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PROCEDURES, NUMERICAL PARAMETERS AND COEFFICIENTS OF THE CREAMS MODEL: APPLICATION AND VERIFICATION IN CZECHOSLOVAKIA

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PREFACE

Mathematical modeling is a very important tool for the analysis of trade-offs between agricultural production and the environment. At present there is a set of mathematical models which reflect the physical processes in the soil. One of them is the CREAMS model which describes the major hydrologic processes (surface and subsurface flow, deep percolation, etc.), erosion processes in the soil, sediment and chemical transport. The CREAMS modelers maintain that the model does not require calibration but needs validation. At present, one of the aims of Task 2, Land and Landcover Resources, is to validate this model. The CREAMS model has been used by investigators in various countries and almost all of them met with difficulties when dealing with the huge volume of initial information and when trying to obtain the numerical values of input data for the model. Therefore, one purpose of this paper is to discuss how the input data for the CREAMS model may be obtained from the Samśin area and how the model may be used to calculate the hydrological, erosion and chemical processes in the Trnávka catchment of the CSSR.

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ABSTRACT

Problems of agricultural nonpoint source pollution have been investigated by the Resources and Environment Area (Task 2) at IIASA. The CREAMS model has been used as a mathematical aid to arrive at an in-depth understanding of erosion and to predict its influence on agriculture.

The CREAMS model was created using data from North America. Investigations of its general use and verification under various conditions were useful. This paper summarizes the results of the verification of this model in a research area in Czechoslovakia and focuses attention on certain points which must be carefully considered during application of this model.

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PROCEDURES, NUMERICAL PARAMETERS AND COEFFICIENTS OF THE CREAMS MODEL: APPLICATION AND VERIFICATION IN CZECHOSLOVAKIA

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1. INTRODUCTION

The environmental consequences of erosion and especially of agricultural nonpoint source pollution require great attention. Mathematical modeling of these phenomena is an important aid in solving these problems. Numerous models have been suggested for this purpose (Haith, 1980). The CREAMS (Chemical Runoff and Erosion from Agricultural Management Systems) model (Knisel, 1980) has been chosen for verification and application because it expresses the basic hydrologic, erosion and chemical relations which occur in a field or in a small catchment.

The CREAMS model is a discrete simulation model, based on a complete hydrologic balance, using the SCS (Soil Conservation Service) runoff equation and the Green and Ampt (1911) infiltration equation. The erosion is simulated by particle size distribution, its transport and deposition. The final output is represented by nitrogen, phosphorus and pesticides content in total runoff and percolated water.

In principle, the model needs no calibration. However, its verification showed that some variables may be chosen within certain limits and if proper results have to be obtained, it is necessary to determine these limits.

1.1 Model Adjustment and Calibration

The CREAMS model, a physical model, does not need calibration. However, numerical expression of the hydrologic, erosion and chemical processes requires simplification and schematization. This could be the first source of possible errors during application. The second could be that data are measured in a spatial grid (in different places and depths), and for the model only one representative number (or several numbers) is taken. The changes in values over time create further problems. Some input data are not measured and have to be estimated from the literature.

All these possible sources of errors may cause the output values of the model to deviate from reality. Therefore, some important input parameters need to be chosen in order to serve as a tool for the corrections necessary in the process of calibration. The technique for determination of these data is sensitivity analysis.

Lane and Ferreira (1980) used sensitivity analysis in a systematic way by variation of the input parameters upto ± 50%. Some parameters can be determined relatively well and the limits mentioned are sufficient. On the other hand, when determining some parameters, the limits may not be sufficient. The acreage of the area can easily be determined (e.g., from a map), whereas hydraulic conductivity on the other hand, differs from place to place and from depth to depth and its determination as the input parameter is much more complicated. Its limit may be ± 100%, or even more.

CREAMS is a multi-parameter model and it is not possible to calibrate each parameter. The sensitivity analysis of Lane and Ferreira (1980) and the suggestions made in this paper do help in the choice of a few parameters to which the model is sensitive and which serve as the calibration parameters.

It was found that within certain limits, the model output does not react too much to the change of the input but beyond these limits, the response is highly nonlinear--a small change in the parameter values may cause a great change in the output: hydraulic conductivity is an example.

The description of some of the input data in the manual (Knisel, et al., 1980, Part II) is accurate enough, so determining the data creates no problems. For other input data, however, some estimation and preliminary calculations are necessary with the aid of various references. Therefore, in this paper guidelines and procedures for determination of some input data on the basis of the experience obtained during application and verification of the CREAMS model are recommended.

During this process, measured output and input data and some estimated input data were compared with the results obtained by the CREAMS model. This verification seems to show that the CREAMS model may give adequate results, if a proper choice of field or catchment is made, the input data is correctly determined, and the parameters for the overall conditions are calibrated. The procedures on how to achieve these results are discussed in greater detail below.

1.2 The CREAMS Model and its Computer Program

Before the calibration phase, the computer program was considered necessary in the light of the following:

(a) Description of the input data deviated in the computer program in some cases from that in the user manual (Knisel et al., 1980, Part II). These deviations are given in Chapters 2, 3 and 4.

(b) The sequence and form of the input data in some cases differ in the manual and in the computer program.

(c) Some parameters are calculated in the program and not read as an input as introduced in the manual.

(d) Instead of the input data described in the manual, constants are used in some cases.

(e) Some discrepancies may be observed between the individual submodels (i.e., hydrologic, erosion and chemical).

(f) Some differences do occur between the equations used in the description of the model and the program.

All the deviations mentioned were discussed, and removed when necessary, by adjustment of the input data and not by changes in the program. This method was most effective during application, calibration and validation of the model in various countries.

The model adjustment and calibration, description of the deviations between the manual and the program used, and recommendations for the application of the model for the conditions in Czechoslovakia and discussed in the following three chapters, in keeping with the division of the CREAMS model into three submodels, i.e., hydrologic, erosion and chemical.

According to a comprehensive structure of the computer program of the CREAMS model, the first step of analysis was the investigation of the structures of the submodels. The flow charts indicating method of calculation, reading of input data, calling of subroutines according to the decision statements in relation to the choice of the input data were the results of this preliminary analysis. In principle, the hydrologic submodel consists of two parts in relation to the form of input precipitation data (Figures 1 and 2). A comprehensive structure of computation in the erosion/sediment submodel is given by different types of runoff. Upto six combinations of elements, i.e., overland flow, channel flow, and impoundment (Figure 3) are possible. A different way of calling these subroutines is related to their combinations (Figure 4).

In the chemical submodel computation can be realized in two ways, depending on the calculation of nitrogen uptake. This fact is reflected in the choice of different computations in the program (Figure 5). As all subroutines are called by the main program, no special flow chart has been given.

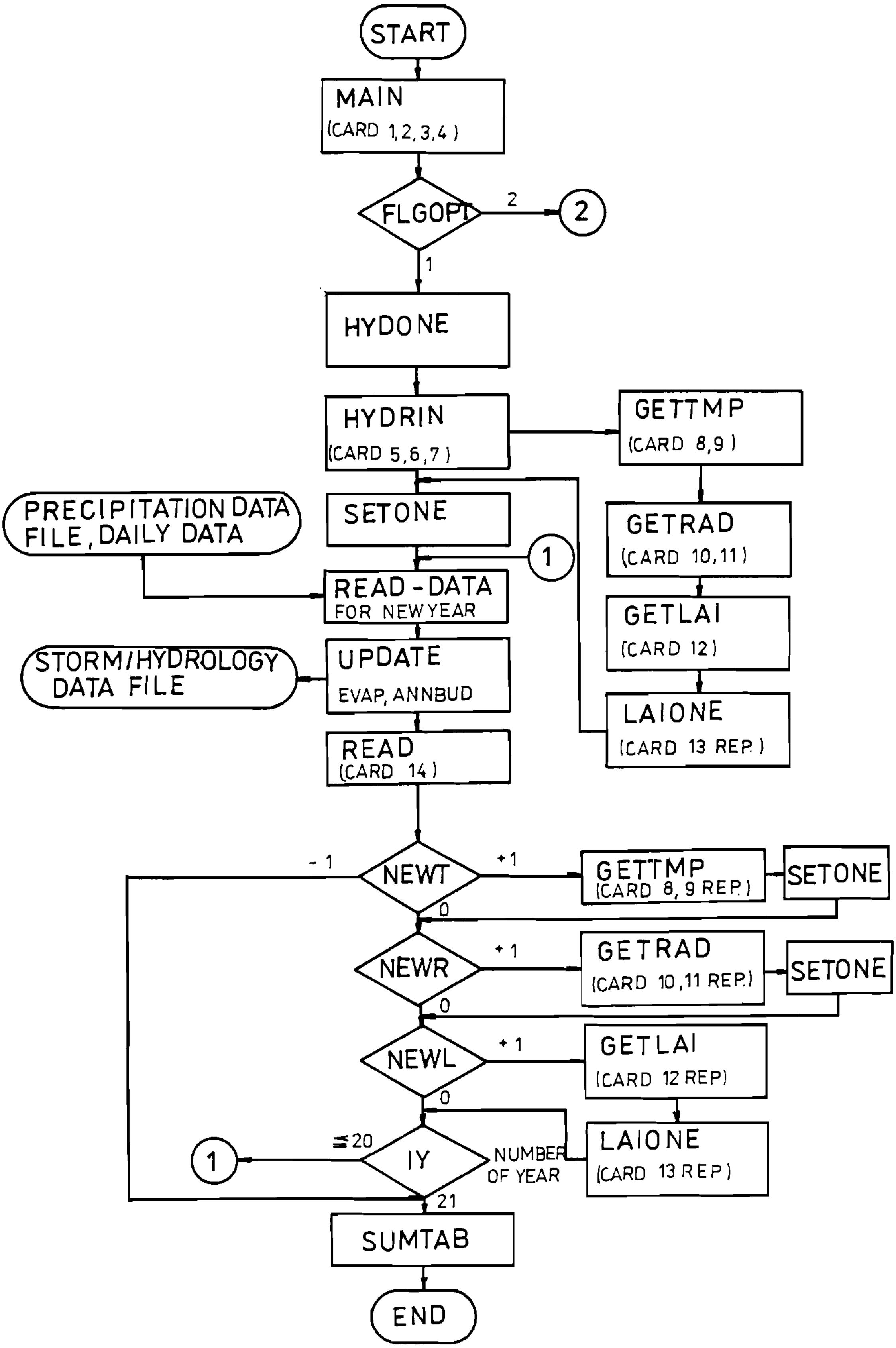

Figure 1. Hydrology submodel--flow chart of main program (structure of computation)

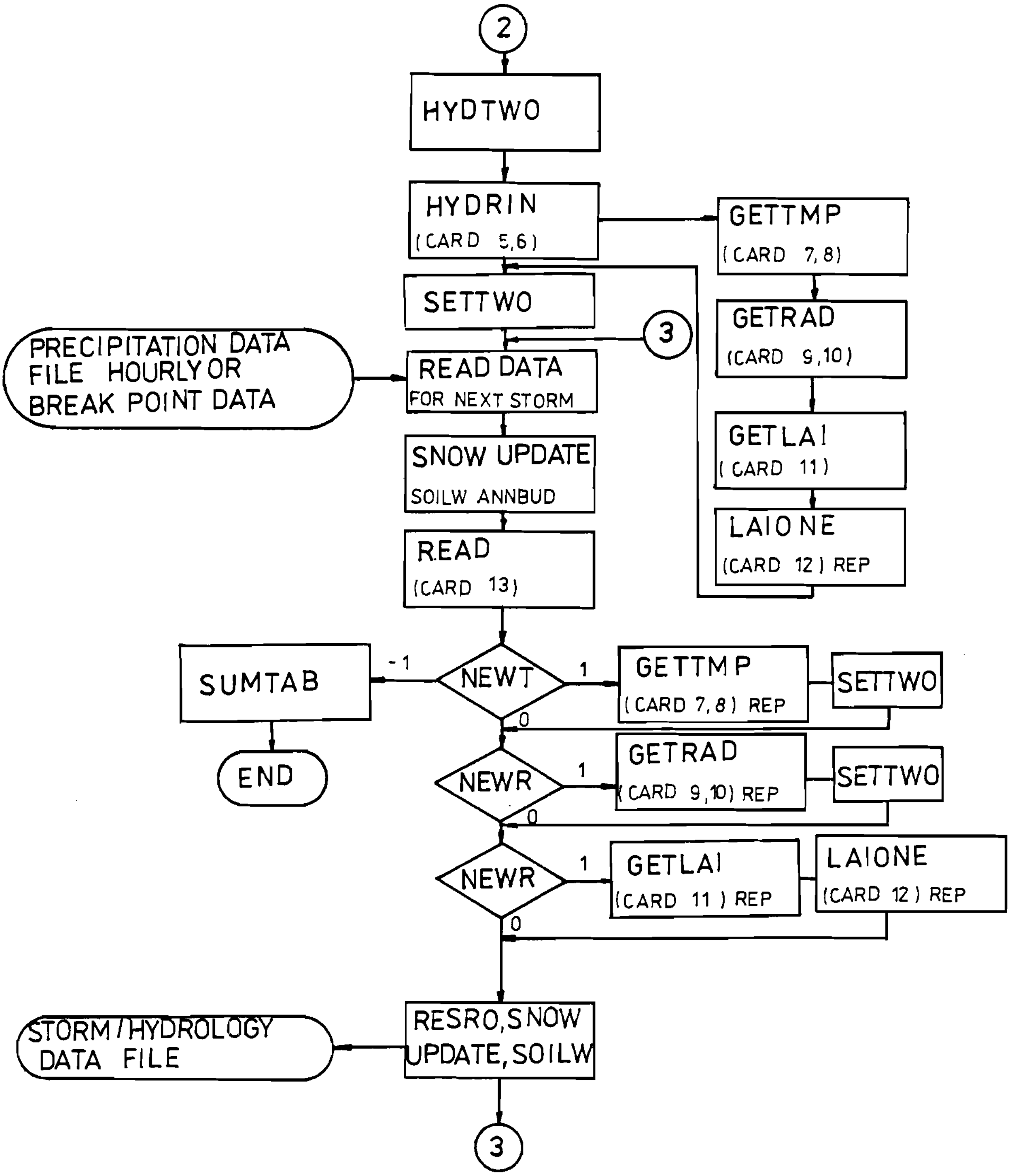

Figure 1. (contd.) Hydrological submodel--flow chart of main program (structure of computation)

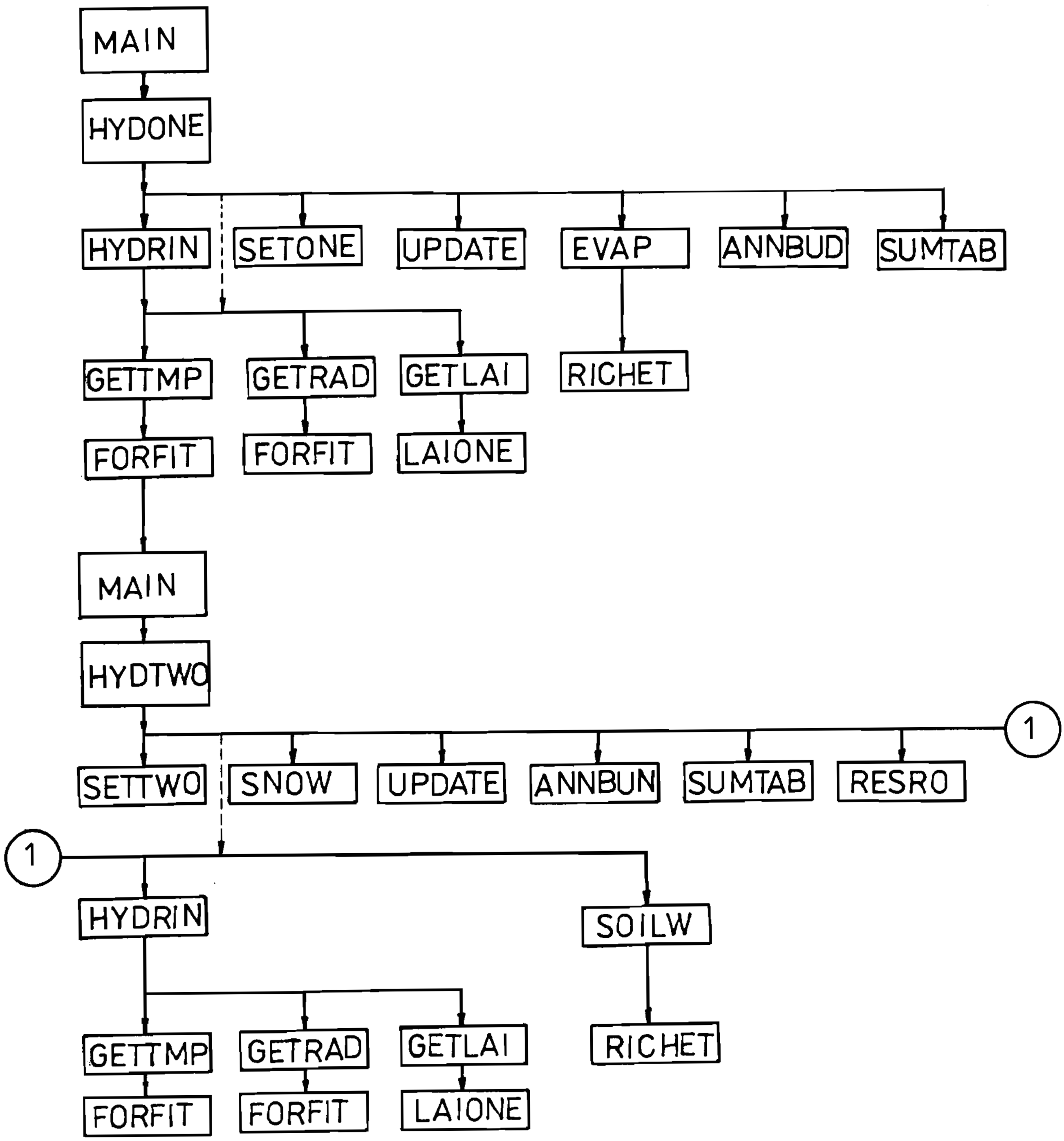

Figure 2. Calling of subroutine--hydrological submodel

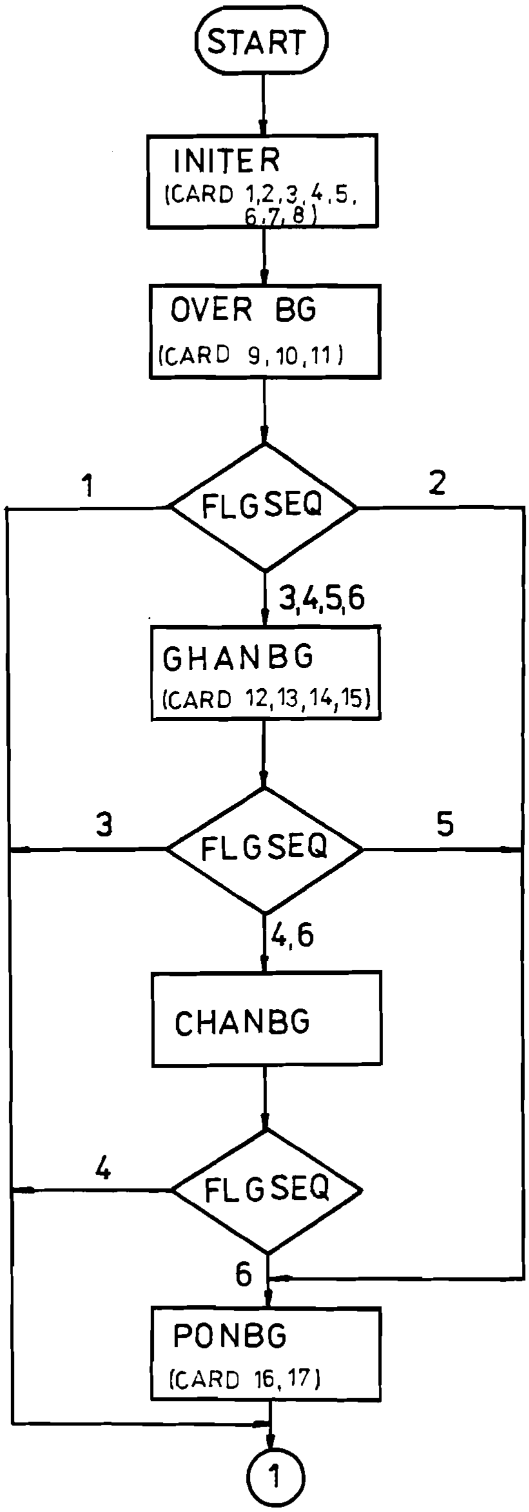

Figure 3. Erosion/sediment submodel--flow chart of main program (structure of computation)

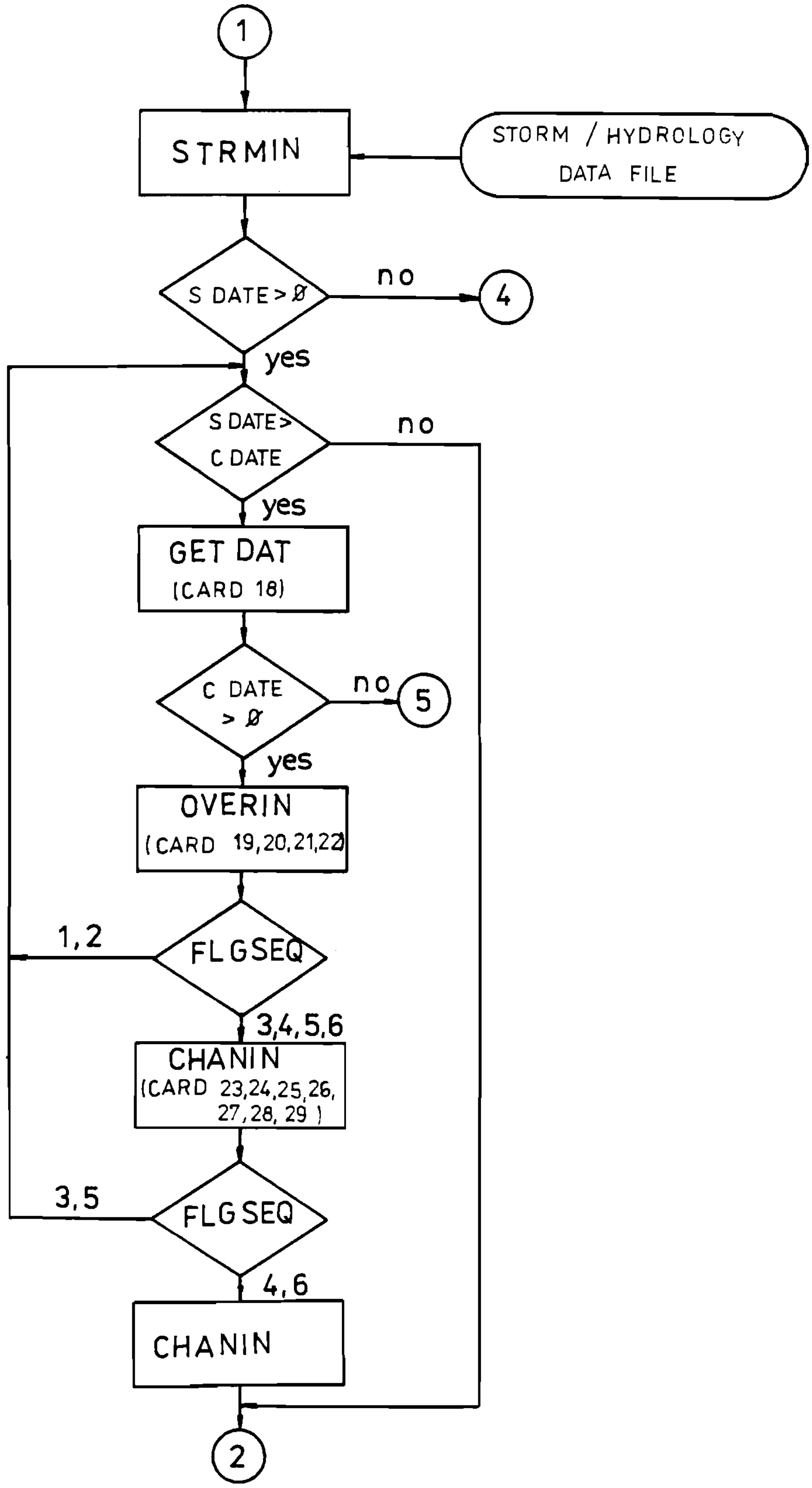

Figure 3 (contd.) Erosion/sediment submodel--flow chart of main program (structure of computation)

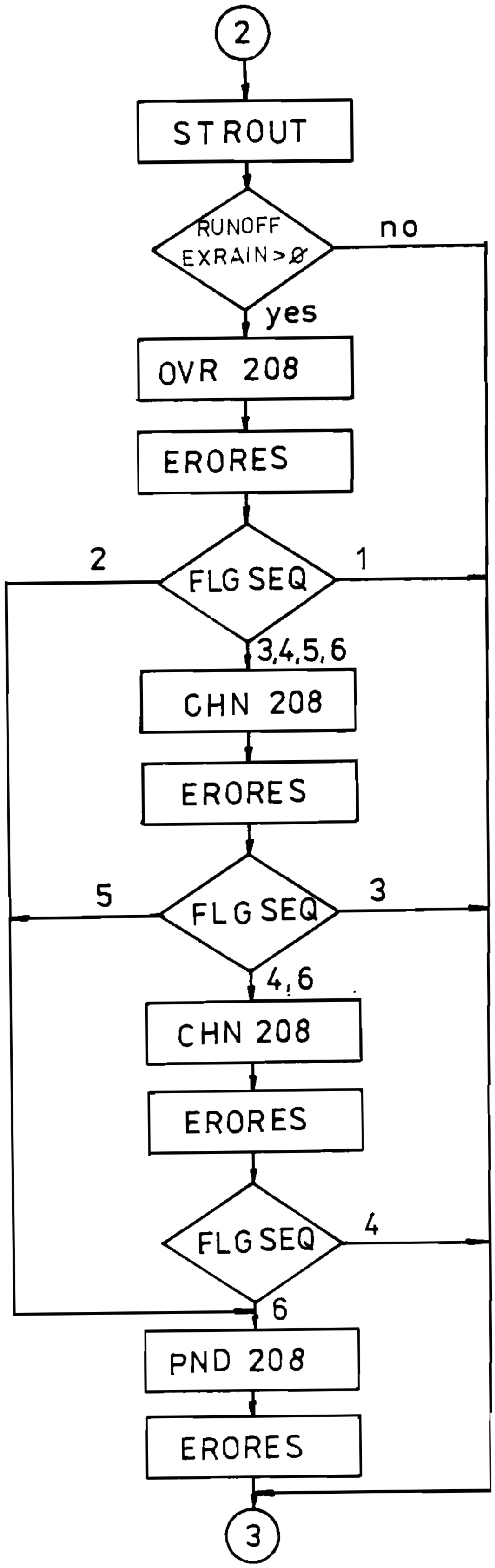

Figure 3 (contd.) Erosion/sediment submodel--flow chart of main program (structure of computation)

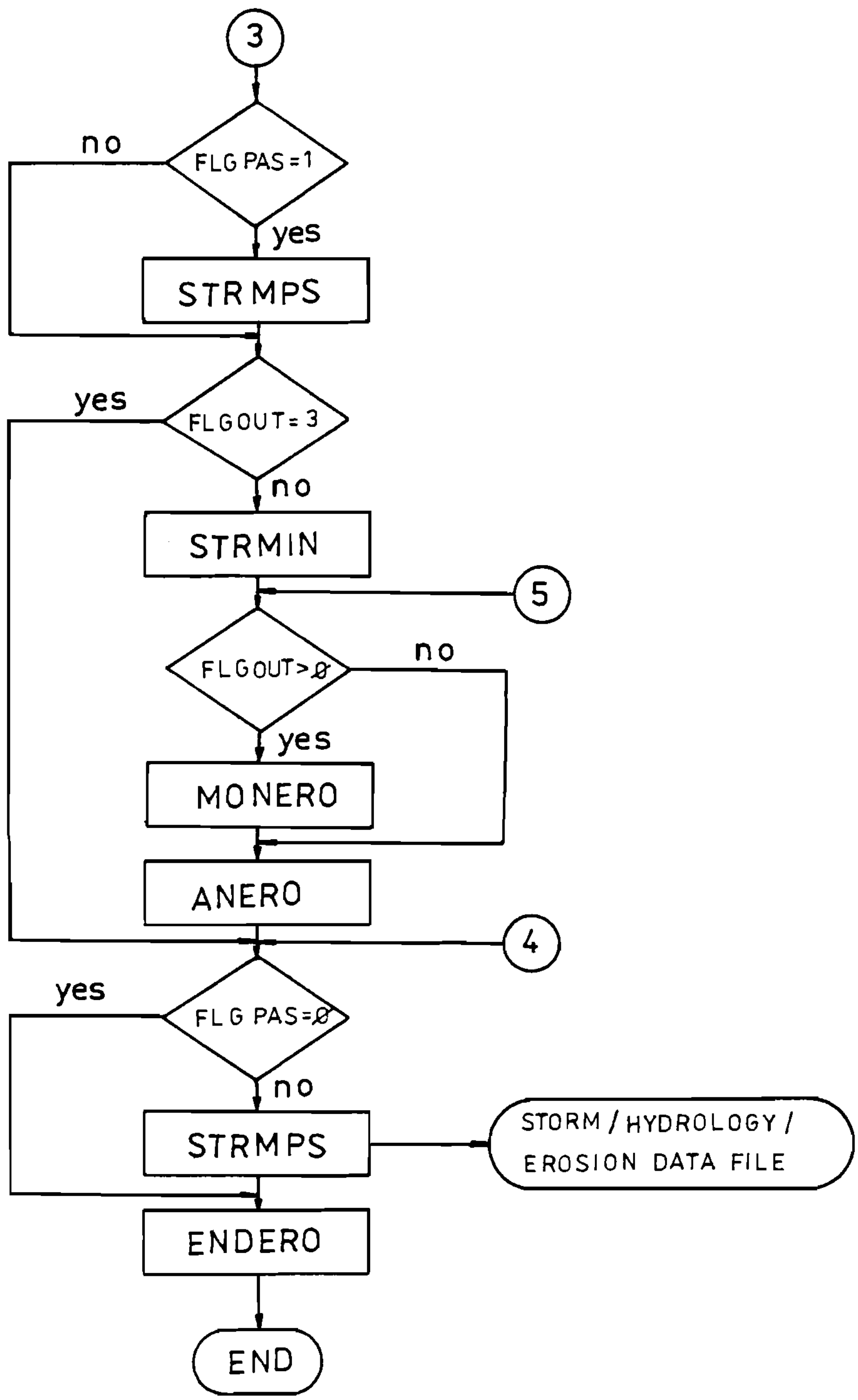

Figure 3 (contd.) Erosion/sediment submodel--flow chart of main program (structure of computation)

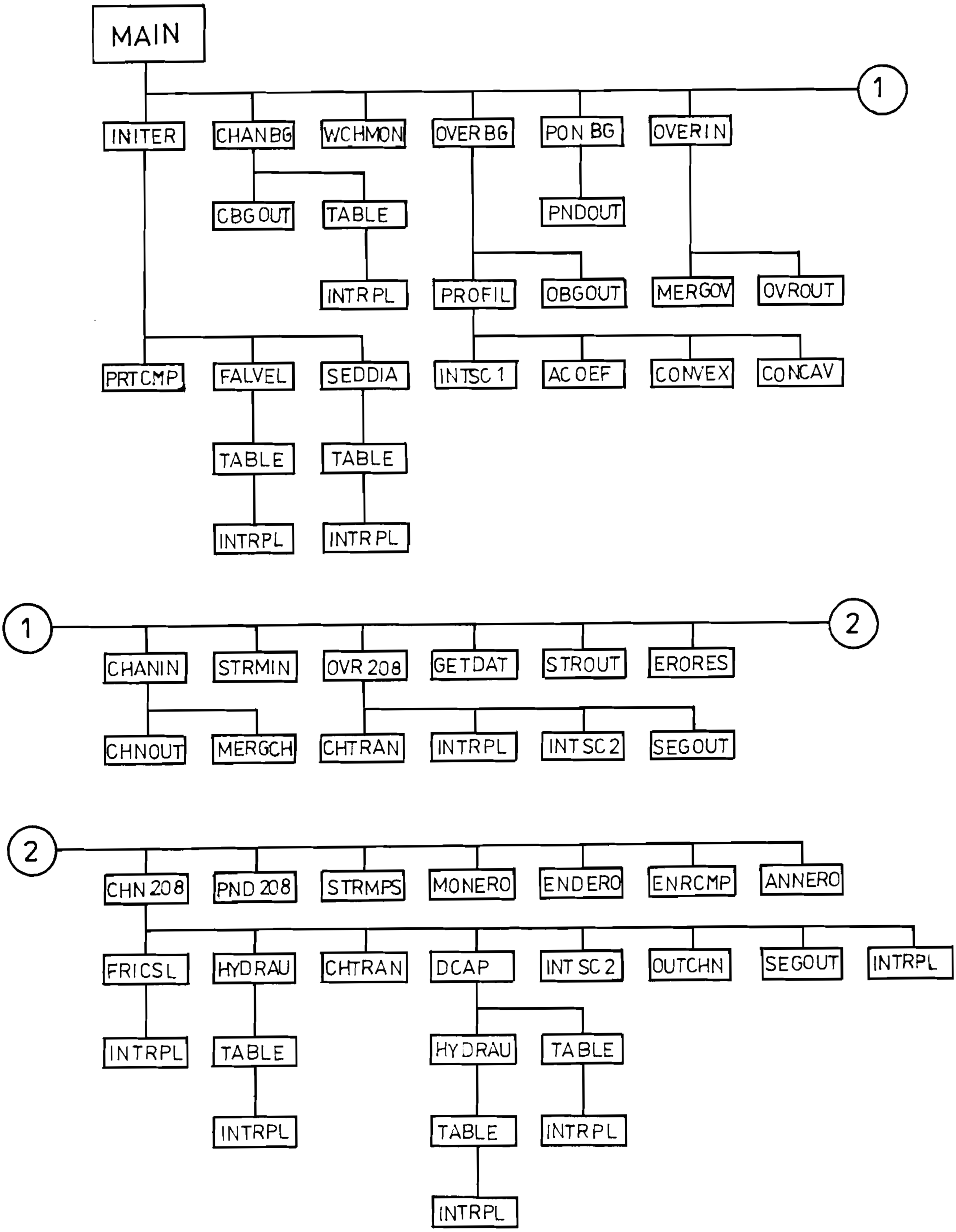

Figure 4. Erosion/sediment submodel--calling of subroutines

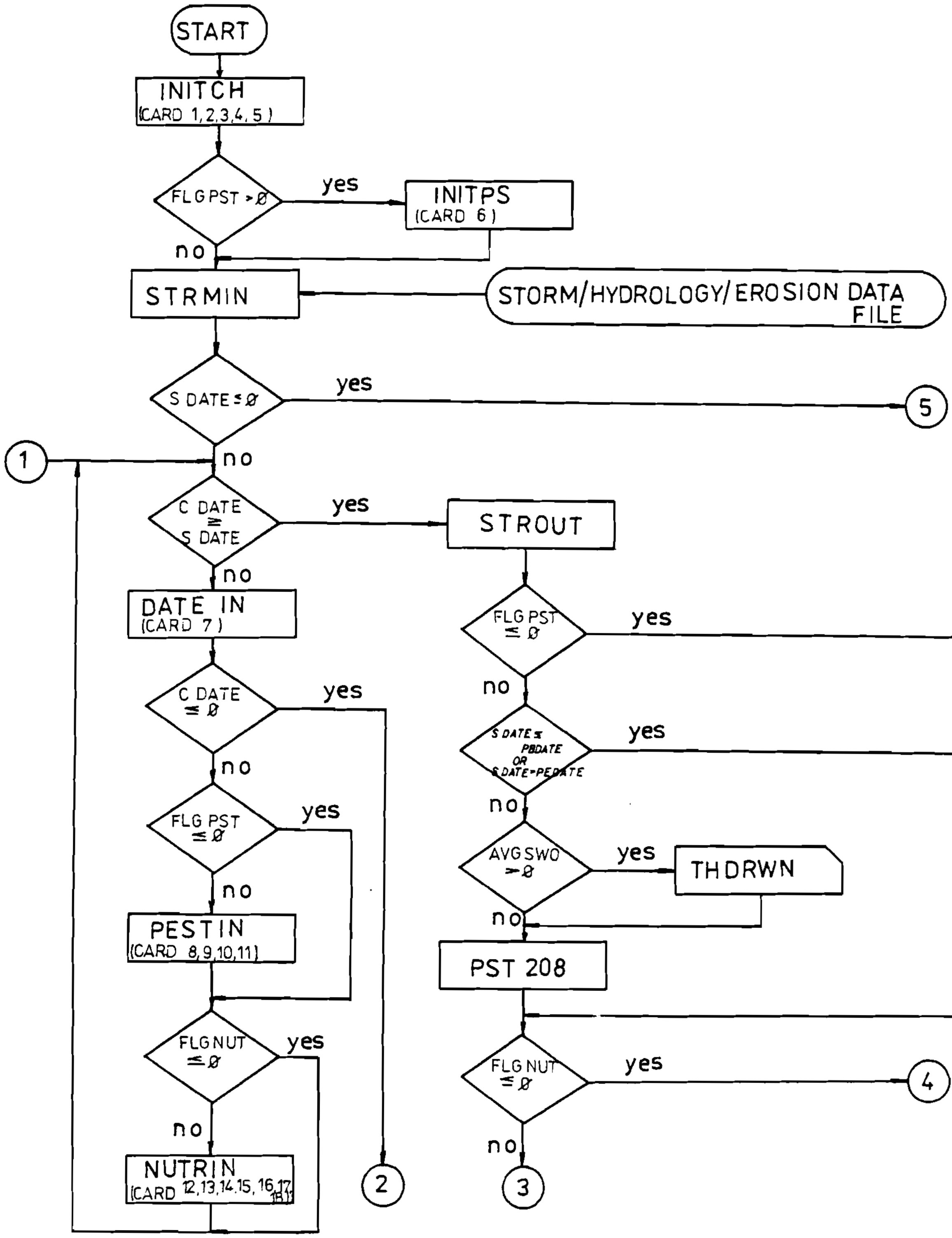

Figure 5. Chemical submodel--flow chart of main program (structure of computation)

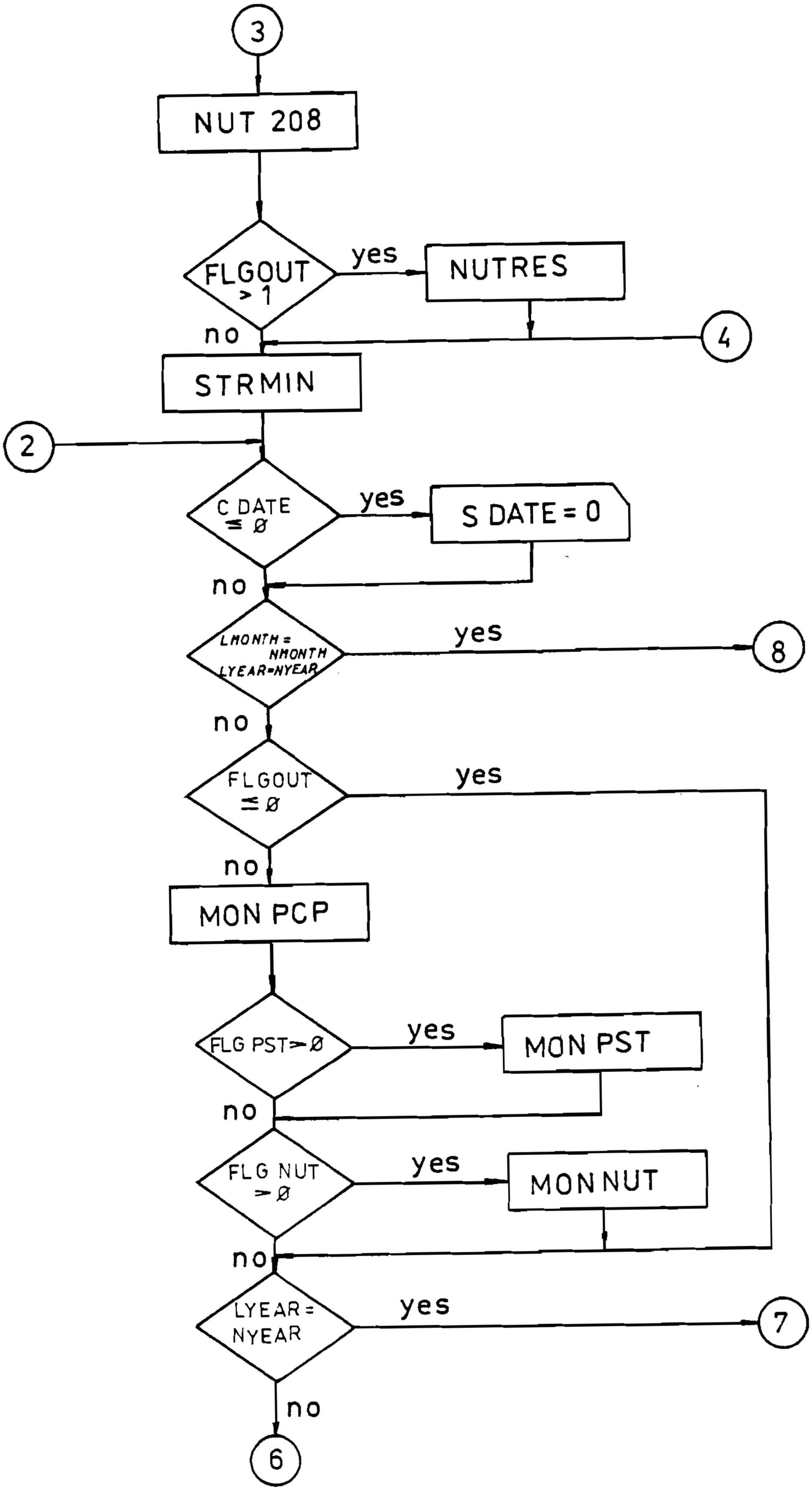

Figure 5. (contd.) Chemical submodel--flow chart of main program (structure of computation)

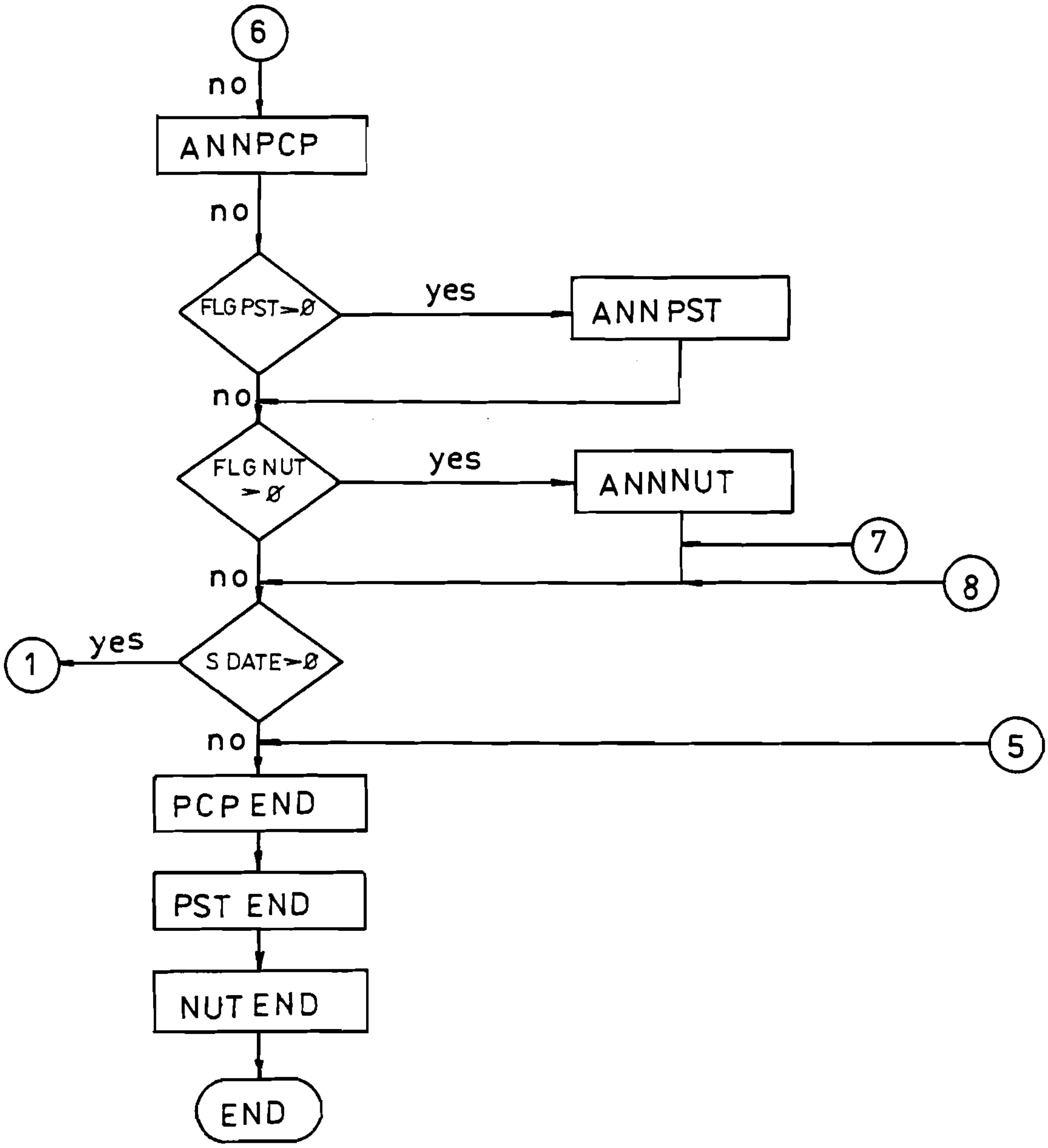

Figure 5 (contd.) Chemical submodel--flow chart of main program (structure of computation)

2. ANALYSIS OF INPUT DATA FOR THE HYDROLOGY SUBMODEL

The hydrology submodel simulates the rainfall/runoff processes, rainfall infiltration, soil water movement and deep percolation. The method differs according to available rainfall data. When only daily rainfall values are available, the Option 1 procedure is used and runoff is estimated by the SCS (Soil Conservation Service) curve number procedure. The SCS equation

$$Q = \frac{(P-0.2\ s)^2}{P+0.8\ s} \quad ,$$

where Q is the daily runoff,

P is the daily rainfall,

S is the retention parameter related to soil water content (but it is rather an oversimplification and correction of this procedure would be useful).

If the actual time pattern of rainfall intensity or rate is available, Option 2 can be used with a much better simulation of soil/water dynamics. In this option, the model is based on the Green and Ampt (1911) infiltration relation. The relation between infiltration time, rate and depth gives the ponding time and infiltration curve. Adjustments are possible for hourly data and multiple storms. For small areas, a relatively simple estimation of runoff peak rates by exponential equation is possible. For greater areas, this procedure needs revision. The water balance is computed by calculation of evapotranspiration, soil water routing and percolation. The input data are arranged into two files--parameter and precipitation files.

In Appendix 1, some of the input data is explained, discussed and complemented (CREAMS Manual, pp. 174-176).

2.1 Precipitation Data for the Hydrology Submodel

The data file can be used for both options. A description of these files is to be found in the manual. No formal problems occurred during application. For special changes in precipitation, especially during storms (Option 2), a precipitation recording station in the vicinity of the research area is preferable.

The output data are arranged into two data files. The first one is printed on the line printer. The second (storm/hydrology data file) is prepared (e.g., on disc) as an input of the erosion/sediment submodel.

2.2 Storm/Hydrology Data File

This file, as created by the computer, differs from the description of the Manual. Each row of the file consists of 11 variables (and not of 13 variables as described in the Manual).

The file is accepted in this form by the erosion/sediemnt submodel (see Manual, p. 200). The input data for initialization and hydrology parameters for the hydrological submodel is given in Table 1.

2.3 Sensitivity of the Hydrology Submodel to Important Input Parameters

As initial information on the sensitivity analysis, the results of Lane and Ferreira (1980) were used. The parameters that are well defined, i.e., with a relatively good possibility of determination, were not discussed in this study. Attention concentrated on parameters where values were very difficult to estimate for various reasons, and they are mentioned in the following discussion. In this discussion, the choice of the research area is also included as it creates the conditions for further investigation.

The area chosen should be a closed catchment. This enables a direct measurement of the surface runoff and the quality of water and thus creates an input data for calibration of the model. It seems quite obvious that the area has to have a significant slope, otherwise no measurable erosion occurs and the erosion/ sediment submodel cannot be calibrated. The area has to be under active cultivation (e.g., permanent meadows are less suitable than row crops).

In the hydrology submodel (Option 1, daily rainfall data), hydraulic conductivity (parameter RC) was the most sensitive. This parameter value is used in computation of percolation and runoff. The RC value serves further for the calculation of the T_i value, as in the following:

$$T_i = \frac{48}{\frac{2 \cdot UL_i}{RC} + 24} \qquad \text{for each soil layer } i=1,2,\dots,7$$

when $T_i > 1$, then $T_i = 1$ is used. Therefore, changing RC is effective when $T_i < 1$, i.e., $RC < UL_i/12$ (for an explanation of UL_i, see Card 7). T_i is used in calcualtion of seepage SEP and content of water ST in each layer of the soil in profile

$$SEP = (ST_i - UF_i) \cdot T_i \quad ,$$

where UF_i is the field capacity of the layer i.

As an example, the relation between T_i and RC for $UL_i = 1.0$ is given below:

RC	0.2	0.15	0.1	0.053	0.05	0.04	0.03	0.02	0.01
T_i	1	1	1	1	0.75	0.65	0.53	0.39	0.21

Table 1. Input data (initialization and hydrology parameters file) for the hydrological submodel

Card Option 1	Card Option 2	Symbol */ MAN / PGM	DEFINITION	SOURCE	DIMEN-SION	DEFAULT VALUES	LIMITS	COMMENTS
1a	1b	2	3	4	5	6	7	8
1-3	1-3	TITLE	Description of the area	RR				Manual p. 174
4	4	BDATE	Beginning date for simulation	RR			less than the date of first storm.	Recommended day 091 (e.g. 78091)= 1.4.1978
		FLGOUT	Type of output	RR			0.1	Manual p. 174
		FLGPAS	Type of output	RR			0.1	Manual p. 174
		FLGOPT	Option of rain-fall input	RR			1.2	Manual p. 174
		FLGPRE	Option of rain-fall input	RR			0.1	Manual 0. 174
5	5	DACRE	Field area	G	acres		1-640	Manual pp. 15, 174
		RC	Saturated hydraulic conductivity	R	in/hr		0.01-10.0	Manual pp. 173, 174, 184, see text of this report.
		FUL	Field capacity/ upper limit of storage	R			0.1-1.0	As a fraction(not in percent)
		BST	Initial fraction of soil water storage	R			0.1-1.0	As a fraction (not in percent)
		CONA	Soil evaporation parameter	M,R			3.3, 3.5, 4.5	Manual p. 32

Table 1. (contd.) Input data (initialization and hydrology parameters file) for the hydrological submodel

1a	1b	2	3	4	5	6	7	8
		POROS	Soil porosity	R			0.3-0.6	Defined by volume.
		BR15 / B15	Immobile water content				0.0-0.25	This value is not read in the program, it is signed as B15.
6	-	SIA	Coefficient c in equation $Q = \frac{(P-c.s)^2}{P+(1-c).s}$	M			c = 0.2, if not calibrated.	P = daily rainfall, Q = daily runoff, S = retention parameter.
		CN2	SCS curve no. for average moisture content	M,H			30-90	Manual Volume III, chapters 2, 3, 4.
		CHS	Main channel slope	G			0.0-0.1	
		WLW	Watershed length, width ratio	G			usually 0.8-5.0	
		RD / 36	Maximum rooting depth		in		15-50	This value is not read in program, the constant 36 in is used.
	6	DS	Depth of surface soil layer.	R	in		2.0-4.0	Subjective
		DP	Maximum rooting depth.	R,H,A	in		15-50	It shall correspond to chemical file
		GA	Effective capillary tension in Green-Ampt Model	M,SS,R				

Table 1. (contd.) Input data (initialization and hydrology parameters file) for the hydrological submodel

1a	1b	2	3	4	5	6	7	8
		RMN	Mannings roughness coefficient for field surface	H,M				Manual p. 241 It shall correspond to erosion file
		SLOPE	Average field slope	G				It shall correspond to erosion file
		XLP	Slope length	G	ft		20-3000	It shall correspond to erosion file
7	-	UL/I/	Plant available water storage	R	in		0.1-2.4	I=1 to 7 Differences between Manual and program due to RD, calculation from POROS and B15
8,9	7,8	TEMP/I/	Average monthly temperature	C	^{o}F		0-80	
10,11	9,10	RADI/I/	Average monthly net radiation	C	langley/day		50-990	Measured or calculated from sunshine by Penman´s formula
12	11	GR	Winter cover factor	M			0.5,1.0	Manual pp.173,176
13	12	LDATE	Date	M,A	day		1-366	Manual p.208 Julian date
		AREA	Leaf area index	M,A			0.0-3.0	Man.p.183,Table II-8

Table 1. (contd.) Input data (initialization and hydrology parameters file) for the hydrological submodel

1a	1b	2	3	4	5	6	7	8
14	13	NEWT	Flag for reading of temperature	M			0,1,-1	Manual p.176 -1 = stop of the program
		NEWR	Flag for reading of radiation	M			0,1	Manual p.176
		NEWL	Flag for reading of leaf area index	M			0,1	Manual p. 176

*/ When the symbol used in the manual differs from that used in the computer program, the manul's symbol is given preference.

Abbreviations used under Source (Column 4):

M - CREAMS Manual
R - Laboratory analysis and references
G - Geographic map
GS - Soil map
H - Hydraulics handbooks
RR - Research reports or studies in the respective area
SS - Soil science handbooks
C - Climatic and meteorological data (measured)
A - Agricultural handbooks

The above shows that the hydrology submodel is in some ranges very sensitive to this value and in some ranges it is not sensitive at all. Therefore, it is recommended that calculations started with the values of RC used in the manual on page 184, Table II-9, and the model is calibrated by changing these values.

In Option 2, the value of RC (designed as FKA and later as KS) is used for calculation of the ponding depth FP and ponding time T_i. As an example of the sequence of daily rainfall 2.26, 0.84 and 0.46 inches (days 212, 213 and 214 Julian date), the following runoff was produced:

	RC					
Rainfall	0.030	0.028	0.027	0.025	0.020	0.010
2.26	0.059	0.059	0.059	0.059	0.059	0.059
0.84	0.583	0.805	0.964	1.459	9.146	negative value
0.46	0.024	0.001	0.0	0.0	0.0	negative value

A comparison with the measured runoff showed that RC = 0.028 was adequate. However, the values for RC = 0.025, 0.020, and 0.01 were not acceptable.

The outputs of the hydrology submodel are sensitive to the values FUL, CN2, and CONA, and are in accordance keeping with the results of Lane and Ferreira (1980). Higher sensitivity was observed as a result of the variation of the values UL_i. It is necessary to take into consideration the problem of proper definition of these values and the FUL values.

The hydrology submodel is the first in a sequence of three submodels. If the results of this submodel are not calibrated, underestimation or overestimation of runoff can disturb the results of both the following submodels. It is not necessary to calibrate the model for each research area; however, it is useful to prepare calibration for a representative area which can be used for similar conditions.

3. EROSION/SEDIMENT YIELD SUBMODEL: ANALYSIS OF INPUT DATA

The erosion/sediment yield submodel simulates the processes of detachment, transport and deposition of soil particles due to the effects of rainfall and runoff. Overland flow, channel flow and impoundment elements are used to represent the major features of the area. The best combination of these elements characterizes the erosion and transport processes within the area. The output from each element is sediment concentration, which becomes the input to the next element. The output from the submodel is sediment yield for all types of particles and for each type individually. The submodel provides information on sediment yield for each storm, monthly and annual summaries.

The inputs of the submodel are formed by two files. The first one is the "Storm/Hydrology Data File". This file contains hydrology variables--rainfall, storm erosivity (EI), volume of runoff and characteristic peak excess rainfall rate. These are generally obtained from the hydrology submodel of CREAMS or the input can be directly observed values. The second file is the parameter file for the erosion/sediment yield submodel which contains values of parameters that characterize the erosion/sediment transport/deposition features of the area as in Appendix 2 (see Manual, pp. 210-218). The erosion/sediment submodel creates the storm/hydrology/erosion data file to be used in the chemical submodel (see Table 2).

3.1 Sensitivity Analysis

A sensitivity analysis was carried out during verification of the CREAMS model in Czechoslovakia to evaluate the sensitivity of the model outputs to changes in basic input data. In general, it can be said that the results of the sensitivity analysis for the Samsin area in Czechoslovakia were similar to the results of the sensitivity analysis given in the CREAMS manual for the overland flow element. The soil loss basic output of the erosion/sediment submodel was only moderately sensitive to changes in most of the basic input para meters (kinematic, viscosity, soil erodibility factor, cropping management factor, and contouring factor). The outputs were significantly influenced by the choice of Manning's roughness coefficient for overland flow (MIN N); the results can be within the limits ± 100%, according to Manning's n. For example, during sensitivity analysis for individual storms, i.e., for storm 78212*, the soil loss was 0.44 tons/acre for n = 0.020 and 0.16 tons/acre for n = 0.030, respectively.

Great attention should also be paid to determination of input data for the characteristic of parameters of overland flow profile. The input parameters overestimate the profile and its shape because in each segment of the slope, the length, elevation, and gradient form a set of input data. If the input data for parameters are not in proper relation, the computer program can construct an unreal profile and therefore the following computation of soil loss does not correspond with reality.

4. CHEMICAL SUBMODEL ANALYSIS OF INPUT DATA

The chemical submodel of CREAMS contains the plant nutrient submodel and pesticide submodel. From 16 known nutrients, only nitrogen and phosphorus are considered in the plant nutrient submodel, because the present evidence indicates that these two elements are the principal nutrient pollutants.

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*All the input and output data of the CREAMS model for the experimental area (Šamšín) in Czechoslovakia is available with Prof. M. Holy of the Technical University of Prague, Civil Engg. Division, 16629 Praha 6, Thakurova 7, Czechoslovakia.

Table 2. The input data/parameter file for the erosion/sediment yield submodel

CARD	SYMBOL */ MAN / PGM	DEFINITION	SOURCE	DIMENSION	DEFAULT VALUES	LIMITS	COMMENTS
1	2	3	4	5	6	7	8
1-3	TITLE	Alphanumeric information					
4	BDATE / DATE	Beginning date for simulation	M				Julian date, Manual p.208
	FLGOUT	Flag for type of output printing	M			0,1,2,3	Manual p.210
	FLGPAS	Flag for type of output file	M			0,1	Manual p.210
	FLGPRT	Flag for sediment particles specification	M			0,1	Manual p.210
	FLGSEQ	Flag for sequence of erosion process elements	M			1,2,3,4, 5,6	Manual pp.210,222
5	KINVIS / KV	Kinematic viscosity	M	ft^2/s	$1.21x10^{-5}$	$1.67x10^{-5}$-$0.74x10^{-5}$	Manual p.223
	NBAROV / NBOV	Coeficient of roughness for overland flow	M		0.010		Value for smooth bare surface
	WTDSOI / WS	Weight density of soil	M,R	lbs/ft^3	96.0	75-103	Values for B-horizon Manual p.224
	KR	Soil erodibility for erosion by concentrated flow	M	$//lbs/ft^2s/ft2/lb/^{1.05}$	0.135	0.04-0.70	Manual p.232
	NBARCH / NBCH	Coefficient of roughness for concentrated flow	M		0.030		Manual p.224
	YALCON / Y	Yalin constant for sediment transport	M		0.635		Manual p. 224

Table 2. (contd.) The input data/paramater file for the erosion/sediment yield submodel

1	2	3	4	5	6	7	8
6	SOLCLY	Fraction of clay in original surface soil layer	R	%		0.0-1.0	0.002 mm
	SOLSLT	Fraction of silt in original surface soil layer	R	%		0.0-1.0	0.002-0.1 mm
	SOLSND	Fraction of sand in original surface soil layer	R	%		0.0-1.0	0.1-2.0 mm
	SOLORG	Fraction of organic matter in original surface soil layer	R	%		0.0-0.05	
	SSCLY	Specific surface area of clay particles	R	m^2/g of soil	20.0	5.0-290.0	
	SSSLT	Specific surface area of silt particles	R	m^2/g of soil	4.0	1.0-10.0	
	SSSND	Specific surface area of sand particles	R	m^2/g of soil	0.05	0.1	
	SSCRG	Specific surface area of organic matter particles	R	m^2/g of organic carbon	1000.0	300.0-1300.0	Organic carbon= org.matter/1.73
7	NPART	No. of particle types in sediment	R			1-20	If known texture of soil in sediment

Table 2. (contd.) The input data/parameter file for the erosion/sediment yield submodel

1	2	3	4	5	6	7	8
8	DIAM / DIA/K/	Diameter of particles of type K in sediment	R	mm			
	SPG: / SPG/K/	Specific gravity of particles of type K in sediment	R	g/cm^3			
	FRAC / FRAC/K/	Fraction of particles of type K in sediment	R	%		0.0 - 1.0	
	FRCLY / FRCLY/K/	Fraction of clay particles in type K	R	%		0.0 - 1.0	> 0.002 mm
	FRSLT / FRSLT/K/	Fraction of silt particles in type K	R	%		0.0 - 1.0	0.002-0.1 mm
	FRSND / FRSND/K/	Fraction of sand particles in type K	R	%		0.0 - 1.0	0.1 - 2.0 mm
	FRORG / FRORG/K/	Fraction of organic matter in type K	R	%		0.0 - 0.5	
9	DATOV	Area represented by overland flow profile	G,F	acres			
	SLNGTH	Slope length of representative overland flow profile	G,F	ft			Manual p.229, 230
	AVGSLP	Average slope of representative overland flow profile	G,F	ft/ft			Manual p.229 230

Table 2. (contd.) The input data/parameter file for the erosion/sediment yield submodel

1	2	3	4	5	6	7	8
	SB	Slope at upper end of profile	G,F	ft/ft			Manual p. 230
	SM	Slope of mid-uniform section	G,F	ft/ft			Manual p. 230
	SE	Slope at lower end of profile	G,F	ft/ft			Manual p. 230
	XIN/3/	Distance from top of slope to beginning of mid-uniform section	G,F	ft			
	YIN/3/	Elevation of beginning of mid-uniform section above lowest point	G,F	ft			
	XIN/4/	Distance from top of slope to end of mid-uniform section	G,F	ft			
	YIN/4/	Elevation of end of mid-uniform section above lowest point	G,F	ft			
10	NK	No. of slope segments differentiated by changes in factor K	GS,F			1 - n	

Table 2. (contd.) The input data/parameter file for the erosion/sediment yield submodel

1	2	3	4	5	6	7	8
11	XKIN/I/	Relative horizontal distance from top of slope to bottom of segment I	G,F			to 1.0	
	KIN/I/	Factor K for segment I	F,R	tons/acres/EI		to 0.7	Manual p.232
12	NS	No. of channel segments differentiated by changes in slope	G,F			1 ÷ n	
	FLAGC	Flag for type of cross section of channel	G,F			1,2,3	
	FLAGS	Flag for type of characteristics of type of flow	F			1,2	
	CONTL	Type of flow at the end of channel	F			1,2,3,4	Only when FLAGS =1
	SECTN	Characterizes cross section of channel at its end	F			1,2	
13	SIDSLP	Side slope of channel at its end	F	cotg		to 20.0	
	BOTWID	Bottom width of channel at its end	F	ft			
	OUTMAN	Coefficient of roughness at the end of channel	H,M			0.030-0.300	Manual p.248
	OUTSLP	Slope of bottom of channel at its end	G,F	ft/ft			

Table 2. (contd.) The input data/parameter file for the erosion/sediment yield submodel

1	2	3	4	5	6	7	8
	RA	Coefficient in rating curve equation	F,H				
	RN	Exponent in rating curve equation	F,H				
	YBASE	Minimum depth for flow to begin	F	ft			
14	LNGTH	Channel length	G,F	ft			
	DATCH	Drainage area of channel at its lower end	G	acres			
	DAUCH	Drainage area above upper end of channel	G	acres			
	Z	Side slope of channel cross section	F	cotg		to 20.0	Manual p.245
15	TX/I/	Distance from lower end of channel to the end of segment I	G	ft			
	TS/I/	Slope of channel in segment I	G,F	ft/ft			
16	CTL	Characterizes type of outflow from ponding	F			1,2,3,	
	PAC	Characterizes relation of water depth to ponding area	F,G			1,2	
	-						
	CONTL	Type of flow at the end of channel in ponding	F			1,2,3,4	

Table 2. (contd.) The input data/parameter file for the erosion/sediment yield submodel

1	2	3	4	5	6	7	8
	SECTN	Characterizes cross section of channel at its end in ponding	F			1,2	
17	DATPO	Total drainage area above the pond	G	acres			
	INTAKE	Soil water intake rate within the pond	R	in/hr			
	FRONT	Slope of dam embankment of ponding	F	ft/ft			
	DRAW	Slope along channel draining into pond	F,G	ft/ft			
	SIDE	Slope of land at pond toward draw	F,G	ft/ft			
	FS	Coefficient in equation for relation "water depth - area"	M,G,F			4500.0-9500.0	Manual pp.252-253
	B	Exponent in equation for relation "water depth - area"	M,G,F			1.10 - 1.77	Manual pp. 252 253
	DIAO	Diameter of outflow pipe	F	in			
	C	Equivalent coefficient of outflow	M				Manual p. 253

Table 2. (contd.) The input data/parameter file for the erosion/sediment yield submodel

1	2	3	4	5	6	7	8
18	PDATE	First date the following parameters are valid	M				Julian date Manual p.208
	CDATE	Last date the following parameters are valid	M				Julian date Manual p. 208
19	NC / NCNEW	No. of slope segments differentiated by changes in factor C	F			1 - n	Min.value= 1
	NP / NPNEW	No. of slope segments differentiated by changes in factor P	F			1 - n	Min.value= 1
	NM / NMNEW	No. of slope segments differentiated by changes in coefficient of roughness	F			1 - n	Min.value= 1
20	XCIN/I/	Relative horizontal distance from top of slope to the bottom of segment I	F,G			to 1.0	I =1 to NC
	CIN/I/	Factor C for segment I	M,F				Manual pp.233 - 237

Table 2. (contd.) The input data/parameter file for the erosion/sediment yield submodel

1	2	3	4	5	6	7	8
21	XPIN/I/	Relative horizontal distance from top of slope to the bottom of segment I	F,G			to 1.0	I = 1 to NP
	PIN/I/	Factor P for segment I	M,F				Manual p.239
22	XMIN/I/	Relative horizontal distance from top of slope to the bottom of segment I	F,G			to 1.0	I = 1 to NN
	MIN/I/	Roughness coefficient for overland flow in segment I	F,M				Manual p.241
23	NN / NNNEW	No. of channel segments differentiated by changes in roughness coefficient	F			1 - n	
	NCR / NCRNEW	No. of channel segments differentiated by changes in critical shear stress	F			1 - n	
	NCV / NCVNEW	No. of channel segments differentiated by changes in shear stress for cover	F			1 - n	

Table 2. (contd.) The input data/parameter file for the erosion/sediment yield submodel

1	2	3	4	5	6	7	8
	NDN / NDNNEW	No. of channel segments differentiated by changes in depth from channel middle to the non-erodible layer	F			1 - n	
	NDS / NDSNEW	No.of channel segments differentiated by changes in depth from the channel side to the non-erodible layer	F			1 - n	
	NW / NWNEW	No. of channel segments differentiated by changes in width	F			1 - n	
24	XN/I/	Distance from lower end of channel to bottom of segment I	G,F	ft			I = 1 to NN
	TN/I/	Roughness coefficient for concentrated flow in segment I	M,H,F				Manual p. 248
25	XCR/I/	Distance from lower end of channel to bottom of segment I	G,F	ft			I = 1 to NCR
	TCR/I/	Critical shear stress of channel in segment I	M,H,F	lbs/ft^2			Manual pp.249, 250

Table 2. (contd.) The input data/parameter file for the erosion/sediment yield submodel

1	2	3	4	5	6	7	8
26	XCV/I/	Distance from lower end of channel to bottom of segment I	G,F	ft			I=1 to NCV
	TCV/I/	Shear stress for cover stability for channel in segment I	M,H,F	lbs/ft^2		to 100.0	Manual p.250
27	XDN/I/	Distance from lower end of channel to bottom of segment I	G,F	ft			I=1 to NDN
	TDN/I/	Depth to non-erodible layer in middle of channel in segment I	F	ft		to 1000.0	
28	XDS/I/	Distance from lower end of channel to bottom of segment I	G,F	ft			I=1 to NDS
	TDS/I/	Depth to non-erodible layer along side of channel in segment I	F	ft		to 1000.0	

Table 2. (contd.) The input data/parameter file for the erosion/sediment yield submodel

1	2	3	4	5	7	8
29	XW/I/	Distance from lower end of channel to bottom of segment I	G,F	ft		I = 1 to NW
	TW/I/	Channel bottom width in segment I	F	ft		

*/When the symbol used in the manual differs from that used in the computer program, the manual's symbol is given preference.

Abbreviations used under Source (Column 4):

M - CREAMS Manaual

R - Laboratory analysis and references

F - Site visit and field measurements

G - Geographic map

GS - Soil map

H - Hydraulic handbooks

From hydrologic and erosion data, the model provides estimates for nutrients:

- the average concentration of soluble N and P in the runoff (total amount or load produced by a storm);
- the amount of nitrate leached;
- the amount of N and P associated with sediments.

For changes in the amount of soil nitrate during the period simulated, processes of mineralization, denitrification, plant uptake, leaching and losses in runoff are considered. The model outputs for pesticides are:

- mass or concentration of pesticides in runoff and sediment;
- total mass of pesticide lossses and average concentration of the remaining residues.

The model provides all these outputs for each storm, monthly and annual summaries.

The input parameters for the chemical submodel are to be found in two files. The first one is the storm/hydrology/erosion data file. This file contains hydrology variables, values of soild loss and enrichment ratio as the output from the erosion submodel. The second one is the chemistry model input parameter file. This one is formed by two independent parts--pesticide and nutrient inputs. The chemistry model parameters are described in the CREAMS manual (pp. 288-293 and 313-318, respectively).

The forms of the files are different, however, the contents differ in the parameters DMY and AWU only. These parameters are listed in the manual and are not used in the computer program input. The organization file used in the computer program is more logical, as the parameters form the subfiles according to their contents. This was followed by the change in the order of the input cards and in some cases in their structures as well. The change of order occurred in pairs, as in the following:

Card No. in Program	Card No. in Manual
7 - 11	10 - 14
13	8
16 - 18	17 - 19

The total number of cards in the program is 18 and 19 in the manual. This was because Cards 7 and 15 (in the manual) were combined with Card 12 of the program. Cards 14 and 15 of the program contain the data from Cards 9 and 16 of the manual. Cards 1-6 are identical in both files, i.e., the program and the manual (see Tables 3 and 4).

Table 3. CREAMS chemical submodel--differences between CREAMS manual and computer program on input cards

CARD No.	CREAMS MANUAL	COMPUTER PROGRAM
1-3	TITLE	TITLE
4	BDATE,FLGOUT,FLGIN, FLGPST,FLGNUT	BDATE,FLGOUT,FLGIN, FLGPST,FLGNUT
5	SOLPOR,FC,OM	SOLPOR,FC,OM
6	NPEST,PBDATE,PEDATE	NPEST,PBDATE,PEDATE
7	OPT	PDATE,CDATE
8	SOLN,SOLP,NO3,SOILN, SOILP,EXKN,EXKP,AN, BN,AP	APDATE
9	BP,RCN	PSTNAM
10	PDATE,CDATE	APRATE, DEPINC, EFFINC, FOLFRC, SOLFRC, FOLRES, SOLRES, WSHFRC, WSHTHR
11	APDATE	SOLH2O,HAFLIF,EXTRCT,DECAY, KD
12	PSTNAM	OPT,NF,DEMERG,DHRVST
13	APRATE,DEPINC,EFFINC, FOLFRC,SOLFRC,FOLRES, SOLRES,WSHFRC,WSHTHR	SOLN,SOLP,NO3,SOILN,SOILP, EXKN,EXKP,AN,BN,AP
14	SOLH2O,HAFLIF,EXTRCT, DECAY,KD	BP,POTM,RCN,RZMAX
15	NF,DEMERG,DHRVST	YP,PWU in OPT 1 DOM,SD,PU in OPT 2
16	RZMAX,YP, DMY,POTM, AWU,PWU in OPT 1 RZMAX,YP,DMY,POTM, DOM,SD,PU in OPT 2	C1, C2, C3, C4

Table 3. (contd.) CREAMS chemical submodel--differences between CREAMS manual and computer program on input cards

CARD No.	CREAMS MANUAL	COMPUTER PROGRAM
17	C1, C2, C3, C4	DF
18	DF	FN,FP,FA
19	FN, FP, FA	-

Note: DMY, AWU is missing in the computer program
OM must be lower than in the erosion submodel

Table 4. Input data (parameter file) for chemical nutrient and pesticide submodel

CARD	SYMBOL	DEFINITION	SOURCE	DIMENSION	DEFAULT VALUES	LIMITS	COMMENTS
1	2	3	4	5	6	7	8
1-3	TITLE	Alphanumeric information					
4	BDATE	Beginning date for simulation					Manual p. 208, Julian date
	FLGOUT	Flag for type of printing	M			0,1, 2	Manual pp.288,313
	FLGIN	Flag for units	M			0,1	Manual pp.288,313
	FLGPST	Flag for pesticides	M			0,1	Manual pp. 288,313
	FLGNUT	Flag for nutrients	M			0,1	Manual pp.288,313
5	SOLPOR	Soil porosity	R,GS	cc/cc		0.26-0.80	
	FC	Field capacity	R,GS	cc/cc			
	OM	Organic matter	R,GS	%		0.0-0.8	
6	NPEST	No. of pesticides				1 - 10	
	PBDATE	Date the model begins to consider pesticides					Julian date Manual p.208
	PEDATE	Date the model stops considering pesticides					Julian date Manual p. 208

Table 4. (contd.) Input data (parameter file) for chemical nutrient and pesticide submodel

1	2	3	4	5	6	7	8
7	PDATE	First date that the following chemical parameters are valid					Manual p. 208 Julian date
	CDATE	Last date that the following chemical parameters are valid					Manual p.208 Julian date
8	APDATE	Date the pesticides are applied					Manual p.208 Julian date
9	PSTNAM	The pesticide name				up to 24 characters	
10	UPRATE	Rate of application	M,P	kg/ha		herbicides 1-5,insecticides 10-20	Manual p.311
	DEPINC	Depth of incorporation	M,R	cm		Surface application 1,normally 8-15	Manual p.321
	EFFINC	Efficiency of incorporation	M,R			0.5-1.0	
	FOLFRC	Fraction of pesticides applied to the foliage	M,R			Aerial appl. 0.4-0.6, ground appl. 0.7-0.8	Manual pp.596-598
	SOLFRC	Fraction of pesticides applied to the soil	M,R			Bare soil 1	Manual pp.596-598

Table 4. (contd.) Input data (parameter file) for chemical nutrient and pesticide submodel

1	2	3	4	5	6	7	8
	FOLRES	Amount of pesticides residue on the foliage prior to new application	M,R,P	mg/g			Manual pp.91-92, 560-585,599-601
	SOLRES	Amount of pesticides residue on the soil prior to new application	M,R,P	mg/g			Manual pp.91-92, 560-585
	WSHFRC	Fraction of pesticides on the foliage available for rainfall wash-off	M,R			organochlorides 0.05-0.10,other pesticides 0.6-0.7	Manual p. 602
	WSHTHR	Rainfall threshold for foliage wash-off	M,R	cm		0.10-0.30	Manual p.602, for dense crop canopy
11	SOLH2O	Water solubility of pesticides	P,M	ppm			Manual pp.311-312
	HAFLIF	Foliar residue half-life	P,M,R	days			Manual pp.599-601
	EXTRCT	Extraction ratio of pesticides	R,M			0.05-0.20	
	DECAY	Decay constant k_s of pesticides in soil	P,M,R				Manual pp.563-567
	KD	Distribution coefficient of pesticides between soil and water	M,R				Manual pp.611-618, 607-610
12	OPT	Option for N uptake by plant				1,2	Manual pp.79-80, 498-503
	NF	No. of fertilizer applications					
	DEMERG	Date of plant emergence					Julian date,no year Manual p.208

Table 4. (contd.) Input data (parameter file) for chemical nutrient and pesticide submodel

1	2	3	4	5	6	7	8
	DHRWST	Date of plant harvesting					Julian date, no year Manual p.208
13	SOLN	Soluble nitrogen	R,GS	kg/ha		0.01-0.40	In 1 cm soil surface layer
	SOLP	Soluble phosphorous	R,GS	kg/ha		0.01-0.40	In 1 cm soil surface layer
	NO3	Nitrate in rootzone	R	kg/ha	20		
	SOILN	Soil nitrogen	R,GS	kg/kg		0.0005-0.003	In 1 cm soil surface layer
	SOILP	Soil phosphorous	R,GS	kg/kg		0.0001-0.0013	In 1 cm soil surface layer
	EXKN	Extraction coefficient for nitrogen	R,M			0.01-0.40	Manual pp.269,509-529
	EXKP	Extraction coefficient for phosphorous	R,M			0.01-0.40	Manual pp.269,509-529
	AN	Enrichment coefficient for nitrogen	R,M		7.4		Manual p.69
	AP	Enrichment coefficient for phosphorous	R,M		7.4		Manual pp.69,486-491
	BN	Enrichment exponent for nitrogen	R,M		-0.2		Manual p.69
14	BP	Enrichment exponent for phosphorous	R,M				Manual pp.69,486 - 491
	POTM	Potential mineralizable nitrogen	R,M,GS,	kg/ha			Manual pp.493-494

Table 4. (contd.) Input data (parameter file) for chemical nutrient and pesticide submodel

1	2	3	4	5	6	7	8
	RCN	Concentration of nitrogen in rainfall	R	mg/l			
	RZMAX	Maximum depth of potential root-zone	R,M	mm			Manual p. 78
15 - for OPT 1							
	YP	Potential economic crop yield	R,M	kg/ha			Manual pp.73,498-501
	PWU	Potential water use		mm			Output from hydrological sub-model, Manual pp.498-501
15 - for OPT 2							
	DOM	Date of mid-point in nitrogen uptake cycle	R,M	days			Manual pp. 501-505
	SD	Standard deviation of DOM	R,M	days			Manual pp.501-505
	PU	Potential nitrogen uptake	R,M	kg/ha			Manual pp. 501-505
16	C1	Cubic coefficient	R,M				Manual pp.498-505
	C2	Cubic exponent	R,M				Manual pp.498-505
	C3	Cubic coefficient	R,M				Manual pp.498-505
	C4	Cubic exponent	R,M				Manual pp.498-505
17	DF	Date of fertilizer application					Manual p.208, Julian date

Table 4. (contd.) Input data (parameter file) for chemical nutrient and pesticide submodel

1	2	3	4	5	6	7	8
18	FN	Nitrogen applied	R	kg/ha			
	FP	Phosphorous applied	R	kg/ha			
	FA	Surface fraction of application	R		1.0-0.3		

Abbreviations used under Source (Column 4):

M - CREAMS Manual

R - Laboratory analysis and references

F - Site visit and field measurements

GS - Soil map

P - Pesticide handbooks

The investigations of the chemical and the erosion/sediment submodels are based on the output from the hydrological submodel which significantly influences the nitrogen cycle and the total loss of nutrients and pesticides. While for loss of nutrients, the value of SOILOSS from the erosion output is significant, it is the value of ENRICH RATION which is significant for the adsorption of pesticides in sediment.

For total ratio of nutrient loss between the liquid and solid phase of surface runoff, the extraction coefficient and enrichment coefficient and exponents for nitrogen phosphorus are highly significant. With respect to the significance of the values mentioned above, it is recommended that estimates of these values should be by experiment for the given conditions of the simulated area. It is possible to get the remaining input parameters for the nutrients submodel from agrochemical soil tests.

To determine the total loss of pesticides and its distribution between the liquid and solid phase of surface runoff, EXTRCT and KD are highly significant. The values of EXTRCT and KD are possible from experiments or references. Further, it is necessary to pay attention to the values of SOILFRC and FOLFRC, because the values of constant decay for pesticides applied on foliage and pesticides applied on soil surface are different.

Calibration and verification of the model is not recommended for winter crops because the total cycle of nitrogen is significantly influenced by hydrological conditions during the winter and is not calculated by the CREAMS hydrological submodel.

5. VERIFICATION OF THE CREAMS MODEL IN CZECHOSLOVAKIA

The CREAMS model has been used to simulate hydrology variables and sediment and chemicals transport in the Samsin area, which is a part of the experimental Trnávka catchment. The hydrological conditions and geochemical processes were observed by the Central Geological Institute in Prague. The observations and experiments started in 1975, so that a comprehensive set of data is available.

5.1 Description of the Catchment

The catchment of the Trnávka river has an area of 152.0 km^2 and is situated at the western end of the Czech/Moravian Hills (Figure 6). The Trnávka is a tributary of the Zelivka river which is a source of water for the Svihov reservoir--the source of potable water for the capital of Prague. Eutrophication is a recent phenomenon. The stable agricultural management practices, non-industrial pollution, and relatively uniform geological conditions were reasons for choosing the Trnávka catchment for verification of the CREAMS model. The Trnávka catchment is moderately undulated; the elevation varies from 456.0 to 747.0 m above sea level. The Trnávka catchment is formed by 6 subcatchments (Figure 7). The drainage area and vegetative cover of individual subcatchments is given in Table 5.

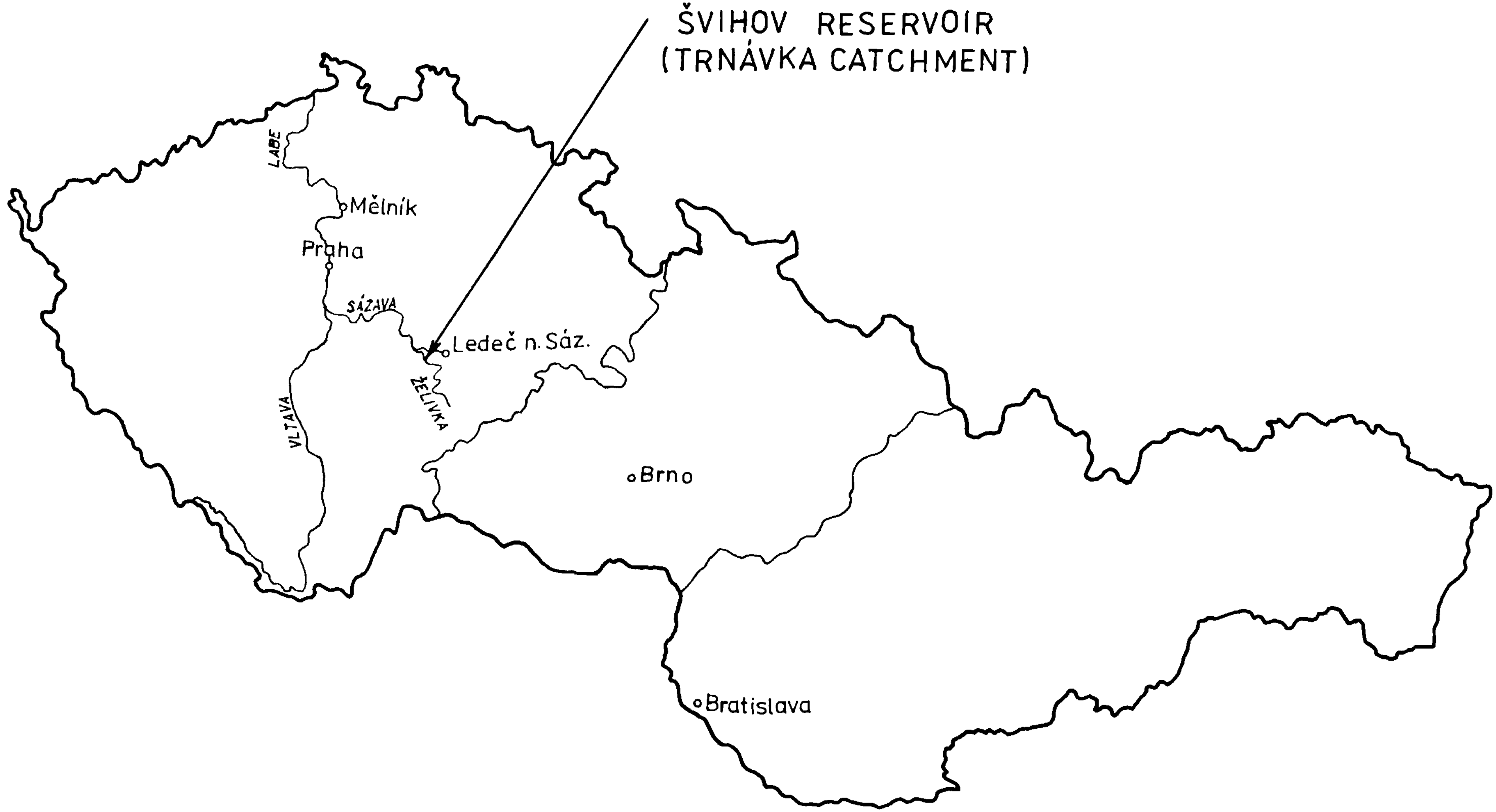

Figure 6. Location of the Svihov reservoir

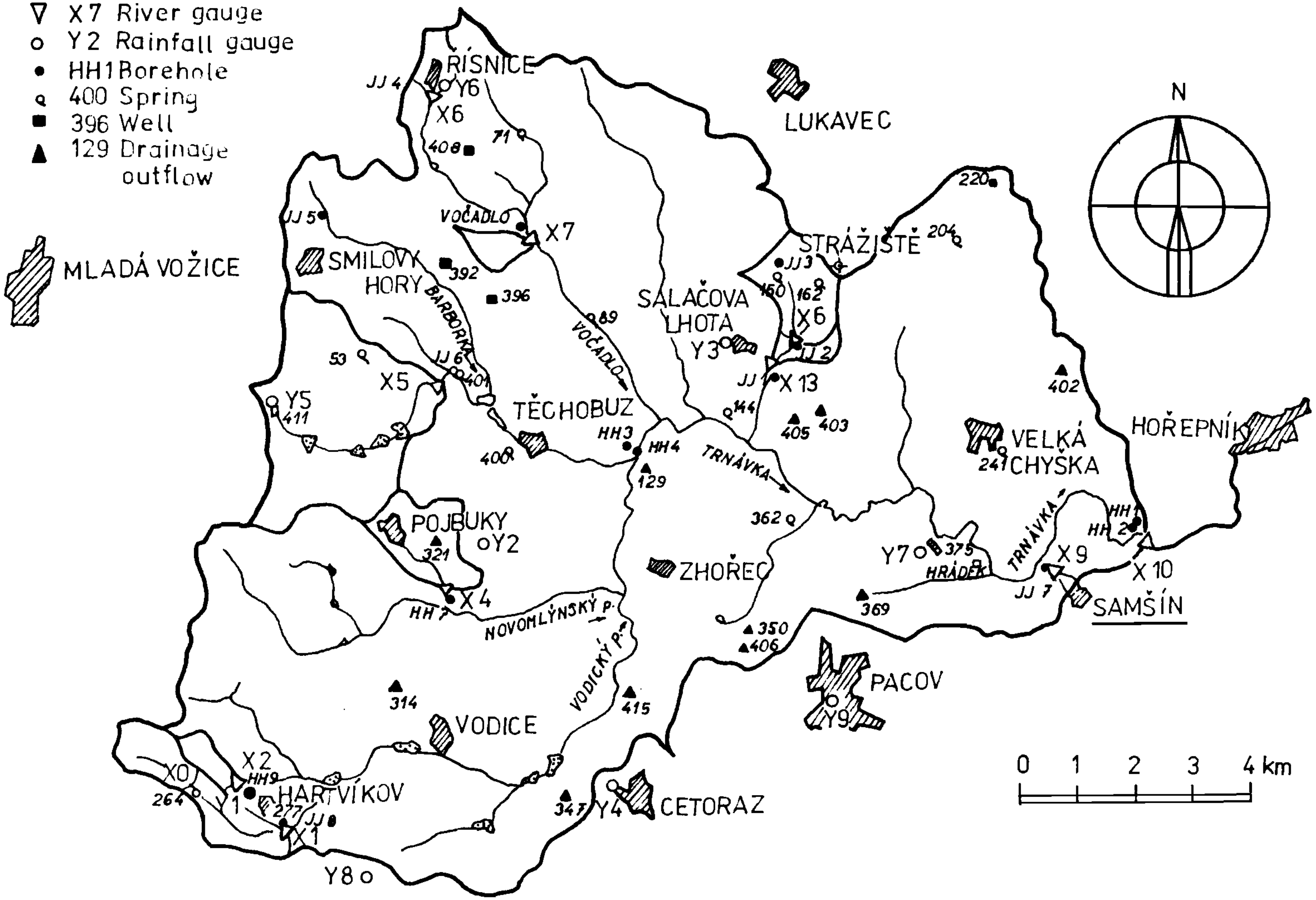

Figure 7. Map of the Trnávka catchment

Table 5. Land use of subcatchment

Catchment	Drainage area (km^2)	Forest (%)	Field (%)	Meadow (%)	Urban (%)
Hartvíkov	0.984	100.0	-	-	-
Pojbuky	2.039	1.5	37.0	40.5	21.0
Vočadlo	0.586	3.0	86.0	11.0	-
Salačova Lhota	1.679	100.0	-	-	-
Samšín	0.060	-	100.0	-	-
Trnávka	152.690	35.0	60.0	-	5.0

The climate in the Trnávka catchment is moderately warm and semi-humid. The annual average temperature is 6°C at the western end, while it is 7°C in the eastern part. Annual average precipitation is 700.0 mm in the west, and 650.0 mm in the east of the Trnávka catchment, respectively. Average annual yield from the catchment is 7.5 $l.s^{-1}.km^{-2}$, and the minimum runoff is 0.44 $l.s^{-1}.km^{-2}$. The catchment is equipped for hydrological and long-term hydrogeological observations. At the outlet point of the catchment there is an analysis unit for automatic observation of changes in the physical and chemical properties of water. The location of observation profiles in the catchment is shown in Figure 7.

The Samsin subcatchment is situated at the eastern end of the Trnavka catchment. The drainage area is 0.06 km^2 and the whole subcatchment is used intensively for agriculture. The annual average precipitation is the lowest from the Trnavka catchment--633.0 mm. The monthly average precipitation varies during the year. The monthly distribution of precipitation for the period 1976-1978 is given for the whole Trnavka catchment in Table 6.

The annual specific yield is 4.5 $l.s.^{-1}.km^{-2}$ in the Samsin subcatchment for the period 1976-1978. The monthly distribution of specific yield is given in Table 7.

5.2 The Results of Verification

The results of verification were divided into six parts--for each submodel, the solution of problems of the application of computer programs and interpretation of the output data were discussed.

Table 6. Monthly precipitation for the period 1976-1978

Month	11	12	1	2	3	4	5	6
Precipitation	65.8	30.1	62.1	33.3	27.5	34.3	64.6	50.1
Month	7	8	9	10				
	91.0	118.1	66.6	48.5				

Table 7. Monthly yield for the period 1976-1978

Month	11	12	1	2	3	4	5	6	7	8
Yield ($l.s^{-1}.km^{-2}$)	0.5	1.5	8.7	10.8	15.8	5.0	2.8	1.8	1.2	3.8
Month	9	10								
	2.0	0.7								

5.2.1. The Hydrology Submodel

This model was applied in Option 1 for daily rainfall data. Some discrepancies between the description in the manual and the computer program were in the form and content of the input data, and the output hydrology file.

The output data was compared with the measured data on the basis of the runoff as the erosion/sediment submodel was very sensitive to these values. At first, the predicted value of the annual total surface runoff was compared with the measured values in the catchment investigated. The difference between the average specific runoff and this value was 15%. The lower value of the runoff given by the model for the research area was due to its relatively small acreage.

For the erosion/sediment submodel, not only the total value of runoff but also the values of runoff of individual storms are important. Therefore, one major sequence of storms was chosen for comparison of the measured and modeled values. The storms on 212, 213, and 214 Julian date (31 July, 1 and 2 August) were used for this purpose. The difference between the modeled and measured sum of runoff from these storms was only 5%. This small deviation was achieved by calibration. This agreement between the modeled and measured data of total runoff is necessary for the smaller deviations of the erosion/sediment submodel and chemical submodel. Therefore, calibration of the hydrology submodel is recommended in all cases when measurements are available or when some information on runoff can be inferred by analogy, from areas with similar conditions.

5.2.2. Erosion/Sediment Submodel

The results of verification of the CREAMS erosion/sediment submodel carried out for the Trnávka catchment has shown the possibility of further prospective uses of CREAMS for sediment transport estimation. At this stage, verification has been carried out for the overland flow element only (FLGSEQ = 1) and the results for a more complicated runoff situation (channel elements, impoundment) is discussed.

On discussion of the computer program, study of the CREAMS manual and entire calculation of sediment transport for the given area, two main problems were identified:

- Necessity for proper characteristics of overland flow profile (for details see Section 3).

- Significant sensitivity of the model to Manning's roughness coefficient for the overland flow element.

There was no observation of soil loss and sediment concentration available in the observed area, therefore, the output of the erosion/sediment submodel was tested analogically. Using this method, it was tested for the:

- value of annual soil loss;

- values of soil loss from individual storms.

The output value of annual soil loss has been compared with the value obtained by other methods. The model output value (3.25 tons/acre) and the calculated value (4.55 tons/acre) are in relatively good agreement.

The results of observation of erosion processes on an experimental field plot in northern Bohemia and results of erosion laboratory tests have been used to verify the output values for individual storms. A comparison of the submodel output and experimentally obtained data shows good agreement between them, especially for storms with high depth, which create high depth of surface runoff.

5.3 The Chemical Submodel

The chemical submodel of CREAMS was calibrated together with the hydrologic and erosion/sediment submodels. The experimental data for the Trnávka catchment (from the period 1976-1980) was used for calibration. This was possible because the vegetative cover, morphology and soil conditions are similar for both the Trnávka and Samsín catchments.

It was necessary to change the chemistry input parameter data file against the file given in the CREAMS manual because of different requirements for the computer program. The changes in the file are given in Section 4.

The results of comparison of the CREAMS chemical submodel output and experimentally observed data from the Trnávka catchment for nutrient loss in runoff and plant nitrogen uptake are given in Table 8.

It may be supposed that these results show a relatively good agreement if we consider the very complicated character of the chemical transport and its modeling. The other input data cannot be analyzed because of lack of experimental data.

However, the value of accumulated denitrification seems to be rather high. It could be explained by the hydrologic and soil conditions of the area. In April, for example, 37% of the total DNI was denitrified, and in August, 41.4%. In August there was a relatively high amount of rainfall with relatively low temperatures so that values rose above average field capacity, creating unusual conditions for denitrification. This of course caused high values in the parameters which characterized field capacity. In conclusion, it is necessary to state that hydrologic data significantly influence the chemical submodel inputs, i.e., the nitrogen cycle.

6. CONCLUSIONS

The CREAMS model can be applied for the description of sediment transport and changes in the nitrogen, phosphorus and pesticides balance in fields, if the experience gained during application of the CREAMS model to the experimental area Samsín is followed. The information obtained can be summarized as follows:

(1) The form of input and output data of the submodel and their interface deviated from that described in the CREAMS manual. When the corrected version described in this paper is used, computation is possible.

(2) For the proper choice of input data, an understanding of its meaning is necessary. When discrepancies between the manual and the computer program were identified (as described earlier), it is possible to determine the input data.

Table 8. Deviation of Experimental Data

Variable	CREAMS model %*	Experimental catchment data %
Nitrogen in runoff + leaching	22.0	15.1
Phosphorus in runoff	8.2	1.3
Plant N-uptake	65.7	55.75

* Values are presented in percentage of applied nutrients.

(3) The relative importance of the choice of input values was determined by sensitivity analysis. The results published in the CREAMS report were examined and some corrections and supplements were suggested.

(4) If the hydrology, erosion and chemistry submodels are used in sequence, then their mutual interrelations are important. This, and the necessary corrections, were investigated and the relative influence of the individual submodels (hydrology and erosion) on the final chemistry submodel was tested.

(5) The possibility and need for calibration of the CREAMS model were investigated. From the verification of the CREAMS model in a research area, it can be concluded that calibration is necessary and the main calibration parameters were recommended in the description of the individual submodels and their sensitivity analyses. When calibration has been done in an area with conditions typical for the whole catchment investigated then the results of the calibration can be transferred to this catchment and no measurements are necessary. However, if the runoff measurement is performed, the results are more reliable.

An evaluation of the results gained from the Samsin research area shows that the CREAMS model can be an effective tool for the description of the hydrological, erosion and chemical processes at the field level, and this model can be used with some modification for small catchments with relatively homogeneous conditions, this was done in the case of the Sedlice catchment (Holy et al. 1981). The CREAMS model can be used not only for description, but also for prediction of the consequences of the changes in agriculture and thus for management purposes.

APPENDIX 1: PARAMETER FILE FOR THE HYDROLOGY SUBMODEL

Card 4. BDATE In option one it has to be defined as the day when no rainfall occurred, as daily rainfall data are supplied for the whole year or more years. To avoid the problem of snow cover, use approximately 1st April (e.g., 78091).

Card 5. DACRE Field area in acres. As the data base of the hydrologic formula was obtained at catchment upto approximately 640 acres, special verifications of the model is needed when using the model for greater areas.

RC Effective saturated conductivity of the soil (in/hr). The hydraulic conductivity of the saturated soil RC is defined by the formula of soil moisture movement (Dacry's law)

$$v = - K \frac{h}{L} \quad ,$$

where v is the rate of movement,

h/L is the potential gradient (e.g. change in water level; it is the difference in water level between the inflow and outflow of water from the soil),

L is distance along the path of greater change in potential.

Information values of RC can be gained from the CREAMS Manual, p. 184, where,

A - deep sands,

B - sandy soils,

C - shallow soils with clays and colloids,

D - clays and shallow soils with little permeable subhorizons.

For calibrations of this value, see Part 2.3 of this study.

FUL Fraction of available water storage for plants filled at field capacity defined as

$$\frac{\text{field capacity}}{\text{upper limit of storage}} = \frac{FK}{UL}$$

Field capacity is given by the amount of water that the soil is able to hold for a longer period after full infiltration. It is the boundary between moist and wet soil between capillary and gravitational water subject to drainage.

The upper limit of storage UL is given by the difference between porosity (see POROS) and wilting point (B15). These values can be obtained by measurement or estimated from a soil science handbook.

Approximate values can be taken from the following Table:

Soil	FK	UL	FUL
sand	0.02-0.20	0.40-0.50	0.05-0.40
loam	0.20-0.35	0.50-0.55	0.40-0.64
clay	0.30-0.45	0.40-0.50	0.75-0.90

There is a discrepancy in the manual: On page 173,proper definition of FUL (used in the program) is given.

On page 174 "fraction of pore space filled at field capacity" is not adequate,as all soil water (especially in heavy soils) is not available to plants.

BST Fraction of available water storage for plants when simulation begins. This value can be measured in the field or estimated according to the BDATE date. The changes of this values influence the beginning of the simulation only, therefore, estimates are adequate in most cases.

POROS Soil porosity is defined as the relative space in soil that is not filled by the solid particles, i.e.,

$$POROS = \frac{V_P}{V_S} \quad ,$$

where V_P is the volume of pores, and V_S is the total volume of soil in field conditions.

Porosity changes with soil texture and structure. It is necessary to consider the relations FK < POROS (FK = field capacity), POROS = UL + B15 where UL is the upper limit of storage, B15 is the soil moisture at wilting point (this value is not read by the program, in contradiction to the statement in the manual, page 174 - value BR15, but calculated from this equation). Approximate values of porosity and wilting point:

Soil	porosity	wilting point
sand	0.30-0.40	0.00-0.05
loam	0.40-0.55	0.05-0.10
clay	0.45-0.60	0.10-0.25

Card 6. (Option 1) SIA — Initial abstraction coefficient c in equation

$$Q = \frac{(P-c.s)^2}{P+(1-c).s} \quad ,$$

where Q is daily runoff,
P is daily rainfall,
s is reduction parameter (eq. I-2 of the CREAMS Manual),
c = 0.2, if not calibrated.

CN2 — SCS curve No. 4 average moisture content (condition two). The values are broadly discussed in Volume III (Chapters 2-4).

Average values are given in the following Table:

Soil	A	B	C	D
crops	70	75	80	85
meadow	50	65	75	80
no vegetation	75	85	90	93

CHS Main channel slope. This value is determined from the map or by measurement. The average value is recommended, given by

$$CHS = \frac{H_s - H_e}{L} ,$$

where H_s is the elevation of the spring, the brook, or upper edge of the small field,

H_e is the elevation of the lowest place of the catchment or of the field,

L is the horizontal distance of these two points.

WLW Watershed length/width ratio is determined from the map as the ratio of the length of the catchment measured along the brook or ridge in the field (with slight curvature, meanders are not measured) to the greatest width of the catchment (field). It is possible to estimate this value by

$$WLW = \frac{L^2}{A} ,$$

where L is the length of the catchment (field),

A is its area.

It is not necessary to calculate this value very precisely.

RD — In contradiction to the manual (page 175-RD) maximum rooting depth is not read by computer; instead 914 mm (36 inches) is used (see statement POROS = POROS.914 in program).

Card 7 (Option 1) UL ( ) — Available soil water storage for plants for each of the 7 soil storages (in.). In the Manual it is described as 1/36, 5/36, 1/6, 1/6, 1/6, 1/6, 1/6, 1/6 of rooting depth (RD).
In the program it is taken as k_i = 1 inch, 5 inches, 6, 6, 6, 6 inches, therefore RD = 1+5+5.6 = 36 inches. It is necessary to compute these values from porosity of the layers P_i and their wilting point moisture content B_i, i.e.
$UL_i = (P_i - B_i) \cdot k_i$ (i=1,2, ...7)
If the maximum rooting depth is substantially smaller than 36 inches, the values of the lower layer chosen could be very small.
In this way it is possible to take into account the difference between the manual and the program. For example, for 20 inches, the following values can be chosen:

i	k_i	P_i	B_i	UL_i
1	1	0.50	0.10	0.40
2	5	0.35	0.10	1.20
3	6	0.35	0.15	1.20
4	6	0.40	0.15	1.50
5	6	0.40	0.15	0.50
6	6	0.40	0.15	0.01
7	6	0.40	0.15	0.01

Card 6 (Option 2) — DS

Depth of surface soil layer (in.)
The soil conditions in the surface layer are different due to agricultural techniques (tillage, etc.,) from that of the other layers, porosity especially is different. Therefore this value is defined as the layers with greater porosity. Usually

$$DS = 2 - 4 \text{ (in.)} \quad .$$

DP

Depth of maximum root growth layer (in.). This value is given by crops planted in the research area. Typically in Central Europe, the following values can be used (in.):

Crop	DP	Crop	DP
small grain	20-30	row crops	20-30
alfalfa	25-40	hops	30-50

GA

Effective capillary tension of soil (in.). When infiltration begins the saturated zone is limited to the depth L_f (wetting depth) between this zone and the dry soil. Capillary tension GA = H_f takes place and Darcy's law can be written

$$v = K\frac{h_o + H_f + L_f}{L_f}$$

where v is the rate of movement (infiltration rate),

K = RC is the hydraulic conductivity,

h_o - is the ponding depth.

The value of GA depends mainly on soil texture and structure, approximate values are:

Soil	GA
sand	3-11
loam	7-17
clay	12-22

RMN Manning's roughness coefficient for field surface. This value has to correpond to the erosion/sediment submodel (see NBARCH). The value for lined channels is 0.01-0.02, for earth channels 0.025-0.045, for vegetation cover it may be expressed as a function of the product of velocity v and hydraulic radius R and changes from 0.04 to 0.20 approx. (for further information see Soil and Water Conservation Engineering, John Wiley, London, 1966, Chapter 2).

SLOPE Average field slope. It is measured in the field or on the map. This value has to correspond to the erosion/sediment file (AVGSLP).

XLP Slope length (ft.). It is measured in the field or on the map. This value has to correspond to the erosion/sediment file (SLNGTH).

Cards 8,9 (Option 1) Cards 7,8 (Option 2)	TEMP	The measurements of climatic station, representative to the research area are used.
Cards 10,11 (Option 1) Cards, 9,10 (Option 2)	RADI	Average monthly net radiation (Langleys/day = cal/cm^2/day). The measurements of radiation of a climatic station representative for the research area are the best values. However, these values are not measured in many stations. Then they can be approximated by Penman's formula:

$$RADI = R_a(0.18 + 0.55\ n/N)$$

where R_a is the maximum solar radiation (cal/cm^2),

n = duration of bright sunshine (hours/day),

N = maximum possible duration of bright sunshine (hours/day),

(R_a,N see WMO hydrological guidebook, Annex). When R_a is expressed in mm, then R_a^1 (Langleys/day) = R_a^m (mm/day)· 58.3. For the 50° North latitude the following data are valid:

Month	J	F	M	A	M	J
R_a	220	352	537	749	909	985
N	8.6	10.0	11.9	13.3	15.9	15.7
Month	J	A	S	O	N	D
R_a	950	820	620	419	260	186
N	15.8	14.4	12.2	10.7	9.0	8.1

Card 12 (Option 2)	AREA	For typical leaf area index see manual, page 183, table II-8.
Card 13 (Option 2)	NEWT	- 1 - stop hydrology subprogram execution (in the manual there is only this -sign; it is not possible to use only this sign, but each negative integer value is acceptable).

APPENDIX 2: PARAMETER FILE FOR EROSION/SEDIMENT YIELD SUBMODEL

Card 4.	BDATE	If BDATE = 0, the submodel is used for simulation of individual storms (Julian date).
Card 5.	KINVIS	Kinematic viscosity (ft^2/sec). The model defaults to a kinematic viscosity 1.21×10^{-5} ft^2/sec, the value for a temperature of 60° F (= 15,5° C). The value of KINVIS is assumed to be constant during the simulation period. The default value was chosen assuming that most erosive storms occur in April and May. The value should be selected according to the temperature when most erosive storms occur (see following Table):

Temperature		Kinematic Viscosity	
(°F)	(°C)	($ft^2/s \times 10^{-5}$)	($m^2.s^{-1} \times 10^{-6}$)
40	4.5	1.67	1.55
50	10.0	1.41	1.31
60	15.5	1.21	1.12
70	21.0	1.05	0.99
80	26.5	0.90	0.88
90	32.2	0.82	0.76
100	37.7	0.74	0.69

WTDSOI — Weight density of soil (lbs/ft^3). This input is for the weight density of the soil mass in areas of flow concentrations. The default value is 96 lbs/ft^3. The recommended values of WTDSOI for different conditions are given in the CREAMS Manual - Table II-18, page 224.

KR — Soil erodibility for erosion by concentrated flow (lbs/ft^2 sec) $(1/lbs/ft^2)^{1.05}$). The default value is 0.135. This value was obtained during experiments in a rill erosion study on tilled silt loam soils. The default value is recommended for most applications. If the KR factor is varied, the KR value is obtained from the first approximation of K from the soil erodibility nomograph of Wischmeier et al. (see CREAMS Manual - Figure II-22, page 232) multiplied by 0.39.

	NBARCH	Manning's <u>n</u> for channel flow over bare soil. The default value is 0.03 which seems typical for an earth channel. This <u>n</u> represents the roughness of flow over a relatively smooth surface.
	YALCON	see page 211 and 224 in manual.
Card 6	SOLCLY	Clay particles are < 0.002 mm. Range of values can be 0.0-1.0.
	SOLSLT	Silt particles are 0.002 - 0.1 mm. Range of values can be 0.0 - 1.0.
	SOLSND	Sand particles are 0.1 - 2.0 mm. Range of values can be 0.0 - 1.0.
	SOLORG	Range of values for mineral soils is 0.0-0.05.
	SSCLY	Specific surface area of clay particles (m^2/gram of soil). Caolinite - range of values is 5.0 - 15.0 m^2/g of soil, Montmorillonite - range of values is 250.0 - 510.0 m^2/g of soil, Illite - range of values is 50.0 - 90.0 m^2/g of soil, Vermiculite - range of values is 190.0 - 290.0 m^2/g of soil,
	SSSLT	Range of values is 1.0 - 10.0 m^2/g of soil.
	SSSND	Range of values is < 0.1 m^2/g of soil.
	SSORG	Range of values is 300.0 - 1300.0 m^2/g of organic carbon.

Card 7.	NPART	The number of particle types in sediment. This card is used if the composition of sediment is available. In this case the FLGPRT = 1 (Card 4). Range of values is 1 - 20 (the model assumed maximum 20 types of sediment particles).
Card 8.	FRCLY	Range of values is 0.0 - 1.0.
	FRSLT	The range of values is 0.0 - 1.0.
	FRSND	The range of values is 0.0 - 1.0.
	FRORG	The range of values is 0.0 - 0.05. Card 8 is repeated for each particle type (NPART, Card 7). The sum of the fractions for clay, silt and sand should equal 1.0, with the organic matter being a fraction of the total organic matter and soil particles. Use results of sediment tests to estimate input values for Card 8.

Initial Overland Flow Inputs

Card 9.		For estimation of slope length and average slope gradient of representative overland flow profile for a complex area the method by Williams and Berndt is recommended (see CREAMS Manual, pp. 228-230). Different shapes of slopes assumed by the submodel are given in Figure II-21, pg. 230 of the manual. Use map and site visit to estimate values for Card 9.

Card 11	XKIN(I)	Relative horizontal distance from the top of the slope to the bottom of segment I (XKIN(I)) is the ratio of the horizontal distance from the top of the slope to the end of segment I to the horizontal length of the slope). The range of the values is 0.0 - 1.0.
	KIN(I)	Values of KIN(I) are estimated from the nomograph by Wischmeier (see CREAMS Manual, Figure II-22, page 232). For estimation of factor KIN(I) it is necessary to know - the percentage fraction of sand particles (0.1-2.0 mm), - percentage fraction of silt and fine sand (0.002-0.01 mm), - fraction of organic matter (%), - type of soil structure, - characteristic of soil permeability. These values can be obtained from soil tests. The range of values of KIN(I) is 0.1-0.8.

Initial Channel Inputs

Card 12.	FLAGS	Flag that characterizes type of flow in channel. 1 for program to use curves for slopes of energy gradeline (friction slope).

It is used for conditions of non-uniform flow and back-water effect in channel
2 for program to assume friction slope equals channel slope. It is used for conditions of uniform flow, supercritical flow along the channel and at the outlet, channels with very flat gradient - 0.001 - 0.005.

Card 13.	SIDSLP	Side slope of a cross-section of the outlet control channel (cotg). The CREAMS manual recommends: 5.0 for terrace channels and grass waterways, 10.0 for concentrated flow in area regularly tilled but susceptible to major erosion, 20.0 for flow concentrations caused by ridges along field boundaries. For rectangular channel or for natural eroded channels the side slope is estimated according to the shape of the channel.
	OUTMAN	Input values from hydraulic handbooks.
	RA	Coefficient in the rating curve equation. Use hydraulic handbooks to estimate values of RA for different types of outlets (weir, pipe outlet, spillway).
	RN	Exponent in the rating curve equation. Use hydraulic handbooks to estimate values of RN for different types of outlets.

RA and RN must be estimated according to units used in rating curve equation - see CONTL Card 12.

Card 14.	LNGTH	Channel length (ft.). Channel length is distance between the outlet channel and the point when concentration of flow begins.

Initial Pond Inputs

Card 16.	CTL	Characterizes type of outlet of impoundment.
	PAC	Characterizes method of calculation for pond surface area - depth relationship.
Card 17.	DATPO	Total drainage area above the pond (acres). Generally it is assumed that the total drainage area above the pond equals the watershed area (DATPO = DATOV).
	INTAKE	Soil water intake rate within the pond (in/hr). A typical value for a silt loam soil with good intake is 0.4 in/hr. Use soil test for indication of INTAKE with adjustments for sealing and tillage within the pond.
	FS	Coefficient for pond surface area - depth relationship. The range of values is 4500.0 - 9500.0; the values were obtained experimentally (see CREAMS Manual, pg. 252). FS value is possible to obtain from equation

		$FS = ((f + d)/f)^2/d.s)$, where f = FRONT, d = DRAW, s = SIDE; the equation is valid for B = 2.
	B	Exponent for pond surface area - depth relationship. The range of values is 1.1 - 1.77, these values were obtained experimentally (see CREAMS manual, pg. 252).
	C	Orifice coefficient. $C = 13\,968 \,.\, d^2$ where d = diameter of pipe outlet (ft.) $C = 3\,600 \,.\, Q/Y^{0.5}$ where Q is maximum discharge (ft^3/s), Y is depth of water above the outlet (ft.).

Updateable Overland Flow Inputs

Card 20.	XCIN(I)	The range of values is upto 1.0.
	CIN(I)	Use site visit to estimate crops within the area. To estimate values CIN(I) use Tables II-21, II-22, II-23, II-24, and Figure II-23 in the CREAMS manual.
Card 21.	XPIN(I)	The range of values is upto 1.0.
	PIN(I)	Use site visit to estimate farming practices within the area. Values for contouring is assumed for PIN(I) only. PIN(I) values can be obtained from table II-25 and figure II-24 of the CREAMS Manual.
Card 22.	XMIN(I)	The range of values is upto 1.0.

MIN(I) The range of values is 0.012 - 0.4. Use hydraulic handbooks or CREAMS Manual (Table II-26, page 248) to estimate values of coefficient of roughness for typical soil covers. The values in Table II-26 are based on n = 0.1 for overland flow over bare soil. If that value is increased the values in Table II-26 should be changed to maintain the same ratio of n for cover to n for bare soil.

Card 24. For lined channels and permanent flow use hydraulic handbooks to estimate coefficient of roughness. For concentrated flow in non-developed channels use Table II-28 of CREAMS manual to estimate coefficient of roughness.

Card 25. Use CREAMS Manual (Table II-29, II-30, and Figure II-27) to estimate the values of critical shear stress as a function of tillage and consolidation for moderately erodible soils. Use hydraulic handbooks to estimate values of critical shear stress for concentrated flow in lined channels.

Card 26.	Use CREAMS Manual (Table II-30) to estimate values of TCV(I). If value of TCV(I) is lower than TCR(I) the cover or channel lining fail and a channel is solved as a non-cover. Input TCV(I) = 100.0 if cover failure is not allowed.
Card 27.	The non-erodible layer is frequently at the bottom of the surface layer of secondary tillage which typically is 0.3 to 0.4 ft. (9-12 cm) deep. In a natural channel a rock layer or an armor layer act as a non-erodible layer, if the effect of the non-erodible layer is to be neglected input of a large value for TDN(I), e.g. 1000.0.
Card 28.	Use CREAMS Manual (Figure II-28) and notes for Card 27 to estimate values for TDS(I).

APPENDIX 3. THE CHEMISTRY MODEL INPUT PARAMETER FILE (Manual pp. 313-318)

Card 5.	SOLPOR	Soil porosity CC/CC - fraction of the soil that can be filled with water or air. The value of it can be calculated from the bulk density of soil (BD) and solid density (SD): SOLPOR = 1 - (BD/SD) Range of values: 0.26-0.8 for mineral soil, 0.4-0.5 for loamy soils, less than 0.3 for gley soil. This value must be the same as POROS in the hydrology submodel.
	FC	Field capacity CC/CC - fraction of the soil volume filled with water after a day's drainage or in equilibrium with tensions of 0.1-0.3 bar. Range of values: 0.2-0.4.

	OM	Organic Matter (%) -
		OM is the percentage of the soil that is composed of biological residues.
		OM = 1.724 • % total organic carbon.
		The value for OM must not be the same as used for SOLORG in the erosion model, since OM is the average in the root zone.
		(OM $\doteq$ 1/2 • SOLORG • 100)
		Range of values:

Soils	Sandy soil	% OM in silty & clay loam
Without OM	0	0
With low content of OM	0.1	0.2
With normal content of OM	0.1-0.2	0.2-0.5
With high content of OM	0.2	0.5

units: % of soil mass

Card 7.	PDATE	The program does not read in the value for PDATE. PDATE is only used as an aid in putting together the data file. Card 7 should always be the first card in a new set of updateable parameters.
Card 10.	APRATE	Rate of application (kg/ha) Range of values: herbicides 1-5 kg/ha, insecticides 10-20 kg/ha. More information: CREAMS Table II-40, p. 311, Handbook of Pesticides. Norms of each country.

DEPINC — More information: CREAMS, p. 321, Norms of each country.

EFFINC — Efficiency of incorporation (unitless). The efficiency factor express uniform mixing of applied pesticide throughout the entire depth.
Range of values: since this type of information is usually unavailable, value 1 would be the input with the assumption of uniform mixing.
For injected pesticide, a value less than 1 (0.5-1) may be the input.

FOLFRC (SOLFRC) — When crops are treated with pesticides applied to the plant canopy, some application depending on the degree of canopy closure will reach the surface of the soil directly, some will remain on the foliage and the rest will be lost by drift and volatilization.
Range of values at full canopy:
FOLFRC - 0.4-0.6 for aerial application,
- 0.7-0.8 for ground application,
SOLFRC - negligible,
LOSS by drift and volatilization 0.2-0.6,
Bare soil SOLFRC = 1,
CREAMS, pp. 596-598, Table 1.

FOLRES (SOLRES) — Amount of pesticide residue on the foliage (soil) prior to new application ($\mu g/g$). An initial residue from the previous application is estimated from equation describing dissipation pesticides with time (CREAMS, pp. 891-892, 560-585)

$$C_{ts} = C_o \cdot e^{-k_s t} \text{ (soil dissipation)}$$

$$C_{tf} = C_o \cdot e^{\frac{-0.693\, t}{C_{1/2}}} \text{ (foliage dissipation).}$$

The values of $k_s t$ and $C_{1/2}$ are in CREAMS Tables 1,2,3 pp. 563-567 and Table 2, pp. 599-601, respectively. This information is also in the Handbook of Pesticides.

WSHFRC — There is little information on the extent and pattern of pesticide washoff from foliage. Some information is given in the CREAMS Manual, Table 4, p. 602.

Range of values:

organochlorides	0.05-0.1
other pesticides	0.6-0.7.

WSHTHR — In the model, an assumption is made that once rainfall exceeds a threshold value corresponding to the amount that can be retained as droplets on the canopy, a fraction potentially dislodgeable is removed during the event. This amount is then added to the soil pesticide residue present at the time of the event.

Range of values:
There is very little information given in the CREAMS Manual, except Table 4, p. 602.

Card 11.	SOLHZO	See CREAMS, Table II-40, pp. 311-312, 323. This information is also in the Handbook of Pesticides.
	HAFLIF	see FOLRES Range of values: CREAMS, Table 2, pp. 599-601, and also in the Handbook of Pesticides.
	EXTRCT	This parameter describes the efficiency of the runoff stream in removing or extracting pesticides. Range of values: 0.05-0.20 A value of 0.1 gives an adequate prediction in most situations.
	DECAY	Decay constant k_s of pesticides in soil (unitless), see SOLRES. Range of values: CREAMS, Tables, 1,2,3 on pp. 563-567. This information is also in the Handbook of Pesticides.
	KD	Distribution coefficient of pesticide between soil and water (unitless). Value of KD is strongly affected by organic carbon in soil and specific surface of soil particles (corresponding to ENRICH in erosion submodel). Range of values: CREAMS, Tables 1-4, pp. 611-618 and 607-610.

Card 12.	OPT	1 - for nitrogen uptake to be simulated by plant growth and nitrogen content. Equation for simulation, CREAMS, pp. 79-80 and 498-501. 2 - nitrogen uptake is described by normal probability curve. Equation for simulation, CREAMS, pp. 80 and 501-503.
Card 13.	SOLN (SOLP)	Soluble nitrogen (phosphorus) in 1 cm of soil surface layer (kg/ha). The initial values of these parameters are best estimated by laboratory tests, by determining the equilibrium nitrate and phosphate concentrations in samples of the soil during leaching in water. CREAMS, pp. 509-527, 534-541, Range of values: 0.01-0.40.
	NO3	Nitrate in root zone (kg/ha). Estimate by routine laboratory analysis of soil. Default value: 20.0 kg/ha.
	SOILN (SOILP)	Estimate by routine laboratory analysis of soil. Range of values for: nitrogen 0.0005-0.003, phosphorus 0.0001-0.0013.
	EXKN (EXKP)	Extraction coefficient for nitrogen and phosphorus (unitless). These coefficients are estimated from laboratory analysis of erosion sediments for several storms from equations in CREAMS, pp. 296, 509-529. Range of values: 0.01-0.40.

	AN(AP)	Enrichment coefficients for calculating the degree of N and P enrichment in the sediments (unitless). These must be calculated from measured values of N and P in sediments by equation, CREAMS, pg. 69. Default value: 7.4 .
	BN	Enrichment exponent for nitrogen, for calculating the degree of N enrichment in the sediment (unitless). It must be calculated from measured values of N in sediments by equation, CREAMS, p. 69. Default value: -0.2.
Card 14	BP	Must be calculated from measured values of P in sediments by equation I-156, I-157, CREAMS, pp. 69, 486-491.
	POTM	Should be measured by laboratory tests and calculated from carbon or organic matter contents, using Equation 1, CREAMS, p. 493 and Table 1, p. 494.
	RZMAX	This value is best obtained from field observation, because many fields have conditions that limit root growth below normal values published in literature or CREAMS, Tables 1-14, p. 78.
Card 15 (For Option 1)	YP	Potential economic crop yield under ideal conditions (kg/ha). These values are published in the literature. In CREAMS, they are in Tables I-12, p. 73 for individual plants.

	PWU	Potential water use (mm) - see hydrological submodel.
Card 15 (For Option 2)	DOM	The number of days after emergence that half the nitrogen is taken up and is equivalent to the mean probability distribution. See CREAMS, pp. 501-505.
	SD	This value expresses the number of days required after 50% uptake to reach 84% uptake N. Values of DOM and SD for different crops are in CREAMS, Table 5, p. 503.
	PU	Potential nitrogen uptake by the crop under ideal conditions (kg/ha). These values are determined best from field studies, but they are also published in agricultural literature.
Card 16		The coefficients and exponents relating to the nitrogen content of the crop to its stage of growth are reflected in its amount of dry matter. For several plants these coefficients are tabulated in CREAMS Table 3, p. 500, where C1, C2, C3, C4 correspond to b_1, b_2, b_3, b_4. Equations for simulating are in CREAMS, pp. 498-501.
Card 18.	FA	Surface fraction of application. Application factor is the reciprocal of the depth of application. Surface application is given a value of 1.

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