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STUDY OF IMPACT OF SOIL AND LAND USE CHANGES ON HYDROLOGIC REGIME USING SHE MODEL

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PREFACE

The increasing water resources development activity has focussed attention on development and application of physically based hydrological models to deal with constantly changing hydrological environment. When the hydrological system is subject to change or when a realistic physical representation of flow in space and time is required, the conceptual representation or traditional rainfall runoff models with lumped approach are not suitable.

The SHE (System Hydrologique European) modelling system developed by Instititutes of three countries, namely: Denmark, France, and U.K. has been transferred to NIH under a collaborative project. This model has capability to consider physical processes of the catchment in a distributed manner including soil, vegetation and land use distribution, topography, etc. Since the commencement of the 3 year project in November 1987, the Model has already been applied to six sub-basins of River Narmada.

The present report describes a study related with impact of land use and soil change on hydrologic regime of a catchment. The study has been carried out by Mr. S K Jain, Scientist 'C' under the guidance of Dr. S M Seth, Scientist 'F' & Project Coordinator, SHE Model studies and in close interaction with the Consultants.

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ABSTRACT

Distributed models, which form an important class of models of land phase of hydrological processes in a catchment, are based on detailed description of component processes. The SHE is one such model. One major potential area of application of the distributed models is prediction of effects of land-use changes on hydrological regime of a catchment. In the present study, the SHE model was used in this context.

The behaviour of a microscale catchment was simulated under different conditions in terms of soil hydraulic properties, soil depth, land use, and surface roughness for overland flow. The results of this study provide insight into behaviour of a real catchment which can be visualized to be composed of a number of small elemental areas.

Based on the results it can be concluded that reduction of soil depth will lead to higher yield from the catchment. In case of shallow soils, the soil properties do not have significant effect on catchment response. Higher soil conductivity will lead to less runoff and less spiky hydrograph. The amount of ET losses will change with vegetation type and properties.

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1.0 INTRODUCTION

A mathematical model is a set of mathematical and logical expressions representing the behaviour of a system. In the area of hydrology, these models are used for a number of applications like rainfall runoff modelling, flood forecasting, reservoir operation and ground water exploitation.

Distributed models, which form an important class of models of land phase of hydrological processes in a catchment, are based on detailed description of these processes. The SHE is one such model. The detailed description of the SHE model is available in model documentation, DHI(1989).

Beven(1985) mentions four major areas which offer the greatest potential for application of the distributed models. One of these areas is forecasting the effects of land-use changes on hydrological regime of a catchment. In the present study, the SHE model was used in this context of study of land use changes.

1.1 STRATEGY ADOPTED

The strategy adopted in this study was to simulate the behaviour of a microscale catchment under different conditions in terms of the soil hydraulic properties, soil depth, land use, and surface roughness for overland flow. The results of this study can be easily applied to predict the impacts of land use change in a big catchment since such catchment can be visualized to be composed of several small elemental areas. Several simulation runs were taken in which these parameters of model response were different. The results of those runs in which only one parameter was different were intercompared to determine the effect of the individual changes.

The changes in the physical characteristics of a catchment lead to changes in the associated parameters of the catchment. In practice, seldom there is a change in only one parameter; a change in one parameter may lead to changes in a number of associated parameters. For example, the change in land use leads to change in the amount of interception of input precipitation, the evapotranspiration losses from the area, ground surface roughness for overland flow, and the soil hydraulic conductivity etc.

1.2 PURPOSE OF THE PRESENT REPORT

The purpose of this report is to describe the results of an investigation related with study of soil and land use changes on the hydrological regime of a catchment. The data pertaining to Kolar sub-basin lying in the Narmada river basin, India was used in this study. The results of simulation of Kolar basin are described in Jain (1990).

2.0 DETAILS OF STUDY AREA

For the purpose of this investigation, the study area consisted of a single square shaped grid with a river flowing along one of the sides. The grid square, which also represents a single soil column in a SHE setup, was assumed to be surrounded by impervious boundaries.

The schematic representation of this catchment area is shown in Fig. 2.1 and 2.2. The dimensions of the grid square were 2km * 2km.

2.1 SCENARIOS STUDIED

The various combinations of soil type, soil depth and land use as used in the simulation of Kolar basin, Jain (1990), are shown in Table 2.1. A percentage sign (%) in a particular column indicates that there was no grid square falling in that particular combination. As seen from this table, there are a total of sixteen combinations of soil depth, soil hydraulic properties, vegetation type and Strickler's roughness coefficient available. Each of these scenario was individually simulated in the present study. The results corresponding to those runs where only one parameter was different were analyzed to determine the effect of a particular parameter.

In Table 2.1, the numbers given in the square brackets are used to refer to the simulation run using the corresponding scenario parameters. In the subsequent discussion, R followed by this number, is used to refer to the particular run, e.g., R1, R4, or R12.

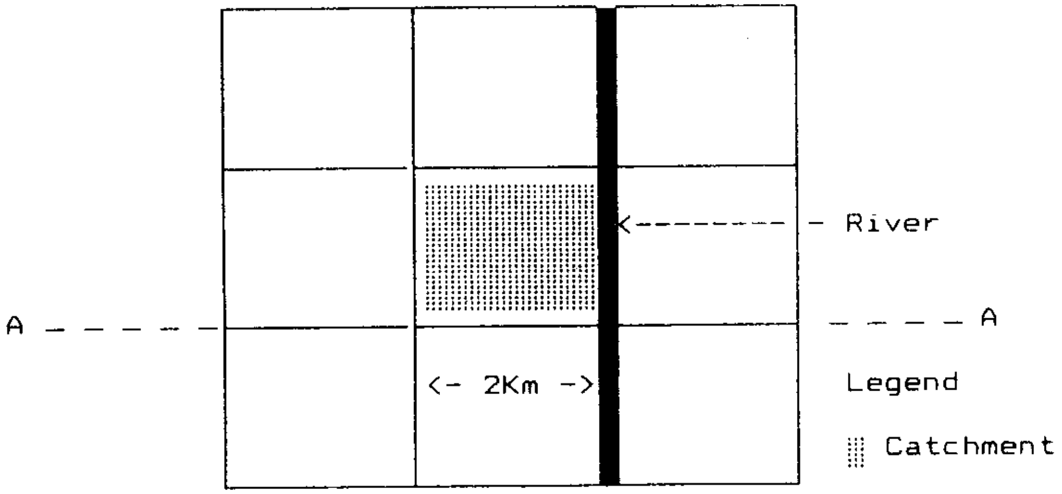

Fig. 2.1 Schematic representation of single column catchment

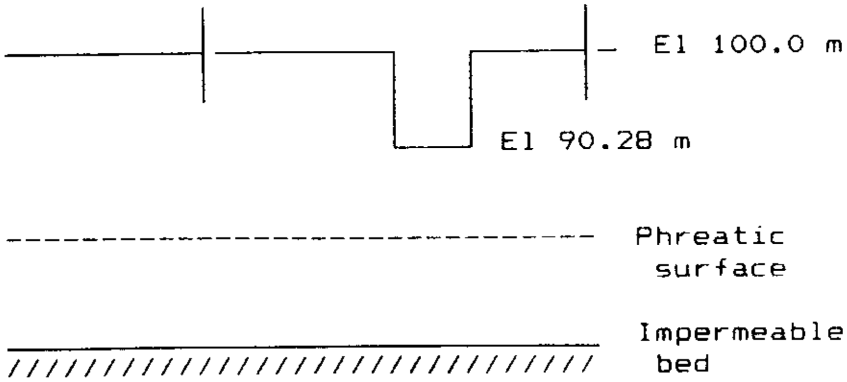

Fig. 2.2 Section along A-A

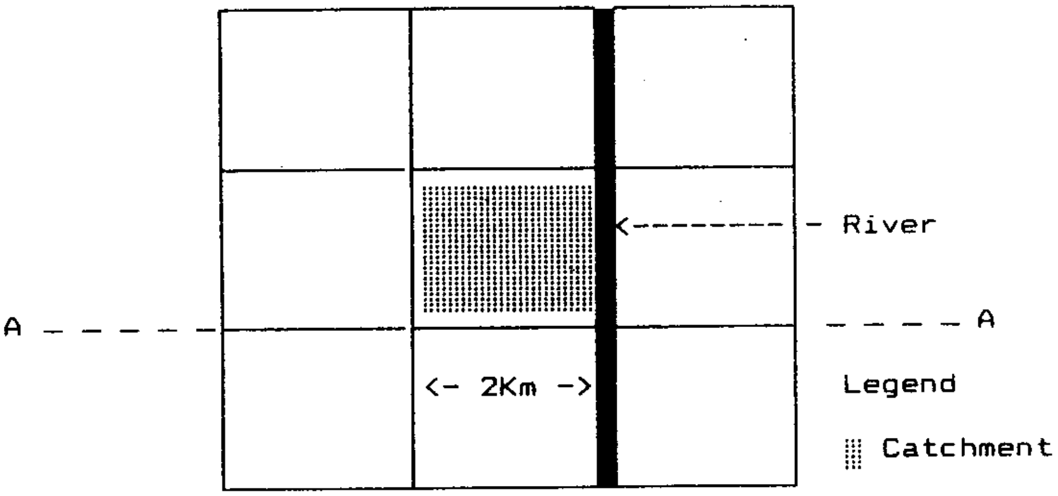

Fig. 2.1 Schematic representation of single column catchment

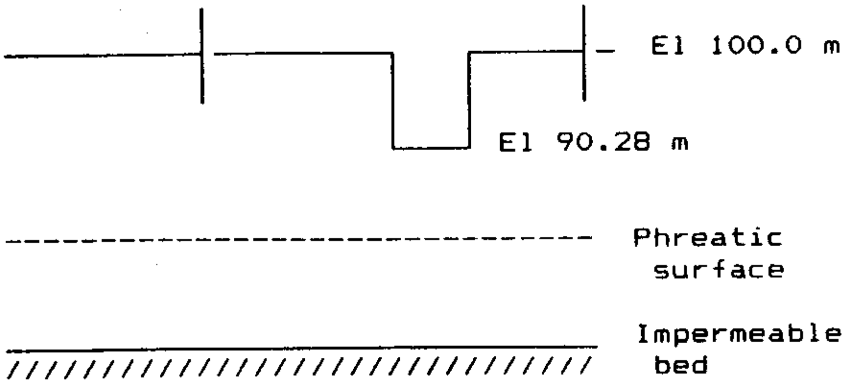

Fig. 2.2 Section along A-A

Table 2.1
COMBINATION OF SIMULATION PARAMETERS

	Black Soil	Yellow Soil	Red Soil	
WASTE LAND				
1. Run Reference No	[01]		[02]	
2. Soil Depth [m]	0.2	%	0.2	
3. Ks {UZ} [mm/h]	2.0		20.0	
4. Kstr {OC} [m 1/3/s]	7.0		7.0	
OPEN FOREST				
1. Run Reference No			[03]	[04]
2. Soil Depth [m]	%	%	0.5	0.7
3. Ks {UZ} [mm/h]			50.	50.
4. Kstr {OC} [m 1/3/s]			5.	5.
MEDIUM DENSE FOREST				
1. Run Reference No		[05]	[06]	[07]
2. Soil Depth [m]	%	0.5	0.5	0.7
3. Ks {UZ} [mm/h]		40.0	50.	50.
4. Kstr {OC} [m 1/3/s]		3.	3.	3.
DENSE FOREST				
1. Run Reference No	[17]*		[08]	
2. Soil Depth [m]	8.0	%	0.5	
3. Ks {UZ} [mm/h]	4.0		50.	%
4. Kstr {OC} [m 1/3/s]	7.0		4.	
AGRICULTURE				
1. Run Reference No	[09]			
2. Soil Depth [m]	8.0	%	%	
3. Ks {UZ} [mm/h]	4.0			
4. Kstr {OC} [m 1/3/s]	7.0			
AGRICULTURE				
1. Run Reference No	[10]		[11]	
2. Soil Depth [m]	4.0		4.0	
3. Ks {UZ} [mm/h]	4.0	%	40.0	
4. Kstr {OC} [m 1/3/s]	7.0		7.0	
AGRICULTURE				
1. Run Reference No	[12]		[13]	
2. Soil Depth [m]	2.5	%	2.5	
3. Ks {UZ} [mm/h]	4.0		40.0	
4. Kstr {OC} [m 1/3/s]	7.0		7.0	
AGRICULTURE				
1. Run Reference No	[14]	[15]	[16]	
2. Soil Depth [m]	1.0	1.0	1.0	
3. Ks {UZ} [mm/h]	4.0	20.0	40.0	
4. Kstr {OC} [m 1/3/s]	7.0	7.0	7.0	

* This is a hypothetical scenario.

2.2 INPUT DATA USED

In addition to the alternate scenarios of basin representations, the input time series data pertaining to Kolar basin was used. The hourly rainfall data for the station Jholiapur was used. The order of rainfall volume at this station is in the same range as is the mean of all four SRRG stations used in Kolar simulation. Therefore, the rainfall data at this station was used in the present study. The pan evaporation data for Powerkheda station, as used in Kolar simulation, was used in this study. The time series of leaf area index and root zone depth for the corresponding vegetations of Kolar basin are also same. These are plotted in Fig. 2.3. The parameters of soils are also same as used in Kolar basin simulation, some important parameters are given in Table 2.2.

The detailed information on all these data is given in the Kolar simulation update report, Jain(1990).

The data for the three year period 1986-88 was used in the present analysis. During these years, the volume of rainfall during the monsoon season was 1491 mm, 983 mm, and 1168 mm respectively. During 1986, rainfall was a mixture of few big isolated events and a number of events of low intensity rainfall spread over time. In 1987, the rainfall occurred mostly in the form of isolated events of short duration intense storms. The year 1988 consisted of low intensity long duration

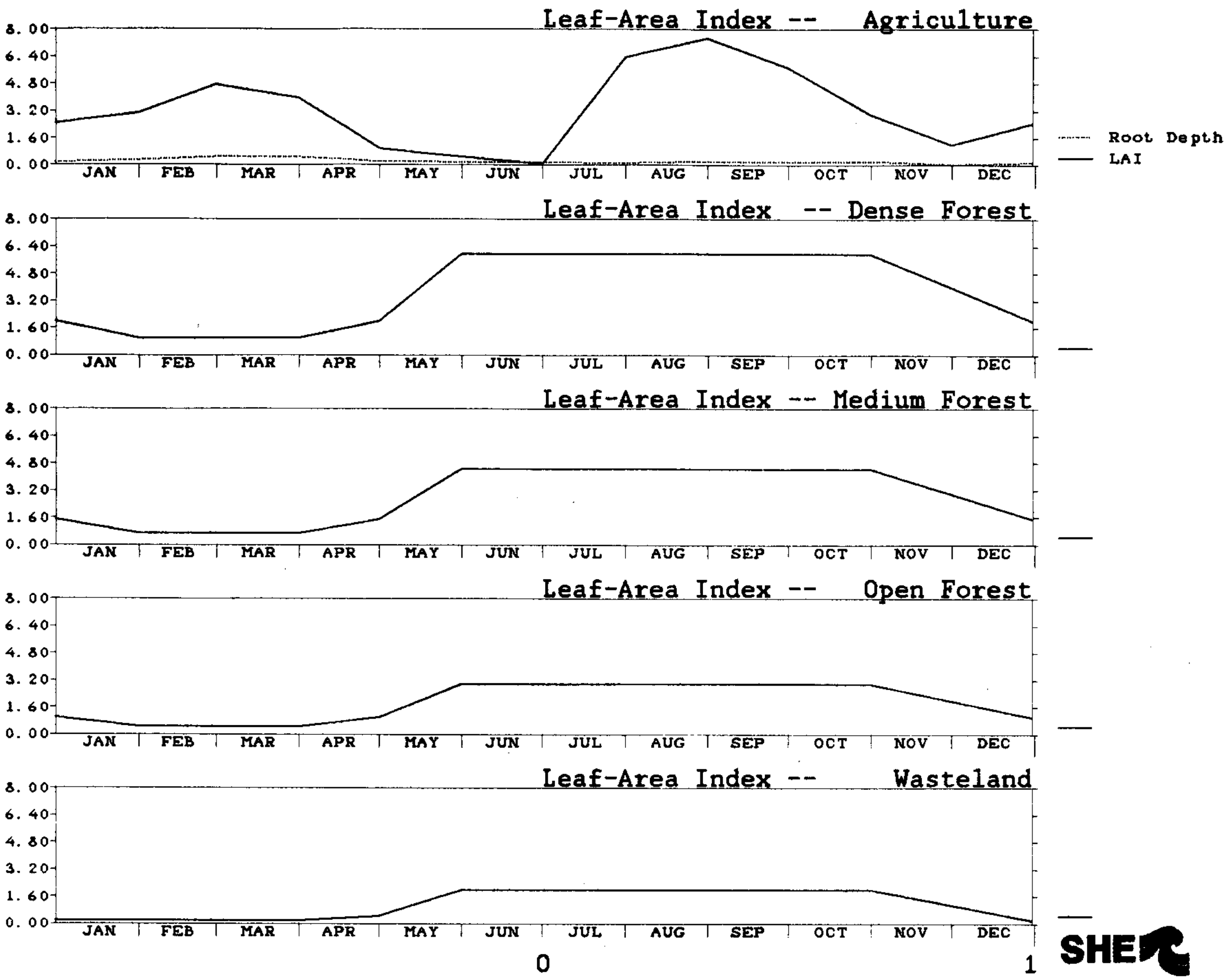
Leaf-Area Index -- Agriculture
Leaf-Area Index -- Dense Forest
Leaf-Area Index -- Medium Forest
Leaf-Area Index -- Open Forest
Leaf-Area Index -- Wasteland
8.00
6.40
4.80
3.20
1.60
0.00
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Root Depth
LAI
0
1

Table 2.2

Properties of different type of soils

Property	Soil type		
	Black	Red	Yellow
Saturated moisture cont.	0.675	0.42	0.47
Effect. sat. moist cont.	0.62	0.403	0.438
Field capacity	0.575	0.31	0.36
Wilting Point	0.36	0.15	0.18
Residual moisture cont.	0.252	0.10	0.17

rainfall events with few intense rainfall events.

The starting date of simulation runs was 01 January 1986. The initial soil moisture profile was field capacity. The results of first year of simulation (1986) are, therefore affected by the initial conditions.

3.0 ANALYSIS OF RESULTS

The analysis of the results obtained in the simulation runs are presented in this section. The results are being analyzed to determine the impact of soil depth, soil hydraulic properties, land use, and the surface roughness characteristics on the hydrologic regime of a catchment.

3.1 OUTPUT VARIABLES MONITORED

The variables representing output from the catchment which were monitored in the present study were discharge in the river, moisture content in the unsaturated zone, and actual evapotranspiration losses from the catchment.

The results of the simulation runs in the form of component wise monthly water balance are given in Appendix A (Table A.1 to Table A.17 for run R1 ro R17 respectively). A summary of these results is given in Table 3.1. The plots of variation of soil moisture in the unsaturated zone, the actual and potential evapotranspiration, the river discharge and the input rainfall corresponding to each simulation run are given in Appendix B (Fig. B.1 to B.17).

3.2 IMPACT OF SOIL DEPTH ON HYDROLOGIC REGIME

The soil depth along with soil properties determines the moisture storage capacity of the sub-surface zone in a catchment. This along with the soil conductivity effects the water available for runoff as well as that available to meet evapotranspiration requirements.

In the run nos. R9, R10, R12, and R14, **all** parameters

Table 3.1
Summary Results of Simulations - River Flow

Run No.	Outflow Volume during monsoon (mm)		
	1986	1987	1988
R1	1253	605	785
R2	1250	591	816
R3	1174	510	684
R4	1122	458	631
R5	1167	506	680
R6	1172	508	684
R7	1120	457	631
R8	1175	508	684
R9	813	79	171
R10	847	70	242
R11	803	109	299
R12	874	151	323
R13	859	174	367
R14	1098	450	611
R15	1100	455	615
R16	1099	455	615
R17	766	73	128
Monsoon RF	1491	983	1168

except the soil depth were same. The results of these runs are given in Tabular form in Tables A.9, A.10, A.12, and A.14; graphical representations are given in Fig. B.9, B.10, B.11, and B.12 respectively. Summary results are given in Table 3.2.

Table 3.2
Summary Results of Simulations - Impact of soil depth

Run No.	Run parameters *SD/Kuz/Kstr	Outflow Volume during monsoon (mm)		
		1986	1987	1988
R9	8.0/ 4./ 7.	813	79	171
R10	4.0/ 4./ 7.	847	70	242
R12	2.5/ 4./ 7.	874	151	323
R14	1.0/ 4./ 7.	1098	450	611
Monsoon Rainfall		1491	983	1168

Note : * - Soil depth.

A comparison of the results of these runs shows that lesser soil depth produces more runoff because lesser moisture can be stored in the soil. In the run R14, the soil depth was 1.0 m and the soil got completely saturated several times during the simulation in this case. In this case, there was about 10 mm of standing water in the column in the year 1987 (Ref. Table A.14). In case of run R9, the runoff volume for the three monsoon seasons was 813 mm, 79 mm, and 171 mm while in case of run R14, this volume was 1098 mm, 450 mm, and 611 mm. From the corresponding graphs, it is seen that many small peaks appearing in Fig. B.14 corresponding to run R14 do not show in Fig. B.9 (run R9). Thus there is a significant difference in the runoff, of the order of 500%, in the two cases where the soil depth was 8.0 m and 1.0 m respectively. The increased soil depth gave lesser runoff coefficient.

The results of the runs R10 and R12, soil depth 4.0 m and 2.5 m respectively, also support these observations (Table 3.3). Here because of less variation in soil depth, the variation in the discharge was also less. Further, as a consequence of less soil depth, the actual evapotranspiration loss was less. This was because lesser water was available to meet the ET demands.

Table 3.3
Summary Results of Simulations - Impact of soil depth

Run No.	Run parameters SD/Kuz/Kstr	Outflow Volume during monsoon (mm)		
		1986	1987	1988
R10	4.0/ 4./ 7.	847	70	242
R12	2.5/ 4./ 7.	874	151	323
Monsoon Rainfall		1491	983	1168

Similar effect of soil depth is seen for the red soil (permeable) while examining the results of the runs R11, R13, and R16, as given in Table 3.4. A comparison of results of R11 (soil depth 4.0 m) and R16 (soil depth 1.0 m), a four fold reduction in soil depth gave about 37% increase in discharge during monsoon of 1986, more than 4 times increase in 1987 and about twice big in 1988. The reduction in soil depth also gives increased flashiness in the basin response. This is because in this case the soil storage acts as a reservoir whose function is to give a delayed yield.

Table 3.4
Summary Results of Simulations - Impact of soil depth

Run No.	Run parameters SD/Kuz/Kstr	Outflow Volume during monsoon (mm)		
		1986	1987	1988
R11	4.0/40./ 7.	803	109	299
R13	2.5/40./ 7.	859	174	367
R16	1.0/40./ 7.	1099	455	615
Monsoon Rainfall		1491	983	1168

This analysis brings out the likely consequences of soil erosion on the catchment yield. It is true that the changes of such a large order as studied here will, if at all, take place over a very big time span. Nevertheless the bottom line is that the changes in yield volume from a big area can not be overlooked.

3.3 IMPACT OF SOIL PROPERTIES ON HYDROLOGIC REGIME

In the runs R1 and R2, everything except the soil properties was same. An intercomparison of the results (Table A.1 and A.2 and summary results in Table 3.5) shows that the difference between the results is not significant. Similarly, in the runs R10 and R11, only soil properties were different but the response of the basin is significantly different in the two cases. It is seen that, in general, the runoff in case of R10 (in which soil conductivity was smaller) is higher than R11 (in which soil conductivity was larger) in the initial months of the wet period while it is vice versa in the later months of the wet period. Overall, the discharge volume in run R10 was higher than R11 in 1986 and was lower in 1987 and 1988. From the Table A.10 and A.11 it is observed that the soil moisture deficit in case of R11 was higher by about 10% in 1987 and 1988 and about 20% higher in 1986. The moisture storage capacity of R10 soil is higher as compared with R11 and hence less runoff is produced. The results of 1986 seem to be affected by initial conditions. The shape of hydrograph was spiky in R10 and smooth in R11. This can be attributed due to UZ conductivity.

Table 3.5
Summary Results of Simulations - Impact of soil properties

Run No.	Run parameters SD/Kuz/Kstr	Outflow Volume during monsoon (mm)		
		1986	1987	1988
R1	0.2/ 2.0/ 7.	1253	605	785
R2	0.2/20. /7.	1250	591	816
Monsoon Rainfall		1491	983	1168

While comparing the results of the runs R12 and R13 and the runs R14, R15, R16 (Table 3.6), not much difference is observed. It appears that in case the soil depth is small, the soil properties do not play a significant role in determining the basin response.

Table 3.6
Summary Results of Simulations - Impact of soil properties

Run No.	Run parameters SD/Kuz/Kstr	Outflow Volume during monsoon (mm)		
		1986	1987	1988
R12	2.5/ 4./ 7.	874	151	323
R13	2.5/40./ 7.	859	174	367
R14	1.0/ 4./ 7.	1098	450	611
R15	1.0/20./ 7.	1100	455	615
R16	1.0/40./ 7.	1099	455	615
Monsoon Rainfall		1491	983	1168

3.4 IMPACT OF SURFACE ROUGHNESS ON HYDROLOGIC REGIME

The results of runs R3, R6, and R8 can be compared to determine the effect of the surface roughness characteristics on the basin response. The summary results are given in Table 3.7. In these runs only the Strickler roughness coefficient was different; its values were 5.0, 3.0, and 4.0 respectively. An examination of the results shows that this coefficient does not have a significant influence on the long term water balance -- of the order of several hours or more (depending on the catchment size) -- of the basin. This factor, however, is very important in determining the shape of the hydrograph during the flood season or the flashiness of the basin response. This fact is also borne out by examining the Fig. B.3, B.6, and B.8.

Table 3.7
Summary Results - Impact of surface roughness

Run No.	Run parameters SD/Kuz/Kstr	Outflow Volume during monsoon (mm)		
		1986	1987	1988
R3	0.5/50. /5.	1174	510	684
R6	0.5/50. /3.	1172	508	684
R8	0.5/50. /4.	1175	508	684
Monsoon Rainfall		1491	983	1168

3.5 IMPACT OF VEGETATION ON HYDROLOGIC REGIME

The results on run R9 (agriculture) and R17 (forest), Table 3.8, provide a comparison to determine the impact of vegetation changes on the hydrologic regime of the catchment. It may be mentioned that the run R17 was a hypothetical run in the sense that this combination of parameters was not found in the Kolar basin. This run was, however, taken with a view to examine this influence.

Table 3.8
Summary Results - Impact of vegetation

Run No.	Run parameters SD/Kuz/Kstr	Outflow Volume during monsoon (mm)		
		1986	1987	1988
R9	8.0/ 4./ 7.	813	79	171
R17	8.0/ 4./ 7.	766	73	128
Monsoon Rainfall		1491	983	1168

It is seen from the results that less runoff was produced in R17 as compared with R9. The reason was that in case of R17, soil was more dry when the monsoon rains arrived. There was high loss of moisture due to evapotranspiration.

However, it is not possible to generalize the results on the basis of this analysis because they will heavily depend on the properties of vegetation regarding interception of input precipitation and the water requirements of the vegetation. In case of agriculture, the behaviour will very much depend upon the type of crop.

Furthermore, the vegetation type is likely to influence the soil hydraulic properties so that, e.g., the hydraulic conductivity would be high for forest than for agriculture areas having the same soil types. This effect is not taken into account here.

3.6 IMPACT OF LAND USE ON HYDROLOGIC REGIME

As mentioned earlier, the change in land use will lead to change in a host of associated parameters. The sum total effect of the changes will be the cumulative effect of the individual influences.

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4.0 CONCLUSIONS

Based on the findings arrived at above, the following conclusions can be made regarding the effects of soil properties and land use change on the hydrologic regime of a micro catchment.

a) Soil Depth -- Reduction of soil depth will lead to higher yield from the catchment and more flashy response (higher peaks). In case of shallow soils, the soil properties do not have significant effect on basin response.

b) Soil Properties -- Higher soil conductivity will lead to less runoff and less spiky hydrograph. Shape of soil moisture retention curve mainly affects the response during early part of wet season. The degree of effect depends on the shape of the curve.

c) Change in vegetation -- the amount of ET losses will change -- it will increase or decrease depending on the related crop characteristics, viz., leaf area index (higher losses with higher index and vice versa), depth and size of roots, and the growth characteristics. Further, vegetation change may affect potential evapotranspiration and soil hydraulic properties, but this effect has not been analysed in this study.

d) Change in surface roughness characteristics -- This will lead to change indegree of flashiness of catchment response.

The composite effect of various changes for a real catchment will be combination of all individual effects along with their interaction for various elemental units. It would therefore, be desirable to carry out studies on similar lines for real catchments.

Furthermore, it would be desirable to carry out studies of the hydrological effects of land use change on catchments with adequate data representing both the "pre" and the "post" land use conditions so that the model predictions could be validated against field data.

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5.0 REFERENCES

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APPENDIX A

Component wise water balance for simulation runs (month wise)

Table A.1

CHANGE IN TOTAL WATER BALANCE

yy mm dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86 1 1	0	0	0	0	0	-2	0
86 2 1	0	33	0	0	0	-36	0
86 3 1	37	25	0	0	0	-23	0
86 4 1	1	30	0	0	0	-53	-1
86 5 1	0	1	0	0	0	-54	0
86 6 1	13	5	0	0	0	-47	0
86 7 1	162	53	0	0	73	-8	3
86 8 1	1047	95	0	0	960	-6	10
86 9 1	269	87	0	0	220	-39	5
86 10 1	0	15	0	0	0	-54	0
86 11 1	0	0	0	0	0	-54	0
86 12 1	0	0	0	0	0	-54	0
87 1 1	0	0	0	0	0	-54	0
87 2 1	45	21	0	0	0	-30	0
87 3 1	30	25	0	0	0	-25	0
87 4 1	5	30	0	0	0	-50	0
87 5 1	0	4	0	0	0	-54	0
87 6 1	18	16	0	0	0	-53	0
87 7 1	96	59	0	0	14	-29	1
87 8 1	239	94	0	0	134	-2	16
87 9 1	516	96	12	0	412	0	8
87 10 1	54	73	-12	0	45	-51	0
87 11 1	62	63	0	0	0	-53	0
87 12 1	0	12	0	0	0	-66	-1
88 1 1	18	10	0	0	0	-58	0
88 2 1	17	14	0	0	0	-55	0
88 3 1	0	10	0	0	0	-65	0
88 4 1	0	1	0	0	0	-66	0
88 5 1	11	8	0	0	0	-63	0
88 6 1	16	18	0	0	0	-66	0
88 7 1	168	52	0	0	56	0	6
88 8 1	551	98	5	0	464	0	16
88 9 1	309	101	-5	0	231	-4	13
88 10 1	85	73	1	0	17	1	12
88 11 1	39	71	-1	0	17	-53	-5

R F = Rainfall,
Evap. = Evaporation,
H-O F = Depth of overland flow,
H-Riv = Water Depth in river,
Riv.fl = River discharge,
Thuz = Unsaturated zone moisture,
Wblerr = Water balance error,
All figures are in mm.

Table A.2

CHANGE IN TOTAL WATER BALANCE

yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-4	0
86	2	1	0	36	0	0	0	-41	0
86	3	1	37	25	0	0	0	-29	0
86	4	1	1	24	0	0	0	-52	-1
86	5	1	0	0	0	0	0	-53	0
86	6	1	13	6	0	0	0	-46	0
86	7	1	162	54	0	0	73	-7	4
86	8	1	1047	96	0	0	958	-4	10
86	9	1	269	92	0	0	219	-42	3
86	10	1	0	10	0	0	0	-53	-1
86	11	1	0	0	0	0	0	-53	0
86	12	1	0	0	0	0	0	-53	0
87	1	1	0	0	0	0	0	-53	0
87	2	1	45	28	0	0	0	-34	1
87	3	1	30	27	0	0	0	-31	0
87	4	1	5	25	0	0	0	-51	-1
87	5	1	0	1	0	0	0	-53	0
87	6	1	18	17	0	0	0	-52	0
87	7	1	96	62	0	0	15	-31	2
87	8	1	239	97	0	0	122	-2	9
87	9	1	516	100	12	0	406	0	6
87	10	1	54	71	-12	0	48	-49	3
87	11	1	62	59	0	0	0	-46	0
87	12	1	0	6	0	0	0	-53	0
88	1	1	18	11	0	0	0	-46	0
88	2	1	17	14	0	0	0	-43	0
88	3	1	0	9	0	0	0	-52	0
88	4	1	0	0	0	0	0	-53	0
88	5	1	11	8	0	0	0	-50	0
88	6	1	16	18	0	0	0	-53	0
88	7	1	168	54	0	0	65	0	3
88	8	1	551	98	12	0	477	5	41
88	9	1	309	101	-12	0	249	-6	18
88	10	1	85	76	0	0	3	0	0
88	11	1	39	77	0	0	22	-60	1

Table A.3

CHANGE IN TOTAL WATER BALANCE

yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-19	0
86	2	1	0	57	0	0	0	-77	-1
86	3	1	37	36	0	0	0	-76	0
86	4	1	1	41	0	0	0	-117	-1
86	5	1	0	16	0	0	0	-133	-1
86	6	1	13	5	0	0	0	-126	0
86	7	1	162	52	0	0	5	-20	2
86	8	1	1047	98	0	0	950	-11	10
86	9	1	269	101	0	0	219	-59	3
86	10	1	0	63	0	0	0	-124	-2
86	11	1	0	8	0	0	0	-133	0
86	12	1	0	0	0	0	0	-133	0
87	1	1	0	0	0	0	0	-133	0
87	2	1	45	18	0	0	0	-105	1
87	3	1	30	20	0	0	0	-95	0
87	4	1	5	33	0	0	0	-123	-1
87	5	1	0	9	0	0	0	-133	0
87	6	1	18	16	0	0	0	-132	0
87	7	1	96	60	0	0	0	-95	1
87	8	1	239	97	0	0	59	-7	6
87	9	1	516	102	13	0	399	0	5
87	10	1	54	89	-13	0	52	-74	-1
87	11	1	62	98	0	0	0	-112	-1
87	12	1	0	21	0	0	0	-133	-1
88	1	1	18	13	0	0	0	-128	0
88	2	1	17	14	0	0	0	-126	0
88	3	1	0	8	0	0	0	-134	0
88	4	1	0	1	0	0	0	-135	0
88	5	1	11	7	0	0	0	-131	0
88	6	1	16	19	0	0	0	-135	0
88	7	1	168	51	0	0	2	-15	5
88	8	1	551	98	3	0	443	0	8
88	9	1	309	101	-3	0	229	-15	4
88	10	1	85	89	0	0	1	-20	0
88	11	1	39	113	0	0	9	-106	-3

Table A.4

CHANGE IN TOTAL WATER BALANCE

yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-30	0
86	2	1	0	62	0	0	0	-92	0
86	3	1	37	44	0	0	0	-98	0
86	4	1	1	48	0	0	0	-145	0
86	5	1	0	36	0	0	0	-181	0
86	6	1	13	9	0	0	0	-177	0
86	7	1	162	51	0	0	0	-66	1
86	8	1	1047	98	0	0	903	-11	9
86	9	1	269	102	0	0	219	-58	4
86	10	1	0	84	0	0	0	-143	-1
86	11	1	0	38	0	0	0	-182	-1
86	12	1	0	4	0	0	0	-186	0
87	1	1	0	1	0	0	0	-187	0
87	2	1	45	16	0	0	0	-158	0
87	3	1	30	19	0	0	0	-146	0
87	4	1	5	31	0	0	0	-173	0
87	5	1	0	13	0	0	0	-186	0
87	6	1	18	16	0	0	0	-185	0
87	7	1	96	54	0	0	0	-142	1
87	8	1	239	97	0	0	10	-9	2
87	9	1	516	102	13	0	396	0	5
87	10	1	54	89	-13	0	52	-72	1
87	11	1	62	115	0	0	0	-126	0
87	12	1	0	47	0	0	0	-173	0
88	1	1	18	17	0	0	0	-172	0
88	2	1	17	15	0	0	0	-171	0
88	3	1	0	10	0	0	0	-181	0
88	4	1	0	3	0	0	0	-184	0
88	5	1	11	7	0	0	0	-181	0
88	6	1	16	18	0	0	0	-183	0
88	7	1	168	50	0	0	0	-64	1
88	8	1	551	98	3	0	392	0	7
88	9	1	309	101	-3	0	229	-15	4
88	10	1	85	89	0	0	1	-20	0
88	11	1	39	120	0	0	9	-112	-2

Table A.5

CHANGE IN TOTAL WATER BALANCE

yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-21	0
86	2	1	0	55	0	0	0	-77	-2
86	3	1	37	37	0	0	0	-77	0
86	4	1	1	45	0	0	0	-122	-1
86	5	1	0	17	0	0	0	-139	0
86	6	1	13	7	0	0	0	-133	0
86	7	1	162	51	0	0	2	-21	4
86	8	1	1047	98	0	0	947	-10	10
86	9	1	269	101	0	0	218	-56	3
86	10	1	0	66	0	0	0	-125	-3
86	11	1	0	10	0	0	0	-136	0
86	12	1	0	1	0	0	0	-137	0
87	1	1	0	0	0	0	0	-137	0
87	2	1	45	21	0	0	0	-112	1
87	3	1	30	22	0	0	0	-103	0
87	4	1	5	32	0	0	0	-131	-1
87	5	1	0	5	0	0	0	-136	0
87	6	1	18	16	0	0	0	-135	0
87	7	1	96	59	0	0	0	-96	1
87	8	1	239	97	0	0	55	-4	7
87	9	1	516	102	18	0	396	0	5
87	10	1	54	89	-18	0	55	-73	-1
87	11	1	62	99	0	0	0	-112	-2
87	12	1	0	24	0	0	0	-137	-1
88	1	1	18	15	0	0	0	-134	0
88	2	1	17	15	0	0	0	-132	0
88	3	1	0	6	0	0	0	-139	0
88	4	1	0	1	0	0	0	-140	0
88	5	1	11	7	0	0	0	-137	0
88	6	1	16	18	0	0	0	-139	0
88	7	1	168	52	0	0	1	-17	7
88	8	1	551	98	6	0	438	0	8
88	9	1	309	101	-6	0	230	-12	4
88	10	1	85	89	0	0	1	-17	0
88	11	1	39	113	0	0	10	-105	-3

Table A.6

CHANGE IN TOTAL WATER B

yy mm dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86 1 1	0	0	0	0	0	-19	0
86 2 1	0	57	0	0	0	-78	-1
86 3 1	37	37	0	0	0	-78	0
86 4 1	1	43	0	0	0	-121	-1
86 5 1	0	12	0	0	0	-133	0
86 6 1	13	5	0	0	0	-126	0
86 7 1	162	52	0	0	5	-20	2
86 8 1	1047	98	0	0	949	-9	12
86 9 1	269	102	0	0	218	-57	3
86 10 1	0	65	0	0	0	-124	-2
86 11 1	0	9	0	0	0	-133	0
86 12 1	0	0	0	0	0	-133	0
87 1 1	0	0	0	0	0	-133	0
87 2 1	45	21	0	0	0	-109	1
87 3 1	30	22	0	0	0	-100	0
87 4 1	5	32	0	0	0	-128	-1
87 5 1	0	5	0	0	0	-133	0
87 6 1	18	16	0	0	0	-132	0
87 7 1	96	60	0	0	0	-95	1
87 8 1	239	97	0	0	57	-6	5
87 9 1	516	102	18	0	395	0	5
87 10 1	54	89	-18	0	56	-72	0
87 11 1	62	98	0	0	0	-109	-1
87 12 1	0	20	0	0	0	-130	-1
88 1 1	18	15	0	0	0	-127	0
88 2 1	17	15	0	0	0	-125	0
88 3 1	0	6	0	0	0	-131	0
88 4 1	0	1	0	0	0	-132	0
88 5 1	11	7	0	0	0	-129	0
88 6 1	16	19	0	0	0	-132	0
88 7 1	168	52	0	0	2	-14	3
88 8 1	551	98	6	0	441	0	8
88 9 1	309	101	-6	0	229	-12	4
88 10 1	85	89	0	0	2	-19	0
88 11 1	39	113	0	0	10	-105	-2

Table A.7

CHANGE IN TOTAL WATER BALANCE

yy mm dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86 1 1	0	0	0	0	0	-30	0
86 2 1	0	62	0	0	0	-91	0
86 3 1	37	45	0	0	0	-100	0
86 4 1	1	51	0	0	0	-150	0
86 5 1	0	32	0	0	0	-182	0
86 6 1	13	8	0	0	0	-178	0
86 7 1	162	51	0	0	0	-66	1
86 8 1	1047	98	0	0	902	-9	10
86 9 1	269	102	0	0	218	-55	4
86 10 1	0	84	0	0	0	-140	0
86 11 1	0	39	0	0	0	-179	0
86 12 1	0	4	0	0	0	-183	0
87 1 1	0	1	0	0	0	-184	0
87 2 1	45	19	0	0	0	-158	0
87 3 1	30	20	0	0	0	-148	0
87 4 1	5	32	0	0	0	-174	0
87 5 1	0	9	0	0	0	-183	0
87 6 1	18	16	0	0	0	-182	0
87 7 1	96	54	0	0	0	-140	0
87 8 1	239	97	0	0	10	-9	0
87 9 1	516	102	18	0	392	0	5
87 10 1	54	89	-18	0	55	-71	1
87 11 1	62	116	0	0	0	-125	0
87 12 1	0	48	0	0	0	-174	0
88 1 1	18	19	0	0	0	-175	0
88 2 1	17	15	0	0	0	-173	0
88 3 1	0	8	0	0	0	-182	0
88 4 1	0	3	0	0	0	-184	0
88 5 1	11	7	0	0	0	-181	0
88 6 1	16	18	0	0	0	-184	0
88 7 1	168	50	0	0	0	-65	1
88 8 1	551	98	6	0	389	0	7
88 9 1	309	101	-6	0	230	-13	4
88 10 1	85	89	0	0	2	-19	0
88 11 1	39	120	0	0	10	-111	-1

Table A.8

CHANGE IN TOTAL WATER BALANCE

yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-19	0
86	2	1	0	59	0	0	0	-80	-1
86	3	1	37	40	0	0	0	-83	0
86	4	1	1	44	0	0	0	-127	-1
86	5	1	0	6	0	0	0	-134	0
86	6	1	13	5	0	0	0	-126	0
86	7	1	162	52	0	0	5	-20	2
86	8	1	1047	98	0	0	951	-10	12
86	9	1	269	102	0	0	219	-58	3
86	10	1	0	64	0	0	0	-125	-2
86	11	1	0	9	0	0	0	-134	0
86	12	1	0	0	0	0	0	-135	0
87	1	1	0	0	0	0	0	-135	0
87	2	1	45	25	0	0	0	-114	1
87	3	1	30	24	0	0	0	-107	0
87	4	1	5	28	0	0	0	-131	-1
87	5	1	0	4	0	0	0	-135	0
87	6	1	18	16	0	0	0	-133	0
87	7	1	96	60	0	0	0	-96	1
87	8	1	239	97	0	0	56	-6	5
87	9	1	516	102	15	0	398	0	6
87	10	1	54	89	-15	0	54	-73	0
87	11	1	62	97	0	0	0	-110	-1
87	12	1	0	20	0	0	0	-130	-1
88	1	1	18	15	0	0	0	-127	0
88	2	1	17	15	0	0	0	-126	0
88	3	1	0	5	0	0	0	-131	0
88	4	1	0	1	0	0	0	-132	0
88	5	1	11	7	0	0	0	-129	0
88	6	1	16	18	0	0	0	-132	0
88	7	1	168	52	0	0	2	-15	3
88	8	1	551	98	3	0	443	0	8
88	9	1	309	101	-3	0	228	-13	4
88	10	1	85	89	0	0	1	-19	0
88	11	1	39	113	0	0	10	-106	-3

Table A.9

CHANGE IN TOTAL WATER BALANCE

yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-324	0
86	2	1	0	73	0	0	103	-498	2
86	3	1	37	77	0	0	54	-592	0
86	4	1	1	138	0	0	17	-746	0
86	5	1	0	135	0	0	0	-882	-1
86	6	1	13	83	0	0	0	-953	-1
86	7	1	162	52	0	0	0	-844	0
86	8	1	1047	86	0	0	540	-420	3
86	9	1	269	100	0	0	163	-411	2
86	10	1	0	87	0	0	87	-586	0
86	11	1	0	112	0	0	23	-720	0
86	12	1	0	69	0	0	0	-790	-1
87	1	1	0	46	0	0	0	-837	-1
87	2	1	45	72	0	0	0	-864	0
87	3	1	30	74	0	0	0	-908	0
87	4	1	5	122	0	0	0	-1025	0
87	5	1	0	110	0	0	0	-1136	0
87	6	1	18	70	0	0	0	-1189	0
87	7	1	96	34	0	0	0	-1127	0
87	8	1	239	82	0	0	20	-989	1
87	9	1	516	99	0	0	59	-629	3
87	10	1	54	88	0	0	0	-663	0
87	11	1	62	114	0	0	1	-714	2
87	12	1	0	70	0	0	0	-784	-1
88	1	1	18	47	0	0	0	-813	0
88	2	1	17	71	0	0	0	-869	0
88	3	1	0	77	0	0	0	-946	0
88	4	1	0	117	0	0	0	-1063	0
88	5	1	11	107	0	0	0	-1160	0
88	6	1	16	70	0	0	0	-1214	0
88	7	1	168	43	0	0	0	-1089	0
88	8	1	551	85	0	0	65	-685	3
88	9	1	309	101	0	0	24	-500	1
88	10	1	85	88	0	0	47	-548	2
88	11	1	39	115	0	0	35	-659	0

Table A.10

CHANGE IN TOTAL WATER BALANCE

yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-158	0
86	2	1	0	73	0	0	40	-269	2
86	3	1	37	78	0	0	0	-310	0
86	4	1	1	144	0	0	0	-453	-1
86	5	1	0	133	0	0	0	-587	0
86	6	1	13	72	0	0	0	-646	0
86	7	1	162	41	0	0	0	-526	0
86	8	1	1047	84	0	0	589	-150	2
86	9	1	269	101	0	0	257	-236	2
86	10	1	0	89	0	0	1	-325	0
86	11	1	0	115	0	0	0	-441	-1
86	12	1	0	69	0	0	0	-510	0
87	1	1	0	45	0	0	0	-555	0
87	2	1	45	70	0	0	0	-580	0
87	3	1	30	70	0	0	0	-620	0
87	4	1	5	98	0	0	0	-713	0
87	5	1	0	76	0	0	0	-789	0
87	6	1	18	55	0	0	0	-827	0
87	7	1	96	27	0	0	0	-758	0
87	8	1	239	76	0	0	14	-609	1
87	9	1	516	96	0	0	51	-238	3
87	10	1	54	89	0	0	5	-277	1
87	11	1	62	118	0	0	0	-333	0
87	12	1	0	72	0	0	0	-406	0
88	1	1	18	48	0	0	0	-436	0
88	2	1	17	72	0	0	0	-491	0
88	3	1	0	76	0	0	0	-567	0
88	4	1	0	107	0	0	0	-675	0
88	5	1	11	88	0	0	0	-752	0
88	6	1	16	59	0	0	0	-796	0
88	7	1	168	34	0	0	0	-662	0
88	8	1	551	83	0	0	56	-247	3
88	9	1	309	101	0	0	147	-186	0
88	10	1	85	89	0	0	24	-215	-1
88	11	1	39	119	0	0	15	-308	2

Table A.11

CHANGE IN TOTAL WATER BALANCE

yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-323	0
86	2	1	0	73	0	0	20	-413	3
86	3	1	37	77	0	0	0	-455	-2
86	4	1	1	140	0	0	0	-595	-1
86	5	1	0	124	0	0	0	-719	-1
86	6	1	13	66	0	0	0	-773	0
86	7	1	162	33	0	0	0	-644	1
86	8	1	1047	82	0	0	419	-93	4
86	9	1	269	101	0	0	319	-244	0
86	10	1	0	89	0	0	65	-398	-1
86	11	1	0	117	0	0	0	-515	0
86	12	1	0	69	0	0	0	-585	0
87	1	1	0	45	0	0	0	-630	0
87	2	1	45	70	0	0	0	-655	0
87	3	1	30	70	0	0	0	-694	0
87	4	1	5	96	0	0	0	-786	0
87	5	1	0	69	0	0	0	-855	0
87	6	1	18	51	0	0	0	-888	0
87	7	1	96	26	0	0	0	-818	0
87	8	1	239	74	0	0	0	-652	1
87	9	1	516	97	0	0	10	-244	1
87	10	1	54	89	0	0	97	-374	2
87	11	1	62	118	0	0	2	-432	1
87	12	1	0	72	0	0	0	-505	-1
88	1	1	18	47	0	0	0	-534	0
88	2	1	17	72	0	0	0	-590	0
88	3	1	0	75	0	0	0	-665	0
88	4	1	0	102	0	0	0	-768	0
88	5	1	11	77	0	0	0	-835	0
88	6	1	16	54	0	0	0	-873	0
88	7	1	168	29	0	0	0	-734	0
88	8	1	551	82	0	0	17	-280	2
88	9	1	309	101	0	0	185	-258	0
88	10	1	85	89	0	0	71	-334	-1
88	11	1	39	118	0	0	26	-438	2

Table A.12

CHANGE IN TOTAL WATER BALANCE

yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-67	0
86	2	1	0	73	0	0	1	-141	0
86	3	1	37	78	0	0	0	-183	-1
86	4	1	1	143	0	0	0	-327	-3
86	5	1	0	115	0	0	0	-444	-2
86	6	1	13	61	0	0	0	-493	-1
86	7	1	162	33	0	0	0	-363	2
86	8	1	1047	82	0	0	645	-32	11
86	9	1	269	101	0	0	229	-92	2
86	10	1	0	89	0	0	0	-182	-1
86	11	1	0	116	0	0	0	-300	-2
86	12	1	0	66	0	0	0	-367	-1
87	1	1	0	43	0	0	0	-410	-1
87	2	1	45	65	0	0	0	-431	0
87	3	1	30	61	0	0	0	-462	0
87	4	1	5	70	0	0	0	-527	-1
87	5	1	0	44	0	0	0	-572	-1
87	6	1	18	35	0	0	0	-590	0
87	7	1	96	21	0	0	0	-515	0
87	8	1	239	75	0	0	11	-359	3
87	9	1	516	98	0	0	75	-12	5
87	10	1	54	89	0	0	65	-110	1
87	11	1	62	120	0	0	0	-169	-1
87	12	1	0	73	0	0	0	-244	-1
88	1	1	18	48	0	0	0	-274	0
88	2	1	17	72	0	0	0	-330	-1
88	3	1	0	73	0	0	0	-404	-1
88	4	1	0	88	0	0	0	-493	-1
88	5	1	11	61	0	0	0	-545	-1
88	6	1	16	46	0	0	0	-576	0
88	7	1	168	25	0	0	0	-432	1
88	8	1	551	82	0	0	70	-27	7
88	9	1	309	101	0	0	225	-42	2
88	10	1	85	89	0	0	13	-62	-2
88	11	1	39	120	0	0	15	-158	1

Table A.13

CHANGE IN TOTAL WATER BALANCE

yy mm dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86 1 1	0	0	0	0	0	-136	0
86 2 1	0	73	0	0	1	-209	1
86 3 1	37	78	0	0	0	-252	-2
86 4 1	1	143	0	0	0	-396	-3
86 5 1	0	107	0	0	0	-505	-2
86 6 1	13	54	0	0	0	-546	-1
86 7 1	162	28	0	0	0	-411	2
86 8 1	1047	82	0	0	602	-37	10
86 9 1	269	102	0	0	251	-118	2
86 10 1	0	90	0	0	6	-213	1
86 11 1	0	118	0	0	0	-335	-4
86 12 1	0	68	0	0	0	-404	-1
87 1 1	0	43	0	0	0	-448	-1
87 2 1	45	65	0	0	0	-468	0
87 3 1	30	59	0	0	0	-496	0
87 4 1	5	62	0	0	0	-554	-1
87 5 1	0	31	0	0	0	-586	0
87 6 1	18	29	0	0	0	-597	0
87 7 1	96	20	0	0	0	-520	1
87 8 1	239	78	0	0	0	-357	3
87 9 1	516	100	6	0	57	0	4
87 10 1	54	89	-6	0	117	-145	1
87 11 1	62	121	0	0	0	-203	0
87 12 1	0	74	0	0	0	-282	-4
88 1 1	18	49	0	0	0	-313	-1
88 2 1	17	72	0	0	0	-370	-1
88 3 1	0	74	0	0	0	-445	-1
88 4 1	0	83	0	0	0	-530	-1
88 5 1	11	50	0	0	0	-570	-1
88 6 1	16	35	0	0	0	-590	0
88 7 1	168	21	0	0	0	-441	2
88 8 1	551	82	0	0	50	-18	5
88 9 1	309	101	0	0	251	-60	2
88 10 1	85	89	0	0	47	-111	1
88 11 1	39	121	0	0	19	-212	0

Table A.14

CHANGE IN TOTAL WATER BALANCE

yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-23	0
86	2	1	0	74	0	0	0	-96	1
86	3	1	37	76	0	0	0	-135	0
86	4	1	1	84	0	0	0	-218	0
86	5	1	0	23	0	0	0	-241	0
86	6	1	13	9	0	0	0	-238	0
86	7	1	162	27	0	0	0	-103	1
86	8	1	1047	88	0	0	880	-15	9
86	9	1	269	101	0	0	218	-61	3
86	10	1	0	86	0	0	0	-148	-1
86	11	1	0	69	0	0	0	-217	0
86	12	1	0	19	0	0	0	-236	0
87	1	1	0	6	0	0	0	-243	0
87	2	1	45	28	0	0	0	-225	0
87	3	1	30	25	0	0	0	-220	0
87	4	1	5	24	0	0	0	-239	0
87	5	1	0	7	0	0	0	-246	0
87	6	1	18	16	0	0	0	-244	0
87	7	1	96	18	0	0	0	-165	0
87	8	1	239	86	0	0	22	-33	2
87	9	1	516	102	10	0	376	0	6
87	10	1	54	89	-10	0	52	-76	1
87	11	1	62	116	0	0	0	-130	-1
87	12	1	0	59	0	0	0	-190	-1
88	1	1	18	34	0	0	0	-206	0
88	2	1	17	35	0	0	0	-225	0
88	3	1	0	14	0	0	0	-239	0
88	4	1	0	6	0	0	0	-246	0
88	5	1	11	9	0	0	0	-245	0
88	6	1	16	16	0	0	0	-245	0
88	7	1	168	21	0	0	0	-97	2
88	8	1	551	89	0	0	372	-1	6
88	9	1	309	101	0	0	228	-18	4
88	10	1	85	89	0	0	1	-24	-1
88	11	1	39	119	0	0	10	-115	-1

Table A.15

CHANGE IN TOTAL WATER BALANCE

yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-37	0
86	2	1	0	74	0	0	0	-111	0
86	3	1	37	76	0	0	0	-150	0
86	4	1	1	75	0	0	0	-224	-1
86	5	1	0	12	0	0	0	-237	0
86	6	1	13	8	0	0	0	-232	0
86	7	1	162	33	0	0	0	-102	1
86	8	1	1047	90	0	0	879	-16	9
86	9	1	269	102	0	0	221	-65	3
86	10	1	0	87	0	0	0	-154	-1
86	11	1	0	66	0	0	0	-221	-1
86	12	1	0	14	0	0	0	-235	0
87	1	1	0	4	0	0	0	-239	0
87	2	1	45	30	0	0	0	-224	0
87	3	1	30	25	0	0	0	-218	0
87	4	1	5	21	0	0	0	-235	0
87	5	1	0	5	0	0	0	-240	0
87	6	1	18	16	0	0	0	-238	0
87	7	1	96	18	0	0	0	-159	1
87	8	1	239	91	0	0	12	-22	2
87	9	1	516	102	10	0	387	0	6
87	10	1	54	89	-10	0	56	-79	1
87	11	1	62	118	0	0	0	-136	0
87	12	1	0	60	0	0	0	-196	0
88	1	1	18	33	0	0	0	-212	0
88	2	1	17	32	0	0	0	-227	0
88	3	1	0	10	0	0	0	-237	0
88	4	1	0	4	0	0	0	-240	0
88	5	1	11	10	0	0	0	-240	0
88	6	1	16	15	0	0	0	-239	0
88	7	1	168	27	0	0	0	-97	1
88	8	1	551	92	0	0	370	-2	6
88	9	1	309	101	0	0	229	-19	4
88	10	1	85	89	0	0	5	-29	0
88	11	1	39	120	0	0	11	-122	0

Table A.16

CHANGE IN TOTAL WATER BALANCE

yy mm dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86 1 1	0	0	0	0	0	-46	0
86 2 1	0	74	0	0	0	-120	0
86 3 1	37	75	0	0	0	-158	0
86 4 1	1	69	0	0	0	-227	-1
86 5 1	0	12	0	0	0	-239	0
86 6 1	13	7	0	0	0	-234	0
86 7 1	162	34	0	0	0	-105	2
86 8 1	1047	91	0	0	876	-17	8
86 9 1	269	102	0	0	223	-68	3
86 10 1	0	88	0	0	0	-157	-1
86 11 1	0	65	0	0	0	-223	-1
86 12 1	0	13	0	0	0	-236	0
87 1 1	0	4	0	0	0	-239	0
87 2 1	45	28	0	0	0	-222	0
87 3 1	30	25	0	0	0	-217	0
87 4 1	5	23	0	0	0	-235	0
87 5 1	0	6	0	0	0	-241	0
87 6 1	18	15	0	0	0	-239	0
87 7 1	96	18	0	0	0	-160	1
87 8 1	239	93	0	0	14	-26	2
87 9 1	516	102	10	0	382	0	6
87 10 1	54	89	-10	0	59	-83	1
87 11 1	62	119	0	0	0	-141	-1
87 12 1	0	59	0	0	0	-201	-1
88 1 1	18	31	0	0	0	-214	0
88 2 1	17	29	0	0	0	-227	0
88 3 1	0	10	0	0	0	-237	0
88 4 1	0	4	0	0	0	-241	0
88 5 1	11	8	0	0	0	-239	0
88 6 1	16	17	0	0	0	-240	0
88 7 1	168	29	0	0	0	-99	2
88 8 1	551	94	0	0	366	-2	6
88 9 1	309	101	0	0	229	-20	4
88 10 1	85	89	0	0	8	-33	0
88 11 1	39	121	0	0	12	-128	-1

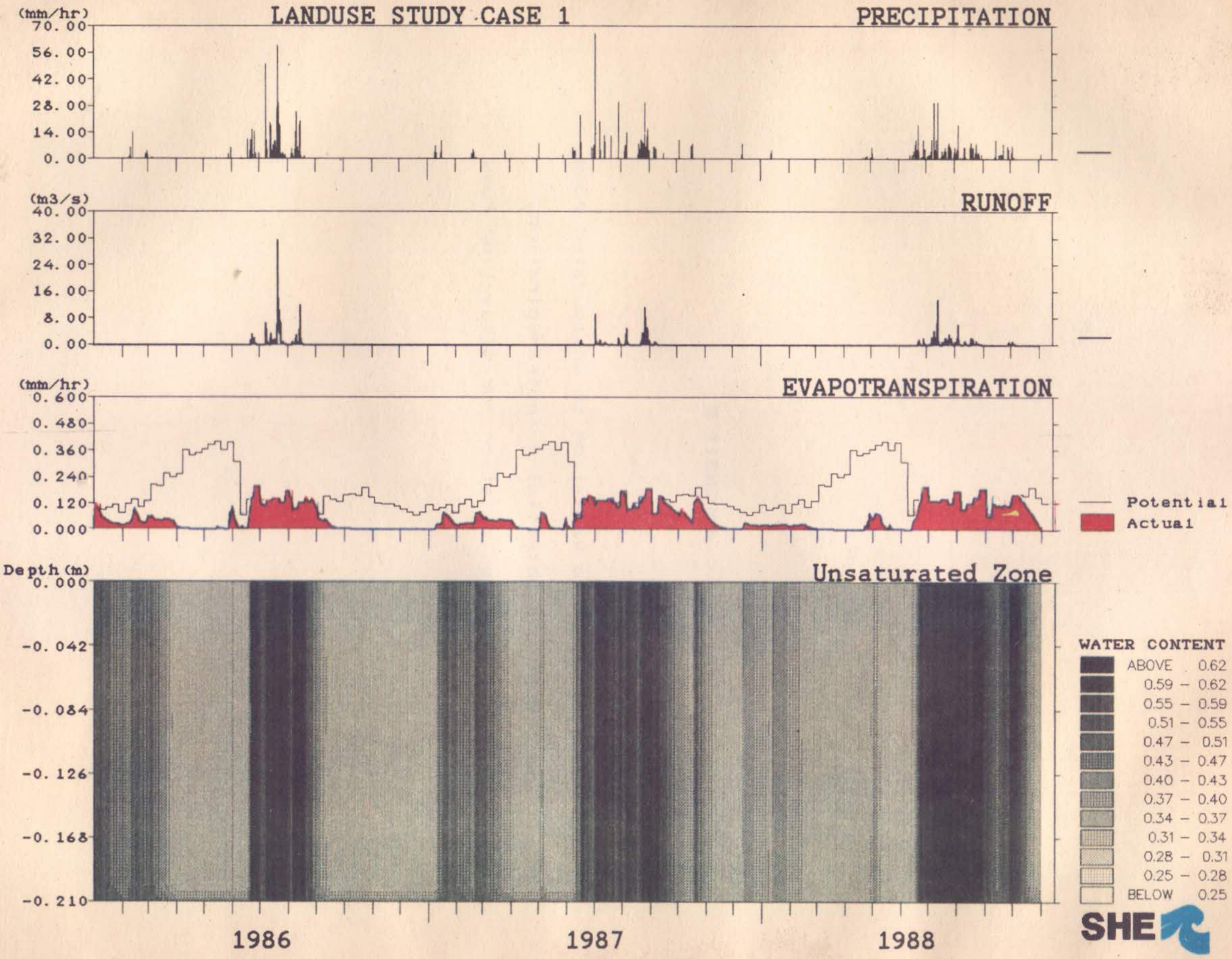
Table A.17

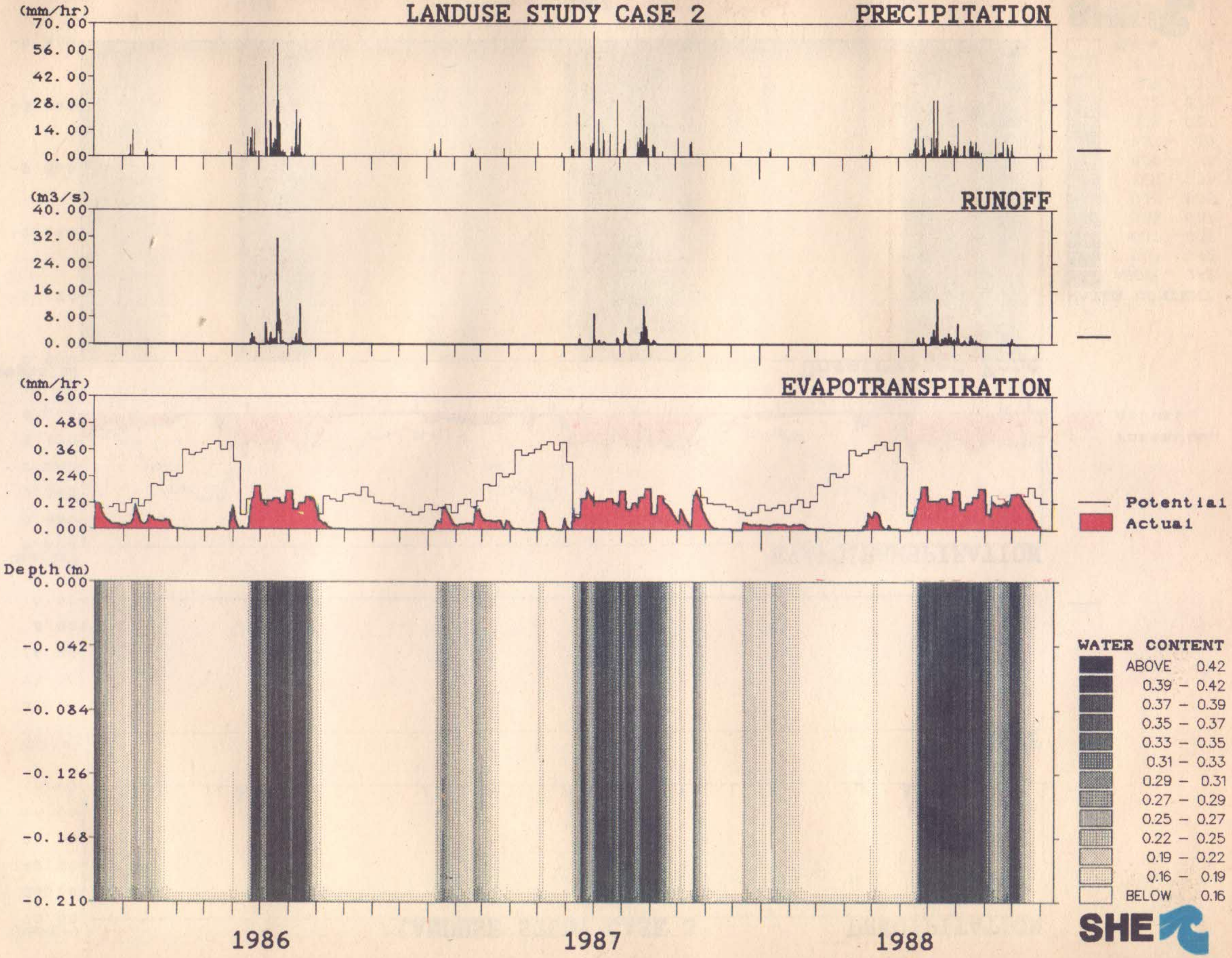
CHANGE IN TOTAL WATER BALANCE

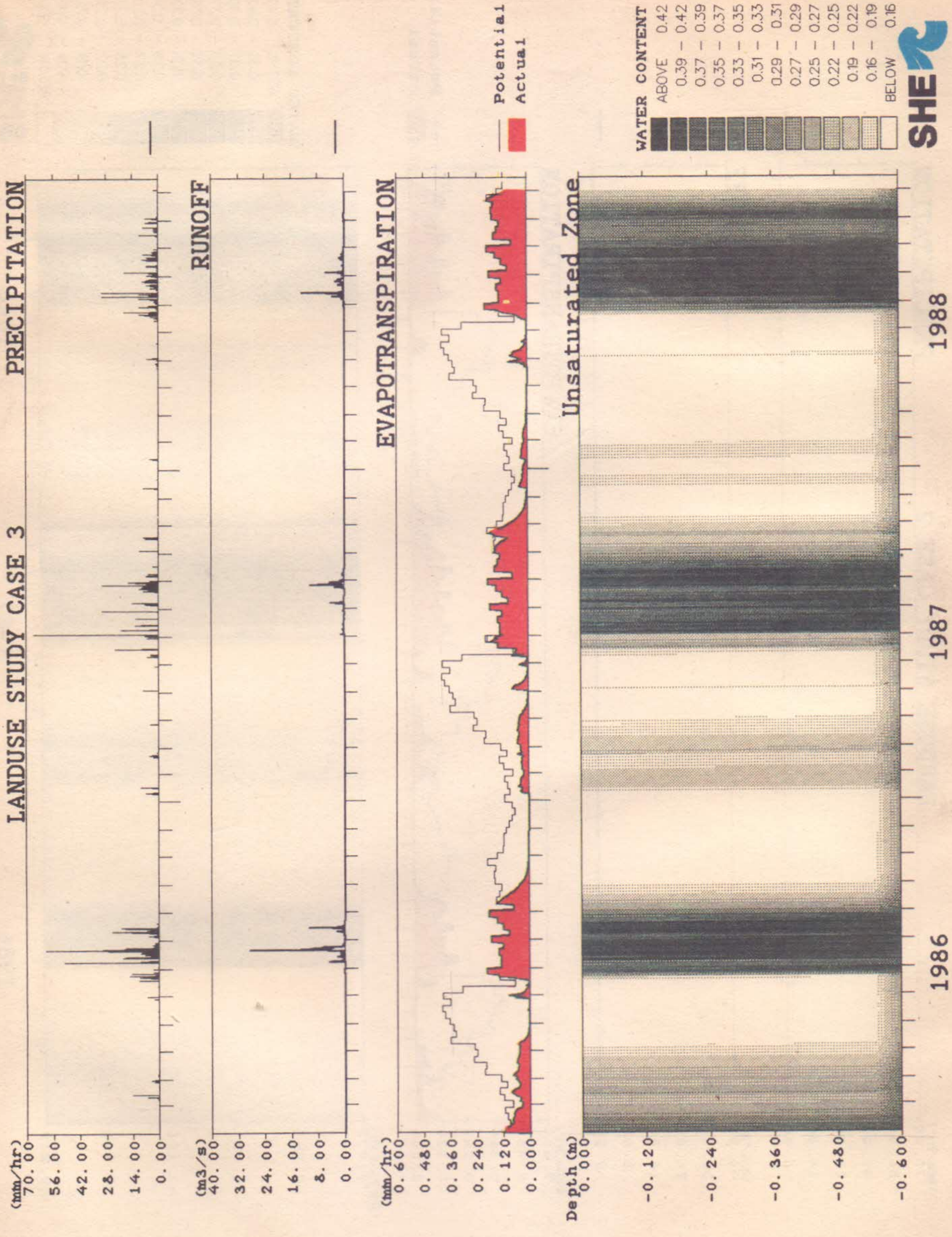
yy	mm	dd	R F	Evap.	H-O F	H-Riv	Riv.fl	Thuz	Wblerr
86	1	1	0	0	0	0	0	-324	0
86	2	1	0	54	0	0	105	-481	3
86	3	1	37	49	0	0	61	-554	-1
86	4	1	1	87	0	0	31	-672	0
86	5	1	0	120	0	0	2	-794	-1
86	6	1	13	164	0	0	0	-947	-1
86	7	1	162	105	-1	0	0	-890	-1
86	8	1	1047	97	0	0	531	-465	6
86	9	1	269	100	0	0	139	-433	2
86	10	1	0	87	0	0	78	-598	0
86	11	1	0	112	0	0	18	-729	-1
86	12	1	0	83	0	0	0	-813	-1
87	1	1	0	59	0	0	0	-872	-1
87	2	1	45	49	0	0	0	-877	0
87	3	1	30	41	0	0	0	-888	0
87	4	1	5	70	0	0	0	-953	0
87	5	1	0	96	0	0	0	-1049	0
87	6	1	18	135	0	0	0	-1167	0
87	7	1	96	89	0	0	0	-1161	0
87	8	1	238	93	0	0	17	-1031	1
87	9	1	516	98	0	0	56	-667	3
87	10	1	54	88	-1	0	0	-698	2
87	11	1	61	114	-1	0	0	-750	0
87	12	1	0	83	-1	0	0	-834	-1
88	1	1	18	59	-1	0	0	-875	-1
88	2	1	17	48	-1	0	0	-907	0
88	3	1	0	39	-1	0	0	-947	0
88	4	1	0	63	-1	0	0	-1010	0
88	5	1	11	94	-1	0	0	-1094	0
88	6	1	16	129	-1	0	0	-1208	0
88	7	1	168	95	-1	0	0	-1135	0
88	8	1	551	96	0	0	59	-739	2
88	9	1	309	101	0	0	17	-546	1
88	10	1	85	88	0	0	28	-575	2
88	11	1	39	115	0	0	24	-676	0

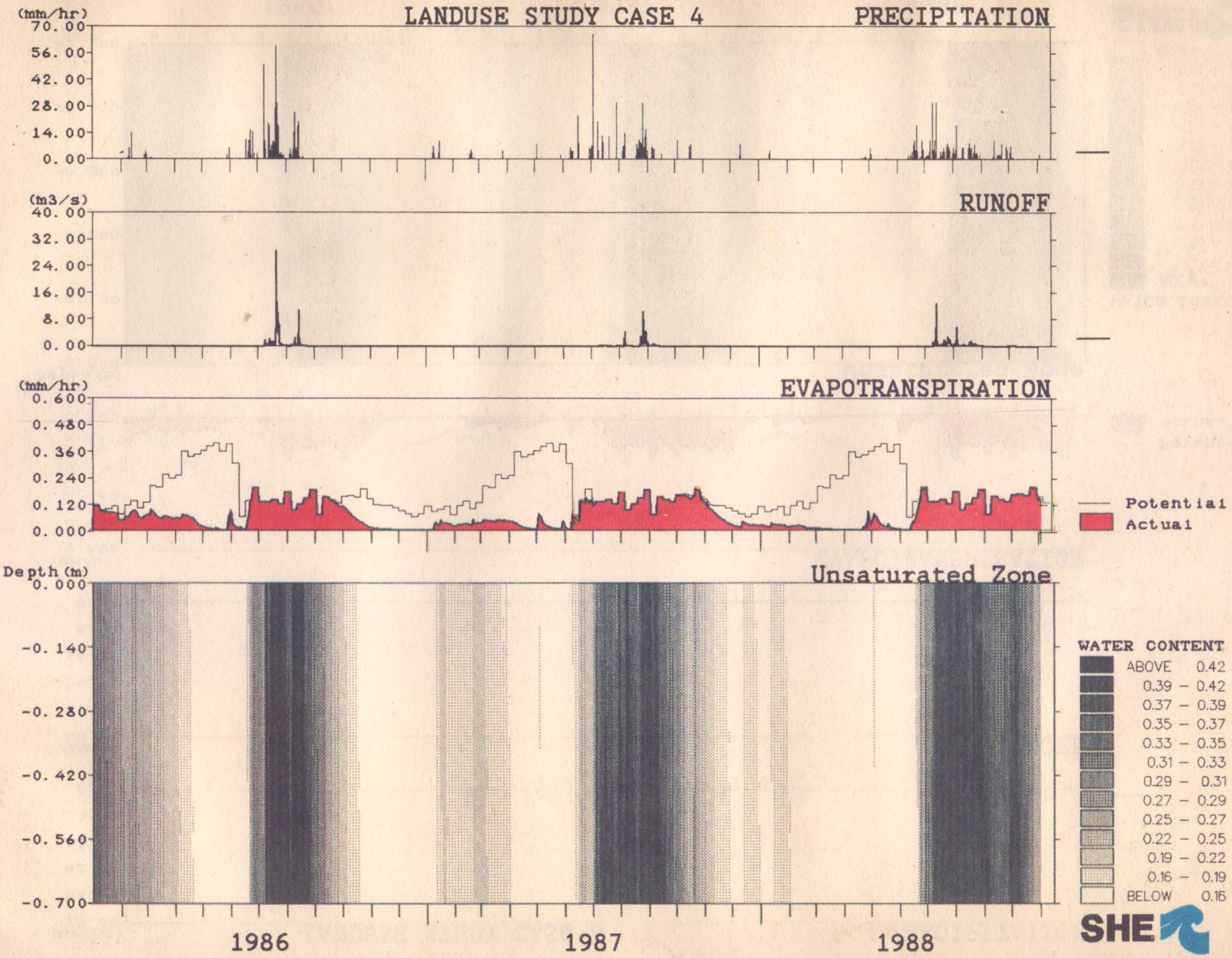
APPENDIX B

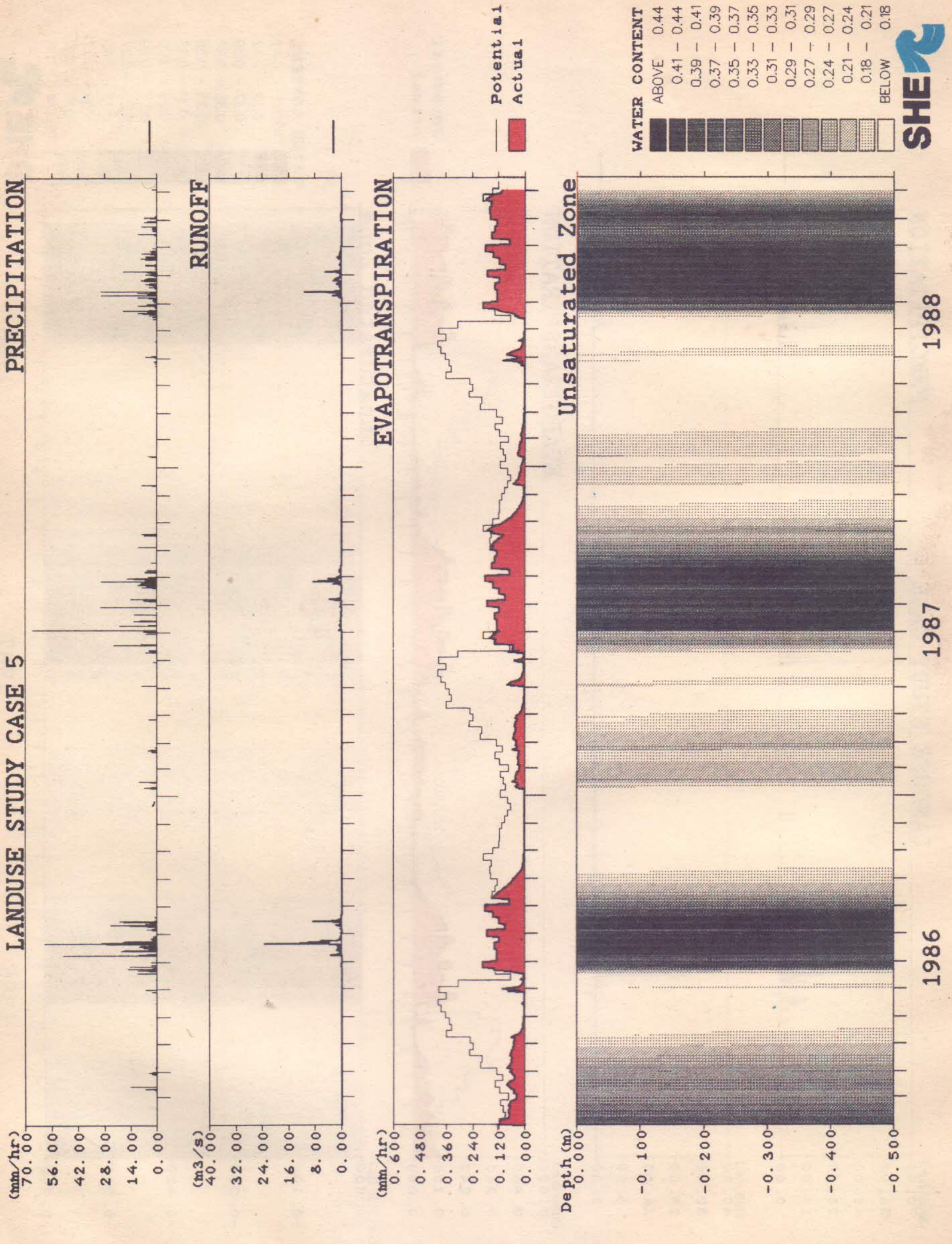
Plots of moisture variation in unsaturated zone, actual and potential evapotranspiration, runoff, and precipitation for simulation runs

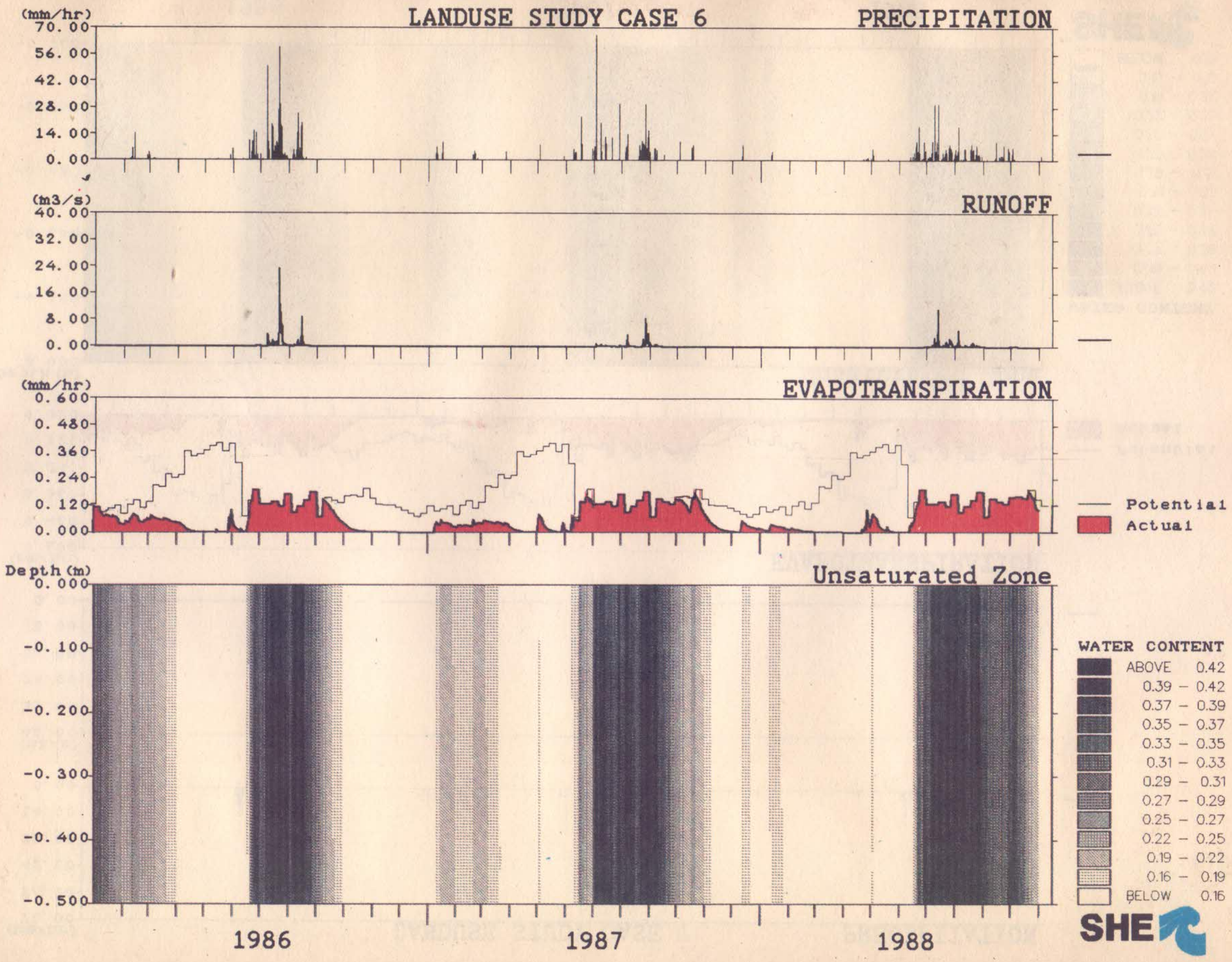

LANDUSE STUDY CASE 1


LANDUSE STUDY CASE 2
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
40.00
32.00
24.00
16.00
8.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Depth (m)
0.000
-0.042
-0.084
-0.126
-0.168
-0.210
1986
1987
1988
WATER CONTENT
ABOVE 0.42
0.39 – 0.42
0.37 – 0.39
0.35 – 0.37
0.33 – 0.35
0.31 – 0.33
0.29 – 0.31
0.27 – 0.29
0.25 – 0.27
0.22 – 0.25
0.19 – 0.22
0.16 – 0.19
BELOW 0.16
SHE

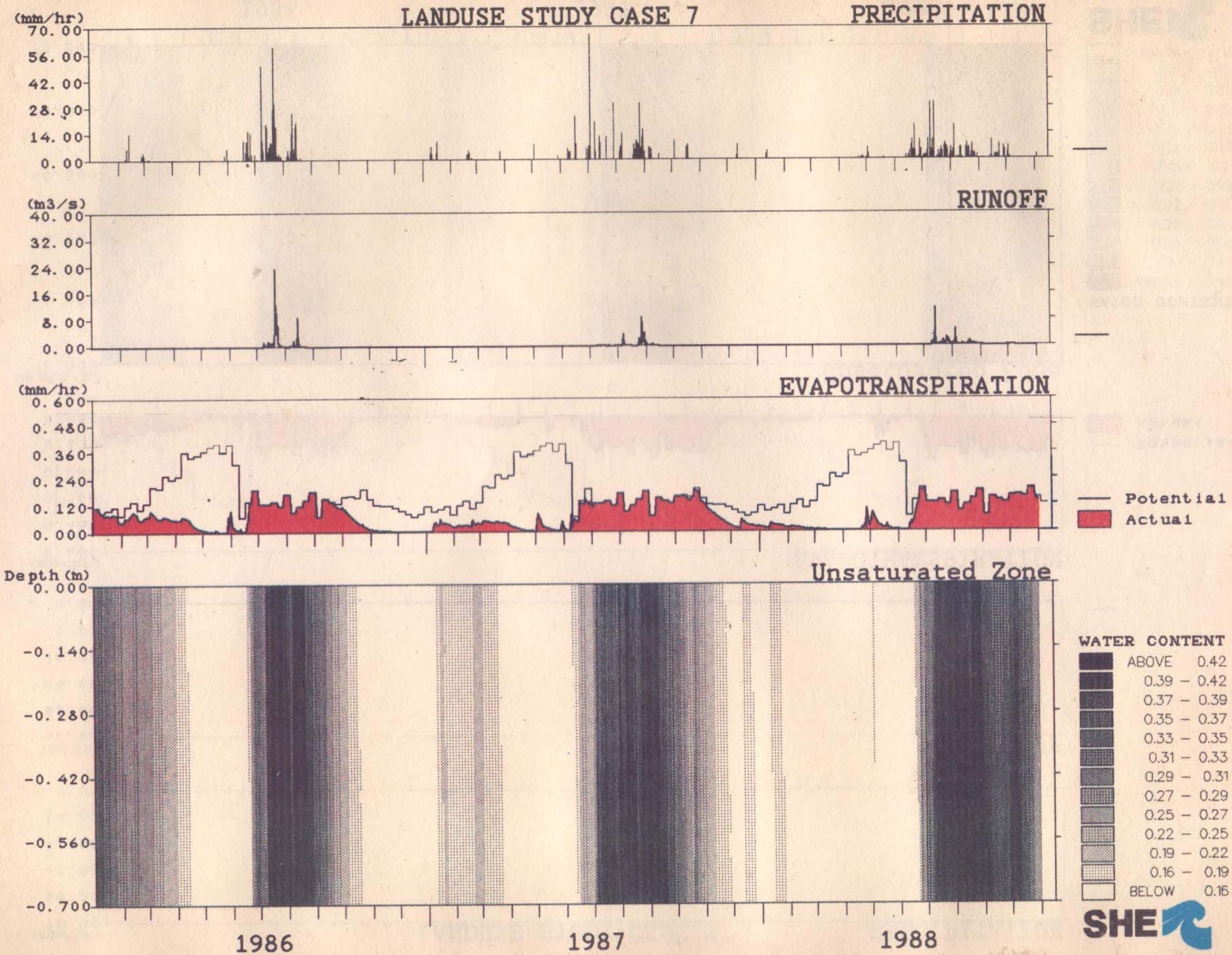

LANDUSE STUDY CASE 3
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
40.00
32.00
24.00
16.00
8.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Unsaturated Zone
Depth (m)
0.000
-0.120
-0.240
-0.360
-0.480
-0.600
WATER CONTENT
ABOVE 0.42
0.39 – 0.42
0.37 – 0.39
0.35 – 0.37
0.33 – 0.35
0.31 – 0.33
0.29 – 0.31
0.27 – 0.29
0.25 – 0.27
0.22 – 0.25
0.19 – 0.22
0.16 – 0.19
BELOW 0.16
SHE
1986
1987
1988

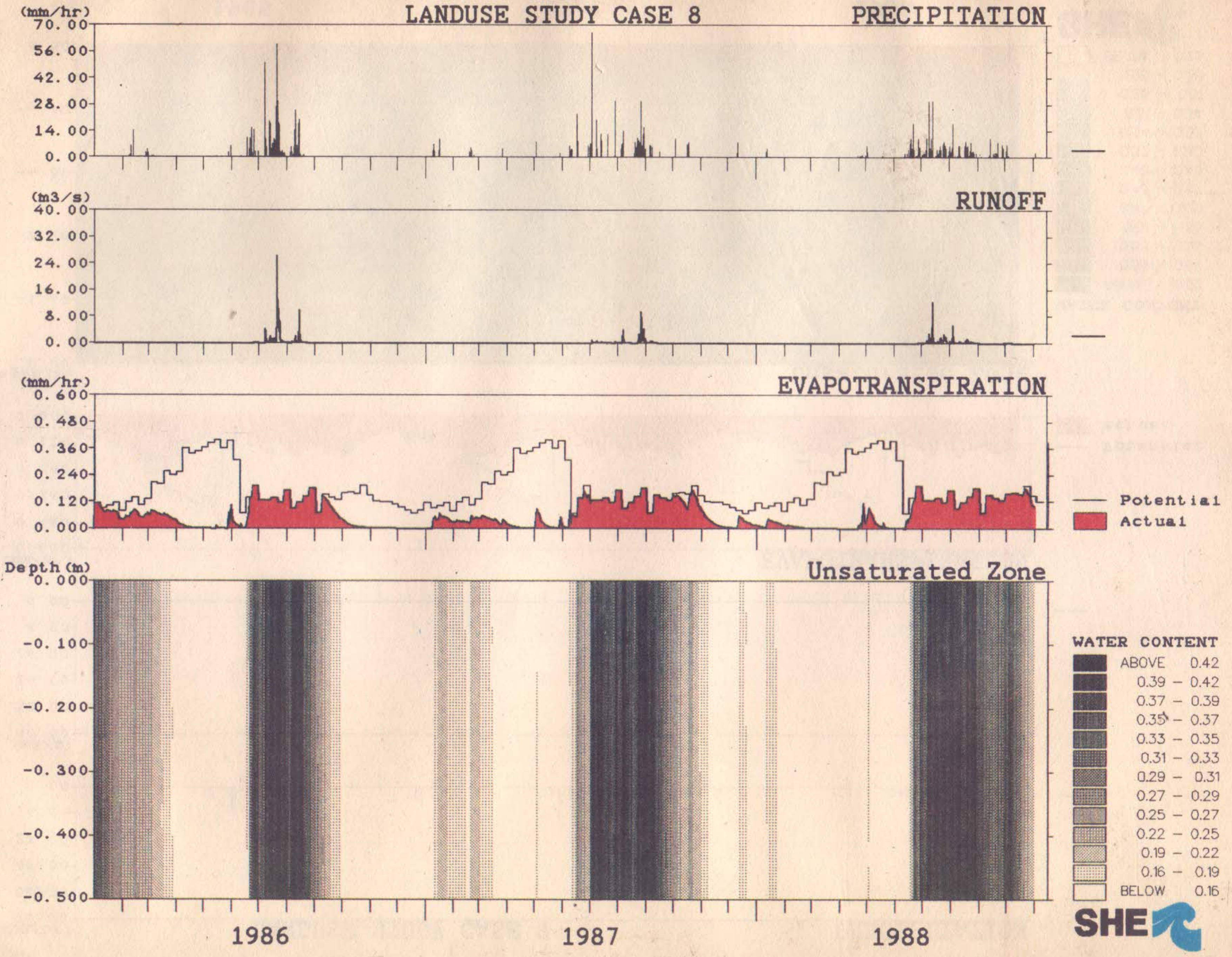

LANDUSE STUDY CASE 4
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
40.00
32.00
24.00
16.00
8.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Unsaturated Zone
Depth (m)
0.000
-0.140
-0.280
-0.420
-0.560
-0.700
1986
1987
1988
WATER CONTENT
ABOVE 0.42
0.39 – 0.42
0.37 – 0.39
0.35 – 0.37
0.33 – 0.35
0.31 – 0.33
0.29 – 0.31
0.27 – 0.29
0.25 – 0.27
0.22 – 0.25
0.19 – 0.22
0.16 – 0.19
BELOW 0.16
SHE

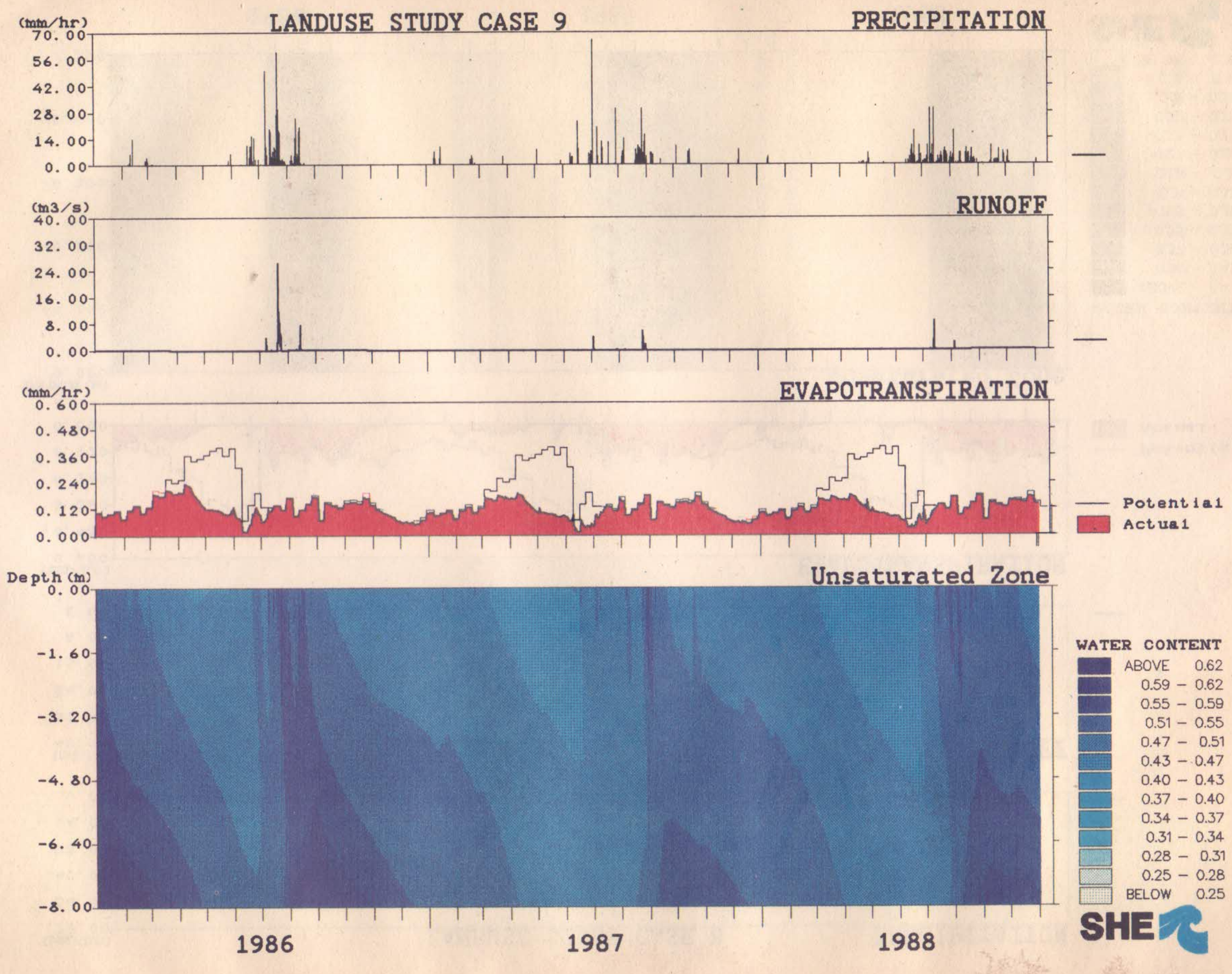

LANDUSE STUDY CASE 5

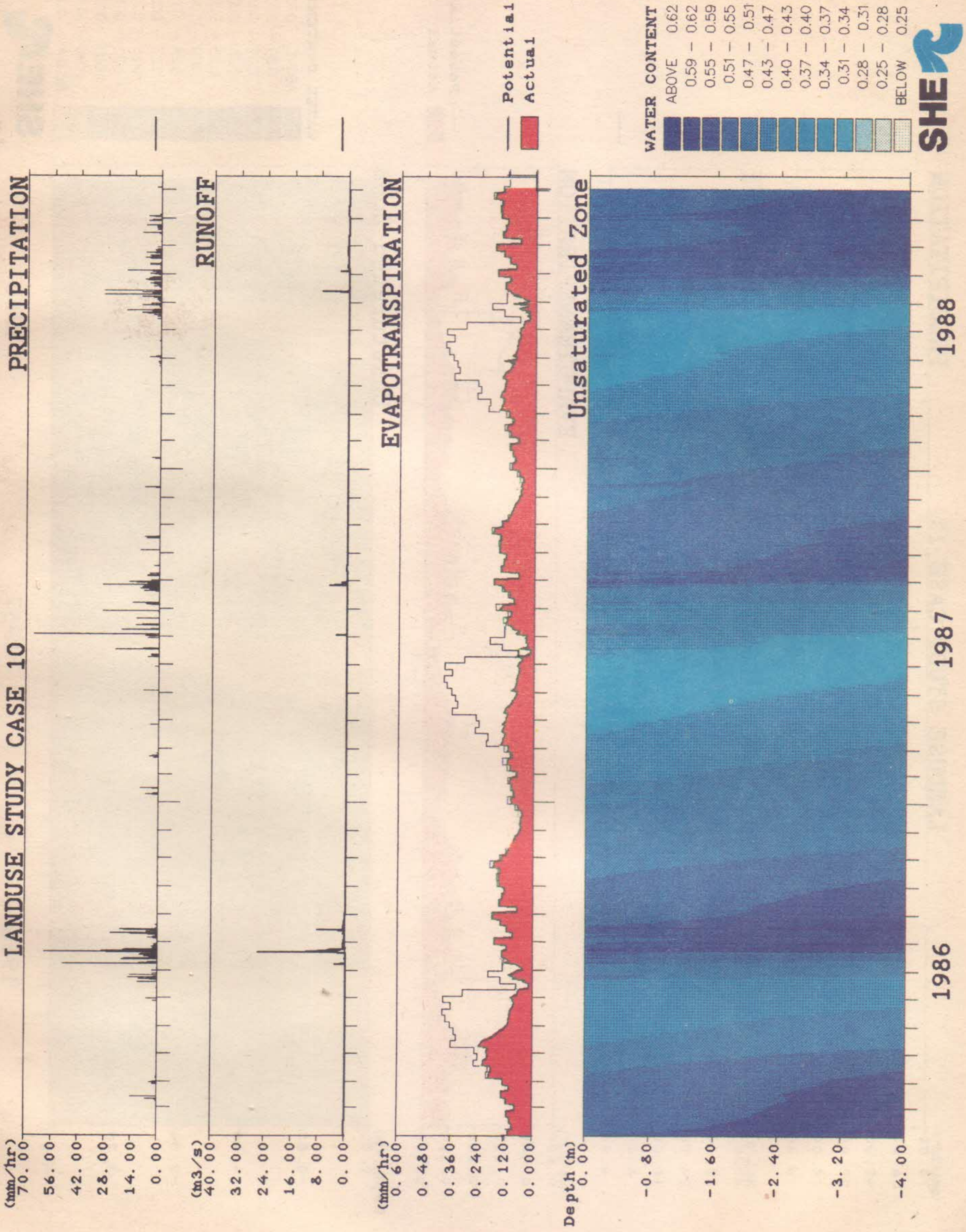

LANDUSE STUDY CASE 6
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
40.00
32.00
24.00
16.00
8.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Unsaturated Zone
Depth (m)
0.000
-0.100
-0.200
-0.300
-0.400
-0.500
1986
1987
1988
WATER CONTENT
ABOVE 0.42
0.39 - 0.42
0.37 - 0.39
0.35 - 0.37
0.33 - 0.35
0.31 - 0.33
0.29 - 0.31
0.27 - 0.29
0.25 - 0.27
0.22 - 0.25
0.19 - 0.22
0.16 - 0.19
BELOW 0.16
SHE

LANDUSE STUDY CASE 7

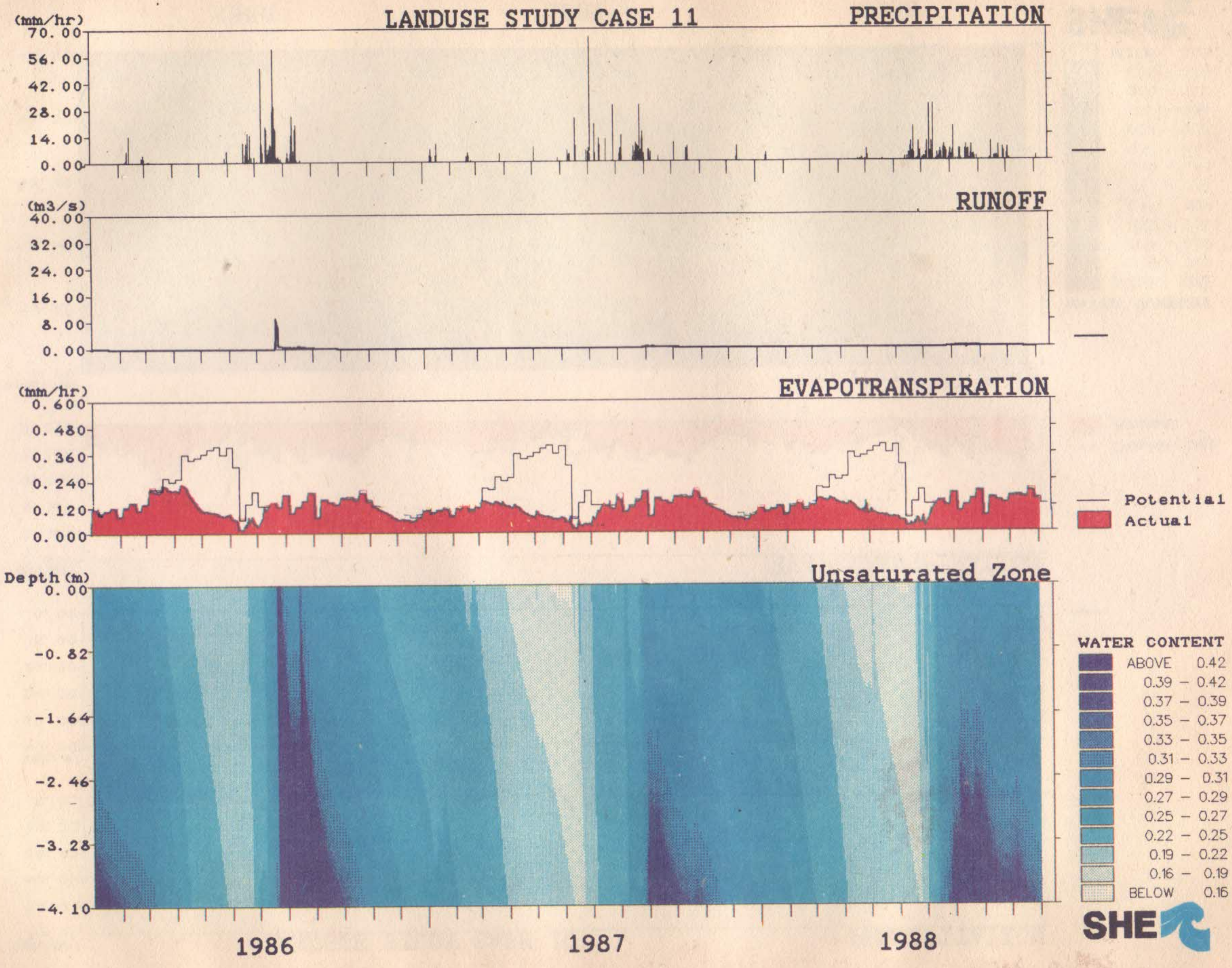



LANDUSE STUDY CASE 8
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
40.00
32.00
24.00
16.00
8.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Unsaturated Zone
Depth (m)
0.000
-0.100
-0.200
-0.300
-0.400
-0.500
1986
1987
1988
WATER CONTENT
ABOVE 0.42
0.39 – 0.42
0.37 – 0.39
0.35 – 0.37
0.33 – 0.35
0.31 – 0.33
0.29 – 0.31
0.27 – 0.29
0.25 – 0.27
0.22 – 0.25
0.19 – 0.22
0.16 – 0.19
BELOW 0.16
SHE

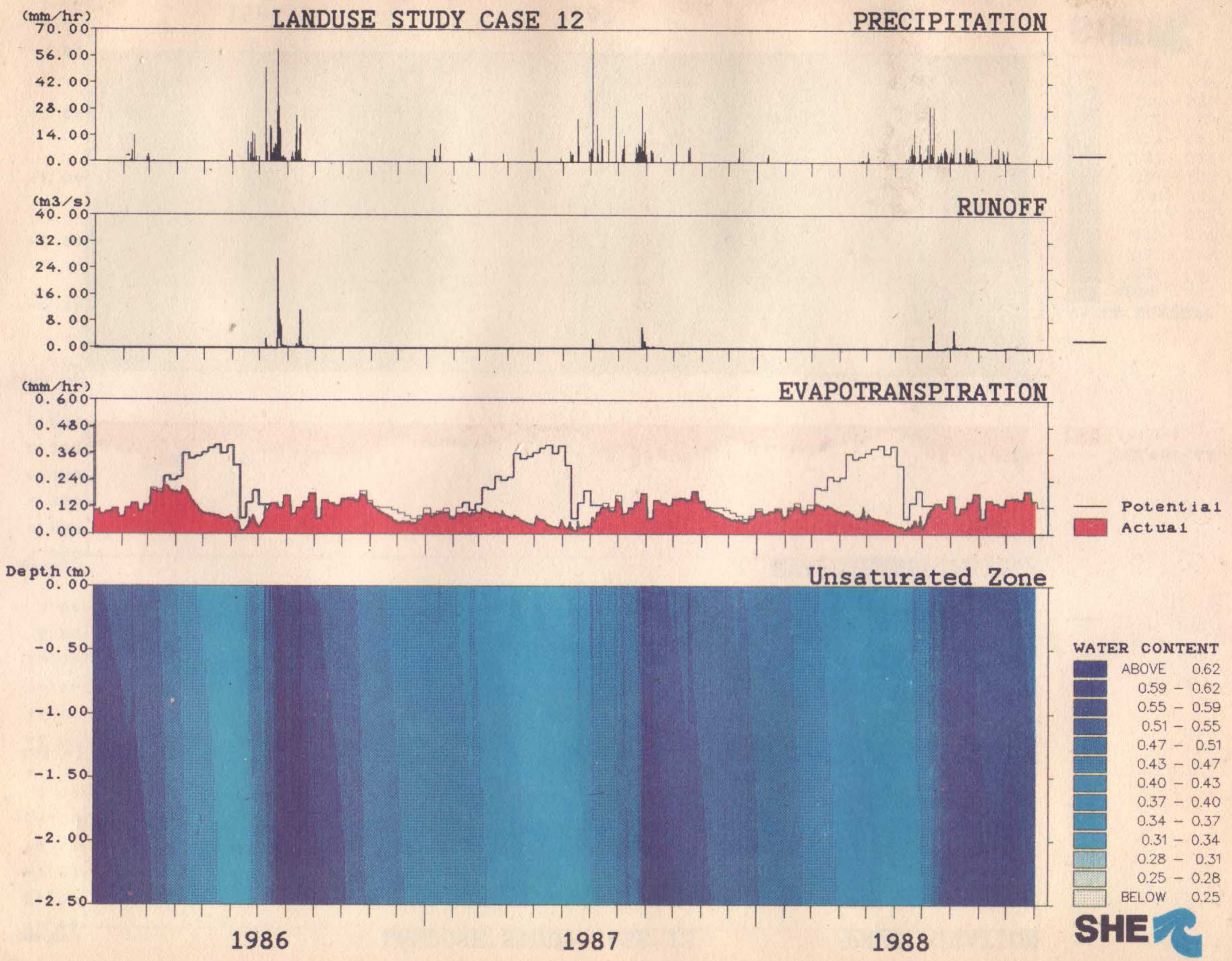

LANDUSE STUDY CASE 9
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
40.00
32.00
24.00
16.00
8.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Unsaturated Zone
Depth (m)
0.00
-1.60
-3.20
-4.80
-6.40
-8.00
1986
1987
1988
WATER CONTENT
ABOVE 0.62
0.59 – 0.62
0.55 – 0.59
0.51 – 0.55
0.47 – 0.51
0.43 – 0.47
0.40 – 0.43
0.37 – 0.40
0.34 – 0.37
0.31 – 0.34
0.28 – 0.31
0.25 – 0.28
BELOW 0.25
SHE

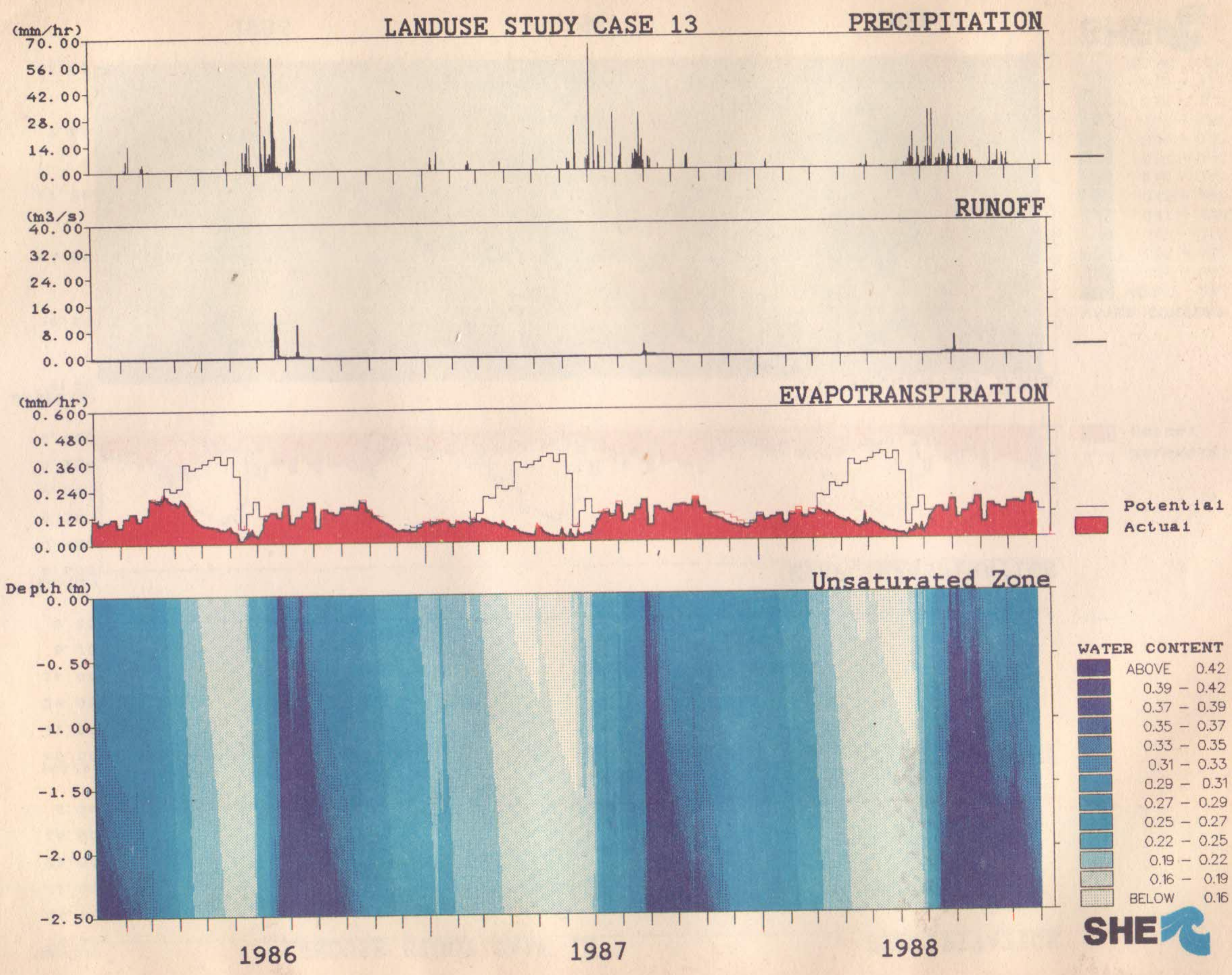

LANDUSE STUDY CASE 10
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
40.00
32.00
24.00
16.00
8.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Unsaturated Zone
Depth (m)
0.00
-0.80
-1.60
-2.40
-3.20
-4.00
1986
1987
1988
WATER CONTENT
ABOVE 0.62
0.59 – 0.62
0.55 – 0.59
0.51 – 0.55
0.47 – 0.51
0.43 – 0.47
0.40 – 0.43
0.37 – 0.40
0.34 – 0.37
0.31 – 0.34
0.28 – 0.31
0.25 – 0.28
BELOW 0.25
SHE

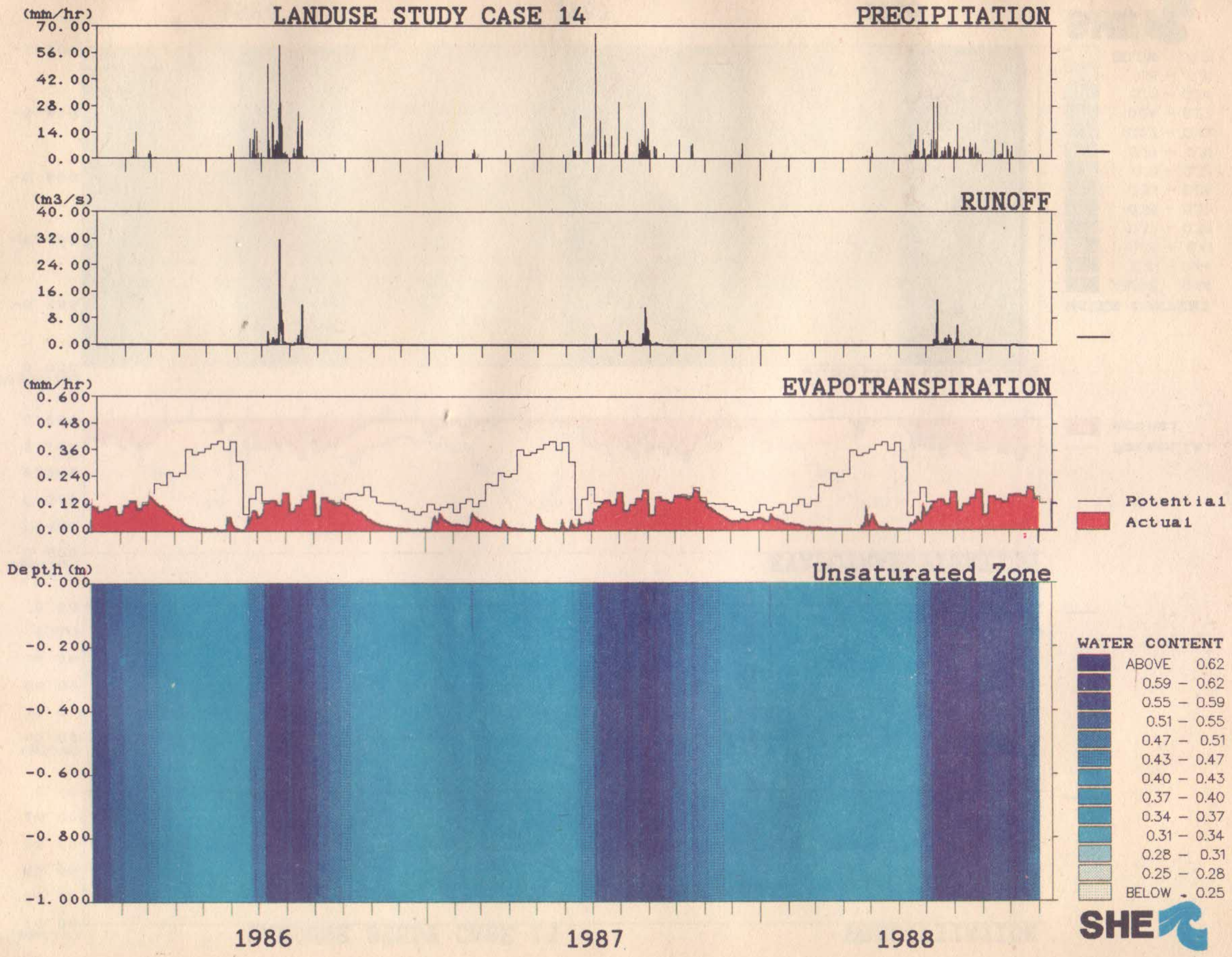
LANDUSE STUDY CASE 11

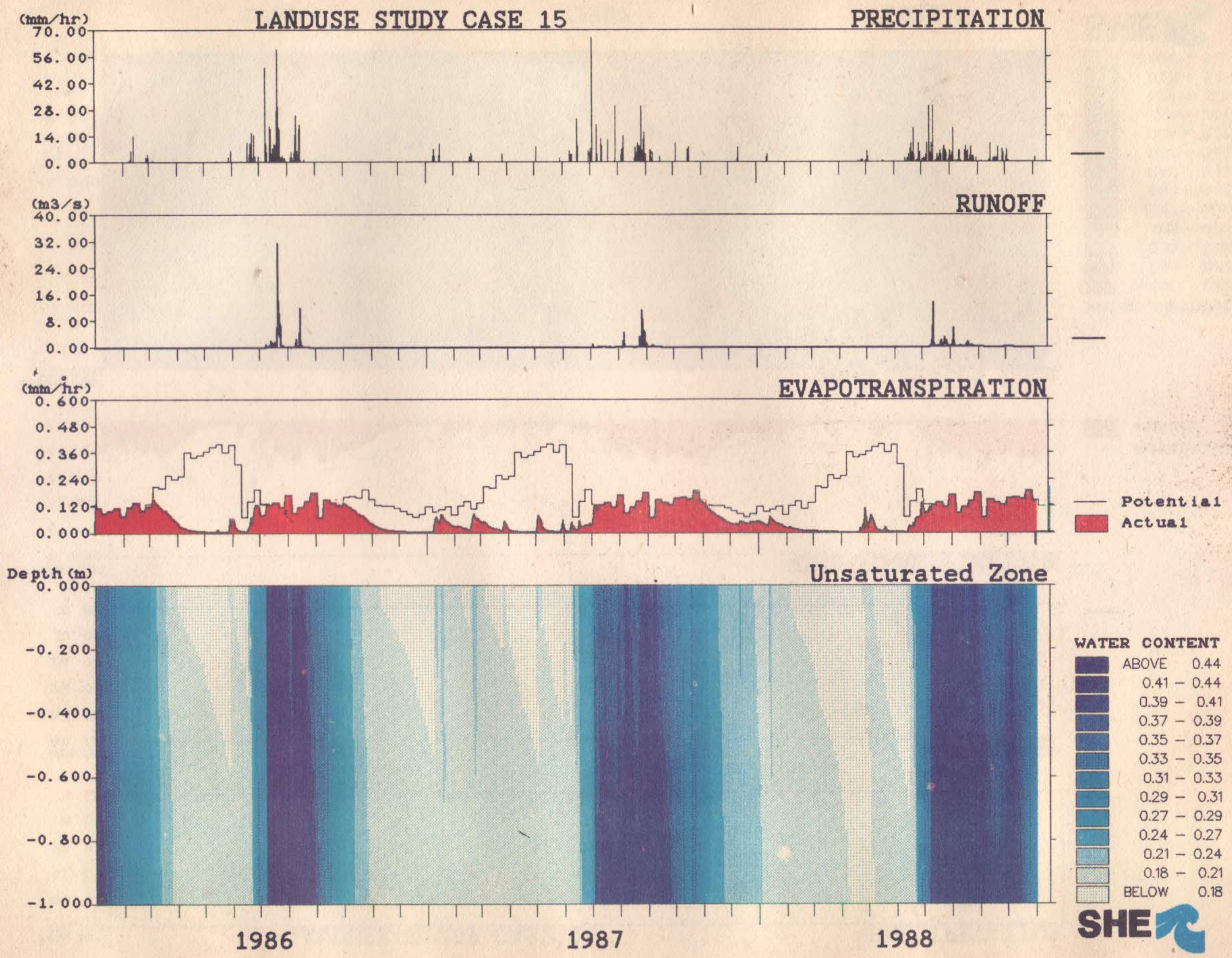


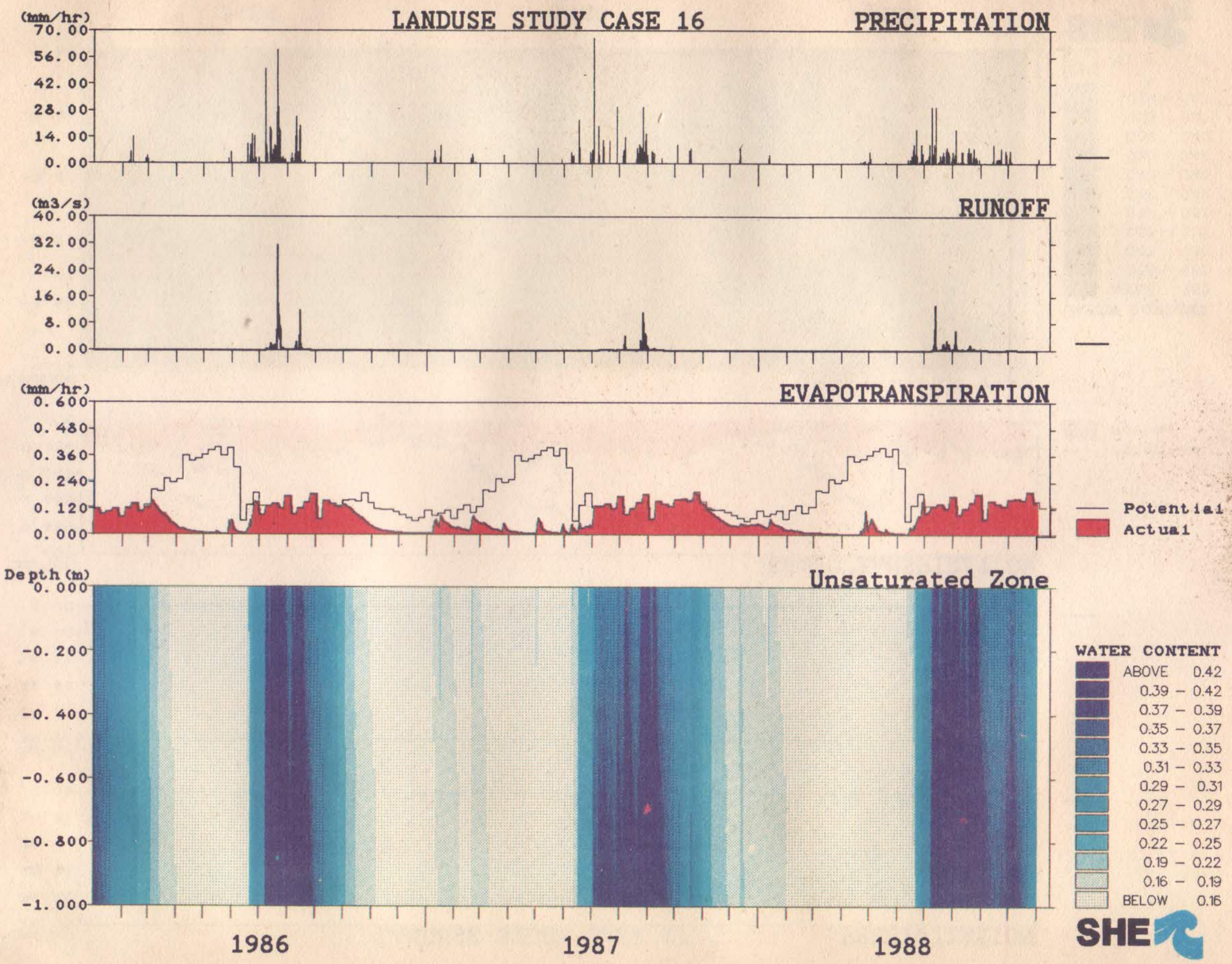
LANDUSE STUDY CASE 12

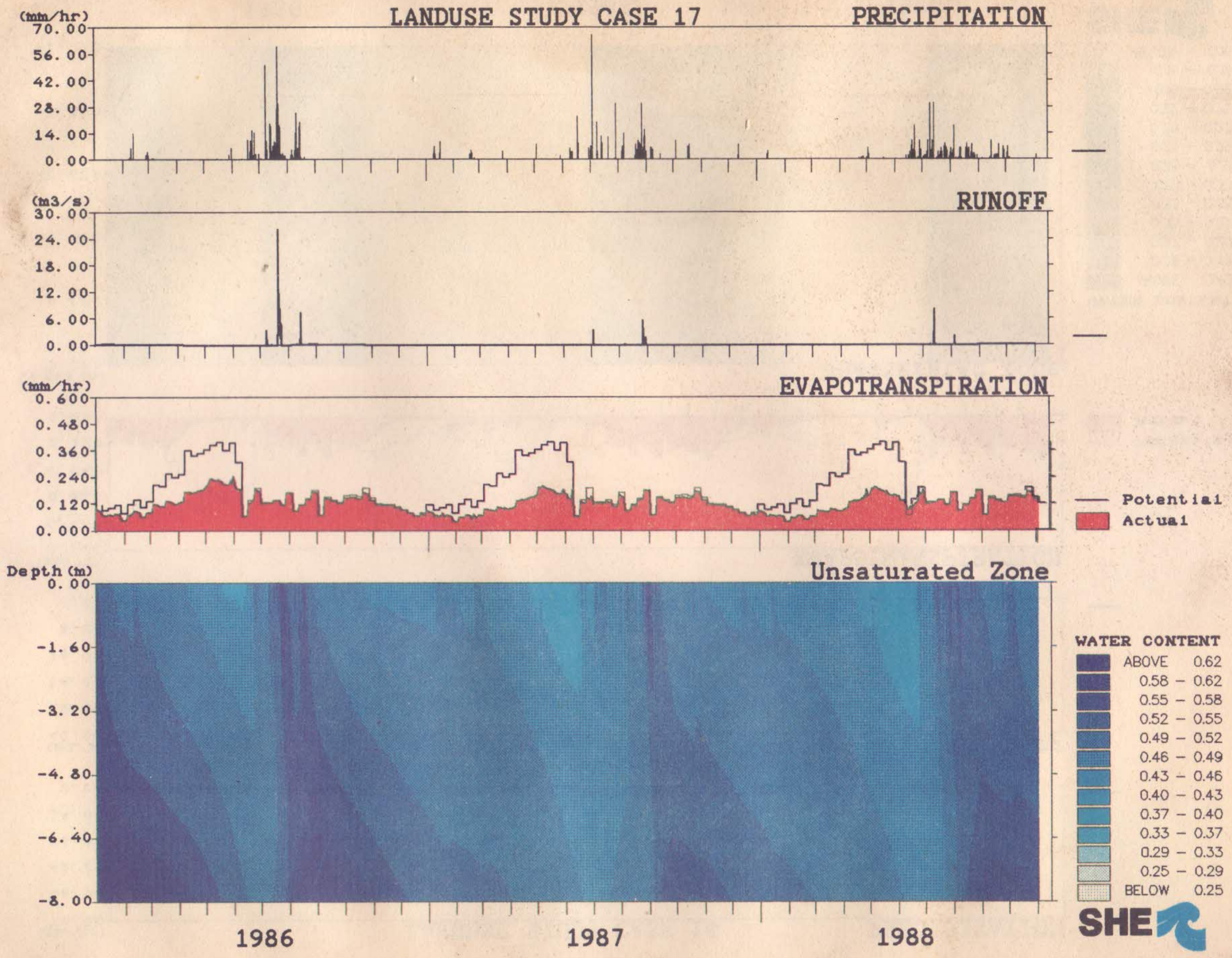



LANDUSE STUDY CASE 13
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
40.00
32.00
24.00
16.00
8.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Unsaturated Zone
Depth (m)
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
1986
1987
1988
WATER CONTENT
ABOVE 0.42
0.39 – 0.42
0.37 – 0.39
0.35 – 0.37
0.33 – 0.35
0.31 – 0.33
0.29 – 0.31
0.27 – 0.29
0.25 – 0.27
0.22 – 0.25
0.19 – 0.22
0.16 – 0.19
BELOW 0.16
SHE


LANDUSE STUDY CASE 14
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
40.00
32.00
24.00
16.00
8.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Unsaturated Zone
Depth (m)
0.000
-0.200
-0.400
-0.600
-0.800
-1.000
WATER CONTENT
ABOVE 0.62
0.59 - 0.62
0.55 - 0.59
0.51 - 0.55
0.47 - 0.51
0.43 - 0.47
0.40 - 0.43
0.37 - 0.40
0.34 - 0.37
0.31 - 0.34
0.28 - 0.31
0.25 - 0.28
BELOW 0.25
1986
1987
1988
SHE


LANDUSE STUDY CASE 15
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
40.00
32.00
24.00
16.00
8.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Unsaturated Zone
Depth (m)
0.000
-0.200
-0.400
-0.600
-0.800
-1.000
1986
1987
1988
WATER CONTENT
ABOVE 0.44
0.41 – 0.44
0.39 – 0.41
0.37 – 0.39
0.35 – 0.37
0.33 – 0.35
0.31 – 0.33
0.29 – 0.31
0.27 – 0.29
0.24 – 0.27
0.21 – 0.24
0.18 – 0.21
BELOW 0.18
SHE


LANDUSE STUDY CASE 16
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
40.00
32.00
24.00
16.00
8.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Unsaturated Zone
Depth (m)
0.000
-0.200
-0.400
-0.600
-0.800
-1.000
1986
1987
1988
WATER CONTENT
ABOVE 0.42
0.39 – 0.42
0.37 – 0.39
0.35 – 0.37
0.33 – 0.35
0.31 – 0.33
0.29 – 0.31
0.27 – 0.29
0.25 – 0.27
0.22 – 0.25
0.19 – 0.22
0.16 – 0.19
BELOW 0.16
SHE


LANDUSE STUDY CASE 17
PRECIPITATION
(mm/hr)
70.00
56.00
42.00
28.00
14.00
0.00
RUNOFF
(m3/s)
30.00
24.00
18.00
12.00
6.00
0.00
EVAPOTRANSPIRATION
(mm/hr)
0.600
0.480
0.360
0.240
0.120
0.000
Potential
Actual
Unsaturated Zone
Depth (m)
0.00
-1.60
-3.20
-4.80
-6.40
-8.00
1986
1987
1988
WATER CONTENT
ABOVE 0.62
0.58 – 0.62
0.55 – 0.58
0.52 – 0.55
0.49 – 0.52
0.46 – 0.49
0.43 – 0.46
0.40 – 0.43
0.37 – 0.40
0.33 – 0.37
0.29 – 0.33
0.25 – 0.29
BELOW 0.25
SHE