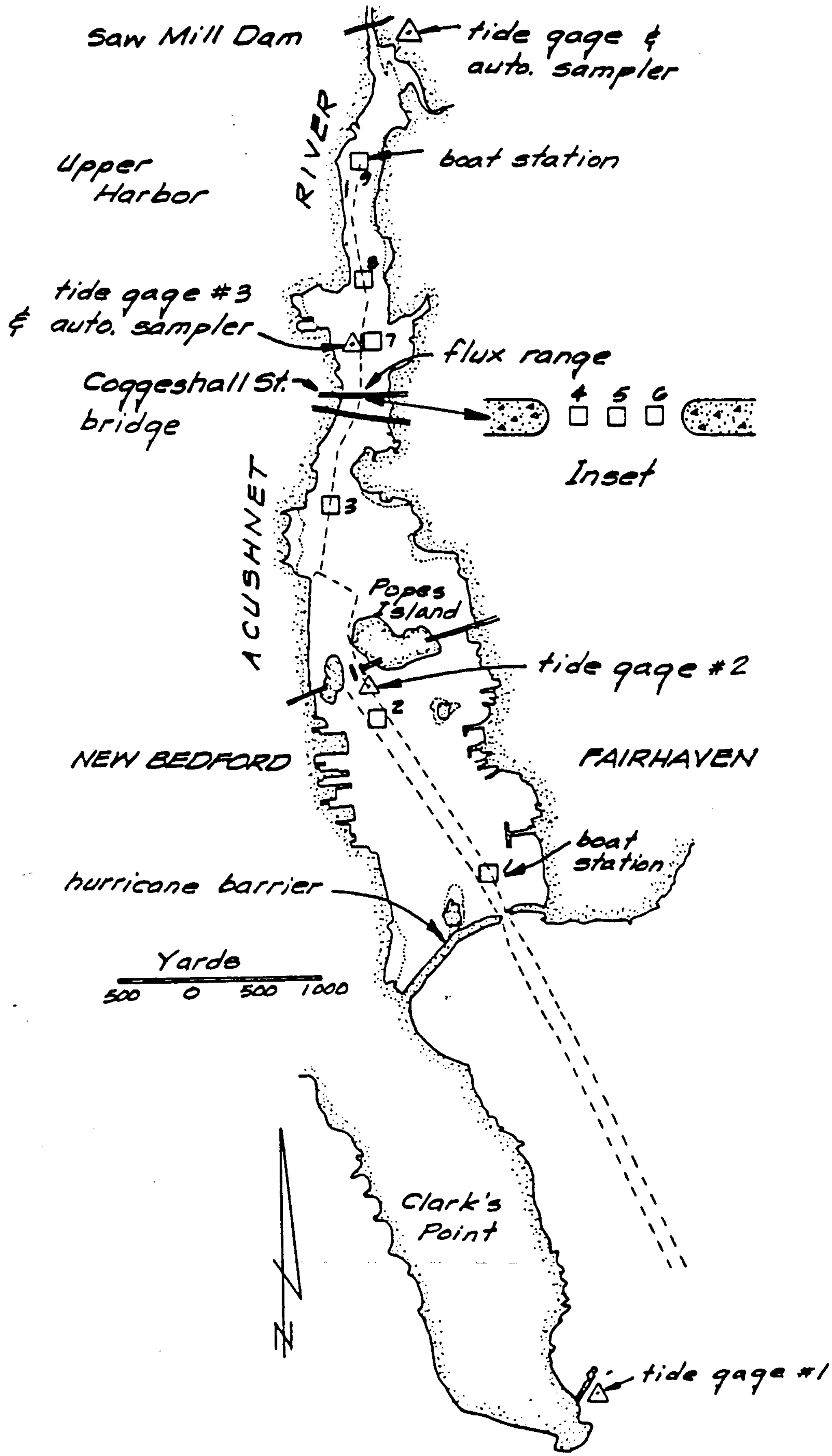
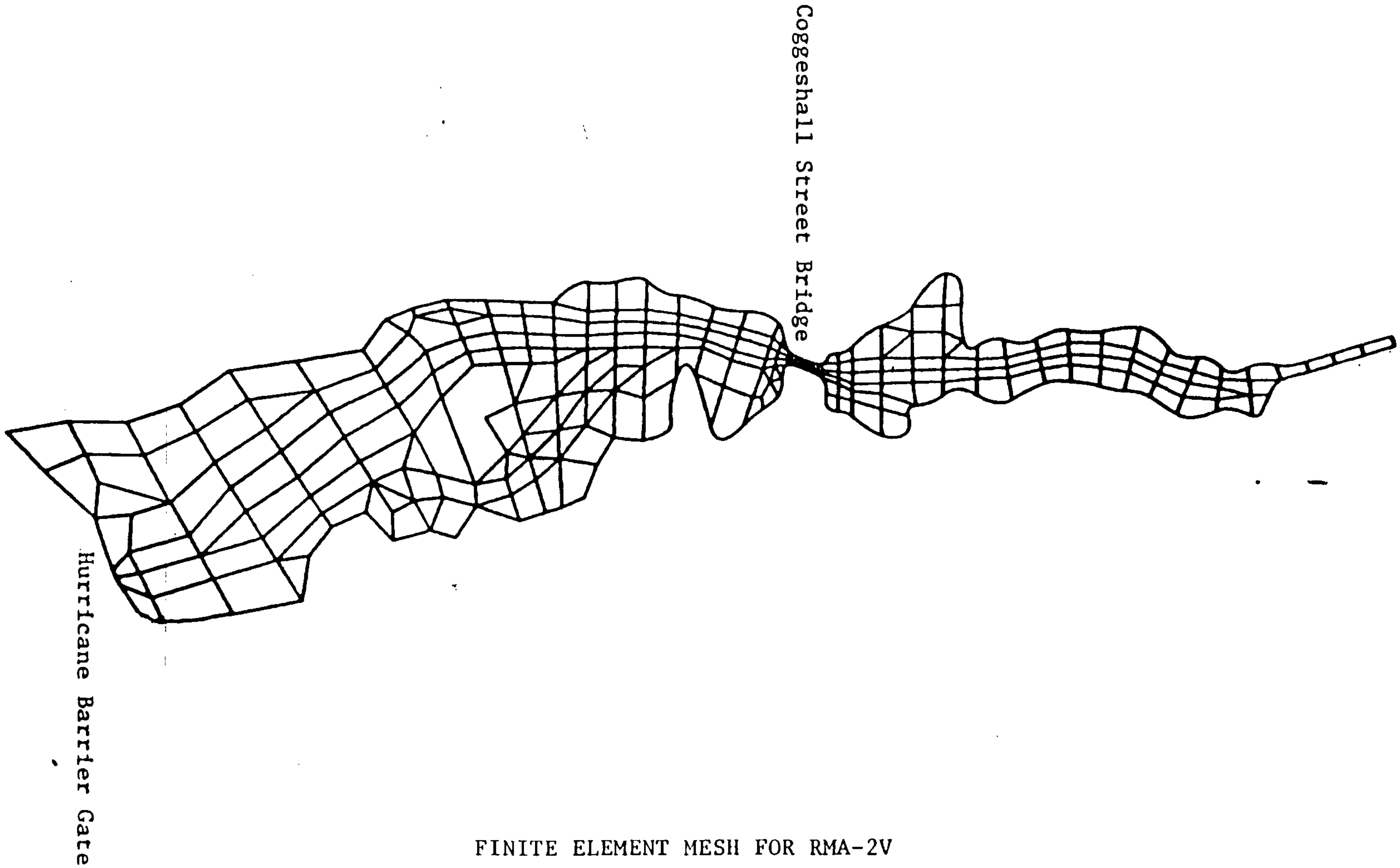
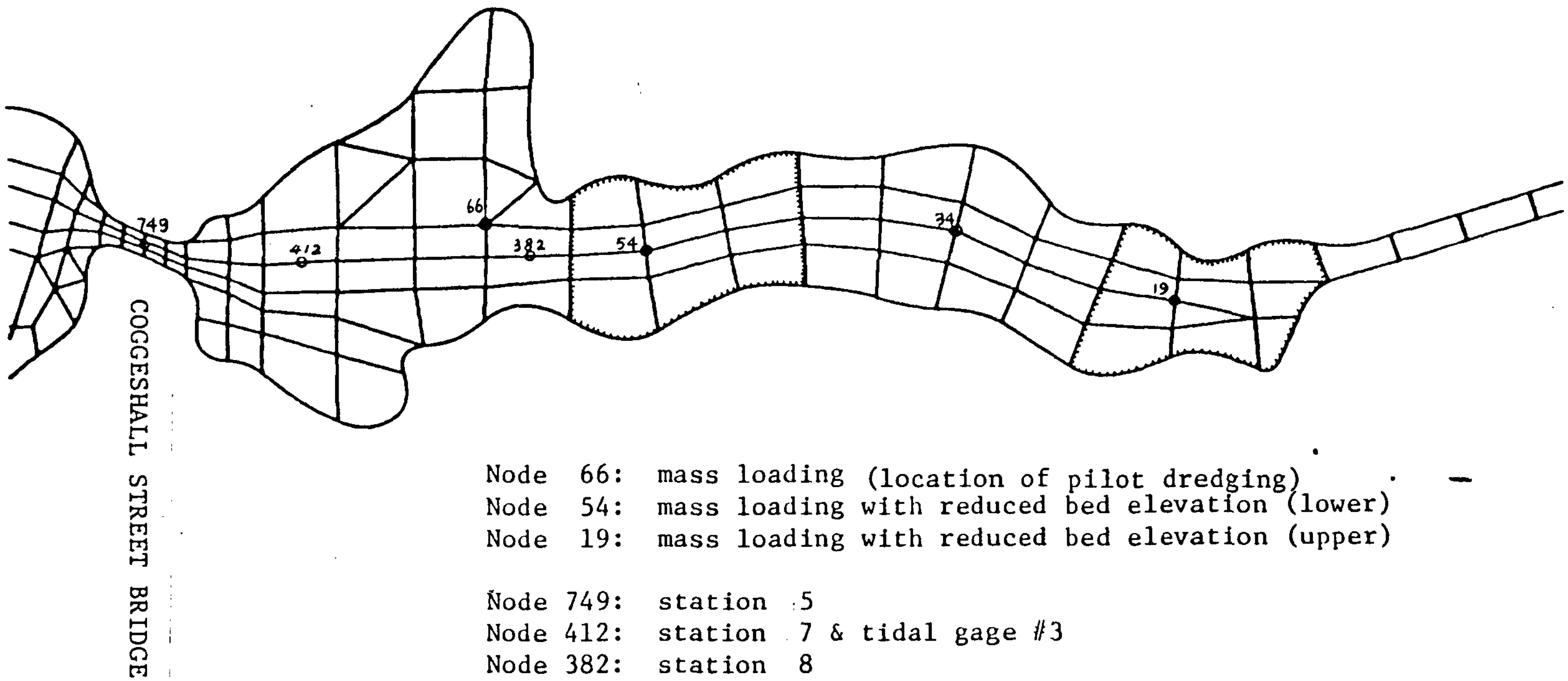


Figure 1. Sampling and gaging locations for New Bedford Harbor



FINITE ELEMENT MESH FOR RMA-2V

Figure 2



Node 66: mass loading (location of pilot dredging)
Node 54: mass loading with reduced bed elevation (lower)
Node 19: mass loading with reduced bed elevation (upper)

Node 749: station 5
Node 412: station 7 & tidal gage #3
Node 382: station 8
Node 34: station 9

Figure 3

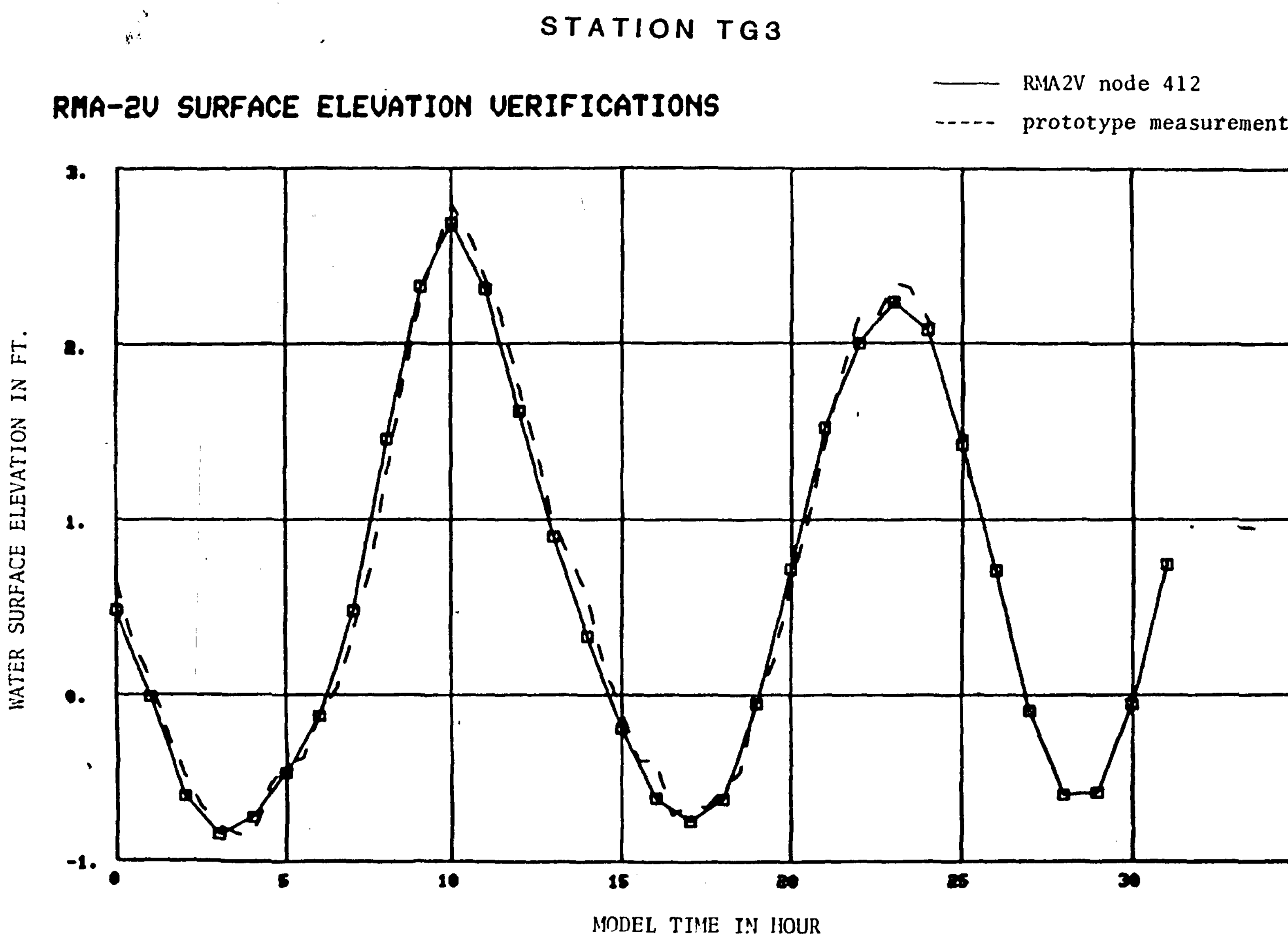
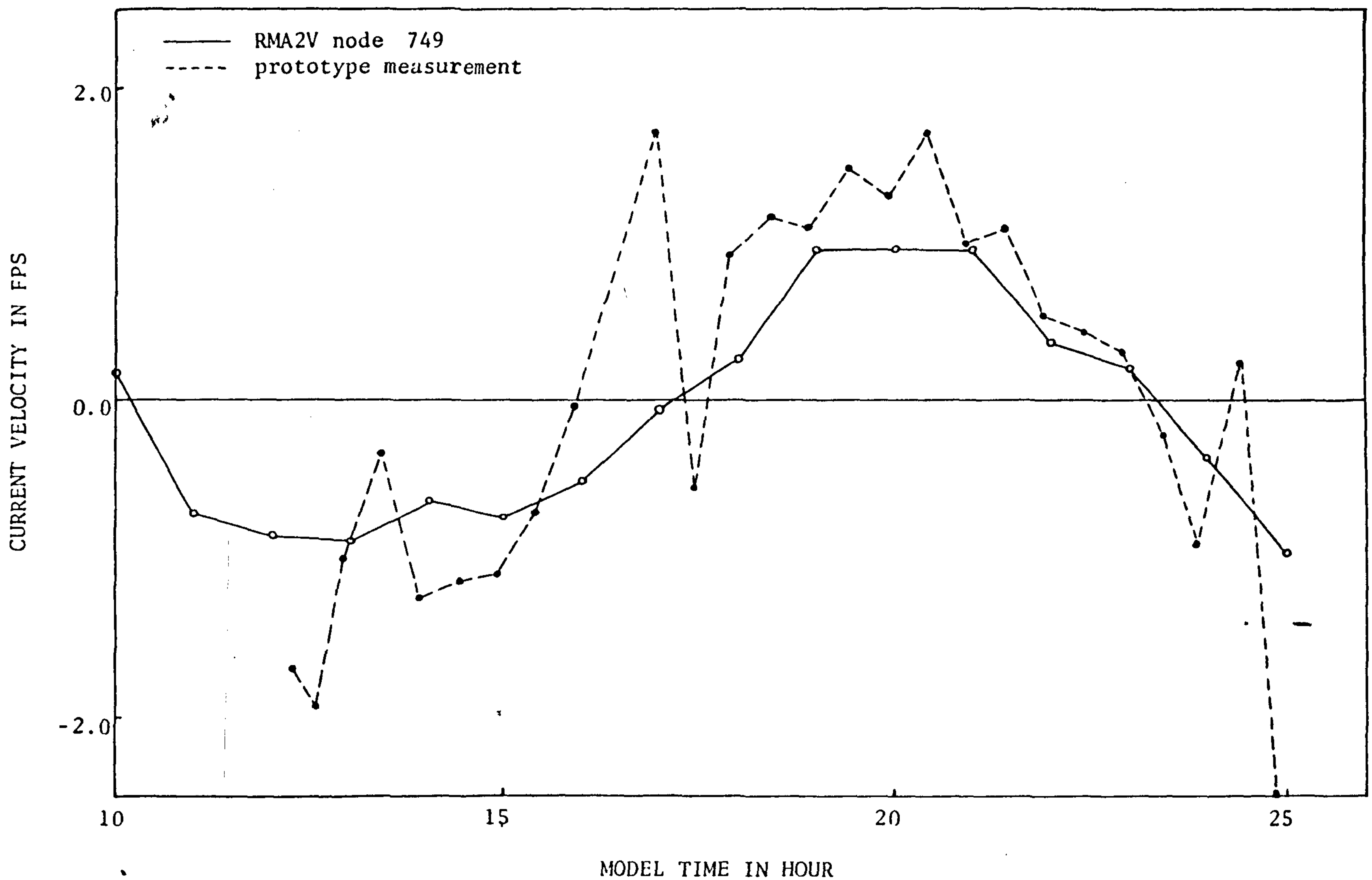
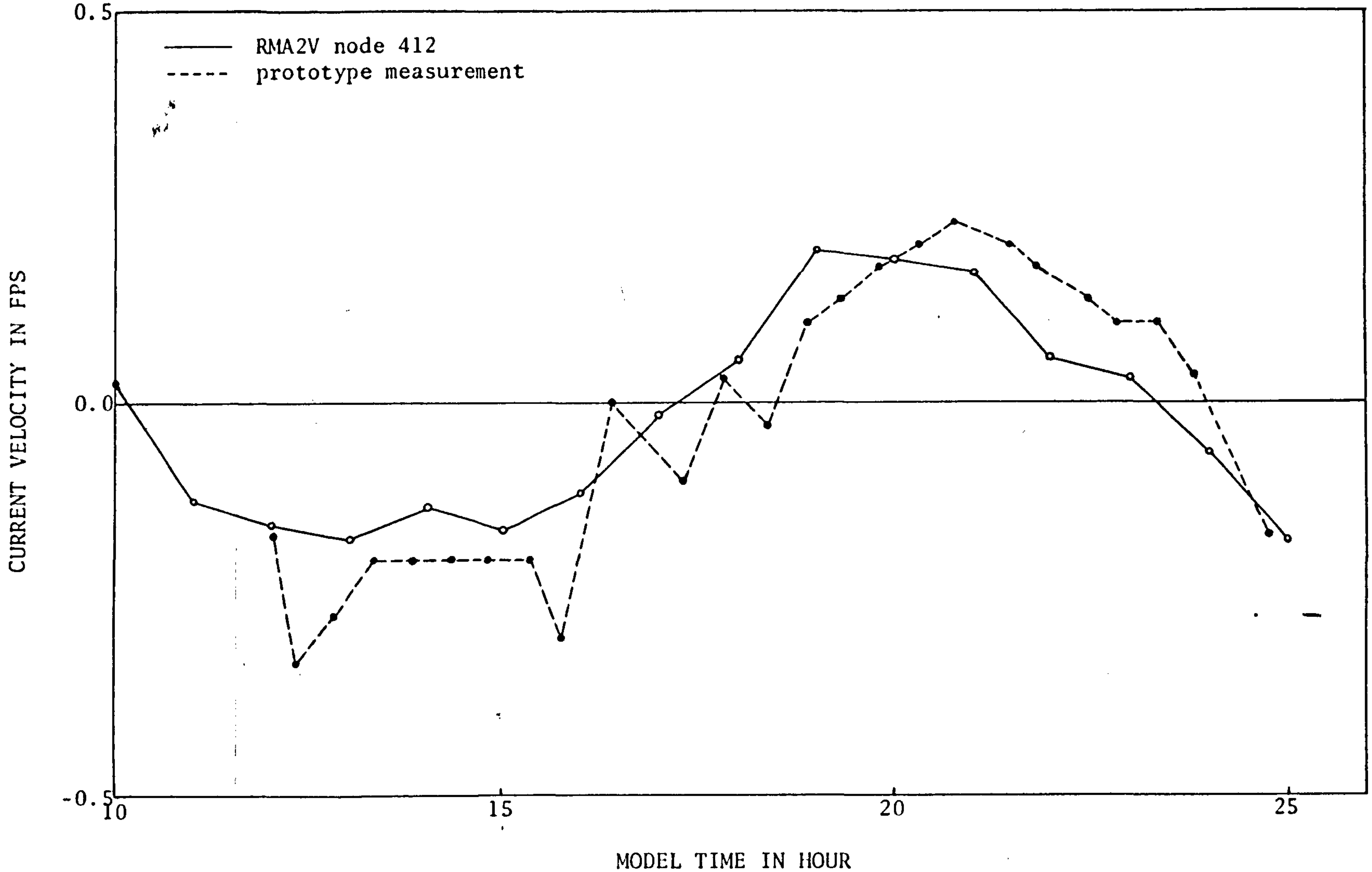

STATION TG3
RMA-2V SURFACE ELEVATION VERIFICATIONS
RMA2V node 412
prototype measurement
3.
2.
1.
0.
-1.
0
5
10
15
20
25
30
35
WATER SURFACE ELEVATION IN FT.
MODEL TIME IN HOUR

Figure 4



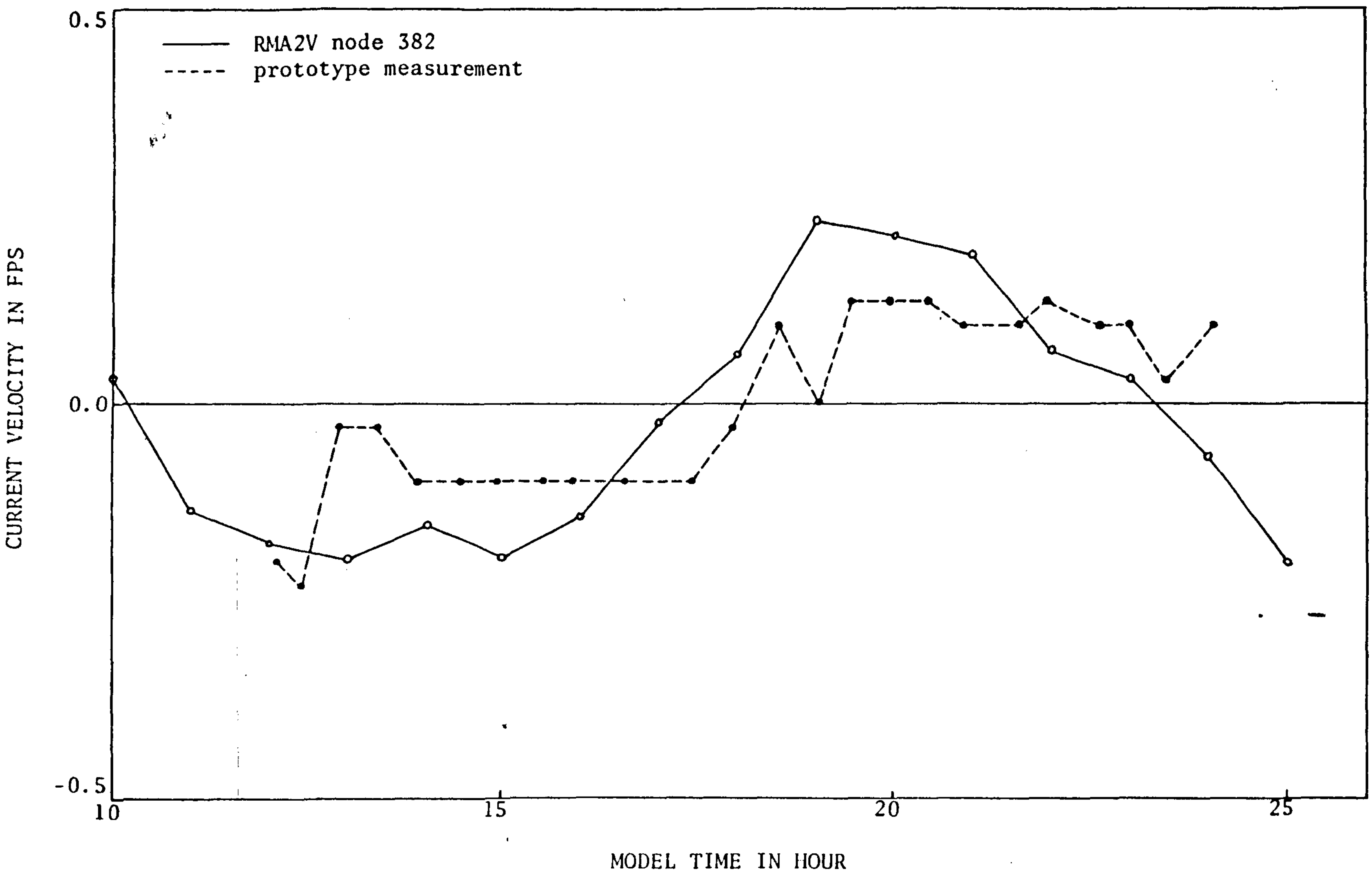
STATION 5

Figure 5



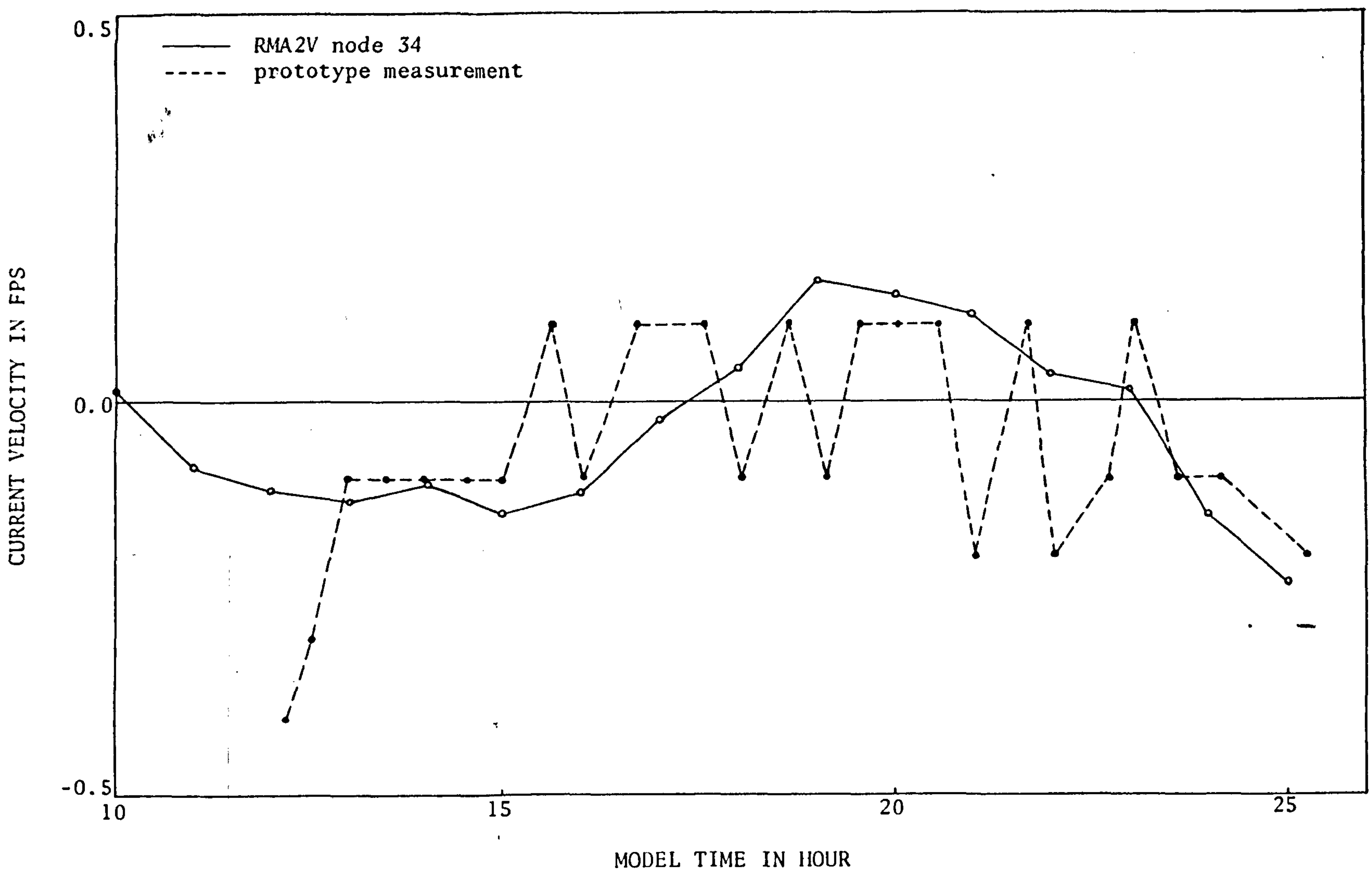
STATION 7

Figure 6



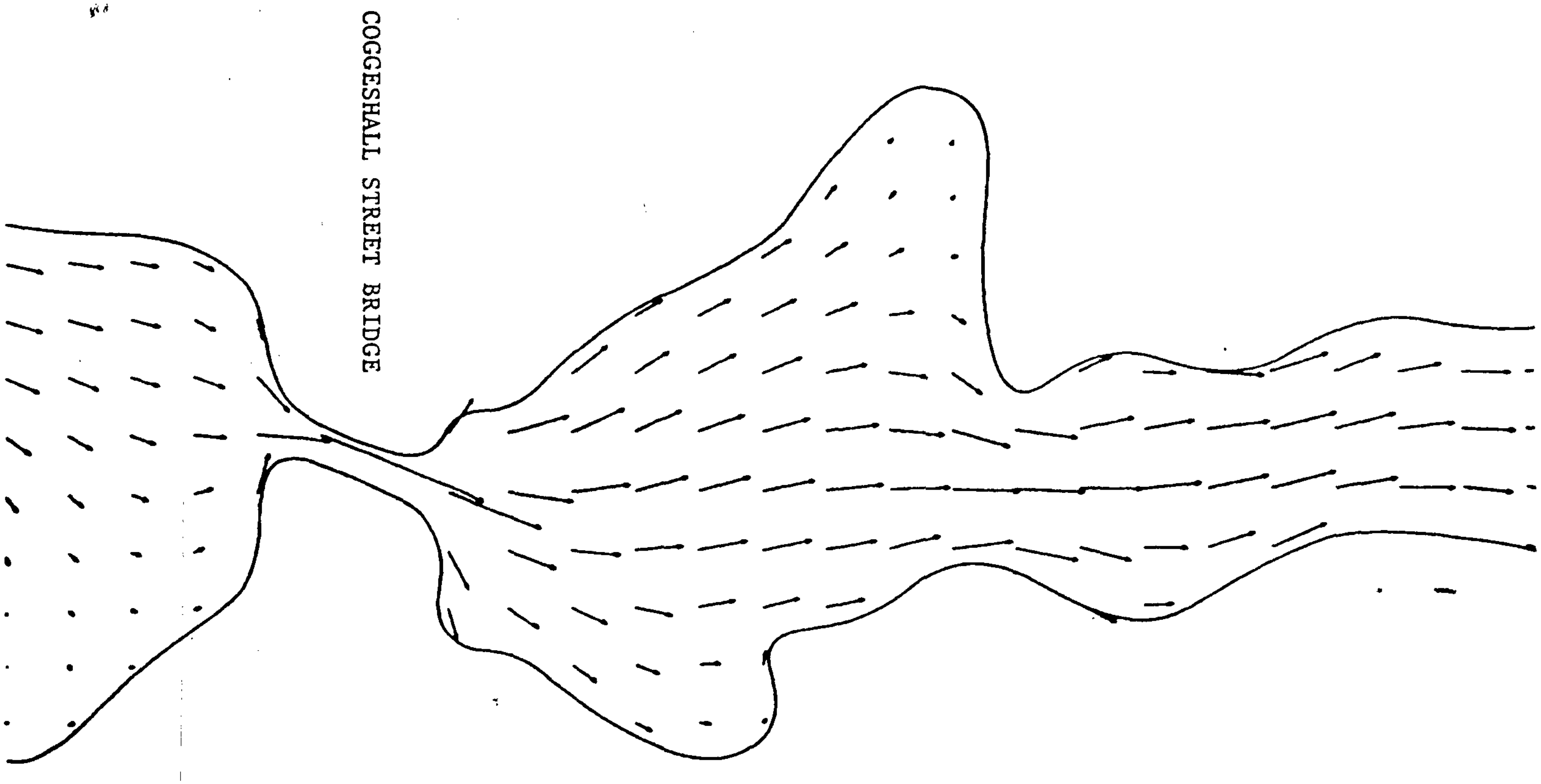
STATION 8

Figure 7



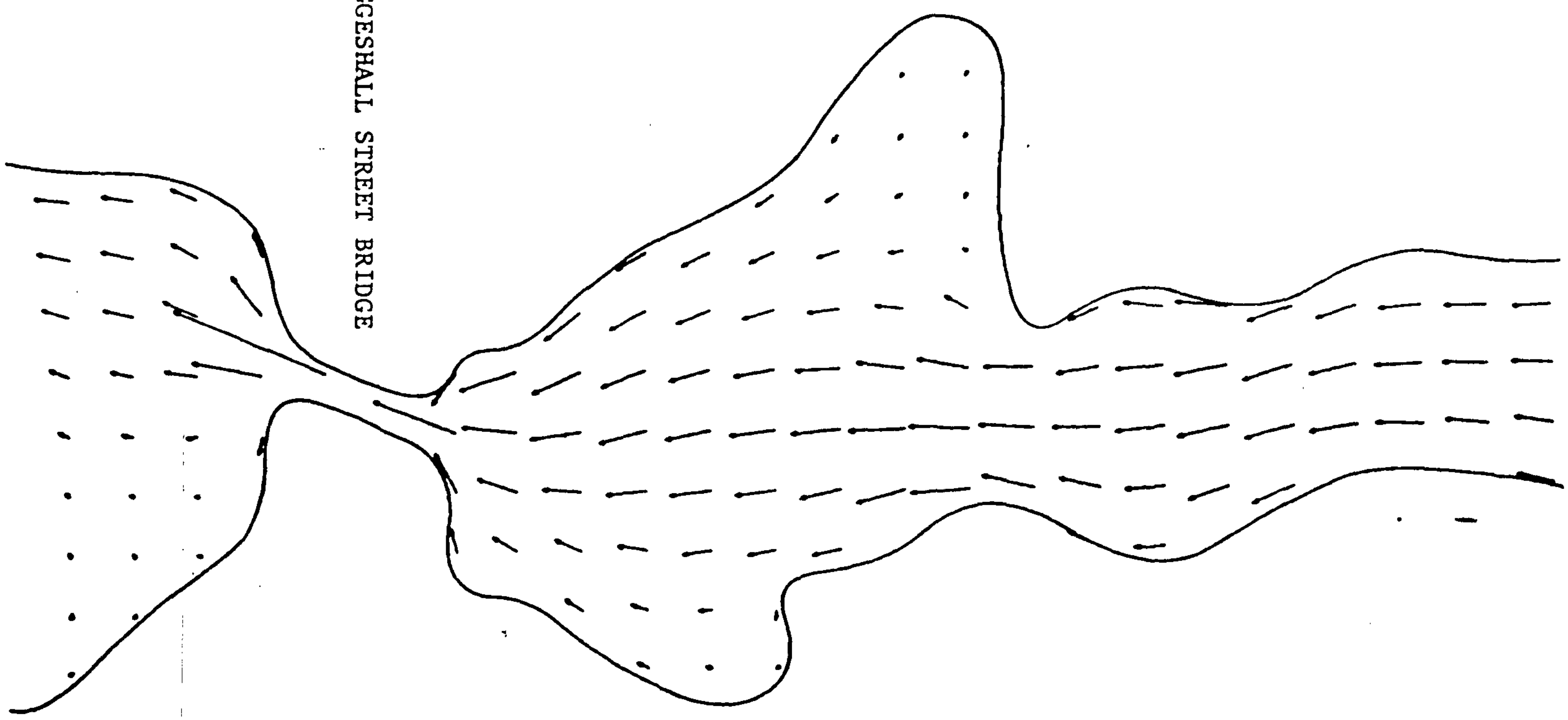
STATION 9

Figure 8



COMPUTED LOCAL VELOCITY FIELD, DURING FLOOD

Figure 9.a



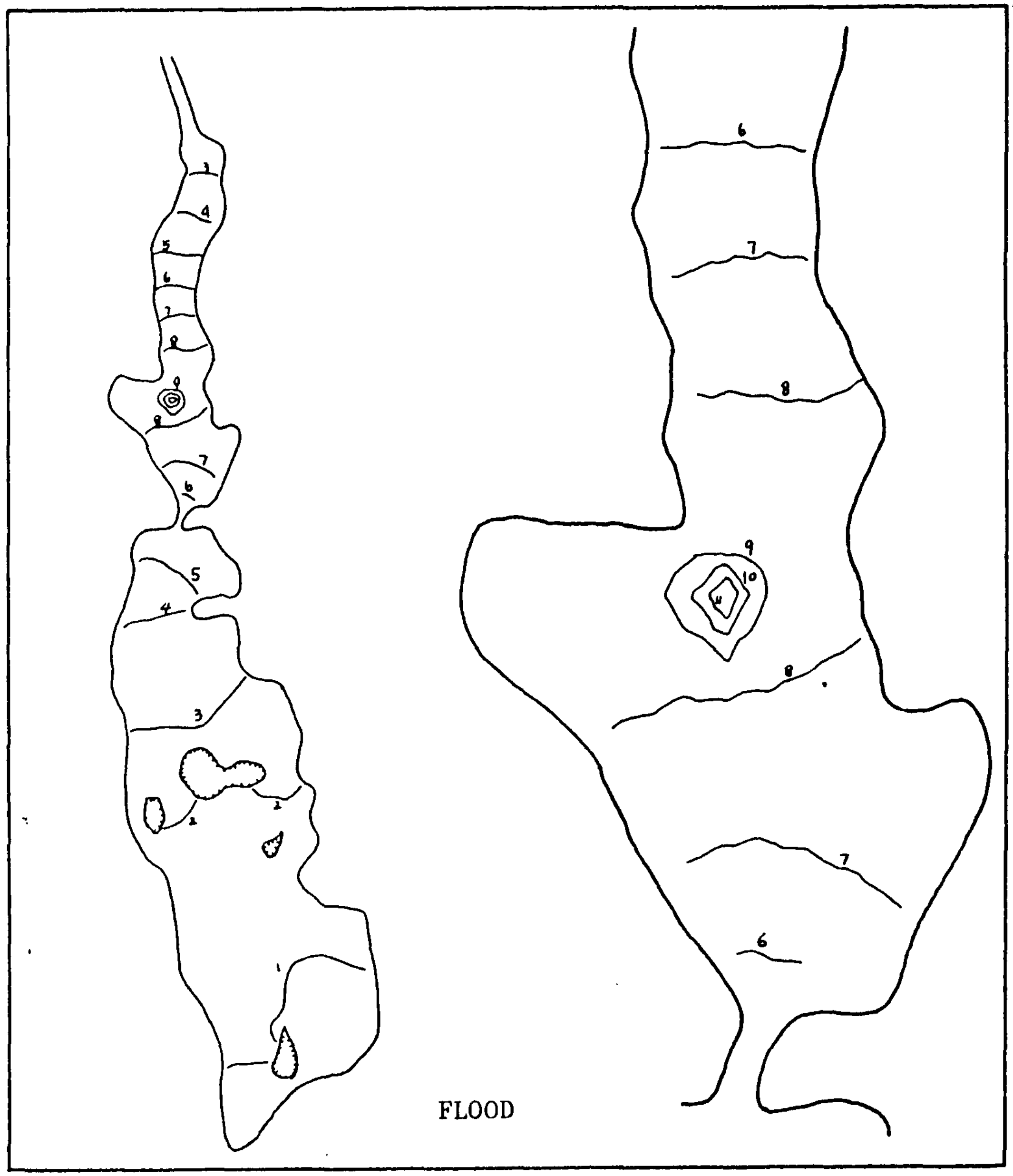
COMPUTED LOCAL VELOCITY FIELD, DURING EBB

Figure 9 .b

ISOLINES

1	.1
2	.4
3	.7
4	1.
5	1.3
6	1.6
7	1.9
8	2.2
9	2.5
10	2.8
11	3.1

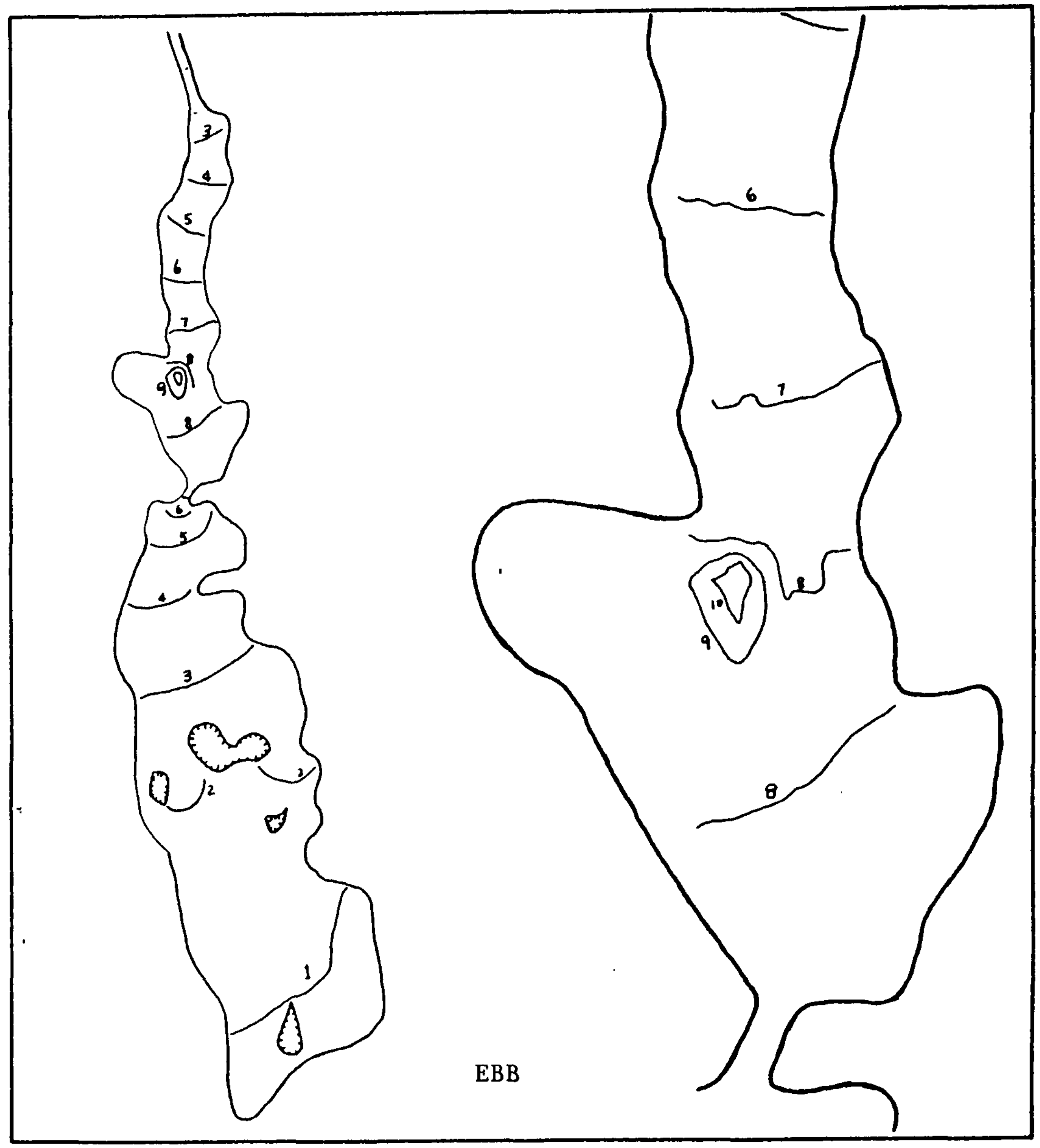
*unit in mg/l.



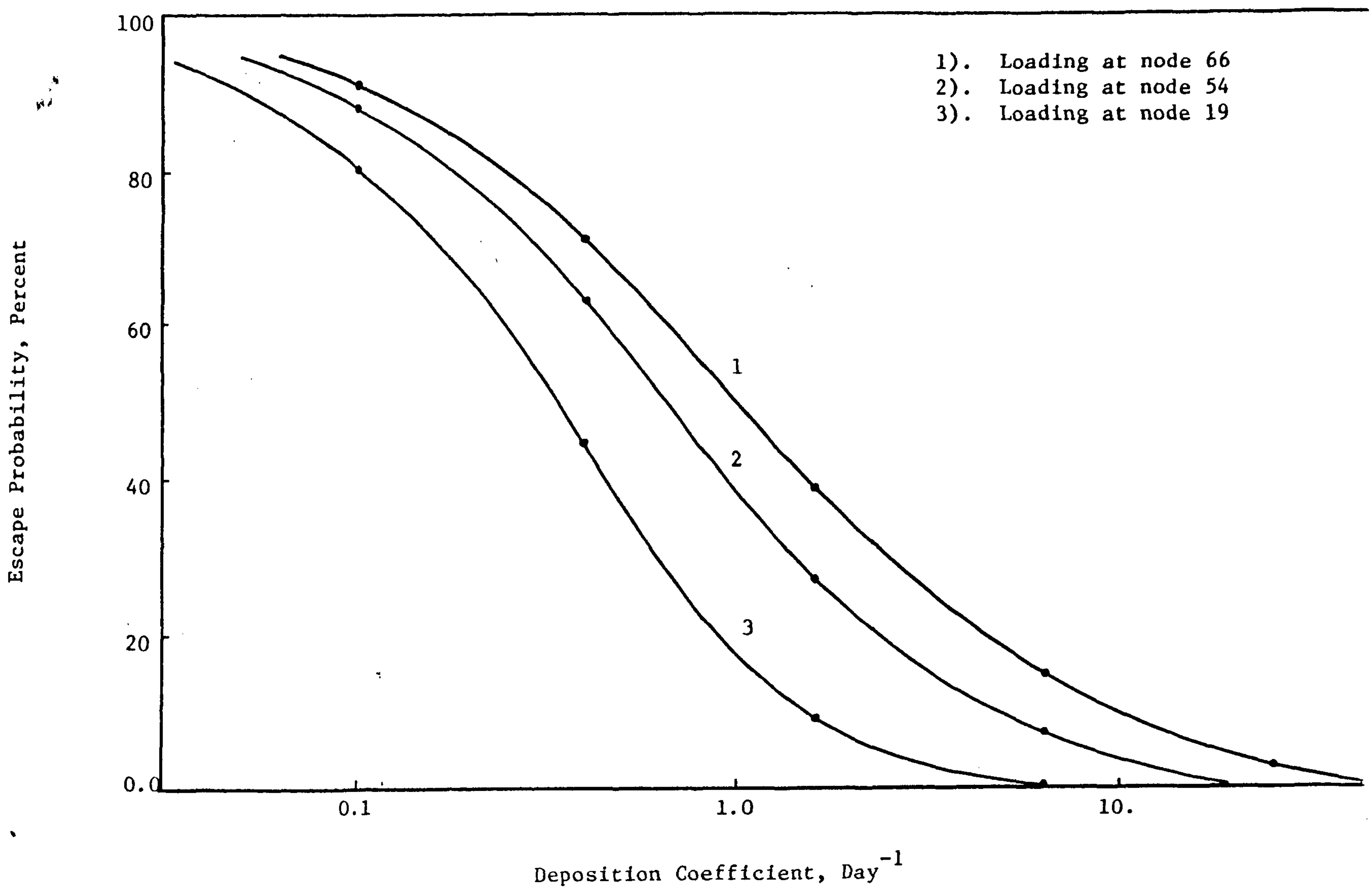
Sediment Concentration Field, Flood
Figure 10a

ISOLINES

1	.1
2	.4
3	.7
4	1.
5	1.3
6	1.6
7	1.9
8	2.2
9	2.5
10	2.8



Sediment Concentration Field, Ebb
Figure 10b



100
80
60
40
20
0.0
0.1
1.0
10.
Escape Probability, Percent
Deposition Coefficient, Day^{-1}
1). Loading at node 66
2). Loading at node 54
3). Loading at node 19
1
2
3

Figure 11