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SEGMENTATION OF CHESAPEAKE BAY:

A REPRESENTATIVE EXERCISE

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Introduction

The goal of the CRC/RANN Waste Water Program is to provide the tools to management agencies which will enable them to make sound quantitative decisions on the siting of future sewage outfalls and the upgrading or elimination of existing sewage treatment plants. Obviously, the available funds do not permit extensive field studies at every possible outfall site. Therefore, some system is needed which will allow data to be transferred from one area to other areas within the Bay which have similar characteristics. A system of "segmentation", as suggested by Dr. D.W. Pritchard, was chosen by the Scientific Management Advisory Committee as the appropriate vehicle to achieve this transferability of the data. The following sections describe the philosophy for segmentation, the criteria to be used and two examples of the segmentation process using the Patuxent and Elizabeth River Estuaries as models.

Philosophy of Segmentation

The goal of the segmentation process is to reduce the number of sites which must be studied in order to characterize all portions of the Bay. Consequently the Bay must be segmented and similar segments grouped into classes. Ideally, for any given class of segments, the individual segments should be alike in physical, chemical and biological characteristics. However, if too stringent a requirement of similarity is made, the number of classes will be very large and many segments would be in classes with only one member. With this in mind, it should be noted that the biotic community is a result of the abiotic driving forces, or in other words, the physical-chemical environment determines the nature of the biological community inhabiting that environment. Presumably, then, if several segments of the Bay had similar physical and chemical properties, the biological communities in those segments would be very much alike as well. One portion of the proposed study is designed to verify this statement and to develop the criteria which will demonstrate biological similarity.

However, man complicates matters by altering the physical-chemical environment by activities such as dredging, nutrient loading, thermal loading and so on. He, thereby, also modifies the biota in those regions. In fact, it is just these modifications of the biological community due to present loadings which must be identified and measured to allow for predictions of the effects of future loadings. Therefore, the criteria for segmenting the Bay should be physical characteristics which are exclusive of the chemical inputs from man. In other words, the philosophy for segmentation is to choose criteria which will group estuarine segments into classes of similar physical characteristics, so that the differences in the biological communities among similar segments can be related to the man-made alterations, especially chemical additions.

Segmentation Criteria

There exist many possible physical characteristics which could serve as criteria for segmenting the Bay. Fortunately, many of these are closely related (e.g. morphometry and flushing rate). Salinity and morphometry appear to be the best physical characteristics for meeting the goals of segmentation. To this end the following preliminary criteria were adopted:

I. Salinity

A. Mean Annual Salinity (A vertical average weighted by width)

1. < 0.5%
2. 0.5 - 5.0
3. 5 - 11
4. 11 - 18
5. 18 - 24
6. 24 - 30
7. > 30

B. Mean Seasonal Range in Salinity

1. < 4%
2. 4 - 8
3. 8 - 12
4. > 12

C. Vertical Range in Salinity (the mean annual difference between bottom and surface)

1. < 1%
2. 1 - 3
3. 3 - 6
4. 6 - 10
5. > 10

II. Morphometry

A. At no point within a segment shall the area of a given cross section differ from the mean cross-sectional area by more than 50%.

B. Volume Mean Depth

1. < 1.5m
2. 1.5 - 3
3. 3 - 6
4. 6 - 10
5. > 10

C. The Ratio of Maximum Depth to Volume Average Depth

1. < 1.5
2. 1.5 - 4.0
3. > 4.0

The Patuxent River

In order to segment according to the above criteria, reasonably detailed seasonal salinity records are necessary. Fortunately, such seasonal data were available for the Patuxent River Estuary from the river study of Flemer et al. (1970) for the portion of the river from Queen Tree Landing (river mile 15) upstream to Hill's Bridge.

The top and bottom seasonal averages are recorded in Table 1 for the fourteen stations monitored. The salinity ranges and top to bottom differences are also included in the table. It should be pointed out that the salinity samples were taken on a monthly basis irrespective of tidal stage, and hence are subject to further refinement. Morphometric data were taken from the CBI report by W. B. Cronin. (W. B. Cronin. Volumetric, Areal, and Tidal Statistics of the Chesapeake Bay Estuary and its Tributaries. CBI Special Report 20, Ref. 71-2, March 1971.)

Although few stations share exactly the same 5-tuple of descriptors, there appear to be definable groupings. Without defining a "metric" between the n-tuple of descriptors to quantify the degree of similarity or overlap between two points, the author has used subjective judgment to arrive at the seven groupings shown in Table 2. Finally, the groupings were compared with the navigation chart and prominent landmarks chosen as segment boundaries.

The first three segments are differentiated predominantly by morphology. All three are mesohaline with a moderate seasonal range and moderate to strong stratification. Segment 1, the Basin, is a deep flat zone in comparison to Segment 2, the Narrows, or the deep narrow channel around Point Patience. Segment 3, the Valley, broadens out into a reasonably straight and uniform channel of a drowned river valley. There is little difference in the natural biota of these three segments, but their respective responses to wastewater loading would be different because of the differing hydrodynamic characteristics.

The next two segments are both in the lower mesohaline salinity range and represent the gradual constriction of the river. Segment 4, the Trap, is where much of the suspended sediment and associated nutrients settle to the bottom. Segment 5, the Transition Zone, is an area of high seasonal variation in salinity.

The final two segments are characterized by the adjacent areas of low-saline marshes. Unfortunately, none of the present criteria specifically

STATION	RIVER MILE	MEAN TOP SALINITY (‰)	MEAN BOTTOM SALINITY (‰)	SALINITY RANGE (‰)	TOP-BOTTOM DIFFERENCE (‰)	VOLUME MEAN DEPTH ([illegible])	MAX.DEPTH MEAN DEPTH	TYPE
1	-	0.173	-	2.1	-	-	-	111--
2	-	-	-	-	-	-	-	111--
3	-	-	-	-	-	-	-	111--
4	-	0.204	-	2.0	-	-	-	111--
5	-	-	-	-	-	-	-	-----
6	34.0	0.611	0.815	2.7	0.2	3.00	3.0	21132
7	30.0	2.314	2.989	4.5	0.7	4.94	1.9	22132
8	27.0	4.089	5.482	8.3	1.4	4.43	1.0	23231
9	26.2	6.085	7.394	9.4	1.3	2.04	2.0	33222
10	25.5	7.900	8.963	8.9	1.1	1.58	2.5	33222
11	24.5	8.736	-	12.2	-	1.75	2.3	34222
12	23.5	9.448	9.867	7.3	0.4	1.08	5.0	32113
13	22.0	10.304	11.889	7.4	1.6	1.55	7.0	32223
14	15.0	12.043	13.900	7.0	1.9	2.91	4.0	42223
15	13.0	-	-	-	-	5.52	1.9	---32
16	12.0	-	-	-	-	4.83	2.8	---32
17	9.0	-	-	-	-	4.41	5.5	---33
18	6.0	-	-	-	-	6.34	4.8	---43
19	3.0	-	-	-	-	8.52	1.8	---42
20	1.0	-	-	-	-	6.43	2.0	---42

Table I. Segmentation data for the Patuxent River addresses the presence of marshes. Nonetheless, Segment 6, the Lower Marsh, is differentiated from Segment 7, the Upper Marsh, in that the former is oligohaline and the latter a brackish-water tidal estuary.

Table 2.

Grouping of Patuxent River Stations by Descriptors

Station	Salinity	Seasonal Range	Vertical Range	Mean Depth	Max. Depth / Avg. Depth	
1	1	1	1	(2)	?	Upper Marsh
2	1	1	1	(2)	?	
3	1	1	1	(2)	?	
4	1	1	1	(2)	?	
5	1	1	1	(2)	?	
6	2	1	1	3	2	Lower Marsh
7	2	2	1	3	2	
8	2	3	2	3	1	Transition Zone
9	3	3	2	2	2	
10	3	3	2	2	2	
11	3	4	2	2	2	
12	3	2	1	1	3	The Trap
13	3	2	2	2	3	
14	4	2	2	2	3	The Valley
15	(4)	(2)	(2)	3	2	
16	(4)	(2)	(2)	3	2	
17	(4)	(2)	(3)	3	3	The Narrows
18	(4)	(2)	(3)	4	3	
19	(4)	(2)	(3)	4	2	The Basin
20	(4)	(2)	(3)	4	2	

Note: Parentheses indicate educated guesses.

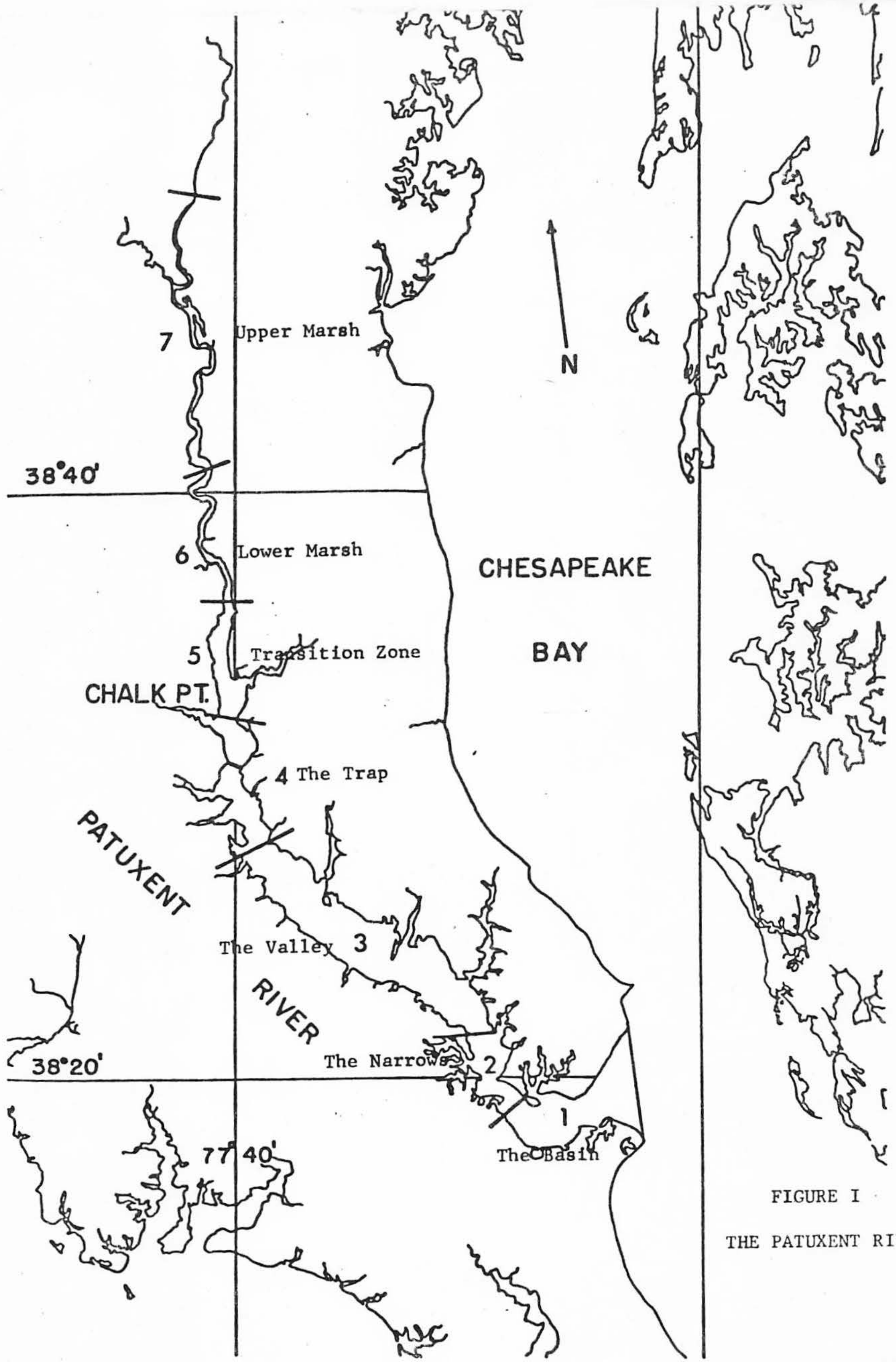

FIGURE I

THE PATUXENT RIVER

The Elizabeth River

The Elizabeth River was surveyed during 1973 and 1974 because it receives a large volume of effluent from the sewage treatment plants in metropolitan Norfolk. The data collected during the RANN-supported hydrographic surveys and the slack water monitoring represent the major portion of the data available on the Elizabeth River system. Therefore, the resulting segments should be viewed as preliminary choices since the data do not cover the spatial and seasonal variations to the extent that is ultimately desired. The multibranched nature of the Elizabeth makes it an interesting variant from those estuaries which have a single major branch and are more typical of the Chesapeake Bay tributaries.

The Elizabeth River also differs from many of the other Bay estuaries since it has a relatively constant salinity structure. The mean annual salinity ranges between 18 and 24 parts per thousand (ppt) for all but the most upstream reaches, and the seasonal variation appears to be less than 4 ppt for the entire river system. The vertical range, however, decreases from 3 - 6 ppt at the mouth, to 1 - 3 ppt between miles 2 and 6, and to less than 1 ppt for the rest of the river. The salinity criteria, then, divide the entire river system into only four segments.

The morphometry of the Elizabeth, on the other hand, is quite complex. The cross-sectional area is reasonably constant ($\pm$ 50%) for only small reaches, none longer than 5 miles. These are connected by transition zones, wherein the area changes much more drastically (more than 50%). The mean depths vary from more than 6 meters to less than 1.5 meters, and the depth ratios vary from less than 1.5 (a reach which has piers on both sides and a wide dredged channel) to greater than 4 (for the most upstream and "natural" portions of the branches). The end result of this segmentation process is a large number of segments that are relatively short (length 1 to 4 nautical miles). The combined segmenting criteria result in the division which is shown in Figure 2. The data for individual mile segments are given in Tables 3 and 4.

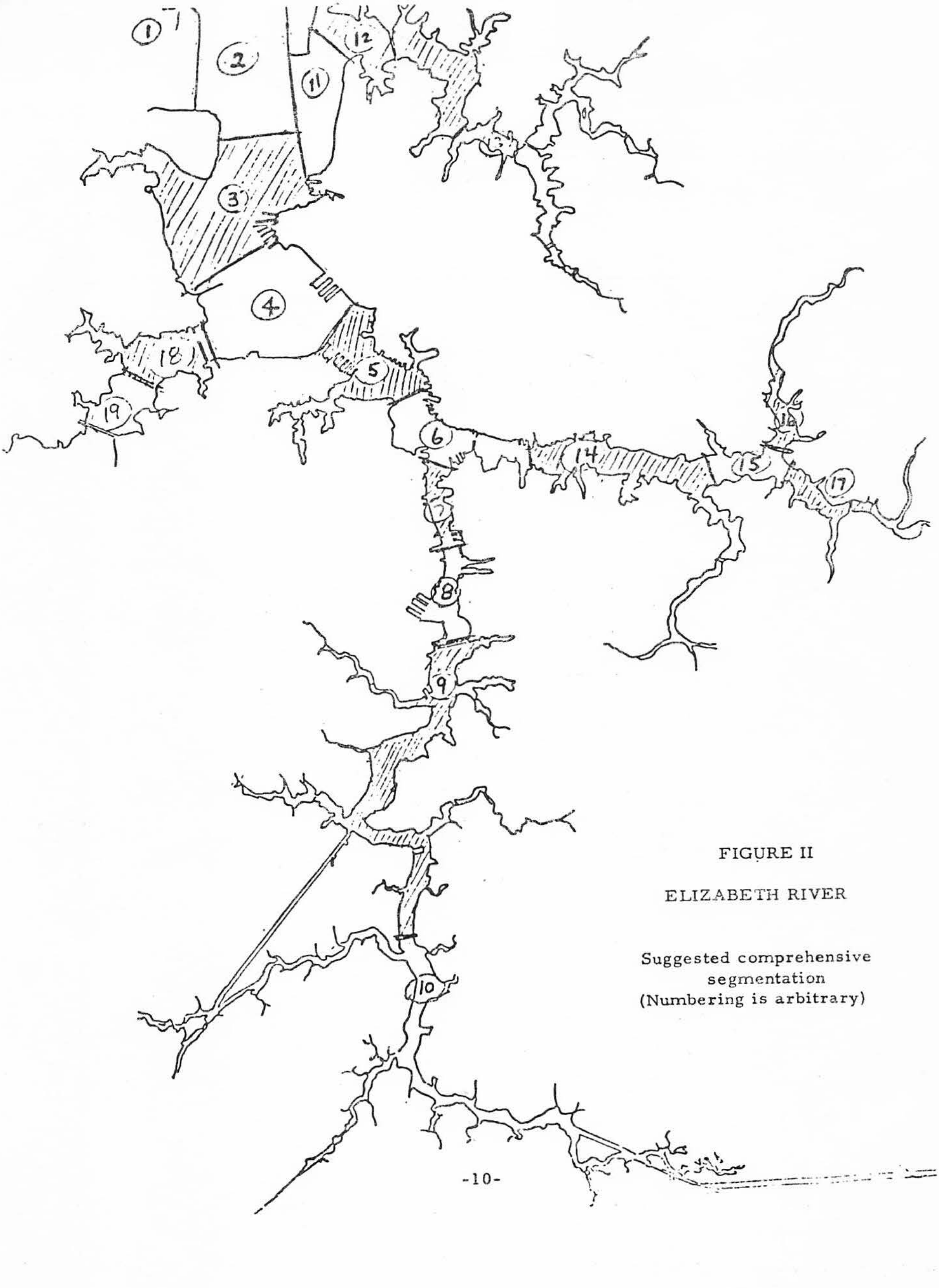

FIGURE II

ELIZABETH RIVER

Suggested comprehensive segmentation
(Numbering is arbitrary)

Table 3. Segmentation Data for the Elizabeth River

River Mile	Mean Salinity	Seasonal Range	Vertical Range	Mean Depth	Depth Ratio	
0-1	18-24‰	<4‰	3-6	7.1	1.9	51342
1-2			3-6	5.1	2.7	51332
2-3			1-3	4.5	3.1	51232
3-4			1-3	3.5	4.0	51233
4-5			1-3	2.5	4.8	51223
L 0-1			<1	1.7	2.4	51122
L 1-2			<1	1.3	4.1	51113
L 2-3			<1	1.3	4.1	51113
L 3-4			<1	.4	13.9	51113
5-6			1-3	2.1	5.8	51223
WBr 0-1			<1	1.5	3.6	51122
WBr 1-2			<1	1.0	5.9	51113
WBr 2-3			<1	0.7	4.4	51113
6-7			<1	2.2	5.5	51123
7-8			<1	4.9	2.5	51132
EBr 0-1			<1	3.8	1.8	51132
EBr 1-2			<1	1.8	4.2	51123
EBr 2-3			<1	2.4	2.9	51122
EBr 3-4			<1	0.9	5.8	51113
EBr 4-5			<1	0.7	3.1	51112
8-9			<1	8.3	1.5	51142
9-10			<1	5.1	2.3	51132
10-11			<1	3.6	3.2	51132
11-12			<1	4.2	2.5	51132
12-13			<1	4.3	2.5	51132
13-14	18-24		<1	6.3	1.7	51142
14-15	11-18		<1	5.2	—	4113(2)
15-16	11-18		<1	3.0	1.2	41132

Table 4. Grouping of Elizabeth River Stations by Descriptors

0-1	5	1	3	4	2	Mouth
1-1	5	1	3	3	2	
2-3	5	1	2	3	2	Craney Island Reach
3-4	5	1	2	3	2	
4-5	5	1	2	2	3	Transition - Lafayette
5-6	5	1	2	2	3	Transition - Western Br.
6-7	5	1	1	2	3	Norfolk Reach
7-8	5	1	1	3	2	Transition - Eastern Br.
8-9	5	1	1	4	2	Navy Piers
9-10	5	1	1	3	2	Transition
10-11	5	1	1	3	2	Southern Br.
11-12	5	1	1	3	2	
12-13	5	1	1	3	2	
13-14	5	1	1	4	2	
14-15	4	1	1	3	—	Upstream Reaches (Intracoastal Waterway)
15-16	4	1	1	2	1	