Appendix P
Dissolved Oxygen Modeling of Dredged Configurations

Flushing Calculations for Ohio and Allegheny River Dredged Areas

The Environmental Fluid Dynamics Model (EFDC) was used to estimate the relative flushing characteristics of several different dredge trench configurations for sand and gravel dredging operations in the Ohio and Allegheny Rivers. EFDC (Hamrick, 1992) is a 3-dimensional hydrodynamic fate and transport model suitable for determining flushing characteristics of a waterbody. Model data sets were developed for a series of 7 different dredge-trench design configurations (see figures for Case #1 through Case #7, Note: 1 unit block equals 3 ft).

Case #1 through #5 were designed to investigate flushing characteristics of different dredge dimensions having equal volumes, with trench depths ranging from 15 to 30 ft deeper than natural river bottom (assumed to be 18 ft deep, therefore, the trenches are 33 to 48 ft deep). Cases #6 and #7 were designed to investigate the differences in flushing rates of a small deep dredged pocket (90 ft long, 48 ft deep) versus a very long dredge trench at the same depth (1,000 ft long and 48 ft deep).

The model was run using the dye state variable to determine flushing times for each case. A constant flow rate of 18 m^3/sec (636 cfs) was specified for each case which resulted in average ambient velocities outside the dredged area of about 0.4 ft/sec. Initially, the dye concentration in all model grid cells was set to a value of 100 ug/L. The model was run for a spin-up period with the upstream boundary dye concentration also set to 100 ug/L to allow hydrodynamic conditions throughout the grid domain to reach an equilibrium steady-state condition. After equilibrium was achieved, the upstream dye concentration was abruptly set to zero and flushing commenced in the dredge trench. Flushing time was defined as the time (hours) it took for the dye concentration in a given model grid cell to be reduced to 5% of its initial value (i.e., reduced from 100 ug/L to 5 ug/L). The flushing times were contoured for each option (see attached figures). The relative mean volume-weighted flushing time for each dredge trench option was also computed from the model results.

The average mean flushing times were ranked to determine which case yielded the fastest overall flushing rate. The results are presented below in Table P-1. These results show that trench morphology has a significant impact on flushing rates. Of the cases presented below, Cases #2, #5, #6, and #7 generally represent realistic dredging profiles that can be found in the rivers today. By comparing the average mean flushing rates for Cases #2 and #5, it is evident that decreasing the dredging depth from 30 ft to 15 ft (or 48 ft to 33 ft when adding the natural river depth of 18 ft) had a marginal benefit on flushing rates (1.2 hours for Case #2 versus 1.7 hours for Case #5). On the other hand, elongating the trench, while keeping depth constant, significantly increased the flushing rate. The flushing rate for Cases #7 was 30 times faster than Case #6, which had the worst flushing rate, even though the depths were the same (i.e., 48 ft deep). In fact, Case #7 which has a dredging depth of 30 ft (48 ft overall) yielded a higher flushing rate than Case #2 which has a dredging depth of only 15 ft (33 ft overall). This result indicates that the aerial shape of the dredged trench (i.e., an elongated trench parallel to river flow) had a significantly greater impact on flushing than the depth of the trench.

Case #6 (90 ft opening with a 48 ft depth) offered the worst relative flushing of the 7 options. In comparison, the flushing rate for Case #7 was 30 times faster than Case #6, even though the depths were both 48 ft deep, as previously discussed. These results indicate that creating elongated dredged trenches may yield significantly higher flushing rates, which would significantly reduce the potential for low dissolved oxygen conditions in isolated deep pockets found in the study area. Furthermore, these results indicate that elongating existing small deep pockets in the study area with known low DO problems may significantly improve flushing and thereby improve DO levels.

Table P-1. Flushing Rates for Dredging Trenches[1]

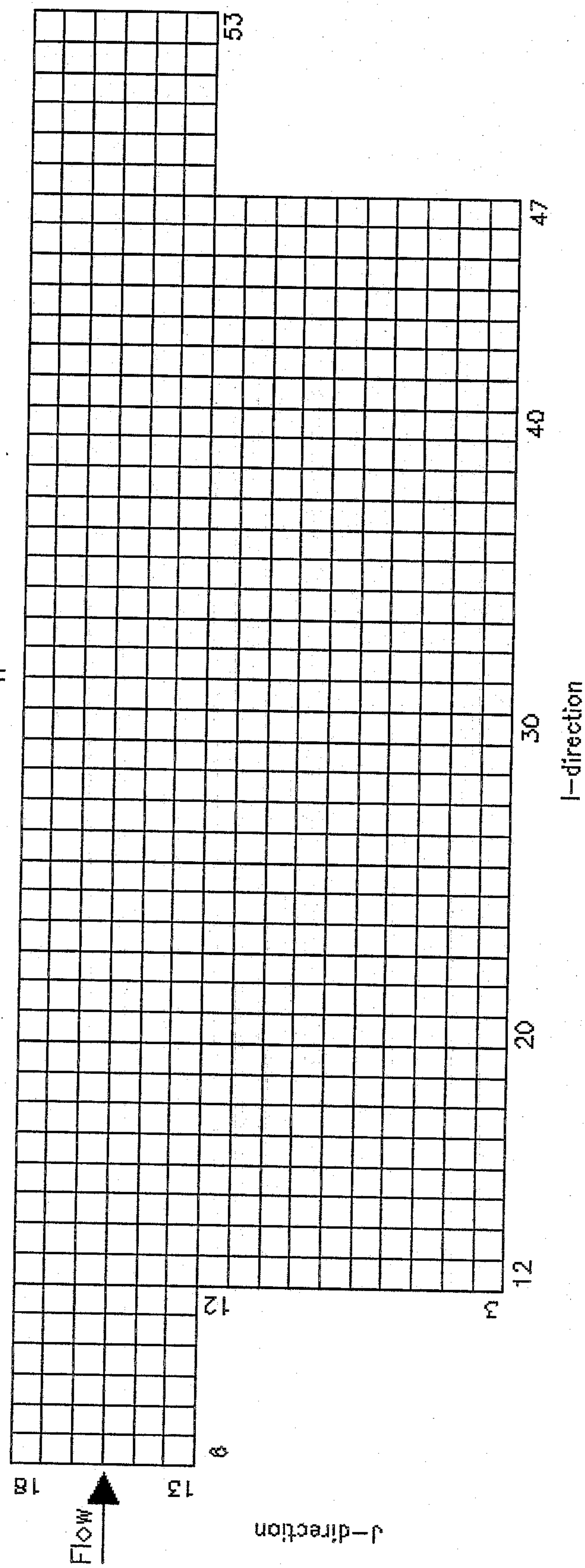
Rank	Case #[1]	Trench Dimensions (ft)		Description of Trench Bank	Mean Flushing Time (hr)[3]	Flushing Rate Relative to Case #7
		Length	Depth[2]			
1 (best)	Case #7	1000	30	Sloped banks upstream and downstream	0.3	
2	Case #3	130	30	Sloped bank upstream, vertical bank downstream	0.8	3x lower than Case #7
3	Case #2	200	15	Box configuration	1.2	4x lower than Case #7
4	Case #5	130	30	Sloped banks upstream and downstream	1.7	6x lower than Case #7
5	Case #4	130	30	Sloped bank downstream, vertical bank upstream	4.2	14x lower than Case #7
6	Case #1	100	30	Box configuration	4.4	15x lower than Case #7
7 (worst)	Case #6	90	30	Sloped banks upstream and downstream	9.1	30x lower than Case #7

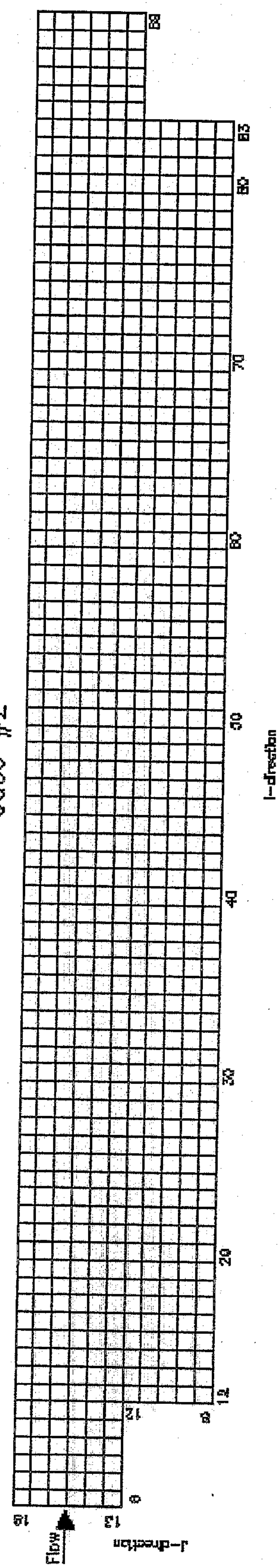
[1]Cases #1 through #5 have the same volume of material dredged with varying length, depth, and bank slope configurations. Cases #6 and #7 have the same depth and bank slope configurations, but vary in length.
[2]Depth represents the depth of trench from natural riverbottom depth which was set to 18 feet for the model. Therefore, a 30 ft dredged trench would be 48 ft deep overall, a 15ft trench would be 33 ft deep overall.
[3]Flush time adjusted to a unit volume equivalent to Case #6.

Reference:

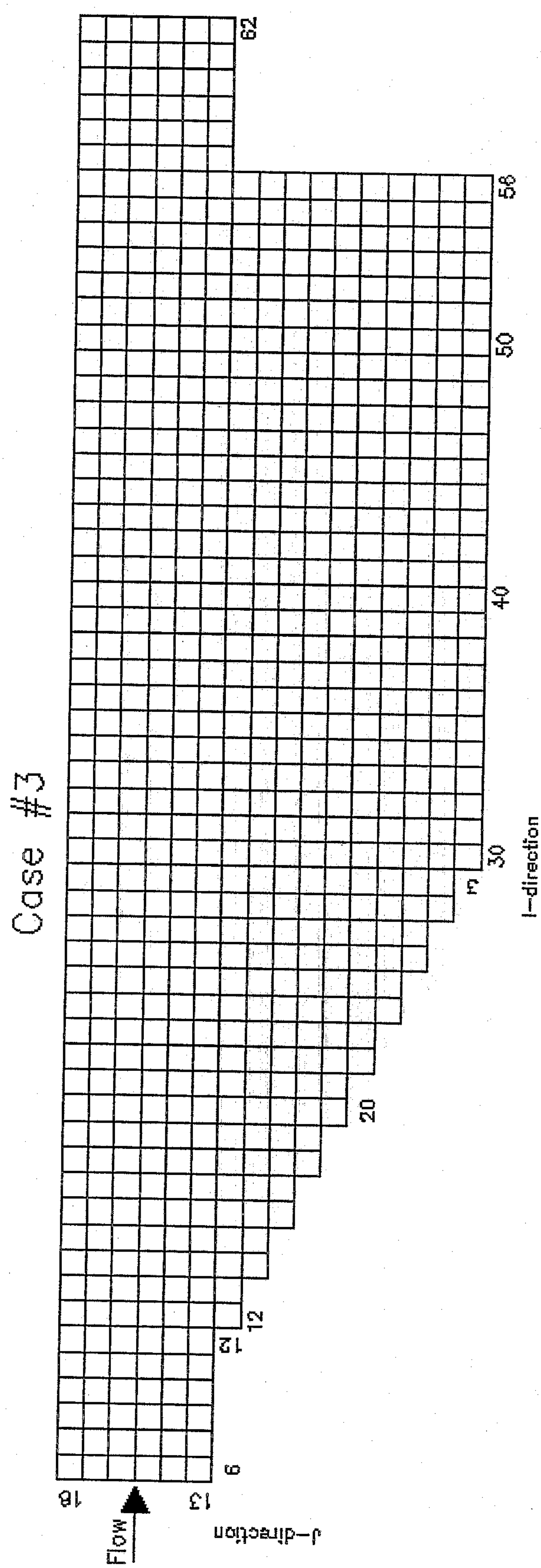
Hamrick, J.M. 1992. A three-dimensional environmental fluid dynamics computer code: theoretical and computational aspects. Virginia Institute of Marine Science, School of Marine Science, College of William and Mary, Gloucester Point, VA. Special Report No. 317, 63 pp.

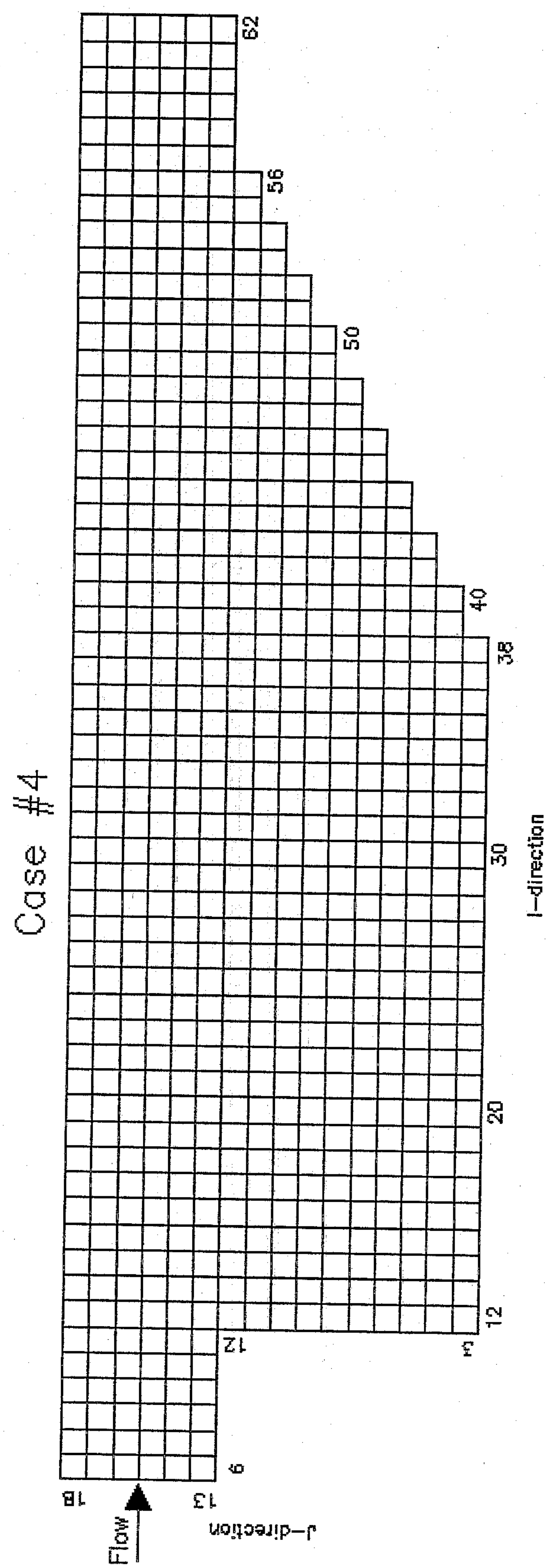
Case #1



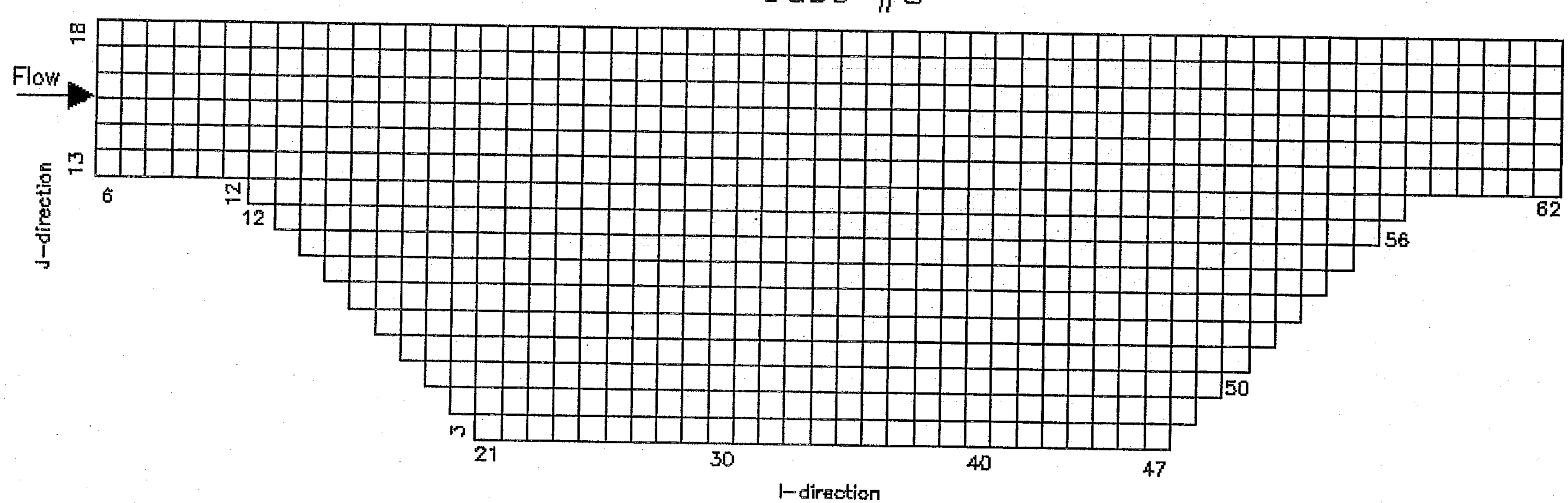


Case #2

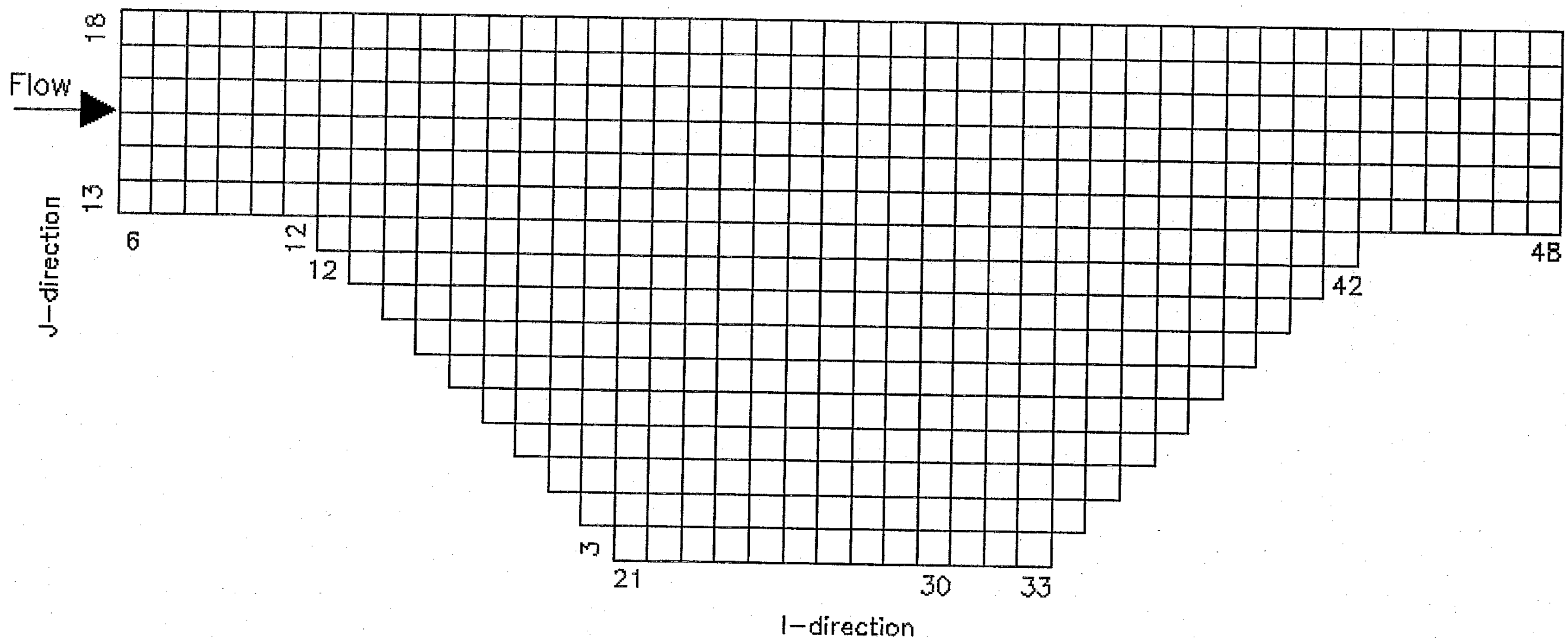

Case #3
I–direction
J–direction
Flow
6
12
20
30
40
50
58
62
13
18


Case #4
62
56
50
40
38
30
20
12
I-direction
3
12
6
18
13
Flow
J-direction

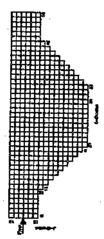
Case #5



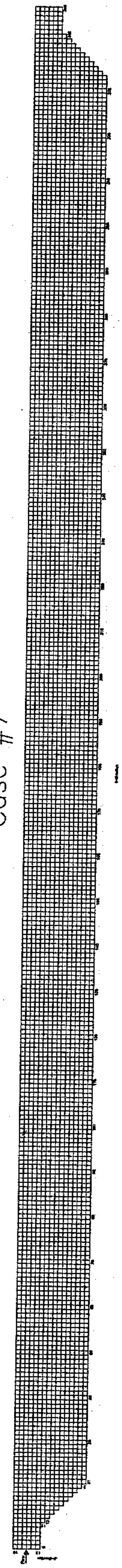
Case #6



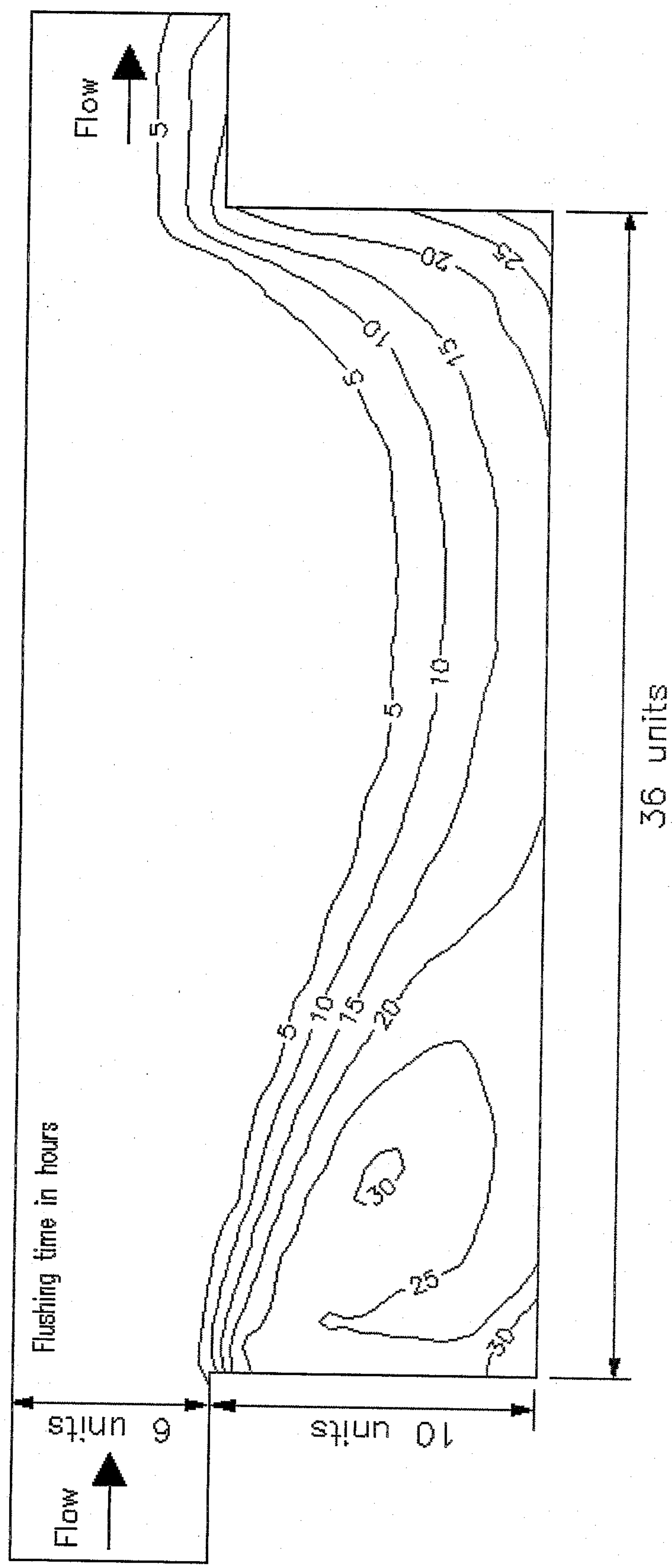
Case #6



Case #7

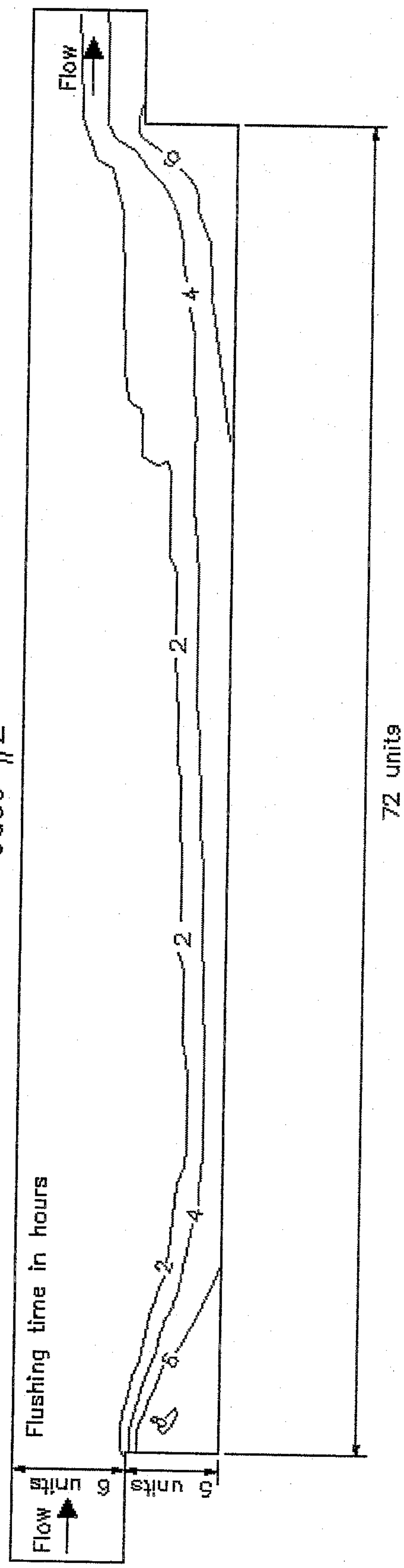


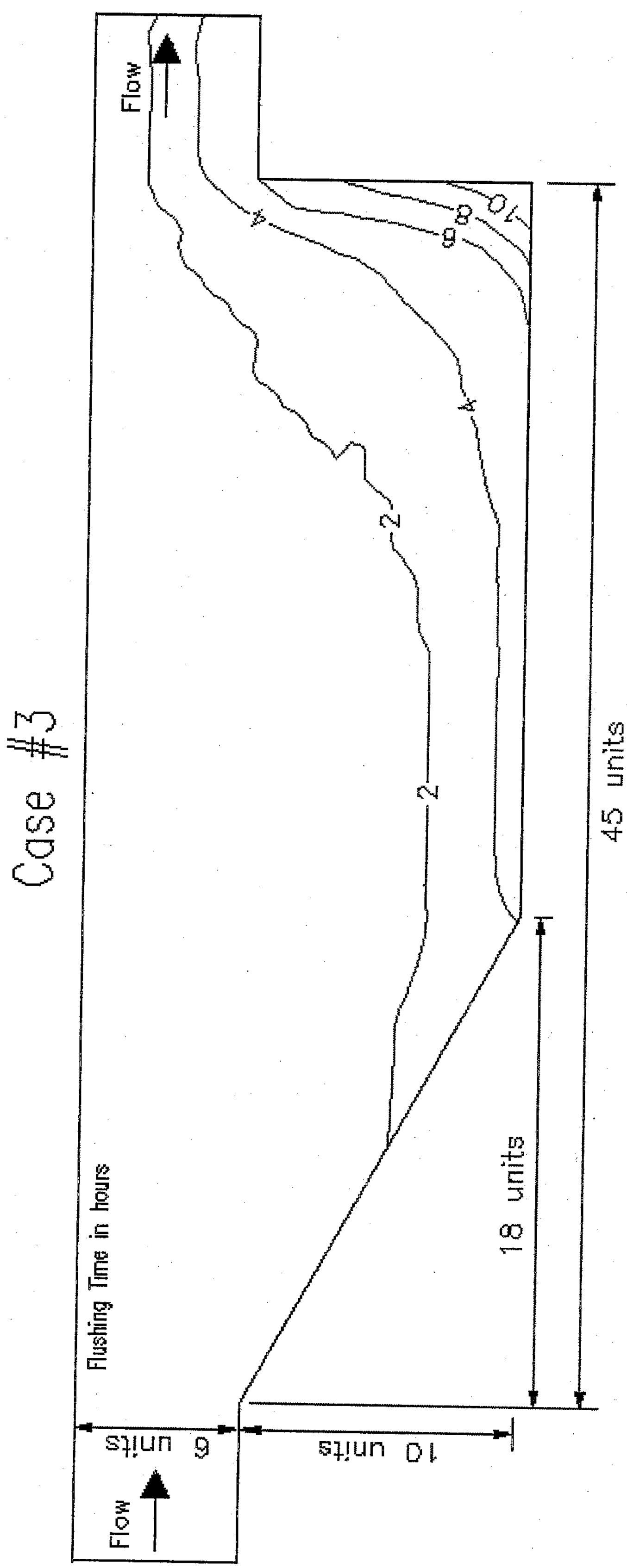
Case #1



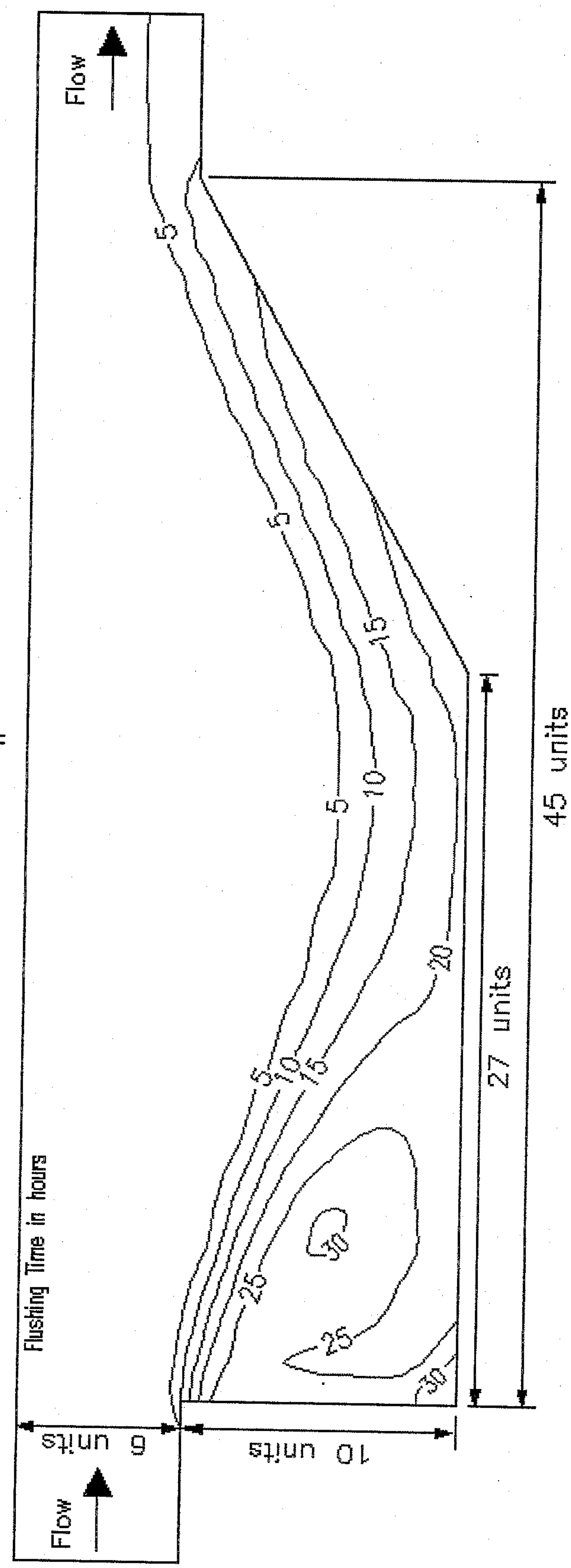
Flushing time in hours
Flow
Flow
5
5
5
5
10
10
10
15
15
20
20
25
25
30
30
6 units
10 units
36 units

Case #2


Flow
Flow
Flushing time in hours
72 units
6 units
5 units
2
2
2
4
4
6
6
8

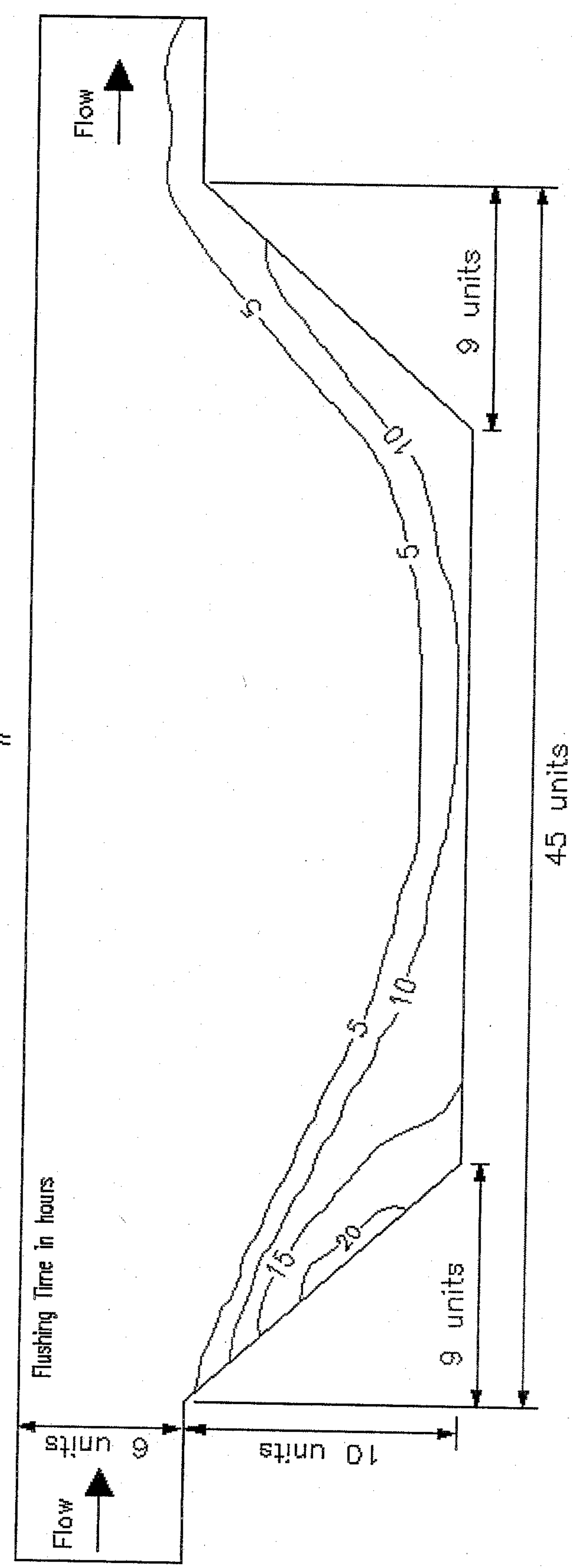

Case #3
Flushing Time in hours
Flow
Flow
6 units
10 units
18 units
45 units
2
2
4
4
6
8
10

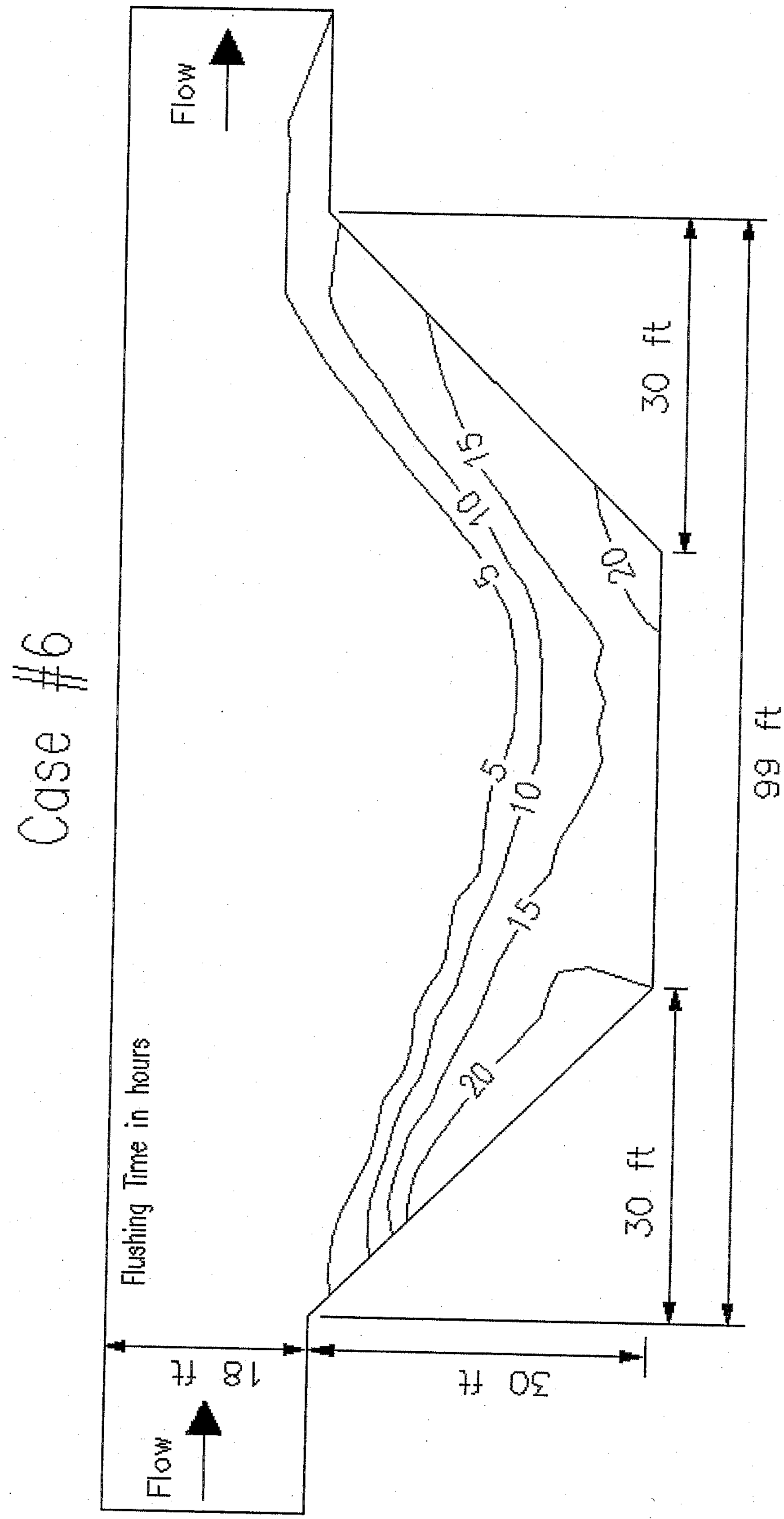
Case #4



Flow
Flushing Time in hours
5
10
15
20
25
30
45 units
27 units
10 units
6 units
Flow

Case #5


Flushing Time in hours
Flow
Flow
6 units
10 units
9 units
9 units
45 units
5
10
5
10
5
15
20


Case #6
Flushing Time in hours
Flow
Flow
18 ft
30 ft
30 ft
30 ft
99 ft
5
10
15
20
5
10
15
20

Case #7

Flushing Time in hours