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Puget Sound Dredged Disposal Analysis



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## MODEL AND ASSESSMENT OF THE CONTRIBUTION OF DREDGED MATERIAL DISPOSAL TO SEA-SURFACE CONTAMINATION IN PUGET SOUND

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ECOLOGY

MODEL AND ASSESSMENT OF THE CONTRIBUTION  
OF DREDGED MATERIAL DISPOSAL TO SEA-SURFACE  
CONTAMINATION IN PUGET SOUND

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### SUMMARY

Hydrophobic or floatable materials released to the water column during dredge disposal operations may accumulate in high concentrations on the water surface. If such surface accumulations occur, they could impact the reproduction of fish and shellfish with neustonic (floating) eggs or larvae. Also, floatable surface contaminants could deposit on nearby beaches. In order to examine the potential impacts of such processes, an interactive computer (IBM PC) model was developed. The FORTRAN model, allows input of contaminant concentrations on the dredge material, the surface area of the disposal site, the floatable fraction of the contaminated material, and the baseline concentrations of contaminants present in the sea-surface microlayer. The model then computes the resultant concentrations of each contaminant in the microlayer and the potential impact on floating fish eggs. The utility of the model would be greatly improved by empirical data, not yet available, on the vertical upward and lateral movement of contaminants during dredge material disposal.

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## INTRODUCTION

The sea-surface microlayer (SSM) is a vital biological habitat (Hardy 1982). Many fish and shellfish, including cod, sole, flounder, hake, anchovy, crab, and lobster have egg or larval stages that develop in this upper layer. Contaminants from atmospheric deposition, urban runoff, wastewater outfalls, industrial point sources, and ocean dumping enter coastal waters and partition. A large portion of these contaminants associate with suspended particles and deposit in the bottom sediments. However, contaminants that have low water solubility or that associate with floatable particles concentrate at the air-water interface. Consequently, high concentrations of toxic PAHs, PCBs, and metals have been found in the surface microlayer at some sites in Puget Sound (Hardy et al. 1986). At present, the spatial distribution of this SSM contamination remains unknown. Also, the relative contribution that dredged material disposal may make to SSM contamination remains to be assessed. As part of the Puget Sound Dredged Disposal Analysis program of the Seattle District Corps of Engineers, this project was undertaken to examine the potential of dredged material contaminants to accumulate in harmful concentrations at the sea surface. This study was performed to 1) develop a model that will allow estimation of the increase in, and the resulting concentration of, a series of pollutants in the SSM caused by dredging activities and 2) to estimate the resulting impact of SSM contamination in terms of its toxicity to fish eggs that float on the water surface during the spawning season.

## CONCLUSIONS AND RECOMMENDATIONS

Significant SSM contamination and toxicity already exists in Elliott Bay. Dredge disposal could only significantly add to this contamination and toxicity within the disposal area if the floatable fraction exceeds  $1 \times 10^{-10}$  to  $10^{-9}$  and most of the surface contamination remains in the microlayer for some time. Also, additional contamination from floatables could, through horizontal transport, add to the load of contamination deposited on nearby beaches. However, several gaps in information seriously impair the usefulness of this model. These include lack of information on the floatable and bioavailable fraction of the dredged material and the "footprint" or area of the water surface likely to be impacted from the disposal.

We recommend that laboratory and field experiments be conducted to

- Determine the floatable fraction of dredged material under a variety of different mixing and disposal regimes.
- Collect and chemically analyze sea-surface microlayer contaminant concentrations during a typical dredge disposal operation.
- Evaluate the toxicity of the floatable fraction of dredged material to neustonic (floating) eggs and larvae.

## MODEL

The model we have developed is written in FORTRAN to run on an IBM PC. The model is interactive and requests all the necessary input data from the user. Results are displayed and can be printed on hard copy. The data from a given simulation can be stored, if desired, on a file specified by the user. The user has the option of changing one or more of the parameters for the simulation including the mass of material dumped, the floatability fraction, the concentration of contaminants in the dredged material and that initially in the microlayer. The program then computes the final concentrations of contaminants in the SSM and the resulting expected fish egg mortality.

The structure for the model is presented in a series of flow charts (see Appendix A), and the program is listed in Appendix B. Basically, the model uses data on the characteristics of the dredged material to determine how much of the contaminated material accumulates in the SSM. Input variables are concentrations of up to 10 contaminants in the sediment, total mass of dredged material to be dumped at the site, area of the disposal site, and a measure of the fraction of the material that is floatable. Floatability is, of course, a function of the particle size and density, and is affected by the presence of organic coatings. This is probably the largest unknown input variable at present. From these parameters the total mass of each contaminant added to the microlayer is computed. Other input variables are the initial (baseline) concentration of each contaminant in the microlayer and the water surface area of the disposal site that is estimated to be affected. When the initial (baseline) concentrations of contaminants are entered as 0, the computed final concentrations and toxicity represent those resulting solely from the dredge material. The thickness of the SSM is 50  $\mu\text{m}$ , a depth that other studies have shown contains the bulk of all surface contaminant enrichments. From the size of the area and the thickness of the microlayer, the volume of water affected by the dredged material is computed and the final resulting concentrations of contaminants in the SSM estimated. Based on a relationship between total organic and metal contaminant concentrations in the SSM and toxicity (Hardy et al. 1985, Table 1; Hardy et al. 1986, Tables 7 and 8 and p. 3), the resultant percent mortality to fish (sole) eggs is calculated.

### ASSUMPTIONS AND LIMITATIONS

The model, in its present form, has several limitations that could be improved through future acquisition of field and laboratory data:

- The model does not include the horizontal transport of SSM contaminants (e.g., movement to the beach).
- The model does not take into account currents or the depth at the disposal site that may affect the area of the resulting "footprint" reaching the surface.
- The model calculates the initial partitioning of dredged material into the SSM, but does not follow the temporal changes in the concentrations of contaminants in the SSM. The model is conservative, because processes that affect the temporal concentration, such as losses due to evaporation, dissolution into the subsurface waters, biological and chemical degradation, and increases caused by gas generation from the sediment, are not included.
- Biological effects on the concentrations in the SSM are not considered. This includes adsorption and settling out on fecal pellets, bioturbation and feeding by organisms in the SSM. The computed toxic effects on fish larval hatch assume that the embryos are exposed to the microlayer contamination throughout their 6- to 7-day period of embryonic development. This may very well represent a realistic situation, because once trapped in an organic surface film, the embryos are likely to remain in association with the film. Also, toxicity is computed using only PAH and metal concentrations; other contaminants are not included in the model that is used to predict fish larval hatching success.

### SAMPLE SCENARIOS

Four sample scenarios have been computed (see Appendix C). All use inputs of 1500 yd<sup>3</sup> of dredged material with a specific gravity of 1.350 g/mL and a radius for the disposal area of 900 ft. Typical contaminant concentrations on dredged material and baseline concentrations in the microlayer of Elliott Bay (Hardy et al. 1985, 1986) are used. The floatable fraction was varied between  $1 \times 10^{-11}$  and  $1 \times 10^{-6}$ . The results of tests 1 to 4 suggest that significant toxicity to fish eggs from the addition of dredged material would not occur if the floatable fraction is less than  $1 \times 10^{-10}$  (tests 1 and 2). Assuming no existing contamination, larval hatch is about 84%. When the mean microlayer contaminant concentrations already present in Elliott Bay are used as input variables, predicted live larval hatch is reduced to 54% and in some areas would be even lower. However, if the floatable fraction is as great as  $1 \times 10^{-8}$ , dredge disposal would decrease larval hatch in the disposal area to 3 to 22% (test 3). At  $1 \times 10^{-6}$  floatable fraction, no larvae would survive in the disposal area (test 4).

In addition to single dredge disposal events, the model can be used to compute average enrichments over longer periods of time or over large areas (e.g., the annual 6-day average disposal contribution to an area the size of Elliott Bay).

## RELATIONSHIP TO WATER QUALITY CRITERIA

How do the predicted microlayer concentrations resulting from dredge material disposal compare to water quality criteria? The quality criteria for metals generally range from 2 to 58  $\mu\text{g/L}$  and for PCBs is 0.001  $\mu\text{g/L}$  (see Table 1). U.S. Environmental Protection Agency (EPA) water quality criteria are not available for most organic compounds. Criteria for aquatic effects have not been established for PAHs, but the EPA suggests that the level where adverse effects may be expected is above 300  $\mu\text{g/L}$  of total PAH. Available information suggests that exposure of eggs and larvae of fish and shellfish to concentrations of petroleum hydrocarbons greater than 100  $\mu\text{g/L}$  will result in harmful effects (Table 1). When herring eggs are exposed to crude oil, droplets adhere to the surface of the eggs and, at exposure concentrations of 4 to 761  $\mu\text{g/L}$ , hatched larvae showed an increased incidence of abnormalities (Pearson et al. 1985). Reduced or abnormal larval hatch of fish eggs can result from exposure to concentrations of an individual PAH compound, benzo(a)pyrene, as low as 0.1 to 0.2  $\mu\text{g/L}$  (Table 1).

The sole egg bioassay, on which our model of microlayer effects is based, provides a very sensitive measure of effects. If sole eggs were exposed for 6 days to a mixture containing all the metals at their EPA water quality criteria concentrations shown in Table 1, the model would predict about a 40% decrease in live larval hatch from these metals alone. The sample dredge disposal scenarios (Appendix C), suggest that scenarios (tests) 1 and 2 would have no effect in increasing microlayer contaminant concentrations. In tests 2 and 3, microlayer concentrations of both metals, PAHs and PCBs reach concentrations that are both expected to be harmful from past studies (see Table 1) and that are also predicted to reduce live larval hatch by our own model.

**TABLE 1. Effects of Contaminants on Marine Organisms**

|                   | Organism                      | Effects                         | Contaminant             | Concentration<br>ug/liter |
|-------------------|-------------------------------|---------------------------------|-------------------------|---------------------------|
| Quality criteria  | Variety of marine organisms   | 24 to 96 h<br>LC <sub>50</sub>  | Pb                      | 8.6                       |
|                   |                               |                                 | Cu                      | 2                         |
|                   |                               |                                 | Ag                      | 2.3                       |
|                   |                               |                                 | Zn                      | 58                        |
|                   |                               |                                 | Cd                      | 12                        |
|                   |                               |                                 | PCB                     | .001                      |
| Acutely lethal    | Variety of eggs and larvae    | 24 to 48 h<br>LC <sub>50</sub>  | Soluble H-carbons       | 100 to 1,000              |
|                   |                               |                                 | #2 Fuel oil or kerosene | 100 to 4,000              |
|                   |                               |                                 | Fresh crude oil         | 100 to 100,000            |
| Sublethal effects | Turbot eggs                   | Delayed hatch & abnormal larvae | Oil                     | 10                        |
|                   | Plaice larvae                 |                                 | Petroleum               | 0 to 10,000               |
|                   | Sea urchin larvae             | Egg fertilization               | Extracts of Bunker C    | 100 to 1,000              |
|                   | Crab larvae                   | Increase respiration            | Oil                     | 10,000 to 100,000         |
|                   | Trout <sup>2</sup> eggs       | Increased abnormal larvae       | Benzo(a)pyrene          | .21                       |
|                   | Sole <sup>3</sup> eggs larvae | Reduced larval hatch            | Benzo(a)pyrene          | .1                        |
|                   | Herring <sup>4</sup> larvae   | increased incidence abnormal    | Crude oil               | 4 to 761                  |

<sup>1</sup> U.S. EPA 1976.

<sup>2</sup> Hannah et al. 1982.

<sup>3</sup> Hose et al. 1982.

<sup>4</sup> Pearson et al. 1985.

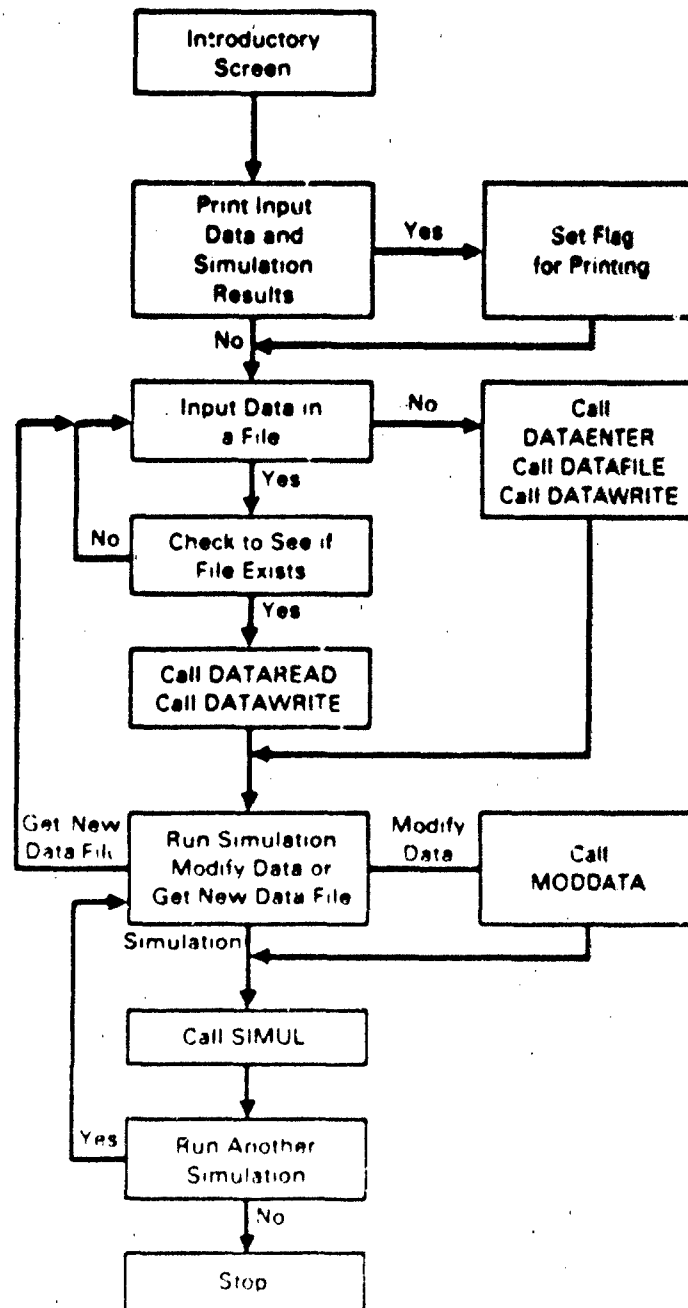
## REFERENCES

- Hannah, J. B., J. E. Hose, M. L. Landolt, B. S. Miller, S. P. Felton and W. T. Iwaoka. 1982. "Benzo(a)pyrene Induced Morphologic and Developmental Abnormalities in Rainbow Trout." Arch. Environ. Contam. Toxicol. 11:727-734.
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- Hose, J. E., J. B. Hannah, D. DiJulio, M. L. Landolt, B. S. Miller, W. T. Iwaoka and S. P. Felton. 1982. "Effects of Benzo(a)pyrene on Early Development of Flatfish." Arch. Environ. Contam. Toxicol. 11:167-171.
- Pearson, W. H., D. L. Woodruff, S. L. Kiesser, G. W. Fellingham and R. A. Elston. 1985. Oil Effects on Spawning Behavior and Reproduction in Pacific Herring (Clupea harengus pallasii). Final Report prepared by Marine Research Laboratory, Sequim, Washington for the American Petroleum Institute, Environmental Affairs Department, Washington D.C.
- U.S. EPA. 1976. Quality Criteria for Water. U.S. Environmental Protection Agency, Washington, D.C. 256 pp.

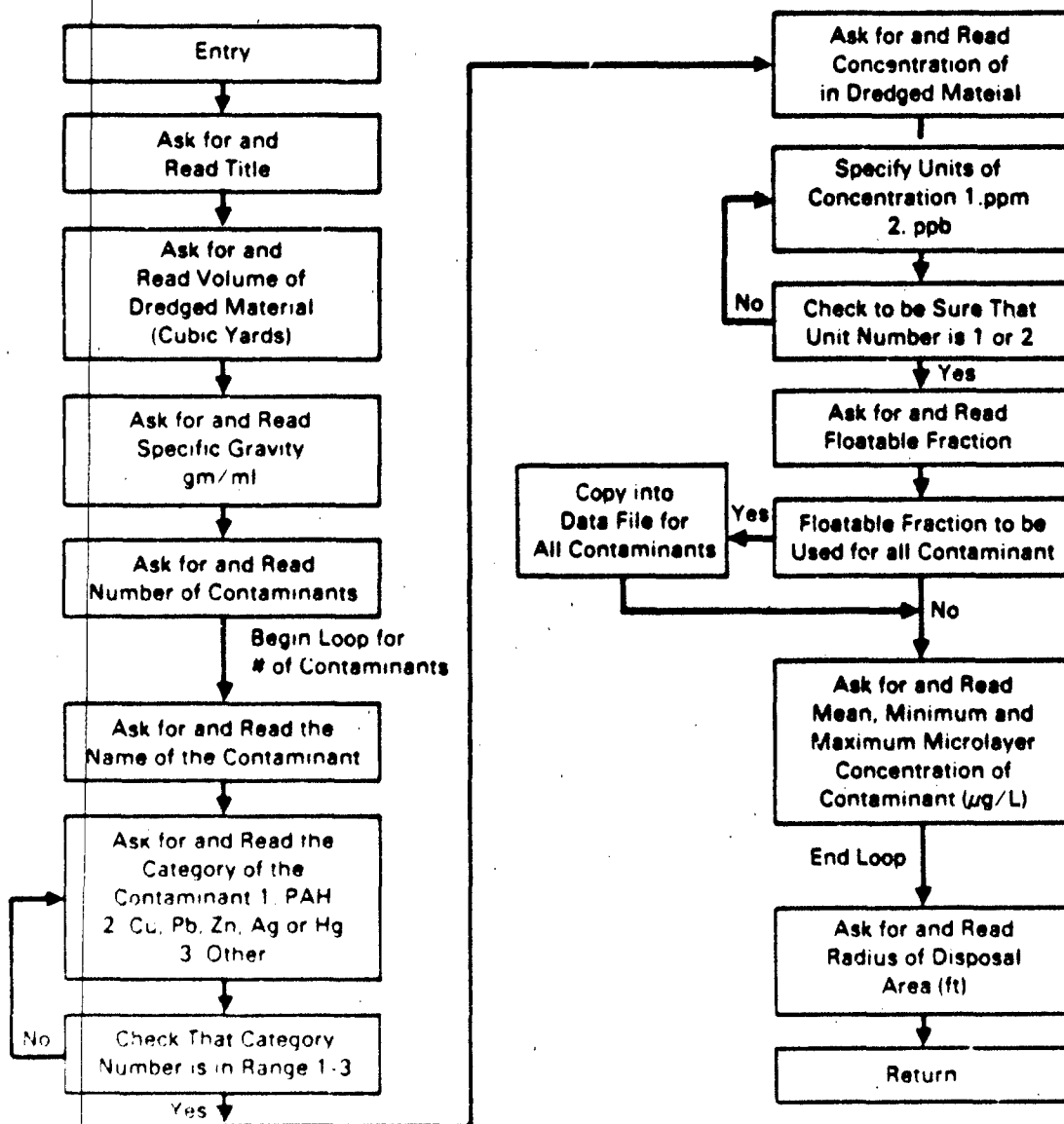
APPENDIX A

FLOW CHART OF MODEL

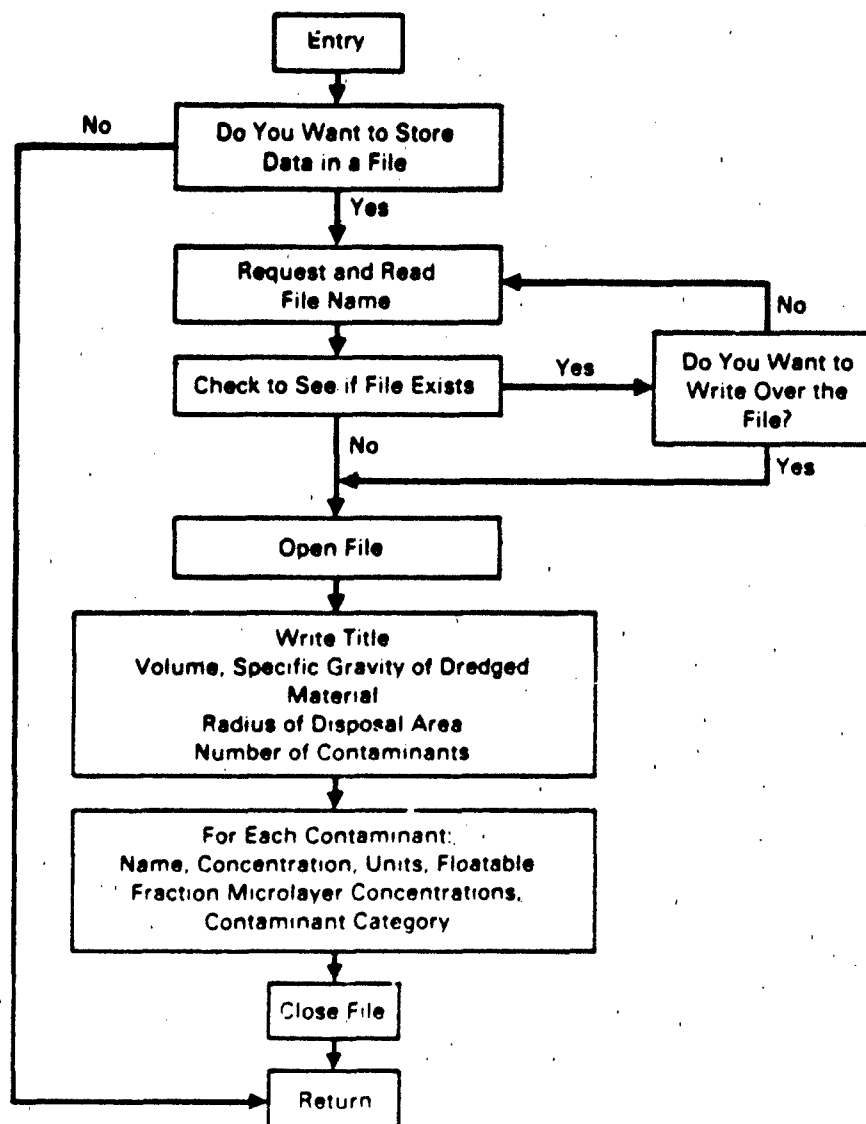
# Flow Chart: Main Program DREDGE



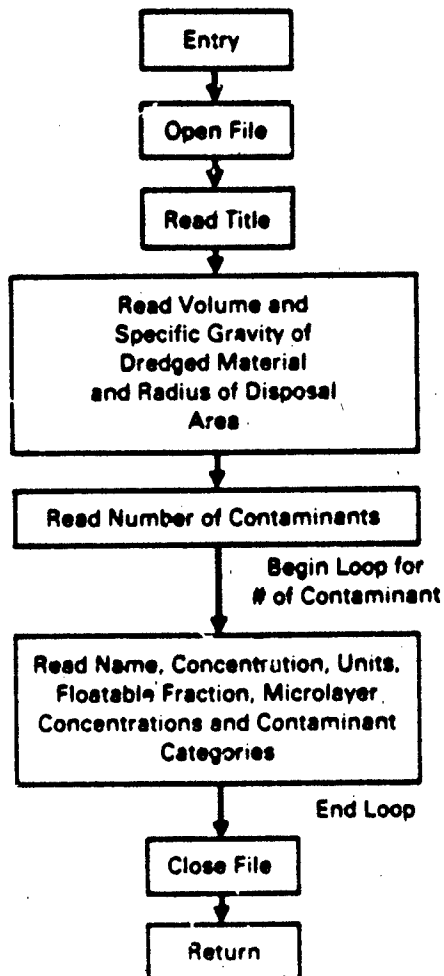
# Flow Chart. Subroutine DATAENTER



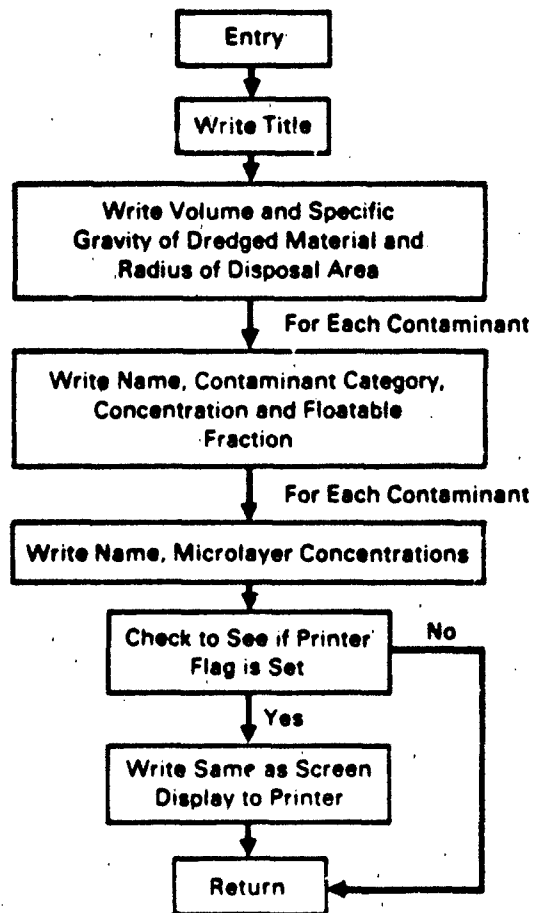
### Flow Chart: Subroutine DATAFILE



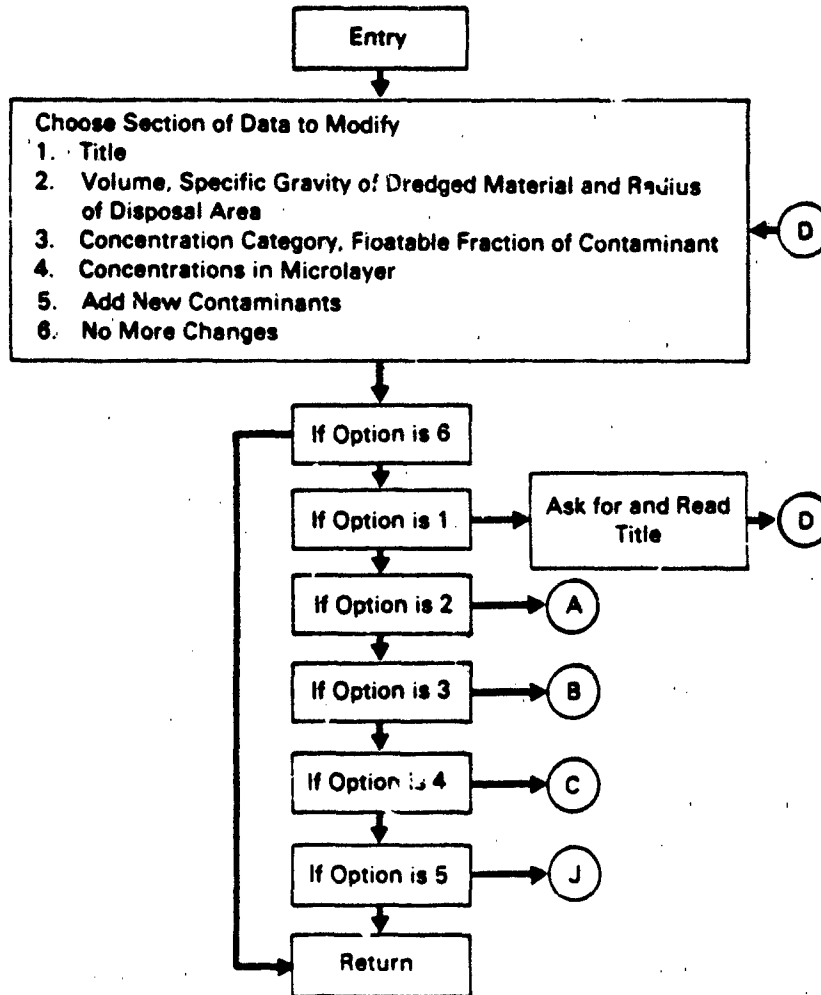
### Flow Chart: Subroutine DATAREAD



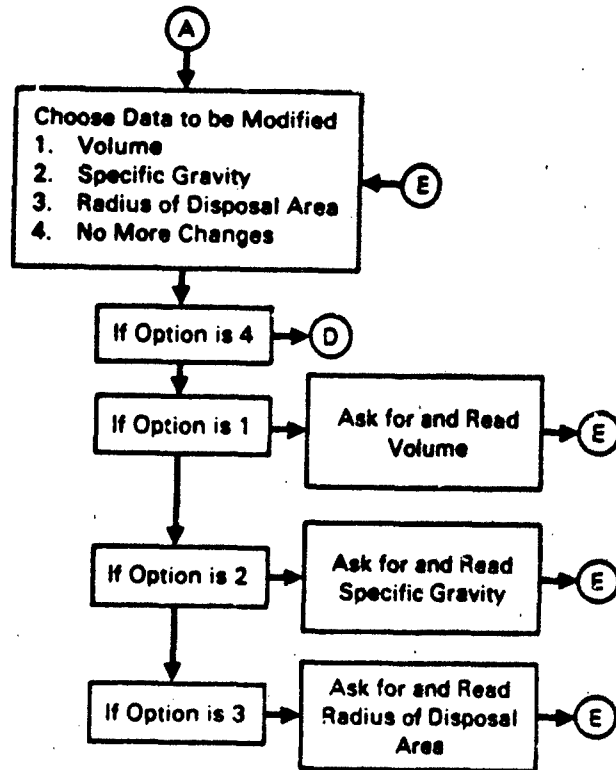
### Flow Chart: Subroutine DATAWRITE



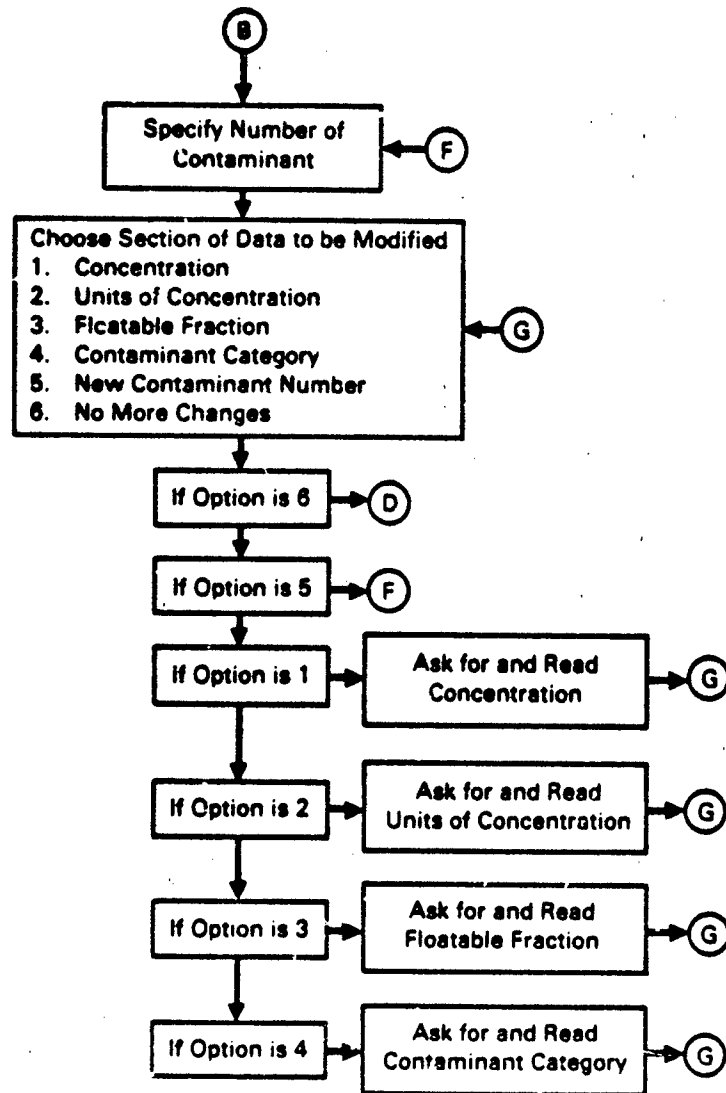
# Flow Chart: Subroutine MODDATA



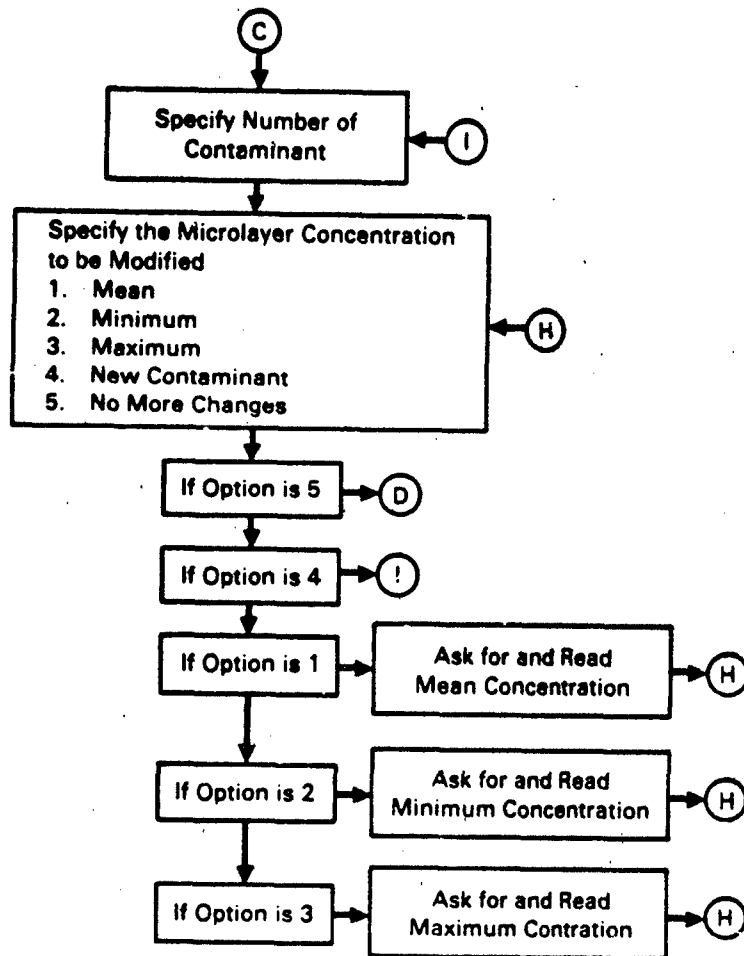
Option is 2



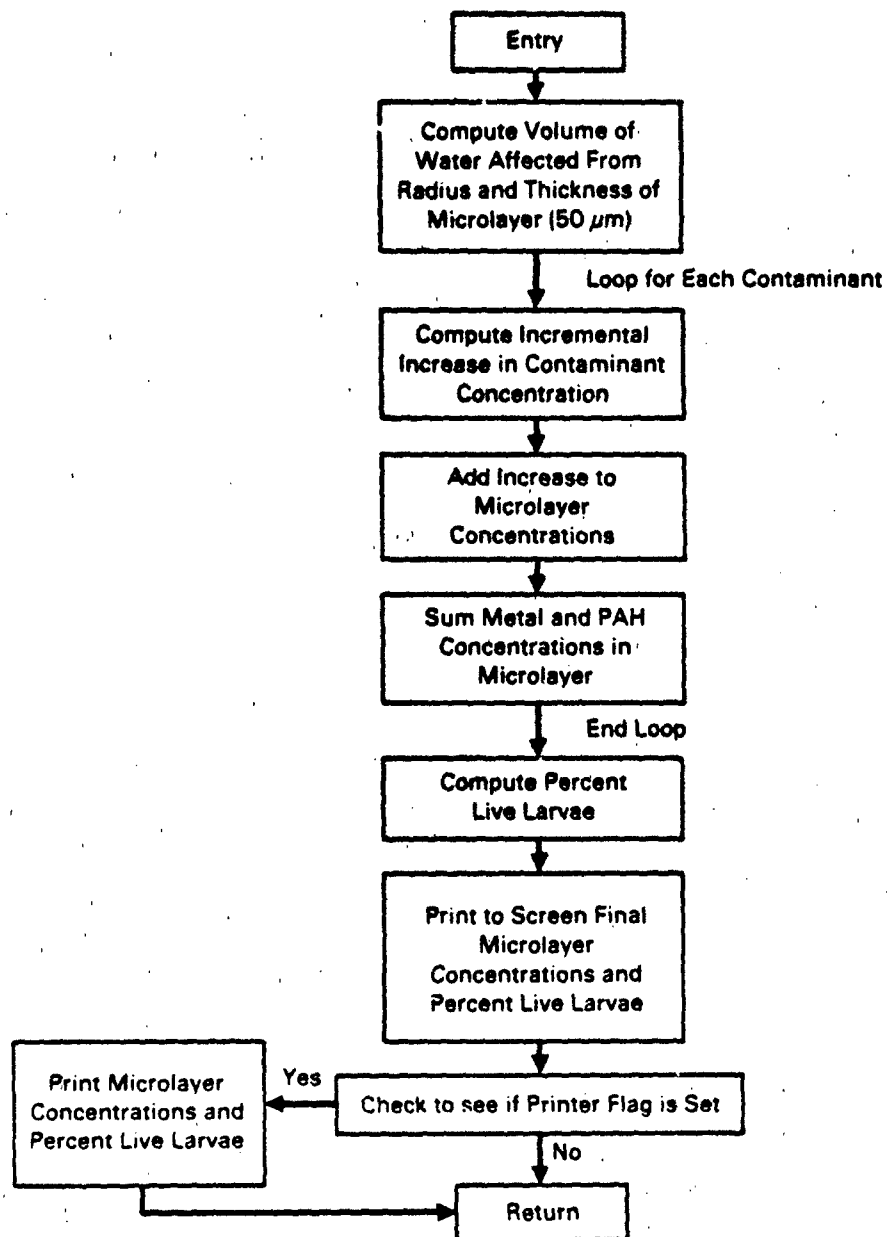
### Option is 3

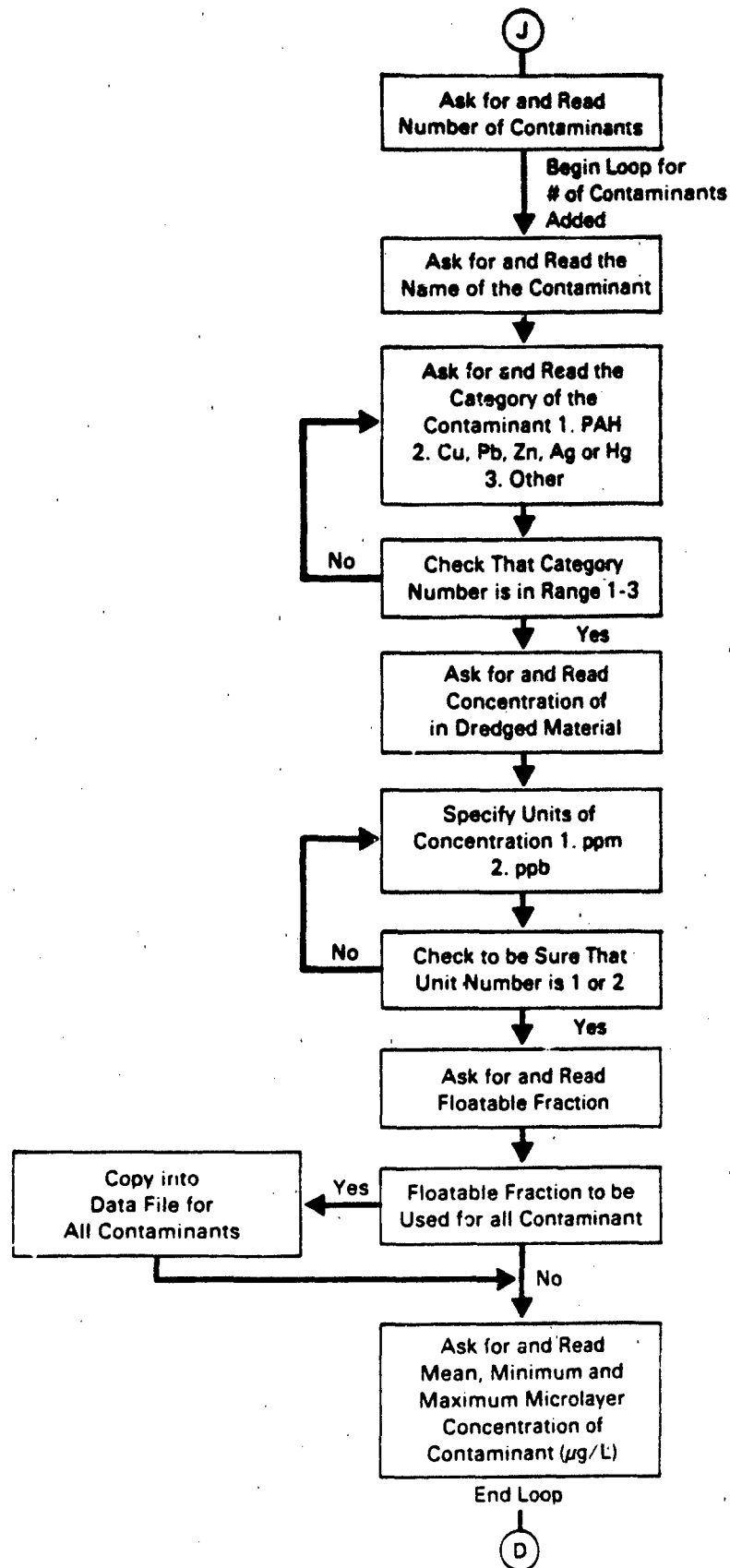


#### Option is 4



# Flow Chart: Subroutine SIMUL





APPENDIX B

DREDGE PROGRAM

```

C
C      PROGRAM DREDGE
C
C      PROGRAM FOR PREDICTING THE ENRICHMENT OF CONTAMINANTS IN THE
C      SEA-SURFACE MICROLAYER DUE TO DREDGING OR DISPOSAL OF
C      DREDGED MATERIAL.
C
C      CALCULATIONS BASED ON SIMPLE PARTITIONING THEORY
C
C      PROGRAMMED BY CHRISTINA E. COWAN
C      JANUARY 1986
C
C      DIMENSIONING
C      INCLUDE 'COMMOND.DAT'
C      LOGICAL*2 TEST
C      TEST4=.FALSE.
C
C      INTRODUCTORY SCREEN
C      WRITE (*,10)
10      FORMAT (//,15X,'IMPACT OF DREDGING AND DREDGED MATERIAL',//
1      ,15X,'DISPOSAL ON THE SEA-SURFACE MICROLAYER',///,
2      5X,'THIS PROGRAM CALCULATES THE ENRICHMENT IN THE SEA-SURFACE'
3      , 'MICROLAYER',//, 'CONCENTRATION OF CONTAMINANTS',
4      'THE INCREASE IN THE EXISTING MICROLAYER',//,
5      'CONCENTRATION IS CALCULATED FROM THE '
6      , 'PROPERTIES OF THE DREDGED MATERIAL',//,
7      'THE ESTIMATES MADE '
8      , 'ARE CONSERVATIVE AND REPRESENT A SINGLE POINT ESTIMATE',//,
9      'OF THE CONCENTRATIONS',//),
C      WRITE (*,23)
23      FORMAT(5X,'THE EQUATION USED TO CALCULATE THE INCREASE IN',
1      'THE MICROLAYER',//, 'CONCENTRATION FOR EACH CONTAMINANT IS:',//
2      , 'I = VOLD*CON*FLOAT/VOLW',//,5X,'WHERE I IS THE '
3      'INCREASE IN THE MICROLAYER CONCENTRATION;',//, 'VOLD IS THE '
4      'VOLUME OF DREDGED MATERIAL; CON IS THE CONCENTRATION',//,
5      'OF CONTAMINANT IN THE DREDGED MATERIAL; FLOAT IS THE '
6      'FLOATABLE',//, 'FRACTION AND VOLW IS THE VOLUME OF WATER THAT'
7      'IS IMPACTED',//, 'VOLW IS COMPUTED FROM THE RADIUS OF THE '
8      , 'DISPOSAL AREA AND THE MICROLAYER',//, 'DEPTH=50UM',//)
C      WRITE (*,92)
C      READ (*,*)
C      WRITE (*,24)
24      FORMAT(5X,'THE PERCENT OF LIVE SAND SOLE LARVAE THAT CAN BE ',
1      'EXPECTED TO HATCH',//, 'FROM EGGS THAT ARE EXPOSED TO THE ',
2      'CALCULATED MICROLAYER CONCENTRATIONS',//, 'IS ESTIMATED USING'
3      , 'THE EQUATION DEVELOPED BY HARDY ET AL. (1986)',//,
4      'THIS PERCENT',
5      'LIVE LARVAE IS CALCULATED FROM POLYAROMATIC HYDROCARBONS',//,
6      'AND METAL CONCENTRATIONS IN THE MICROLAYER ONLY. THE '
7      'EQUATION IS:',//,5X,'% LIVE = EXP(4.43 - 7.0E-4* PAH - '
8      , '6.0E-3*MET)',//, 'WHERE PAH IS THE TOTAL CONCENTRATION OF PAH',
9      'IN UG/L AND MET IS THE TOTAL',//,
9      'METAL CONCENTRATION IN MG/L',//)
C
C      CHOOSE TO PRINT THE INPUT DATA AND RESULTS OUT ON PRINTER

```

```

C
WRITE(*,92)
READ (*,*)
WRITE(*,22)
22  FORMAT(' DO YOU WANT A PRINTER LISTING OF THE INPUT DATA AND',
1  ' THE SIMULATION RESULTS?',/, ' ANS: Y OR N (DEFAULT = Y)')
READ (*,21) ANS2
IF(ANS2.EQ.'N' OR ANS2.EQ.'n') GOTO 90
OPEN(5,FILE='LPT1',STATUS='NEW')
TEST4=.TRUE.
90  WRITE (*,11)
11  FORMAT (5X,'YOU HAVE THE OPTION OF ENTERING THE INPUT DATA ',
1  ' FOR THE MODEL FOR EACH',/, ' SIMULATION AND SAVING THE DATA',
2  ' IN A ',
3  ' FILE OR YOU MAY RETRIEVE A',/, ' FILE OF INPUT DATA FOR USE IN '
4  ' THIS SIMULATION',/)
100 WRITE(*,12)
12  FORMAT(5X,'DO YOU HAVE AN EXISTING FILE OF DATA THAT YOU ',
1  ' WANT TO USE?',/, ' ANS: Y OR N (DEFAULT = Y)')
READ (*,21) ANS
21  FORMAT(A2)
IF (ANS.EQ.'N' OR ANS.EQ.'n') THEN
    CALL DATAENTER
    CALL DATAWRITE
    CALL DATAFILE
    GOTO 110
ENDIF
WRITE (*,13)
13  FORMAT (1X,'TYPE IN NAME OF FILE: ')
READ (*,14) FILEIN
14  FORMAT (A12)
INQUIRE (FILE=FILEIN,EXIST=TEST)
IF (TEST) THEN
    CALL DATAREAD
    CALL DATAWRITE
ELSE
    WRITE (*,15)
15  FORMAT (1X,'FILE NOT FOUND: TRY AGAIN')
    GOTO 100
ENDIF
110 CONTINUE
120 WRITE(*,16)
16  FORMAT(' DO YOU WISH TO RUN SIMULATION WITH THIS DATA OR',
1  ' /, ' MODIFY THIS DATA BEFORE RUNNING THE SIMULATION OR',/,
2  ' GET A NEW DATA FILE?',/,
3  ' 1) RUN SIMULATION',/, ' 2) MODIFY DATA',/,
4  ' 3) GET NEW DATA FILE OR START OVER',/,
5  ' GIVE NUMBER OF OPTION : ')
READ(*,17) IANS
17  FORMAT (I1)
IF(IANS.GT.3 OR IANS.LT.1) THEN
    WRITE(*,18)
18  FORMAT (' OPTION NUMBER NOT CORRECT: TRY AGAIN')
    GOTO 120
ENDIF

```

```

        IF (IANS.EQ.3) GOTO 90
        IF (IANS.EQ.2) THEN
            CALL MODDATA
            WRITE(*,22)
92      FORMAT ('CONTINUE')
            READ(*,*)
            ENDIF
            CALL SIMUL
            WRITE(*,19)
19      FORMAT('DO YOU WANT TO RUN ANOTHER SIMULATION? ',
              /, 'ANS: Y OR N (DEFAULT = N)')
            READ(*,21) ANS1
            IF (ANS1.EQ.'Y' OR ANS1.EQ.'y') THEN
                GOTO 120
            ENDIF
            IF (TEST4) THEN
                CLOSE(5)
            ENDIF
            STOP
            END
C*****
        SUBROUTINE DATAENTER
C
C  DATA ENTRY ROUTINE FOR THE PROGRAM
C
        INCLUDE 'COMMOND.DAT'
        LOGICAL*2 TEST2
        TEST2= TRUE
C ENTER TITLE OF THE SIMULATION
        WRITE(*,29)
29      FORMAT('GIVE TITLE OF THE SIMULATION')
        READ(*,28) TITLE
28      FORMAT (A80)
C ENTER MASS OF DREDGED MATERIAL
        WRITE(*,30)
30      FORMAT('ENTER VOLUME OF DREDGED MATERIAL (CUBIC YARDS) ')
        READ(*,31) DMASS
31      FORMAT (F9.0)
        WRITE(*,32)
32      FORMAT('ENTER SPECIFIC GRAVITY OF THE DREDGED MATERIAL'
              /, ' (GM/ML) ')
        READ(*,31) SPGRV
C ENTER INFORMATION ON THE CONTAMINANTS IN THE DREDGED MATERIAL
        WRITE(*,35)
35      FORMAT('SPECIFY NUMBER OF CONTAMINANTS FOR WHICH ',
              /, 'MICROLAYER ENRICHMENT IS TO BE CALCULATED  NUMBER IS ')
        READ(*,34) NUMC
34      FORMAT (I2)
        DO 210 I=1,NUMC
            WRITE(*,37) I
37      FORMAT('ENTER THE NAME OF CONTAMINANT ',I2,' (MAXIMUM'
              /, ' 5 CHARACTERS LONG) ')
            READ(*,38) CNAM(I)
38      FORMAT (A5)
32      WRITE(*,50)

```

```

30      FORMAT(' INDICATE CATEGORY TO WHICH CONTAMINANT BELONGS: ',
1      ' 1) PAH',/, ' 2) CU, PB, ZN, AG, OR HG',/, ' 3) OTHER ',
2      ' GIVE NUMBER OF THE CATEGORY')
      READ(*,33) CCAT(1)
      IF(CCAT(1) LT 1 OR CCAT(1) GT 3) THEN
        WRITE(*,51)
51      FORMAT(' ERROR IN CATEGORY SPECIFIED: TRY AGAIN')
        GOTO 32
      ENDIF
      WRITE (*,39) CNAM(1)
39      FORMAT (' ENTER CONCENTRATION OF ',AS,' IN DREDGED ',
1      ' MATERIAL. ')
      READ(*,31) CMASO(1)
211     WRITE(*,40) CNAM(1)
40      FORMAT (' SPECIFY UNITS OF ',AS,' CONCENTRATION: ',/,
1      ' 1. PPM      2. PPB',/, ' GIVE NUMBER : ')
      READ (*,33) UNITC(1)
33      FORMAT(I1)
      IF (UNITC(1) GT 2 OR UNITC(1) LT 0) THEN
        WRITE(*,41)
41      FORMAT(' ERROR IN UNITS SPECIFIED: TRY AGAIN')
        GOTO 211
      ENDIF
      IF (TEST2) THEN
        WRITE(*,42) CNAM(1)
42      FORMAT (' SPECIFY FLOATABLE FRACTION OF ',AS,' : ')
        READ (*,43) CFRAC(1)
43      FORMAT(E6.3)
        WRITE(*,44)
44      FORMAT(' IS THIS FLOATABLE FRACTION TO BE USED FOR ALL',
1      ' CONTAMINANTS?  ANS: Y OR N (DEFAULT N) ')
        READ (*,45) ANS
45      FORMAT(A2)
        IF (ANS.EQ.'Y' OR ANS.EQ.'y') THEN
          DO 214 J=1, NUMC
            CFRAC(J)=CFRAC(1)
214          CONTINUE
          TEST2 = .FALSE.
        ENDIF
      ENDIF
      WRITE(*,46) CNAM(1)
46      FORMAT (' SPECIFY BASELINE CONCENTRATION OF ',AS,' IN ',
1      ' MICROLAYER',/, ' MEAN (UG/L) : ')
      READ (*,31) CMMICRO(1)
      WRITE (*,47)
47      FORMAT (' MINIMUM (UG/L) : ')
      READ (*,31) CLMICRO(1)
      WRITE (*,48)
48      FORMAT (' MAXIMUM (UG/L) : ')
      READ (*,31) CUMICRO(1)
219     CONTINUE
C      RADIUS OF DISPOSAL AREA
      WRITE(*,49)
49      FORMAT (' SPECIFY THE RADIUS OF DISPOSAL AREA POTENTIALLY
1      ' EFFECTED BY DREDGING OR DREDGED MATERIAL DISPOSAL (FEET) ')

```

```

      READ (*,31) RAD
      RETURN
      END
*****
      SUBROUTINE DATAREAD
C
C  READS THE DATA FROM THE SPECIFIED INPUT DATA FILE
C
      *INCLUDE 'COMMC.DAT'
      OPEN (7,FILE=FILEIN)
      READ (7,10) TITLE
      READ (7,11) DMASS, SPCRAV, RAD
      READ (7,12) NUMC
      DO 400 I=1,NUMC
      READ(7,13) CNAM(I), CMASS(I), UNITC(I), CFRAC(I), CMICRO(I)
1      , CLMICRO(I), CUMICRO(I), CCAT(I)
400    CONTINUE
      CLOSE (7)
      RETURN
10     FORMAT(A80)
11     FORMAT(3(F9.3))
12     FORMAT(I2)
13     FORMAT(A3,F9.3,I2,E9.3,3(F9.3),I2)
      END
*****
      SUBROUTINE DATAFILE
C
C  WRITES SIMULATION DATA TO A FILE SPECIFIED BY THE USER
C
      *INCLUDE 'COMMON.DAT'
      CHARACTER*20 FILEOUT
      LOGICAL*2 TEST3
      WRITE (*,60)
40     FORMAT(' DO YOU WANT TO STORE THE DATA IN A FILE SO THAT'
1      ' IT MAY BE USED IN FUTURE SIMULATIONS? ANS: Y OR N '
2      ' (DEFAULT: Y)')
      READ (*,20) ANS
20     FORMAT(A2)
      IF (ANS EQ 'N' OR ANS EQ 'n') GOTO 390
310    WRITE(*,61)
61     FORMAT(' TYPE IN THE NAME OF THE FILE: FORMAT FILENAME EXT.'
1      ' ,//, FILENAME CAN BE ONLY 8 CHARACTERS LONG AND EXT ONLY '
2      ' ,3 CHARACTERS LONG ')
      READ (*,14) FILEOUT
14     FORMAT (A20)
      INQUIRE (FILE=FILEOUT, EXIST=TEST3)
      IF (TEST3) THEN
        WRITE(*,62)
62     FORMAT(' FILE ALREADY EXISTS ,//,
1      ' DO YOU WANT TO OVERWRITE THE FILE? ANS: Y OR N '
2      ' (DEFAULT = N) ')
      READ (*,20) ANS
      IF (ANS EQ 'N' OR ANS EQ 'n') GOTO 310
      ENDIF
      OPEN (6,FILE=FILEOUT,STATUS='NEW')

```

```

WRITE (6,10) TITLE
WRITE (6,11) DMASS, SPGRV, RAD
WRITE (6,12) NUMC
DO 320 I=1,NUMC
WRITE(6,13) CNAM(I), CMASS(I), UNITC(I), CFRAC(I),CMMICRO(I),
1 CLMICRO(I), CUMICRO(I), CCAT(I)
320 CONTINUE
CLOSE(6)
390 RETURN
10 FORMAT(A80)
11 FORMAT(3(F9.3))
12 FORMAT(I2)
13 FORMAT(A5,F9.3,I2,E9.3,3(F9.3),I2)
END
C*****
SUBROUTINE DATAWRITE
C
C WRITE SUMMARY OF INPUT DATA TO THE SCREEN
C
$INCLUDE 'COMMON.DAT'
CHARACTER*3 UNITP
CHARACTER*3 CCATP
WRITE(*,70) TITLE
70 FORMAT(/,' TITLE OF THE SIMULATION IS:',/,I2,A80,/)
WRITE (*,71) DMASS, SPGRV, RAD
71 FORMAT(' VOLUME OF DREDGED MATERIAL IS '
1 ,F9.3,' CUBIC YARDS'
2 ,/, ' SPECIFIC GRAVITY OF THE DREDGED MATERIAL IS ',F9.3,
3 ' CM/ML ',/, ' RADIUS OF THE DISPOSAL AREA IS ',F9.3,' FEET',/)
WRITE (*,72)
72 FORMAT (15X,'CONTAMINANT INFORMATION',/,
1 ' NAME CATEGORY CONCENTRATION FLOATABLE '
2 ,/,23X,' IN MATERIAL FRACTION')
DO 74 I=1,NUMC
IF(UNITC(I).EQ.1) THEN
UNITP = 'PPH'
ELSE
UNITP = 'PPB'
ENDIF
IF(CCAT(I).EQ.1) THEN
CCATP='PAH'
ELSEIF(CCAT(I).EQ.2) THEN
CCATP='METAL'
ELSE
CCATP=' '
ENDIF
WRITE (*,73) CNAM(I), CCATP, CMASS(I), UNITP, CFRAC(I)
73 FORMAT( 1X,A5,5X,A5,8X,F9.3,1X,A3,6X,1P,E9.3)
74 CONTINUE
WRITE(*,75)
75 FORMAT (/, ' INITIAL MICROLAYER CONCENTRATIONS',/,
1 ' NAME CONCENTRATION (UG/L)',/,
2 ' MSAN MINIMUM MAXIMUM')
DO 77 I=1,NUMC
WRITE(*,76) CNAM(I), CMMICRO(I), CLMICRO(I), CUMICRO(I)

```

```

76     FORMAT (1X,A5,4X,F9.3,6X,F9.3,7X,F9.3)
77     CONTINUE
C     WRITE TO PRINTER
      IF(TEST4) THEN
C     WRITE(S,80)
C80    FORMAT('L'H')
      WRITE(S,78) TITLE
      WRITE (S,71) DMASS, SPGRV, RAD
      WRITE (S,72)
      DO 79 I=1,NUMC
      IF(UNITC(I).EQ.1) THEN
        UNITP = 'PPH'
      ELSE
        UNITP = 'PPB'
      ENDIF
      IF(CCAT(I).EQ.1) THEN
        CCATP='PAH'
      ELSEIF(CCAT(I).EQ.2) THEN
        CCATP='METAL'
      ELSE
        CCATP=' '
      ENDIF
      WRITE (S,73) CNAM(I), CCATP, CMASS(I), UNITP, CFPAC(I)
79     CONTINUE
      WRITE(S,75)
      DO 85 I=1,NUMC
      WRITE(S,76) CNAM(I), CMMICRO(I), CLMICRO(I), CUMICRO(I)
85     CONTINUE
      ENDIF
      RETURN
      END
C*****
      SUBROUTINE MODDATA
C
C THIS SUBROUTINE ALLOWS AN EXISTING DATA SET TO BE MODIFIED
C BEFORE CONDUCTING THE SIMULATION
C
      INCLUDE 'COMMON.DAT'
      LOGICAL*2 TEST2
      TEST2 = .TRUE.
300    WRITE (*,50)
50     FORMAT (' INDICATE WHICH SECTION OF DATA YOU WISH TO MODIFY ',
1      /, ' 1) TITLE OF THE SIMULATION',/, ' 2) VOLUME AND SPECIFIC',
2      ' GRAVITY OF DREDGED MATERIAL, RADIUS OF DISPOSAL AREA',/,
3      ' 3) CONCENTRATION, CATEGORY, FLOATABLE FRACTION OF CONTAMINANTS',
4      /, ' IN DREDGED MATERIAL',/, ' 4) CONCENTRATIONS IN MICROLAYER',
5      /, ' 5) ADD NEW CONTAMINANTS',
6      /, ' 6) NO MORE CHANGES',/, ' GIVE NUMBER OF OPTION: ')
      READ(*,*) OPT ON
      IF (OPTION LT 1 OR OPTION GT 6) THEN
        WRITE(*,51)
51     FORMAT (' ERROR IN OPTION SPECIFIED TRY AGAIN')
        GOTO 300
      ENDIF
C     EXIT

```

```

      IF (OPTION.EQ.4) GOTO 900
C
C CHANGE THE TITLE
C
      IF (OPTION.EQ.1) THEN
        WRITE (*,29)
29      FORMAT(' GIVE TITLE OF THE SIMULATION')
        READ (*,28) TITLE
28      FORMAT (A80)
        GOTO 300
      ENDIF
C
C CHANGES IN VOLUME, SPECIFIC GRAVITY OF DREDGED MATERIAL
C OR IN RADIUS OF DISPOSAL AREA
C
      IF (OPTION.EQ.2) THEN
301     WRITE (*,32)
32     FORMAT(' INDICATE WHICH DATA YOU WISH TO MODIFY: ',/,
1      ' 1) VOLUME OF DREDGED MATERIAL',/, ' 2) SPECIFIC GRAVITY ',
2      ' 3) DREDGED MATERIAL',/, ' 3) RADIUS OF DISPOSAL AREA',/,
3      ' 4) NO MORE CHANGES',/, ' GIVE NUMBER OF OPTION: ')
        READ (*,*) OPTION2
        IF (OPTION2.LT.1.OR.OPTION2.GT.4) THEN
          WRITE (*,31)
          GOTO 301
        ENDIF
        IF (OPTION2.EQ.4) GOTO 300
        IF (OPTION2.EQ.1) THEN
          WRITE (*,30)
30      FORMAT (' ENTER VOLUME OF DREDGED MATERIAL (CUBIC YARDS): ')
          READ (*,31) DMASS
31      FORMAT (F9.0)
          GOTO 301
        ENDIF
        IF (OPTION2.EQ.2) THEN
          WRITE(*,32)
32      FORMAT(' ENTER SPECIFIC GRAVITY OF THE DREDGED MATERIAL',
1      ' (GM/ML): ')
          READ (*,31) SPCGRAV
          GOTO 301
        ENDIF
        IF (OPTION2.EQ.3) THEN
          WRITE(*,49)
49      FORMAT (' SPECIFY THE RADIUS OF DISPOSAL AREA POTENTIALLY ',
1      ' EFFECTED BY DREDGING OR DREDGED MATERIAL DISPOSAL (FEET) : ')
          READ (*,31) RAD
          GOTO 301
        ENDIF
      ENDIF
C
C CHANGES IN CONCENTRATION, CATEGORY AND FLOATABLE FRACTION OF CONTAMINANTS
C
      IF (OPTION.EQ.3) THEN
303     WRITE (*,34)
34     FORMAT (' SPECIFY NUMBER OF THE CONTAMINANT: ')

```

```

DO 56 I=1,NUMC
WRITE(*,55) I, CNAM(I)
55 FORMAT(12,3I,A5)
56 CONTINUE
WRITE(*,57)
57 FORMAT (' GIVE CONTAMINANT NUMBER:')
READ(*,*) ICONT
302 WRITE (*, 53)
53 FORMAT (' INDICATE WHICH DATA YOU WANT TO MODIFY:',/,
1 ' 1) CONCENTRATION IN DREDGED MATERIAL',/,
2 ' 2) UNITS OF CONCENTRATION',/, ' 3) FLOATABLE FRACTION',/,
3 ' 4) CONTAMINANT CATEGORY',/, ' 5) NEW CONTAMINANT NUMBER ',/,
4 ' 6) NO MORE CHANGES',/, ' GIVE NUMBER OF OPTION:')
READ (*,*) OPTIONS3
IF (OPTIONS3.LT.1.OR.OPTIONS3.GT.6) THEN
WRITE (*,51)
GOTO 302
ENDIF
IF (OPTIONS3.EQ.6) GOTO 300
IF (OPTIONS3.EQ.5) GOTO 303
IF (OPTIONS3.EQ.1) THEN
WRITE (*,39) CNAM(ICONT)
39 FORMAT (' ENTER CONCENTRATION OF ',A5,' IN DREDGED',
1 ' MATERIAL: ')
READ(*,31) CMASS0(ICONT)
GOTO 302
ENDIF
IF (OPTIONS3.EQ.2) THEN
211 WRITE(*,40) CNAM(ICONT)
40 FORMAT (' SPECIFY UNITS OF ',A5,' CONCENTRATION: ',/,
1 5X,'1. PPM      2. PPF',/, ' GIVE NUMBER OF UNITS : ')
READ (*,33) UNITC(ICONT)
33 FORMAT(11)
IF (UNITC(ICONT).GT.2.OR.UNITC(ICONT).LT.0) THEN
WRITE(*,41)
41 FORMAT(' ERROR IN UNITS SPECIFIED: TRY AGAIN')
GOTO 211
ENDIF
GOTO 302
ENDIF
IF (OPTIONS3.EQ.3) THEN
WRITE(*,42) CNAM(ICONT)
42 FORMAT (' SPECIFY FLOATABLE FRACTION OF ',A5,' : ')
READ (*,43) CFRAC(ICONT)
43 FORMAT(E9.3)
WRITE(*,44)
44 FORMAT(' IS THIS FLOATABLE FRACTION TO BE USED FOR ALL',
1 ' CONTAMINANTS?  ANS: Y OR N (DEFAULT N) ')
READ (*,45) ANS
45 FORMAT(A2)
IF (ANS.EQ.'Y'.OR.ANS.EQ.'y') THEN
DO 214 J=1, NUMC
CFRAC(J)=CFRAC(ICONT)
214 CONTINUE
ENDIF

```

```

      GOTO 302
    ENDIF
    IF (OPTION3.EQ.4) THEN
32    WRITE(*,80) CNAME(ICONT)
80    FORMAT(' INDICATE CATEGORY TO WHICH CONTAMINANT BELONGS:',
1    /, ' 1) PAH',/, ' 2) CU, PB, ZN, AG, HG',/, ' 3) OTHER',/
2, ' GIVE NUMBER OF THE CATEGORY:')
    READ(*,33) CCAT(ICONT)
    IF(CCAT(1).LT.1.OR.CCAT(1).GT.3) THEN
      WRITE(*,84)
84    FORMAT(' ERROR IN CATEGORY SPECIFIED: TRY AGAIN')
      GOTO 82
    ENDIF
    GOTO 302
  ENDIF
ENDIF
ENDIF

C
C CHANGE CONCENTRATIONS IN MICROLAYER
  IF (OPTION.EQ.4) THEN
305  WRITE (*,54)
    DO 40 I=1,NUMC
      WRITE(*,55) I, CNAME(I)
60    CONTINUE
      WRITE(*,57)
      READ(*,*) ICONT
306  WRITE (*,58)
58    FORMAT (' SPECIFY THE BASELINE MICROLAYER '
1    , 'CONCENTRATION YOU WANT',
2    ' TO MODIFY:',/, ' 1) MEAN',/, ' 2) MINIMUM',/, ' 3) MAXIMUM',/,
3    ' 4) NEW CONTAMINANT',/, ' 5) NO MORE CHANGES',/,
4    ' GIVE NUMBER OF OPTION :')
      READ (*,*) OPTION4
      IF (OPTION4.LT.0.OR.OPTION4.GT.5) THEN
        WRITE(*,51)
        GOTO 306
      ENDIF
      IF (OPTION4.EQ.5) GOTO 300
      IF (OPTION4.EQ.4) GOTO 305
      IF (OPTION4.EQ.1) THEN
        WRITE(*,46) CNAME(ICONT)
46    FORMAT (' SPECIFY MEAN CONCENTRATION OF ',A5,' IN MICROLAYER')
        READ (*,31) CMMICRO(ICONT)
        GOTO 306
      ENDIF
      IF (OPTION4.EQ.2) THEN
        WRITE (*,47)
47    FORMAT (' SPECIFY MINIMUM CONCENTRATION OF ',A5,' IN MICROLAYER')
        READ (*,31) CLMICRO(ICONT)
        GOTO 306
      ENDIF
      IF (OPTION4.EQ.3) THEN
        WRITE (*,48)
48    FORMAT (' SPECIFY MAXIMUM CONCENTRATION OF ',A5,' IN MICROLAYER')
        READ (*,31) CUMICRO(ICONT)
        GOTO 306

```

```

      ENDIF
      ENDIF
C
C ADD ADDITIONAL CONTAMINANTS
C
      IF(OPTION.EQ.5) THEN
      NUM=NUMC
      WRITE (*,70)
70      FORMAT(' SPECIFY THE NUMBER OF ADDITIONAL CONTAMINANTS ',
1      ' TO BE ENTERED:')
      READ(*,36) NUMA
36      FORMAT(I2)
      DO 210 I=1,NUMA
      NUMC=NUMC+1
      WRITE (*,37) NUMC
37      FORMAT (' ENTER THE NAME OF CONTAMINANT ',I2,' (MAXIMUM'
1      ' 5 CHARACTERS LONG) ')
      READ (*,38) CNAM(NUMC)
38      FORMAT (A5)
92      WRITE(*,80)
      READ(*,33) CCAT(NUMC)
      IF(CCAT(NUMC).LT.1.OR.CCAT(NUMC).GT.3) THEN
      WRITE(*,86)
      GOTO 92
      ENDIF
      WRITE (*,39) CNAM(NUMC)
      READ(*,31) CMASS0(NUMC)
93      WRITE(*,40) CNAM(NUMC)
      READ (*,33) UNITC(NUMC)
      IF (UNITC(I).GT.2.OR.UNITC(I).LT.0) THEN
      WRITE(*,41)
      GOTO 93
      ENDIF
      IF (TEST2) THEN
      WRITE(*,42) CNAM(NUMC)
      READ (*,43) CFRAC(NUMC)
      WRITE(*,44)
      READ (*,45) ANS
      IF (ANS.EQ.'Y'.OR.ANS.EQ.'y') THEN
      NUMT=NUM+NUMA
      DO 94 J=1, NUMT
      CFRAC(J)=CFRAC(I)
94      CONTINUE
      TEST2 = .FALSE.
      ENDIF
      ENDIF
      WRITE(*,95) CNAM(NUMC)
95      FORMAT (' SPECIFY BASELINE CONCENTRATION OF ',A5,' IN ',
1      ' MICROLAYER',/, ' MEAN (UG/L) : ')
      READ (*,31) CMMICRO(NUMC)
      WRITE (*,96)
96      FORMAT (' MINIMUM (UG/L) : ')
      READ (*,31) CLMICRO(NUMC)
      WRITE (*,97)
97      FORMAT (' MAXIMUM (UG/L) : ')

```

```

      READ (*,31) CUMICRO(NUMC)
210  CONTINUE
      ENDIF
900  CALL DATAFILE
      CALL DATAWRITE
      RETURN
      END
C*****
      SUBROUTINE SIMUL
C
C  THIS SUBROUTINE CALCULATES THE INCREMENTAL INCREASES IN THE
C  CONCENTRATION OF THE CHEMICALS IN THE MICROLAYER AND COMPUTES
C  THE MORTALITY TO FISH LARVA
C
C  INCLUDE 'COMMOND.DAT'
      DIMENSION CINC(10), CMFINAL(10), CLFINAL(10), CUFINAL(10)
C  SPECIFY CONSTANTS FOR CALCULATIONS
      CON1 = 0.744E+6
      CON2 = 50.0E-6
      CON3 = 3.14159
      CON4 = 9.290E-2
      CON5 = 1.0E+3
      CON6 = 1.0E+3
      CMPAH=0.0
      CLPAH=0.0
      CUPAH=0.0
      CMMET=0.0
      CLMET=0.0
      CUMET=0.0
C
C  CALCULATE THE INCREASE IN THE MICROLAYER CONCENTRATION
C  FINAL CONCENTRATION IN UG/L
C
      AREA = (RAD**2)*CON3*CON4
      VOL = CON2*AREA*CON6
      DO 90 I=1,NUMC
      IF(UNITC(I).EQ.1) THEN
        CON5=1.0E+3
      ELSE
        CON5=1.0
      ENDIF
      CINC(I)= CMASS(I)*SPGRAV*CFRAC(I)*DMASS*CON1*CON5
      CMFINAL(I)=CMMICRO(I) + CINC(I)/VOL
      CLFINAL(I) = CLMICRO(I) + CINC(I)/VOL
      CUFINAL(I) = CUMICRO(I) + CINC(I)/VOL
      IF(CCAT(I).EQ.1) THEN
        CMPAH=CMPAH+CMFINAL(I)*CON6
        CLPAH= CLPAH + CLFINAL(I)*CON6
        CUPAH= CUPAH+CUFINAL(I)*CON6
      ENDIF
      IF(CCAT(I).EQ.2) THEN
        CMMET= CMMET + CMFINAL(I)
        CLMET = CLMET + CLFINAL(I)
        CUMET = CUMET+CUFINAL(I)
      ENDIF

```

```

90      CONTINUE
      AMLARVA = EXP( 4.43-0.000007*CHPAH-0.006*CMHET)
      ALLARVA = EXP( 4.43-0.000007*CLPAH-0.006*CLHET)
      AULARVA = EXP( 4.43-0.000007*CUPAH-0.006*CUHET)
      IF(AMLARVA.LT.0.0) AMLARVA=0.0
      IF(AMLARVA.GT.100.0) AMLARVA =100.0
      IF(ALLARVA.LT.0.0) ALLARVA=0.0
      IF(ALLARVA.GT.100.0) ALLARVA =100.0
      IF(AULARVA.LT.0.0) AULARVA=0.0
      IF(AULARVA.GT.100.0) AULARVA =100.0
      DAMLARVA = ABS(83.93-AMLARVA)
      DALLARVA = ABS(83.93-ALLARVA)
      DAULARVA = ABS(83.93-AULARVA)
      WRITE(*,88) AREA
88      FORMAT(//,' AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED'
1      ' MATERIAL',/, ' IS ',1P,E9.3,' SQUARE METERS',/)
      WRITE (*,91)
91      FORMAT (//,' FINAL CONTAMINANT CONCENTRATIONS IN THE ',
1      ' MICROLAYER'
2      ',/,10X,'CONCENTRATION (UG/L)',/, ' NAME      MEAN
3      ', 'MINIMUM      MAXIMUM')
      DO 95 I=1,NUMC
      WRITE(*,76) CNAM(I), CMFINAL(I), CLFINAL(I), CUFINAL(I)
76      FORMAT (1X,A5,1P,3(2X,E9.3))
95      CONTINUE
      WRITE (*,93) DAMLARVA,DALLARVA,DAULARVA
93      FORMAT(//,5X,' REDUCTION IN THE PERCENT OF LIVE SOLE LARVAE'
1      ' FROM A BACKGROUND ',/, ' PERCENT OF 83.93% IS',
2      ' F9.3,' WHEN CALCULATED FROM ',/, ' MEAN MICROLAYER ',
3      ' CONCENTRATIONS; ',F9.3,' WHEN CALCULATED FROM MINIMUM',
4      ',/, ' MICROLAYER CONCENTRATIONS; AND ',F9.3,' WHEN ',
5      ' CALCULATED FROM MAXIMUM',/,
6      ' MICROLAYER CONCENTRATIONS OF POLYAROMATIC
7      ' HYDROCARBON AND METALS',/)
      IF(TEST4) THEN
      WRITE(5,88) AREA
      WRITE (5,91)
      DO 96 I=1,NUMC
      WRITE(5,76) CNAM(I), CMFINAL(I), CLFINAL(I), CUFINAL(I)
96      CONTINUE
      WRITE (5,93) DAMLARVA,DALLARVA,DAULARVA
      ENDIF
      RETURN
      END

```

APPENDIX C

SAMPLE DREDGE DISPOSAL SCENARIOS

TITLE OF THE SIMULATION IS  
TEST :

VOLUME OF DREDGED MATERIAL IS 1500.000 CUBIC YARDS  
SPECIFIC GRAVITY OF THE DREDGED MATERIAL IS 1.353 GM/ML  
RADIUS OF THE DISPOSAL AREA IS 900.000 FEET

| CONTAMINANT INFORMATION |          |                              |                       |
|-------------------------|----------|------------------------------|-----------------------|
| NAME                    | CATEGORY | CONCENTRATION<br>IN MATERIAL | FLOATABLE<br>FRACTION |
| PB                      | METAL    | 90.000 PPM                   | 1.000E-11             |
| CU                      | METAL    | 80.000 PPM                   | 1.000E-11             |
| PAH                     | PAH      | 500.000 PPB                  | 1.000E-11             |
| PCB                     |          | 500.000 PPB                  | 1.000E-11             |

| INITIAL MICROLAYER CONCENTRATIONS |                      |         |          |
|-----------------------------------|----------------------|---------|----------|
| NAME                              | CONCENTRATION (UG/L) |         |          |
|                                   | MEAN                 | MINIMUM | MAXIMUM  |
| PB                                | 30.000               | .000    | 60.000   |
| CU                                | 28.000               | .000    | 55.000   |
| PAH                               | 13.000               | .000    | 166.000  |
| PCB                               | 100.000              | .000    | 1500.000 |

AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED MATERIAL  
IS 2.364E+05 SQUARE METERS

| FINAL CONTAMINANT CONCENTRATIONS IN THE MICROLAYER |                      |           |           |
|----------------------------------------------------|----------------------|-----------|-----------|
| NAME                                               | CONCENTRATION (UG/L) |           |           |
|                                                    | MEAN                 | MINIMUM   | MAXIMUM   |
| PB                                                 | 3.012E+01            | 1.178E-01 | 6.012E+01 |
| CU                                                 | 2.810E+01            | 1.047E-01 | 5.510E+01 |
| PAH                                                | 1.300E+01            | 6.544E-04 | 1.660E+02 |
| PCB                                                | 1.000E+02            | 6.544E-04 | 1.500E+03 |

REDUCTION IN THE PERCENT OF LIVE SOLE LARVAE FROM A BACKGROUND  
PERCENT OF 83.93% IS 29.893 WHEN CALCULATED FROM  
MEAN MICROLAYER CONCENTRATIONS; .111 WHEN CALCULATED FROM MINIMUM  
MICROLAYER CONCENTRATIONS; AND 70.777 WHEN CALCULATED FROM MAXIMUM  
MICROLAYER CONCENTRATIONS OF POLYAROMATIC HYDROCARBON AND METALS

TITLE OF THE SIMULATION IS:  
TEST 2

VOLUME OF DREDGED MATERIAL IS 1500.000 CUBIC YARDS  
SPECIFIC GRAVITY OF THE DREDGED MATERIAL IS 1.350 GM/ML  
RADIUS OF THE DISPOSAL AREA IS 900.000 FEET

| CONTAMINANT INFORMATION |          |                              |                       |
|-------------------------|----------|------------------------------|-----------------------|
| NAME                    | CATEGORY | CONCENTRATION<br>IN MATERIAL | FLOATABLE<br>FRACTION |
| PB                      | METAL    | 90.000 PPM                   | 1.000E-10             |
| CU                      | METAL    | 80.000 PPM                   | 1.000E-10             |
| PAH                     | PAH      | 500.000 PPB                  | 1.000E-10             |
| PCB                     |          | 500.000 PPB                  | 1.000E-10             |

| INITIAL MICROLAYER CONCENTRATIONS |                      |         |          |
|-----------------------------------|----------------------|---------|----------|
| NAME                              | CONCENTRATION (UG/L) |         |          |
|                                   | MEAN                 | MINIMUM | MAXIMUM  |
| PB                                | 30.000               | .000    | 60.000   |
| CU                                | 28.000               | .000    | 55.000   |
| PAH                               | 13.000               | .000    | 166.000  |
| PCB                               | 100.000              | .000    | 1500.000 |

AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED MATERIAL  
IS 2.364E+05 SQUARE METERS

| FINAL CONTAMINANT CONCENTRATIONS IN THE MICROLAYER |                      |           |           |
|----------------------------------------------------|----------------------|-----------|-----------|
| NAME                                               | CONCENTRATION (UG/L) |           |           |
|                                                    | MEAN                 | MINIMUM   | MAXIMUM   |
| PB                                                 | 3.118E+01            | 1.178E+00 | 6.118E+01 |
| CU                                                 | 2.905E+01            | 1.047E+00 | 5.405E+01 |
| PAH                                                | 1.301E+01            | 6.544E-03 | 1.660E+02 |
| PCB                                                | 1.000E+02            | 6.544E-03 | 1.500E+03 |

REDUCTION IN THE PERCENT OF LIVE SOLE LARVAE FROM A BACKGROUND  
PERCENT OF 83.93% IS 30.541 WHEN CALCULATED FROM  
MEAN MICROLAYER CONCENTRATIONS; 1.115 WHEN CALCULATED FROM MINIMUM  
MICROLAYER CONCENTRATIONS; AND 70.934 WHEN CALCULATED FROM MAXIMUM  
MICROLAYER CONCENTRATIONS OF POLYAROMATIC HYDROCARBON AND METALS

TITLE OF THE SIMULATION IS  
TEST 3

VOLUME OF DREDGED MATERIAL IS 1500.000 CUBIC YARDS  
SPECIFIC GRAVITY OF THE DREDGED MATERIAL IS 1.350 GM/ML  
RADIUS OF THE DISPOSAL AREA IS 900.000 FEET

| CONTAMINANT INFORMATION |          |                              |                       |
|-------------------------|----------|------------------------------|-----------------------|
| NAME                    | CATEGORY | CONCENTRATION<br>IN MATERIAL | FLOATABLE<br>FRACTION |
| PB                      | METAL    | 90.000 PPM                   | 1.000E-08             |
| CU                      | METAL    | 80.000 PPM                   | 1.000E-08             |
| PAH                     | PAH      | 500.000 PPB                  | 1.000E-08             |
| PCB                     |          | 500.000 PPB                  | 1.000E-08             |

| INITIAL MICROLAYER CONCENTRATIONS |                      |         |          |
|-----------------------------------|----------------------|---------|----------|
| NAME                              | CONCENTRATION (UG/L) |         |          |
|                                   | MEAN                 | MINIMUM | MAXIMUM  |
| PB                                | 30.000               | .000    | 60.000   |
| CU                                | 28.000               | .000    | 53.000   |
| PAH                               | 13.000               | .000    | 166.000  |
| PCB                               | 100.000              | .000    | 1500.000 |

AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED MATERIAL  
IS 2.364E+05 SQUARE METERS

| FINAL CONTAMINANT CONCENTRATIONS IN THE MICROLAYER |           |           |           |
|----------------------------------------------------|-----------|-----------|-----------|
| CONCENTRATION (UG/L)                               |           |           |           |
| NAME                                               | MEAN      | MINIMUM   | MAXIMUM   |
| PB                                                 | 1.478E+02 | 1.178E+02 | 1.778E+02 |
| CU                                                 | 1.327E+02 | 1.047E+02 | 1.597E+02 |
| PAH                                                | 1.365E+01 | 6.544E-01 | 1.667E+02 |
| PCB                                                | 1.007E+02 | 6.544E-01 | 1.501E+03 |

REDUCTION IN THE PERCENT OF LIVE SOLE LARVAE FROM A BACKGROUND  
PERCENT OF 83.93% IS 49.757 WHEN CALCULATED FROM  
MEAN MICROLAYER CONCENTRATIONS, 61.945 WHEN CALCULATED FROM MINIMUM  
MICROLAYER CONCENTRATIONS, AND 90.480 WHEN CALCULATED FROM MAXIMUM  
MICROLAYER CONCENTRATIONS OF POLYAROMATIC HYDROCARBON AND METALS

TITLE OF THE SIMULATION IS  
TEST 4

VOLUME OF DREDGED MATERIAL IS 1500.000 CUBIC YARDS  
SPECIFIC GRAVITY OF THE DREDGED MATERIAL IS 1.350 GM/ML  
RADIUS OF THE DISPOSAL AREA IS 700.000 FEET

| CONTAMINANT INFORMATION |          |                              |                       |
|-------------------------|----------|------------------------------|-----------------------|
| NAME                    | CATEGORY | CONCENTRATION<br>IN MATERIAL | FLOATABLE<br>FRACTION |
| PB                      | METAL    | 90.000 PPM                   | 1.000E-06             |
| CU                      | METAL    | 80.000 PPM                   | 1.000E-06             |
| PAH                     | PAH      | 500.000 PPB                  | 1.000E-06             |
| PCB                     |          | 500.000 PPB                  | 1.000E-06             |

| INITIAL MICROLAYER CONCENTRATIONS |                      |         |          |
|-----------------------------------|----------------------|---------|----------|
| NAME                              | CONCENTRATION (UG/L) |         |          |
|                                   | MEAN                 | MINIMUM | MAXIMUM  |
| PB                                | 30.000               | .000    | 60.000   |
| CU                                | 28.000               | .000    | 55.000   |
| PAH                               | 13.000               | .000    | 166.000  |
| PCB                               | 100.000              | .000    | 1500.000 |

AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED MATERIAL  
IS 2.364E+05 SQUARE METERS

| FINAL CONTAMINANT CONCENTRATIONS IN THE MICROLAYER |                      |           |           |
|----------------------------------------------------|----------------------|-----------|-----------|
| NAME                                               | CONCENTRATION (UG/L) |           |           |
|                                                    | MEAN                 | MINIMUM   | MAXIMUM   |
| PB                                                 | 1.181E+04            | 1.178E+04 | 1.184E+04 |
| CU                                                 | 1.050E+04            | 1.047E+04 | 1.053E+04 |
| PAH                                                | 7.844E+01            | 6.544E+01 | 2.314E+02 |
| PCB                                                | 1.654E+02            | 6.544E+01 | 1.565E+03 |

REDUCTION IN THE PERCENT OF LIVE SOLE LARVAE FROM A BACKGROUND  
PERCENT OF 83.93% IS 83.930 WHEN CALCULATED FROM  
MEAN MICROLAYER CONCENTRATIONS, 83.930 WHEN CALCULATED FROM MINIMUM  
MICROLAYER CONCENTRATIONS, AND 83.930 WHEN CALCULATED FROM MAXIMUM  
MICROLAYER CONCENTRATIONS OF POLYAROMATIC HYDROCARBON AND METALS

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