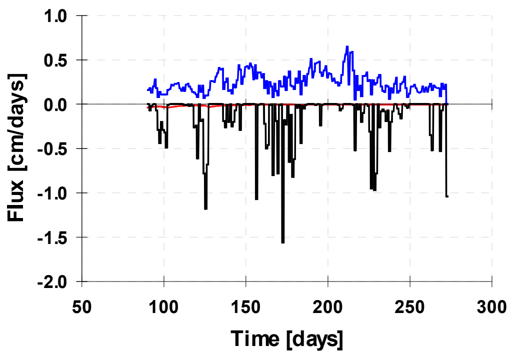
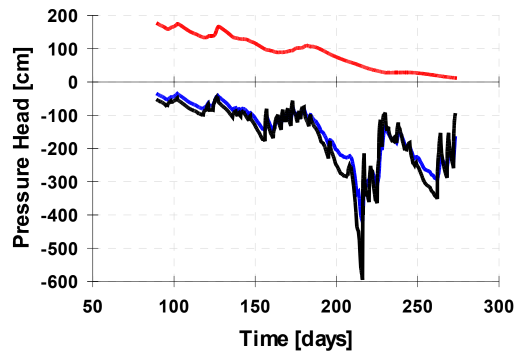
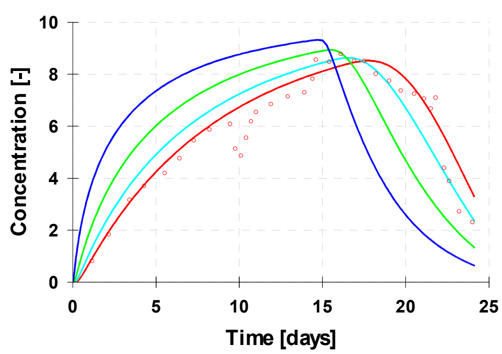
The HYDRUS-1D Software Package for Simulating the One-Dimensional Movement of Water, Heat, and Multiple Solutes in Variably-Saturated Media







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DEPARTMENT OF ENVIRONMENTAL SCIENCES
UNIVERSITY OF CALIFORNIA RIVERSIDE
RIVERSIDE, CALIFORNIA

10. PROBLEM DEFINITION

10.1. *Construction of Finite Element Mesh*

The finite element mesh is constructed by dividing the soil profile into linear elements whose sizes are defined by the *x*-coordinates of the nodes that form the element corners. Neighboring elements should have approximately the same size. The ratio of the sizes of two neighboring elements is not recommended to exceed about 1.5. The nodes are numbered sequentially from 1 to *NumNP* (total number of nodes) from the bottom of the soil profile to the soil surface.

The element dimensions must be adjusted to a particular problem. They should be made relatively small at locations where large hydraulic gradients are expected. Such a region is usually located close to the soil surface where highly variable meteorological factors can cause rapid changes in the soil water content and corresponding pressure heads. Therefore, it is usually recommended to use relatively small elements near the soil surface, and gradually larger sizes with depth. The element dimensions are also dependent on soil hydraulic properties. Coarse textured soils generally require a finer discretization than fine-textured soils (loams, clays). No special restrictions are necessary to facilitate the soil root zone.

10.2. *Coding of Soil Types and Subregions*

Soil Types - An integer code beginning with 1 and ending with *NMat* (the total number of soil materials) is assigned to each soil type in the flow region. The appropriate material code is subsequently assigned to each nodal point *n* of the finite element mesh.

Interior material interfaces do not coincide with element boundaries. When different material numbers are assigned to the nodes of a certain element, the finite element algorithm will assume that the material properties will change linearly over the element. This procedure will somewhat smooth soil interfaces. A set of soil hydraulic parameters, and solute and heat transport characteristics must be specified for each soil material.

Subregions - Water and solute mass balances are computed separately for each specified subregion. The subregions may or may not coincide with the material regions. Subregions are characterized by an integer code, which runs from 1 to *NLay* (the total number of subregions). A subregion code is assigned to each element in the flow domain.

10.3. *Coding of Boundary Conditions*

Boundary codes *KodTop* and *KodBot* must be assigned to surface and bottom boundary nodes, respectively. If a boundary node is to have a prescribed pressure head during a time step (a Dirichlet boundary condition), *KodTop* and *KodBot* must be set positive during that time step. If the volumetric flux of water entering or leaving the system is prescribed during a certain time step (a Neumann boundary condition), *KodTop* and *KodBot* must be negative or zero.

Constant Boundary Conditions - The value of a constant boundary condition for a particular boundary node, *n*, is given by the initial value of the pressure head, *h*(*n*), in case of Dirichlet boundary conditions, or by the initial value of the recharge/discharge flux, *rTop* or *rBot*, in case of Neumann boundary conditions. Table 10.1 summarizes the use of the variables *KodTop* (*KodBot*), *rTop* (*rBot*), and *h*(*n*) for various types of nodes.

Table 10.1. Initial settings of *KodTop* (*KodBot*), *rTop* (*rBot*), and *h*(*n*) for constant boundary conditions.

Node Type	*KodTop* (*KodBot*)	*rTop* (*rBot*)	*h*(*n*)
Specified Head Boundary	1	0.0	Prescribed
Specified Flux Boundary	-1	Prescribed	Initial Value

Variable Boundary Conditions - Four types of variable boundary conditions can be imposed:

1. Atmospheric boundary conditions for which *TopInf*=*AtmInf*=**.true.**,
2. Variable pressure head boundary conditions for which *TopInf*=**.true.** and *KodTop*=+3, or *BotInf*=**.true.** and *KodBot*=+3, or
3. Variable flux boundary conditions for which *TopInf*=**.true.** and *KodTop*=-3, or *BotInf*=**.true.** and *KodBot*=-3.
4. Variable pressure head/flux boundary conditions for which *TopInf*=**.true.** and *KodTop*=-3 or +3.

Initial settings of the variables *KodTop* (*KodBot*), *rTop* (*rBot*), and *h*(*n*) for the time-dependent boundary conditions are given in Table 10.2.

Table 10.2. Initial settings of *KodTop* (*KodBot*), *rTop* (*rBot*), and *h*(*n*) for time-variable boundary conditions.

Node Type	*KodTop* (*KodBot*)	*rTop* (*rBot*)	*h*(*n*)
Atmospheric Boundary	-4	0.0	Initial Value
Variable Head Boundary	+3	0.0	Initial Value
Variable Flux Boundary	-3	0.0	Initial Value

Atmospheric boundary conditions are implemented when *TopInf*=*AtmInf*=**.true.**, in which case time-dependent input data for the precipitation, *Prec*, and evaporation, *rSoil*, rates must be specified in the input file ATMOSPH.IN. The potential fluid flux across the soil surface is determined by *rAtm*=*rSoil*-*Prec*. The actual surface flux is calculated internally by the program. Two limiting values of surface pressure head must also be provided: *hCritS* which specifies the maximum allowed pressure head at the soil surface (usually 0.0), and *hCritA* which specifies the minimum allowed surface pressure head (defined from equilibrium conditions between soil water and atmospheric vapor). The program automatically switches the value of *KodTop* from -4 to +4 if one of these two limiting points is reached. Table 10.3 summarizes the use of the variables *rAtm*, *hCritS* and *hCritA* during program execution.

Variable head or flux boundary conditions on the soil surface (bottom of the soil profile) are implemented when *KodTop* (*KodBot*)=+3 or -3 and *TopInf* (*BotInf*)=**.true.**, respectively. In that case, the input file ATMOSPH.IN must contain the prescribed time-dependent values of the pressure head, *hT* (*hB*), or the flux, *rT* (*rB*), imposed on the boundary. The values of *hT* (*hB*) or *rT* (*rB*) are assigned to particular nodes at specified times according to rules given in Table 10.4.

Table 10.3. Definition of the variables *KodTop*, *rTop*, and *h*(*n*) when an atmospheric boundary condition is applied.

KodTop	*rTop*	*h*(*n*)	Event
-4	*rAtm*	Unknown	*rAtm=rSoil-Prec*
+4	Unknown	*hCritA*	Evaporation capacity is exceeded
+4	Unknown	*hCritS*	Infiltration capacity is exceeded

Table 10.4. Definition of the variables *KodTop* (*KodBot*), *rTop* (*rBot*), and *h*(*n*) when variable head or flux boundary conditions are applied.

Node Type	*KodTop* (*KodBot*)	*rTop* (*rBot*)	*h*(*n*)
Variable Head Boundary	+-3	Unknown	*hT* (*hB*)
Variable Flux Boundary	-3	*rT* (*rB*)	Unknown

Water Uptake by Plant Roots - The program calculates the rate at which plants extract water from the root zone by evaluating equation (2.6). Values of the potential transpiration rate, *rRoot*, must be specified at preselected times in the input file ATMOSPH.IN. These time-dependent values must be provided by the user and can be calculated in various ways, such as from the temperature and crop coefficients. Actual transpiration rates are calculated internally by the program as discussed in Section 2.2. The root water uptake parameters are taken from an input file, SELECTOR.IN. Values of the function *Beta*(*n*), which describes the potential water uptake distribution over the root zone, must be specified for each node in the flow domain. If the root growth model is considered, then the exponential function for the spatial distribution of the potential root water uptake is used (equation (2.14)). All parts of the flow region where *Beta*(*n*)>0 are treated as the soil root zone.

Root Growth Model - The program calculates the time variable rooting depth if the logical variable *lRoot* in input file SELECTOR.IN is equal to **.true.**. The classical Verhulst-Pearl logistic function (2.19) (see Section 2.2) is used to model the rooting depth. The exponential

(2.14) spatial distribution function for the root water uptake function is always used along with the time-variable rooting depth option. The root growth factor, *r*, can be calculated either from the known value of root depth (*xRMed*) at a specified time (*tRMed*), or from the assumption that 50% of the rooting depth is reached after 50% of the growing season.

Deep Drainage from the Soil Profile - Vertical drainage, $q(h)$, across the lower boundary of the soil profile is sometimes approximated by a flux which depends on the position of the groundwater level [e.g., *Hopmans and Stricker*, 1989]. If available, such a relationship can be implemented in the form of a variable flux boundary condition; the code in that case internally sets the variable *KodBot* equal to -7. This boundary condition will be implemented in HYDRUS if the logical variable *qGWLF* in the input file SELECTOR.IN is set equal to **.true.**. The discharge rate $q(n)$ assigned to bottom node n is determined by the program as $q(n)=q(h)$, where h is the local value of the pressure head, and $q(h)$ is given by

$$q(h) = -A_{qh} \exp(B_{qh} \,|\, h - GWL0L \,|) \tag{10.1}$$

where A_{qh} and B_{qh} are empirical parameters which must be specified in input file SELECTOR.IN, together with *GWL0L* which represents the reference position of the groundwater level (sometimes set equal to the x-coordinate of the soil surface).

Free Drainage - Unit vertical hydraulic gradient boundary conditions can be implemented in the form of a variable flux boundary condition. The program in that case will internally set the variable *KodBot* equal to -5. This boundary condition is implemented in HYDRUS by setting the logical variable *FreeD* in the input file SELECTOR.IN equal to **.true.**. The discharge rate $q(n)$ assigned to bottom node n is determined by the program as $q(n)=-K(h)$, where h is the local value of the pressure head, and $K(h)$ is the hydraulic conductivity corresponding to this pressure head.

Seepage Faces - The initial settings of the variables *KodBot*, *rBot* and $h(n)$ for node on a seepage face are summarized in Table 10.5. This boundary condition is implemented in HYDRUS by setting the logical variable *SeepF* in the input file SELECTOR.IN equal to **.true.**.

Table 10.5. Initial settings of *KodBot*, *rBot*, and $h(n)$ for seepage faces.

Node Type	*KodBot*	*rBot*	$h(n)$
Seepage Face (initially saturated)	+-2	0.0	0.0
Seepage Face (initially unsaturated)	-2	0.0	Initial Value

Flow to Horizontal Drains - This boundary condition is implemented when the logical variable *lDrain* in the input file SELECTOR.IN is equal to **.true.**. Five conceptual models can be used to describe the tile-drained soil profile:

a) homogeneous soil profile; drain is located immediately above the impervious layer,

b) homogeneous soil profile; drain is located some distance above the impervious layer,

c) layered soil profile (two layers); drain is located at interface between soil layers,

d) layered soil profile (two layers); drain is located in the bottom layer,

e) layered soil profile (two layers); drain is located in the top layer.

The first three cases are solved with the Hooghoudt equation (2.51), and the last two cases with the Ernst equation (2.53).

Heat Transport Boundary Conditions - The type of applied boundary condition is specified by the input variables *kTopT* and *kBotT* for the upper and lower boundaries, respectively. Positive values for these variables means that a first-type boundary condition is used. When *kTopT* or *kBotT* is negative, then a third-type boundary condition is applied. On the other hand, when *kBotT* is equal to zero, a Neumann boundary condition with zero gradient is implemented. All initial and boundary conditions must be specified in ^{o}C.

Solute Transport Boundary Conditions - The type of applied boundary condition is specified by the input variables *kTopCh* and *kBotCh* for the upper and lower solute transport boundaries, respectively. Similarly as for heat transport, positive values for these variables means that a first-type boundary condition will be assumed. When *kTopCh* or *kBotCh* is negative, then a third-type boundary condition is applied. When *kBotCh* is equal to zero, a Neumann boundary condition with zero gradient is used.

10.4. *Program Memory Requirements*

One single parameter statement is used at the beginning of the code to define the problem dimensions. All major arrays in the program are adjusted automatically according to these dimensions. This feature makes it possible to change the dimensions of the problem to be simulated without having to recompile all program subroutines. Different problems can be investigated by changing the dimensions in the parameter statement at the beginning of the main program, and subsequently linking all previously compiled subroutines with the main program when creating an executable file. Table 10.6 lists the array dimensions, which must be defined in the parameter statement.

Table 10.6. List of the array dimensions.

Dimension	Current setting	Description
NumNPD	1001	Maximum number of nodes in finite element mesh
NMatD	20	Maximum number of materials
NTabD	100	Maximum number of items in the table of hydraulic properties generated by the program for each soil material
NObsD	10	Maximum number of observation nodes

12. INPUT DATA

The input data for HYDRUS are given in four separate input files. These input files consist of one or more input blocks identified by the letters from A through L. The input files and blocks must be arranged as follows:

SELECTOR.IN

A. Basic Information
B. Water Flow Information
C. Time Information
D. Root Growth Information
E. Heat Transport Information
K. Carbon Dioxide Transport Information
F. Solute Transport Information
L. Major Ion Chemistry Information
G. Root Water Uptake Information

PROFILE.DAT

H. Nodal Information

ATMOSPH.IN

I. Atmospheric Information

FIT.IN

J. Inverse Solution Information

All input files must be placed into one subdirectory. Output files are printed into the same subdirectory. Another file, **HYDRUS1D.DAT**, which is not read by the executable code, enables communication between particular modules of the user-interface and will be described in part B of this manual. The input files can be created manually or with the graphics-based user-friendly interface **HYDRUS1D** also described in part B.

Tables 12.1 through 12.12 describe the data required for each input block. All data are read in using list-directed formatting (free format). Comment lines are provided at the beginning of, and within, each input block to facilitate, among other things, proper identification of the function of the block and the input variables. The comment lines are ignored during program execution; hence, they may be left blank but should not be omitted. The program assumes that all input data are specified in a consistent set of units for mass M, length L, and time T. The values of temperature should be specified in degrees Celsius.

Most of the information in Tables 12.1 through 12.12 should be self-explanatory. Table

Table 12.1. Block A - Basic Information.

Record	Type	Variable	Description
0	Char	iVer	HYDRUS-1D version
1,2	-	-	Comment lines.
3	Char	*Hed*	Heading.
4	-	-	Comment line.
5	Char	*LUnit*	Length unit (e.g., 'cm').
6	Char	*TUnit*	Time unit (e.g., 'min').
7	Char	*MUnit*	Mass unit for concentration (e.g., 'g', 'mol', '-').
8	-	-	Comment line.
9	Logical	*lWat*	Set this logical variable equal to **.true.** when transient water flow is considered. Set this logical variable equal to **.false.** when initial condition is to be kept constant during the simulation.
9	Logical	*lChem*	Set this logical variable equal to **.true.** if solute transport is to be considered.
9	Logical	*lTemp*	Set this logical variable equal to **.true.** if heat transport is to be considered.
9	Logical	*SinkF*	Set this logical variable equal to **.true.** if water extraction from the root zone occurs.
9	Logical	*lRoot*	Set this logical variable equal to **.true.** if root growth is to be considered.
9	Logical	*ShortF*	**.true.** if information is to be printed only at preselected times, but not at each time step (T-level information, see Section 10), **.false.** if information is to be printed at each time step.
9	Logical	*lWDep*	**.true.** if hydraulic properties are to be considered as temperature dependent. **.false.** otherwise (see Section 2.5).
9	Logical	*lScreen*	**.true.** if information is to be printed on the screen during code execution.
9	Logical	*AtmInf*	**.true.** if variable boundary conditions are supplied via the input file ATMOSPH.IN, **.false.** if the file ATMOSPH.IN is not provided (i.e., in case of time independent boundary conditions).
9	Logical	*lEquil*[*]	**.true.** if equilibrium or no adsorption is considered in the solute transport equation. **.false.** if nonequilibrium adsorption is considered for at least one solute species.
9	Logical	*lInverse*[+]	**.true.** if inverse problem is to be solved. **.false.** if direct problem is to be solved.
10	-	-	Comment line.
11	Logical	*lSnow*	Set this logical variable equal to **.true.** if snow accumulation of the soil surface is to be considered (heat transport needs to be considered as well).

Table 12.1. (continued)

Record	Type	Variable	Description
12	-	-	Comment line.
13	Integer	*NMat*	Number of soil materials. Materials are identified by the material number, *MatNum*, specified in Block H.
13	Integer	*NLay*	Number of subregions for which separate water balances are being computed. Subregions are identified by the subregion number, *LayNum*, specified in Block H.
13	Real	*CosAlfa*	Cosine of the angle between the flow direction and the vertical axis (i.e., cos α = 1 for vertical flow, cos α = 0 for horizontal flow, and 0 < cos α < 1 for inclined flow.

*Parameter *lEquil* is replaced with parameter *lCO2* when the major ion chemistry module is used, indicating whether or not the carbon dioxide transport is to be considered.

+Parameter *lInverse* is replaced with parameter *lKRed* when major ion chemistry module is used, indicating that a reduction in the hydraulic conductivity due to solution composition is to be considered.

Table 12.2. Block B - Water Flow Information.

Record	Type	Variable	Description
1,2	-	-	Comment lines.
3	Integer	*MaxIt*	Maximum number of iterations allowed during any time step (usually 20).
3	Real	*TolTh*	Absolute water content tolerance for nodes in the unsaturated part of the flow region [-] (its recommended value is 0.0001). *TolTh* represents the maximum desired absolute change in the value of the water content, θ, between two successive iterations during a particular time step.
3	Real	*TolH*	Absolute pressure head tolerance for nodes in the saturated part of the flow region [L] (its recommended value is 0.1 cm). *TolH* represents the maximum desired absolute change in the value of the pressure head, *h*, between two successive iterations during a particular time step.
4	-	-	Comment line.
5	Logical	*TopInf*	**.true.** if time dependent boundary condition is to be imposed at the top of the profile; data are supplied via input file ATMOSPH.IN. **.false.** in the case of time independent surface boundary conditions.
5	Logical	*WLayer*	Set this variable equal to **.true.** if water can accumulate at the surface with zero surface runoff.
5	Integer	*KodTop*	Code specifying type of boundary condition (BC) for water flow at the surface. Code number is positive for Dirichlet BC and negative for Neumann BC. In the case of 'Atmospheric BC' set *KodTop*=-1. Set *KodTop*=0 when a prescribed BC can change from Dirichlet BC to Neumann BC and vice versa.
5	Logical	*lInitW*	Set this variable equal to **.true.** if the initial condition is given in terms of the water content. Set this variable equal to **.false.** if the initial condition is given in terms of the pressure head
6	-	-	Comment line.
7	Logical	*BotInf*	**.true.** if time dependent boundary condition is to be imposed at the bottom of the profile; control data are supplied via input file ATMOSPH.IN. **.false.** in the case of time independent bottom boundary conditions.
7	Logical	*qGWLF*	Set this variable equal to **.true.** if the discharge-groundwater level relationship *q*(*GWL*) is applied as bottom boundary condition.
7	Logical	*FreeD*	**.true.** if free drainage is to be considered as bottom boundary condition.
7	Logical	*SeepF*	**.true.** if seepage face is to be considered as the bottom boundary condition.
7	Integer	*KodBot*	Code specifying type of boundary condition for water flow at the bottom of the profile. Code number is positive for a Dirichlet BC and negative for a Neumann BC. In case of a seepage face or free drainage BC set *KodBot*=-1.
7	Logical	*qDrain*	**.true.** if flow to horizontal drains is considered as bottom boundary condition.
8a	-	-	Comment line.

Table 12.2. (continued)

Record	Type	Variable	Description
9a	Real	*rTop*	Prescribed top flux [LT^{-1}] (in case of a Dirichlet BC set this variable equal to zero).
9a	Real	*rBot*	Prescribed bottom flux [LT^{-1}] (in case of a Dirichlet BC set this variable equal to zero).
9a	Real	*rRoot*	Prescribed potential transpiration rate [LT^{-1}] (if no transpiration occurs or if transpiration is variable in time set this variable equal to zero).
			Records 8a and 9a are provided only when lower or upper boundary conditions are independent of time and at least one of them is a Neumann BC.
8b	-	-	Comment line.
9b	Real	*GWL0L*	Reference position of the groundwater table (e.g., the *x*-coordinate of the soil surface).
9b	Real	*Aqh*	Value of the parameter A_{qh} [LT^{-1}] in the $q(GWL)$-relationship, equation (10.1); set to zero if *qGWLF*=**.false.**
9b	Real	*Bqh*	Value of the parameter B_{qh} [L^{-1}] in the $q(GWL)$-relationship, equation (10.1); set to zero if *qGWLF* =**.false.**
			Records 8b and 9b are provided only when the logical variable *qGWLF*=**.true.**.
8c	-	-	Comment line.
9c	Integer	*iPosDr*	Code for position of the drain. = 1: Homogeneous profile; drain on top of impervious layer. = 2: Homogeneous profile; drain above impervious layer. = 3: Layered profile; drain at interface between both soil layers. = 4: Layered profile; drain in bottom layer. = 5: Layered profile; drain in top layer.
10c	-	-	Comment line.
11c	Real	*zBotDr*	Coordinate of the bottom of the drain system [L].
11c	Real	*rSpacing*	Drain spacing, L_{dr} [L].
11c	Real	*Entres*	Entrance resistance, γ_{entr} [T].
12c	-	-	Comment line.
			The following value is specified when *iPosDr* = 1.
13c	Real	*KhTop*	Horizontal saturated hydraulic conductivity above the drain, K_{hTop} [LT^{-1}].
			The following three values are specified when *iPosDr* = 2.
13c	Real	*BaseGW*	Coordinate of the impervious layer [L].
13c	Real	*KhTop*	Horizontal saturated hydraulic conductivity above the drain, K_{hTop} [LT^{-1}].
13c	Real	*WetPer*	Wet perimeter of the drain, *u* [L].

Table 12.2. (continued)

Record	Type	Variable	Description
			The following four values are specified when *iPosDr* = 3.
13c	Real	*BaseGW*	Coordinate of the impervious layer [L].
13c	Real	*KhTop*	Horizontal saturated hydraulic conductivity above the drain, K_{hTop} [LT^{-1}].
13c	Real	*KhBot*	Horizontal saturated hydraulic conductivity below the drain, K_{hBot} [LT^{-1}].
13c	Real	*WetPer*	The wet perimeter, u, of the drain [L].
			The following six values are specified when *iPosDr* = 4.
13c	Real	*BaseGW*	Coordinate of the impervious layer [L].
13c	Real	*KvTop*	Vertical saturated hydraulic conductivity above the drain, K_{vTop} [LT^{-1}].
13c	Real	*KvBot*	Vertical saturated hydraulic conductivity below the drain, K_{vBot} [LT^{-1}].
13c	Real	*KhBot*	Horizontal saturated hydraulic conductivity below the drain, K_{hBot} [LT^{-1}].
13c	Real	*WetPer*	The wet perimeter, u, of the drain [L].
13c	Real	*zInTF*	Coordinate of the transition between the upper and lower soil layer [L].
			The following seven values are specified when *iPosDr* = 5.
13c	Real	*BaseGW*	Coordinate of the impervious layer [L].
13c	Real	*KhTop*	Horizontal saturated hydraulic conductivity above the drain, K_{hTop} [LT^{-1}].
13c	Real	*KvTop*	Vertical saturated hydraulic conductivity above the drain, K_{vTop} [LT^{-1}].
13c	Real	*KhBot*	Horizontal saturated hydraulic conductivity below the drain, K_{hBot} [LT^{-1}].
13c	Real	*WetPer*	The wet perimeter, u, of the drain [L].
13c	Real	*zInTF*	Coordinate of the transition between the upper and lower soil layers [L].
13c	Real	*GeoFac*	Geometry factor, a_{dr} [-], as obtained by the relaxation method [*Ernst*, 1962] (see Table below).

K_{hbot}/K_{htop}	D_{bot}/D_{top}					
	1 2	4	8	16	32	
1	2.0	3.0	5.0	9.0	15.0	30.0
2	2.4	3.2	4.6	6.2	8.0	10.0
3	2.6	3.3	4.5	5.5	6.8	8.0
5	2.8	3.5	4.4	4.8	5.6	6.2
10	3.2	3.6	4.2	4.5	4.8	5.0
20	3.6	3.7	4.0	4.2	4.4	4.6
50	3.8	4.0	4.0	4.0	4.2	4.6

Table 12.2. (continued)

Record	Type	Variable	Description
10	-	-	Comment line.
11	Real	*ha*	Absolute value of the upper limit [L] of the pressure head interval below which a table of hydraulic properties will be generated internally for each material (h_a must be greater than 0.0; e.g. 0.001 cm) (see Section 5.4.7).
11	Real	*hb*	Absolute value of the lower limit [L] of the pressure head interval for which a table of hydraulic properties will be generated internally for each material (e.g. 1000 m). One may assign to h_b the highest (absolute) expected pressure head to be expected during a simulation. If the absolute value of the pressure head during program execution lies outside of the interval [h_a ,h_b], then appropriate values for the hydraulic properties are computed directly from the hydraulic functions (i.e., without interpolation in the table).
12	-	-	Comment line.
13	Integer	*iModel*	Soil hydraulic properties model: = 0; *van Genuchten*'s [1980] model with six parameters. = 1; modified van Genuchten's model with ten parameters [*Vogel and Císlerová*, 1988]. = 2; *Brooks and Corey*'s [1964] model with six parameters. = 3; *van Genuchten*'s [1980] model with air-entry value of -2 cm and with six parameters. = 4; *Kosugi*'s [1996] model with six parameters. = 5; dual porosity model of *Durner* [1994] with nine parameters. = 6; dual-porosity system with transfer proportional to the effective saturation (9 parameters) (see Sections 2.2.1. and 2.8.). = 6; dual-porosity system with transfer proportional to the pressure head (11 parameters) (see Sections 2.2.1. and 2.8.). iModel>3 options are not available with the major ion chemistry module.
13	Integer	*iHyst*	Hysteresis in the soil hydraulic properties: = 0; No hysteresis = 1; Hysteresis in the retention curve only = 2; Hysteresis in both the retention and hydraulic conductivity functions = 3; Hysteresis using Bob Lenhard's model [*Lenhard et al.*, 1991; *Lenhard and Parker*, 1992]. (Not available with major ion chemistry module.)
14	-	-	Comment line.
15	Integer	*iKappa*	= -1 if the initial condition is to be calculated from the main drying branch. = 1 if the initial condition is to be calculated from the main wetting branch. Records 14 and 15 are provided only when *iHyst* > 0.
16	-	-	Comment line.
17	Real	*Par*(1,*M*)	Parameter θ_r for material *M* [-].
17	Real	*Par*(2,*M*)	Parameter θ_s for material *M* [-].
17	Real	*Par*(3,*M*)	Parameter α for material *M* [L^{-1}].

Table 12.2. (continued)

Record	Type	Variable	Description
17	Real	*Par*(4,*M*)	Parameter n for material *M* [-].
17	Real	*Par*(5,*M*)	Parameter K_s for material *M* [LT^{-1}].
17	Real	*Par*(6,*M*)	Parameter l for material *M* [-].
			The following four parameters are specified only when *iModel*=1.
17	Real	*Par*(7,*M*)	Parameter θ_m for material *M* [-].
17	Real	*Par*(8,*M*)	Parameter θ_a for material *M* [-].
17	Real	*Par*(9,*M*)	Parameter θ_k for material *M* [-].
17	Real	*Par*(10,*M*)	Parameter K_k for material *M* [LT^{-1}].
			The following four parameters are specified only when *iModel*=0 and *iHyst*>1.
17	Real	*Par*(7,*M*)	Parameter θ_m for material *M* [-].
17	Real	*Par*(8,*M*)	Parameter θ_s^w for material *M* [-].
17	Real	*Par*(9,*M*)	Parameter α^w for material *M* [L^{-1}].
17	Real	*Par*(10,*M*)	Parameter K_s^w for material *M* [LT^{-1}].
			The following three parameters are specified only when *iModel*=5 [*Durner*, 1994].
17	Real	*Par*(7,*M*)	Parameter w for material *M* [-]. The weighting factor for the sub-curve for the second overlapping subregion.
17	Real	*Par*(8,*M*)	Parameter α for material *M* [L^{-1}] for the second overlapping subregion.
17	Real	*Par*(9,*M*)	Parameter n for material *M* [-] for the second overlapping subregion.
			The following four parameters are specified only when *iModel*=6 (dual-porosity system with transfer proportional to the water content gradient).
17	Real	*Par*(7,*M*)	Parameter θ_r^{im} for the immobile region of material *M* [-].
17	Real	*Par*(8,*M*)	Parameter θ_s^{im} for the immobile region of material *M* [-].
17	Real	*Par*(9,*M*)	Parameter ω (mass transfer coefficient in (2.63)) for material *M* [-].
			The following four parameters are specified only when *iModel*=7 (dual-porosity system with transfer proportional to the pressure head gradient).
17	Real	*Par*(7,*M*)	Parameter θ_r^{im} for the immobile region of material *M* [-].
17	Real	*Par*(8,*M*)	Parameter θ_s^{im} for the immobile region of material *M* [-].
17	Real	*Par*(9,*M*)	Parameter α^{im} for the immobile region of material *M* [-].
17	Real	*Par*(10,*M*)	Parameter n^{im} for the immobile region of material *M* [-].
17	Real	*Par*(11,*M*)	Parameter K_a (mass transfer coefficient in (2.67)) for material *M* [-].
			Record 17 information is provided for each material *M* (from 1 to *NMat*).
			If *lWDep*=**.true.** (Block A) then the soil hydraulic parameters *Par*(*i,M*) must be specified at reference temperature T_{ref}=20^{o}C.

Table 12.3. Block C - Time information.

Record	Type	Variable	Description
1,2	-	-	Comment lines.
3	Real	*dt*	Initial time increment, Δt [T]. Initial time step should be estimated in dependence on the problem being solved. For problems with high-pressure gradients (e.g. infiltration into an initially dry soil), Δt should be relatively small.
3	Real	*dtMin*	Minimum permitted time increment, Δt_{min} [T].
3	Real	*dtMax*	Maximum permitted time increment, Δt_{max} [T].
3	Real	*dMul*	If the number of required iterations at a particular time step is less than or equal to *ItMin*, then Δt for the next time step is multiplied by a dimensionless number *dMul* ≥ 1.0 (its value is recommended not to exceed 1.3).
3	Real	*dMul*2	If the number of required iterations at a particular time step is greater than or equal to *ItMax*, then Δt for the next time step is multiplied by *dMul*2 ≤ 1.0 (e.g. 0.33).
3	Integer	*ItMin*	If the number of required iterations at a particular time step is less than or equal to *ItMin*, then Δt for the next time step is multiplied by a dimensionless number *dMul* ≥ 1.0 (its value is recommended not to exceed 1.3).
3	Integer	*ItMax*	If the number of required iterations at a particular time step is greater than or equal to *ItMax*, then Δt for the next time step is multiplied by *dMul*2 ≤ 1.0 (e.g. 0.33).
3	Integer	*MPL*	Number of specified print-times at which detailed information about the pressure head, water content, flux, temperature, concentrations, and the water and solute balances will be printed.
4	-	-	Comment line.
5	Real	*tInit*	Initial time of the simulation [T].
5	Real	*tMax*	Final time of the simulation [T].
6	-	-	Comment line.
7	Logical	*lPrint*	Set this logical variable equal to **.true.** if information about the pressure heads, water contents, temperatures, and concentrations in observation nodes, and the water and solute fluxes is to be printed at a constant time interval *tPrintInterval*.
7	Integer	*nPrintSteps*	Information to the screen and output files is not printed at each time step, but after each *nPrintSteps*.
7	Real	*tPrintInterval*	A constant time interval after which information about the pressure heads, water contents, temperatures, and concentrations in observation nodes, and the water and solute fluxes is to be printed.

Table 12.3. (continued)

Record	Type	Variable	Description
7	Logical	*lEnter*	Set this logical variable equal to **.true.** if the Enter key is to be pressed at the end of simulation.
8	-	-	Comment line.
9	Real	*TPrint*(1)	First specified print-time [T].
9	Real	*TPrint*(2)	Second specified print-time [T].
.	.	.	.
.	.	.	.
9	Real	*TPrint*(*MPL*)	Last specified print-time [T]. (Maximum six values on one line.)

Table 12.4. Block D - Root Growth Information.+

Record	Type	Symbol	Description
1,2	-	-	Comment lines.
3	Integer	*iRFak*	Method to calculate the root growth factor, *r*. = 0; the root growth factor is calculated from given data [*xRMed*, *tRMed*]. = 1; the root growth factor is calculated based on the assumption that 50% of the rooting depth, (*xRMax*+*xRMin*)/2., is reached at the midpoint of the growing season, (*tRMin*+*tRHarv*)/2.
3	Real	*tRMin*	Initial time of the root growth period [T].
3	Real	*tRMed*	Time of known rooting depth (set equal to zero if *iRFak*=1) [T].
3	Real	*tRHarv*	Time at the end of the root water uptake period [T].
3	Real	*xRMin*	Initial value of the rooting depth at the beginning of the growth period (recommended value = 1 cm) [L].
3	Real	*xRMed*	Value of known rooting depth (set equal to zero if *iRFak*=1) [L].
3	Real	*xRMax*	Maximum rooting depth, which may be reached at infinite time [L].

+ Block D is not needed if the logical variable *lRoot* (Block A) is set equal to **.false.**

Table 12.8. Block H - Nodal information.

Record	Type	Variable	Description
1	Integer	*NFix*	Number of fixed nodes.
2	Integer	*i*	Fixed node.
2	Real	*xFix*(*i*)	*x*-coordinate of the fixed node *i*.
2	Real	*wTop*(*i*)	Nodal density above fixed node *i*.
2	Real	*wBot*(*i*)	Nodal density below fixed node *i*.
			Record 2 must be specified for each fixed node.
			Records 1 and 2 have relevant information only for the module PROFILE of the user interface. When the code is used without the user interface, then only two fixed points (top and bottom of the soil profile) with unit nodal density have to be specified.
3	Integer	*NumNP*	Number of nodal points.
3	Integer	*NS*	Number of solutes (set equal to zero if *lChem* is equal to **.false.**).
3	Integer	*iTemp*	This variable is read only if the user interface is used. = 1; initial condition for the temperature is specified (must be equal to 1 when *lTemp* or *lChem* is equal to **.true.**). = 0; initial condition for the temperature is not specified.
3	Integer	*iEquil*	This variable is read only if the user interface is used. = 1; Equilibrium solute transport is considered. = 0; Nonequilibrium solute transport is considered.
			Set equal to 1 if *lChem* is equal to **.false.**.
4	Integer	*n*	Nodal number.
4	Real	*x*(*n*)	*x*-coordinate of node *n* [L].
4	Real	*hNew*(*n*)	Initial value of the pressure head at node *n* [L]. If *lWat*=**.false.** in Block A, then *hNew*(*n*) represents the pressure head which will be kept constant during simulation.
4	Integer	*MatNum*(*n*)	Index for material whose hydraulic and transport properties are assigned to node *n*.
4	Integer	*LayNum*(*n*)	Subregion number assigned to node *n*.
4	Real	*Beta*(*n*)	Value of the water uptake distribution, *b*(*x*) [L^{-1}], in the soil root zone at node *n*. Set *Beta*(*n*) equal to zero if node *n* lies outside the root zone.
			Following three numbers, i.e., *Ah*(*n*), *Ak*(*n*), and *Ath*(*n*), are given only when neither carbon dioxide transport nor major ion chemistry is considered.
4	Real	*Ah*(*n*)	Nodal value of the dimensionless scaling factor α_h [-] associated with the pressure head.

Table 12.8. (continued)

Record	Type	Variable	Description
4	Real	*Ak*(*n*)	Nodal value of the dimensionless scaling factor α_K [-] associated with the saturated hydraulic conductivity.
4	Real	*Ath*(*n*)	Nodal value of the dimensionless scaling factor α_θ [-] associated with the water content.
			The following number, i.e., CO2(*n*), is given only when either carbon dioxide transport or major ion chemistry is considered.
4	Real	*CO2*(*n*)	Initial value of the carbon dioxide concentration at node *n* [L^3L^{-3}].
4	Real	*Temp*(*n*)	Initial value of the temperature at node *n* [°C] (do not specify if both *lTemp* or *lChem* are equal to **.false.**; if *lTemp*=**.false.** and *lChem*=**.true.** then set equal to 0 or any other initial value to be used later for temperature dependent water flow and solute transport).
			Following dissolved and sorbed concentrations, i.e., *Conc*(*i*,*n*) and *Sorb*(*i*,*n*), are given only when neither carbon dioxide transport nor major ion chemistry is considered.
4	Real	*Conc*(1,*n*)	Initial value of the concentration of the first solute at node *n* [ML^{-3}] (omit if *lChem*=**.false.**).
4	Real	*Conc*(2,*n*)	Initial value of the concentration of the second solute at node *n* [ML^{-3}] (omit if *lChem*=**.true.** and *NS* < 2).
.	.	.	.
.	.	.	.
4	Real	*Conc*(*i*,*n*)	Initial value of the concentration of the last solute at node *n* [ML^{-3}] (omit if *lChem*=**.true.** and *NS* < *i*).
4	Real	*Sorb*(1,*n*)	Initial value of the adsorbed concentration on type-2 sites of the first solute at node *n* [ML^{-3}]. Omit this variable if *lChem*=**.false.** or *lEquil*=**.true.** .
4	Real	*Sorb*(2,*n*)	Initial value of the adsorbed concentration on type-2 sites of the second solute at node *n* [ML^{-3}]. Omit this variable if *lChem*=**.false.** or *lEquil*=**.true.** or *NS* < 2.
.	.	.	.
.	.	.	.
4	Real	*Sorb*(*i*,*n*)	Initial value of the adsorbed concentration on type-2 sites of the *NS*th solute at node *n* [ML^{-3}]. This variable does not have to be specified if *lChem*=**.false.** or *lEquil*=**.true.** and *NS* < *i*).
			Following three numbers, i.e., *nC*(*n*), *nX*(*n*), and *nS*(*n*), are given only when major ion chemistry is considered.
4	Integer	*nC*(*n*)	Code which specifies which solution concentration combination (see Block H) is to be used as an initial condition at node *n* [-] (omit if *lChem*=**.false.**).
4	Integer	*nX*(*n*)	Code which specifies which surface species combination (see Block H) is to be used as an initial condition at node *n* [-] (omit if *lChem*=**.false.**).
4	Integer	*nS*(*n*)	Code which specifies which mineral phase combination (see Block H) is to be used as an initial condition at node *n* [-] (omit if *lChem*=**.false.**).

Table 12.8. (continued)

Record	Type	Variable	Description
			In general, record 4 information is required for each node *n*, starting with *n*=1 and continuing sequentially until *n*=*NumNP*. Record 4 information for certain nodes may be skipped if several conditions are satisfied (see beginning of this section).
5	Integer	*NObs*	Number of observation nodes for which values of the pressure head, the water content, temperature (for *lTemp*=**.true.**), and the solution and sorbed concentrations (for *lChem*=**.true.**) are printed at each time level.
6	Integer	*iObs*(1)	Nodal number of the first observation node.
6	Integer	*iObs*(2)	Nodal number of the second observation node.
.	.	.	.
.	.	.	.
6	Integer	*iObs*(*NObs*)	Nodal number of the last observation node.

Table 12.9. Block I - Atmospheric information.[+]

Record	Type	Variable	Description
1,2	-	-	Comment lines.
3	Integer	*MaxAl*	Number of atmospheric data records.
4	-	-	Comment line.
5	Real	*hCritS*	Maximum allowed pressure head at the soil surface [L].
6	-	-	Comment line.
7	Real	*tAtm*(*i*)	Time for which the *i*-th data record is provided [T].
7	Real	*Prec*(*i*)	Precipitation rate [LT^{-1}] (in absolute value).
7	Real	*rSoil*(*i*)	Potential evaporation rate [LT^{-1}] (in absolute value). *rSoil*(*i*) is interpreted as *KodTop* when a time variable Dirichlet or Neumann boundary condition is specified.
7	Real	*rRoot*(*i*)	Potential transpiration rate [LT^{-1}] (in absolute value).
7	Real	*hCritA*(*i*)	Absolute value of the minimum allowed pressure head at the soil surface [L].
7	Real	*rB*(*i*)	Bottom flux [LT^{-1}] (set equal to 0 if *KodBot* is positive, or if one of the logical variables *qGWLF*, *FreeD* or *SeepF* is **.true.**).
7	Real	*hB*(*i*)	Groundwater level [L], or any other prescribed pressure head boundary condition as indicated by a positive value of *KodBot* (set equal to 0 if *KodBot* is negative, or if one of the logical variables *qGWLF*, *FreeD* or *SeepF* is **.true.**).
7	Real	*hT*(*i*)	Prescribed pressure head [L] at the surface (set equal to 0 if *KodBot* is negative).
7	Real	*tTop*(*i*)	Soil surface temperature [^oC] (omit if both *lTemp* and *lChem* are equal to **.false.**).
7	Real	*tBot*(*i*)	Soil temperature at the bottom of the soil profile [^oC] (omit if both *lTemp* and *lChem* are equal to **.false.**, set equal to zero if *kBotT*=0).
7	Real	*Ampl*(*i*)	Temperature amplitude at the soil surface [K] (omit if both *lTemp* and *lChem* are equal to **.false.**).
			The following values, i.e., *cTop*(*i*,*j*) and *cBot*(*i*,*j*), are given only when neither carbon dioxide transport nor major ion chemistry is considered.
7	Real	*cTop*(*i*,1)	Soil surface concentration [ML^{-3}] for the first solute (not needed if *lChem* is equal to **.false.**).
7	Real	*cTop*(*i*,2)	Soil surface concentration [ML^{-3}] for the second solute (not needed if *lChem* is equal to **.false.** or *NS* < 2).
.	.	.	.
.	.	.	.
7	Real	*cTop*(*i*,*NS*)	Soil surface concentration [ML^{-3}] for the *NS*th solute (not needed if *lChem* is equal to **.false.**).
7	Real	*cBot*(*i*,1)	Concentration at the bottom of the soil profile [ML^{-3}] for the first solute (not needed if *lChem* is equal to **.false.**, set equal to zero if *cBotSolute*=0).

Table 12.9. (continued)

Record	Type	Variable	Description
7	Real	*cBot*(*i*,2)	Concentration at the bottom of the soil profile [ML^{-3}] for the second solute (not needed if *lChem* is equal to **.false.**, set equal to zero if *cBotSolute*=0 or *NS* < 2).
7	Real	*cBot*(*i*,*NS*)	Concentration at the bottom of the soil profile [ML^{-3}] for the *NS*th solute (not needed if *lChem* is equal to **.false.**, set equal to zero if *cBotSolute*=0).
			Following two number, i.e., *kTopCh*(*i*) and *kBotCh*(*i*), are given only when major ion chemistry is considered.
7	Real	*kTopCh*(*i*)	Code which refers to the field *ConcTab* for the value of the solute transport upper boundary condition. Sign of *kTopCh*(*i*) indicates whether a Dirichlet (positive) or Neumann (negative) boundary condition is to be applied at the soil surface. *ConcTab*(abs(*kTopCh*(*i*)),*j*) is the boundary condition for the soil surface for species *j*. Permissible values are ±1,±2,±3,...,±*nSolConc*.
7	Real	*kBotCh*(*i*)	Code which refers to the field *ConcTab* for the value of the solute transport lower boundary condition. Sign of *kBotCh*(*i*) indicates whether a Dirichlet (positive) or Neumann (negative) boundary condition is to be applied at the bottom of the soil profile. *ConcTab*(abs(*kBotCh*(*i*)),*j*) is the boundary condition for the bottom of the soil profile for species *j*. Permissible values are ±1,±2,±3,...,±*nSolConc*.
			The total number of atmospheric data records is *MaxAl* (i=1,2, ..,*MaxAl*).

[+] Block I is not needed if the logical variable *AtmInf* (Block A) is set equal to **.false.** .

13. OUTPUT DATA

The program output consists of 9+(n_s-1) output files (when major ion chemistry is not considered), where n_s is the number of solutes considered in the first-order decay chain. When major ion chemistry is considered the program output consists of 13 output files. The output is organized into 3 groups:

T-level information
- T_LEVEL.OUT
- RUN_INF.OUT
- SOLUTE.OUT
- OBS_NODE.OUT
- CO2_INF.OUT*

P-level information
- NOD_INF.OUT
- BALANCE.OUT
- CONC.OUT*
- SOLID.OUT*
- EQUIL.OUT*
- CHEMBAL.OUT*

A-level information
- A_LEVEL.OUT

*Major ion chemistry module output files

In addition, some of the input data are printed to files I_CHECK.OUT and PROFILE.OUT. A separate output file SOLUTE.OUT is created for each solute. Results of the inverse solution are directed into an output file FIT.OUT. All output files are directed to the same directory as the input files, which must be created by the user prior to program execution (the directory is created automatically if the user interface is used). The various output files are described in detail in this section.

File I_CHECK.OUT contains a complete description of the space discretization, the hydraulic characteristic, and the transport properties of each soil material.

Table 13.1. T_LEVEL.OUT - pressure heads and fluxes on the boundaries and in the root zone.

Time	Time, *t*, at current time-level [T].
rTop	Potential surface flux [LT^{-1}] (infiltration/evaporation: -/+).
rRoot	Potential transpiration rate [LT^{-1}].
vTop	Actual surface flux [LT^{-1}] (infiltration/evaporation: -/+).
vRoot	Actual transpiration rate [LT^{-1}].
vBot	Actual flux across the bottom of the soil profile [LT^{-1}] (inflow/outflow: +/-).
sum(*rTop*)	Cumulative value of the potential surface flux [L] (infiltration/evaporation: -/+).
sum(*rRoot*)	Cumulative value of the potential transpiration rate [L].
sum(*vTop*)	Cumulative value of the actual surface flux [L] (infiltration/evaporation: -/+).
sum(*vRoot*)	Cumulative value of the actual transpiration rate [L].
sum(*vBot*)	Cumulative value of the actual flux across the bottom of the soil profile [L] (inflow/outflow: +/-).
hTop	Pressure head at the soil surface [L].
hRoot	Mean value of the pressure head over the region for which *Beta(n)*>0 (i.e., within the root zone) [L].
hBot	Pressure head at the bottom of the soil profile [L].
RunOff	Surface runoff [LT^{-1}].
sum(*RunOff*)	Cumulative surface runoff [L]
Volume	Volume of water in the entire flow domain [L].
sum(*Infil*)	Cumulative infiltration [L]
sum(*Evap*)	Cumulative evaporation [L]
TLevel	Time-level (current time-step number) [-].
sum(*WTrans*)	Cumulative mass transfer of water between mobile and immobile regions for dual porosity model [L]

Table 13.2. RUN_INF.OUT - time and iteration information.

TLevel	Time-level (current time-step number) [-].
Time	Time, t, at current time-level [T].
dt	Time step, Δt [T].
IterW	Number of iterations necessary for solution of the water flow equation [-].
IterC	Number of iterations necessary for solution of the solute transport equation [-].
ItCum	Cumulative number of iterations [-].
KodT	Code for the boundary condition at the soil surface.
KodB	Code for the boundary condition at the bottom of the soil profile.
Converg	Information whether or not the numerical convergence was achieved at the current time-level.
Peclet	Maximum local Peclet number [-].
Courant	Maximum local Courant number [-].

Table 13.4. NOD_INF.OUT - profile information.

Node	Number of nodal point *n*.
Depth	*x*-coordinate of node *n*.
Head	Nodal value of the pressure head [L].
Moisture	Nodal value of the water content [-].
K	Nodal value of the hydraulic conductivity [LT^{-1}].
C	Nodal value of the hydraulic capacity [L^{-1}].
Flux	Nodal value of the Darcian velocity [LT^{-1}].
Sink	Nodal value of the root water uptake [T^{-1}].
Ks/KsTop	Ratio between the local hydraulic conductivity and the saturated hydraulic conductivity at the soil surface [-].
v/KsTop	Ratio between the local velocity and the saturated hydraulic conductivity at the soil surface [-].
Temp	Nodal value of the temperature [K].
Conc(1,..,*NS*)	Nodal value of the concentration [ML^{-3}]. Only given when *lChem*=.true. .
Sorb(1,..,*NS*)	Nodal value of the sorbed concentration [MM^{3}] or concentration in the immobile regions [ML^{-3}]. Only given when *lChem*=.true. and *lEquil*=.false. .

The following information is printed when dual-porosity models are used.

WTrans	Water mass transfer between mobile and immobile regions [T^{-1}].
Im.Moist.	Water content in the immobile region [-].
STrans	Solute mass transfer between mobile and immobile regions [T^{-1}]. Only given when *lChem*=.true.

Table 13.5. BALANCE.OUT - mass balance variables.

Area	Length of the entire flow domain or a specified subregion [L].
W-Volume	Volume of water in the entire flow domain or in a specified subregion [L].
InFlow	Inflow/outflow to/from the entire flow domain or a specified subregion [LT^{-1}].
hMean	Mean pressure head in the entire flow domain or a specified subregion [L].
TVol	Amount of heat in the entire flow domain or a specified subregion [MT^{-2}].
TMean	Mean temperature in the entire flow domain or a specified subregion [K].
COVol	Volume of CO_2 in the entire flow domain or in a specified subregion [L^3L^{-2}].
COMean	Mean CO_2 concentration in the entire flow domain or in a specified subregion [L^3L^{-3}].
ConcVol	Amount of solute in the entire flow domain or a specified subregion [ML^{-2}] excluding *ConcVolIm*. This variable is given for all solutes from 1 to *NS*.
ConcVolIm	Amount of solute in the entire flow domain, or in a specified subregion, either adsorbed at type-2 (kinetic) adsorption sites or in the immobile liquid region [ML^{-2}]. This variable is given for all solutes from 1 to *NS*.
cMean	Mean concentration in the entire flow domain or a specified subregion [ML^{-3}]. This variable is given for all solutes from 1 to *NS*.
Top Flux	Actual surface flux [LT^{-1}] (infiltration/evaporation: -/+).
Bot Flux	Actual flux across the bottom of the soil profile [LT^{-1}] (inflow/outflow: +/-).
WatBalT	Absolute error in the water mass balance of the entire flow domain [L].
WatBalR	Relative error in the water mass balance of the entire flow domain [%].

The following information is printed when carbon dioxide transport is considered.

CO2BalT	Absolute error in the CO_2 mass balance for the entire flow domain [L].
CncBalT	Absolute error in the solute mass balance of the entire flow domain [ML^{-2}]. This variable is given for all solutes from 1 to *NS*.
CncBalR	Relative error in the solute mass balance of the entire flow domain [%]. This variable is given for all solutes from 1 to *NS*.

The following information is printed when dual-porosity models are used.

W-VolumeI	Volume of water in the immobile domain of the entire flow domain or a specified subregion [L].
cMeanIm	Mean concentration in the immobile domain of the entire flow domain or a specified subregion [ML^{-3}]. This variable is given for all solutes from 1 to *NS*.

Table 13.6. A_LEVEL.OUT - pressure heads and cumulative fluxes on the boundary and in the root zone.

Time	Time, *t*, at current time-level [T].
sum(*rTop*)	Cumulative potential surface flux [L] (infiltration/evaporation: -/+).
sum(*rRoot*)	Cumulative potential transpiration [L].
sum(*vTop*)	Cumulative value of the actual surface flux [L] (infiltration/evaporation: -/+).
sum(*vRoot*)	Cumulative value of the actual transpiration [L].
sum(*vBot*)	Cumulative value of the bottom boundary flux [L] (inflow/outflow: +/-).
hTop	Pressure head at the soil surface [L].
hRoot	Mean value of the pressure head in the soil root zone for which *Beta(n)*>0 [L].
hBot	Pressure head at the bottom of the soil profile [L].
ALevel	A-level number (current variable boundary condition number) [-].