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Chapter A3

A MODULAR FINITE-ELEMENT MODEL (MODFE) FOR AREAL AND AXISYMMETRIC GROUND-WATER-FLOW PROBLEMS, PART 1: MODEL DESCRIPTION AND USER'S MANUAL

By Lynn J. Torak

Book 6
MODELING TECHNIQUES

condition zone 2 begin with values for KZ (= 2), NOS (= 16), and IZIN (= 0). The zero value for IZIN indicates that distinct values for α and q_B will be input for each boundary side in zone 2. These inputs are made on the same line as inputs for the boundary-side number, nodes defining the side, and boundary heads. Program variables ALPH(J) and QBND(J) are used to represent α and q_B, respectively, for these inputs to boundary-side J. Note that for the example-aquifer problem, QBND(J) is set to zero or left blank.

Input Instructions

Inputs to MODFE follow a sequential order according to the Input-Type number and particular version of the main program that is used. Because the user can create versions containing only the simulation capabilities that are pertinent to the aquifer problem to be solved, all inputs listed here may not be required for a particular version of MODFE. Inputs are omitted if they correspond to simulation capabilities that are not contained in the version of MODFE that has been created for the aquifer problem. Specific instructions are given in this section about input types that can be omitted when using certain versions of MODFE, and about input types that are required for all versions. Additional information about inputs for a particular hydrologic feature is given in the corresponding sections preceding the input instructions and in the section "Examples of Model Input." The versions of MODFE are listed in tables 4–6, and program structures for these versions are given in the section "Program Structures and Lists of Main Programs," in Torak (1993).

Table 4.—Linear versions of MODular Finite-Element model (MODFE) and simulation capabilities

Simulation capabilities of linear versions of MODFE	
Nonhomogeneous, anisotropic flow having changing directions of anisotropy within model region Steady vertical leakage (no storage effects) Point and areally distributed sources and sinks Specified head (Dirichlet), specified flux (Neumann), and head-dependent (Cauchy-type) boundary conditions	Axisymmetric (radial) flow Zoned input of hydraulic properties and boundary conditions Nonsteady-state or steady-state conditions Vertical cross sections Changing stresses and boundary conditions with time

Simulation options	Solver options	
	Direct, symmetric-Doolitle method	Iterative, MICCG method
Steady vertical leakage (no storage effects)	LMFE1	LMFE2
Vertical leakage having storage effects (transient leakage)	LMFE3	LMFE4

Table 5.—Nonlinear versions of MODular Finite-Element model (MODFE) and simulation capabilities

Simulation capabilities of nonlinear versions of MODFE	
Nonhomogeneous, anisotropic flow having changing directions of anisotropy within model region Steady vertical leakage (no storage effects) Point and areally distributed sources and sinks Specified head (Dirichlet), specified flux (Neumann), and head-dependent (Cauchy-type) boundary conditions Axisymmetric (radial) flow	Zoned input of hydraulic properties and boundary conditions Nonsteady-state conditions Unconfined (water-table) conditions Partial drying and resaturation of a water-table aquifer Conversion between confined- and unconfined-aquifer conditions Change stresses and boundary conditions with time

Simulation options	Solver options	
	Direct, triangular-decomposition method	Iterative, MICCG method
Steady vertical leakage (no storage effects)	NLMFE1	NLMFE2
Vertical leakage having storage effects (transient leakage)	NLMFE3	NLMFE4
Nonlinear steady vertical leakage	NLMFE5	NLMFE6
Nonlinear head-dependent (Cauchy-type) boundaries	NLMFE7	NLMFE8

Table 6.—Nonlinear steady-state versions of MODular Finite-Element model (MODFE) and simulation capabilities

Simulation capabilities of nonlinear versions of MODFE	
Nonhomogeneous, anisotropic flow having changing directions of anisotropy within model region Steady vertical leakage (no storage effects) Point and areally distributed sources and sinks Specified head (Dirichlet), Specified flux (Neumann), and head-dependent (Cauchy-type) boundary conditions Axisymmetric (radial) flow	Zoned input of hydraulic properties and boundary conditions Steady-state conditions Unconfined (water-table) conditions Partial drying and resaturation of a water-table aquifer Conversion between confined- and unconfined-aquifer conditions

Simulation options	Solver options	
	Iterative, MICCG method	Direct, triangular-decomposition method
Water-table conditions only	NSSFE1	NSSFE2
Nonlinear steady vertical leakage	NSSFE3	NSSFE4
Nonlinear head-dependent (Cauchy-type) boundaries	NSSFE5	NSSFE6

Input-Types 1 and 2: Title and Problem Specifications

Required for all versions of MODFE. Replace MBW by NIT, the maximum number of iterations, if the conjugate-gradient method, MICCG, is used for solution.

Input Type	Number of Records	Format	Program Variable	Definition
1	3	20A4	TITLE	Title of simulation problem.
2	1	16I5	NELS	Number of triangular elements or element pairs for which element incidences will be input (see section "Combined-Element Incidences").
			NNDS	Number of nodes.
			MXSTPS	Maximum number of time steps in any stress period. (Number of time steps in first stress period is input later as NTMP.)
			NPER	Number of stress periods. See section "Selecting Stress Periods and Time-Step Sizes" for establishing stress periods.
			NZNS	Number of aquifer-property zones.
			NWELS	Initial number of point sources or sinks (wells).
			NQBND	Total number of element sides on Cauchy-type boundaries, includes specified-flux and head-dependent (Cauchy-type) flux boundaries.
			NBCZ	Number of zones for Cauchy-type boundaries (see section "Grouping Element Sides into Zones").
			NHDS	Number of specified-head nodes.
			MBWC	Maximum condensed-matrix bandwidth (see section "Node Numbering and Determining Bandwidth").
			MBW	Reduced-matrix bandwidth.

Input-Type 2A is required for the iterative, MICCG method of solution (see section "Iterative-- Modified Incomplete-Cholesky Conjugate Gradient").

OMIT INPUT-TYPE 2A IF DIRECT-METHOD OF TRIANGULAR DECOMPOSITION IS USED FOR SOLUTION (SUBROUTINE BAND)

2A	1	F10.0	TOL	Closure tolerance for conjugate-gradient solution.

Input-Type 2B is required for simulating nonlinear steady-state conditions.

OMIT INPUT TYPE 2B FOR SIMULATION OF NONSTEADY-STATE CONDITIONS AND LINEAR STEADY-STATE CONDITIONS (See sections "Linear Conditions and Nonlinear Conditions.")

2B	1	I5, 2F10.0	NITSW	Maximum number of water-table iterations.
			TOLSW	Closure tolerance for steady state.
			DSMX	Maximum allowable displacement, or head change during a water-table iteration.

Input-Type 2C is required for simulating nonlinear head-dependent fluxes. (See sections "Nonlinear Head-Dependent Flux," "Cauchy Type," and "Point Sinks.")

OMIT INPUT-TYPE 2C IF NONLINEAR HEAD-DEPENDENT FLUXES ARE NOT SIMULATED

2C	1	16I5	NBNC	Number of element sides on nonlinear head-dependent (Cauchy-type) flux boundaries.
			NLCZ	Number of zones for nonlinear head-dependent (Cauchy-type) boundaries.
			NPNB	Number of nonlinear point sinks.

Input-Type 2D is required for simulating nonlinear steady vertical leakage (see subsection "Steady Vertical Leakage and Evapotranspiration" of section "Nonlinear Head-Dependent Flux").

OMIT INPUT-TYPE 2D IF NONLINEAR STEADY VERTICAL LEAKAGE IS NOT SIMULATED

2D	1	16I5	NVNZ	Number of nonlinear steady vertical-leakage zones.

Input-Type 2E is required for simulating transient leakage (see section "Vertical Leakage of Water Stored Elastically in a Confining Bed").

OMIT INPUT-TYPE 2E IF TRANSIENT LEAKAGE IS NOT SIMULATED

Input Type	Number of Records	Format	Program Variable	Definition
2E	1	2I5	NCBZ	Number of transient-leakage zones.
			MCBN	Maximum number of nodes where transient-leakage is simulated.

Input-Type 3: Indicator Variables for Axisymmetric-Cylindrical Flow, Scaled Coordinates, and Steady-State Simulations

Required for all versions of MODFE.

Input Type	Number of Records	Format	Program Variable	Definition
3	1	16I5	IRAD	Indicator for coordinate system: = 0 for Cartesian (x-y), = 1 for axisymmetric cylindrical.
			IUNIT	Indicator for scaling units of nodal coordinates: = 0 for no scaling, = 1 for scaling (see definition of SCALE below).
			ISTD	Indicator for steady-state simulations: = 0 for nonsteady state, = 1 for steady state.

Input-Type 4: Title and Scale Factor for Scaling Map Units into Field Units

OMIT INPUT-TYPE 4 IF IUNIT = 0

Input Type	Number of Records	Format	Program Variable	Definition
4	1	20A4	TITLE	Title for scaling factor. Example, "1 inch (map unit) equals 1,000 feet (field unit)."
	1	8F10.0	SCALE	Scale (multiplication) factor for converting map units of length to field units. Used to scale nodal coordinates, lengths, and areas. In above example, SCALE = 1000.

Input-Type 5: Suppress Printout of Initial Conditions

Required for all versions of MODFE.

Input Type	Number of Records	Format	Program Variable	Definition
5	1	16I5	IPXY	Indicator for nodal coordinates: = 0 to print coordinates, = 1 to suppress printout.
			IPH	Indicator for aquifer heads: = 0 to print initial heads, = 1 to suppress printout.
			IPHR	Indicator for source-bed heads: = 0 to print source-bed heads, = 1 to suppress printout.
			IPQW	Indicator for point sources and sinks: = 0 to print sources and sinks, = 1 to suppress printout.
			IPCB	Indicator for specified-flux and head-dependent (Cauchy-type) flux: = 0 to print boundary input, = 1 to suppress printout.
			IPHB	Indicator for initial values on specified-head boundaries: = 0 to print specified heads, = 1 to suppress printout.
			IPND	Indicator for element incidences (node numbers for each element): = 0 to print incidence list, = 1 to suppress printout.

Input-Type 6: Node Coordinates and Head Data

Required for all versions of MODFE.

Input Type	Number of Records	Format	Program Variable	Definition
6	NNDS	I5, 7F10.0	I	Node number.
			XG(I)	X coordinate of node [length].
			YG(I)	Y coordinate of node [length].
			H(I)	Initial hydraulic head [length].
			HR(I)	Source-bed head [length].

Input-Types 7-9: Boundary Conditions

For steady-state simulations, at least one specified-head boundary, Input-Type 9, or one head-dependent (Cauchy-type) boundary with ALPHZ or ALPH(J) > 0, Input-Type 8, is required to obtain a unique solution. A nonlinear head-dependent (Cauchy-type) boundary with GCZ or GC(I) > 0, Input-Types 13C or 13D may replace Input-Type 8 for this requirement.

Input-Type 7: Point Sources and Sinks

OMIT INPUT-TYPE 7 IF NWELS = 0

Input Type	Number of Records	Format	Program Variable	Definition
7	NWELS	I5, 7F10.0	I	Node number of point source/sink.
			QWEL	Volumetric flow rate [length^3 / time] of point source/sink.

Input-Type 8: Specified-Flux and Head-Dependent (Cauchy-Type) Flux

Input-Type 8A is followed by either Input-Type 8B or Input-Type 8C for each zone (see section "Grouping Element Sides into Zones" for details).

OMIT INPUT-TYPES 8A-8C IF NQBND = 0

Input Type	Number of Records	Format	Program Variable	Definition
8A	NBCZ	16I5	KZ	Zone number for specified flux or head-dependent (Cauchy-type) flux boundary.
			NOS	Number of element sides in zone.
			IZIN	Indicator for zone input of α and/or q_B: = 0 for inputting unique values for each side in zone, = 1 for inputting one value for all sides in zone.

Input-Type 8B follows Input-Type 8A for each zone.

OMIT INPUT-TYPE 8B IF IZIN = 0

Input Type	Number of Records	Format	Program Variable	Definition
8B	NBCZ	8F10.0	ALPHZ	α term for head-dependent (Cauchy-type) boundary [length/time]. See section "Head-Dependent (Cauchy-Type) Flux" for applications.
			QBNZ	q_B term for specified-flux boundary [length^2/time]. See section "Specified Flux" for applications.
	NOS	3I5, 4F10.0	J	Number of the boundary side.
			KQB(J)	Node k of element side J on boundary.
			LQB(J)	Node l of element side J on boundary.
			HK(J)	Boundary or external head, H_B [length], at node k on boundary (see fig. 16).
			HL(J)	Boundary or external head, H_B [length], at node l on boundary (see fig. 16).

Input-Type 8C follows Input-Type 8A for each zone.

OMIT INPUT-TYPE 8C IF IZIN = 1

Input Type	Number of Records	Format	Program Variable	Definition
8C	NOS	3I5, 4F10.0	J	Number of the boundary side (see figs. 15-18, 20).
			KQB(J)	Node k of element side J on boundary.
			LQB(J)	Node l of element side J on boundary.
			ALPH(J)	α term for head-dependent Cauchy-type boundary [length/time]. See section "Head-Dependent (Cauchy-Type) Flux" for applications.
			QBND(J)	q_B term for specified-flux boundary [length^2/time]. See section "Specified Flux" for applications.
			HK(J)	Boundary or external head, H_B [length], at node k on boundary (see fig. 16).
			HL(J)	Boundary or external head, H_B [length], at node l on boundary (see fig. 16).

Input-Type 9: Specified Heads

OMIT INPUT-TYPE 9 IF NHDS = 0

Input Type	Number of Records	Format	Program Variable	Definition
9	NHDS	I5, 7F10.0	J	Node number of specified-head boundary.
			HB	Initial value of specified head at node J [length].

Input-Types 10 and 11: Hydraulic-Property Values and Element Incidences

Required for all versions of MODFE. Enter input-types 10 and 11 together for each hydraulic-property zone, KZ (see section "Combined-Element Incidences" and "Grouping Elements into Zones" for details).

Input Type	Number of Records	Format	Program Variable	Definition
10	NZNS	2I5, 6F10.0	KZ	Hydraulic-property-zone number.
			NO	Number of elements or element pairs in zone.
			XTR	X transmissivity, T_{xx} [length^2 / time], for confined flow or x hydraulic conductivity, K_{xx} [length/time], for unconfined flow in areal dimensions; radial hydraulic conductivity, K_{rr}, [length/time], for axisymmetric (radial) flow, or horizontal hydraulic conductivity K_{xx} or K_{yy} for cross-sectional flow.
			YTR	Y transmissivity, T_{yy} [length^2 / time], for confined flow or y hydraulic conductivity, K_{yy} [length/time], for unconfined flow in areal dimensions; vertical hydraulic conductivity K_{zz}, [length/time], for radial or cross-sectional flow.
			ANG	Rotation angle (in degrees) for transforming global x-y coordinates to the local $\bar{x}$-$\bar{y}$ system for varying directions of anisotropy.
			VLC	Hydraulic conductance (vertical hydraulic conductivity divided by thickness) of confining bed [time^{-1}].
			STR	Storage coefficient [dimensionless] for confined conditions; specific yield [dimensionless] for unconfined conditions without conversion between confined and unconfined aquifer conditions, or specific storage [length^{-1}] for cross-sectional or radial flow
			QD	Unit rate of areally distributed stress [length/time].
11	NO	16I5	IEL	Element number.
			ND(I)	Element incidences. Four values required for each element or element pair. Element pair is counted as one element and is divided along first and third entries of incidences (see section "Combined-Element Incidences" for details.

Input-Type 12: Unconfined (Water-Table) Conditions

Required for the following nonlinear, nonsteady-state simulations: water-table conditions, conversion between confined and unconfined aquifer conditions, drying and resaturation of aquifer material, and nonlinear head-dependent fluxes. See appropriate sections pertaining to these hydrologic conditions for information on additional inputs. The value for * appearing in the "Number of Records" column of Input-Types 12B and 12C is computed as (NNDS+7)/8 by using integer math.

OMIT INPUT-TYPE 12 FOR SIMULATION OF CONFINED CONDITIONS

OMIT INPUT-TYPE 12D FOR NONLINEAR, STEADY-STATE SIMULATIONS

Input Type	Number of Records	Format	Program Variable	Definition
12A	1	16I5	IPTK	Indicator to suppress printout of aquifer thickness at each node: = 0 to print thickness values, = 1 to suppress printout.
			IPTP	Indicator to suppress printout of altitude of top of aquifer or bottom of overlying confining bed at each node: = 0 to print altitude values, = 1 to suppress printout.
12B	*	8F10.0	THK(I)	Nodal value of aquifer thickness [length].
12C	*	8F10.0	TOP(I)	Nodal value for altitude of top of water-table aquifer or bottom of overlying confining bed [length].
12D	NZNS	2I5, F10.0	KZ	Zone number for specific yield.
			NO	Number of elements in zone.
			SY	Specific yield [dimensionless].

Input-Types 13-15: Nonlinear Head-Dependent Flux

Input requirements vary depending on the program structure of MODFE and type of nonlinear conditions that are simulated. For details about inputs, refer to instructions at the beginning of each Input Type and in corresponding sections of this report. See sections "Nonlinear Head-Dependent Flux" and "Program Structures and Lists of Main Programs" in Torak (1992) for programming details.

OMIT INPUT-TYPES 13-15 FOR SIMULATION OF LINEAR-FLOW CONDITIONS

Input-Type 13: Nonlinear Head-Dependent (Cauchy-Type) Flux and Point Sinks

Input-Type 13A required for simulating nonlinear head-dependent (Cauchy-type) flux and nonlinear point sinks.

Input Type	Number of Records	Format	Program Variable	Definition
13A	1	2I5	IPNC	Indicator to suppress printout of input for nonlinear head-dependent (Cauchy-type) boundaries: = 0 to print boundary values, = 1 to suppress printout.
			IPNP	Indicator to suppress printout of input for nonlinear point-sink boundaries: = 0 to print boundary values, = 1 to suppress printout.

Input-Type 13B: Nonlinear Head-Dependent (Cauchy-Type) Flux

Input-Type 13B is followed by either Input-Type 13C or Input-Type 13D for each zone (see section "Grouping Element Sides into Zones" for details).

OMIT INPUT-TYPES 13B-13D IF NBNC = 0

Input Type	Number of Records	Format	Program Variable	Definition
13B	NLCZ	16I5	KZ	Zone number for nonlinear head-dependent (Cauchy-type) boundary.
			NOS	Number of sides in zone.
			IZIN	Indicator for zone input of α terms: = 0 for inputting unique values for each side in zone, = 1 for inputting one value for all sides in zone.

Input-Type 13C: Nonlinear Head-Dependent (Cauchy-Type) Flux

Input-Type 13C follows Input-Type 13B for each zone. The value of GCZ for zone KZ is followed, on separate lines, by inputs for the boundary-side number, J; nodes on the boundary side, KR(J) and LR(J); and boundary and controlling heads, in a manner similar to Input-Type 8B (see section "Cauchy Type" for applications of this boundary condition and descriptions of inputs).

OMIT INPUT-TYPE 13C IF IZIN = 0

Input Type	Number of Records	Format	Program Variable	Definition
13C	NLCZ	F10.0	GCZ	α term for nonlinear head-dependent (Cauchy-type) boundary zone [length/time].
	NOS	3I5, 5F10.0	J	Number of the boundary (element side) in zone KZ.
			KR(J)	Node k of element side J on boundary.
			LR(J)	Node l of element side J on boundary.
			HRK(J)	Boundary or external head H_r at node k on boundary [length].
			HRL(J)	Boundary or external head H_r at node l on boundary [length].
			ZRK(J)	Controlling head or altitude z_r at node k on boundary [length].
			ZRL(J)	Controlling head or altitude z_r at node l on boundary [length].

Input-Type 13D: Nonlinear Head-Dependent (Cauchy-Type) Flux

Input-Type 13D follows Input-Type 13B for each zone. See section "Cauchy Type" for applications of this boundary condition and descriptions of inputs.

OMIT INPUT-TYPE 13D IF IZIN = 1

Input Type	Number of Records	Format	Program Variable	Definition
13D	NOS	3I5, 5F10.0	J	Number of boundary (element side) in zone KZ.
			KR(J)	Node k of element side J on boundary.
			LR(J)	Node l of element side J on boundary.
			GC(J)	α term for nonlinear head-dependent (Cauchy-type) boundary side [length/time].
			HRK(J)	Boundary or external head H_r at node k on boundary [length].
			HRL(J)	Boundary or external head H_r at node l on boundary [length].
			ZRK(J)	Controlling head or altitude z_r at node k on boundary [length].
			ZRL(J)	Controlling head or altitude z_r at node l on boundary [length].

Input-Type 14: Nonlinear Point Sinks

See section "Point Sinks" for applications of this boundary condition and descriptions of inputs.

OMIT INPUT-TYPE 14 IF NPNB = 0

Input Type	Number of Records	Format	Program Variable	Definition
14	NPNB	2I5, 2F10.0	I	Number of the point boundary.
			KP(I)	Node number at point boundary.
			GCP	Discharge coefficient C_{p_i} for point boundary [length^2/time].
			ZP(I)	Reference altitude, z_p, for point sink [length].

Input-Type 15: Nonlinear Steady Vertical Leakage

Input-Type 15A is followed by entries of Input-Type 15B for all nonlinear steady vertical-leakage zones. One entry of Input-Type 15A is required; the option to print or suppress printout of zone inputs and nodal values of HS is applied to all nonlinear steady vertical-leakage zones and to all nodes. The value for * appearing in the "Number of Records" column of Input-Type 15C is computed as (NNDS+7)/8 by using integer math. See subsection "Steady Vertical Leakage" under "Nonlinear Head-Dependent Flux" and section "Zones for Nonlinear Steady Vertical Leakage, Transient Leakage, and Specific Yield" for applications of this boundary condition and descriptions of inputs.

OMIT IF NONLINEAR STEADY VERTICAL LEAKAGE IS NOT SIMULATED

Input Type	Number of Records	Format	Program Variable	Definition
15A	1	3I5	IPNV	Indicator to suppress printout of zone input for all nonlinear steady vertical-leakage zones: = 0 to print zone values, = 1 to suppress printout.
			IPHS	Indicator to suppress printout of controlling head or altitude, HS, by node: = 0 to print HS, = 1 to suppress printout.
15B	NVNZ	3I5, F10.0	L	Zone number for nonlinear leakage.
			NBE	Beginning element number in zone.
			NO	Number of elements in zone.
			VNCF	Conductance terms, R_a or R_e [time^{-1}].
15C	*	8F10.0	HS(I)	Controlling head, H_a, or altitude, z_e or z_t, at node I.

Input-Type 16: Transient-Leakage Approximation

See section "Zones for Nonlinear Steady-Vertical Leakage, Transient Leakage, and Specific Yield" for descriptions about establishing zones and program variables.

OMIT INPUT-TYPE 16 IF TRANSIENT LEAKAGE IS NOT SIMULATED

Input Type	Number of Records	Format	Program Variable	Definition
16	NCBZ	3I5, 2F10.0	L	Transient-leakage-zone number.
			NBE	Beginning element number in zone.
			NO	Number of elements in zone.
			VCON	Vertical hydraulic conductivity of confining bed [length/time].
			SPST	Specific storage of confining bed [length $^{-1}$].

Input-Types 17-25: Stress-Period Inputs

Begin inputs for each stress period with Input-Type 17, followed by optional Input-Types 18-25 for each time step when changes in stresses or boundary conditions are to be made. The number of inputs of Input-Type 17 followed by the appropriate entries of Input-Types 18-25 is given by the value entered for the number of stress periods, NPER. Thus, the "1" appearing in the "Number of Records" column for Input-Type 17A implies that the Input Type is used once for a stress period. The value for * appearing in the "Number of Records" column of Input-Type 17B is computed as (NTMP+7)/8 by using integer math (see sections "Changing Stresses and Boundary Conditions with Time" and "Examples of Model Input" for details).

OMIT INPUT TYPES 17-25 FOR NONLINEAR STEADY-STATE SIMULATIONS

Input-Type 17A: Indicators for Time Varying Stresses and Boundary Conditions

Required for nonsteady-state and linear steady-state versions of MODFE.

Input Type	Number of Records	Format	Program Variable	Definition
17A	1	16I5	NTMP	Number of time steps in stress period. Exception: set to zero (0) to use time steps from previous stress period; set to one (1) for linear steady-state simulations.
			NWCH	Time-step number when point sources and sinks are changed.
			NQCH	Time-step number when areally distributed sources and sinks are changed.
			NHRCH	Time-step number when source-bed heads, H, are changed for simulating steady vertical leakage (no transient leakage from confining bed).
			NBQCH	Time-step number when specified flux or head-dependent (Cauchy-type) flux boundaries are changed.
			NHCH	Time-step number when values for specified-head boundaries are changed.
			NCBCH	Time-step number when source-bed heads, H, are changed for simulating transient leakage.
			NVNCH	Time-step number when controlling heads or altitudes, H_a, z_e, or z_t, for nonlinear steady vertical leakage are changed.
			NGNCH	Time-step number when boundary or external heads, H_r, on nonlinear head-dependent (Cauchy-type) boundaries are changed.

Input-Type 17B: Time Steps

Required for first stress period of nonsteady-state versions of MODFE and subsequent stress periods if NTMP > 0 (see section "Selecting Stress Periods and Time-Step Sizes" for details). Required for linear steady-state versions of MODFE (see definition of DELT(I) below).

OMIT FOR STRESS PERIODS SUBSEQUENT TO STRESS PERIOD 1 IF NTMP = 0

Input Type	Number of Records	Format	Program Variable	Definition
17B	*	8F10.0	DELT(I)	Time-step sizes [time]; any units consistent with hydraulic properties. Exception: set to one (1.) for linear steady-state simulations.

Input-Types 18-25: Changing Stresses and Boundary Conditions with Time

Required on the time step and stress period when changes are to occur. The "1" listed in the "Number of Records" column for Input-Types 18A, 19A, ..., 25A indicates that these inputs are entered once on the time step in which the corresponding change in stress or boundary condition is made. Each of the "A" Input Types is followed by inputs of the corresponding "B" types. Some changes are implemented by inputs on two successive time steps (see section "Changing Stresses and Boundary Conditions with Time" and "Examples of Model Input" for details).

Input-Type 18: Changes to Point Sources and Sinks

OMIT FOR TIME STEPS IN WHICH POINT SOURCES AND SINKS ARE UNCHANGED FROM PREVIOUS VALUES

Input Type	Number of Records	Format	Program Variable	Definition
18A	1	16I5	N	Number of point sources and sinks to be changed on this time step.
			NWCH	Time-step number for additional changes to point sources and sinks during present stress period.
18B	N	I5, 4F10.0	J	Node number of point source or sink to be changed.
			QOLD	Old value of stress [length ^{3}/ time] to be changed.
			QNEW	New value of stress [length ^{3}/ time] to replace old value.

Input-Type 19: Changes to Areally Distributed Sources and Sinks

OMIT FOR TIME STEPS IN WHICH AREALLY DISTRIBUTED SOURCES AND SINKS ARE UNCHANGED FROM PREVIOUS VALUES

Input Type	Number of Records	Format	Program Variable	Definition
19A	1	16I5	N	Number of zones for areally distributed sources and sinks that are changed on this time step.
			NQCH	Time-step number for additional changes to areally distributed sources and sinks during present stress period.
19B	N	3I5, 2F10.0	L	Zone number for areally distributed source or sink to be changed.
			NBE	Beginning element number in zone.
			NO	Number of elements in zone.
			QOLD	Old value of unit-areal stress [length/time] to be changed.
			QNEW	New value of unit-areal stress [length/time] to replace old value.

Input-Type 20: Changes to Source-Bed Heads for Steady Vertical Leakage

OMIT FOR TIME STEPS IN WHICH SOURCE-BED HEADS FOR STEADY VERTICAL LEAKAGE ARE UNCHANGED FROM PREVIOUS VALUES

Input Type	Number of Records	Format	Program Variable	Definition
20A	1	16I5	N	Number of nodes for source-bed heads that are changed on this time step.
			NHRCH	Time-step number for additional changes to source-bed heads during present stress period.
20B	N	I5, F10.0	J	Node number of source-bed head to be changed.
			HR(J)	New value of source-bed head [length].

Input-Type 21: Changes to Specified Flux or Boundary Head on Cauchy-Type Boundaries

OMIT INPUT-TYPE 21 IF CAUCHY-TYPE BOUNDARIES ARE UNCHANGED FROM PREVIOUS VALUES

Input Type	Number of Records	Format	Program Variable	Definition
21A	1	16I5	N	Number of boundary sides to be changed on this time step.
			NBQCH	Time-step number for making additional changes to Cauchy-type boundaries in present stress period.
21B	N	I5, 4F10.0	J	Number of the boundary side.
			QNEW	New value of unit discharge, q_B [length^2/time], to replace old value.
			HK(J)	New value for boundary or external head, H_B [length], at node k on boundary side J (see fig. 16).
			HL(J)	New value for boundary or external head, H_B [length], at node l on boundary side J (see fig. 16).

Input-Type 22: Changes to Specified-Head Boundaries

OMIT INPUT-TYPE 22 IF SPECIFIED HEADS ARE UNCHANGED FROM PREVIOUS TIME STEP

Input Type	Number of Records	Format	Program Variable	Definition
22A	1	16I5	N	Number of specified-head boundaries (nodes) to be changed on this time step.
			NHCH	Time-step number for additional changes to specified-head boundaries during present stress period.
22B	N	I5, 4F10.0	J	Node number of the specified-head boundary to be changed.
			HB	New value of the specified head for node J [length].

Input-Type 23: Changes to Source-Bed Heads for Transient Leakage

OMIT INPUT-TYPE 23 IF SOURCE-BED HEADS FOR TRANSIENT LEAKAGE ARE UNCHANGED FROM PREVIOUS TIME STEP

Input Type	Number of Records	Format	Program Variable	Definition
23A	1	2I5	N	Number of nodes where source-bed heads are to be changed on this time step.
			NCBCH	Time-step number for additional changes to source-bed heads during present stress period.
23B	N	I5, F10.0	J	Node number of the source-bed head to be changed.
			HR(J)	New value of the source-bed head for node J [length].

Input-Type 24: Changes to Boundary or External Heads on Nonlinear Head-Dependent (Cauchy-Type) Boundaries

OMIT INPUT-TYPE 24 IF BOUNDARY OR EXTERNAL HEADS ARE UNCHANGED FROM PREVIOUS TIME STEP

Input Type	Number of Records	Format	Program Variable	Definition
24A	1	16I5	N	Number of boundary sides to be changed on this time step.
			NGNCH	Time-step number for additional changes to boundary or external heads during present stress period.
24B	N	I5, 2F10.0	J	Number of the nonlinear boundary side to be changed.
			HRK(J)	New value of the boundary head, H_r, for node k on side J of nonlinear boundary [length].
			HRL(J)	New value of the boundary head, H_r, for node l on side J of nonlinear boundary [length].

Input-Type 25: Changes to Controlling Heads for Nonlinear Steady Vertical Leakage

OMIT INPUT-TYPE 25 IF CONTROLLING HEADS ARE UNCHANGED FROM PREVIOUS TIME STEP

Input Type	Number of Records	Format	Program Variable	Definition
25A	1	2I5	N	Number of nodes where controlling heads are to be changed on this time step.
			NVNCH	Time-step number for additional changes to controlling heads during present stress period.
25B	N	I5, F10.0	J	Node number of the controlling head to be changed.
			HR(J)	New value of the controlling head for node J [length].

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