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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

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Book 6

MODELING TECHNIQUES

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Table 1.—Program variables and subroutines used to change stresses and boundary conditions with time

Stress or boundary condition	Number of time steps to implement change	Indicator variable	Old value	New value	Subroutine
Source-bed head for transient leakage	1	NCBCH	--	HRJ	CBCHG
Point sources/sinks	2	NWCH	QOLD	QNEW	COCHG
Areally distributed recharge/discharge	2	NQCH	QOLD	QNEW	COCHG
Source-bed head for steady leakage	2	NHRCH	--	HR(J)	COCHG
Specified-flux boundary	2	NBQCH	--	QNEW	COCHG
Head-dependent (Cauchy-type) boundary	2	NBQCH	-- --	HK(J) HL(J)	COCHG
Specified-head boundary	1	NHCH	--	HB	COCHG
Nonlinear head-dependent (Cauchy-type) boundary	2	NGNCH	-- --	HRK(J) HRL(J)	GNCHG
Controlling head for nonlinear steady leakage	2	NVNCH	--	HS(J)	VNCHG

easily by using the input mechanisms designed for initial conditions (see section "Input Instructions" for descriptions of indicator variables and other inputs) than the subroutines and inputs designed to change these values.

Inputs consisting of the changed values for stresses or controlling heads are made on each time step according to the sequence given in the input instructions. Entries are omitted from the sequence of inputs for a particular time step if the related stress or controlling head is not to be changed. Conversely, multiple inputs of changes to one type of stress or boundary condition may precede entries for other types, if a particular change is made more frequently than others. Details of these inputs are given in the sections "Input Instructions" and "Examples of Model Input."

Data Preparation

All data that are required for simulating a given aquifer problem are prepared for input to MODFE according to the instructions given in the section "Input Instructions." However, the input of hydraulic properties, boundary conditions, and the finite-element mesh to MODFE can be simplified. Hydraulic properties and boundary conditions that are input by element and element side can be grouped by common values into hydraulic-property and boundary-condition zones. Another simplification involves combining the input of node numbers that define elements (element incidences) so that one set of incidences define two triangular elements. The following sections describe how to combine element incidences, establish hydraulic-property and boundary-condition zones, and input values to MODFE.

Combined-Element Incidences

The node numbers that define an element, termed element incidences, can be combined for two contiguous elements for input to MODFE. Combining element incidences simplifies input, decreases computer-storage requirements, and utilizes the efficient programming style of MODFE most effectively. To combine element incidences, the four node numbers that define an element pair (two contiguous elements) are written in counterclockwise order (fig. 30*A*). The element pair is divided into two triangular elements (fig. 30*B*) along the element side defined by the first and third element incidences (nodes 35 and 42 in fig. 30*A*).

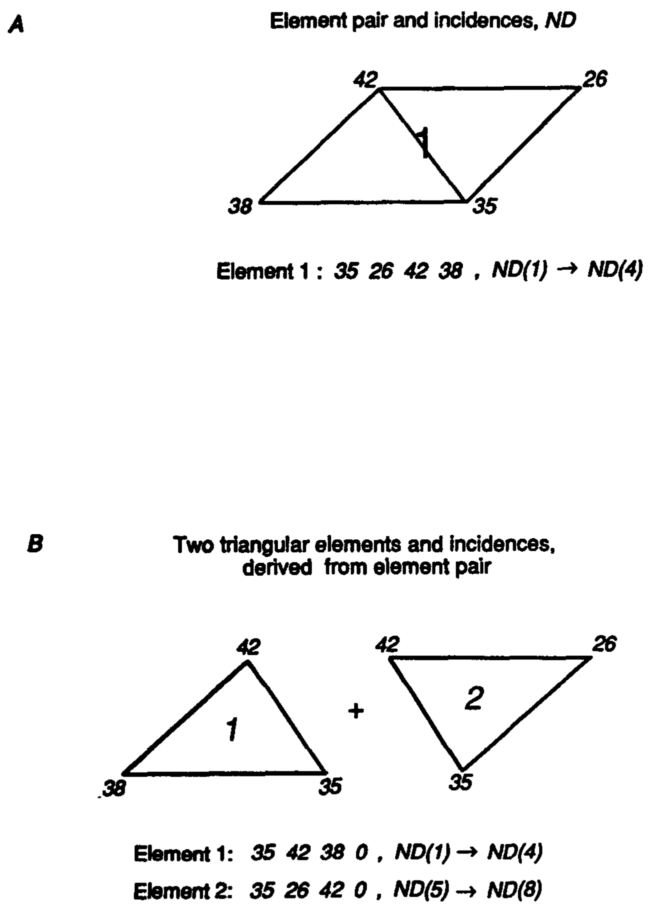


Figure 30.—Input of element incidences to MODular Finite-Element model (MODFE) for (*A*) two contiguous elements having combined element-incidences and (*B*) two elements having separate element incidences.

Element incidences are represented in MODFE by the program variable ND. MODFE is designed to use combined-element incidences; thus, all elements or element pairs require four values of incidences. For a triangular element (fig. 30*B*), the fourth entry of the incidences is zero. Note that by combining element incidences, four nonzero values, ND(1) through ND(4) (fig. 30*A*), can define the element pair, whereas eight values, ND(1) through ND(8) (fig. 30*B*), are required to define individually the two triangular elements. Both methods shown in figure 30 for representing two triangular elements with incidences are equivalent, and both methods can be used simultaneously within the same finite-element mesh.

Savings in computer storage and computational efficiency is realized by using combined-element incidences. The amount of storage needed for the program variable ND is decreased by combining the input of element incidences. The element pair is counted as one element when determining the number of elements in the mesh. Thus, computer storage is decreased for program variables that are dimensioned in terms of the number of elements. Computations for element areas and nodal terms in the finite-element equations are performed more efficiently when element incidences are combined than if incidences were input separately.

Because combined-element incidences cause the element pair to be counted as one element, both triangles of the element pair contain the same values for hydraulic properties and for the rotation angle of anisotropy. Consequently, both triangles of the element pair are located within the same hydraulic-property zone. Details of establishing hydraulic-property zones are given in the following section.

Hydraulic-Property and Boundary-Condition Zones

Inputs for hydraulic properties and boundary conditions that are made to MODFE by elements or by element sides can be simplified greatly by grouping elements or element sides into zones. A zone is a group of elements or element sides that requires the same values to define hydraulic properties or boundary conditions. A zone can contain one element (or side) or as many as all elements (or sides) in the mesh. Different types of zones are used in MODFE to simplify data input. Descriptions of zones that are created by grouping elements are given first. These are followed by descriptions of zones that are created by grouping element sides. Examples of establishing zones for an aquifer problem are given after these descriptions.

One type of hydraulic-property zone contains elements that have identical values for the following information:

- aquifer transmissivity or hydraulic conductivity in the x (or horizontal) and y (or vertical) directions,
- rotation angle for transforming x-y coordinates to local coordinates for anisotropic flow,
- vertical hydraulic conductance of a confining bed (linear case),
- aquifer storage coefficient (or specific storage for cross-section or axisymmetric flow), and
- areally distributed stresses.

Another type of element zone groups elements according to the value of one hydraulic property. Grouping of this type may be used for inputting the following hydraulic properties:

- specific yield for water-table simulations,
- specific storage and vertical hydraulic conductivity for transient leakage, and

- coefficient (R_a or R_e) for nonlinear steady vertical leakage or evapotranspiration.

Boundary conditions may be input by zone either to group element sides that contain the same value for terms defining the hydrologic condition or to identify a group of element sides that require distinct values for boundary-condition identification. Zones may be created for the following boundary conditions:

- specified flux (linear case),
- linear, head-dependent (Cauchy-type) flux, and
- nonlinear, head-dependent (Cauchy-type) flux.

The establishment of hydraulic-property and boundary-condition zones for data inputs to MODFE is demonstrated with the following example. The area of interest contains a water-table aquifer that is dissected by two rivers (fig. 31*A*). Aquifer heads are affected by steady vertical leakage (no storage effects) through an underlying confining bed. Alluvium in the valley of one of the rivers creates confined- and semiconfined-aquifer conditions with the potential for conversion between confined and unconfined conditions. There is head-dependent (regional) inflow of ground water from the northeast and outflow to the southwest.

The pertinent hydraulic properties and boundary conditions to be considered for zoning are the aquifer hydraulic conductivity, vertical hydraulic conductances of the underlying confining bed and of the alluvium, and the α coefficients for the head-dependent (Cauchy-type) boundaries, which represent the rivers and regional flow. Distributions of these hydraulic properties and boundary conditions are shown in figures 31 and 32.

The finite-element mesh of the area of interest is shown in figure 33A. Note the finer discretization by elements that are located in areas covered by alluvium and near the inflow boundary. It is anticipated that the aquifer head will be more time variant in these areas than in other areas because of conversion between confined and unconfined conditions and because of varying boundary inflow.

The zoning process begins by superposing the finite-element mesh on the distributions of hydraulic properties and boundary conditions. Element sides that approximate the boundaries of each distribution are identified (figs. 33 and 34). Nodes are moved from their original positions in the mesh so that locations of hydraulic-property zones and boundary conditions are defined by element sides.

Grouping Elements into Zones

Zones containing elements that have identical values for the hydraulic properties listed at the beginning of the section "Hydraulic-Property and Boundary-Condition Zones" are created first by defining boundaries for the distributions within each property (by using element sides) and then by combining the boundaries of different properties. For the example aquifer problem, boundaries for the distributions of aquifer hydraulic conductivity and vertical hydraulic conductance of the underlying confining bed (figs. 33*B* and 34*A*) are combined to form hydraulic-property zones for input to MODFE. Also, for this example, it is assumed that the other hydraulic properties in the list, which could be used to create other zone boundaries, are either constant over the aquifer area or have a value of zero. Thus, the intersection of boundaries for aquifer hydraulic conductivity and vertical hydraulic conductance create seven hydraulic-property zones (fig. 35*A*); all elements within each zone have the same values of vertical hydraulic conductance and hydraulic conductivity.

Inputs for each hydraulic-property zone consist of values that define the zone number, number of elements in the zone, and hydraulic properties, followed by the element numbers and element incidences (node numbers that define the element). The zone number and the number of elements contained in a zone are represented in MODFE by the program variables KZ and NO, respectively. The hydraulic properties that are listed in the previous section for hydraulic-property zones are represented by the variables XTR, YTR, ANG, VLC, STR, and QD, respectively. The element number is represented by the program variable IEL, and element incidences are represented by the program variable ND. Four values of incidences are used for each element instead of three because MODFE permits the incidences of two adjacent elements to be combined, or paired, for input (see section "Combined-Element Incidences"). An example of the inputs for hydraulic-property zone 1 containing 120 elements or element pairs is given in figure 35*B*.

Elements are identified within hydraulic-property zones and sequenced in the finite-element mesh according to the order in which the incidences are input. For zone 1, the incidences for all 120 elements (or element pairs) are input consecutively following the input of hydraulic properties for the zone. Thus, 120 sets of 4-node incidences, or 480 contiguous storage locations for ND, define nodes that correspond to elements or element pairs within zone 1 and also define the first 120 elements or element pairs in the mesh. The first four incidences are associated with the first element or element pair in the mesh, and the last four incidences (for zone 1) are associated with the 120th element or element pair.

Element numbering within a zone can be arbitrary as element numbers are not used in MODFE. However, the element numbers that are printed by MODFE correspond to the order in which the inci-

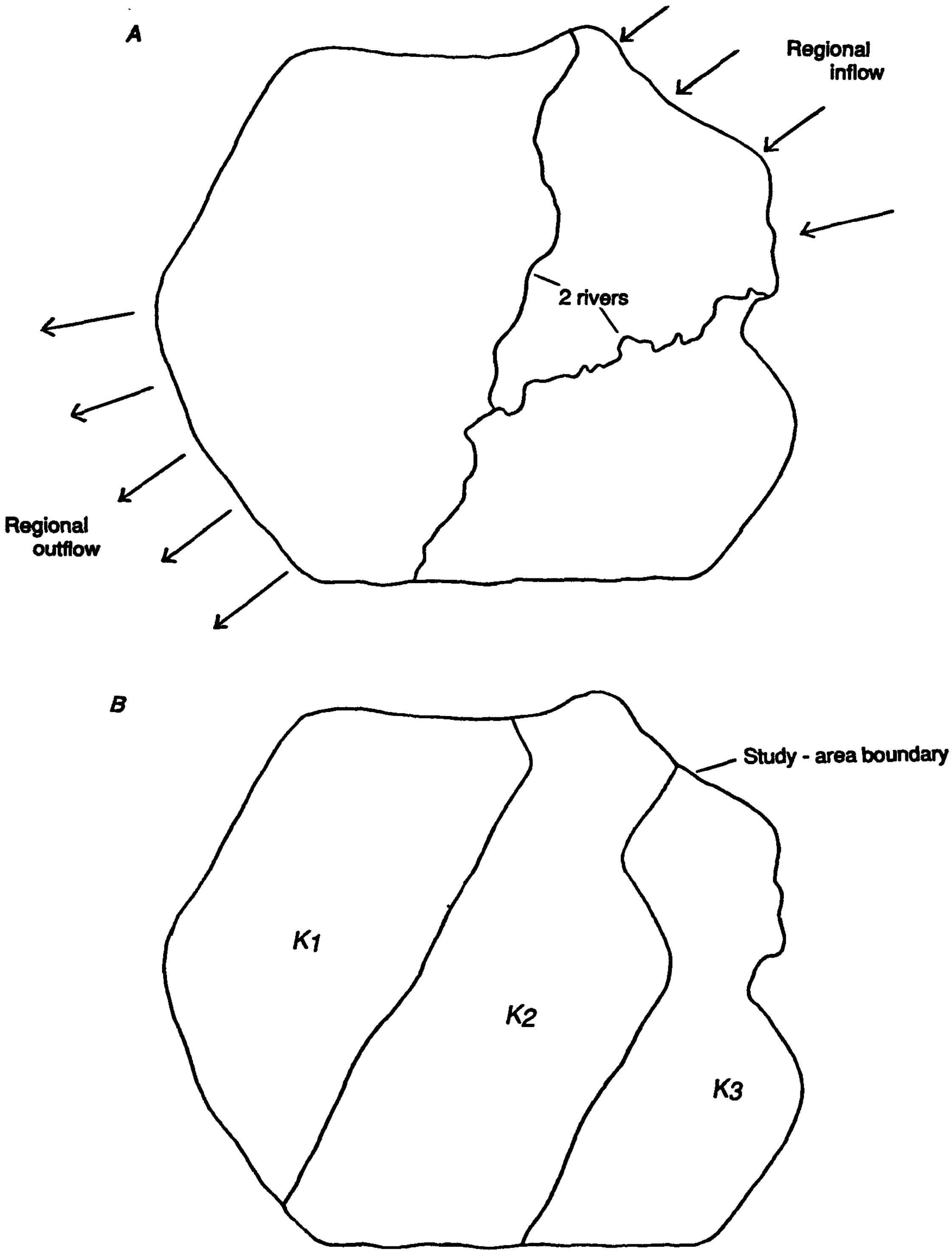


Figure 31.—(*A*) Areal representation of water-table aquifer dissected by two rivers and (*B*) hydraulic conductivity zones, *K1*, *K2*, and *K3*, for water-table aquifer.

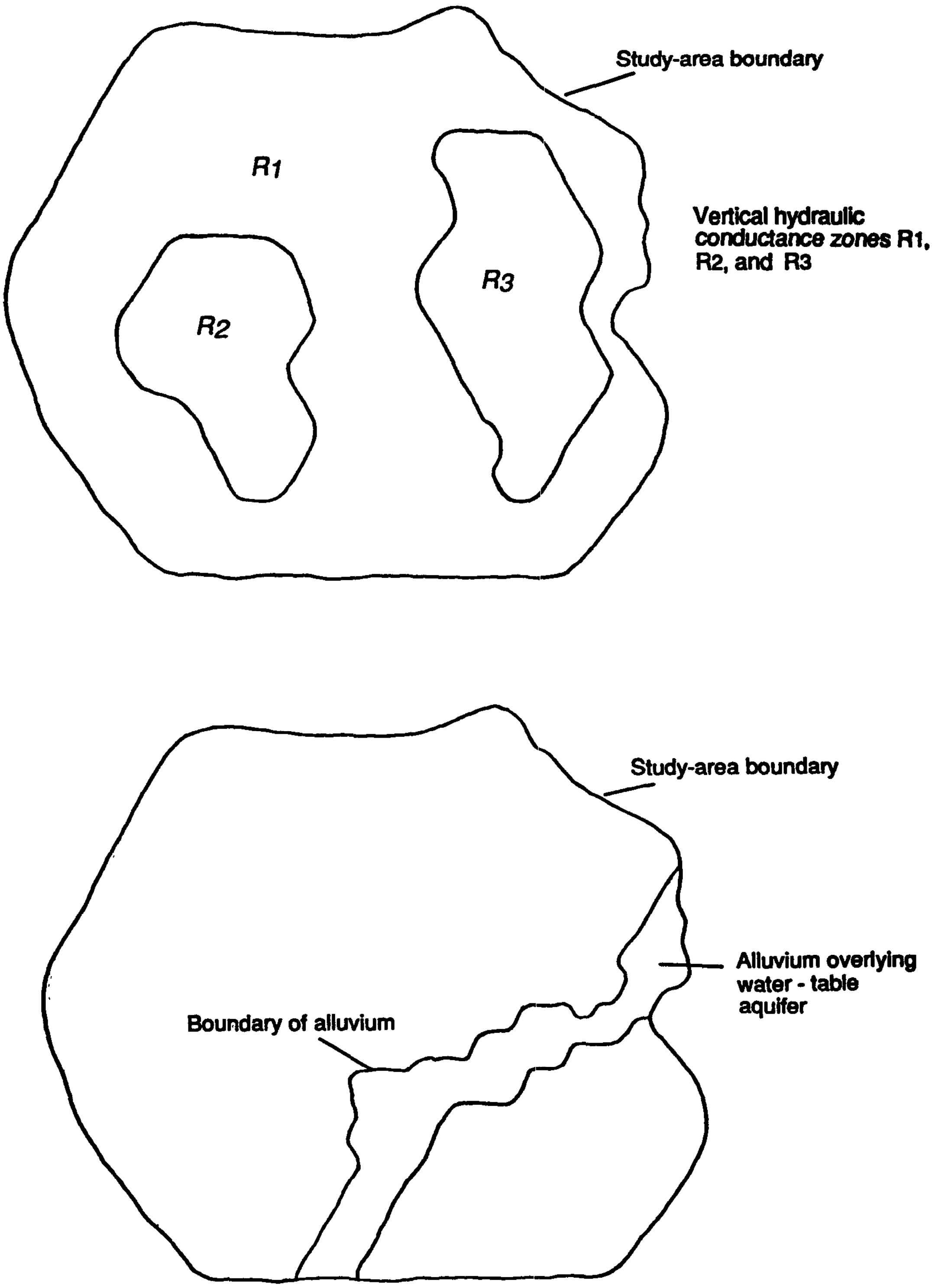


Figure 32.—Areal distribution of vertical hydraulic conductance for (*A*) confining bed underlying water-table aquifer; and (*B*) alluvium overlying water-table aquifer.

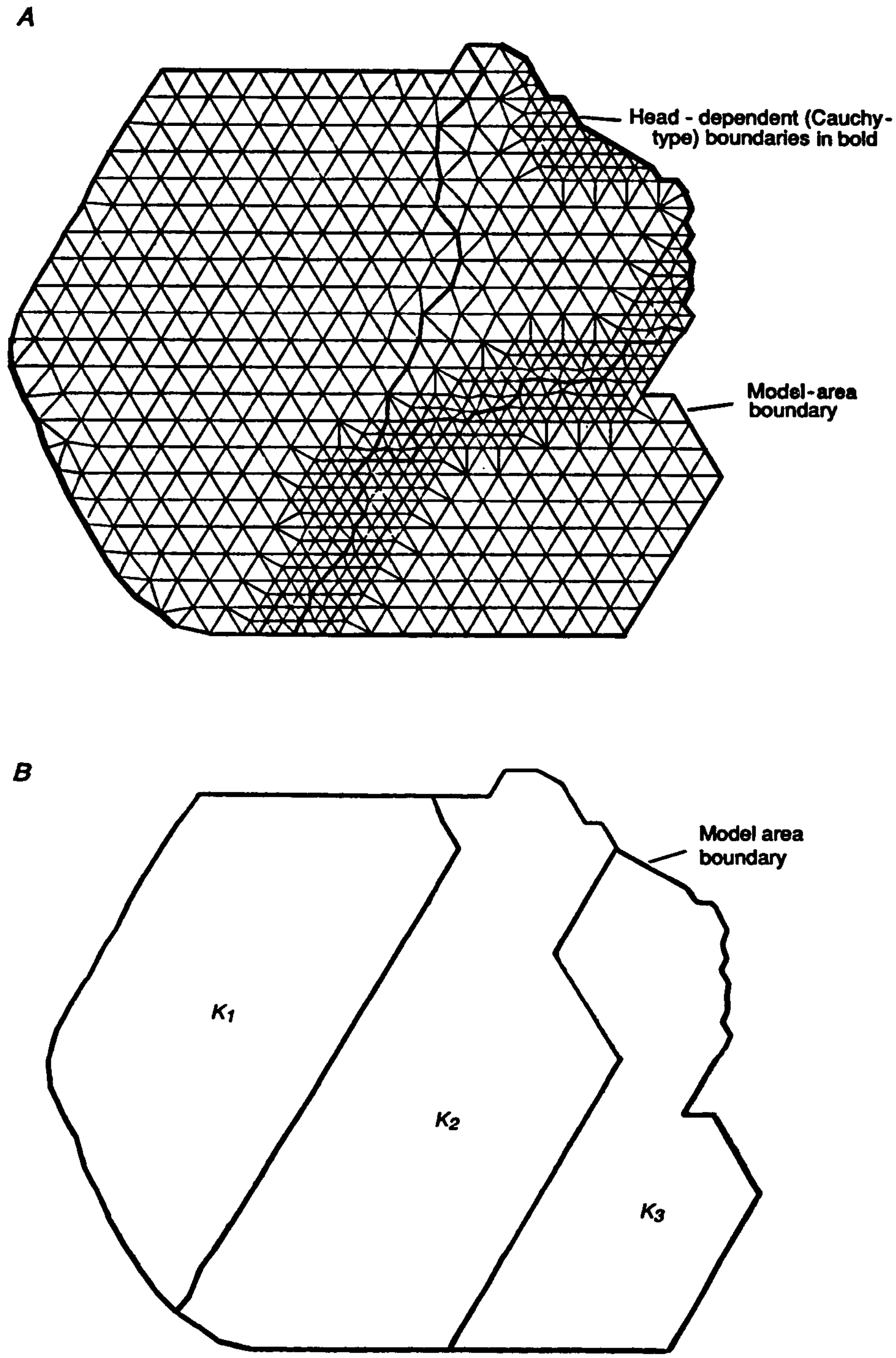


Figure 33.—(*A*) Finite-element mesh for example aquifer problem and boundary conditions and (*B*) hydraulic-conductivity zones, *K1*, *K2*, and *K3*, bounded by element sides.

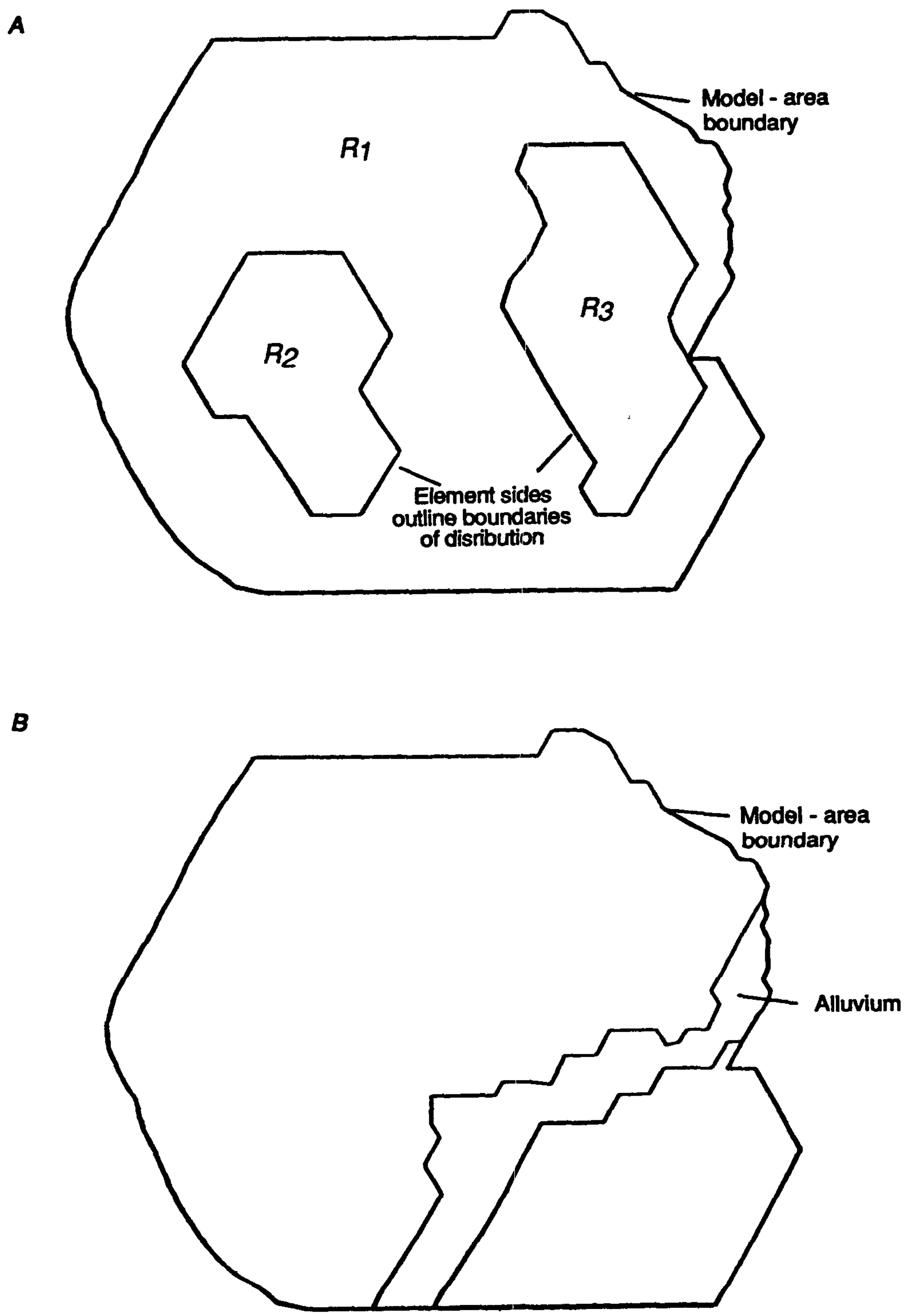
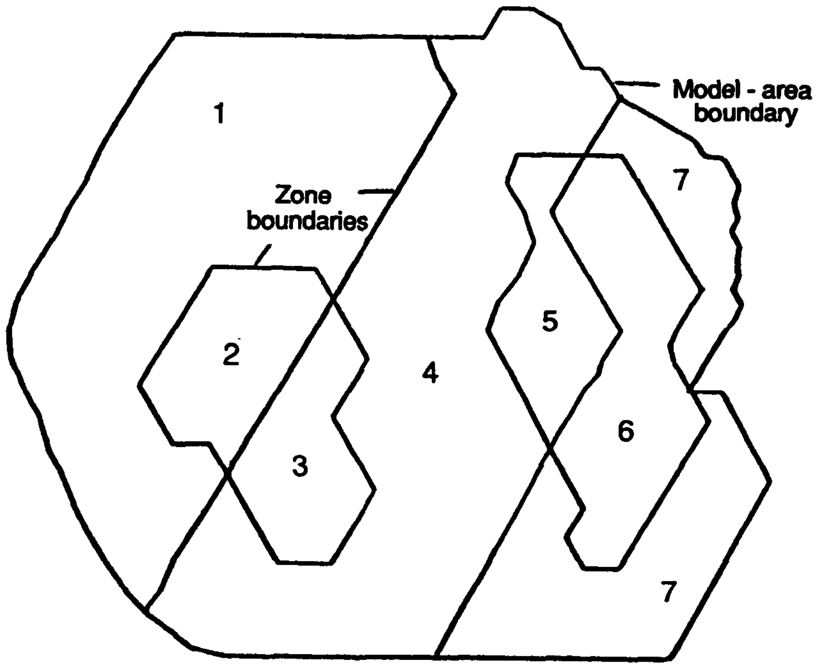


Figure 34.—Element sides used to represent (*A*) vertical-hydraulic conductance zones, *R1*, *R2*, and *R3*, for confining bed underlying aquifer and (*B*) boundary of alluvium overlying water-table aquifer.

A



B

KZ	NO	XTR	YTR	ANG	VLC	STR	QD
1	120	1200.	1200.	0.	1.E-2	1.E-4	0.

1	30	14	31	55
2	14	4	15	31
3	4	1	5	0
4	15	5	8	20
5	17	18	6	16
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
116	18	19	7	0
117	16	6	4	14
118	6	7	1	0
119	2	8	5	1
120	97	68	100	138
IEL	ND(I), I=1,480			

Figure 35.—(*A*) Hydraulic-property zones (7) resulting from intersecting boundaries for vertical hydraulic conductance and aquifer hydraulic conductivity and (*B*) example of input and program variables for zone 1.

dences have been input. Because the finite-element equations are formed and solved at nodes, it is the node numbers (defined by the element incidences), not the element numbers, that determine where computations will occur within a zone.

Zones may be input in any order, that is, values for zone 1 do not have to be input first. In this manner, the order of the element incidences within a hydraulic-property zone and the order of the zones can be used to define additional zones for nonlinear steady vertical leakage, transient leakage, and specific yield, discussed in the following section.

Zones for Nonlinear Steady Vertical Leakage, *Transient Leakage, and Specific Yield*

The order in which element incidences are input for hydraulic-property zones can be used to create other zones for nonlinear steady vertical leakage, transient leakage, and specific yield. The example-aquifer problem is used to demonstrate the creation of zones for simulating nonlinear steady vertical leakage between the water-table aquifer and the alluvium. By superposing the distribution of vertical hydraulic conductance of the alluvium (fig. 34*B*) on the hydraulic-property zones (fig. 35*A*), five zones for nonlinear steady vertical leakage are created from the intersecting boundaries (fig. 36*A*). However, reordering the input of element incidences within hydraulic-property zones 3 through 7 results in creating only three zones of nonlinear steady vertical leakage (fig. 36*B*). (Fewer zones decrease the number of changes to be made during calibration, and hence, decrease the potential for making errors when changing zone values.)

One zone for nonlinear steady vertical leakage consists of the elements within hydraulic-property zones 3 and 4 that contain alluvium (fig. 36*A*). The inputs of hydraulic-property data and incidences are arranged so that incidences for elements corresponding to nonlinear steady vertical leakage are placed in contiguous storage locations within the program vector ND. That is, incidences of elements in hydraulic-property zone 3 that contain alluvium are input last in the incidence list for zone 3, and incidences for elements that contain alluvium in zone 4 are input first in the incidence list for zone 4. Thus, a contiguous set of node numbers from hydraulic-property zones 3 and 4 corresponding to the nonlinear vertical leakage zone is stored in ND. If the number of elements in hydraulic-property zones 3 and 4 that contain nonlinear steady vertical leakage are 2 and 70, respectively, then the leakage zone would contain 72 elements (assuming the data for zones 3 and 4 are input consecutively).

Another vertical hydraulic-conductance zone can be created by ordering the incidences of elements within hydraulic-property zones 5 and 6 that contain nonlinear steady vertical leakage. Incidences of elements in hydraulic-property zone 5 that contain nonlinear steady vertical leakage are input last in the incidence list for zone 5. These incidences are followed by those in zone 6 that contain nonlinear steady vertical leakage, thereby creating a contiguous set of storage locations in ND that contain node numbers of elements in the nonlinear-leakage zone. Note that elements in the nonlinear-leakage zone can be separated in the finite-element mesh from other elements in the same zone as long as their incidences are input consecutively. A third vertical hydraulic-conductance zone for nonlinear steady vertical leakage can be created by using elements in hydraulic-property zone 7 that contain the alluvium.

Inputs for nonlinear steady vertical leakage and transient leakage are used to identify contiguous storage locations within ND for establishing zones and for assigning values to hydraulic properties. The inputs consist of values for the beginning element number in the leakage zone, number of elements contained in the zone, and, depending on the physical process that is simulated, vertical hydraulic conductance for nonlinear steady vertical leakage and (or) vertical hydraulic conductance and specific storage of the confining bed for transient leakage. The beginning element number of the zone is input as the program variable NBE, and the number of elements in a zone is input as the program variable NO. The zone number is represented by the program variable L. For nonlinear steady vertical leakage, vertical hydraulic conductance is represented by the program variable VNCF, and for transient leakage, vertical hydraulic conductance and specific storage of the confining bed are represented, respectively, by the program variables VCON and SPST. Descriptions of these inputs are given in the section "Input Instructions."

The value of NBE is used in MODFE to locate the incidences associated with elements in zone L. For instance, the value of NBE-1 gives the number of sets of 4-node incidences (stored in the program vector ND) that precede the incidences associated with zone L. The value of NO is used to determine the number of sets of incidences contained in zone L, which are evaluated by MODFE when terms for either nonlinear steady vertical leakage or transient leakage are formed for the finite-element equations.

The use of NBE and NO in MODFE is demonstrated in the example-aquifer problem described above and in some of the inputs for creating nonlinear

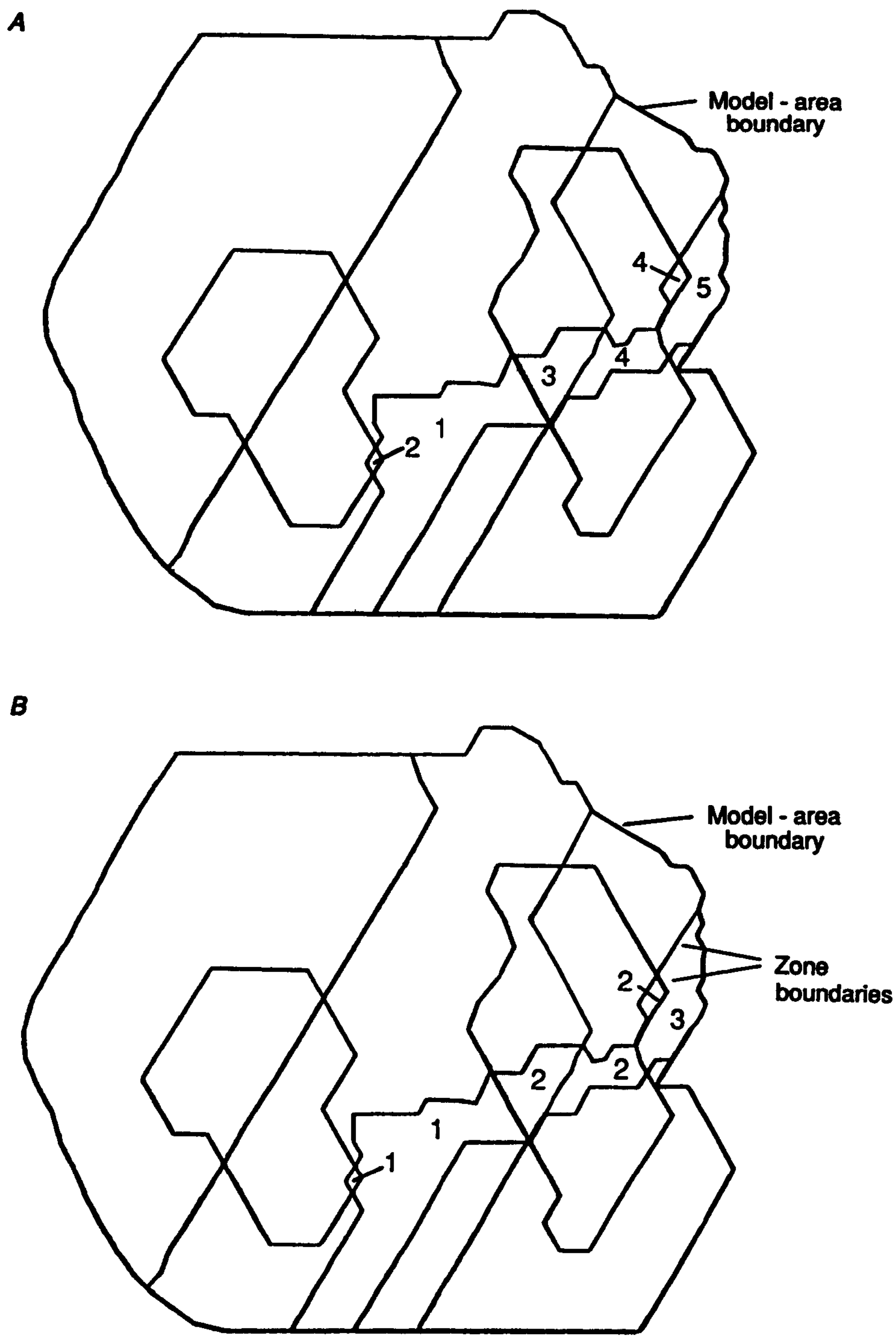


Figure 36.—Areal representation of simulated aquifer showing effect of ordering element incidences on establishing zones for nonlinear steady vertical leakage; (*A*) no ordering; (*B*) ordered incidences.

steady vertical-leakage zones (Table 2). The notation to the right of the incidence lists defines the values for NBE and NO that are used to locate incidences associated with nonlinear steady vertical-leakage zones. Assume that inputs for the hydraulic-property zones were made sequentially (1 through 7), and that element incidences were arranged to create three nonlinear steady vertical leakage zones. Inputs defining the beginning element and the number of elements within each nonlinear steady vertical leakage zone are listed in Table 2A as values for program variables NBE and NO, respectively. Thus, there are 157 elements contained in the three nonlinear steady vertical leakage zones.

From Table 2A, the beginning element number, NBE, for the first nonlinear steady vertical leakage zone is 156, and the number of elements, NO, in the leakage zone is 72. Element incidences for hydraulic-property zones 3 and 4 are arranged so that the last two sets of incidences in zone 3 (for elements 156 and 157) and the first 70 sets of incidences in zone 4 contain the values that correspond to elements in the first zone of nonlinear steady vertical leakage (Table 2B). Similar arrangement of element incidences and specification of NBE and NO define the other two nonlinear steady vertical-leakage zones (Table 2).

Zones of specific yield for water-table simulations are identical to hydraulic-property zones, discussed in the section "Hydraulic-Property and Boundary-Condition Zones." Therefore, only values for the number of elements in a zone, NO, are required to achieve the appropriate correspondence of specific yield to nodes. Values of NBE are not required because specific yield is assigned to nodes within each element in the finite-element mesh according to the order of element incidences that was previously established by the hydraulic-property zones. Thus, hydraulic-property zones and element incidences are arranged in such a manner that a minimum number of zones for specific yield is created and all elements are assigned a value (see section "Input Instructions" for details).

Grouping Element Sides into Zones

The bold element sides in figure 33*A* represent head-dependent (Cauchy-type) boundaries that simulate rivers and boundary flows. Seven boundary-condition zones result from intersecting the bold element sides with the boundaries of the hydraulic-conductivity zones and alluvium (fig. 37). The assumption made in this example is that the value of the α coefficient for a head-dependent (Cauchy-type) boundary changes whenever the boundary condition is located in a different hydraulic-property zone. Note that element sides do not have to be connected to one another in order to be grouped in the same boundary-condition zone (see boundary-condition zone 1 in fig. 37).

Inputs for boundary-condition zones consist of the boundary-zone number, number of element sides contained in the zone, and an indicator variable for the type of zone input (described below). These inputs are followed by values for the α and q_B terms, number of the boundary side, node numbers, and boundary heads. Details of these inputs are given in the section "Input Instructions," as the type of zone input determines the sequence of the other inputs. The zone number and number of element sides are represented in MODFE, respectively, by the program variables KZ and NOS. The number of the boundary side, node numbers, and boundary heads are represented, respectively, by the program variables J; KQB(J) and LQB(J); and, HK(J) and HL(J), as described in the sections "Specified Flux" and "Head-Dependent (Cauchy-Type) Flux."

For each boundary-condition zone, the user has the option of inputting either one value for α and q_B, which will be applied to all boundary sides in the zone, or distinct values for each boundary side. An indicator variable, represented in MODFE as IZIN, is evaluated to determine which type of zone input for α and q_B is used. A value of one (1) for IZIN causes the same value of α and q_B to be applied to all boundary sides in the zone; a value of zero (IZIN = 0 or blank) causes distinct values for α and q_B to be applied to each boundary side in the zone.

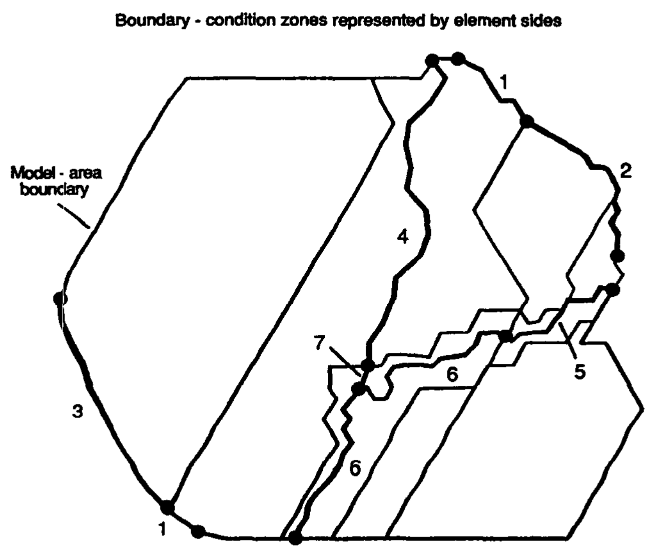


Figure 37.—Areal representation of simulated aquifer showing changes in boundary-condition zones corresponding to changes in hydraulic-property zones.

Table 2.—Data input for nonlinear steady vertical-leakage zones and element incidences

A. **Data defining nonlinear steady vertical-leakage zones for example aquifer problem**

L	NBE	NO	VNCF
1	156	72	5.E-5
2	343	45	1.E-3
3	702	30	3.13E-6

B. **Element incidences for finite-element mesh in example aquifer problem**

Ele. No.	Incidences				
1	30	14	31	55	
2	14	4	15	31	
3	4	1	5	0	
4	15	5	8	20	
5	17	18	6	16	
.	.	.	.	.	
.	.	.	.	.	
.	.	.	.	.	
154	18	19	7	0	
155	16	6	4	14	
156	6	7	1	0	NBE=156
157	2	8	5	1	NO=72
160	97	68	100	138	
.	.	.	.	.	Incidences for
.	.	.	.	.	nonlinear steady
.	.	.	.	.	vertical leakage zone 1
226	505	506	427	426	(72 elements)
227	580	581	506	505	
228	645	646	581	580	
229	700	701	646	645	
230	756	757	701	700	
.	.	.	.	.	
.	.	.	.	.	
.	.	.	.	.	
341	814	815	757	756	
342	874	875	815	814	
343	932	933	875	874	NBE=343
344	991	992	933	932	NO=45
345	953	954	992	991	
.	.	.	.	.	Incidences for
.	.	.	.	.	nonlinear steady
.	.	.	.	.	vertical leakage zone 2
386	506	507	428	427	(45 elements)
387	581	582	507	506	
388	646	647	582	581	

Ele. No.	Incidences				
389	701	702	647	646	
390	757	758	702	701	
.	.	.	.	.	
.	.	.	.	.	
700	875	876	816	815	
701	933	934	876	875	
702	992	993	934	933	NBE=702
703	876	877	817	816	NO=30
704	934	935	877	876	
.	.	.	.	.	Incidences for
.	.	.	.	.	nonlinear steady
.	.	.	.	.	vertical leakage zone 3
729	993	994	935	934	(30 elements)
730	877	878	818	817	
731	935	936	878	877	
732	994	995	936	935	
733	878	879	819	818	
734	936	937	879	878	
735	995	996	937	936	
.	.	.	.	.	
.	.	.	.	.	
.	.	.	.	.	

Details of inputs for boundary-condition zones are discussed below and are given in table 3. The first line of input defines, respectively, the values for the zone number (= 1), number of boundary sides (= 9), and *the indicator IZIN* for the type of input for α and q_B (= 1 for applying the same value to all boundary sides in the zone). The second line gives the values for α (0.05) and q_B (0.). Program variables ALPHZ and QBNZ are used to represent input values for α and q_B, respectively, which are applied to all boundary sides in zone KZ. These inputs are followed by nine lines of input that, for each line, define the number of the boundary side, node numbers on the side, and boundary heads, respectively. The inputs for boundary-

Table 3.—Data input and program variables for boundary-condition zones

A. Boundary-condition zone 1

Variables:	KZ	NOS	IZIN		
Input:	1	9	1		
Variables:	ALPHZ		QBNZ		
Input:	0.05		0.		
Variables:	J	KQB(J)	LQB(J)	HK(J)	HL(J)
Input:	1	102	88	176.	175.
	2	88	97	175.	174.
	3	97	92	174.	172.
	4	92	86	172.	170.
	5	86	80	170.	168.
	6	80	74	168.	165.
	7	74	69	165.	163.
	8	207	156	137.	135.
	9	156	113	135.	134.

B. Boundary-condition zone 2

Variables:	KZ	NOS	IZIN				
Input:	2	16	0				
Variables:	J	KQB(J)	LQB(J)	ALPH(J)	QBND(J)	HK(J)	HL(J)
Input:	10	113	78	24.21	0.	163.	163.
	11	78	49	28.46		163.	163.
	12	49	26	32.32		163.	164.
	13	26	11	36.57		164.	165.
	14	11	2	41.25		165.	165.
	15	2	5	45.62		165.	166.
	16	5	15	47.80		166.	167.
	17	15	14	53.60		167.	168.
	18	14	16	55.37		168.	168.
	19	16	12	53.25		168.	167.
	20	12	27	51.80		167.	166.
	21	27	50	50.64		166.	164.
	22	50	77	48.90		164.	164.
	23	77	48	47.30		164.	163.
	24	48	25	46.60		163.	162.
	25	26	80	45.20	0.	162.	160.

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	Axisymmetric (radial) flow
Steady vertical leakage (no storage effects)	Zoned input of hydraulic properties and boundary conditions
Point and areally distributed sources and sinks	Nonsteady-state or steady-state conditions
Specified head (Dirichlet), specified flux (Neumann), and head-dependent (Cauchy-type) boundary 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