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ASSESSMENT OF CREAMS AND ERHYM-II COMPUTER MODELS FOR SIMULATING SOIL WATER MOVEMENT ON THE IDAHO NATIONAL ENGINEERING LABORATORY

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ABSTRACT

The major goal of radioactive waste management is long-term containment of radioactive waste. Long-term containment is dependent on understanding water movement on, into, and through trench caps. Several computer simulation models are available for predicting water movement. Of the several computer models available, CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) and ERHYM-II (Ekalaka Rangeland Hydrology and Yield Model) were tested for use on the Idaho National Engineering Laboratory (INEL). The models were calibrated, tested for sensitivity, and used to evaluate some basic trench cap designs.

Each model was used to postdict soil moisture, evapotranspiration, and runoff of two watersheds for which such data were already available. Initial estimated soil moisture patterns from CREAMS did not fit field data well. Adjustment of the snow melt routine in the model and use of field based wilting point data produced a better concurrence with field data. The ERHYM-II model produced adequate estimates of soil moisture without internal adjustments. Both models adequately predicted annual evapotranspiration. The CREAMS model did not estimate runoff very well and the ERHYM-II model only performed slightly better. Sensitivity of the models was tested by adjusting various input parameters from high to low values and then comparing model outputs to those generated from average values. Ten input parameters of the CREAMS model were tested for sensitivity. The least sensitive parameters were watershed width/length ratio and slope. The most sensitive were soil porosity, wilting point and vegetative cover. Of the 14 parameters tested for the ERHYM-II model, the least sensitive were watershed width/length ratio, the relative growth curve parameters CSHAPE and DSHAPE, and the temperature weighting factor. The most sensitive was wilting point. Three trench cap designs were tested with the models. The designs were similar in material and only differed in thickness. Both models predicted failure, penetration of moisture, of the thinnest cap (60 cm) during years of average and greater precipitation. The CREAMS model predicted failure of the intermediate cap (120 cm) during a higher than average precipitation year.

INTRODUCTION

The major goal of radioactive waste management is long-term containment of radioactive waste. Long-term containment is dependent on maintaining the integrity of earthen caps that cover waste trenches. Several factors can disrupt proper function of the trench caps (Fig. 1) (Hakonson et al. 1982). All of these factors directly or indirectly involve water movement. Long-term containment then, is dependent on understanding water movement over, into, and through trench caps. Several computer simulation models are available for predicting water movement. These models have common and unique subroutines. Evaluation of these models under a variety of climate, soil and vegetation conditions has demonstrated calibration is required before they are used for a particular area (Hakonson et al. 1986). To calibrate a model, appropriate input values are selected and then model output is compared with field data. Discrepancies between field data and model output are reconciled by refining model input values or model subroutines.

Of the several computer models available, CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems) and ERHYM-II

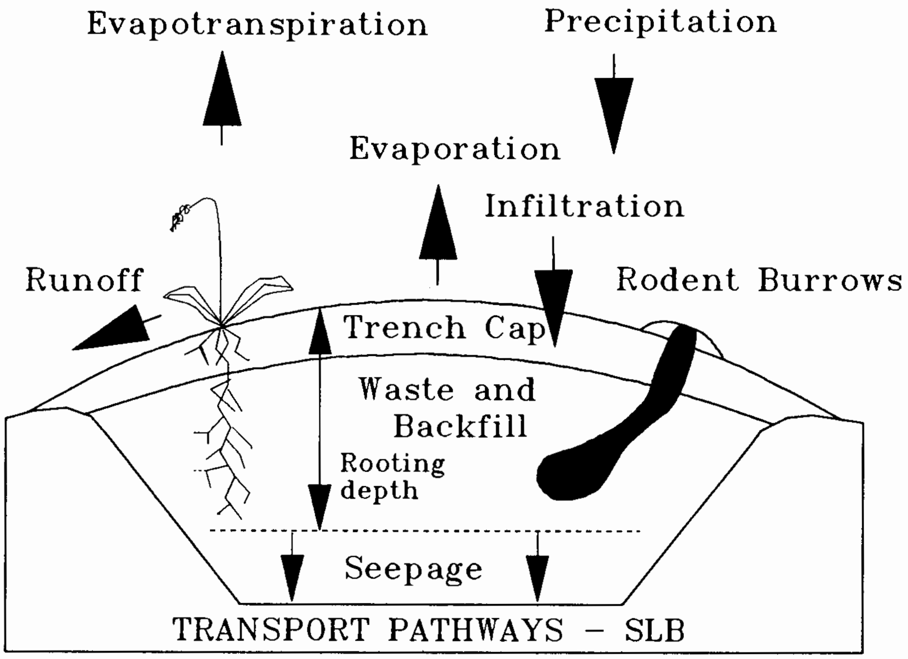

Fig. 1. Various pathways contributing to radionuclide transport from a shallow burial (SLB) low-level radioactivte waste site (after Hakonson et al. 1982).

(Ekalaka Rangeland Hydrology and Yield Model) were tested for use at the Idaho National Engineering Laboratory (INEL). Both models yield monthly estimates of soil moisture, evapotranspiration, and soil runoff. Additionally, the CREAMS model will yield estimates of erosion.

Both models were initially developed to simulate water flow patterns in watersheds from geographic areas other than southeastern Idaho. Before they are usable for modeling purposes on the subsurface disposal area (SDA) of the Radioactive Waste Management Complex (RWMC), they need to be calibrated (Cooley and Robertson 1984).

The purpose of this report is to document calibration of the ERHYM-II and CREAMS models for specific conditions of the INEL and provide a guide for use of the models by INEL personnel.

MODEL INPUTS

Each model requires different input variables. There are two basic types of data bases required by both models. The first data base consists of information pertaining to soil texture, soil porosity, plant productivity, and watershed characteristics. The second data base contains precipitation and temperature data. For the INEL, the necessary soil data were obtained from a variety of sources including RWMC reports and standard tabular values (Lane 1984; Wight 1987).

Table 1 lists the variables required by the CREAMS model and Table 2 lists variables for ERHYM-II. Tables 3 and 4 present the line by line layout of input data files for CREAMS and ERHYM-II. Initial runs of both models were made with versions designed for the VAX 11/750 mini-computer. Subsequent to those initial runs, personal computer (PC) versions of CREAMS (FORTRAN) and ERHYM-II (BASIC) were released. File structure of the PC version of CREAMS is similar to the mini-computer version. Data files for CREAMS can be constructed with "front-end software" supplied with the main program. This front-end software prompts the user for the various input values listed in Table 1. The front end software does not allow modification of an existing file but modifications can be made with most word processing packages and then saved as an ASCII text file. In the BASIC version of ERHYM-II, the input data are arranged in a series of DATA statements (Table 5) at the end of the code. The user must modify these data statements as needed. Disk copies (3.5-inch format) of all the program codes are available from personnel of the Radiological and Environmental Sciences Laboratory (RESL) of the Department of Energy (DOE) at the INEL.

Climatological data files contain characteristics such as daily precipitation, daily temperature and solar radiation. Personnel of the National Oceanographic and Atmospheric Administration (NOAA) provided these data. Tables 6 and 7 present the format for climatological data files used by CREAMS and ERHYM-II. These formats are the same for the VAX and PC versions. Climatological files can be constructed with most word processing programs and then saved as ASCII text files. Appropriate climatological files for both models from 1976 to 1987 are supplied with the computer codes.

Table 1. Input variables required by the CREAMS model and explanations of each. For more detailed descriptions than given here for some of these variables see Lane (1984).

BDATE	Beginning date of simulation run
FLGOUT	Used to indicate the type of output wanted. FLGOUT = 1 is used for a storm by storm and annual summary output. FLGOUT = 0 will give annual summaries only.
FLAGPAS	Used to control creation of pass file for the erosion component of the CREAMS model. FLAGPAS = 1 will create file.
FLGOPT	This variable is used to indicate which hydrologic model is desired. FLGOPT = 1 is normally used.
FLGPRE	Unused variable. Always set equal to 0.
DACRE	Size of watershed in acres.
RC	Effective saturated hydraulic conductivity of soil. This value can be field calculated or estimated from Table 2 (Appendix A).
FUL	Fraction of the soil pore space filled at field capacity. This value is obtained by subtracting field capacity from wilting point and dividing that value by the difference between soil porosity and the wilting point.
BST	The decimal fraction of plant available water in the soil at the beginning of the simulation run.
CONA	A bare soil evaporation parameter (mm/day$^{1/2}$) obtained from Table 2 (Appendix A).
POROS	Porosity of soil, expressed as a decimal based on percent volume. This value can be field calculated or obtained from Table 1 (Appendix A).
BR15	Wilting point expressed as a decimal based on percent volume. Normally wilting point is based on soil water content at -15 bars but for the INEL, a good estimate of BR15 can be obtained by calculating soil moisture of study area in late summer.
SIA	Initial abstraction coefficient for the Soil Conservation Service runoff curve number method. The recommended value is 0.20.
CN2	A runoff curve number used in the runoff curve equation. This is a tabular value obtained from Table 3 (Appendix A).
CHS	Decimal expression of the slope of the watershed.
WLW	Length/width ratio of the watershed. A recommended value is 2.0 unless there are unusual dimensions for the watershed.
RD	Rooting depth (inches) or the depth to which you want to simulate water movement.
UL(i)	Plant available water storage for each of the 7 layers of soil the model uses.
TEMP(i)	Twelve monthly mean temperatures.
RADI(i)	Twelve monthly mean solar radiation values in langleys/day.
GR	Winter cover factor. A value of 0.5 is the user recommended value.
LDATE(i)	Julian dates that correspond to user supplied values for leaf area indices. The first date must be 1 and the last 366. As many dates as desirable in between can be used.
AREA(i)	Actual leaf area indices corresponding to the provided Julian dates. Estimates for short grass prairie and western rangelands are provided in Table 4 (Appendix A).
NEWT NEWR NEWL	This and the next two variables act as switches which signify whether or not temperature, solar radiation, and leaf area indices will be updated. If no update is required, these variables will be 0. There must be one set of these variables for each year of the simulation and NEWT for the last year of the simulation must have a value of -1.

To verify model output, empirical data from the study area are required. Personnel from the RWMC collected soil moisture information on the SDA during 1976 to 1980 (Wickham and Janke 1980). They measured soil moisture with Bouyocous resistance cells (Anonymous 1975). I compared their data to the output generated by the two models run under the climatological conditions present during those years.

Table 2. Description of the variables required by the ERHYM-II model. For further details see Wight (1987).

RUNOPT	Determines length of simulation. 1 - simulate a single year's growing season, 2 - continuous simulation over more than 1 year.
INOPT	Determines whether soil characteristics are tabular values (set to 1) or supplied by user (set to 2).
WIDOPT	Set to 1 for 80-column printout, set to 2 for 132 column printout.
LOPT	Set to 1 if inputs and outputs are in centimeters, set to 2 if inputs and outputs are in inches, set to 3 if precipitation input is in inches and other inputs and outputs are in centimeters.
DAYOPT	Set to 1 if you want daily printout, set to 2 if you want printout only on days with precipitation, set to 3 for yearly summary printout only.
CUROPT	Set to 1 if you do not want the relative growth curve plotted, set to 2 if you want the curve plotted.
INTLEN	The number of days between subtotal printouts, if set to 0, no subtotals will be printed.
TTDLEN	Number of days between total-to-date printouts, set to 0 for seasonal or yearly printout only.
FILEO	Set to 1, an 8th file will open to hold tables of output when run in forecast mode (RUNOPT = 1). Set to 0 if not in forecast mode.
STARTY	The last two digits of the first year of a run
ENDY	The last two digits of the last year of a run.
STRDAY	The Julian day of year in which the model starts.
ENDDAY	The Julian day of each year the model stops, usually 365 if RUNOPT = 2.
SHISD	If in forecast mode (RUNOPT = 1), Julian day the model starts using historical climatic data, otherwise set to 0.
FYEAR	If in forecast mode, the last two digits of the forecast year, otherwise set to 0.
SOLOPT	Set to 0 if solar radiation values are generated with internal subroutine. Set to 1 if actual solar radiation values are read from climate input file.
PRTOPT	If set to 0, printout will be as directed by DAYOPT, CUROPT, and INTLEN. If set to 1 only final summary of all years will be printed. This is primarily used in the forecast mode.
CONOPT	Set to 0 for normal parameter input, set to 1 if batch runs with multiple parameter sets is used. Usually set to 0.
FURCAP	Surface storage capacity of contour furrows in linear units. For non-agricultural areas, set to 0.
SLARES	The number of soil layers you desire, maximum of 4.
SOILT	Numeric code for type of soil in each layer. See Table 1, Appendix A for soil types and corresponding codes. If you input explicit soil characteristics (option 2 of INOPT) SOILT should be 0.
ROCKF(i)	Volumetric rock content, expressed as a decimal, for each soil layer.
ROOTF(i)	The root density per layer, expressed as a decimal, relative to the surface layer which is always 1.0 (ROOTF(1) = 1.0).
THK(i)	The thickness of each soil layer. Units should correspond to LOPT, e.g. if LOPT = 1 then should be centimeters, if LOPT = 2 then should be in inches. No layer should exceed 12 inches or 30.5 cm.
MHC(i)	Soil water content by percent weight expressed as a decimal at field capacity for each soil layer.
UNASM(i)	Soil water content by percent weight expressed as a decimal at permanent wilting point for each soil layer.
BULKD(i)	Bulk density in grams per cubic centimeter for each soil layer (Table 6, Appendix A).
INITSM(i)	Initial soil water content by weight expressed as a decimal for each soil layer.
AIRDRY	The amount of soil water below permanent wilting that can be evaporated (Table 6, Appendix A).
STFW	Temperature weighing factor, usually 0.70.
TEMOPT	If set to 0, daily maximum and minimum air temperatures are generated by internal subroutine. If set to 1, daily maximum and minimum air temperatures are provided by the user.
STRRGC	The value along the Julian day scale for the start of the desired relative growth curve.
TAO(12)	Mean air temperature for the 12 months.
CROPCO	Crop coefficient based on actual evapotranspiration calculated by a lysimeter/ potential transpiration when water is nonlimiting.
TRANCO	Transpiration coefficient calculated by equation: TRANCO = 0.0213+0.0162(average site yield)$^{1/2}$. Where site yield is in lbs/acre.
STRGRO	Julian day the model begins to accumulate transpiration and potential transpiration.
PSCDAY	Julian day of peak standing crop.
ENDGRO	Julian day that the relative growth curve will terminate. This is used only in plotting the relative growth curve.
YIBASE	Set to 1.5 to calculate the yield index as a decimal fraction of long-term average site yield. Set to 1.0 to calculate yield as a decimal fraction of the potential site yield.
CSHAPE	A shape parameter for the left side of the relative growth curve.
DSHAPE	A shape parameter for the right side of the relative growth curve.
RGCMIN	The minimum value that the relative growth curve can have during the entire year (must be between 0.0 and 1.0).
DACRE	The area of the watershed in acres.
CS	The slope of the watershed (ft/ft).
LW	Watershed length width ratio calculated by squaring length and dividing by watershed area. User recommended is 2.0.
CN2	Soil Conservation Service curve number (Table 3, Appendix A).
SIA	Initial abstraction coefficient for the Soil Conservation Service curve number. User recommended is 0.20.
KSEED(4)	Numbers to initiate the random number generator subroutine. They must be odd integers with values greater than 100.
ALAT	The latitude of study site in degrees.
TXMD	The mean of daily maximum temperature (Appendix B, Fig. 1).
ATX	The amplitude of daily maximum temperature (Appendix B, Fig. 2).
CVTX	The mean coefficient of variation of daily maximum temperature (Appendix B, Fig. 3).
ACVTX	Amplitude of coefficient of variation of the daily minimum temperature (Appendix B, Fig. 4).
TXMW	The mean of daily maximum temperature (wet or dry)(Appendix B, Fig. 5).
TN	Mean of daily minimum temperature (Appendix B, Fig. 6).
ATN	Amplitude of daily minimum temperature (Appendix B, Fig. 7).
CVTN	Mean of coefficient of variation of daily minimum temperature (Appendix B, Fig. 8).
ACVTN	Amplitude of coefficient of variation of daily minimum temperature (Appendix B, Fig. 9).
RMD	Mean of solar radiation (dry), langleys (Appendix B, Fig. 10).
AR	Amplitude of solar radiation (Appendix B, Fig. 11).
RMW	Mean of solar radiation (wet) in langleys (Appendix B, Fig. 12).

Table 3. File layout for input variables for CREAMS. The top section lists the variables and the bottom section is an example of the file.

Line 1-3:	Title cards. Use columns 1-80 to identify a particular run.
Line 4:	BDATE,FLGOUT,FLAGPAS,FLGOPT,FLGPRE. Format (5I8).
Line 5:	DACRE,RC,FUL,BST,CONA,POROS,BR15. Format (7F8.0).
Line 6:	SIA,CN2,CHS,WLW,RD. Format (58.0).
Line 7:	UL(1-7). Format (7F8.0).
Line 8:	TEMP(1-10). Format (10F8.0).
Line 9:	TEMP(11-12). Format (2F8.0).
Line 10:	RADI(1-10). Format (10F8.0).
Line 11:	RADI(11-12). Format (2F8.0).
Line 12:	GR Format (F8.0).
Line 13-x):	LDATE,AREA Format (2F8.0). Use as many lines as you have dates and leaf area indices.
Line x+1-y:	NEWT,NEWR,NEWL Format (3I8). Use as many lines as years you plan on running the model. NEWT should be -1 on the last line.

```
                                  Field #

   1       2       3       4       5       6       7       8       9      10

-------/-------/-------/-------/-------/-------/-------/-------/-------/-------/
                                  Daily Hydrology Parameters - INEL Site
                                Snow Melt at -6, Frozen Soil, LAI- Range Grass
                                    Sage Rhizotron near Field Station
83001       0       1       1       0
88.00    0.08    0.40    0.01    3.80    0.47    0.13
  0.2    86.0    0.05    2.00    24.0
  .23    1.13    1.32    1.36    1.36    1.36    1.36
 14.8    21.5    28.9    41.9    51.8    59.7    68.5    65.9    56.4    44.9
 29.8    20.3
 69.0   112.0   230.0   310.0   414.0   465.0   437.0   387.0   307.0   180.0
113.0    80.0
   .2
    1     .00
   32     .00
   91     .02
  105     .03
  121     .05
  166     .60
  182    1.00
  196    1.00
  213    1.00
  227     .90
  258     .50
  305     .01
  335     .00
  366     .00
    0       0       0  Note: this is a three year run with no
    0       0       0  updating of temperature and solar radiation
   -1       0       0  data.
```

Table 4. File layout for input variables for ERHYM-II (VAX computer version). The top section explains where each variable goes and the bottom section is an example of a file.

Line 1: Title of the simulation run. 48 characters maximum.
Line 2: RUNOPT,INOPT,WIDOPT,LOPT,DAYOPT,CUROPT,INTLEN,TTDLEN,FILEO. Format(F8.0,I8,F8.0,I8,2F8.0,I8,2F8.0)
Line 3: STARTY,ENDY,STRDAY,ENDDAY,SHISD,FYEAR,SOLOPT,PRTOPT,CONOPT Format(9F8.0)
Line 4: FURCAP,SLARES,SOILT. Format(2F8.0,XF8.0), X = number of layers.
Line 5: ROCKF Format(XF8.0), X = number of soil layers.
Line 6: ROOTF Format(XF8.0), X = number of soil layers.
Line 7: THK Format(XF8.0), X = number of soil layers.
Line 8: MHC Format(XF8.0). This and the next three lines are optional depending on the value of INOPT.
Line 9: UNASM Format(XF8.0).
Line 10: BULKD Format(XF8.0)
Line 11: AIRDRY Format(F8.0)
Line 12: INITSM Format(XF8.0)
Line 13: STFW, TEMOPT, STRRGC Format(3F8.0)
Line 14: TAO Format(12F6.2)
Line 15: CROPCO, TRANCO, STRGRO, PSCDAY, ENDGRO, YIBASE, CSHAPE, DSHAPE, RGCMIN Format(9F8.0)
Line 16: DACRE, CS, LW, CN2, SIA Format(5F8.0)
Line 17: KSEED(1), KSEED(2), KSEED(3), KSEED(4), ALAT Format(5F8.0)
Line 18: TXMD, ATX, CVTX, ACVTX, TXMW, TN. Format(6F8.0)
Line 19: ATN, CVTN, ACVTN, RMD, AR, RMW. Format(6F8.0)

```
                                    Field #

   1        2        3        4        5        6        7        8        9
-------/-------/-------/-------/-------/-------/-------/-------/-------/
    ******TABULAR VALUES FOR INITIAL RUN OF ERHYM ******
       2        2        2        2        1        2        0       30        0
      76       80      305      365        0        0        0        0
       0        4        0
     .05      .05      .05      .05
     1.0      1.0       .5      0.4
     9.0      9.0      9.0      9.0
     .30      .30      .30      .30
     .15      .15      .15      .15
    1.20     1.20     1.20     1.20
     .83
     .15      .15      .15      .15
     .70        1      100
  14.8  21.5  28.9  41.9  51.8  59.7  68.5  65.9  56.4  44.9  29.8  20.3
     .80      .50      100      196      280      1.0      2.0      5.0      .03
    88.0     0.05     2.00     86.0      .20
     109      111      561     1001     44.0
    63.0     26.5      .17    -0.11     54.0     36.0
    19.0     0.30    -0.20    435.0    265.0    295.0
```

Soil moisture and evapotranspiration data for 1984-1986 were collected at the Experimental Field Station on the INEL (Anderson et al. 1987) and were used in additional comparisons. Anderson et al. (1987) measured soil moisture with a neutron probe. They estimated evapotranspiration by adding changes in soil moisture during the growing season to recorded precipitation amounts.

Initial simulation runs for both models were based on input data derived from tabulated values (Tables 1-6, Appendix A). Outputs from these runs were compared visually and statistically (least squares regression) to field data on soil moisture from the SDA and Experimental Field Station.

capacity, and wilting point for this soil type were used (Table 1, Appendix A). Field measured soil moisture during the winter was always at or only slightly above the wilting point, so the fraction of plant available water in the soil at the beginning of the run (BST) was set at 0.01 to reflect this low moisture level. The fraction of soil pore space filled at field capacity (FUL) was calculated based on tabulated values of field capacity and wilting point (Table 1, Appendix A). The size of the watershed was set at 88 acres (35.6 ha), the approximate size of the SDA (Wickham and Janke 1980). Watershed slope (CHS) was set at 2%; the

Table 5. Data file layout for the BASIC version of ERHYM-II. Parameter names correspond to those in Table 2. Values for parameters required for each soil layer are only needed for the number of layers specified by the parameter SLARES.

Line #	Parameters
9001	DATA Title for the run
9002	DATA PRTOPT,DAYOPT,LOPT
9003	DATA STARTY,ENDY,STRDAY,ENDDAY
9004	DATA SLARES,AIRDRY,FURCAP
9005	DATA THK(1),THK(2),THK(3),THK(4)
9006	DATA BULKD(1),BULKD(2),BULKD(3),BULKD(4)
9007	DATA ROCKF(1),ROCKF(2),ROCKF(3),ROCKF(4)
9008	DATA INITSM(1),INITSM(2),INITSM(3),INITSM(4)
9009	DATA MHC(1),MHC(2),MHC(3),MHC(4)
9010	DATA UNASM(1),UNASM(2),UNASM(3),UNASM(4)
9011	DATA CROPCO,TRANCO,STRGRO,ENDGRO
9012	DATA ROOTF(1),ROOTF(2),ROOTF(3),ROOTF(4)
9013	DATA STRRGC,PSCDAY,CSHAPE,DSHAPE,RGCMIN
9014	DATA DACRE,CS,LW,CN2,SIA
9015	DATA TEMOPT,SOLOPT,ALAT,DEL,STFW (DEL for INEL is always 0)
9016	DATA KSEED(1),KSEED(2),KSEED(3),KSEED(4)
9017	DATA TXMD,ATX,CVTX,ACVTX,TXMW,TN
9018	DATA ATN,CVTN,ACVTN,RMD,AR,RMW
9019	DATA TAO(1),TAO(2),TAO(3),TAO(4),TAO(5),TAO(6)
9020	DATA TAO(7),TAO(8),TAO(9),TAO(10),TAO(11),TAO(12)

CREAMS INPUT

The data base used for initial runs of CREAMS is presented in Table 8. Based on texture analyses, the soil from the trench caps on the RWMC is classified as a silty clay loam. For the initial run, tabulated values of porosity, field

RWMC is a relatively level area. The watershed length/width ratio (WLW) was set at the recommended value of 2.0. A rooting depth (RD) of 36 inches (91 cm) was used which represented the median thickness of the trench cap on the RWMC. The CREAMS model uses the English system of measurement so all measurements are expressed primarily in English units. CREAMS divides the soil

Table 6. Layout of one year of climatological data for CREAMS model. The format is F10.0, 10F5.0, F5.0. The number in the first field is not read but is used to identifying the year (e.g. '83'). The next 10 fields in the first line are the daily precipitation (inches) for January 1 thru 10. The same 10 fields in line 2 are precipitation for January 11 thru 20 and the sequence repeats itself over the year. The last field is optional and is used here to keep count of the number of lines.

Field #

1	2	3	4	5	6	7	8	9	10	11	12
---------/	----/	----/	----/	----/	----/	----/	----/	----/	----/	----/	----/
83	0	0	.02	0	0	0	0	0	0	0	1
83	0	0	0	0	0	0	.04	0	0	0	2
83	0	0	.03	0	.02	0	0	.01	0	0	3
83	.001	0	0	0	0	0	0	.01	.03	0	4
83	0	0	0	0	.03	0	.02	0	0	0	5
83	0	0	0	0	0	0	0	0	.10	0	6
83	.01	0	0	0	0	0	0	0	0	.11	7
83	.08	0	.43	0	0	.18	.02	0	0	0	8
83	0	.09	0	0	0	0	.01	0	.03	.02	9
83	0	0	.14	0	0	0	0	0	0	0	10
83	0	0	0	0	0	0	0	0	0	0	11
83	0	0	.03	0	0	0	.01	0	.24	.001	12
83	0	0	.02	.14	.12	.06	0	0	0	0	13
83	.03	0	0	0	0	.05	0	0	.08	0	14
83	0	0	0	0	0	0	0	0	0	0	15
83	.001	0	0	0	0	0	.63	0	.05	.04	16
83	0	.15	0	0	0	0	0	0	0	0	17
83	0	.03	.15	0	0	0	0	.49	.15	0	18
83	.02	0	0	0	.05	0	0	0	0	0	19
83	0	0	0	0	0	0	0	0	0	0	20
83	0	0	.02	0	0	.15	0	0	.04	.25	21
83	0	.001	0	0	0	0	0	0	0	0	22
83	.14	0	.02	0	0	0	0	0	0	0	23
83	0	.60	0	.06	0	0	0	0	0	0	24
83	0	.06	.001	0	.03	0	0	0	0	0	25
83	.02	0	0	0	0	0	0	0	0	0	26
83	0	0	.02	0	0	0	0	0	0	.22	27
83	.37	.03	.36	.58	.26	0	0	0	0	0	28
83	0	.39	.05	0	0	0	.14	.13	0	0	29
83	0	0	0	0	0	0	.12	0	0	0	30
83	0	0	0	.001	0	.09	0	0	0	0	31
83	.10	0	0	0	.30	0	.16	.02	0	0	32
83	.16	.03	0	.07	.05	0	0	.04	.16	0	33
83	0	0	0	.001	.10	0	0	.12	.07	.05	34
83	.11	0	0	0	0	.29	0	0	.02	0	35
83	0	0	.01	.01	0	0	0	0	0	0	36
83	0	0	0	.03	.001		--	not used		--	37

Table 7. Layout of Climatological data for ERHYM-II model. The format is 6X, F2.0, F3.0, F4.0, F3.0, 2F4.0. The first field contains the last two digits of the simulation year and the next field contains the Julian day. The next two fields contain the maximum and minimum daily temperatures and field 5 is daily precipitation. Field 6 is for actual daily solar radiation values, usually they are generated by internal subroutines and this field is left blank.

```
                Field #

6x   1  2   3    4   5    6
-----/-/--/---/--/---/---/
      83  1  10 -15   0
      83  2  13 -17   0
      83  3  25   4 .02
      83  4  21  13   0
      83  5  41  20   0
      83  6  39  33   0
      83  7  36  34   0
      83  8  41  31   0
      83  9  28  17   0
      83 10  63  15   0
      83 11  32   5   0
      83 12  31   2   0
      83 13  30   2   0
      83 14  32   3   0
      83 15  32   0   0
       Continue for the
      length of the simulation
```

profile into seven layers; plant available water for each layer (UL) was calculated with Equation 1.

Equation 1: $UL(I)=D(I)[P(I)-WP(I)]RD$ (Lane 1984)

Where:

$D(I)$ = weighting factors for each layer I and are equal to 1/36, 5/36, 1/6, 1/6, 1/6, 1/6, and 1/6 for I = 1 to 7.

$P(I)$ = Porosity averaged over the depth interval D(I)RD

$WP(I)$ = Wilting point averaged over the depth interval D(I)RD.

RD = Plant rooting depth (inches)

Monthly mean temperature values (TEMP(I)) were calculated based on unpublished data obtained from NOAA personnel in Idaho Falls and are 30-year averages for the Central Facilities Area (CFA).

ERHYM-II INPUT

The data base used for the initial run of the ERHYM-II model is in Table 4. As with the CREAMS model, tabulated values for the initial run were used. All input values common to both models were the same. Some different variables exist between ERHYM-II and CREAMS. Field capacity (MHC(i)) rather than porosity is used and an estimate of soil bulk density (BULKD(i)) is needed. Values for field capacity and wilting point (UNASM(i)) are entered as percent

Table 8. Variable values used for initial run of CREAMS for lake bed material on the RWMC. Data are laid out as they would be in the input file.

```
                                     Field #

   1        2        3        4         5       6         7        8        9        10

-------/-------/-------/-------/-------/-------/-------/-------/-------/-------/
                                 Daily Hydrology Parameters - INEL Site
                                                 Test Run
                                   RWMC Disturbed Silty-Clay Loam Soil
76001       1        1        1         0
88.00     0.08     0.40     0.01      3.80     0.47     0.18
  0.2     86.0     0.02     2.00      36.0
  .46     2.30     2.77     2.77      2.77     2.77     2.77
 11.6     23.3     31.1     45.5      47.5     65.9     68.4     65.6     55.6     44.2
 29.0     24.0
 69.0    112.0    230.0    310.0     414.0    465.0    437.0    387.0    307.0    180.0
113.0     80.0
   .2
    1      .00
   32      .00
   60      .00
   91      .02
  105      .03
  121      .05
  135      .10
  152      .20
  166      .20
  182     1.00
  196     1.00
  213     1.00
  227      .90
  224      .80
  258      .50
  274      .20
  305      .01
  335      .00
  366      .00
    0        0        0
    0        0        0
    0        0        0
    0        0        0
    0        0        0
   -1        0        0
```

soil moisture by weight rather than percent volume as they were in CREAMS. In addition to field capacity and wilting point, the ERHYM-II model also requires a variable (AIRDRY(i)) that accounts for the amount of soil water below wilting point that can be evaporated. For the silty clay loam soil of the SDA, a tabulated value of 0.83 inches (2.0 cm) is recommended and was used for the initial run (Table 6, Appendix A). The parameter FURCAP is an estimate of the surface storage capacity of contour furrows. This parameter is primarily designed for agricultural applications. However, Hart et al. (1986) found abundant microtopographic relief on native soils on the INEL and concluded surface storage could be important. In leu of available estimates of FURCAP, a value of 0.5 inches (1.3 cm) was arbitrarily selected for initial runs of the model.

Volumetric rock content (ROCKF(i)) and root density per layer (ROOTF(i)) are required by this model. Rock content was considered minimal and given a value of 5%. Root densities, expressed as a decimal relative to the surface layer (ROOTF(1) = 1.0) were set at ROOTF(2) = 0.5, ROOTF(3) = 0.5, and ROOF(4) = 0.9. These relative densities are based on the average root densities of five species [big sage (*Artemisia tridentata*), Russian thistle (*Salsola kali*), great basin wild rye (*Elymus cinereus*), crested wheatgrass (*Agropyron desertorum*), and streambank wheatgrass (*Elymus lanceolatus*) (Reynolds 1990)].

The soil profile can be divided into a maximum of four layers. Different field capacity, wilting point, bulk density, rock content, and root density values can be specified for each layer. This capacity allows modeling of highly developed soils with distinct zonation or, in the case of trench caps, differing layers of cover material. The soil presently used on the SDA is relatively uniform in structure and texture and equal values for each parameter were assumed for the four layers with each layer being 9 inches (22.9 cm) thick.

Model inputs and/or outputs can be in metric (LOPT = 1) or english units (LOPT = 2). English units were used so as to compare output with the CREAMS model.

Daily solar radiation values and daily maximum and minimum temperatures can be supplied by the user (SOLOPT = 1, TEMOPT = 1) (Table 7) or generated internally (SOLOPT =0, TEMOPT = 0). Solar radiation values were internally generated for all runs. Actual daily maximum and minimum temperatures were used and were based on weather data for CFA supplied by NOAA.

The ERHYM-II model does not use leaf area indices in its subroutines for evapotranspiration. Rather, it uses a range crop coefficient (CROPCO), a transpiration coefficient (TRANCO), and a relative growth curve (RGC). CROPCO is based on lysimeter data and is calculated by equation 2.

Equation 2: $\mathrm{CROPCO} = \mathrm{ET}/\mathrm{ET}_p$ (Wight 1987)

Where: ET is evapotranspiration estimates based on lysimeter data and ET_p is potential evapotranspiration based on Equation 3.

Equation 3: $\mathrm{ET}_p = (0.014\ F - 0.37)R_s/580$ (Jensen et al. 1963)

Where: F is daily mean air temperature in $^{\circ}$F and R_s is solar radiation in langleys

Daily mean air temperatures and solar radiation values are available for the INEL but lysimeter estimates of evapotranspiration are unavailable. Thus, CROPCO could not be calculated directly for the INEL. Wight and Hanks (1981) used a CROPCO value of 0.85 for a mixed prairie grassland in eastern Montana and Wight et al. (1986) used the same value for a sagebrush-grass range in southwest Idaho. Based on their work, a CROPCO value of 0.85 was used for the initial runs.

The quantity TRANCO is calculated by equation 4.

Equation 4: $\text{TRANCO} = 0.0213 + 0.0162(\text{average site yield})^{1/2}$

Where: Average site yield is expressed in lb/acre

No estimates of community biomass production could be found for the INEL. Estimates of annual above ground productivity in 1986 of a uniform stand of western wheatgrass (*Agropyron smithii*) on a silt loam at the Experimental Field Station averaged 713 lb/acre (80 g/m^2) (Laundre′ unpub. data). Uresk et al. (1977) estimated sagebrush production for a site on the U.S. DOE's Hanford Reservation, Washington to be 615 lb/acre (69g/m^2). Wight and Hanks (1981) estimated a 12-year average yield of 107g/m^2 (950 lb/acre) for a loamy range site in eastern Montana. The estimates for wheatgrass and sagebrush are likely lower and the estimate from eastern Montana higher than the sage-grass mixture common on the INEL. In leu of a more accurate estimate, 800 lb/acre (90 g/m^2) was used as an approximation of site yield.

The relative growth curve (RGC) is a Poisson density function (Parton and Innis 1972) which expresses seasonal growth as a decimal fraction of 1.0 (Wight 1987). Six quantities are needed to generate RGC values: STRRGC, RGCMIN, PSCDAY, ENDGRO, CSHAPE and DSHAPE. STRRGC is the value along the Julian day scale used to obtain the desired RGC. RGCMIN is the minimum value the RGC can have during the year. PSCDAY is the Julian day RGC is at its maximum (1.0), and ENDGRO is the last day of plant growth and RGC reaches its minimum. Based on a 10-year average, the frost free season on the INEL starts on May 14 (Julian day 134). Many spring plants are frost hardy and actual plant growth begins before that date. Julian day 100 (April 8) was chosen as a realistic but arbitrary day for the onset of the relative growth curve. The 10-year average for the end of the frost free season is September 16 (Julian day 259). As in the spring, some fall plant species can withstand these initial frosts so October 7 (Julian day 280) was chosen as a realistic date for the end of the relative growth curve.

CSHAPE and DSHAPE are two shape parameters that control the shape of the left side (CSHAPE) and right side (DSHAPE) of the RGC curve (Fig. 2). No information was available on what shape RGC curve was most appropriate so a bell shaped curve (CSHAPE = 2, DSHAPE = 5) similar to types A and C in Figure 2 was selected as an approximation.

The ERHYM-II model also required data on a variety of parameters (Table 2) pertaining to internal weather subroutines. These data were obtained

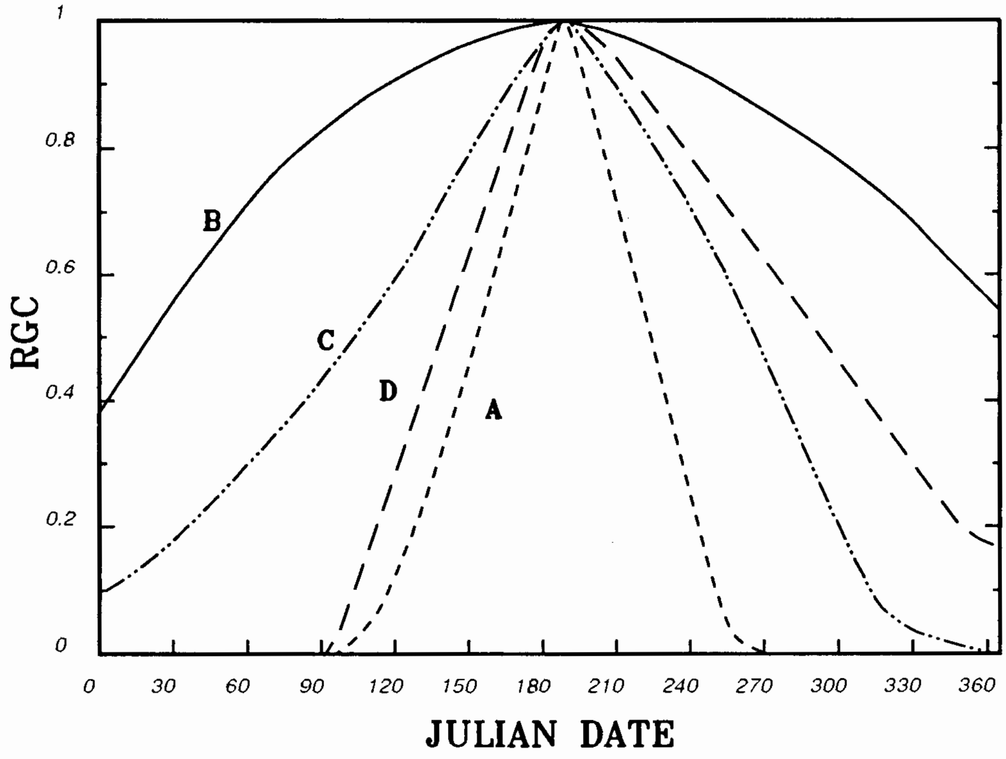

Fig. 2. Examples of relative growth curves (RGC) possible by modifying the Julian day for starting the RGC (STRRGC), peak standing crop (PSCDAY), left side parameter (CSHAPE), and right side shape parameter (DSHAPE). Curves A, B, C, and D, respectively have values for these four parameters of 91, 182, 1, and 5; -120, 182, 2, and 2; -40, 182, 2, and 5; and 91, 182, 2, and 1 (From Wight 1987).

from tabulated values supplied in the users manual (Wight 1987). Copies of the necessary figures are provided in Appendix B.

SIMULATIONS: SOIL MOISTURE

CREAMS

For the initial run with tabulated data, predicted monthly soil moisture levels for CREAMS did not fit field data from the SDA (Fig. 3a). The data disagreed in both the minimum and maximum soil moisture levels attained. Initiation of spring recharge occurred one month sooner in the field than what was predicted by the model.

Differences in wilting point levels between model output and field data existed. The tabulated wilting point value was 18% (volumetric) (Table 1 Appendix A) while in the field, the soil often dried down to 10%. When the data base was adjusted to reflect field values for wilting point (BR15), model output adjusted accordingly and more closely patterned field values (Fig. 3b).

The monthly offset between field and model values indicated that snow melt in the spring was occurring one month sooner than predicted by the model. The daily temperature routine in the model

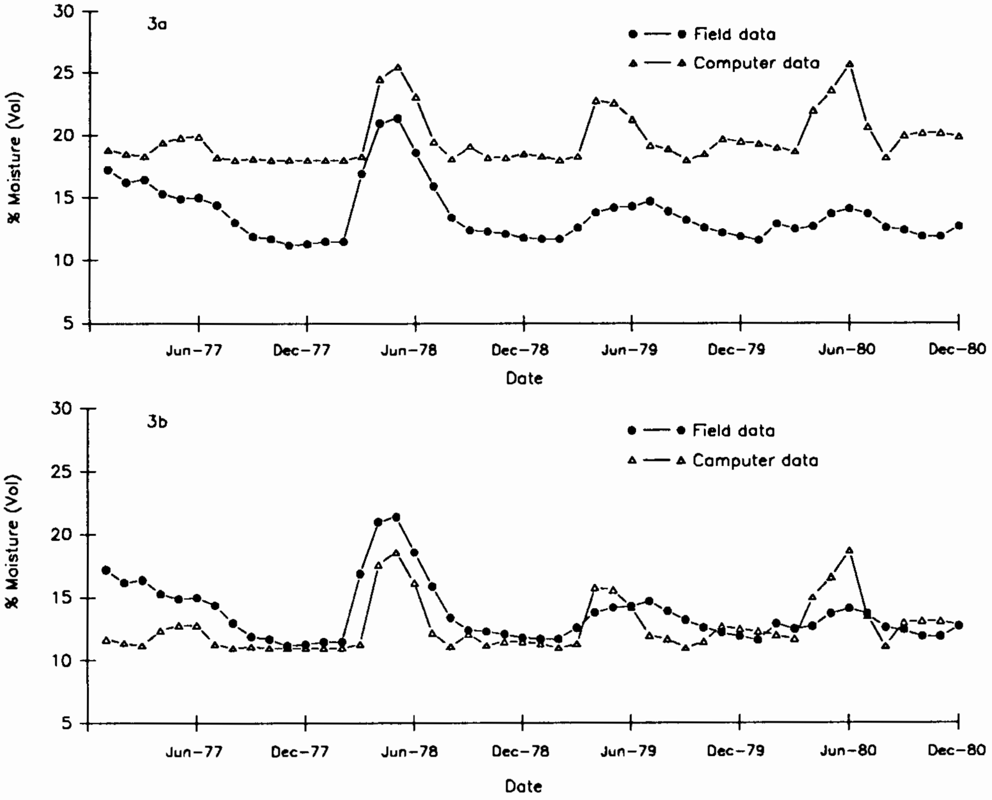

Fig. 3. Results of simulation runs of CREAMS with tabulated values (3a) and with wilting point (BR15) based on field values (3b). Moisture levels are the average over the rooting depth.

predicted consistently lower than actual temperatures, especially during March when snow melt normally occurs (Fig. 4). During January through March, predicted average daily temperatures were always less than 0° C, while field temperatures periodically rose above freezing. As the snow melt routine in the model produced snow melt only if the average daily temperature was above 0° C, snow melt in the model would not occur until the end of March. The snow melt routine was modified to initiate snow melt when the average daily temperature was -6° C or more. This adjustment produced relatively close concordance between model output and field data (Fig. 5). This modification was incorporated for all subsequent runs.

In a manner similar to Wight and Hanks (1981) and Cooley and Robertson (1984), simulated estimates of percent soil moisture were regressed against field values (Fig. 6). Regression was forced through the origin because perfect correspondence between simulated and field values would result in a line through the origin with a regression coefficient of 1.0. Thus the calculated regression coefficient was tested against a slope of 1.0 rather than zero. The regression coefficient was not significantly different from 1.0 but the coefficient of determination (r^2) was 0.27.

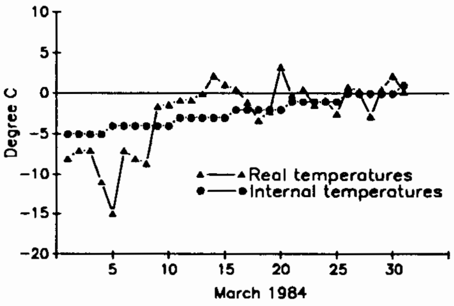

Fig. 4. Average daily temperature recorded on the INEL in March, 1984 and average daily temperature generated by the CREAMS model for the same time period.

In years of low precipitation, the model consistently predicted greater soil moisture during spring recharge than what was found in the field. These differences likely produced the low r^2 value.

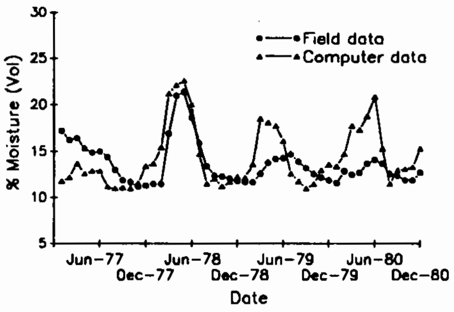

Fig. 5. Comparison of field measured soil moisture levels and CREAMS generated estimate based on field derived wilting point and the 6^0 F change in the snow melt routine.

The modified model was used to postdict soil moisture from a study plot at the Experimental Field Station with similar soil for which data were available. The plot had a stand of transplanted sagebrush established the fall before the run dates. Wilting point was set at 13% (volumetric) based on field data (unpub. data, J.E. Anderson). Precipitation was measured at the site. All other variables used were the same as those used for the SDA (Table 9). Output for the modified model concurred closely with field data (Fig. 7). The regression coefficient (b = 0.99) was not significantly different from 1.0 (t = 0.13, $t_{(0.05,\ 23)}$ = 2.07). The variation explained by the regression (r^2 = 0.53) indicated an acceptable fit between simulated and field data.

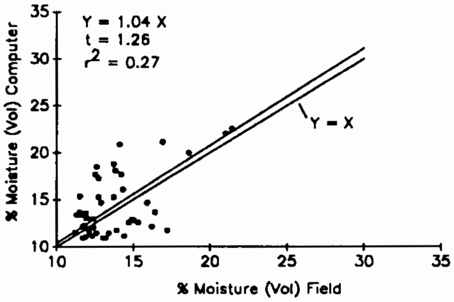

Fig. 6. Regression of soil moisture values generated by CREAMS on soil moisture based on field estimates. A slope of 1.0 and a y-intercept of zero were assumed.

Table 9. Variable values used for initial run of CREAMS for a silty clay loam soil at the Experimental Field Station. Data are laid out as they would be in the input file.

```
                                     Field #

   1       2       3       4       5       6       7       8       9      10

-------/-------/-------/-------/-------/-------/-------/-------/-------/-------/
                                    Daily Hydrology Parameters - INEL Site
                                            Silty clay loam soil
                                        Experimental Field Station
   83001       1       1       1       0
   88.00    0.08    0.47    0.06    3.80    0.47    0.13
     0.2    86.0    0.02    2.00    24.0
     .23    1.13    1.36    1.36    1.36    1.36    1.36
    11.6    23.3    31.1    45.5    47.5    65.9    68.4    65.6    55.6    44.2
    29.0    24.0
    69.0   112.0   230.0   310.0   414.0   465.0   437.0   387.0   307.0   180.0
   113.0    80.0
      .2
       1     .00
      32     .00
      60     .00
      91     .02
     105     .03
     121     .05
     135     .10
     152     .20
     166     .20
     182    1.00
     196    1.00
     213    1.00
     227     .90
     224     .80
     258     .50
     274     .20
     305     .01
     335     .00
     366     .00
       0       0       0
       0       0       0
       0       0       0
       0       0       0
       0       0       0
      -1       0       0
```

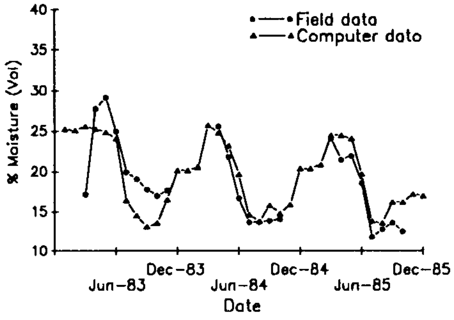

Fig. 7. Comparison of soil moisture estimates from CREAMS model and field estimates from the Experimental Field Station on the INEL (unpub. data, J. E. Anderson, Idaho State University).

ERHYM-II

The initial run of ERHYM-II with all tabulated values (Fig. 8a) also predicted elevated moisture levels. When field values for wilting point (9% by weight) were used (Fig. 8b), levels of minimum soil moisture were reduced below field data. The variable AIRDRY represents the amount of water that can be extracted below the wilting point by evaporation. The recommended value of 0.83 is realistic for mesic soils, however, it is likely too high for the arid soils of the INEL. AIRDRY was assumed minimal and given a value of 0.01. This change brought the model output more in line with field estimates of soil moisture

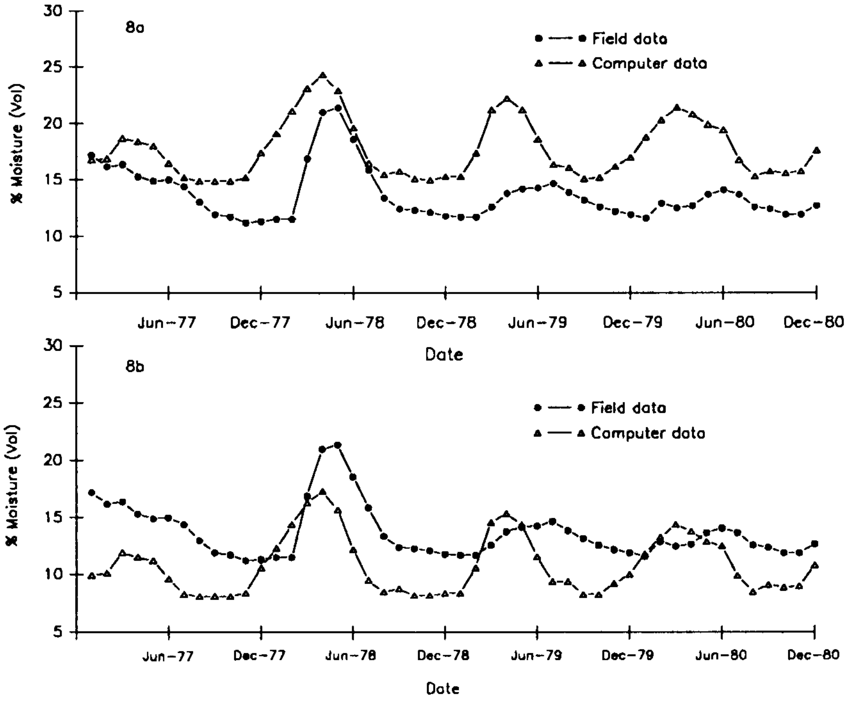

Fig. 8. Soil moisture estimates for the SDA from ERHYM-II and field data. In Fig. 8a, input variables were tabulated values. In Fig. 8b, wilting point was based on field values from the INEL.

(Fig. 9a). The regression coefficient was not significantly different from a slope of 1.0 (b = 1.02, t = 0.69, $t_{(0.05,45)}$ = 2.01) but the coefficient of determination was quite low (r^2 = 0.10). As with CREAMS, ERHYM-II predicted higher spring moisture levels in dry years than was found in the field. Outputs of CREAMS and ERHYM-II models (Fig. 9b) visually compared quite well.

The ERHYM-II model gives the user the option of supplying daily maximum and minimum temperatures or having the computer generate them (TEMOPT). For the initial runs, actual air temperatures were used. An additional computer run was made with all parameters similar to those in Figure 9a, except temperatures were computer generated (10a). Regression analysis of simulated estimates based on computer generated temperatures with field data resulted in a regression coefficient not significantly different from 1.0 (t = 1.50) but an r^2 of only 0.07. There was a slight difference in spring recharge patterns between runs with computer generated daily temperatures and those with actual maximum and minimum temperatures (Fig. 10b). Although neither regression

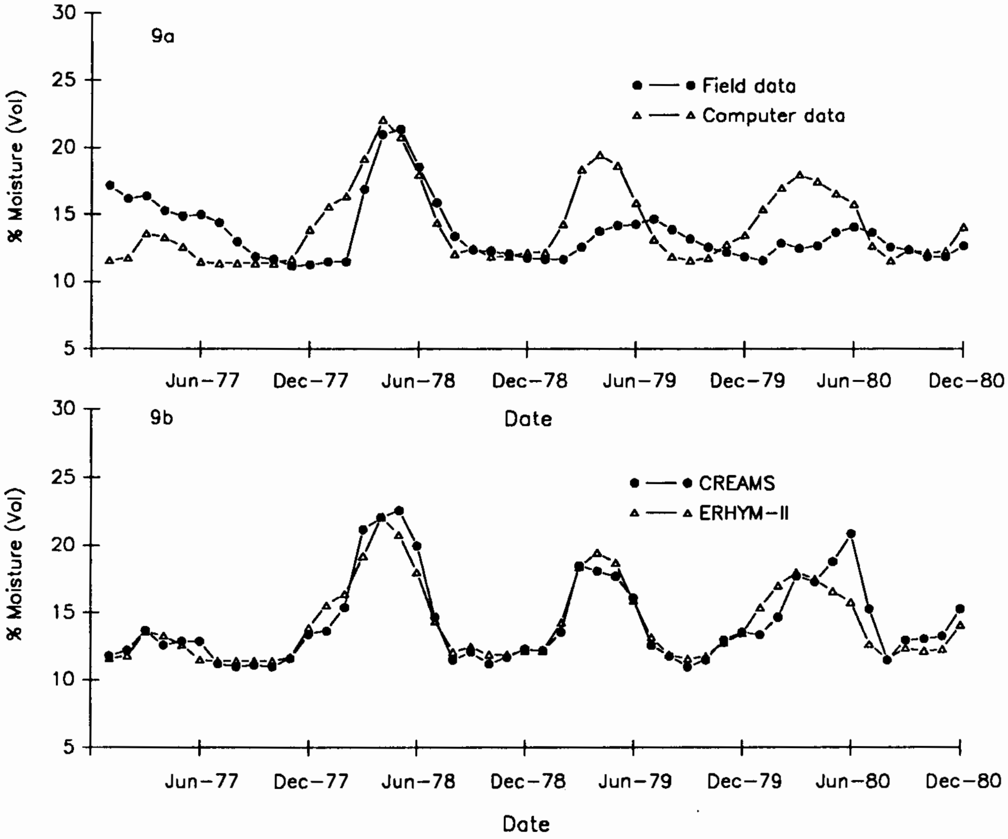

Fig. 9. Soil moisture estimates for the SDA from field values and ERHYM-II with AIRDRY at 0.01 (9a). Fig. 9b is a comparison of soil moisture estimates from CREAMS and ERHYM-II.

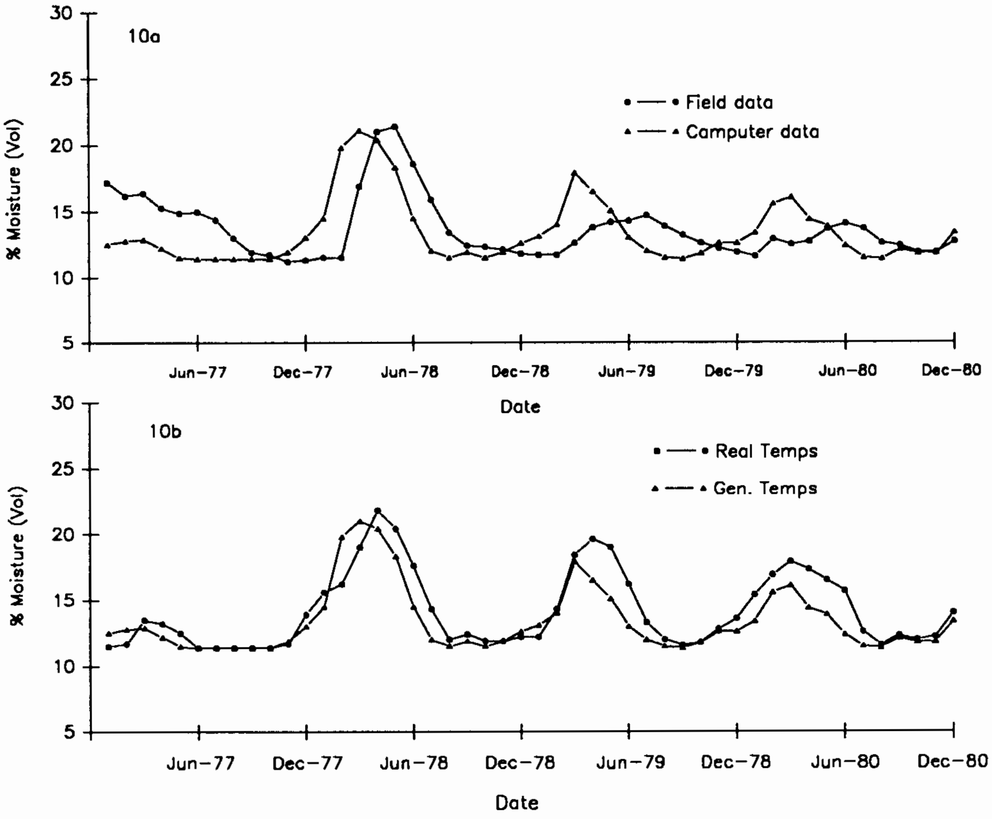

Fig. 10. Soil moisture estimates from ERHYM-II for the SDA with model generated air temperatures (10a) and comparisons of moisture estimates from generated and field values (10b).

coefficient differed from 1.0, results of the run using field temperatures had a higher coefficient of determination. Thus, field temperatures were used for all subsequent runs.

Model output for the area at the Experimental Field Station was visually similar to field estimates of soil moisture (Fig. 11). The regression coefficient from simulated estimates with field data was not significant (t = 0.51, $t_{(0.05,\ 23)}$ = 2.07) and fit well (r^2 = 0.68). The difference in fit between the Experimental Field Station and the RWMC may be related to the accuracy of measuring soil moisture with resistance blocks verses with the neutron probe.

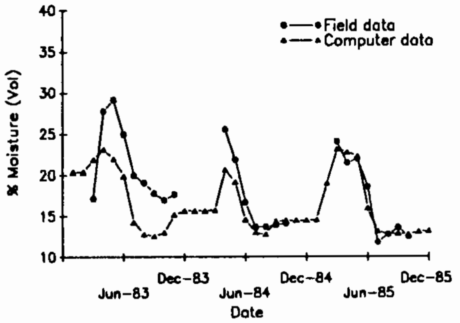

Fig. 11. Comparisons of field estimates of soil moisture from the Experimental Field Station and estimates of soil moisture for the area from the ERHYM-II model.

SIMULATIONS: EVAPOTRANSPIRATION

Predicted seasonal values of evapotranspiration by CREAMS and ERHYM-II were compared with field values from the Experimental Field Station (Fig. 12). Predicted values matched well with field derived figures (Anderson et al. 1987). In all cases, annual evapotranspiration approximated annual precipitation (Fig. 12).

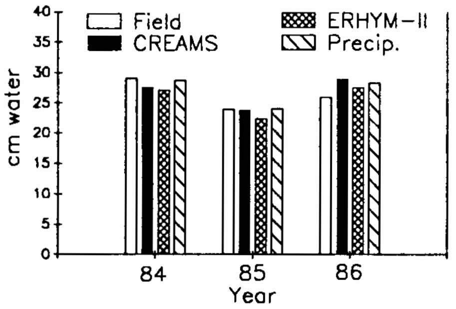

Fig. 12. Evapotranspiration estimates for the sagebrush plot at the Experimental Field Station. Field estimates are from Anderson et al. (1987).

SIMULATIONS: RUNOFF AND EROSION

CREAMS

The CREAMS model has a separate code for assessing erosion from a watershed. For the analysis of this component, I modeled runoff and erosion patterns from experimental erosion plots that are currently being studied near the RWMC. Several types of treatment plots were constructed (Hart et al. 1985), two were selected for modeling. The first plot modeled was the plot consisting of lakebed material with a transplanted stand of crested wheatgrass. The second plot consisted of native undisturbed soil and primarily sagebrush plant cover. Soil parameters for the first plot were assumed to be similar to those used for the modeling of the RWMC. Soil for the native plot was classified as a silt loam (Hart et al. 1986). Both erosion plots were constructed with a 6% slope. An extensive list of parameters are needed for the erosion component of CREAMS. The front end software used to construct the data file lists the parameters and provides default or estimated values for each.

Data on runoff, expressed in mm, and erosion, expressed in megagrams of soil per hectare, were collected in 1986 and 1987 by Hart et al. (1986, 1987). Data are available from natural precipitation events in 1987 and rainfall simulation runs from 1986 (one run) and 1987 (six runs). Rainfall simulation runs were made with a rainfall simulator (rainulator). In 1986 one run was made with soil under "dry" conditions. In 1987 two sets of three runs were made with soil under "dry", "wet", and "very wet" conditions (Hart et al. 1987). The three runs per set were made within a few hours of each other. However multi-rainfall events on a single day can not be simulated with CREAMS. Rainfall amounts for each run within a set were spaced three days in a row within the precipitation file to simulate the three moisture conditions. Field estimates of runoff and erosion for both vegetation types are means from three erosion plots.

Computer generated estimates of runoff and erosion for the crested wheatgrass plots were mostly less than average field values (Fig. 13) but half of the erosion predictions fell within the 95% confidence limits of the field

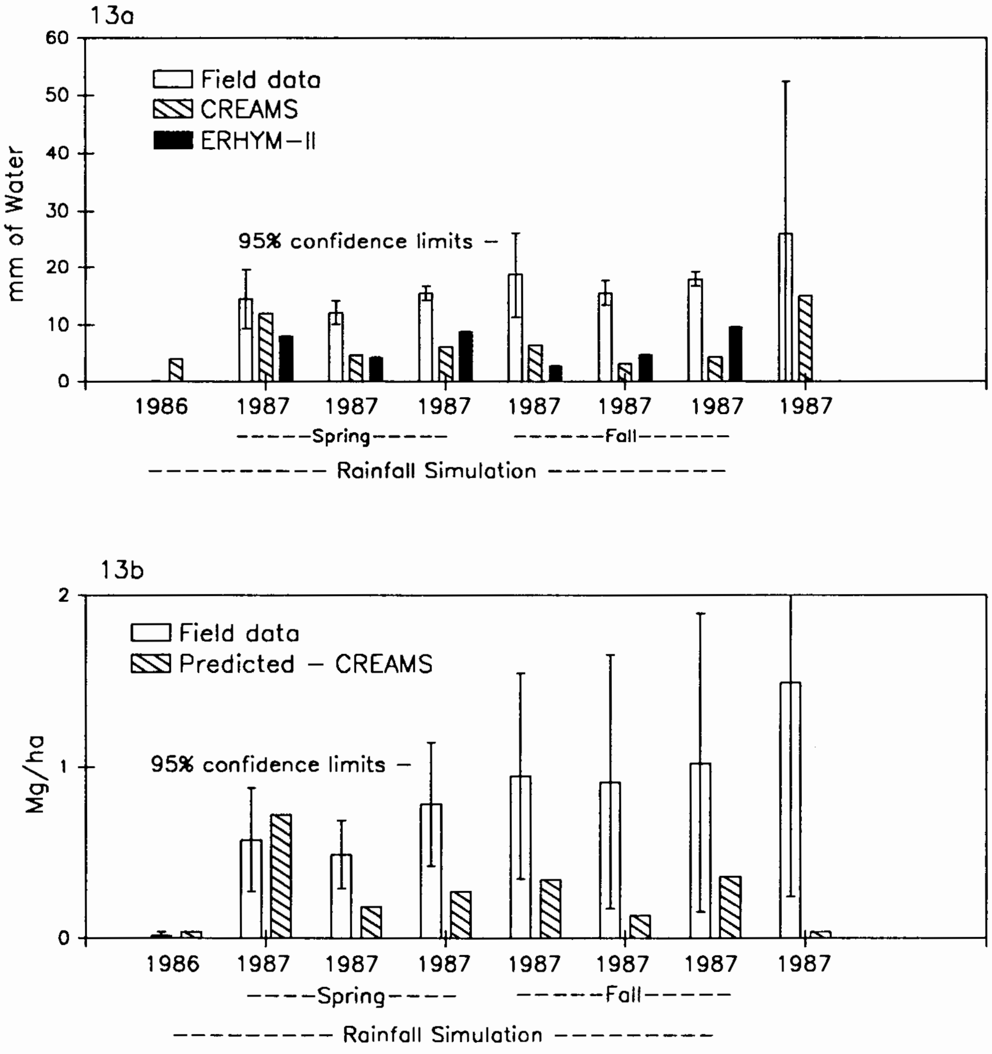

Fig. 13. Field and model estimates of runoff (13a) and erosion (13b) from experimental erosion plots planted to crested wheatgrass (Hart et al. 1987) on the INEL. Field data estimates are averages from three plots. Data for 1986 and the first six samples in 1987 are from rainfall simulation events. The last sample for 1987 is from natural annual runoff and erosion.

estimates. Runoff and erosion estimates from CREAMS for the native sagebrush plots were greater than field values (Fig 14). The lack of conformity between field data and predicted values indicates the model is not overly accurate in predicting erosion in this semi-arid environment. Becker (1984) had similar results with the model in New Mexico. Work is continuing on the erosion project to develop better erosion models. A recent model (WEPP, water erosion prediction project) has been developed (Dobrowolski, pers. comm.) and is being tested at Utah State University for its application on the INEL.

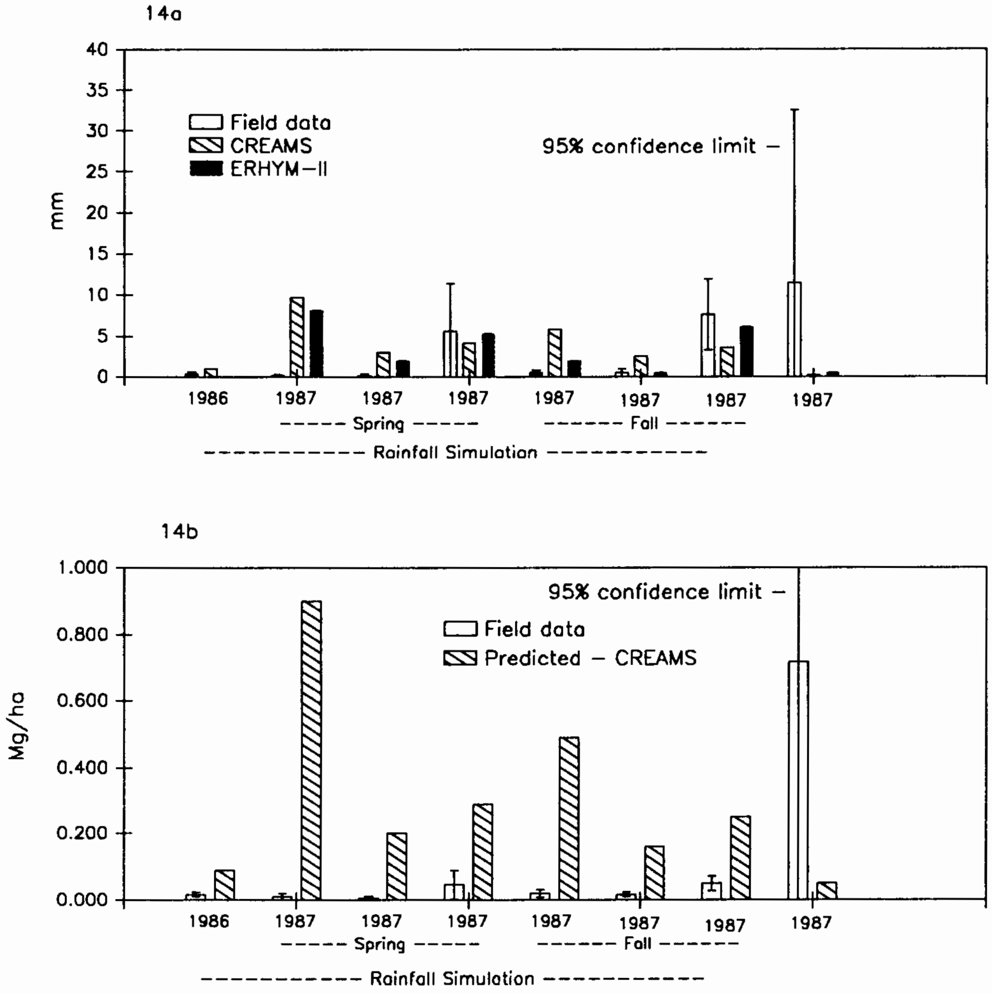

Fig. 14. Field and model estimates of runoff (14a) and erosion (14b) from experimental erosion plots with native undisturbed vegetation (Hart et al. 1987) on the INEL. Field data estimates are averages from three plots. Data for 1986 and the first six samples in 1987 are from rainfall simulation events. The last sample for 1987 is from natural annual runoff and erosion.

ERHYM-II

The ERHYM-II model does not have a specific erosion component as does the CREAMS model. It does provide an estimate of runoff and these estimates for the simulation years were compared with estimates from the erosion study plots. Runoff predictions from ERHYM-II for crested wheatgrass were similar to CREAMS estimates and less than field values. (Fig. 13a). However, runoff values generated by the model for the native sagebrush plots were closer to field values with five of the eight estimates being within the 95% confidence limits (Fig. 14a).

SENSITIVITY ANALYSIS

CREAMS

Sensitivity analyses were conducted by separately altering an input value for the model to a high and then low value while holding all other values at the levels used in the initial runs. Patterns of soil moisture, evapotranspiration, runoff, and drainage below the rooting depth were then compared to determine the sensitivity of the model to each parameter. A silty clay loam soil with a 48 inch (120 cm) rooting depth was used for the runs. The standard soil parameters used are listed in Table 10 along with the high and low values used. High and low values were chosen based on tabulated ranges of these parameters for the soil type used (Appendix A). The model was also tested for sensitivity to different vegetative covers (Table 11). The cover types were selected from Lane (1984) and represent ranges of vegetative covers possible. A fourth "cover type" consisting of bare ground, LAI = 0, was also tested.

Table 10. Values of parameters used in sensitivity analysis. Standard values are those recommended for use or are based on tabulated values for the particular soil type being used.

Parameter	High	Standard	Low
CHS	10%	5%	2.5%
RC	0.20 in./hr	0.08 in./hr	0.02 in./hr
CONA	4.6 mm/d^5	3.8 mm/d^5	3.1 mm/d^5
SIA	0.30	0.20	0.10
CN2	92	86	70
WLW	3.0	2.0	1.0
POROS	55%	47%	38%
BR15	22%	11%	9%
FC	30%	25%	20%

Ten input parameters were tested. Simulation runs were for seven years. Annual precipitation for the first five years represented actual rainfall patterns (Fig. 15). The sixth year (model year 1981) represented the wettest year on record (1973) and the last year (model year 1982) was the wettest year plus supplemental moisture added during the summer. The monthly values of soil moisture and annual totals for evapotranspiration and runoff averaged over the seven years were used for comparisons.

Table 11. Leaf area indices used for CREAMS sensitivity runs.

Julian day	High LAI[a]	Standard LAI[b]	Low LAI[c]
1	0	0	0
32	0	0	0
60	0	0	0
91	0.06	0.02	0.02
105	0.35	0.03	0.06
121	0.65	0.05	0.10
135	1.10	0.10	0.20
152	1.49	0.20	0.33
166	1.57	0.20	0.44
182	1.52	1.00	0.39
196	1.32	1.00	0.32
213	1.15	1.00	0.25
227	1.03	0.90	0.24
244	0.85	0.80	0.05
258	0.70	0.50	0.05
274	0.69	0.20	0.02
305	0.40	0.01	0
335	0	0	0
365	0	0	0

[a] Based on a mid-grass prairie (Lane 1984)
[b] Based on a range grass system (Lane 1984)
[c] Based on a short-grass system (Lane 1984)

The sensitivity of the computer model for each parameter varied. The least

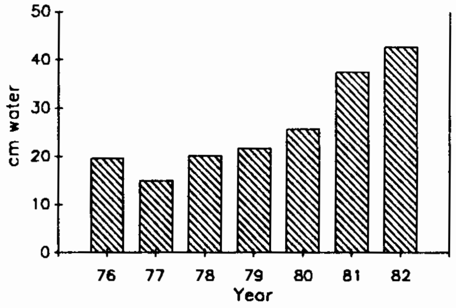

Fig. 15. Annual precipitation for the seven years used for simulation runs of CREAMS and ERHYM-II.

sensitive of the input parameters were watershed width to length ratio (WLW), and slope (CNS). No differences in soil moisture, evapotranspiration, nor runoff among high, medium, and low values were noted for each of these parameters.

Table 12. Annual evapotranspiration predictions for various values of the CREAMS input parameters. Numbers are in annual cm of water and are means of seven year runs.

Parameter	High	Standard	Low	
CHS	26.6	26.6	26.6	
RC	26.6	26.6	26.6	
CONA	26.6	26.6	26.6	
SIA	26.6	26.6	26.4	
CN2	26.1	26.6	26.8	
WLW	26.6	26.6	26.6	
POROS	26.6	26.6	26.5	
BR15	26.6	26.6	26.6	
FC	26.6	26.6	26.6	
LEAF[1]	26.6	26.6	25.3	24.9[2]

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[1] Leaf area index

[2] Bare ground

Evapotranspiration was inversely related to runoff curve number (CN2) (Table 12). Runoff was affected by relative conductivity (RC), initial soil abstraction coefficient (SIA), runoff curve number (CN2), porosity (POROS), and field capacity (FC) (Table 13). Decreases in runoff and evapotranspiration with low field capacity resulted in deep percolation of 0.1 cm of moisture beyond the 48 inch (120 cm) rooting depth.

Table 13. Results of sensitivity analyses regarding runoff. Values are in annual cm of water and are means of seven year runs.

Parameter	High	Standard	Low	
CHS	0.46	0.46	0.46	
RC	0.46	0.46	0.48	
CONA	0.46	0.46	0.48	
SIA	0.43	0.46	0.66	
CN2	0.94	0.46	0.20	
WLW	0.46	0.46	0.46	
POROS	0.51	0.46	0.41	
BR15	0.46	0.46	0.46	
FC	0.51	0.46	0.41	
LEAF[1]	0.46	0.46	0.46	0.46[2]

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[1] Leaf area index

[2] Bare ground

Increases in the runoff curve number (CN2) and soil evaporation parameter (CONA) depressed soil moisture levels slightly during the spring months (Fig. 16). The parameters that had the greatest effect on soil moisture levels were porosity (POROS), wilting point (BR15), and vegetative cover. An increase in porosity did not affect soil moisture (Fig. 17a), but decreasing porosity decreased moisture levels. The main effect of altering wilting point on soil moisture was in changing the base level to which

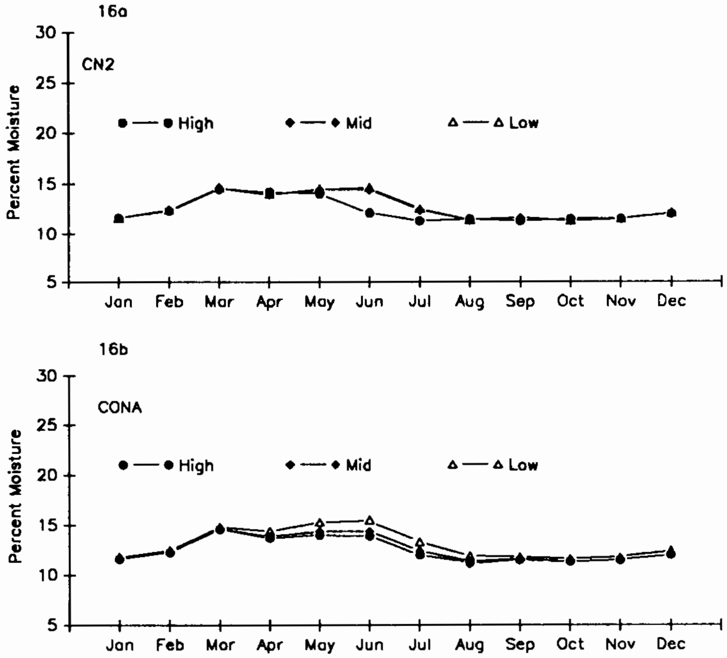

Fig. 16. Average monthly soil moisture, % volume, predicted by the CREAMS model for high, average, and low values of CN2 (16a) and CONA (16b).

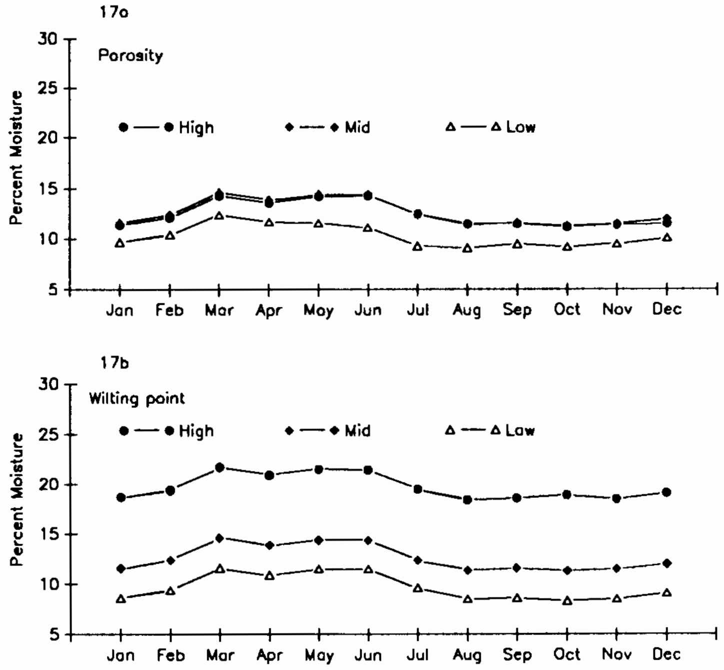

Fig. 17. Average monthly soil moisture, % volume, predicted by the CREAMS model for high, average, and low values of porosity (17a) and wilting point (17b).

soils would dry down in the summer (Fig. 17b). As noted earlier, higher wilting point levels resulted in higher base soil moisture levels.

Relative to vegetative cover, the main effect of increasing vegetation was a more rapid decline in soil moisture in the spring months than with the standard used (Fig. 18a). Base levels of soil moisture in late summer and early fall for high and medium cover did not differ. With a more sparse vegetative cover, spring moisture patterns resembled those of the standard but summer and fall levels were elevated (Fig. 18a). With less dense vegetation, not all the soil water was extracted by the end of the growing and resulted in a build up of soil moisture over the last three years (Fig. 18b).

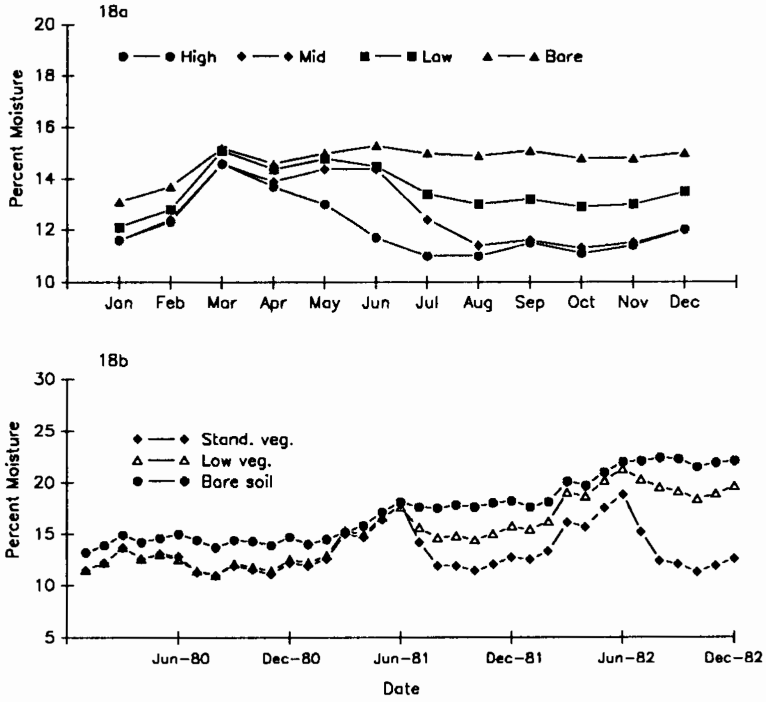

Fig. 18. Soil moisture, % volume, predicted by CREAMS with high, average, low and bare ground averaged over the seven simulation years (18a) and for just 1980-82 (18b).

As vegetative cover became sparser, evapotranspiration levels decreased due to less transpiration and reached their lowest on the bare soil (Table 12). Evapotranspiration on the bare soil was not much less than with vegetative cover. This indicates evaporation can be a major component of evapotranspiration especially in the upper soil layer. During years of low snowpack in 1976-79, spring recharge only penetrated to 20-30 cm and was susceptible to evaporation.

Runoff was not affected by decreasing vegetation (Table 13). Runoff was likely minimal because of the relatively flat slope of the watershed. It was of interest that even a relatively steep slope did not affect runoff. For the runs with different slopes, a moderate vegetative stand was assumed. To test the synergic effect of vegetation density and slope on runoff, additional runs were made where sparse vegetative cover and bare ground were paired with moderate and steep slopes.

Table 14 presents the outcome of these runs. No difference in runoff was seen for various combinations of slope and vegetation. The lack of response to increasing slopes likely resulted because of low annual precipitation and low intensity precipitation events that occurred during the simulation years.

Table 14. Effect of combined changes in slope and vegetative cover on evapotranspiration and runoff. Measurements are in centimeters of water.

Cover	Slope			
	2%	5%	10%	20%
	Evapotranspiration			
Standard	26.6	26.6	26.6	26.6
Low	25.3	25.3	25.3	25.4
Bare ground	24.9	24.9	24.9	25.0
	Runoff			
Standard	0.46	0.46	0.46	0.46
Low	0.46	0.46	0.46	0.48
Bare ground	0.46	0.46	0.46	0.46

ERHYM-II

In a similar manner as the CREAMS analysis, most input values for the ERHYM-II model were altered to high and then low values while holding all other values constant. As with the CREAMS analysis, a silty clay loam soil with a 48 inch (120 cm) rooting depth was assumed. The standard soil parameters tested are listed in Table 15 along with high and low values selected. High and low values were chosen based on tabulated ranges of these parameters for the soil type used (Appendix A). For the parameters that were the same as the CREAMS model, identical values were selected. The model was tested for sensitivity to different vegetative covers by adjusting the parameter TRANCO. The bare ground situation was simulated by setting TRANCO to 0.02.

Fourteen input parameters were tested. Simulation runs were over the same seven years used for the CREAMS runs. Precipitation patterns were the same as for the CREAMS runs. Monthly values of soil moisture and annual totals for evapotranspiration, runoff, and deep drainage averaged over the seven years were used for comparison.

Table 15. Values of parameters used in ERHYM-II sensitivity analysis. Standard values are those recommended for use or are based on tabulated values for the particular soil type being used.

Parameter	High	Standard	Low	
CROPCO	0.99	0.80	0.50	
TRANCO	0.60	0.50	0.20	0.02[1]
CS	10%	5%	2.5%	
CN2	92	86	70	
STFW	0.90	0.70	0.10	
CSHAPE	5.0	2.0	1.0	
DSHAPE	5.0	2.0	1.0	
LW	3.0	2.0	1.0	
SIA	0.30	0.20	0.10	
AIRDRY	0.50	0.01	--[2]	
BD[3]	1.40	1.20	1.00	
MHC[4]	25%	21%	17%	
UNASM[4]	18%	9%	8%	
FURCAP	1.0	0.5	0	

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[1] Represents a bare ground situation.

[2] Only two AIRDRY values were used, based on initial runs.

[3] Initial bulk density runs were made without making corresponding adjustments in MHC and UNASM.

[4] Percent moisture based on weight.

The least sensitive input parameters were watershed width to length ratio (LW), CSHAPE, DSHAPE, and the temperature weighting factor (STFW). There were no differences in soil moisture, evapotranspiration, runoff, or drainage among high, medium, and low values. The width to length ratio was also one of the least sensitive parameters for the CREAMS model. The last three parameters are unique to the ERHYM-II model.

Evapotranspiration was positively related to changes in CROPCO, FURCAP, and field capacity (MHC) and inversely related to wilting point (UNASM) (Table 16). Runoff was positively related to slope (CS), CN2, and UNASM but inversely related to CROPCO, TRANCO, FURCAP, AIRDRY, and MHC (Table 17). Deep percolation of moisture beyond the 120 cm rooting depth was positively related to CS, SIA, UNASM, and FURCAP and inversely changed with CN2, AIRDRY, TRANCO, BD, and MHC (Table 18). As with CREAMS, deep percolation only occurred in the year of high precipitation.

Table 16. Annual evapotranspiration predictions for various values of the ERHYM-II input parameters. Numbers are in annual cm of water and are means of seven year runs.

Parameter	High	Standard	Low	
CROPCO	26.2	25.7	21.9	
TRANCO	25.9	25.7	24.4	21.3[1]
CS	25.7	25.7	25.7	
CN2	25.7	25.7	25.7	
STFW	25.7	25.7	25.7	
CSHAPE	25.7	25.7	25.7	
DSHAPE	25.7	25.7	25.7	
LW	25.7	25.7	25.7	
SIA	25.7	25.7	25.7	
AIRDRY	25.9	25.7	--[2]	
BD[3]	25.7	25.7	25.7	
BD[4]	25.9	25.7	25.6	
MHC[5]	25.7	25.7	24.9	
UNASM[5]	19.1	25.7	26.1	
FURCAP	25.9	25.7	23.6	

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[1] Represents a bare ground situation.
[2] Only two AIRDRY values were used, based on initial runs.
[3] Initial bulk density runs were made without making corresponding adjustments in MHC and UNASM.
[4] Runs where MHC and UNASM were adjusted based upon the bulk density used so that MHC and UNASM on a % volume basis remained the same.
[5] Percent moisture based on weight.

Table 17. Results of sensitivity analysis of ERHYM-II regarding runoff. Values are in annual cm of water and are means of seven year runs.

Parameter	High	Standard	Low	
CROPCO	0.18	0.36	0.61	
TRANCO	0.36	0.36	0.46	0.66[1]
CS	0.41	0.36	0.36	
CN2	0.51	0.36	0.06	
STFW	0.36	0.36	0.36	
CSHAPE	0.36	0.36	0.36	
DSHAPE	0.36	0.36	0.36	
LW	0.36	0.36	0.36	
SIA	0.36	0.36	0.36	
AIRDRY	0.31	0.36	--[2]	
BD[3]	0.36	0.36	0.36	
BD[4]	0.36	0.36	0.39	
MHC[5]	0.24	0.36	0.42	
UNASM[5]	0.95	0.36	0.32	
FURCAP	0.00	0.36	2.80	

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[1] Represents a bare ground situation.
[2] Only two AIRDRY values were used, based on initial runs.
[3] Initial bulk density runs were made without making corresponding adjustments in MHC and UNASM.
[4] Runs where MHC and UNASM were adjusted based upon the bulk density used so that MHC and UNASM on a % volume basis remained the same.
[5] Percent moisture based on weight.

Altering field capacity (MHC) slightly affected soil moisture in the spring (Fig. 19a). Increases in CROPCO decreased soil moisture (Fig. 19b). As with CREAMS, the parameter that affected soil moisture the most was wilting point (UNASM) (Fig. 20a). As noted earlier, raising the wilting point increased the base level to which soils would dry in the summer. An opposite effect was seen when AIRDRY was altered (Fig. 20b). Bulk density also altered the base level of soil moisture throughout the year (Fig. 21a). When field capacity and wilting point were not adjusted relative to bulk density changes, the differences in soil moisture among the three bulk density values were greater than when adjustments were made (Fig. 21b). This greater difference can be attributed to changes in field capacity and wilting point that automatically occur when bulk density is altered.

Table 18. Results of sensitivity analysis of ERHYM-II regarding deep drainage beyond the 120 cm rooting depth. Values are in annual cm of water and are means of seven year runs.

Parameter	High	Standard	Low	
CROPCO	0	0.16	5.94	
TRANCO	0.08	0.16	0.71	3.96[1]
CS	0.18	0.16	0.16	
CN2	0.04	0.16	0.29	
STFW	0.16	0.16	0.16	
CSHAPE	0.16	0.16	0.16	
DSHAPE	0.16	0.16	0.16	
LW	0.16	0.16	0.16	
SIA	0.16	0.16	0.09	
AIRDRY	0	0.16	–[2]	
BD[3]	0	0.16	0.42	
BD[4]	0.15	0.16	0.19	
MHC	0	0.16	1.25	
UNASM	13.57	0.16	0	
FURCAP	0.32	0.16	0	

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[1] Represents a bare ground situation.

[2] Only two AIRDRY values were used, based on initial runs.

[3] Initial bulk density runs were made without making corresponding adjustments in MHC and UNASM.

[4] Runs where MHC and UNASM were adjusted based on the bulk density used so that MHC and UNASM on a % volume basis remained the same.

Decreasing vegetative cover (TRANCO) resulted in increasingly higher base levels of soil moisture (Fig. 22) that paralleled denser vegetation covers. When the model was run with little vegetation (TRANCO = 0.02), water levels in the soil did not fluctuate as much and built up over the seven years in a similar manner as seen in CREAMS.

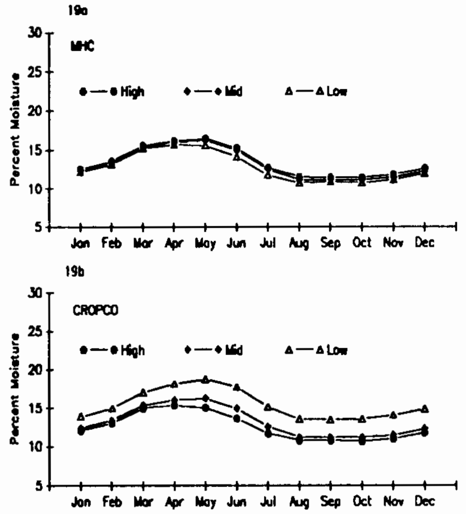

Fig. 19. Average monthly soil moisture, % volume, predicted by the ERHYM-II model for high, average, and low values of field capacity (19a) and CROPCO (19b).

Evapotranspiration and runoff did not differ much between heavy and moderate vegetative cover (Tables 16 & 17). With less plant cover, evapotranspiration decreased and was lowest with bare ground (Table 16). The reverse pattern was seen for runoff (Table 17). Deep drainage (Table 18) was lowest at the high TRANCO value and increased substantially as TRANCO decreased.

Synergic effects of vegetation and slope on runoff (Table 19) were determined in a similar manner as for CREAMS. The ERHYM-II model proved more sensitive to combinations of slope and vegetative cover than CREAMS.

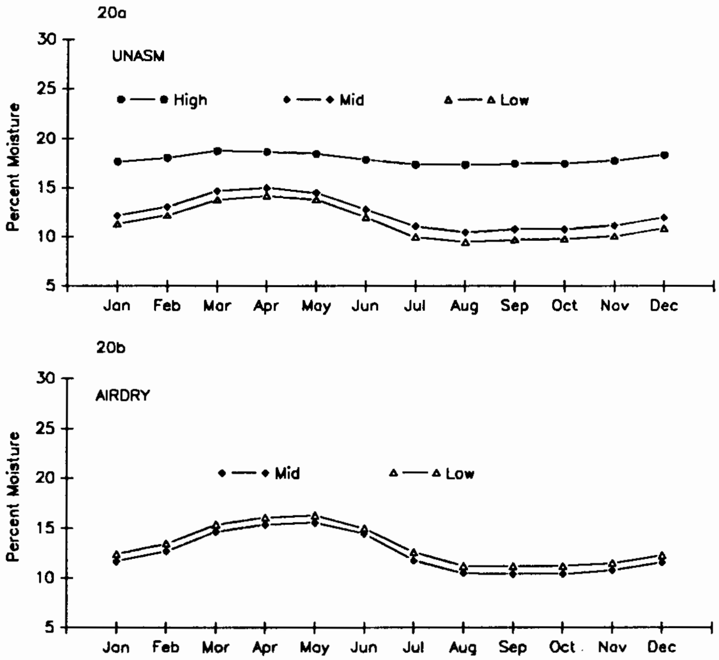

Fig. 20. Average monthly soil moisture, % volume, predicted by ERHYM-II model for high, average, and low values of wilting point (UNASM) (20a) and the parameter AIRDRY (20b).

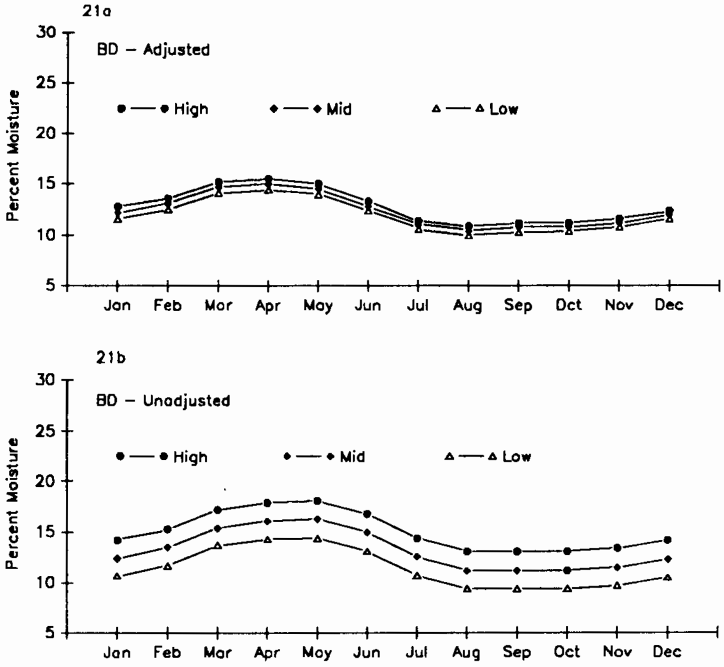

Fig. 21. Average soil moisture, % volume, predicted by ERHYM-II for high, average, and low values of bulk density (BD) with field capacity and wilting point adjusted (21a) and unadjusted (21b).

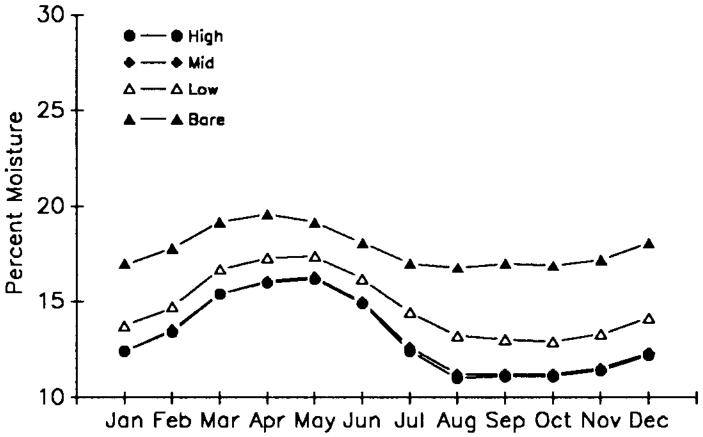

Fig. 22. Average monthly soil moisture, % volume, predicted by the ERHYM-II model for high, average, low, and zero values of TRANCO.

Major differences in runoff and deep drainage were found as vegetation decreased within each slope tested. Within a given vegetative cover, few differences were seen as slope was increased.

Table 19. Effect of combined changes in slope and vegetative cover on outcome of sensitivity runs of ERHYM-II. Units are cm of water.

Cover	Slope			
	2%	5%	10%	20%
	Evapotranspiration			
Standard	25.7	25.7	25.7	25.7
Low	24.6	24.4	24.5	24.6
Bare ground	21.4	21.3	21.4	21.2
	Runoff			
Standard	0.36	0.36	0.41	0.36
Low	0.46	0.46	0.44	0.45
Bare ground	0.65	0.66	0.62	0.66
	Drainage			
Standard	0.16	0.16	0.18	0.19
Low	0.58	0.17	0.65	0.59
Bare ground	3.76	3.96	3.70	4.10

RECOMMENDATIONS AND IMPLICATIONS

Results of the sensitivity analyses indicate that accuracy of input values for the CREAMS and ERHYM-II models for the INEL need not be critical for most parameters. However, relatively accurate estimates (±1%) of porosity, field capacity, and wilting point are necessary. For ERHYM-II, the parameter FURCAP affects predictions of soil moisture, evapotranspiration, runoff, and deep drainage, so realistic estimates of this parameter are necessary. Porosity and field capacity of soils on the INEL should correspond to standard tabulated values based on the soil texture. If these properties do not correspond to such values, field estimates should be made. Tabulated wilting point values however, are based on extraction levels by plants in more mesic areas. Plants on the INEL are able to extract water to much lower levels, making tabulated figures of little value. Reliable estimates of wilting point levels for a watershed on the INEL can be made by sampling soil moisture at 30-60 cm depths in late August when soil moisture at these levels has been reduced to a minimum by transpiration alone.

Data on vegetative cover of an area to be modeled is important for modeling wetting and drying cycles of the soil. However, the LAI schedules used for the standard run or greater for CREAMS are sufficient to pattern the extent of moisture removal for most vegetated habitats on the INEL.

The results of the sensitivity analysis have implications relative to trench cap designs on the RWMC. Two major concerns in the maintenance of the integrity of a trench cap are surface erosion and percolation of water through the cap. Results of the sensitivity analysis indicate a healthy stand of vegetation will prevent runoff from the SDA, regardless of slope, as long as the soil is not frozen. Such a vegetative cover will also prevent percolation through a 48 inch (120 cm) cap under most moisture circumstances. Sparse stands of vegetation will result in increased runoff and percolation deeper into the soil. Of equal importance is the compaction of the soil cap. Soils with lower field capacity will actually increase the amount of water percolating deeper into the soil. These are general considerations to guide trench cap designs. Specific designs should be modeled.

EFFECTS OF SMALL MAMMAL BURROWS ON INFILTRATION

Neither CREAMS nor ERHYM-II incorporate potential effects of small mammal burrows on infiltration of water into the soil (Hakonson et al. 1986). The extent of burrow influence is being studied on the INEL. Final analysis of field data has not been completed to date. However, preliminary data analysis allow some comparisons to be made at this time. A test grid containing different densities of artificial burrows of Townsend's ground squirrels (*Spermophilus townsendii*) was set up at the Experimental Field Station on the INEL (Laundre' 1986). Soil moisture patterns during 1986 for control grid cells (no burrows) and grid cells with a density of 0.2 holes/m^2 were used for comparisons with moisture predictions generated from CREAMS and ERHYM-II. The soil in the test grid was classified as a loam with a bulk density of 1.3 g/cm^3. Vegetation on the area consisted of a uniform stand of western wheatgrass with an average above ground biomass production during the year simulated of 713 lb/acre (80 g/m^2). Soil moisture measurements were made with a neutron probe and readings were taken at 8 inch (20 cm) intervals from 8 inches (20 cm) deep to a depth of 40 inches (100 cm). Computer simulations were run for a rooting depth of 32 inches (80 cm) so comparisons of deep drainage to the 40 inch (100 cm) depth could be made. Input values for the various parameters were selected assuming no burrows in the watershed.

Soil moisture levels at peak recharge in March were higher in the grids with burrows than the controls (Fig. 23). Moisture levels predicted by ERHYM-II and CREAMS were lower than both field estimates. For both models, the difference in moisture levels between the control and predicted moisture levels was larger than that between the control and grids with burrows. Thus the accuracy of the models in patterning moisture levels would be insufficient to distinguish the added effects of the burrows.

Drainage below 32 inches (80 cm) on the control grid cells averaged 0.6 inches (1.5 cm) (SD = 0.23, n = 4) while average drainage on the grids with burrows was 0.9 inches (2.3 cm) (SD =0.35, n = 2). Thus, the presence of burrows increased deep drainage. The CREAMS model did not predict any deep drainage while ERHYM-II predicted 1.1 inches (2.8 cm). Again, accuracy of the models in predicting deep drainage would be insufficient to distinguish between watersheds with burrows and those without them.

It is possible that higher precipitation levels may further accentuate differences between areas with and without burrows. Further data analysis will determine effects of precipitation on recharge

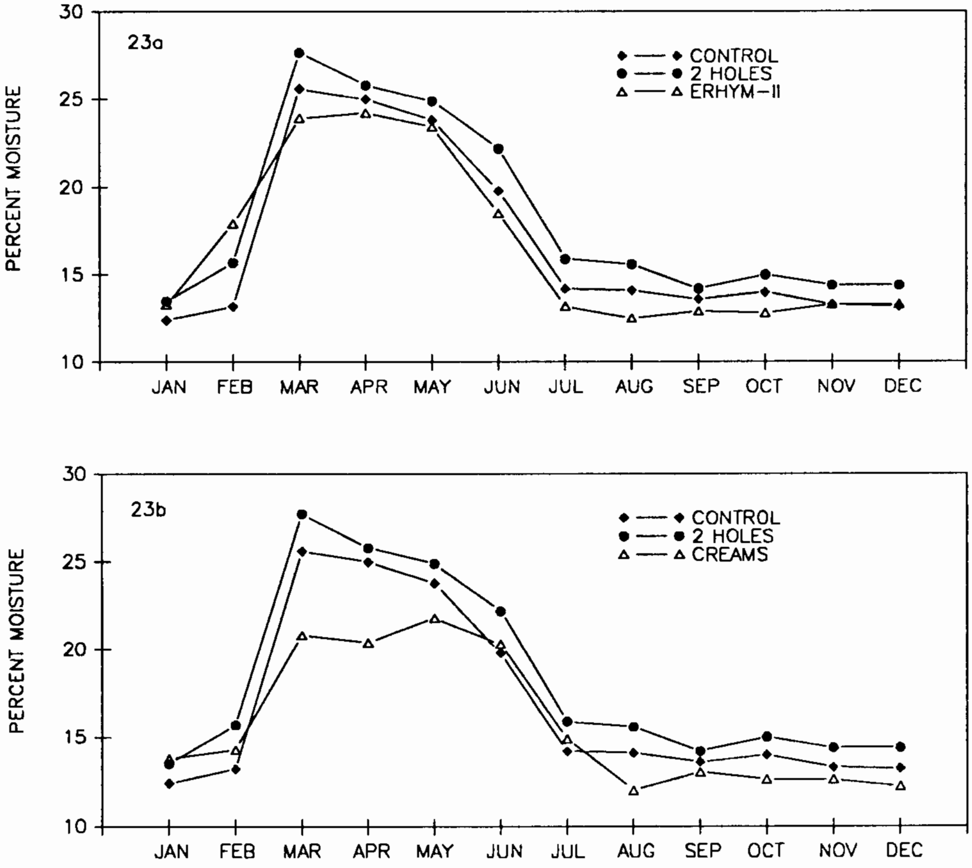

Fig. 23. Monthly soil moisture for 1986 in grid cells with no burrows and 0.2 burrows/m^2 compared with estimates from ERHYM-II (23a) and CREAMS (23b) for similar soils and vegetation.

patterns. If greater differences in soil moisture levels and drainage amounts are found, it is possible to modify various input parameters such as saturated hydraulic conductivity to better pattern watersheds with small mammal burrows.

TESTING OF TRENCH CAP DESIGNS: AN EXAMPLE

The main use of the models is to test various trench cap designs for the RWMC. The CREAMS model was used to test cap designs in conjunction with Golder Associates Consulting Company and EG&G of Idaho. For this report, the ERHYM-II model was also used to test the designs reported herein. Several designs were proposed. Results of analyses for three of them are presented here. The designs consisted of uncompacted lakebed material and differed only in thickness of the soil cap. The first two designs had thicknesses of 2 ft (60 cm) and 4 ft (120 cm) and represent the minimum and maximum depths of the trench cap presently on the SDA. The third design had a 6 ft (180 cm) thick cap. All other parameters were the same for the three runs and equaled those used for the initial adjusted runs of the two models. Failure of the design occurred if the model predicted percolation of water below the proposed thickness of the cover.

Each design was tested for its ability to absorb average annual precipitation amounts of 8.1 inches (20.6 cm) for five years. For the sixth year (model year 1981), a worst case scenario of 15.0 inches (38.0 cm) annual precipitation was used. The worst case was the maximum annual precipitation (1973) recorded for the INEL since 1950.

Results of the runs (Table 20) indicate the minimum depth soil cap will absorb annual precipitation amounts in dry years but will fail in years with amounts over 8.0 inches (20 cm). A 4 ft (120 cm) thick cap will prevent moisture intrusion most years but the CREAMS model predicted failure in extremely wet years. The 6 ft (180 cm) cap prevented intrusion even during the wettest scenario.

Table 20. Tests of trench cap designs with the CREAMS and ERHYM-II models. Measurements are in cm of water predicted to percolate beyond three trench cap thicknesses.

Year		1976	1977	1978	1979	1980	1981
Precipitation		7.8	5.9	8.0	8.6	10.2	15.0
180 cm cap	CREAMS	0	0	0	0	0	0
	ERHYM	0	0	0	0	0	0
120 cm cap	CREAMS	0	0	0	0	0	1.8
	ERHYM	0	0	0	0	0	0
60 cm cap	CREAMS	0	0	1.0	0	1.0	5.0
	ERHYM	0	0	0.9	1.1	1.1	3.0

The three designs tested differed only in thickness; soil properties were uniform throughout the profile. In CREAMS and ERHYM-II, soil properties can be altered on a layer by layer bases (seven in CREAMS and four in ERHYM-II). This ability allows testing of designs with layers of different texture and structure such as a compacted layer of high clay material overlaid with a layer of less compacted soil (Hakonson et al. 1986).

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APPENDIX A:

Tabulated values for use in CREAMS and ERHYM-II for different soils likely to be found on the INEL Site.

Table 1. Porosity, field capacity (-1/3 bar), and wilting point (-15 bar) by soil texture classes. Porosity, field capacity, and wilting point are in terms of water content in % by volume (from Lane 1984).

Soil Texture Class	Computer Code	Total Porosity			Field Capacity			Wilting point			FUL
		avg	low	high	avg	low	high	avg	low	high	avg
Sand	020	41	39	43	9	7	15	3	2	6	0.16
Loamy sand	060	43	39	45	12	10	20	6	4	8	0.16
Sandy loam	100	45	39	52	20	14	29	9	5	12	0.31
Loam	130	47	45	52	26	20	36	12	9	18	0.40
Silt loam	140	50	49	55	31	20	36	13	7	20	0.49
Silt	150	51	49	55	28	26	30	9	6	12	0.45
Sandy clay l.	160	42	38	45	27	17	34	17	11	21	0.40
Clay loam	170	47	40	51	34	29	38	20	16	24	0.52
Sil. clay l.	180	47	46	51	36	33	40	21	18	24	0.58
Sandy clay	190	42	40	44	31	27	40	21	18	30	0.48

Table 2. Effective saturated hydraulic conductivity and bare soil evaporation parameter estimates for the INEL by soil texture class (from Lane 1984).

Soil Texture Class	Saturated Hydraulic Conductivity (inch /hr)			Bare Soil Evaporation Parameters (mm/d$^{1/2}$)		
	avg	low	high	avg	low	high
Sand	9.1	4.6	17.0	3.3	3.05	3.32
Loamy sand	2.4	1.4	4.6	3.3	3.05	3.32
Sandy loam	0.87	0.67	1.4	3.5	3.10	4.06
Loam	0.51	0.36	0.67	4.5	3.20	4.57
Silt loam	0.27	0.18	0.36	4.5	3.20	4.57
Silt	0.20	0.12	0.24	4.0	3.15	4.40
Sandy clay loam	0.12	0.10	0.18	3.8	3.15	4.32
Clay loam	0.08	0.07	0.10	3.8	3.15	4.32
Silty clay loam	0.07	0.06	0.10	3.8	3.15	4.32

Table 3. Runoff curve numbers for various hydrologic soil group-cover complexes for the INEL (Table 5) (from Lane 1984).

Cover type and conditions	Runoff curve numbers by soil group A	B	C	D
Unimproved bare soil	72	82	87	90
Desert brush				
< 10% cover	a	84	88	93
20% cover	a	83	87	92
40% cover	a	82	86	90
Herbaceous plants, brush and grass				
20% cover	a	79	86	92
40% cover	a	74	82	90

[a]Data not available

Table 4. Summary of leaf area index (LAI) data for areas in the northwestern United States (From Lane 1984).

Calendar date	Julian date	Shortgrass prairie	Range grass
Jan	1	0	0
Feb 1	32	0	0
Mar 1	60	0	0
Apr 1	91	0.02	0.02
Apr 15	105	0.06	0.03
May 1	121	0.10	0.05
May 15	135	0.20	0.10
June 1	152	0.33	0.20
June 15	166	0.44	0.60
July 1	182	0.39	1.00
July 15	196	0.32	1.00
Aug 1	213	0.25	1.00
Aug 15	227	0.24	0.90
Sept 1	244	0.05	0.80
Sept 15	258	0.05	0.50
Oct 1	274	0.05	0.20
Nov 1	305	0.02	0.01
Dec 1	335	0	0
Dec 31	366	0	0

Table 5. Approximate composition of soil textural classes of the INEL and their relationship with hydrologic soil groups without infiltration restricting layers. (from Lane 1984).

Soil Texture Class	Representative Composition As Percent by Weight Clay	Silt	Sand	Hydrologic Soil Group Association
Sand	3	7	90	A
Loamy sand	5	15	80	A
Sandy loam	10	20	70	A to B
Loam	20	40	40	A to C
Silt loam	15	65	20	A to D
Silt	5	87	8	B to C
Sandy clay loam	30	10	60	A to D
Clay loam	35	35	30	C to D
Silty clay loam	35	55	10	D
Sandy clay	45	5	50	B to D

Table 6. Average bulk density and AIRDRY values for soils likely to be found on the INEL.

Soil Texture Class	Bulk Density (g/cm^3)	AIRDRY (inches H_2O)
Sand	1.49	0.34
Loamy sand	1.49	0.40
Sandy loam	1.45	0.48
Loam	1.42	0.52
Silt loam	1.32	0.56
Sandy clay loam	1.60	0.60
Clay loam	1.42	0.80
Silt clay loam	1.40	0.83
Sandy clay	1.51	0.92

Appendix B

Figures for calculating TXMD, ATX, CVTX, ACVTX, TXMW, TN, ATN, CVTN, ACVTN, RMD, AR, and RMW for the ERHYM-II model (From Wight 1987).

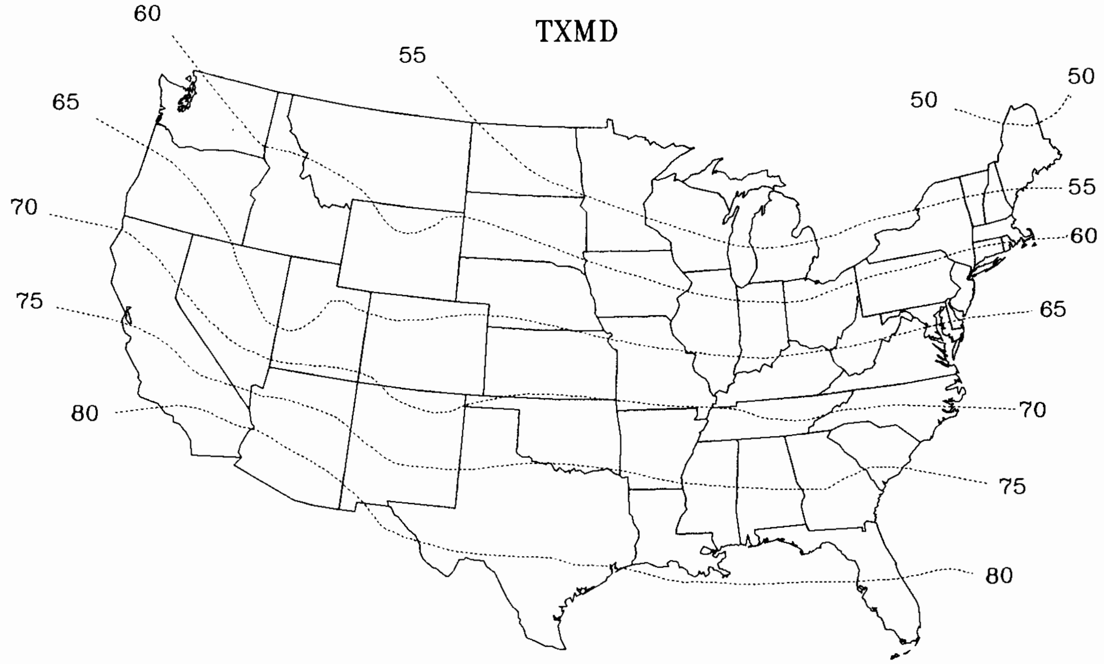

Fig. 1. Distribution of TXMD within the contiguous United States.

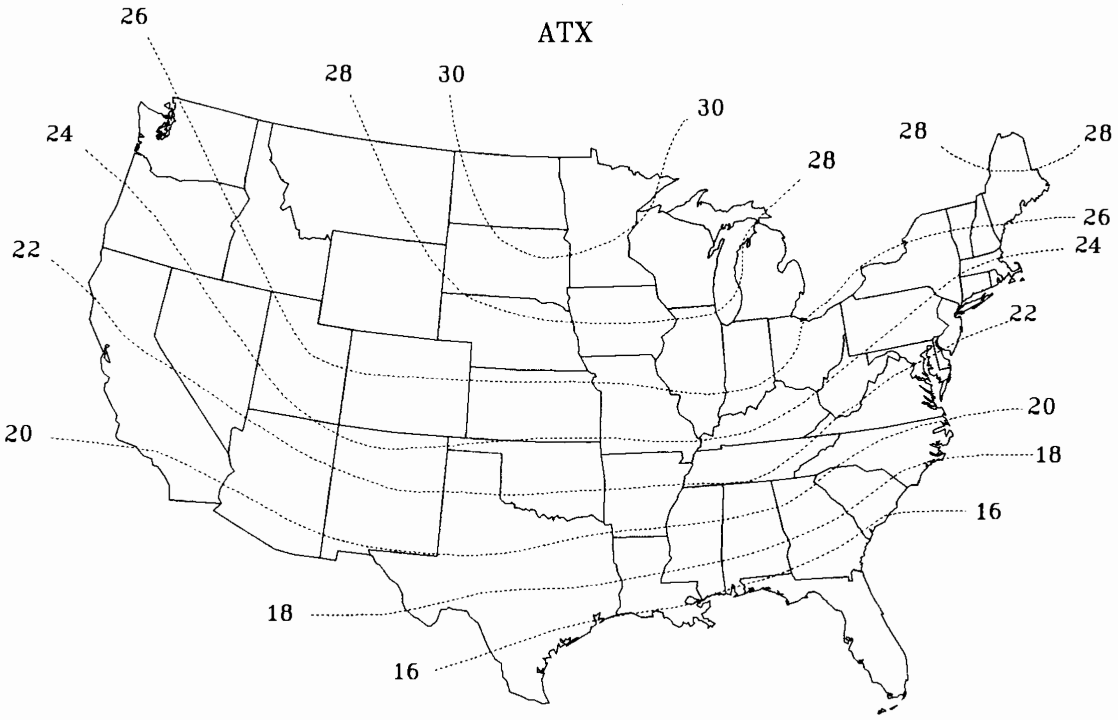

Fig. 2. Distribution of ATX within the contiguous United States.

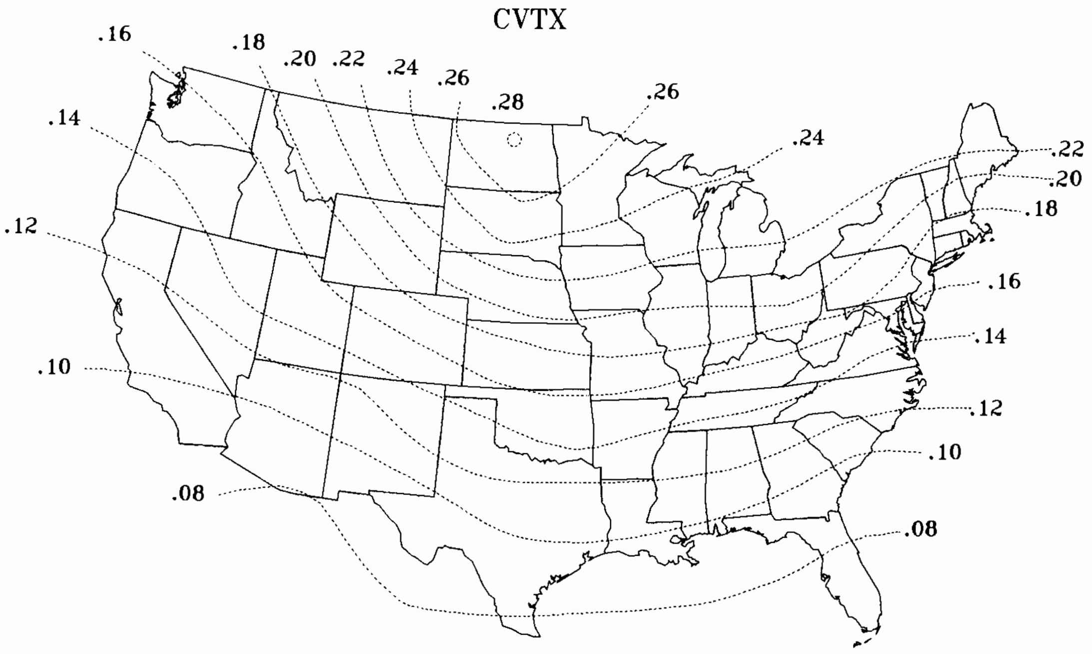

Fig. 3. Distribution of CVTX within the contiguous United States.

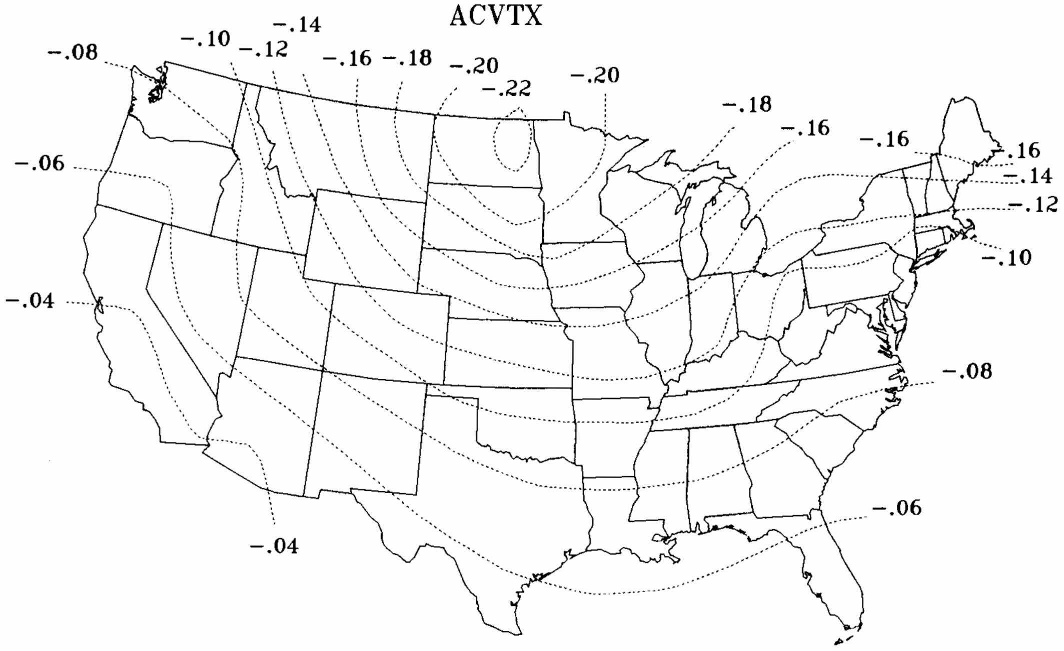

Fig. 4. Distribution of ACVTX within the contiguous United States.

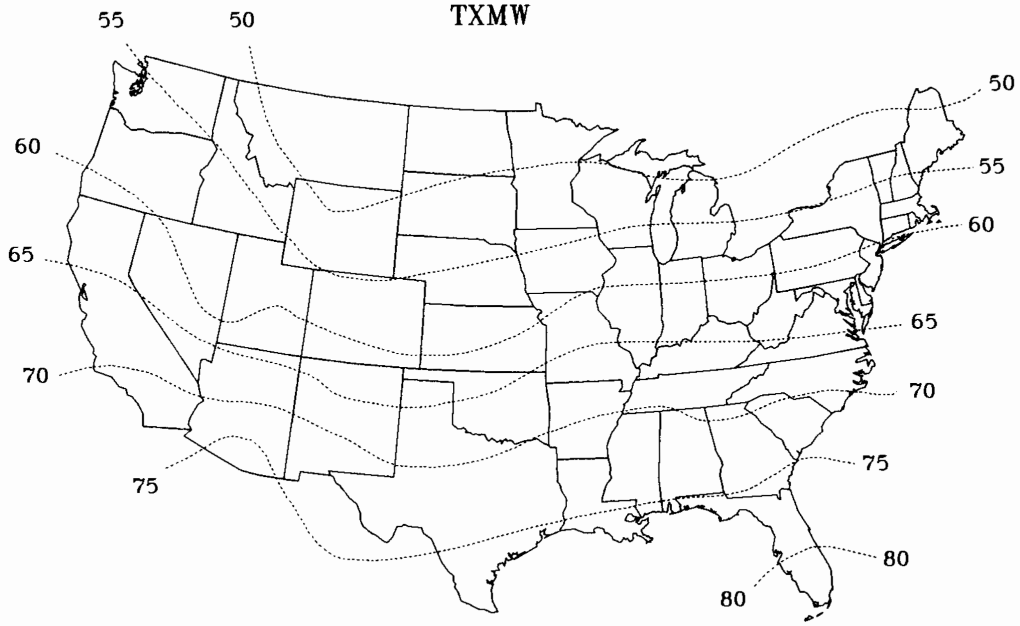

Fig. 5. Distribution of TXMW within the contiguous United States.

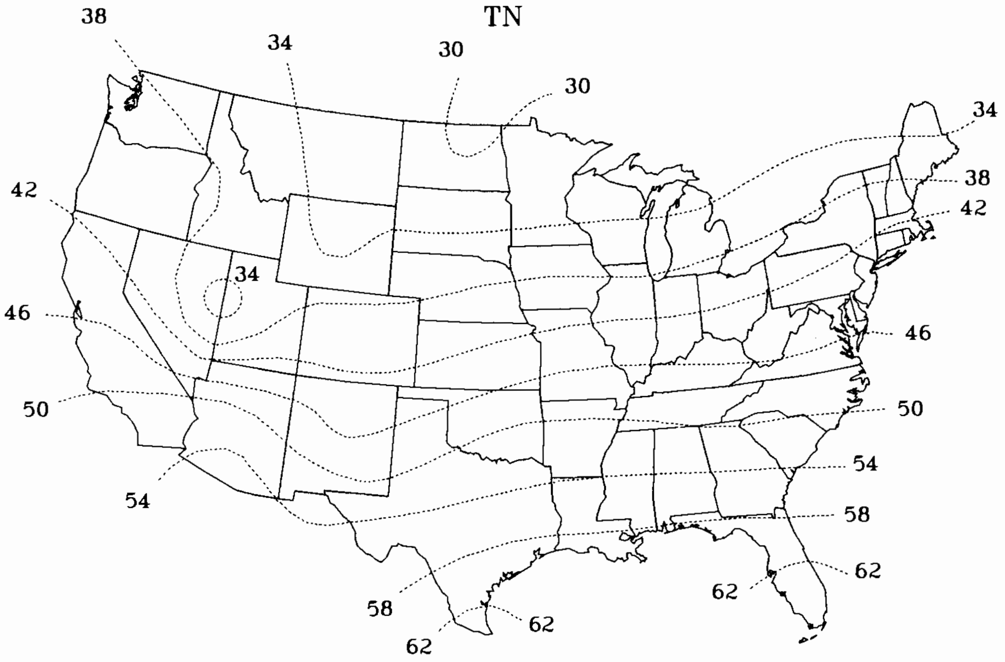

Fig. 6. Distribution of TN within the contiguous United States.

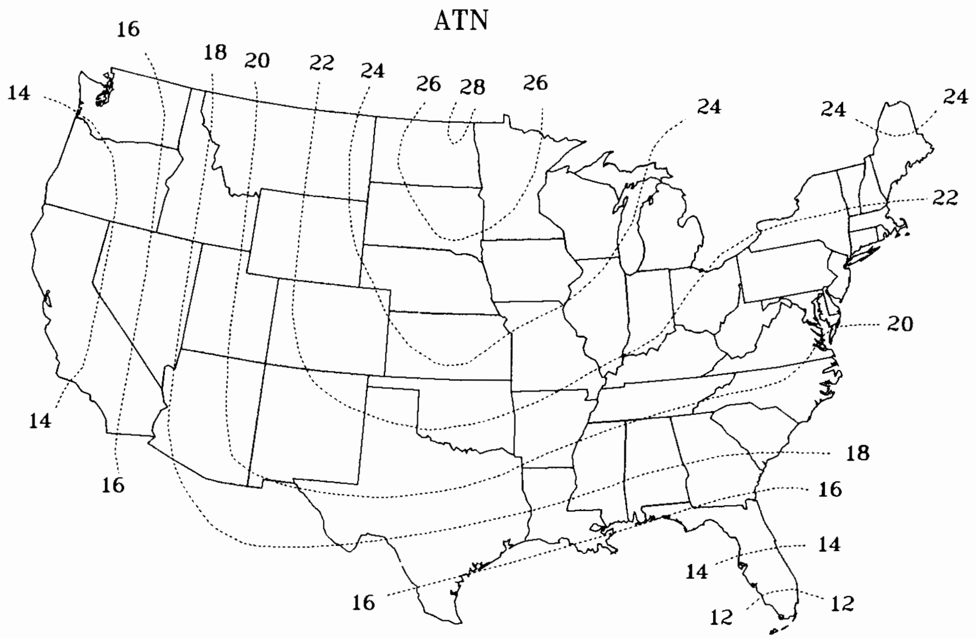

Fig. 7. Distribution of ATN within the contiguous United States.

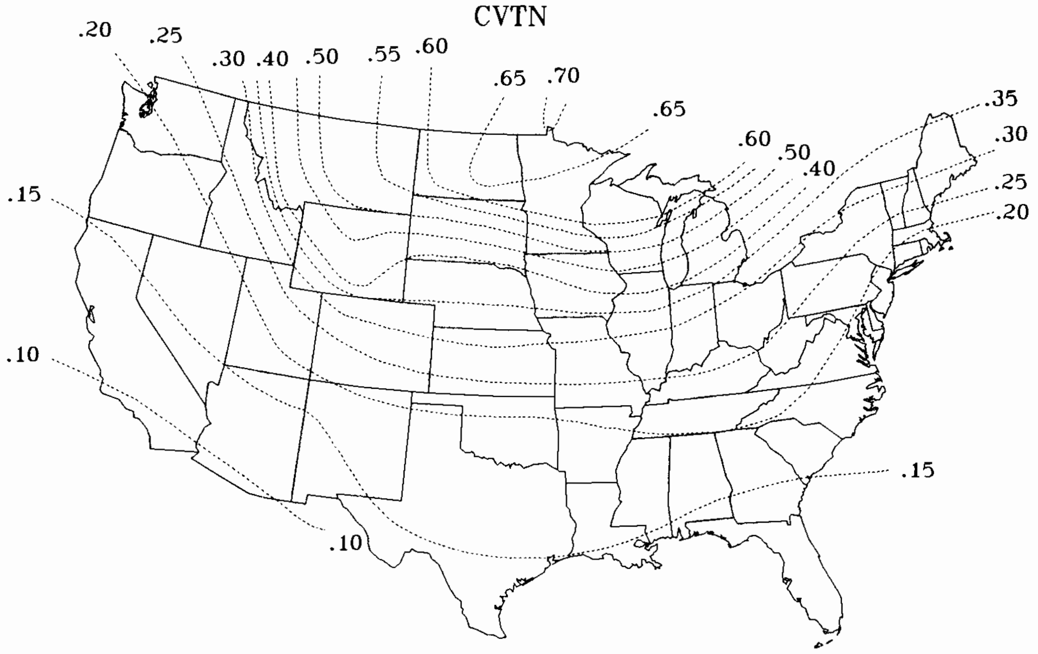

Fig. 8. Distribution of CVTN within the contiguous United States.

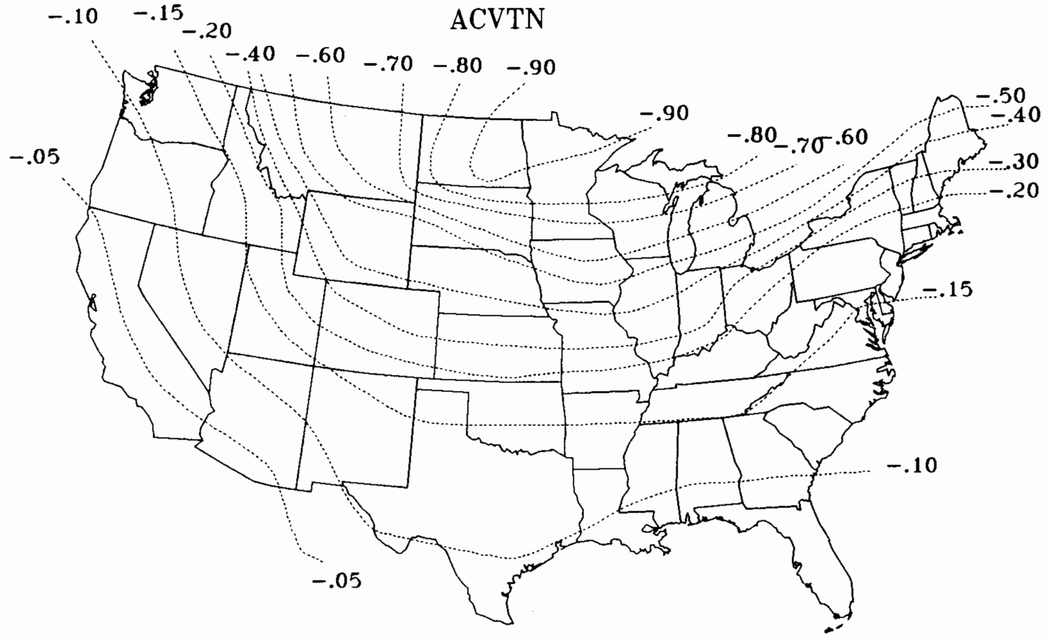

Fig. 9 Distribution of ACVTN within the contiguous United States.

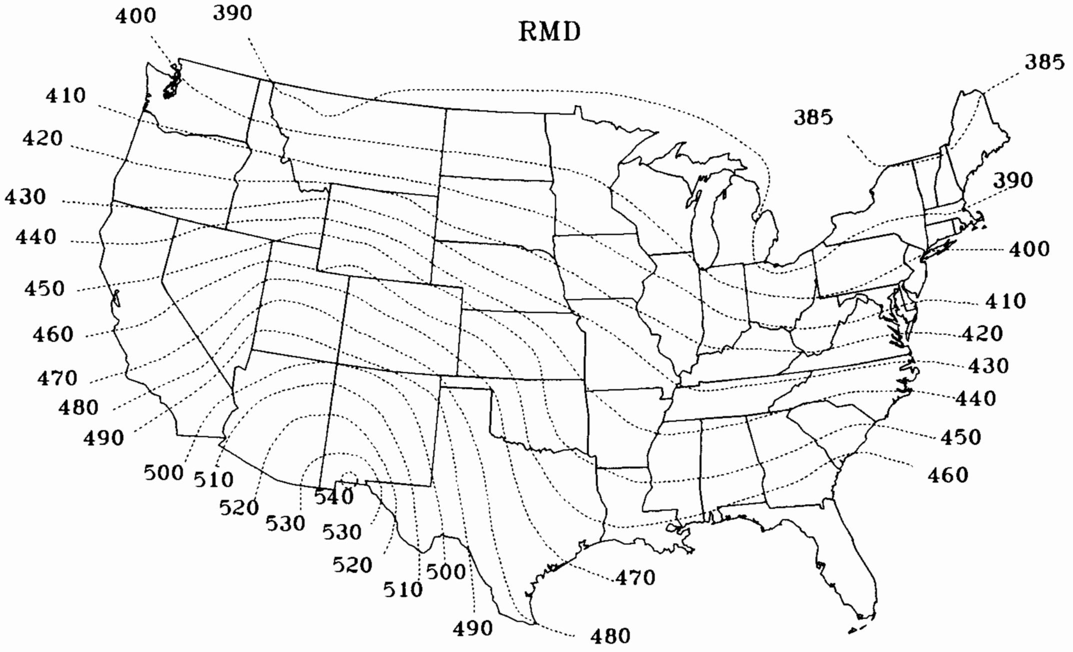

Fig. 10. Distribution of RMD within the contiguous United States.

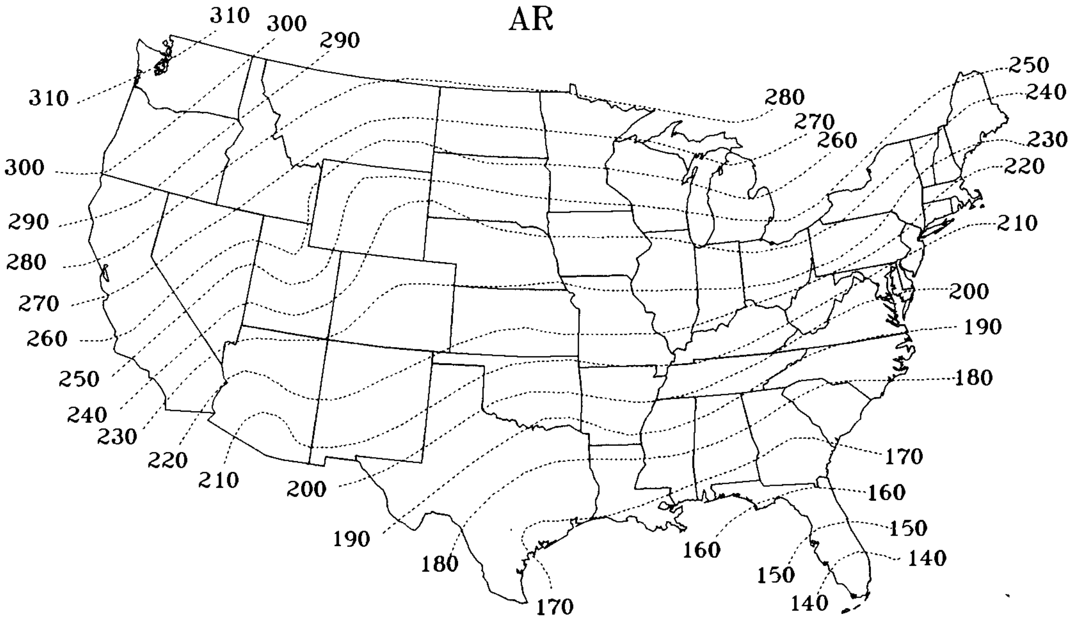

Fig. 11. Distribution of AR within the contiguous United States.

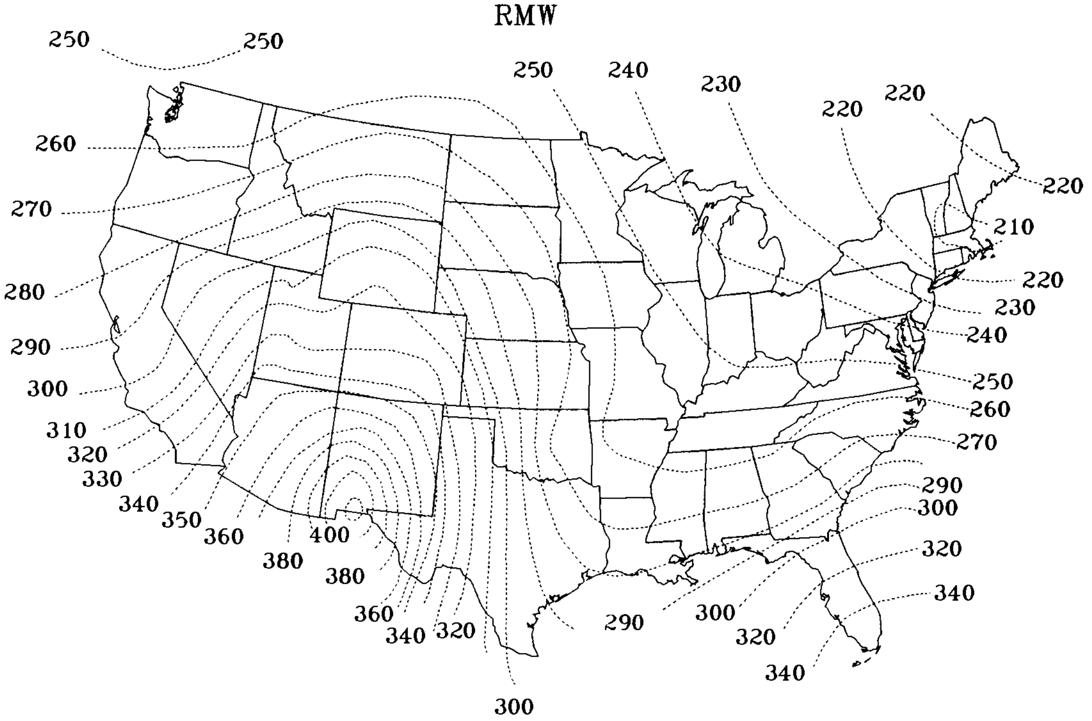

Fig. 12. Distribution of RMW within the contiguous United States.