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

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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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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 andpartition. 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 μm, 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, bicturbation 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$^3$ 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 μg/L and for PCBs is 0.001 μg/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 μg/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 μg/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 μg/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 μg/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

<table>
<thead>
<tr>
<th>Organism</th>
<th>Effects</th>
<th>Contaminant</th>
<th>Concentration µg/liter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality criteria</td>
<td></td>
<td>Pb</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cu</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ag</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Zn</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cd</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PCB</td>
<td>.001</td>
</tr>
<tr>
<td>Acutely lethal</td>
<td>Variety of marine</td>
<td>Soluble</td>
<td>100 to 1,000</td>
</tr>
<tr>
<td></td>
<td>organisms</td>
<td>H-carbons</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>#2 Fuel oil</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>or kerosene</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fresh crude</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>oil</td>
<td>100 to 100,000</td>
</tr>
<tr>
<td></td>
<td>Variety of</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>eggs and larvae</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>24 to 48 h</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LC50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sublethal effects</td>
<td>Turbot</td>
<td>Delayed</td>
<td>011</td>
</tr>
<tr>
<td></td>
<td>eggs</td>
<td>hatch &amp;</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>abnormal</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>larvae</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plaice</td>
<td>Petroleum</td>
<td>0 to 10,000</td>
</tr>
<tr>
<td></td>
<td>larvae</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sea urchin</td>
<td>Egg</td>
<td>100 to 1,000</td>
</tr>
<tr>
<td></td>
<td>larvae</td>
<td>fertilization</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Creb larvae</td>
<td>Increase</td>
<td>011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>respiration</td>
<td>10,000 to 100,000</td>
</tr>
<tr>
<td></td>
<td>Trout²</td>
<td>Increased</td>
<td>Benzo(a)pyrene</td>
</tr>
<tr>
<td></td>
<td>eggs</td>
<td>abnormal</td>
<td>.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>larvae</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sole³</td>
<td>Reduced</td>
<td>Benzo(a)pyrene</td>
</tr>
<tr>
<td></td>
<td>eggs</td>
<td>larval</td>
<td>.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>hatch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Herring⁴</td>
<td>Increased</td>
<td>Crude oil</td>
</tr>
<tr>
<td></td>
<td>larvae</td>
<td>incidence</td>
<td>4 to 761</td>
</tr>
<tr>
<td></td>
<td></td>
<td>abnormal</td>
<td></td>
</tr>
</tbody>
</table>

REFERENCES


Flow Chart: Main Program DREDGE

Introductory Screen

Print Input Data and Simulation Results

Set Flag for Printing

Input Data in a File

Call DATAENTER Call DATAFILE Call DATAWRITE

Check to See if File Exists

Call DATAREAD Call DATAWRITE

Get New Data File

Run Simulation Modify Data or Get New Data File

Call SIMUL

Run Another Simulation

Stop
Flow Chart. Subroutine DATAENTER

Entry

Ask for and Read Title

Ask for and Read Volume of Dredged Material (Cubic Yards)

Ask for and Read Specific Gravity gm/ml

Ask for and Read Number of Contaminants

Begin Loop for # of Contaminants

Ask for and Read the Name of the Contaminant

Ask for and Read the Category of the Contaminant
1. PAH
2. Cl, Pb, Zn, Ag or Hg
3. Other

Check That Category Number is in Range 1-3

Ask for and Read Concentration of in Dredged Material

Specify Units of Concentration
1. ppm
2. ppb

Check to be Sure That Unit Number is 1 or 2

Yes

Ask for and Read Floatable Fraction

No

Copy into Data File for All Contaminants

Floatable Fraction to be Used for all Contaminant

Ask for and Read Mean, Minimum and Maximum Microlayer Concentration of Contaminant (µg/L)

End Loop

Ask for and Read Radius of Disposal Area (ft)

Return

A.2
Flow Chart: Subroutine DATAFILE

Entry

Do You Want to Store Data in a File

Yes

Request and Read File Name

Check to See if File Exists

Yes

No

Open File

Write Title
Volume, Specific Gravity of Dredged Material
Radius of Disposal Area
Number of Contaminants

Do You Want to Write Over the File?

Yes

No

For Each Contaminant:
Name, Concentration, Units, Floatable Fraction Microlayer Concentrations,
Contaminant Category

Close File

Return

A.3
Flow Chart: Subroutine DATAREAD

Entry

Open File

Read Title

Read Volume and Specific Gravity of Dredged Material and Radius of Disposal Area

Read Number of Contaminants

Begin Loop for # of Contaminant

Read Name, Concentration, Units, Floatable Fraction, Microlayer, Concentrations and Contaminant Categories

End Loop

Close File

Return
Flow Chart: Subroutine DATAWRITE

Entry

Write Title

Write Volume and Specific Gravity of Dredged Material and Radius of Disposal Area

For Each Contaminant

Write Name, Contaminant Category, Concentration and Floatable Fraction

For Each Contaminant

Write Name, Microlayer Concentrations

Check to See if Printer Flag is Set

No

Yes

Write Same as Screen Display to Printer

Return
Flow Chart: Subroutine MODDATA

Entry

Choose Section of Data to Modify
1. Title
2. Volume, Specific Gravity of Dredged Material and Radius of Disposal Area
3. Concentration Category, Floatable Fraction of Contaminant
4. Concentrations in Microlayer
5. Add New Contaminants
6. No More Changes

If Option is 6
If Option is 1
If Option is 2
If Option is 3
If Option is 4
If Option is 5
Return

Ask for and Read Title

A
B
C
J

D

A.6
Option is 2

Choose Data to be Modified
1. Volume
2. Specific Gravity
3. Radius of Disposal Area
4. No More Changes

If Option is 4

If Option is 1

If Option is 2

If Option is 3

Ask for and Read Volume

Ask for and Read Specific Gravity

Ask for and Read Radius of Disposal Area
Option is 3

Specify Number of Contaminant

Choose Section of Data to be Modified
1. Concentration
2. Units of Concentration
3. Floatable Fraction
4. Contaminant Category
5. New Contaminant Number
6. No More Changes

If Option is 6

If Option is 5

If Option is 1

Ask for and Read Concentration

If Option is 2

Ask for and Read Units of Concentration

If Option is 3

Ask for and Read Floatable Fraction

If Option is 4

Ask for and Read Contaminant Category
Option is 4

Specify Number of Contaminant

Specify the Microlayer Concentration to be Modified
1. Mean
2. Minimum
3. Maximum
4. New Contaminant
5. No More Changes

If Option is 5
If Option is 4
If Option is 1
Ask for and Read Mean Concentration
If Option is 2
Ask for and Read Minimum Concentration
If Option is 3
Ask for and Read Maximum Concentration
Flow Chart: Subroutine SIMUL

- Entry
  - Compute Volume of Water Affected From Radius and Thickness of Microlayer (50 μm)
  - Loop for Each Contaminant
    - Compute Incremental Increase in Contaminant Concentration
    - Add Increase to Microlayer Concentrations
    - Sum Metal and PAH Concentrations in Microlayer
    - End Loop
- Compute Percent Live Larvae
- Print to Screen Final Microlayer Concentrations and Percent Live Larvae
- Check to see if Printer Flag is Set
  - Yes: Print Microlayer Concentrations and Percent Live Larvae
  - No: Return
Ask for and Read Number of Contaminants

Begin Loop for # of Contaminants Added

Ask for and Read the Name of the Contaminant

Ask for and Read the Category of the Contaminant
1. PAH
2. Cu, Pb, Zn, Ag or Hg
3. Other

Check That Category Number is in Range 1-3

Yes

Ask for and Read Concentration of in Dredged Material

Specify Units of Concentration
1. ppm
2. ppb

No

Check to be Sure That Unit Number is 1 or 2

Yes

Ask for and Read Floatable Fraction

Copy into Data File for All Contaminants

Floatable Fraction to be Used for all Contaminant

No

Ask for and Read Mean, Minimum and Maximum Microlayer Concentration of Contaminant (µg/L)

End Loop
APPENDIX B

DREDGE PROGRAM
PROGRAM DREDGE

PROGRAM FOR PREDICTING THE ENRICHMENT OF CONTAMINANTS IN THE SEA-SURFACE MICROLAYER DUE TO DREDGING OR DISPOSAL OF DREDGED MATERIAL.

CALCULATIONS BASED ON SIMPLE PARTITIONING THEORY

PROGRAMMED BY CHRISTINA E. COWAN

JANUARY 1966

DIMENSIONING

INCLUDE: COMMON DAT

LOGICAL*2 TEST

TEST4 = .FALSE.

INTRODUCTORY SCREEN

WRITE (*,10)

10 FORMAT ('HE IMPACT OF DREDGING AND DREDGED MATERIAL',/,
    1 'DISPOSAL ON THE SEA-SURFACE MICROLAYER',/,
    2 'THIS PROGRAM CALCULATES THE ENRICHMENT IN THE SEA-SURFACE MICROLAYER',/,
    3 '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'. '/

WRITE(*,23)

23 FORMAT('THE EQUATION USED TO CALCULATE THE INCREASE IN',
    1 'CONCENTRATION FOR EACH CONTAMINANT IS:',//,
    2 'I = VOLD*CON*FLOAT/VOLW',//, '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'.//)

WRITE(*,92)

READ(*,92)

WRITE(*,24)

24 FORMAT('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: ' ,//, 'LIVE = EXP(4.43 - 7.0E-6*PAH - '
    8 '4.0E-3*MET)',//, 'WHERE PAH IS THE TOTAL CONCENTRATION OF PAH',
    9 'IN UG/L AND MET IS THE TOTAL ',//,
    10 'METAL CONCENTRATION IN MG/L'.//)

CHOOSE TO PRINT THE INPUT DATA AND RESULTS OUT ON PRINTER
WRITE(*,92)
READ(*,*)
WRITE(*,92)
92 FORMAT('DO YOU WANT A PRINTER LISTING OF THE INPUT DATA AND THE SIMULATION RESULTS?',//,'ANS: Y OR N [DEFAULT = Y]')
READ(*,92)ANS2
IF(ANS2.EQ.'N' OR ANS2.EQ.'m') GOTO 90
OPEN(S,FILE='LPT/',STATUS='NEW')
TEST=.TRUE.
WRITE(*,11)
11 FORMAT('YOU HAVE THE OPTION OF ENTERING THE INPUT DATA FOR THE MODEL FOR EACH SIMULATION AND SAVING THE DATA IN A FILE OR YOU MAY RETRIEVE A FILE OF INPUT DATA FOR USE IN THIS SIMULATION',//)
WRITE(*,12)
12 FORMAT('DO YOU HAVE AN EXISTING FILE OF DATA THAT YOU WANT TO USE?',//,'ANS: Y OR N [DEFAULT = Y]')
READ(*,21)ANS
21 FORMAT(A1)
IF(ANS.EQ.'-N.' OR ANS.EQ.*m') THEN
CALL DataEnter
CALL DataWrite
CALL DataFile
GOTO 110
ENDIF
WRITE(*,13)
13 FORMAT('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('FILE NOT FOUND: TRY AGAIN')
GOTO 100
ENDIF
100 CONTINUE
120 WRITE(*,15)
16 FORMAT('DO YOU WISH TO RUN SIMULATION WITH THIS DATA OR',//,'MODIFY THIS DATA BEFORE RUNNING THE SIMULATION OR',//,'GET A NEW DATA FILE',//,'1) RUN SIMULATION',//,'2) MODIFY DATA',//,'3) GET NEW DATA FILE OR START OVER',//,'GIVE NUMBER OF OPTION:')
READ(*,17)IANS
17 FORMAT(11)
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 120
IF (IANS EQ 2) THEN
   CALL MODDATA
   WRITE(*,92)
92 FORMAT ('CONTINUE?')
   READ(*,*)
   ENDIF
   CALL SIMUL
   WRITE(*,19)
19 FORMAT ('DO YOU WANT TO RUN ANOTHER SIMULATION? 
1 / ' ANS: Y OR N (DEFAULT = N)'
   READ(*,1) ANS1
   IF (ANS1 EQ 'Y' OR ANS1 EQ 'y') THEN
      GOTO 120
   ENDIF
   IF (TEST4) THEN
      CLOSE(5)
   CLOSE(5)
   STOP
   END

********************************************************************
SUBROUTINE DATAENTER
C
C DATA ENTRY ROUTINE FOR THE PROGRAM
C
C INCLUDE 'COMMON DATA'
LOGICAL TEST2
TEST2 = .TRUE.
C ENTER TITLE OF THE SIMULATION
WRITE(*,29)
29 FORMAT ('GIVE TITLE OF THE SIMULATION')
   READ(*,29) TITLE
25 FORMAT (A)
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
   1 (GM/ML)
   READ(*,31) SPCGRAV
C ENTER INFORMATION ON THE CONTAMINANTS IN THE DREDGED MATERIAL
WRITE(*,33)
33 FORMAT ('SPECIFY NUMBER OF CONTAMINANTS FOR WHICH: 
1 MICROLAYER ENRICHMENT IS TO BE CALCULATED NUMBER IS 
   READ(*,34) NUMC
34 FORMAT (I)
   DO 10 I =1,NUMC
      WRITE(*,35)
35 FORMAT ('ENTER THE NAME OF CONTAMINANT : ',15X)
   READ(*,38) CNAM(I)
36 FORMAT (A)
   12 WRITE(*,12)

FORMAT ("INDICATE CATEGORY TO WHICH CONTAMINANT BELONGS:");
1: 1) PAH, 2) CU, Pb, Zn, Ag, Au, HG, 3) OTHER;
2: GIVE NUMBER OF THE CATEGORY:
READ(*,33) CCAT(I)
IF (CCAT(I) LT 1 OR CCAT(I) GT 3) THEN
WRITE(*,35)
51 FORMAT ("ERROR IN CATEGORY SPECIFIED: TRY AGAIN")
GOTO 52
ENDIF
WRITE(*,39) CNAM(I)
39 FORMAT ("ENTER CONCENTRATION OF ',AS,' IN DREDGED :");
1) MATERIAL
READ(*,31) CMASS(I)
31: WRITE(*,40) CNAM(I)
40 FORMAT ("SPECIFY UNITS OF ',AS,' CONCENTRATION :");
1) SE, '1 PPB 2) FPB', '4 GIVE NUMBER :")
READ(*,33) UNITC(I)
33 FORMAT(I)
IF (UNITC(I).GT 2 OR UNITC(I).LT 0) THEN
WRITE(*,41)
41 FORMAT ("ERROR IN UNITS SPECIFIED: TRY AGAIN")
GOTO 211
ENDIF
IF (TEST(I)) THEN
WRITE(*,42) CNAM(I)
42 FORMAT ("SPECIFY FLOATABLE FRACTION OF ',AS,' :");
READ(*,43) CFRAC(I)
43 FORMAT(E6.3)
WRITE(*,44)
44 FORMAT ("IS THIS FLOATABLE FRACTION TO BE USED FOR ALL'
1) CONTAMINANTS? AMS: Y OR N [DEFAULT N]")
READ(*,45) AMS
45 FORMAT(A2)
IF (AMS.EQ.'Y'.OR.AMS.EQ.'Y') THEN
DO 214 J=1, NUMC
CFRAC(J)=CFRAC(I)
214 CONTINUE
TEST(I)=FALSE.
ENDIF
WRITE(*,46) CNAM(I)
46 FORMAT ("SPECIFY BASELINE CONCENTRATION OF ',AS,' IN :");
1) MICROLAYER', '/ MEAN (UG/L)
READ(*,31) CMICRO(I)
WRITE(*,47)
47 FORMAT ("MINIMUM (UG/L) :");
READ(*,31) CLMICRO(I)
WRITE(*,48)
48 FORMAT ("MAXIMUM (UG/L) :");
READ(*,31) CMICRO(I)
210 CONTINUE.
C RADIUS OF DISPOSAL AREA
WRITE(*,49)
49 FORMAT ("SPECIFY THE RADIUS OF DISPOSAL AREA POTENTIALLY EFFECTED BY DREDGING OR DREDGED MATERIAL DISPOSAL (FEET) :");
SUBROUTINE DATAREAD
C
C READS THE DATA FROM THE SPECIFIED INPUT DATA FILE
C
INCLUDE 'COMMIC 3.DAT'
OPEN (7, FILE=FILEIN)
READ (7, 10) TITLE
READ (7, 11) Dmass, sgrav, rad
READ (7, 12) NUmC
DO 460 I=1, NUmC
READ (7, 13) CNAM(I), CMass(I), UNITC(I), CFRAC(I), CMICRO(I)
CONTINUE
CLOSE (7)
RETURN
C
C---------------------------------------------------------------------------
C SUBROUTINE DATAPFILE
C
INCLUDE 'COMNONODAT'
CHARACTER*10 FILEOUT
LOGICAL TEST3
WRITE (*, 60)
60 FORMAT(' DO YOU WANT TO STORE THE DATA IN A FILE SO THAT IT MAY BE USED IN FUTURE SIMULATIONS? ANS: Y OR N ', ' ' '(DEFAULT: Y')'
READ (*, 20) ANS
WRITE (*, 61)
20 FORMAT(A2)
IF (ANS EQ 'N' OR ANS EQ 'n') GOTO 398
WRITE(*, 61)
61 FORMAT(' TYPE IN THE NAME OF THE FILE: FORMAT FILENAME EXIT, ' ' ' ' ' 'FILENAME CAN ONLY 8 CHARACTERS LONG AND EXT ONLY ' ' ' ' ' '3 CHARACTERS LONG ' ' ' ' ' ' READ (*, 14)
WRITE (*, 14)
FILEOUT
READ (*, 14)
FILEOUT
INQUIRE (FILE=FILEOUT, EXIST=TEST3)
IF (TEST3) THEN
WRITE(*, 62)
62 FORMAT(' FILE ALREADY EXISTS ' ' ' ' ' ' READ (*, 20) ANS
IF (ANS EQ 'N' OR ANS EQ 'n') GOTO 310
ENDIF
OPEN (4, FILE=FILEOUT, STATUS='NEW')
WRITE (6,10) TITLE
WRITE (6,11) DMASS, SFGRAV, RAD
WRITE (6,12) NUMC
DO 320 I=1,NUMC
WRITE (6,13) CNAM(I), DMASS(I), UNITC(I), CFRAC(I), CMMICRO(I), CLMICRO(I), CCAT(I)
320 CONTINUE
CLOSE (6)
RETURN
FORMAT (A80)
10 FORMAT (F9.3)
11 FORMAT (F9.3)
12 FORMAT (F9.3)
13 FORMAT (A5,F9.3,12,E9.3,12)
END

SUBROUTINE DAVRITE

WRITE 'SUMMARY OF INPUT DATA TO THE SCREEN'

INCLUDE 'COMMON DATA'
CHARACTER*3 UNITP
CHARACTER*5 CCATP
WRITE (*,78) TITLE
78 FORMAT (' TITLE OF THE SIMULATION IS: ',A30)
WRITE (*,79) DMASS, SFGRAV, RAD
79 FORMAT (' VOLUME OF DREDGED MATERIAL IS ',F9.3,' CUBIC YARDS',
1 ' SPECIFIC GRAVITY OF THE DREDGED MATERIAL IS ',F9.3,
2 ' RADIUS OF THE DISPOSAL AREA IS ',F9.3,' FEET',/
3 WRITE (*,80)
80 FORMAT (' CONTAMINANT INFORMATION',/,
1 ' NAME CATEGORY CONCENTRATION FLOATABLE ',
2 ' MATERIAL FRACTION')
DO 74 I=1,NUMC
IF(UNITC(I).EQ.1) THEN
   UNITP = 'PPM'
ELSE
   UNITP = 'PPB'
ENDIF
IF(CCAT(I).EQ.1) THEN
   CCATP = 'PAM'
ELSEIF(CCAT(I).EQ.2) THEN
   CCATP = 'METAL'
ELSE
   CCATP = ' '
ENDIF
WRITE (*,75) CNAM(I), CCATP, DMASS(I), UNITP, CFRAC(I)
75 FORMAT (A5,AS,5X,AS,F9.3,12,E9.3,12,F9.3)
76 CONTINUE
WRITE (*,76)
76 FORMAT (A30,' INITIAL MICROLAYER CONCENTRATIONS',/,
1 ' NAME CONCENTRATION (UG/L)',/
2 ' MEAN MINIMUM MAXIMUM')
DO 77 I=1,NUMC
WRITE (*,75) CNAM(I), CMMICRO(I), CLMICRO(I), CUMICRO(I)
77 CONTINUE
FBAB IN X.M.41.EF F9 3.61.EF 93.72.EF F9.3
97 CONTINUE
C WRITE TO PRINTER
    IF (TEST4) THEN
C WRITE (5, 88)
C8W FORMAT (' L.M')
        WRITE (5, 78) Title
        WRITE (5, 71) DMAS, SGRAV, RAD
        WRITE (5, 72)
        DO 79 I=1, NUMC
            IF (UNITC(I) .EQ. 1) THEN
                UNITP = ' FPM'
            ELSE
                UNITP = ' FPM'
            END IF
            IF (CCAT(I) .EQ. 1) THEN
                CCATP = ' PAH'
            ELSEIF (CCAT(I) .EQ. 2) THEN
                CCATP = ' METAL'
            ELSE
                CCATP =
            END IF
            WRITE (5, 73) CNAM(I), CCATP, DMAS, SGRAV, RAD, UNITP, CFrac(I)
79 CONTINUE
    WRITE (5, 75)
    DO 85 I=1, NUMC
        WRITE (5, 76) CNAM(I), CMN_MICRO(I), CLMICRO(I), CUMICRO(I)
85 CONTINUE
END
C**********************************************************************************************
SUBROUTINE MODDATA
C
C THIS SUBROUTINE ALLOWS AN EXISTING DATA SET TO BE MODIFIED
C BEFORE CONDUCTING THE SIMULATION
C
$INCLUDE 'CONMON.DAT'
LOGICAL TEST2
TEST2 = TRUE
300 WRITE (*, 50)
50 FORMAT (' INDICATE WHICH SECTION OF DATA YOU WISH TO MODIFY: ', 60)
      1 /,' 1) TITLE OF THE SIMULATION', '/. 1', ' VOLUME AND SPECIFIC', 1
      2 /,' GRAVITY OF DREDGED MATERIAL, RADIUS OF DISPOSAL AREA', ' /,
      3 /,' 3) CONCENTRATION, CATEGORY, FLOATABLE FRACTION OF CONTAMINANTS',
      4 /,' 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
END IF
C EXIT

8.7
IF (OPTION.EQ.4) GOTO 900

CHANGE THE TITLE

IF (OPTION.EQ.1) THEN
WRITE (*,29)
29 FORMAT(' GIVE TITLE OF THE SIMULATION')
READ(*,28) TITLE
28 FORMAT(A80)
GOTO 300
ENDIF

IF (OPTION.EQ.2) THEN
WRITE (*,52)
52 FORMAT(' INDICATE WHICH DATA YOU WISH TO MODIFY:',/,
1 ' 1) VOLUME OF DREDGED MATERIAL',/,
2 ' 2) SPECIFIC GRAVITY',/,
2 ' 3) RADIUS OF DISPOSAL AREA',/,
3 ' 4) NO MORE CHANGES',/,' GIVE NUMBER OF OPTION: ')
READ (*,*) OPTION2
IF (OPTION2.LT 1.OI.OTION2.GT.4) THEN
WRITE (*,51)
51 FORMAT (' ENTER VOLUME OF DREDGED MATERIAL (CUBIC YARDS): ')
READ (*,31) DMASS
31 FORMAT (F9.0)
GOTO 301
ENDIF
IF (OPTION2.EQ.4) GOTO 300
ENDIF

IF (OPTION.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
31 FORMAT (F9.0)
GOTO 301
ENDIF
ENDIF

IF (OPTION.EQ.3) THEN
WRITE (*,54)
54 FORMAT (' SPECIFY NUMBER OF THE CONTAMINANT:')
DO 56 I=1,NUMC
WRITE(*,55) I, CNAM(I)
55 FORMAT(12,3X,A5)
56 CONTINUE
WRITE(*,57)
57 FORMAT(' GIVE CONTAMINANT NUMBER:')
READ(*,*) ICONT
WRITE(*,53)
53 FORMAT(' INDICATE WHICH DATA YOU WANT TO MODIFY: ',/,' 1) CONCENTRATION IN DREDGED MATERIAL',/,' 2) UNITS OF CONCENTRATION',/,' 3) FLOATABLE FRACTION',/,' 4) CONTAMINANT CATEGORY',/,' 5) NEW CONTAMINANT NUMBER ',/,' 6) NO MORE CHANGES',/,' GIVE NUMBER OF OPTION:')
READ(*,*) OPTION3
IF (OPTION3.LE.1.OR.OPTION3.GT.6) THEN
WRITE(*,51)
GOTO 302
ENDIF
IF (OPTION3.EQ.6) GOTO 300
IF (OPTION3.EQ.5) GOTO 303
IF (OPTION3.EQ.1) THEN
WRITE(*,39) CNAM(ICONT)
FORMAT(' ENTER CONCENTRATION OF ',AS,' IN DREDGED MATERIAL: ')
READ(*,31) CMASSO(ICONT)
GOTO 302
ENDIF
IF (OPTION3.EQ.2) THEN
WRITE(*,40) CNAM(ICONT)
FORMAT(' SPECIFY UNITS OF ',AS,' CONCENTRATION: ',/,' 1) PPM  2) PPB',/,' GIVE NUMBER OF UNITS:')
READ(*,33) UNITC(ICONT)
WRITE(*,33)
33 FORMAT(I1)
IF (UNITC(ICONT).GT.2.OR.UNITC(ICONT).LT.0) THEN
WRITE(*,41)
41 FORMAT(' ERROR IN UNITS SPECIFIED: TRY AGAIN')
GOTO 211.
ENDIF
IF (OPTION3.EQ.3) THEN
WRITE(*,42) CNAM(ICONT)
FORMAT(' SPECIFY FLOATABLE FRACTION OF ',AS,' : ')
READ(*,43) CFRAC(ICONT)
WRITE(*,44)
44 FORMAT(' IS THIS FLCATABE FRACTION TO BE USED FOR ALL',/,' CONTAMINANTS? 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 (OPTION.EQ.4) THEN
WRITE(*,50) CNAM(icont)
FORMAT(' INDICATE CATEGORY TO WHICH CONTAMINANT BELONGS:',
1 / , ' 1) PAH,/' , ' 3) CU, Pb, Zn, Ag, Hg',/ , ' 3) OTHER',/
2. ' GIVE NUMBER OF THE CATEGORY: ')
READ(*,33) CCAT(icont)
IF(CCAT(I).LT.1.OR.CCAT(I).GT.3) THEN
WRITE(*,86)
FORMAT(' ERROR IN CATEGORY SPECIFIED: TRY AGAIN')
GOTO 302
ENDIF
GOTO 302
ENDIF
ENDIF
C
CHANGE CONCENTRATIONS IN MICROLAYER
IF (OPTION.EQ.4) THEN
WRITE(*,54)
DO 60 I=1,NUMC
WRITE(*,55) I, CNAM(I)
CONTINUE
WRITE(*,57)
READ(*,*) ICONT
WRITE(*,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(*,31)
GOTO 306
ENDIF
IF (OPTION4.EQ.5) GOTO 380
IF (OPTION4.EQ.4) GOTO 305
IF (OPTION4.EQ.1) THEN
WRITE(*,46) CNAM(icont)
FORMAT(' SPECIFY MEAN CONCENTRATION OF ',AS,' IN MICROLAYER')
READ(*,31) CMICRO(icont)
GOTO 306
ENDIF
IF (OPTION4.EQ.2) THEN
WRITE(*,47)
FORMAT(' SPECIFY MINIMUM CONCENTRATION OF ',AS,' IN MICROLAYER')
READ(*,31) CMICRO(icont)
GOTO 306
ENDIF
IF (OPTION4.EQ.3) THEN
WRITE(*,48)
FORMAT(' SPECIFY MAXIMUM CONCENTRATION OF ',AS,' IN MICROLAYER')
READ(*,31) CMICRO(icont)
GOTO 306
B.10
C ADD ADDITIONAL CONTAMINANTS

C

IF(OPTION.EQ.3) THEN
  NUM=NUMC
  WRITE(*,70)
END IF
C ADD ADDITIONAL CONTAMINANTS

70 FORMAT(' SPECIFY THE NUMBER OF ADDITIONAL CONTAMINANTS ',
  1 ' TO BE ENTERED: ')
  READ(*,36) NUMA
  FORMAT(12)
  DO 210 I=1,NUMA
       NUMC=NUMC+1
       WRITE(*,37) NUMC
    210 FORMAT(' ENTER THE NAME OF CONTAMINANT ',I2,' ',
       1 ' , 5 CHARACTERS LONG: ')
    36 FORMAT(A5)
    37 WRITE(*,80)
    38 READ(*,33) CCAT(NUMC)
    39 IF(CCAT(NUMC).LT.1.OR.CCAT(NUMC).GT.3) THEN
       WRITE(*,66)
       GOTO 37
    40 END IF
    41 WRITE(*,39) CNAM(NUMC)
    42 READ(*,31) CNAM(NUMC)
    43 WRITE(*,40) CNAM(NUMC)
    44 READ(*,33) UNITC(NUMC)
    45 IF (UNITC(I).GT.2.OR.UNITC(I).LT.0) THEN
       WRITE(*,41)
       GOTO 45
    46 END IF
    47 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
          NUNT=NUM+NUMA
          DO 94 J=1, NUNT
             CFRAC(J)=CFRAC(I)
          CONTINUE
          TEST2=.FALSE.
       END IF
    48 END IF
    49 WRITE(*,95) CNAM(NUMC)
    50 FORMAT(' SPECIFY BASELINE CONCENTRATION OF ',A5,' IN ',
       1 'MICROLAYER',/,' MEAN (UG/L): ')
    51 READ(*,31) CMMICRO(NUMC)
    52 WRITE(*,96)
    53 FORMAT(' MINIMUM (UG/L): ')
    54 READ(*,31) CLMICRO(NUMC)
    55 WRITE(*,97)
    56 FORMAT(' MAXIMUM (UG/L): ')

B.11
READ (*) CUMICRO(NUMC)
210 CONTINUE
ENDIF
900 CALL DATAFILE
CALL DATAWRITE
RETURN
END

**********************************************************************
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
INCLUDE 'COMMON.DAT'
DIMENSION CINC(10), CMFINAL(10), CLFINAL(10), CUNFINAL(10)
C
SPECIFY CONSTANTS FOR CALCULATIONS
CON1 = 0.744E-6
CON2 = 5.0E-6
CON3 = 3.1E+1
CON4 = 9.2E-2
CON5 = 1.0E+3
CON6 = 1.0E+3
CMFAH=0.0
CLFAH=0.0
CPFAH=0.0
CMMET=0.0
CLMET=0.0
CUMET=0.0
C
CALCULATE THE INCREASE IN THE MICROLAYER CONCENTRATION
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)= CMASS3(I)*SPGRAV*CFRAC(I)*DMASS*CON1*CON3
CMFINAL(I)=CMICRO(I) + CINC(I)/VOL
CLFINAL(I) = CLMICRO(I) + CINC(I)/VOL
CUNFINAL(I) = CUMICRO(I) + CINC(I)/VOL
IF(CCAT(I).EQ.1) THEN
CMFAH=CMFAH+CMFINAL(I)*CON6
CLFAH= CLFAH + CLFINAL(I)*CON6
CPFAH= CPFAH+CPFINAL(I)*CON6
CMMET= CMMET + CMFINAL(I)*CON6
CLMET = CLMET + CLFINAL(I)
CUMET = CUMET+CFINAL(I)
ENDIF
IF(CCAT(I).EQ.2) THEN
CMMET+ CMMET = CMFINAL(I)
CLMET = CLMET + CLFINAL(I)
CUMET = CUMET+CFINAL(I)
ENDIF
CONTINUE

AMLARVA = EXP( 4.43 - 0.000007 * CMFAN - 0.006 * CMNET)
ALLARVA = EXP( 4.43 - 0.000007 * CLFMAN - 0.006 * CLMNET)
AULARVA = EXP( 4.43 - 0.000007 * CUFAN - 0.006 * CUMET)
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
DMARVA = ABS(A3.93 - AMLARVA)
DALLARVA = ABS(A3.93 - ALLARVA)
DAULARVA = A2S(A3.93 - 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 //, '16X,' '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(ZZ,E9.3))
95 CONTINUE
WRITE (*,93) DMARVA, DALLARVA, DAULARVA

93 FORMAT(///,5X,'REDUCTION IN THE PERCENT OF LIVE SOLE LARVAE',
1 ' FROM A BACKGROUND', //, 'PERCENT OF 93.95% IS',
2 'F9.3, ' WHEN CALCULATED FROM', //, 'MEAN MICRO LAYER',
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(*,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) DMARVA, DALLARVA, DAULARVA
END IF
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 1.333 GM/ML
RADIUS OF THE DISPOSAL AREA IS 700,000 FEET

CONTAMINANT INFORMATION

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<tr>
<th>NAME</th>
<th>CATEGORY</th>
<th>CONCENTRATION</th>
<th>FLOATABLE</th>
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<tr>
<td>Pb</td>
<td>Metal</td>
<td>90.000 PPM</td>
<td>1.00E-11</td>
</tr>
<tr>
<td>Cu</td>
<td>Metal</td>
<td>80.000 PPM</td>
<td>1.00E-11</td>
</tr>
<tr>
<td>PAH</td>
<td>PAH</td>
<td>500.000 PPM</td>
<td>1.00E-11</td>
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<tr>
<td>PCB</td>
<td></td>
<td>500.000 PPM</td>
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INITIAL MICROLAYER CONCENTRATIONS

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<th>MAXIMUM</th>
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<td>18.000</td>
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<td>100.000</td>
<td>.000</td>
<td>1500.000</td>
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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)

<table>
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<th>MEAN</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
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</thead>
<tbody>
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<td>1.179E-01</td>
<td>6.012E+01</td>
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<td>Cu</td>
<td>2.810E+01</td>
<td>1.047E-01</td>
<td>5.510E+01</td>
</tr>
<tr>
<td>PAH</td>
<td>1.300E+01</td>
<td>6.544E-04</td>
<td>1.660E+02</td>
</tr>
<tr>
<td>PCB</td>
<td>1.000E+02</td>
<td>6.544E-04</td>
<td>1.500E+03</td>
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</table>

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 1

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
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<tr>
<td>PB</td>
<td>METAL</td>
<td>90 000 PPM</td>
<td>1.000E-10</td>
</tr>
<tr>
<td>CU</td>
<td>METAL</td>
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<tr>
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INITIAL MICROLAYER CONCENTRATIONS
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<th>MAXIMUM</th>
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<tr>
<td>Cu</td>
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AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED MATERIAL IS 2.364E+05 SQUARE METERS

FINAL CONTAMINANT CONCENTRATIONS IN THE MICROLAYER
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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 1

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

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<thead>
<tr>
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<td>Cu</td>
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<tr>
<td>PAH</td>
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<tr>
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INITIAL MICROLAYER CONCENTRATIONS

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<td>Cu</td>
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AREA OF WATER IMPACTED BY THE DISPOSAL OF DREDGED MATERIAL IS 2.364E+05 SQUARE METERS

FINAL CONTAMINANT CONCENTRATIONS IN THE MICROLAYER

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<tbody>
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REDUCTION IN THE PERCENT OF LIVE SOLE LARVAE FROM A BACKGROUND PERCENT OF 83% IS 49.757 WHEN CALCULATED FROM MEAN MICROLAYER CONCENTRATIONS. 41.943 WHEN CALCULATED FROM MINIMUM MICROLAYER CONCENTRATIONS. AND 90.480 WHEN CALCULATED FROM MAXIMUM MICROLAYER CONCENTRATIONS OF POLYAROMATIC HYDROCARBON AND METAL.
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

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INITIAL MICROLAYER CONCENTRATIONS

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

FINAL CONTAMINANT CONCENTRATIONS IN THE MICROLAYER

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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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</tbody>
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