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A REVISED USER'S GUIDE TO COSMOS
(COMPOSITE OIL SPILL MODEL FOR OPERATIONAL SERVICES)

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PREFACE

This User's Guide is meant to describe the use of the National Weather Service's oil spill behavior forecast model, COSMOS (Composite Oil Spill Model for Operational Services), produced by the Techniques Development Laboratory. The model is designed to predict the behavior of floating oil from a fixed source point in the coastal zone (shoreline out to 360 miles), excluding small bays. A forecast of the oil slick geometry for each 12 hours, out to 48 hours is plotted on a background map showing the local coastline. The primary input data for the model are the latitude and longitude of the spill site, the width of the map desired, the oil flow rate, and the initial distribution of oil on the water. Wind forecasts for the spill can be made automatically by COSMOS using atmospheric model pressure and temperature forecasts. Otherwise the user codes in his or her own forecast.

This manual contains a brief description of the model physics, and gives a detailed explanation of the input data format. Sample runs and outputs are given in appendices to help acquaint the model user with COSMOS.

USER'S GUIDE TO COSMOS
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1. INTRODUCTION

COSMOS is the National Weather Service's (NWS's) oil spill behavior model. This version computes the two-dimensional motion of a finite thickness of oil at the sea surface under the action of wind stress and water currents. The position of the oil slick is plotted each 12 hours on a map which includes the local geography.

The user gives the latitude-longitude coordinates of the spill and other input data, and COSMOS computes the wind stress at the sea surface. This stress drives a hydrodynamic model of the continental shelf region, which computes horizontal velocities and water surface elevations. Then the current at the surface is used to calculate the stress at the under side of the oil. Another model for two-dimensional oil motion is used to compute the time history of the oil slick. The positions of oil on the water are drawn on a map which uses the National Meteorological Center (NMC) geography files. Map width (degrees) and height can vary.

COSMOS is accessed by the program WE1OILY7. The user can call up the NMC computer over the FTS line and communicate using any terminal with dial-up capability (e.g., TI Silent 700). After the proper information has been entered, the user submits COSMOS through batch processing. The data necessary to run COSMOS is stored on several files, and these data can be changed at will for specific user needs. The following is a brief description of the technical aspects of COSMOS. For more details, refer to Hess and Kerr (1979).

2. MODEL PHYSICS

The vector equation for oil motion comes from the depth-integrated form of the horizontal fluid momentum equation. The mass equation comes from the vertically-integrated continuity equation and gives the oil thickness. The equations are solved on a finite-difference grid of 2-km size. The mass equation uses a mass flux correction scheme to eliminate nearly all artificial diffusion. The vector momentum and mass conservation equations are:

$$\frac{\partial \underline{u}}{\partial t} = -(\rho_w - \rho_o)/\rho_w g \nabla h + (\underline{\tau}_s - \underline{\tau}_b)/(\rho_o h) + f \hat{k} \times \underline{u} \quad \text{and}$$

$$\frac{\partial h}{\partial t} = -\nabla \cdot (h \underline{u}) - R .$$

where \underline{u} = oil velocity vector (m/s),
 ρ_w = mass density of water (gm/cc)
 ρ_o = mass density of oil (gm/cc),
 g = gravitational acceleration (m/s²),
 h = oil thickness (m),
 \underline{I}_s = surface tangential stress vector
 ρ_a = mass density of air (gm/cc),
 \underline{I}_b = bottom tangential stress vector
 f = Coriolis parameter (s⁻¹),
 \hat{k} = unit vector in the vertical, and
 R = weathering function.

The wind stress is computed from the wind forecast supplied by the user, or it is made by the COSMOS program if necessary. If the user supplies a forecast, the wind stress is

$$\underline{I}_s = \rho_a C_{aw} |\underline{V}_{10}| \underline{V}_{10}$$

where C_{aw} = air-water drag coefficient (0.001), and \underline{V}_{10} = wind velocity at 10 m, supplied by user.

If no wind forecast is available, COSMOS computes the stress by

$$\underline{I} = \rho_a |\underline{V}_*| \underline{V}_*$$

where \underline{V}_* is the air friction velocity.

The COSMOS wind stress is obtained by applying an atmospheric boundary layer model (BLM) to compute the friction velocity and surface deflection angle. The input for this BLM is the geostrophic wind computed from the LFM 1000-mb heights and 1000-mb temperatures. Implicit equations for the friction velocity and deflection angle, based on Rossby number similarity, are:

$$\ln(R_o) = A - \ln(V_*/G) + ((kG/V_*)^2 - B^2)^{1/2} \text{ and}$$

$$\sin(\alpha) = BV_*/kG$$

where R_o = surface Rossby number = G/fz_o ,
 G = magnitude of the geostrophic wind (m/s),
 z_o = surface roughness height (m) = $0.035V_*^2/g$,
 $A = 1.1 + 0.20 S_x - 0.40 S_y$,
 $B = 4.3 - 0.32 S_x - 0.35 S_y$,
 $S_x = (k/f)^2 (g/T) \partial T / \partial x$,
 $S_y = (k/f)^2 (g/T) \partial T / \partial y$,
 T = boundary layer temperature (^oK),

k = von Karman's constant = 0.40, and

α = deflection angle from geostrophic wind to the stress vector.

Surface water currents are computed on a grid representing the local bathymetry by the equations of momentum balance and continuity. The vertically-integrated flow rate is computed with the storm surge equations and wind stress; the bottom stress condition is the slip relationship (Jelesnianski, 1967). Continuity is used to find the surface elevation. Then the horizontal pressure gradient can be used in the horizontal momentum equation. The equation is solved with the same surface and bottom stresses. This equation is:

$$\partial w / \partial t = p - ifw + \partial / \partial z (E \partial w / \partial z) - rw ,$$

where w = complex horizontal velocity (m/s),
 p = complex horizontal pressure gradient term (m/s²),
 i = (-1)^{1/2},
 E = vertical eddy viscosity (m²/s), and
 r = linear damping factor (s⁻¹).

Eddy viscosity varies from a surface value, E_0 , linearly increasing with depth to a value E_1 , and remains constant down to the bottom of the mixed layer, of depth D_e . Here

$$E_0 = kW_*z_0 \text{ (m}^2\text{/s),}$$

$$W_* = \text{water friction velocity (m/s) = } (\tau_s / \rho_w)^{1/2}$$

$$E_1 = 0.004 W_*^2 / f \text{ (m}^2\text{/s),}$$

$$D_1 = E_1 / k W_* \text{ (m), and}$$

$$D_e = 0.25 W_* / f \text{ (m).}$$

3. OPERATIONAL USE OF THE MODEL

COSMOS is permanently mounted on NWS production files for ready access on short notice. The model program takes less than a minute to execute, and has an operational priority for running on the NMC computer in Suitland, Md. COSMOS is accessible by submitting a batch or time-share job at an available terminal. If a remote terminal is unavailable, results of the model run can be telecopied to the field user.

For each oil spill, the input data expected to change are the latitude-longitude coordinates of the site, the width of the map upon which

the oil slick is plotted, the initial distribution of oil on the water, and possibly the oil flow rate. Oil density is assumed to be 0.950 grams per cubic centimeter, and its value has little influence on the predicted oil behavior. Oil surface tension effects are not included in the model. Although COSMOS can make its own wind forecasts out to 48 hours over the coastal region around the oil spill, the user has the option of substituting his or her own wind forecast.

The following discussion describes the version of the COSMOS model which is stored on the data set 'NWS.SDO.TDL.PROD.OILSPILL.DATA', with member name COSMOS1L. This version is set up for spills in United States coastal waters, excluding bays. Another version, with member name COSMOS1S, is set up to access the Spectral Model, and can make forecasts out to 72 hours.

The output for COSMOS is given on files FT06F001 and FT12F001, of which the latter is the more important. FT12F001 contains a list of the input data, a table giving the wind forecasts at the oil spill site, and a set of five maps, one each for the 0-, 12-, 24-, 36-, and 48-h forecasts (see Appendix III). Each map shows the local coastline and oil slick in a region centered about the latitude-longitude of the spill with the given map width. The heading block of each map explains what the various map symbols mean and gives the volume of spilled oil depicted. File FT06F001 contains details of the model calculations.

Data input for COSMOS is through three files. For the first day's run, the spill latitude and longitude and the map width are reset in file FT09F001. Initial volume and distribution of oil are also specified in the same file. The flow rate, in thousands of gallons per day, the initial oil distribution (as a number of circular patches), map parameters, and the weathering coefficient are also specified.

4. DESCRIPTION OF THE DATA INPUT FILES

All the user-supplied data for COSMOS are entered in the Data Table (Appendix II). This Data Table is organized so that an explanation accompanies the input data. The first 30 spaces in each line of input give a brief description of the type and form of the data. A more detailed description of the data and its format follows.

<u>File FT09F001</u>	This file contains most of the essential data for running COSMOS for a coastal oil spill.
Line 1	Title. The user can insert any title for model run. FORMAT(30X,42A1).
Line 2	Spill latitude (west) and longitude (north), in degrees. FORMAT(30X,2F8.3).
Line 3	Start time for the forecast (year, month, day, hour GMT), and maximum projection time (hours). FORMAT(30X,I8,I4).

- Line 4 Number of simulated oil releases of constant discharge rate. FORMAT(30X,I4).
- Line 5 If one or more releases, this line gives the start time, after the beginning of the simulation (hours), the duration of the constant discharge (hours), and the discharge rate (thousands of gallons per hour). Up to 10 such discharges (one per line) are allowed. FORMAT(30X,2I4,F8.3).
- Line 6 Number of initial circular oil patches allowed. FORMAT(30X,I9).
- Line 7 If the number of initial patches is greater than zero, this line contains the time the patch is to be introduced (hour after start of run), the latitude and longitude of the patch center, the patch radius (km), and the volume of oil in the first patch (thousands of gallons). If the volume is unknown, use a few thousand gallons. If the volume is set equal to zero, no patch is added. FORMAT(30X,I4,4F8.0). Up to 9 patches (one per line) are allowed.
- Line 8 The map width (degrees), the number of lines at the top and bottom of the 80-line map array not printed, and the number of spaces the source point is moved to the left of center of the map. FORMAT(30X,F8.3,3I4).
- Line 9 The interval between successive printing of the maps (hours). FORMAT(30X,I4).
- Line 10 The wind input index. 0 means no wind, 1 means user-supplied winds (in file FT15FOO1), and 2 means COSMOS-supplied winds using the LFM. FORMAT(30X,I4).
- Line 11 The weathering factor, C_e . Generally, it will be in the range of 0.0 (no weathering) to 10.0 (high weathering). Weathering is based on the instantaneous wind speed V_{10} , and has the form

$$R = 10^{-13} C_e (V_{10} + 0.1) (\text{m/s}).$$

FILE FTI5FOO1

- Line 1 Time (year, month, day, hour (GMT), minute) of the first current value. FORMAT(30X,4I2,I4).
- Lines 2, 3, etc. Eight values of the current at 6-h intervals which is simply added to the wind drift current. The data are the direction from which the current comes (tens of degrees, 0 to 36), and the current speed in tenths of knots. FORMAT(30X,8I5).

FILE FT25FO01

Lines 1, 2, etc. Eight values of the wind at 6-h intervals, given in meteorological form (direction from, in tens of degrees, and speed, in knots). First value has the time of start of the run (see FT09FO01, Line 3). FORMAT(30X,8I5).

5. MODEL LIMITATIONS

The COSMOS model is set up to run on the 360/195 at Suitland, Maryland, through remote terminal or batch processing. It is too large to be loaded on minicomputer memory in its present form.

The hydrodynamic model, which supplies the surface current, needs basin geometry and bathymetry to run. A total of 18 basins are now stored on disk, representing United States coastline from the Bay of Fundy to Brownsville, Texas, and from the Mexican boarder to Kodiak Island, Alaska. The Hawaiian Island chain is also included. As now set up, the model cannot be run for other areas without modification.

Tidal currents are not included in the model dynamics. If these are needed, they can be entered as currents in file FT15FO01. Semipermanent currents, such as the Gulf Stream, can be added in the same way.

Coastal geography is taken from NMC data files. The high resolution data covers the conterminous 48 states. Outside the conterminous states, the geography is of lower resolution. This can be a problem along the Alaskan coastline. Beaching occurs when oil intersects the coastline. There is no provision to refloat the oil.

The oil speed in COSMOS is limited by the grid size in the oil mesh, which is 2000 m. The limiting speed is 1.39 m/s, or about 2.7 kt. Using the approximation that oil speed is 3.5% of wind speed, the maximum wind is 39.7 m/s or 77 kt. The oil speed is checked at each grid and not allowed to exceed this speed. Therefore, when wind exceeds 77 kt, simulated oil motion may be less than that actually occurring.

When the run finishes, the phrase 'End of COSMOS Run' is printed at the bottom of file FT12FO01. If this phrase is missing, the run has terminated abnormally. Many error messages are printed at the bottom of file FT06FO01, so this would be the first place to look. If the cause of the abnormal termination cannot be corrected, call the author at (301) 427-7613.

REFERENCES

Hess, K. W. and C. L. Kerr, 1979: A model to forecast the motion of oil on the sea. Proceedings 1979 Oil Spill Conference, Los Angeles, Amer. Petroleum Inst., Environ. Prot. Agency, U.S. Coast Guard, 653-663.

Jelesnianski, C. P., 1967: Numerical computations of storm surges with bottom stress. Mon. Wea. Rev., 95, 740-756.

APPENDIX I:
SAMPLE RUN #1; SUBMITTING A JOB

The following is a step-by-step listing of terminal commands used to submit a run. The steps correspond to commands and responses listed on the next page. For batch processing, new data are punched on the cards and the deck is submitted.

Step	Remarks
1	Log on the terminal with user ID.
2	Set the terminal output to teletype specification.
3	Using the Quick Editor utility, enter the oil spill program.
4	Find the character string 'SPILL LAT'.
5	Change the spill longitude.
6	Move pointer down one line.
7	Change the data.
8	Find the characters 'MAP WID'.
9	Change the map width.
10	Save the changes.
11	End the Quick Editor utility.
12	Submit the job.
13	After the job is run the user is notified.

```

1 O LOGON $WE20KH/MARINE
IKJ564551 $WE20KH LOGON MOD 195 TSO AT 07:17:42 ON AUGUST 27, 1981
IKJ562511 NO BROADCAST MESSAGES
READY
2 O TERMTTY
READY
3 O QED /NWS.EDD.TDL.PROD.OILSPILL.DATA(COSMOSIL)/
QED
4 O FT /SPILL LAT/
00810 SPILL LAT, LONG          = 37.000 76.000
5 O c /76.00/75.80/
00810 SPILL LAT, LONG          = 37.000 75.800
6 O +
00820 TIME, RUN (HR)           =81072300 48
7 O c /0723/0827/
00820 TIME, RUN (HR)           =81082700 48
8 O F /MAP WID/
00870 MAP WIDTH,NOTOP, NOBOT, JLEF= 5.000 20 20 0
9 O c /5.00/0.90/
00870 MAP WIDTH,NOTOP, NOBOT, JLEF= 0.900 20 20 0
10 O S
SAVED
11 O END
READY
12 O SUB /NWS.EDD.TDL.PROD.OILSPILL.DATA(COSMOSIL)/
IKJ562501 JOB WE1DILY7 SUBMITTED
READY
13 O IEF4041 WE1DILY7 ENDED      TIME=07.31.10
ADSG19 DATA SET CATALOGED, DATA SET NAME = $WE20KH.WE1DILY7.SYSMSG.DATA
ADSG19 DATA SET CATALOGED, DATA SET NAME = $WE20KH.WE1DILY7.SYSPRINT.DATA
ADSG19 DATA SET CATALOGED, DATA SET NAME = $WE20KH.WE1DILY7.FT06F001.DATA
ADSG19 DATA SET CATALOGED, DATA SET NAME = $WE20KH.WE1DILY7.FT12F001.DATA

```

APPENDIX II
LISTING OF THE COSMOS DATA TABLE

After the changes given in Appendix I have been made, the COSMOS Data Table, lines 710-1020 in COSMOS ('NWS.SDO.TDL.PROD.OILSPILL.DATA(COSMOS1L)') appears as follows:

```

00710 -----
00720                                     DATA TABLE
00730 INPUT DATA FOR THE COSMOS MODEL (VERSION 1.0). NUMERICAL VALUES BEGIN
00740 IN COLUMN 31, AND ARE IN 14 DP F8.3 FORMAT EXCEPT WIND & CURRENT (IS).
00750 YOUR FORECAST MAPS WILL APPEAR ON OUTPUT FILE FT12F001.
00760 THIS PROGRAM STOPPED ON NWS.SDO.TDL.PROD.OILSPILL.DATA(COSMOS1L).
00770 DETAILS OF THE CALCULATIONS WILL APPEAR ON OUTPUT FILE FT06F001.
00780 NOTE: 1 BEL = 42 GAL, 1 TON = (APPX) 240 GAL, 1 MIN = 0.01667 DEG.
00790
00800 //SD.FT09F001 ID *
00810 TITLE (NAME, PLACE, TIME) =
00820 SPILL LAT, LONG = 37.000 75.800
00830 TIME, RUN (HR) = 81082700 48
00840 NO. OF OIL RELEASES = 1
00850 HR, DURATION (HR), TGPH = 06 48 5.000
00860 NO. OF INITIAL CIRC PATCHES = 1
00870 HR, LAT, LONG, RAD KM, T, GAL = 0 29.400 88.800 2.000 0.000
00880 MAP WIDTH, NOTOP, NOBOT, JLEF = 0.900 20 20 0
00890 MAP PRINT INTERVAL (HR) = 12
00900 WIND: 0=ND, 1=FEED IN, 2=LPM = 2
00910 WEATHERING FACTORS (0 TO 10.) = 5.000 0.000 0.000
00920
00930 //SD.FT15F001 ID *
00940 START TIME (YR, MD, DY, ZHR, MIN) = 81081200 30
00950
00960 6-HRLY CURRENTS IN MET FORM = 0000 0000 0000 0000 0000 0000 0000 0000
00970 = 0000
00980 //SD.FT25F001 ID *
00990 6-HRLY WINDS IN MET FORM = 0000 0000 0000 0000 0000 0000 0000 0000
01000 = 0000
01010
+
01020 -----

```

APPENDIX III:
SAMPLE RUN #2; LISTING A JOB OUTPUT

When the forecast for the oil behavior is made, the user retrieves the results. The steps correspond to commands listed on the following two pages.

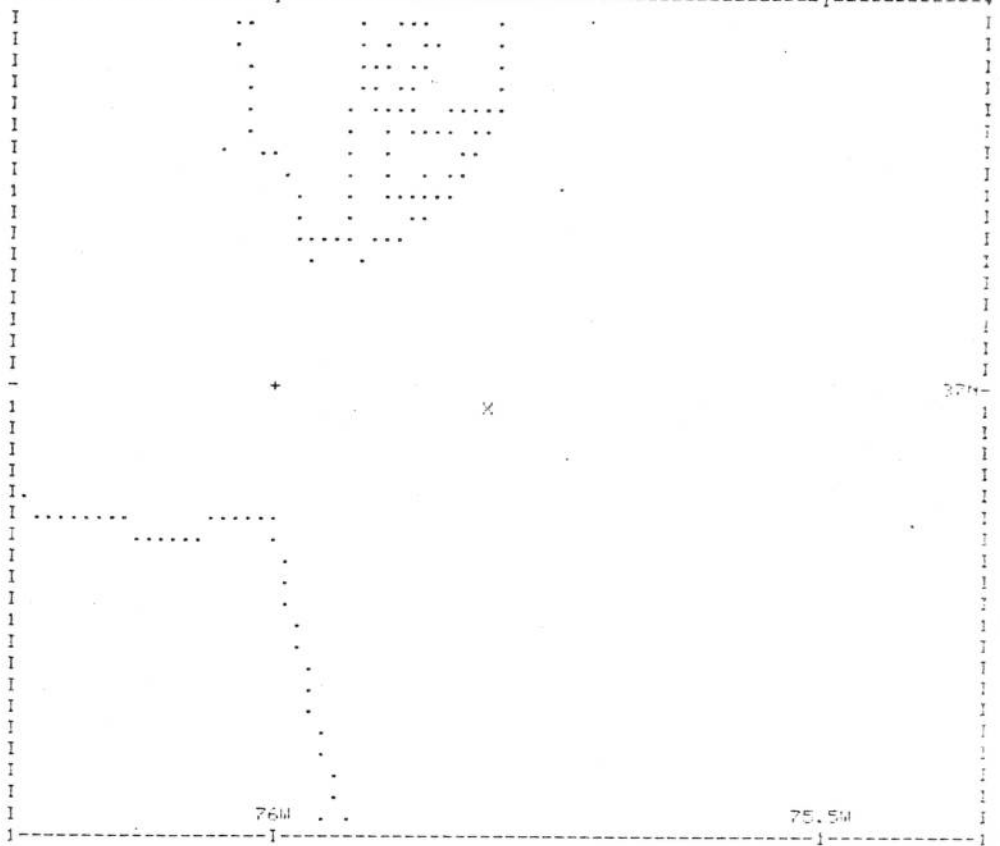
Steps	Remarks
1	Log on.
2	Enter the user ID.
3	Set the terminal output to teletype specifications.
4	Use the Quick Editor to access the data set.
5	List the data set.
6	Enter 'END' to exit the data set.

```

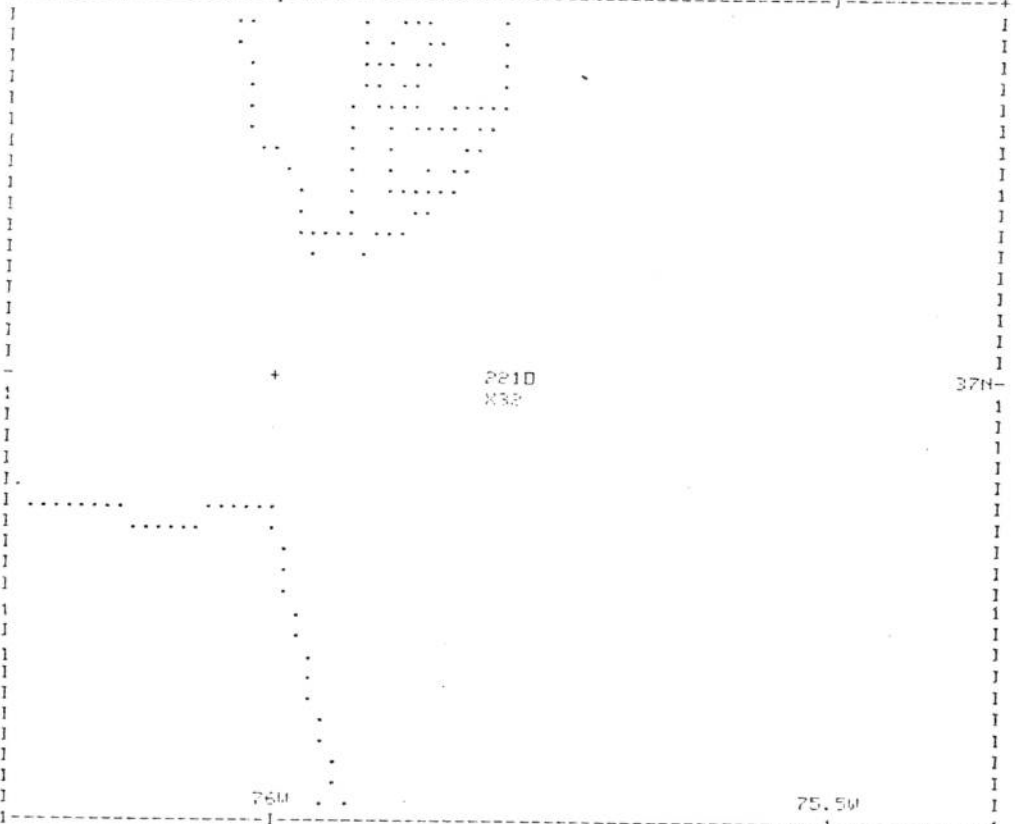
1 ○ IKJ562501 JOB WERH548 SUBMITTED
   ○ READY
   ○ LOGON
   ○ IKJ562501 ENTER USERID =
   ○ THE2000000000
   ○ IKJ562501 $M2000H LOGON MOD 195 TSD AT 09:31:06 ON AUGUST 27, 1981
   ○ IKJ562501 NO BROADCAST MESSAGES
   ○ READY
   ○ TERTTY
   ○ READY
   ○ PFD WEID01Y7.ET12E001.DAT
   ○ DATASET NOT LINE NUMBERED-NOTUM ACQUIRED
   ○ LOED
   ○ L
   ○ COMMOD. THE 'COMPOSITE OIL SPILL MODEL FOR OPERATIONAL SERVICES', IS AT WORK.
-----
THIS RUN IS FOR:
SPILL SITE AT LATITUDE = 37.000     LONGITUDE = 75.800
TIME OF RUN=81082700  RUN(HRS)= 48  LSTD (GMT - LOCAL STD TIME, HRS)= 0
NUMBER OF OIL RELEASES = 1
   HRS= 6  DURATION(HRS)= 48  RATE(THOU.GAL/HRS)= 5.000
NO. OF INITIAL OIL PATCHES = 1
   HRS= 0  LAT=29.400  LON= 89.800  RADIUS(KM)= 2.00  VOL(UGALS)= 0.0
MAP WIDTH (DEG)= 0.90  TOP LINES=20  BOT LINES=20  LEFT= 0
MAP PRINTED EACH 12 HRS
WIND LEVEL= 2  (1 FM WIND)
WEATHERING PARAMETER= 5.00
6-HRLY CURRENTS (DIR/TENTHS OF KTS) STARTING @ 0120 AND 30 MIN.
   DAY      02      62      102     182
   1         0         0         0         0
   2         0         0         0         0
   3         0         0         0         0
   4         0         0         0         0
-----
PROGRAM RUN AT 1130 P. 27 AUG 81. WADATA FROM 27 AUG 02 CYC OF LF22
HR(ZY)  MET WIND      AIR TEMP (DEG F)
  0      801          293.1
  3      1906          295.0
 12      2302          296.1
 18      2205          298.0
  0      2105          299.4
  6      2003          299.5
 12      1904          299.4
 18      1793          300.5
  0      1305          300.5

```

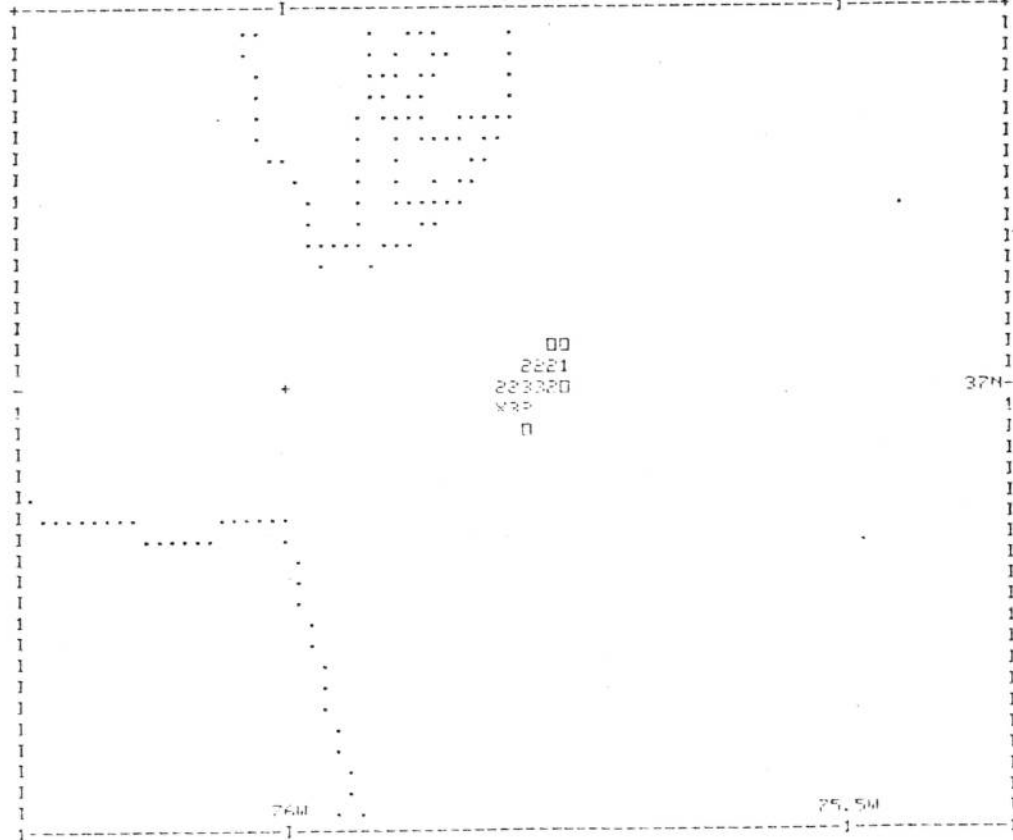
 TIME= 0HR. OIL SLICK THICKNESS DISTRIBUTION FORECAST. NET OIL= 0 GAL
 KEY: X=SPILL SITE, =COASTLINE, O=1, 2, 3=DIL ON WATER, *==REACHED OIL= 0 GAL
 EACH HORIZONTAL MAP SPACE= 0.54 NM = 1.00 KM



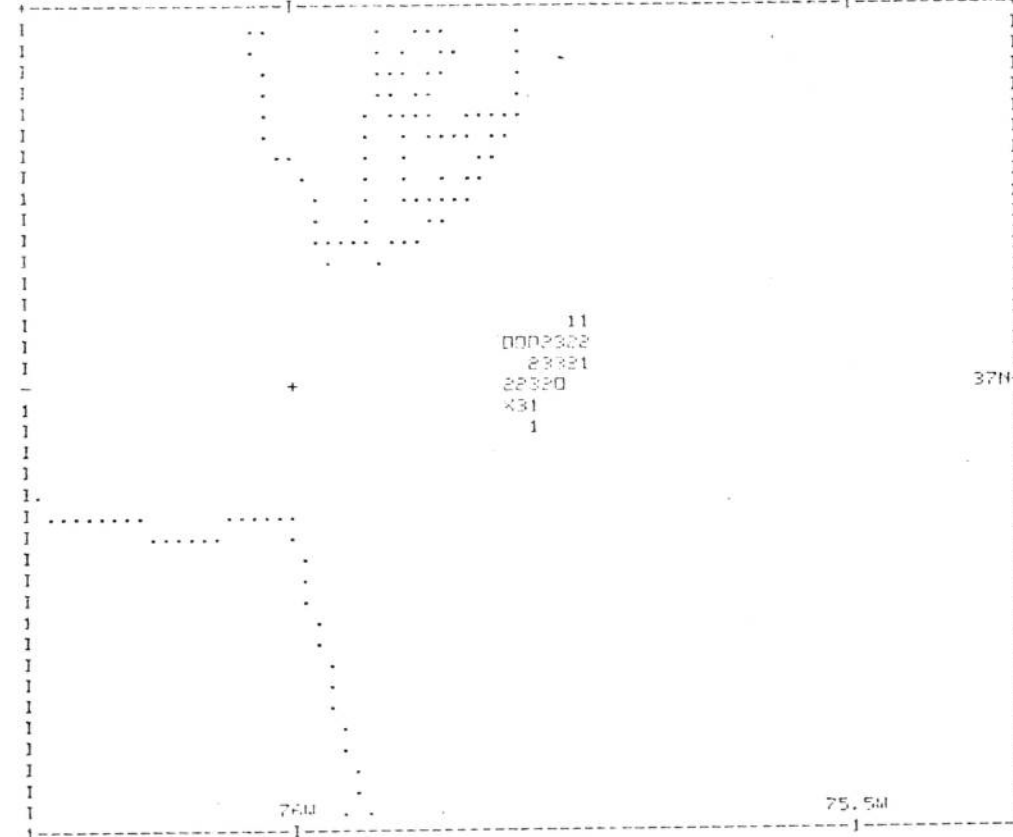
 TIME= 12HR. OIL SLICK THICKNESS DISTRIBUTION FORECAST. NET OIL= 30251 GAL
 KEY: X=SPILL SITE, =COASTLINE, O=1, 2, 3=DIL ON WATER, *==REACHED OIL= 0 GAL
 EACH HORIZONTAL MAP SPACE= 0.54 NM = 1.00 KM



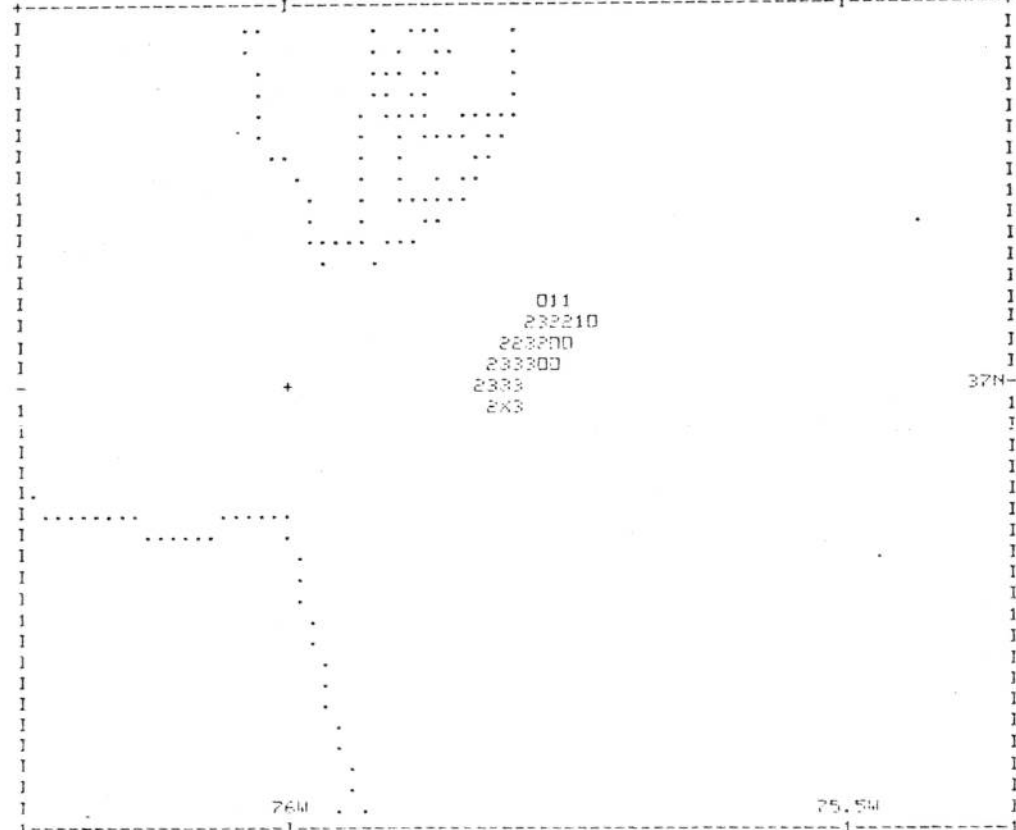
TIME= 24HR. OIL SLICK THICKNESS DISTRIBUTION FORECAST. NET OIL= 90972 GAL
 KEY: X=SPILL SITE, =COASTLINE/D.1.2.3=OIL ON WATER/*=REACHED OIL= 0 GAL
 EACH HORIZONTAL MAP SPACE= 0.54 NM = 1.00 KM



TIME= 36HR. OIL SLICK THICKNESS DISTRIBUTION FORECAST. NET OIL= 151111 GAL
 KEY: X=SPILL SITE, =COASTLINE/D.1.2.3=OIL ON WATER/*=REACHED OIL= 0 GAL
 EACH HORIZONTAL MAP SPACE= 0.54 NM = 1.00 KM



 TIME= 48HR. OIL SLICK THICKNESS DISTRIBUTION FORECAST. NET OIL= 210573 GAL
 KEY: X=SPILL SITE, =COASTLINE, D=1, 2, 3=OIL ON WATER, +=REACHED OIL= 0 GAL
 EACH HORIZONTAL MAP SPACE= 0.54 NM = 1.00 KM



 END OF COMMANDS FOR
 END OF DATA

6 ○ END
 READY