A FINITE-ELEMENT MODEL FOR SIMULATING HYDRAULIC INTERCHANGE OF SURFACE AND GROUND WATER

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CONVERSION FACTORS

For those readers interested in using the International System of Units (SI), the following table may be used to convert inch-pound units of measurement used in this report to SI units:

Multiply inch-pound unit	*By*	*To obtain SI unit*
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
foot per foot (ft/ft)	1.0000	meter per meter
foot per second (ft/s)	0.3048	meter per second
foot squared per second (ft^2/s)	0.0929	meter squared per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

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ABSTRACT

A model that is useful for predicting changes in streamflow as a result of ground-water pumping has been developed. The stream-aquifer model is especially useful for simulating streams that flow intermittently due to leakage to the aquifer or diversion for irrigation or become perched due to declining hydraulic head in the aquifer. The model couples the equation of two-dimensional ground-water flow with the kinematic equations of one-dimensional open-channel flow. Darcy's law for vertical flow through a semipermeable streambed is used to couple the ground-water flow and streamflow equations. The equations of flow are approximated numerically by the finite-element method. A listing of the Fortran program that solves the equations of flow, and a description of data-input formats are given in the report. The program can simulate a variety of hydrologic characteristics including perched streams, streamflow diversions, springs, recharge from irrigated acreage, and evapotranspiration from the water table and phreatophytes. Time-dependent boundary conditions can be simulated. The program can be modified easily to simulate unconfined aquifers and aquifers with variable directions of anisotropy.

The stream-aquifer model was evaluated for numerical accuracy by comparing model results with results from an analytical method. Model results compared favorably with results obtained by the analytical solution technique. A case study of the stream-aquifer system in the Bear River valley of western Wyoming showed that stream-aquifer leakage is more accurately calculated when using the kinematic equations to simulate streamflow than when using only the continuity equation.

INTRODUCTION

Water managers and hydrologists commonly are faced with the problem of evaluating the effects of ground-water pumpage on streamflow. The entire flow of many streams is allocated to numerous users, and during low-flow periods, regulation of diversions is common. Withdrawals from large-yield wells completed in alluvium and associated bedrock aquifers can reduce streamflow by inducing leakage or by capturing water that otherwise would discharge to the stream. During periods of above average streamflow, this effect rarely causes problems; but during low flow, well pumpage may decrease the already limited quantity of streamflow available to meet the demand. Because streamflow can continue to be affected after pumping stops, regulating the use of wells only during droughts can have limited benefit.

Purpose and Scope

This report documents a model that couples two-dimensional ground-water flow with the kinematic equations of one-dimensional open-channel flow. The kinematic equations are solved with considerably less computational effort than the complete dynamic equations. The model is intended primarily for studying the effects of ground-water pumpage on streamflow. The model was developed in cooperation with the Wyoming State Engineer.

The stream-aquifer model described in this report was developed to more accurately simulate a particular hydrologic system--the Bear River, in western Wyoming. Because many hydrologic characteristics of this stream-aquifer system are similar to characteristics of other systems in the western United States, this model could have wide application. Coupled stream-aquifer models are especially useful for simulating streams that flow intermittently owing to leakage to the aquifer or diversion for irrigation, or for streams that become perched owing to a declining hydraulic head in the aquifer. The use of the model also is appropriate when streamflow and stage vary significantly from initial conditions.

The ground-water system in the coupled stream-aquifer model is simulated using the two-dimensional equation for flow in porous media. Aquifer transmissivity is assumed to be unchanged by changes in head. The model may be applied to problems where transmissivity changes in response to changes in aquifer head by following procedures outlined in this report. The model may be extended to unconfined-flow problems by following the procedures outlined in this report. The aquifer may be simulated as anisotropic with respect to transmissivity, and heterogeneous with respect to transmissivity and storage coefficient. Boundary conditions include both specified flux and hydraulic head. All boundary conditions may vary during a simulation. Pumping or injecting wells may be simulated but are assumed to fully penetrate the aquifer. Options within the model allow for simulating evapotranspiration from the water table and linking distributed aquifer recharge to streamflow diversions and consumptive use of crops.

Streamflow is simulated with the kinematic equations of one-dimensional open-channel flow. Diversion of water to irrigation canals may also be simulated. Stream-aquifer leakage is simulated using Darcy's law for flow through a semipermeable streambed. The model can simulate stream-aquifer leakage when the stream is perched above the water table as well as when it is hydraulically connected. In addition, transitions between hydraulically connected and perched streams may occur with time at a given point. By combining stream-aquifer leakage with kinematic routing, it is possible to simulate intermittent streams.

Previous Investigations

Digital models of hydraulic interchange between ground water and surface water have been used to evaluate the effects of pumping wells on streamflow. The models tend to fall into two categories: Ground-water-flow models that give inadequate consideration to stream hydraulics, and ground-water-flow models coupled with open-channel flow, which were developed for dam-break problems and other flood studies. The latter category of models uses the dynamic-wave equations of streamflow to simulate the flood wave. These coupled models, when used to simulate large distributed-parameter systems, can prove to be computationally laborious.

One of the more widely applied techniques for evaluating the effects of pumping wells on streamflow is described by Jenkins (1968). This method computes the rate and volume of streamflow depletion by assuming that the aquifer is isotropic, homogeneous, and semi-infinite in areal extent. Other simplifying assumptions are that a stream fully penetrates the aquifer and that a stream and aquifer are always hydraulically connected. Jenkins (1968) also suggests that digital models can be used with the method to evaluate the effects of different kinds of hydrologic boundaries on streamflow depletion. Taylor and Luckey (1974) used Jenkins' streamflow-depletion method to simulate the conjunctive use of ground water and surface water along the Arkansas River in Colorado.

Digital models of ground-water flow, such as those developed by Trescott and others (1976) and McDonald and Harbaugh (1984), can be used to simulate stream-aquifer systems. Several of the assumptions needed for the streamflow-depletion method are not necessary when using these models. Anisotropic, heterogeneous aquifers with irregular boundaries can be simulated. Partially penetrating streams separated from the aquifer by a streambed with small permeability also can be simulated. The McDonald and Harbaugh (1984) model simulates stream-aquifer leakage when the material adjacent to the streambed is either saturated or unsaturated.

The streamflow-depletion method and digital models of ground-water flow do not explicitly simulate streamflow. As a result, the methods incorrectly estimate the effects of pumpage when streamflow and stream depth change significantly. One model that attempts to solve this problem is described by Hoxie (1977). In that model, streamflow is routed through the model area while accounting for diversions and tributaries. The model is based on the assumption that momentum of water in the stream channels can be ignored. The velocity distribution is held constant throughout the simulation, and stream depth is varied to ensure continuity of mass within the stream system. A model used by Barker and others (1983) and documented by Dunlap and others (1984) follows a streamflow routing procedure similar to the procedure of Hoxie (1977) but treats stream depth as a user-supplied function of streamflow.

Investigators of surface-water flow have long recognized that stream momentum cannot be ignored for most applications. Consequently, Pinder and Sauer (1971), Zitta and Wiggert (1971), and Cunningham (1977) have developed models that simultaneously solve the differential equation of ground-water flow and the two equations of open-channel flow. The computational effort involved in these models is large but needed for studies of dam breaks and floods. When studying the effects of ground-water pumpage on streamflow, the effort rarely is justified.

THEORETICAL CONCEPTS

Differential Equations of Surface- and Ground-Water Flow

Streamflow is simulated with the kinematic equations of one-dimensional open-channel flow. The stream channel is assumed to be rectangular in cross section. Diversion of water to irrigation canals also may be simulated. Although accurate simulation of unsteady flow conditions using the kinematic equations is possible, Miller (1984) describes limitations to the approach in detail. He concludes that errors resulting from the kinematic models may be masked by large lateral inflow to the stream channel and the overall computational strategy. In general, kinematic models are appropriate for water movement that is governed primarily by the law of conservation of mass and only secondarily by momentum. Kinematic waves only propogate in a downstream direction; whereas, flood waves described by the complete dynamic equations may propogate upstream as well. When investigating the effects of ground-water withdrawals on streamflow, the quantity of stream-aquifer leakage often is large and the limitations of the kinematic equations typically will not be significant.

The kinematic equations of open-channel flow are obtained from the complete dynamic equations by assuming that the effects of acceleration are negligible. Terms in the equation of motion related to friction and channel slope are retained. Manning's formula is used to model the energy lost as a result of channel friction. Miller and Cunge (1975, p. 189) indicate that the friction of the channel bottom seldom can be neglected in studies of streamflow. The resulting equations of open-channel flow, written for unit width of a rectangular channel, are

$$q_{GW} = \frac{\partial}{\partial t}(d) + \frac{\partial}{\partial \ell}(ud) \quad \text{,and} \tag{1}$$

$$u = \frac{1.486}{n} S_0^{\frac{1}{2}} d^{\frac{2}{3}} \tag{2}$$

where q_{GW} is a stream-aquifer leakage, positive for leakage from stream to aquifer, in feet per second;

t is time, in seconds;

d is stream depth, in feet;

ℓ is stream length, in feet;

u is Manning's coefficient of roughness, dimensionless; and

S_0 is channel slope, dimensionless.

The form of Manning's formula given in equation 2 is based on an assumption that the width of the stream is quite large relative to the depth.

Initial and boundary conditions are required to solve equations 1 and 2. The initial conditions used in this model are the depth and velocity of flow in the channel. The boundary condition is a description of discharge throughout the simulation at the upstream boundary. When specifying initial conditions, care must be taken to ensure that the stream velocity and stream depth are consistent with coefficients used in equation 2. The program described later in this report checks initial conditions for consistency but makes no attempt to resolve conflicting data.

A flood wave is not completely simulated by equations 1 and 2 because the calculated flood wave neither lengthens nor disperses, nor does it subside as it moves downstream. Backwater effects also cannot be simulated by equations 1 and 2. Numerical methods, such as finite-difference or finite-element approximations in conjunction with kinematic-wave theory, can introduce numerical dispersion. Although the effects of numerical dispersion are similar to actual dispersion occurring in water waves, there is no channel characteristic that can be used as a calibration parameter to control how much dispersion and attenuation occurs.

The governing equation of ground-water flow in two dimensions is

$$\frac{\partial}{\partial x_i}\left(T_{ij}\frac{\partial h}{\partial x_j}\right) - q_{GW} = S\frac{\partial h}{\partial t} + Q \qquad i,j = 1,2 \tag{3}$$

where T_{ij} is the transmissivity tensor, in feet squared per second;

x_i and x_j are the Cartesian coordinates, in feet;

h is the hydraulic head of the aquifer, in feet;

q_{GW} is the stream-aquifer leakage, positive for leakage from stream to aquifer, in feet per second;

S is the storage coefficient, dimensionless;

t is time, in seconds; and

Q is the source-sink term, positive for a source, in feet per second.

Boundary conditions that apply to this equation are known specific discharge normal to the boundary, known hydraulic head, or a mixture of the two.

The equation of ground-water flow used in this model simulates a simplified form of the three-dimensional flow pattern that can develop in an aquifer. The simplification to two dimensions is justified in cases where the vertical component of flow in an aquifer is negligible and in unconfined aquifers where changes in hydraulic head are small relative to the initial saturated thickness. In many situations, the error caused by treating transmissivity as a constant is small compared to other errors, such as inaccurately estimating aquifer properties.

To couple equations 1, 2, and 3, an expression describing the movement of water between the stream and aquifer system is needed. Darcy's law for vertical flow through a semipermeable streambed is used. The form of Darcy's law used in the model is

$$q_{GW} = \frac{K_z}{m} (d+y - h) \tag{4}$$

where q_{GW} is the stream-aquifer leakage, positive for leakage from stream to aquifer, in feet per second;

K_z is the vertical hydraulic conductivity of the streambed, in feet per second;

m is the thickness of the streambed, in feet;

d is the stream depth, in feet;

y is the altitude of the top of the streambed, in feet; and

h is the hydraulic head of the aquifer, in feet.

Model options, described later in this report, are available to use an appropriately modified form of equation 4 when aquifer head drops below the bottom of the streambed.

Numerical Approximations

The equations of flow in a stream-aquifer system cannot be solved analytically for the complex set of boundary conditions that usually occur in practical studies. Therefore, the differential equations are of necessity approximated numerically by an equivalent set of linear algebraic equations. Finite-element approximations are used with Galerkin's method of weighted residuals (Zienkiewicz, 1971; Pinder and Gray, 1977).

Numerical approximation of the flow equations begins by dividing the stream-aquifer system into separate finite elements. Triangular elements with linear sides are used to approximate the aquifer while one dimensional linear elements located along the sides of aquifer elements are used to approximate the stream network. Aquifer nodes are located at corners of the triangular elements and stream nodes are located at ends of the linear elements.

Stream depth, stream velocity, and aquifer head are approximated throughout the stream-aquifer system by piecewise linear functions of nodal values. Piecewise linear means that stream depth, stream velocity, and aquifer head vary linearly within elements and are continuous between adjacent elements. For a given stream-aquifer system, increasing the number of nodes would make it possible to approximate increasingly complex distributions of stream depth, stream velocity, and aquifer head. Algebraically the piecewise linear functions are written as

$$
\begin{aligned}
d \simeq \hat{d} &= \sum_{s=1}^{ns} \sum_{i=1}^{ms} d_i(t) M_i^s(\ell) \\
u \simeq \hat{u} &= \sum_{s=1}^{ns} \sum_{i=1}^{ms} u_i(t) M_i^s(\ell) \qquad (5) \\
h \simeq \hat{h} &= \sum_{a=1}^{na} \sum_{j=1}^{ma} h_j(t) N_j^a(x,y)
\end{aligned}
$$

where $\hat{d}$ is an approximation of stream depth;

ns is the number of stream elements;

ms is the number of stream nodes;

$d_i(t)$ is the time dependent value of stream depth at node i;

$M_i^s(\ell)$ is the linear basis function associated with stream node i in stream element s;

$\hat{u}$ is an approximation of stream velocity;

$u_i(t)$ is the time dependent value of stream velocity at node i;

$\hat{h}$ is an approximation of aquifer head;

na is the number of aquifer elements;

ma is the number of aquifer nodes;

$h_j(t)$ is the time dependent value of aquifer head at node j;

$N_j^a(x,y)$ is the linear basis function associated with aquifer node j in aquifer element a.

If the approximations for stream depth, stream velocity, and aquifer head are substituted in the governing differential equations (eq. 1-3) the resulting equations will be approximate. In each case a residual can be defined as the amount by which the approximating equation varies from the exact equation. If an approximation is exact, the residual would be zero. Residuals for the continuity equation of open-channel flow (R_s) and the equation of ground-water flow (R_a) are

$$R_s = \frac{\partial}{\partial t}(\hat{d}) + \frac{\partial}{\partial \ell}(\hat{u}\hat{d}) - q_{GW}$$

$$R_a = \frac{\partial}{\partial x_i}\left(T_{ij}\frac{\partial \hat{h}}{\partial x}\right) - q_{GW} - S\frac{\partial \hat{h}}{\partial t} - Q \qquad i,j, = 1,2. \tag{6}$$

Galerkin's method of weighted residuals requires that the weighted average residual of the approximate solution be zero. Galerkin's method used the finite-element basis functions as weighting functions. The weighted residual equations corresponding to equations 6 are

$$\int_s R_s M_i \, ds = 0 \qquad (i = 1,2,3,\ldots ms)$$

$$\int_{x_2}\int_{x_1} R_a N_j \, dx_1 dx_2 = 0 \qquad (j = 1,2,3,\ldots ma). \tag{7}$$

Substituting the approximate differential equations into the weighted residual equations results in a set of algebraic equations equal to the number of nodes.

Before writing weighted residual equations for a stream-aquifer system it is convenient to describe the basis functions (M_i^s and N_j^a). Basis functions are defined for each node in each element such that (1) the sum of all basis functions at any point with an element is one, (2) each basis function has a value only over the element for which it is defined and is zero over all other elements, and (3) each basis function has a value of one at the node for which it is defined and decreases linearly to zero at all other nodes associated with the element. For a linear stream element with node 1 located at the origin of a local coordinate system and node 2 separated from node 1 by a distance Δ, the basis functions are

$$M_1^s = \left(1 - \frac{\ell}{\Delta}\right) \qquad M_2^s = \frac{\ell}{\Delta}. \tag{8}$$

The linear basis functions for a triangular aquifer element with nodes 1, 2, and 3 numbered counterclockwise, node 1 located at the origin of a local coordinate system, and area A are

$$
\begin{aligned}
N_1^a &= [1 - \frac{(y_3 - y_2)x}{2A} + \frac{(x_3 - x_2)y}{2A}] \\
N_2^a &= [\frac{y_3}{2A} x - \frac{x_3}{2A} y] \qquad (9) \\
N_2^a &= [\frac{-y_2}{2A} x - \frac{x_2}{2A} y].
\end{aligned}
$$

The weighted residual equation corresponding to the continuity equation of open-channel flow may be written in matrix form as

$$
\sum_{s=1}^{ns} \left(\int_s \begin{bmatrix} M_1 M_1 & M_1 M_2 \\ M_2 M_1 & M_2 M_2 \end{bmatrix} \begin{Bmatrix} \frac{\partial(d_1)}{\partial t} \\ \frac{\partial(d_2)}{\partial t} \end{Bmatrix} ds \; + \right.
$$

$$
\int_s \begin{bmatrix} M_1 \frac{\partial M_1}{\partial s} & M_1 \frac{\partial M_2}{\partial s} \\ M_2 \frac{\partial M_1}{\partial s} & M_2 \frac{\partial M_2}{\partial s} \end{bmatrix} \begin{Bmatrix} u_1 d_1 \\ u_2 d_2 \end{Bmatrix} ds \; - \qquad (10)
$$

$$
\left. \int_s [M_1 \;\; M_2] \begin{Bmatrix} q_{GW_1} \\ q_{GW_2} \end{Bmatrix} ds \right) = 0.
$$

Because shape functions are dimensionless, the units of each integral expression are square feet per second. This equation is written as a summation over all stream elements of terms integrated within individual elements. By routine algebraic manipulation, the equation also can be written as a series of equations equal to the number of stream nodes. The above form of the equation is given because it most closely corresponds to the procedure used in the computer program.

The notation for equation 10 within a single element can be simplified as

$$[D]\left\{\frac{\partial(d}{\partial t}\right\} + [E]\left\{ud\right\} = \left\{Q_{GW}\right\} \tag{11}$$

where $$[D] = \int_s \begin{bmatrix} M_1 M_1 & M_1 M_2 \\ M_2 M_1 & M_2 M_2 \end{bmatrix} ds$$

$$\left\{\frac{\partial(d)}{\partial t}\right\} = \begin{Bmatrix} \dfrac{\partial(d_1)}{\partial t} \\ \dfrac{\partial(d_2)}{\partial t} \end{Bmatrix}$$

$$[E] = \int_s \begin{bmatrix} M_1 \dfrac{\partial M_1}{\partial s} & M_1 \dfrac{\partial M_2}{\partial s} \\ M_2 \dfrac{\partial M_1}{\partial s} & M_2 \dfrac{\partial M_2}{\partial s} \end{bmatrix} ds$$

$$\left\{ud\right\} = \begin{Bmatrix} u_1 d_1 \\ u_2 d_2 \end{Bmatrix}$$

$$\left\{Q_{GW}\right\} = \int_s [M_1 M_2] \begin{Bmatrix} q_{GW_1} \\ q_{GW_2} \end{Bmatrix} ds.$$

Finite-difference approximation is used to eliminate the derivative of stream depth with respect to time. Within a time step Δt beginning at time t and ending at time $t+\Delta t$,

$$\left\{ \frac{\partial(d)}{\partial t} \right\} = \frac{1}{\Delta t} \left(\left\{ d \right\}_{t+\Delta t} - \left\{ d \right\}_{t} \right) \qquad \text{and}$$

$$\left\{ ud \right\} = \left\{ (1-\varphi)\{ud\}_t + \varphi\{ud\}_{t+\Delta t} \right\} \tag{12}$$

where φ may range from 0 to 1,

and the notation $\{\ \}_t$ indicates that the enclosed quantity is evaluated at time t. Substituting these approximations into equation 11 gives

$$\frac{1}{\Delta t}\,[D]\,\{d\}_{t+\Delta t} + \varphi\,[E]\,\{ud\}_{t+\Delta t} =$$

$$\left\{ Q_{GW} \right\} + \frac{1}{\Delta t}\,[D]\,\{d\}_t - (1-\varphi)\,[E]\,\{ud\}_t. \tag{13}$$

Equation 13 is formed sequentially for each element moving downstream from a boundary with known stream depth and velocity. For any element, stream depth and velocity are known for time t at both upstream and downstream nodes, and for time $t+\Delta t$ at the upstream node. The fact that stream depth and velocity for time $t+\Delta t$ is known at the upstream node is derived from the fact that kinematic water waves only propagate in a downstream direction. Therefore, solution for stream depth and velocity can be obtained in a sequential manner, moving downstream an element at a time, with the downstream node of one element becoming the upstream node of the next element.

Even with the sequential solution algorithm made possible by kinematic routing, numerical approximation to the continuity equation for open-channel flow (eq. 13) involves two unknowns (depth and velocity) for each algebraic equation. Either the number of unknowns must be reduced or the number of algebraic equations increased before solutions can be obtained. One approach would be to apply Galerkin's method of weighted residuals to Manning's equation (eq. 2); doubling the number of equations without increasing the number of unknowns. However, the resulting set of algebraic equations would be nonlinear.

To reduce the number of unknowns, a procedure is used in this model that is analogous to one used in rainfall-runoff modeling (Dawdy and others, 1978). This procedure generally is stable for most ratios of element length to time step.

The procedure begins by modifying the definition of the [D] matrix as

$$[D] = \int_s \begin{bmatrix} M_1^* M_1^* & M_1^* M_2^* \\ M_2^* M_1^* & M_2^* M_1^* \end{bmatrix} ds \tag{14}$$

where $M_1^* = 2\varphi M_1$

$M_2^* = 2(1-\varphi)M_2$.

The modification is such that the element mass associated with [D] is unchanged for values of φ between 0 and 1.

Depending on the value of φ selected, the modified definition of [D] reduces the number of unknowns in equation 13 to equal the number of equations. If a value $\varphi = 1$ is selected for an element, the only unknown in equation 13 is stream depth at the downstream node (d_2). If a value $\varphi = 0$ is selected, the unknown is stream velocity at the downstream node (u_2). In either case, Manning's equation is used to solve for the remaining unknown. The decision to use $\varphi = 1$ or $\varphi = 0$ is based on the average velocity at the upstream node during the time step and the ratio of element length to time step. If the water wave would travel through the entire element, φ is set equal to 1. If the water wave would not travel through the element, φ is set equal to 0.

The weighted residual equation corresponding to the governing equation of ground-water flow may be obtained by substituting the approximate differential equation (eq. 6) into equation 7 with aquifer head defined by equation 5 and basis functions defined by equation 9. After algebraic manipulation, the weighted residual equation may be written in matrix form as

$$\sum_{a=1}^{na}\left(\int_{x_2}\int_{x_1}\begin{bmatrix}\frac{\partial^2 N_1}{\partial x_1^2} & \frac{\partial^2 N_1}{\partial x_2^2}\\ \frac{\partial^2 N_2}{\partial x_1^2} & \frac{\partial^2 N_2}{\partial x_2^2}\\ \frac{\partial^2 N_3}{\partial x_1^2} & \frac{\partial^2 N_3}{\partial x_2^2}\end{bmatrix}\begin{bmatrix}T_{x_1x_1} & T_{x_1x_2}\\ T_{x_2x_1} & T_{x_2x_2}\end{bmatrix}\begin{bmatrix}N_1 & N_2 & N_3\\ N_1 & N_2 & N_3\end{bmatrix}\begin{Bmatrix}h_1\\ h_2\\ h_3\end{Bmatrix}dx_1\,dx_2\right.$$

$$\left.-\int_{x_2}\int_{x_1} S\begin{bmatrix}N_1N_1 & N_1N_2 & N_1N_3\\ N_2N_1 & N_2N_2 & N_2N_3\\ N_3N_1 & N_3N_2 & N_3N_3\end{bmatrix}\begin{Bmatrix}\frac{\partial h_1}{\partial t}\\ \frac{\partial h_2}{\partial t}\\ \frac{\partial h_3}{\partial t}\end{Bmatrix}dx_1\,dx_2+\begin{Bmatrix}Q_1\\ Q_2\\ Q_3\end{Bmatrix}\right)=0 \qquad (15)$$

where $\begin{Bmatrix}Q_1\\ Q_2\\ Q_3\end{Bmatrix}$ = nodal values of source and sink terms including stream leakage, in cubic feet per second.

Because shape functions are dimensionless, the units of each integral expression in equation 15 are cubic feet per second.

Because basis functions are linear, the second derivative is not defined, and the first integral expression in equation 15 cannot be evaluated directly. To avoid this problem, Green's theorem is used. In addition to avoiding second derivatives of basis functions, the application of Green's theorem also introduces flux-boundary conditions--used to approximate stream leakage. The resulting weighted residual equation is

$$\sum_{a=1}^{na}\left([K] = \{h\} + [C] \quad \frac{\partial h}{\partial t} \quad - \{Q\}\right) = 0 \tag{16}$$

where $$[K] = \int_{x_1}\int_{x_1} \begin{bmatrix} \frac{\partial N_1}{\partial x_1} & \frac{\partial N_1}{\partial x_2} \\ \frac{\partial N_2}{\partial x_2} & \frac{\partial N_2}{\partial x_2} \\ \frac{\partial N_3}{\partial x_1} & \frac{\partial N_3}{\partial x_2} \end{bmatrix} \begin{bmatrix} T_{x_1 x_1} & T_{x_1 x_2} \\ T_{x_2 x_1} & T_{x_2 x_2} \end{bmatrix} \begin{bmatrix} \frac{\partial N_1}{\partial x_1} & \frac{\partial N_2}{\partial x_1} & \frac{\partial N_2}{\partial x_1} \\ \frac{\partial N_1}{\partial x_2} & \frac{\partial N_2}{\partial x_2} & \frac{\partial N_3}{\partial x_3} \end{bmatrix} dx_1 dx_2$$

$$\{h\} = \begin{Bmatrix} h_1 \\ h_2 \\ h_3 \end{Bmatrix}$$

$$[C] = \int_{x_2}\int_{x_1} S \begin{bmatrix} N_1N_1 & N_1N_2 & N_1N_3 \\ N_2N_1 & N_2N_2 & N_2N_3 \\ N_3N_1 & N_3N_2 & N_3N_3 \end{bmatrix} dx_2 dx_1$$

$$\left\{\frac{\partial h}{\partial t}\right\} = \begin{Bmatrix} \frac{\partial h_1}{\partial t} \\ \frac{\partial h_2}{\partial t} \\ \frac{\partial h_3}{\partial t} \end{Bmatrix}$$

$$\{Q\} = \begin{Bmatrix} Q_1 \\ Q_2 \\ Q_3 \end{Bmatrix} + \sum_{k=1}^{3} \int_{s} \begin{bmatrix} M_1 M_2 \end{bmatrix} + \begin{Bmatrix} w_k q_{GW_k} \\ w_{k+1} q_{GW_{k+1}} \end{Bmatrix} ds$$

where w_k = stream width at node k.

Finite-difference approximation is used to eliminate the derivative of aquifer head with respect to time. Within a time step Δt

$$\left\{ \frac{\partial h}{\partial t} \right\} = \frac{1}{\Delta t}\left(\{h\}_{t+\Delta t} - \{h\}_{t}\right)$$

$$\{h\} = \left\{(1 - \theta)\ \{h\}_{t} + \theta\ \{h\}_{t = \Delta t}\right\} \tag{17}$$

where θ may range from 0 for an explicit solution to 1 for an implicit solution, and the notation $\{\ \}_t$ indicates that the enclosed quantity is evaluated at time t. Substituting these approximations into equation 16 gives

$$\sum_{a=1}^{na}\left(\left[\frac{1}{\Delta t}\ [C] + \theta\ [K]\right]\{h\}_{t+\Delta t}\right) =$$

$$\sum_{a=1}^{na}\left(\{Q\} + \left\{Q_{GW}\right\} + \left[\frac{1}{\Delta t}\ [C] - (1 - \theta)\ [K]\right]\{h\}_{t+\Delta t}\right) \tag{18}$$

The numerical approximation given in equation 18 can be manipulated algebraically to form a system of ma linear equations with ma unknown values of aquifer head, where ma is the number of aquifer nodes. The final matrix equation is written as

$$[LHS]\ \{h\}_{t+\Delta t} = \{RHS\} \tag{19}$$

where [LHS] is formed from the matrices on the left-hand side of equation 18 and {RHS} is formed from the matrices and column vectors on the right-hand side. Solution of equation 19 for unknown values $\{h\}_{t+\Delta t}$ is obtained by direct methods.

The numerical approximations for stream-aquifer leakage used in equations 10 through 19 also can be written in terms of stream depth and aquifer head. The approximation is obtained by integrating along stream elements as

$$\left\{q_{GW}\right\} = \int_s \frac{K_z}{m} \begin{bmatrix} M_1M_1 & M_1M_2 \\ M_2M_1 & M_2M_2 \end{bmatrix} \begin{Bmatrix} d_1+y_1-h_1 \\ d_2+y_2-h_2 \end{Bmatrix} ds. \tag{20}$$

This is equivalent to

$$\left\{q_{GW}\right\} = [R] \begin{Bmatrix} d_1+y_2-h_1 \\ d_1+y_2-h_2 \end{Bmatrix} \tag{21}$$

where $$[R] = \int_s \frac{K_z}{m} \begin{bmatrix} M_2M_1 & M_1M_2 \\ M_2M_1 & M_2M_2 \end{bmatrix} ds.$$

Solution Procedure

The iterative procedure of Pinder and Sauer (1971) is used for solving the equations in the coupled stream-aquifer model. As a first step in the iterative procedure, a steady-state solution to the kinematic-wave equations (eq. 13) can be obtained if no leakage is assumed. The steady-state distribution of stream depth is used to solve the steady-state equation of ground-water flow (eq. 19) and to calculate a nonzero leakage distribution. The kinematic equations are solved using the new leakage distribution (eq. 21). Iteration continues between equation 13, and equations 19 and 21 until the difference in calculated leakage is less than a predetermined error tolerance. The final steady-state solution is used as the initial condition for transient simulations in which the iterative procedure described above is repeated for each time step.

Experience with the model has shown that convergence usually is rapid, typically in less than 10 iterations. However, large changes in boundary conditions can cause slow convergence. The effort required to solve the kinematic equations is much less than required to solve the complete dynamic equations. At the same time, the computational effort needed to solve the kinematic equations is not significantly greater than needed to solve a problem using only the continuity equation.

COMPUTER PROGRAM FOR SIMULATING HYDRAULIC INTERCHANGE OF SURFACE AND GROUND WATER

A listing of the Fortran program that solves the equations of flow in a stream-aquifer system is given in table 1 (at the end of the report). The program uses ANSI standard Fortran 77 and should easily operate on many computers. Data-input formats are described in table 2 (at the end of the report). Input and output for a sample simulation are given in tables 3 and 4 (at the end of the report), respectively.

Program Design

The design of a finite-element grid is the first step in most model applications. The program listed in table 1 uses two-dimensional triangular elements, with nodes located at each vertex, to simulate the aquifer system. The stream system is simulated by one-dimensional elements located along the sides of the aquifer elements.

Although data entry into a finite-element program typically is more cumbersome than for finite-difference programs, the increased data-entry time usually is more than compensated by increased flexibility in locating nodes. With a finite-element model, nodes can be accurately located at observation or pumping wells. In general, fewer nodes are needed to accurately model stream and aquifer geometry when using a finite-element model.

Data entry into a finite-element program is more cumbersome because of the need to identify the relationships among all nodes and elements. As a result, all nodes and elements must be numbered, the Cartesian coordinates of all nodes must be coded, and the nodes associated with each element must be designated. The relationship between stream and aquifer nodes also must be indicated. Figure 1 shows a finite-element grid with nodes and elements for both stream and aquifer systems. As a general practice, interior angles of triangular elements probably should be no greater than 90 degrees (Narasimhan and others, 1978).

The system used to number aquifer nodes and elements has a significant impact on the efficiency and size of the computer program. The coefficient matrices [C] and [K], developed in equation 7 represent the largest block of computer storage used by the program. The solution technique is more efficient, in terms of time and storage requirements, if the size of these coefficient matrices is minimized. Storage requirements of the coefficient matrices are directly related to the largest difference between two node numbers in an aquifer element. Therefore, efficient nodal ordering minimizes this difference and improves the efficiency of the solution.

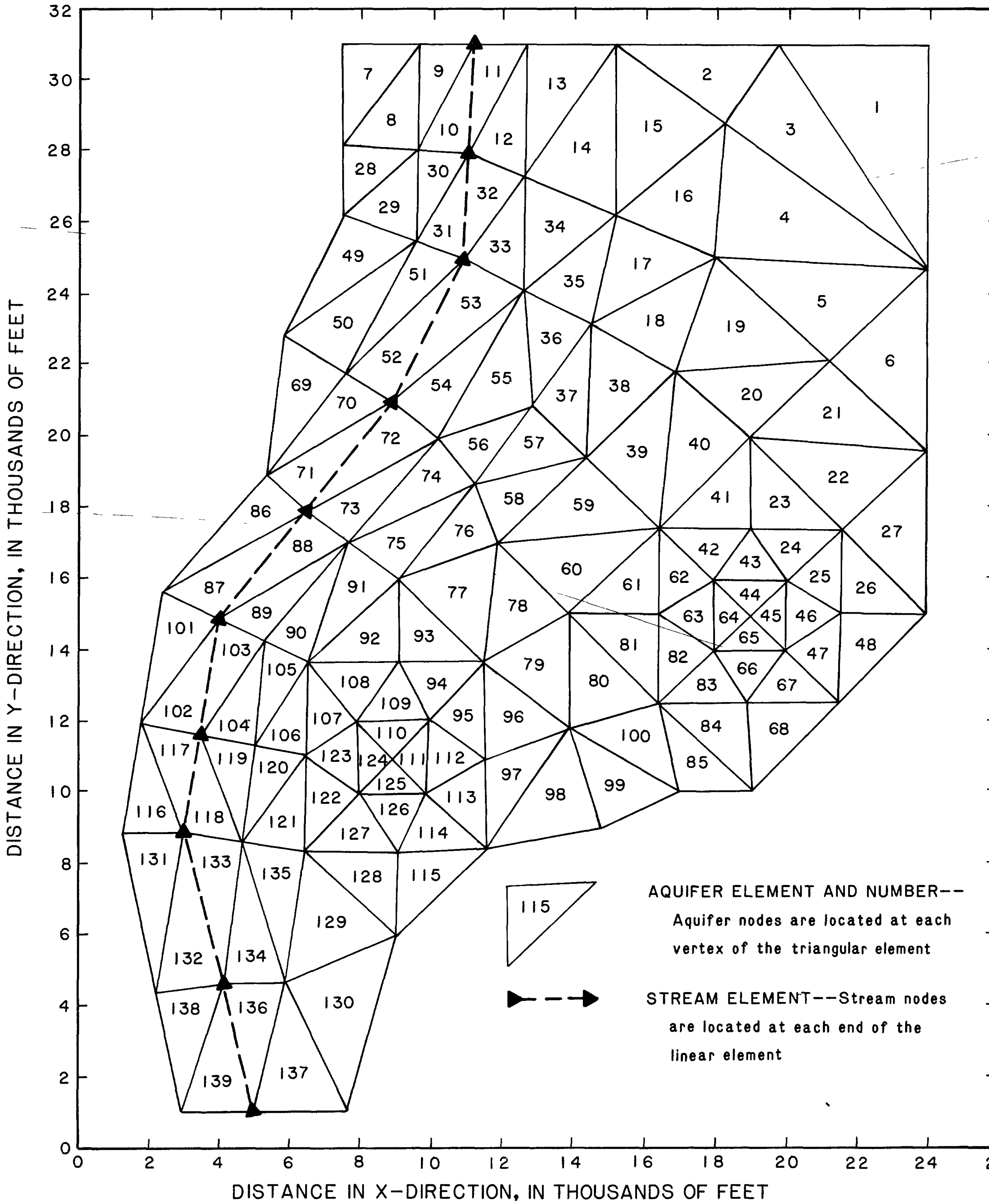

Figure 1.--Example of a finite-element grid.

The model procedure used to enter aquifer properties (such as transmissivity or distributed recharge from precipitation) and stream-channel properties (such as slope) is both flexible and easy to use. Aquifer elements are grouped into a number of user-defined aquifer zones, and stream elements are grouped into stream zones. An aquifer property, transmissivity for example, is simulated as the product of an element value and a zonal factor. Because transmissivity may be anisotropic, a separate zonal multiplication factor is used for each of the two principal directions. By using unique factors for each aquifer zone, it is possible to simulate varying degrees of anisotropy throughout the aquifer. Stream-channel properties also are simulated as the product of element and zonal values.

Describing aquifer properties and stream-channel properties as the products of zonal factors and element values has proven useful in model applications when extensive model calibration is required. Although there are many possibilities for using zonal factors and element values, the following guidelines may be useful. Zonal factors could be used to represent relative magnitudes of aquifer properties and stream-channel properties that are varied during the calibration process. Element values could be used to represent the distribution of properties within each zone. Such an approach to using zonal factors can greatly reduce the tedium of coding and recoding input data; particularly when a majority of time required to calibrate a model is spent varying relative magnitudes of calibration parameters, without changing distributions locally. One possible drawback to the approach is that a hydrologist rarely would change zonal boundaries in any significant way. Fortunately, it often is possible to identify zonal boundaries accurately on the basis of climatic or geologic conditions.

An example of using zonal factors in conjunction with element values can be given by considering areally distributed recharge to a water-table aquifer. While it may not be possible to conduct a detailed investigation of recharge rates through the unsaturated zone, it may be possible as a first approximation to relate recharge to the rate of precipitation, soil type, and vegetative cover. Zonal boundaries based on soil type and vegetative cover probably could be identified accurately on the basis of field reconnaissance. Assuming that sufficient precipitation-measurement stations are present in the modeled region, the distribution of precipitation could be mapped and used as element values of recharge. Model calibration would concentrate on finding appropriate zonal factors to translate precipitation into recharge. Within each soil type and vegetative cover, the distribution of recharge would be similar to the distribution of precipitation.

Transient conditions are solved by dividing the total period being simulated into a number of pumping periods. Boundary conditions, such as specified hydraulic head in the aquifer, discharge, and well pumping rates may be changed at the beginning of each pumping period. Information about stream diversions also may be changed each pumping period. Each pumping period is divided into a number of time steps to ensure that the differential equations of flow are approximated accurately. The length of the first time step during a pumping period usually is small, typically one hour or less. Each successive time step is lengthened by a multiplication factor.

Simulation results may be printed several times during the course of a pumping period, but the distribution of hydraulic head or drawdown may be plotted only at the end of a pumping period. Subroutine TOPO produces a contour-plot file by using plotting routines that are available with many plotters. The subroutine was tested successfully with Calcomp and Zeta plotters.[1] Minor program modifications may be needed if the program is used with other plotters.

Program Options

Several options were added to the program. Some of the options allow users to simulate perched streams, springs, and streamflow diversions. Other options allow users to: (1) Calculate aquifer recharge distributed to nodes representing distributed aquifer recharge over irrigated acreage when diverted streamflow exceeds crop consumptive use; (2) calculate ground-water withdrawals from wells with supplemental water rights when diverted streamflow does not meet consumptive-use requirements, and (3) simulate evapotranspiration from the water table and from phreatophytes.

The model can be used to simulate perched and dry streams by modifying the expression for stream-aquifer leakage. When a stream is perched above the water table, the streambed remains saturated, and the expression for leakage through the streambed is obtained from Darcy's law as

$$q_{GW} = \frac{K_z}{m}(d+m). \tag{22}$$

Any water infiltrating into the unsaturated zone beneath the streambed is assumed to percolate to the water table. This assumption is reasonable in strongly coupled stream-aquifer systems where vertical hydraulic conductivity of the unsaturated zone is greater than the vertical hydraulic conductivity of the saturated streambed. In many cases the moisture content of the unsaturated zone will be greater than or equal to field capacity, and the vertical hydraulic conductivity of the unsaturated materials will not be sufficiently small to restrict vertical movement. Weekly coupled systems, where vertical hydraulic conductivity of the unsaturated zone is significantly smaller than the vertical hydraulic conductivity of the saturated streambed, should be simulated by models such as the model of the fluid flow in variably saturated porous media developed by Lappala and others (1987).

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[1] Use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Spring discharge and evapotranspiration are simulated as head-dependent sinks in the equation of ground-water flow. The major difference in the model between spring discharge and evapotranspiration is that leakage to springs that flow into a stream is included as a boundary flux for the stream system; however, evapotranspiration is not. Spring discharge, in feet per second, from the aquifer is computed by

$$q = 0, \quad \text{if} \quad h \le y; \tag{23}$$

$$q = \frac{K_z}{m}(h - y), \quad \text{if} \quad y < h$$

where h is the hydraulic trend in the aquifer;

y is the altitude of the spring bottom;

K_z is the vertical hydraulic conductivity of the spring bottom; and

m is the thickness of the spring bottom.

For evapotranspiration, discharge, in feet per second, from the aquifer is computed by

$$q = 0, \quad \text{if} \quad h \le Zmin; \tag{24}$$

$$q = c(h - Zmin), \quad \text{if} \quad Zmin < h < Zmax; \text{ or} \tag{25}$$

$$q = c(Zmax - Zmin), \quad \text{if} \quad Zmax \le h \tag{26}$$

where h is the hydraulic head in the aquifer;

$Zmin$ is the altitude below which evapotranspiration from the water table is zero;

$Zmax$ is the land surface altitude; and

c is the maximum rate of evapotranspiration divided by the effective depth of evapotranspiration.

The program calculates streamflow-diversion rates on the basis of water-right priorities. The right to divert streamflow in much of the western United States depends upon the availability of water and the priority date of the water rights. Diversion of water is not permitted unless the needs of downstream users with earlier priority dates can be met. Therefore, realistically, streamflow must exceed some minimum rate at a specified downstream location before water can be diverted by any user except for the one with the first priority. As streamflow increases, the rate of diverted water may also increase. However, diversion rights usually are limited to some maximum flow rate. The program calculates diversion rates for each diversion during each iteration of a simulation using streamflow information from the previous iteration. Data entered into the program are the point of diversion, the minimum streamflow required before diversion can begin, the nodal location where the minimum streamflow occurs, and the maximum rate of diversion.

The quantity of water diverted to a field for irrigation usually exceeds the consumptive-use requirements of the crop, particularly when the field is flood irrigated. Water not consumptively used by the crops may percolate to the ground-water system or may flow from the field as return flow. The model accounts for recharge from irrigation by calculating the diversion flow rate where the diversion enters the field, distributing the water uniformly over the irrigated acreage, subtracting the consumptive-use requirement of the crop, and treating the remainder as recharge to the aquifer. No corrections are made for surface runoff from irrigated lands, canal leakage, or loss of water to storage in the unsaturated zone.

The model simulates supplemental ground-water rights by pumping designated wells when the diverted surface water is not sufficient to meet the consumptive-use requirements of the crop. In areas where streamflow-diversion rights exist that have a junior priority date, regulation limiting the quantity of water available for irrigation is common. Typically, regulation occurs during the peak growing season, July and August. To compensate for the lack of surface water, irrigators often obtain water by pumping wells. The ground-water right is considered to be supplemental to the original surface-water right. The well pumpage can be simulated as the quantity required to eliminate the water deficit over all or part of the irrigated acreage.

Program Modification for Unconfined Aquifers

The equations of ground-water flow used in the model calculate the distribution of hydraulic head in a confined aquifer but also can be used to calculate the hydraulic head in an unconfined aquifer. When an aquifer exists under water-table conditions, the transmissivity is a function of hydraulic head and, in a strict sense, the equations do not apply. However, if changes of hydraulic head are small, only a small error in the calculated head results and is caused by treating transmissivity as a constant. Usually, errors in calculated results caused by treating transmissivity as a constant are smaller than errors caused by inaccurately estimating aquifer properties and boundary conditions. The storage property of the aquifer entered as storage coefficient ought to be the specific yield value for an unconfined aquifer.

If changes in hydraulic head are large, the program can be modified to calculate transmissivity as a function of hydraulic head. These modifications are outlined as follows:

1. Dimension a new array, called BOTTOM, to represent the altitude of the base of the aquifer. The size of the array must be greater than number of aquifer nodes.
2. Add statements to read values of the altitude of the base of the aquifer at each node. The BOTTOM array can be read with values of nodal locations (XORD and YORD) and initial hydraulic head (PHI) if desired.
3. Enter hydraulic-conductivity estimates in the transmissivity (TRAN) array.
4. Initialize BOTOMJ to 0.0 at the beginning of DO loop 340.
5. Include the following statement before label 310.
   BOTOMJ = BOTOMJ+SF(1,K,J)*BOTTOM(NPK).
6. Replace statements within DO loop 329 that calculate the values of transmissivity at each quadrature point. The new statements should calculate transmissivity as
   RXJ = TRAN(I)*RX(MATI)*(PHIJ-BOTOMJ), and
   RYJ = TRAN(I)*RY(MATI)*(PHIJ-BOTOMJ).
7. Check that RXJ and RYJ are greater than zero. If they are not, print a message, and either set RXJ and RYJ to small positive values or stop the simulation.
8. Within SUBROUTINE SHAFAC, delete the first IF statement and replace the statement labeled 360 by
   360 CONTINUE.
   The changes within SHAFAC ensure that integration of the flow equations will be exact.

When simulating a stream-aquifer system with the changes for water-table conditions, the user should increase the maximum number of iterations allowed per time step.

Program Modifications for Variable Directions of Anisotropy

The program listed in table 1 can be modified to simulate flow in an aquifer where the principal directions of anisotropy vary from zone to zone. These modifications are outlined below:

1. Dimension a new array, called AROT, to represent the angle of rotation for the principal directions of anisotropy. The size of the array must be greater than the number of aquifer zones.
2. Add statements to read values of AROT for each aquifer zone. The angle should be read in radians of rotation from the positive x axis. The AROT array can be read with values of other zonal factors (RX, RY, RC, and QXY) if desired.
3. Add the following as the second statement of DO loop 390.
   AROTI = AROT(MATI)
4. Add the following as the second and third statements in DO loop 310.
   XE = XORD(NPK)*COS(AROTI)+YORD(NPK)*SIN(AROTI)
   YE = YORD(NPK)*COS(AROTI)+YORD(NPK)*SIN(AROTI)
5. Replace XORD(NPK) with XE, and YORD(NPK) with YE in all other statements of DO loop 310.

MODEL EVALUATION

Comparison with Analytical Solution for Streamflow Depletion Due to Ground-Water Pumpage

The stream-aquifer model was evaluated by comparing model results with those obtained by the streamflow depletion method of Jenkins (1968). In order to compare model results with the analytical solution for streamflow depletion, the simplifying assumptions of the analytical method were reproduced in the model. The assumptions of homogeneity and isotropy were reproduced in the model with relative ease. The assumptions of a stream that fully penetrated the aquifer, no streambed confining unit, and a stream depth that did not vary with time were simulated by treating all stream nodes as a boundary of constant head and setting the vertical hydraulic conductivity of the streambed to an artificially large value.

A finite-element grid with uniform node spacing of 50 ft was used for comparing results. Modeled pumpage was 1.0 ft^3/s from a well 250 ft from the stream. The assumed ratio of transmissivity to storage coefficient was 0.025 ft^2/s. The lateral aquifer boundaries were sufficiently distant from the pumping well to have no effect on the drawdown distribution.

The comparison between model-calculated streamflow depletion and streamflow depletion calculated by the analytical method is quite good (fig. 2). Differences in the two curves probably can be attributed to the small differences in assumptions of the two methods. During the early time steps of the simulation, the difference between curves also is the result of relatively large cumulative errors in the numerical approximations for the equation of ground-water flow.

Evaluation of Numerical Dispersion in the Streamflow Model

Numerical dispersion in the streamflow model was evaluated after the streamflow model was uncoupled from the model of ground-water flow. In the evaluation, all ground-water nodes were modeled as boundaries of known head and variables used in the streamflow model were given the following values: Vertical hydraulic conductivity of the streambed, an artificially small value of 1×10^{-20} ft/s; stream discharge, initially 100 ft^3/s; channel width, 50 ft; Manning's coefficient of roughness, 0.025, a value indicating a smooth stream channel; and channel slope, 0.001 ft/ft. Equation 2 was used to calculate initial values of stream depth.

The dispersion of a flood wave approximated by the model was used to evaluate the numerical dispersion by using different time steps and nodal spacings. Figures 3 and 4 show the dispersion of the calculated flood wave 1 day after stream discharge at the upstream boundary was increased to 250 ft^3/s. The model-calculated flood waves shown in figure 3 were obtained by using 5-, 10-, and 20-minute time steps with a uniform nodal spacing of 5,400 ft. Using time steps of 10 minutes or less, numerical dispersion in the solution is similar for 5- and 10-minute time steps. A 20-minute time step results in the calculated flood wave moving downstream with little dispersion. Model--calculated flood waves shown in figure 4 were obtained by using nodal spacings 2,700, 5,400, and 8,400 ft and a uniform time step of 5 minutes. Decreasing the nodal spacing will decrease numerical dispersion.

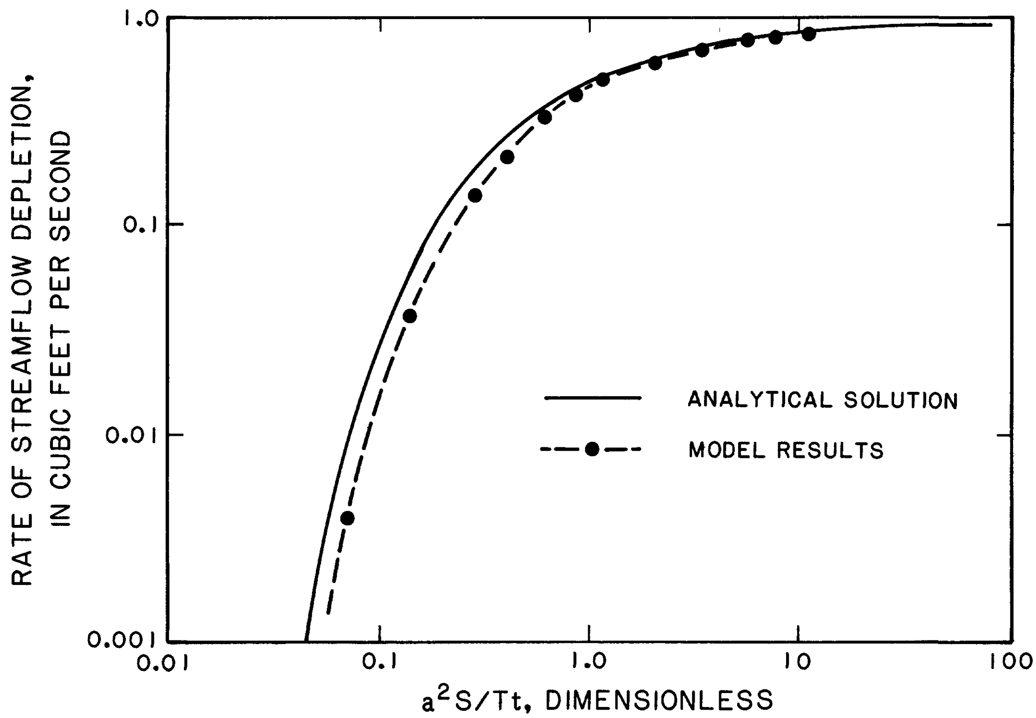

Figure 2.--Comparison of model results with Jenkins' analytical solution for stream depletion (t is time, S is storage coefficient, a is distance from the pumping well to the stream, and T is transmissivity).

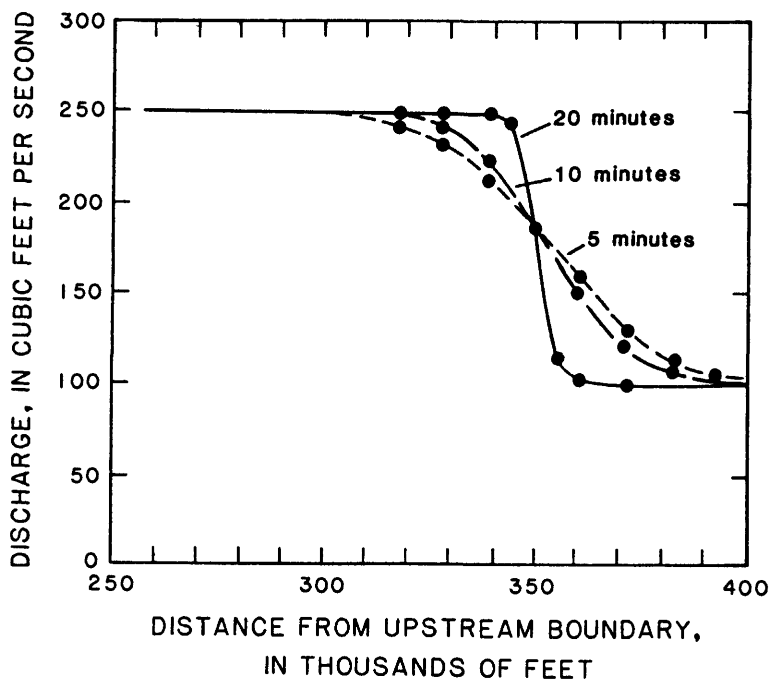

Figure 3.--Dispersion of flood wave calculated by the model after one day using various time steps and a nodal spacing of 5,400 feet.

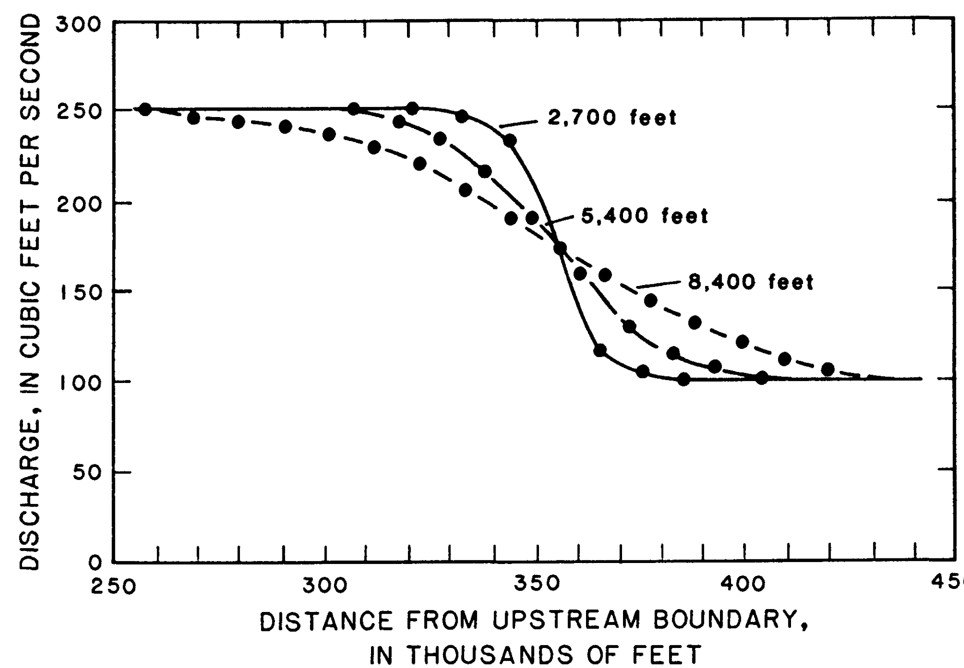

Figure 4.--Dispersion of flood wave calculated by the model after one day using a time step of 5 minutes and various nodal spacings.

Simulation results shown in figures 3 and 4 indicate that numerical dispersion decreases as the ratio of nodal spacing to time increment approaches kinematic-wave celerity. Wave celerity is the derivative of stream discharge with respect to cross-sectional area. For the simulation results shown in figures 3 and 4, wave celerity is approximately 4 ft/s. Therefore, in figure 3 with uniform nodal spacing 5,400 ft minimum numerical dispersion should occur with a time step of approximately 22 minutes. In figure 4 with 5-minute time steps, minimum numerical dispersion should occur with nodal spacing of approximately 1,200 ft.

The effects of numerical dispersion on a flood wave (figs. 3 and 4) can be significant and in some cases produce results similar to those caused by physically-based dispersion. However, no recommendations can be given regarding lengths of time steps or nodal spacings that will produce reasonable attenuation and dispersion of flood waves. In many stream-aquifer applications, it is not as important to accurately simulate dispersion as it is to simulate stream-aquifer leakage rates. If accurate simulation of flood-wave attenuation and dispersion is important, then a model based on the complete dynamic equations of open-channel flow may be more appropriate than the model described in this report.

Bear River Valley Case Study

The northern Bear River valley in Wyoming is a good example of a stream-aquifer system where ground-water development could affect or deplete streamflow. Also, because the velocity of water in the Bear River is relatively small during low flow, the stream-aquifer system represents a useful test of the need for kinematic routing. The Bear River originates in the Uinta Mountains of Utah and flows northward along the Utah-Wyoming border. Turning west into Idaho and then south into Utah, the river finally discharges into the Great Salt Lake. The stream reach of interest in this simulation is shown in figure 5. Average channel slope is 2.1 ft/mi, and the mean annual streamflow is 422 ft^3/s at the downstream Idaho-Wyoming border. The total thickness of alluvium along the Bear River has not been determined but is known to exceed 450 ft. Bedrock aquifers underlying the alluvium have small permeability.

The Bear River study reach is typical of many stream-aquifer systems in the western United States. Potentiometric-surface maps indicate that the principal discharge from the aquifer occurs along the main river stem and that recharge to the aquifer occurs along the tributaries. During the irrigation season, diversions of surface water result in additional recharge. Streamflow increases as much as an order of magnitude during spring snowmelt, but returns to approximately the same base flow of 210 ft^3/s during October through February. Water levels in the alluvium rise and decline in response to changes in depth of the stream and irrigation recharge, but generally return to the same levels each winter.

The coupled model of stream-aquifer flow was used to simulate stream-aquifer conditions along the Bear River during the 1980 and 1981 irrigation seasons. The flow system was divided into nine aquifer zones and nine stream zones. Streamflow diversions and recharge to ground water from surface irrigation were simulated. Effects of ground-water pumping and evapotranspiration from the water table and phreatophytes also were simulated.

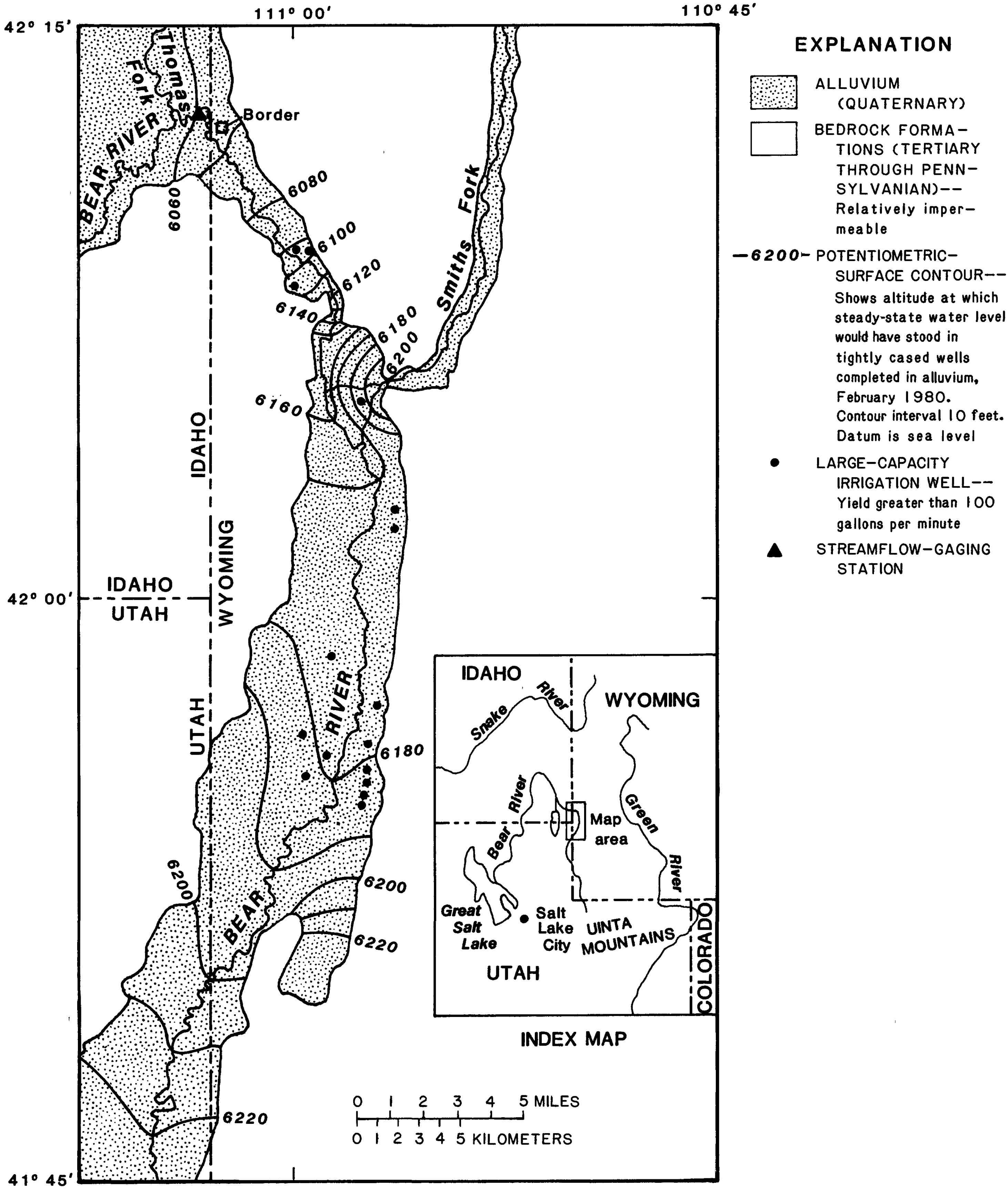

Figure 5.--Study reach of the Bear River.

Two simulations, made during the course of model development, illustrate the difference between streamflow calculated by the kinematic equations and by the continuity equation. The first simulation used the kinematic equations (eqs. 1 and 2). A value of 0.025 was used for Manning's coefficient of roughness. Channel slope was estimated from topographic maps, and initial stream velocity and head distribution were calculated from equation 2. The second simulation used only the continuity equation (eq. 1) to route water through the stream channel and was conceptually the same as a simulation using the model described by Hoxie (1977). The depth of water in the channel varied throughout the simulation period in response to changes in streamflow and was calculated by holding the velocity distribution constant.

The simulation results are compared to streamflow measured at the downstream model boundary (fig. 6). The hydrograph of streamflow calculated using the kinematic equations reproduces the hydrograph of measured streamflow fairly well, but the hydrograph calculated using only the continuity equation does not. The slope of the recession curve is much too gradual; in fact, streamflow calculated by the continuity equation does not return to initial conditions during the winter of 1980 and 1981.

The difference between hydrographs is the result of different calculated distributions of stream head. In turn, this causes different rates of stream-aquifer leakage. The ability to solve for both stream depth and velocity, using the kinematic equations, has resulted in a calculated stream-depth distribution that is similar to the actual depth distribution during the peak runoff period (April to July). The stream-depth distribution calculated by the continuity equation is too large. Overestimating stream depth means that the quantity of water leaving the stream channel as bank storage is calculated accurately by the kinematic equations but is grossly overestimated by the continuity equation. When demand for irrigation water is greatest (July to October), the kinematic equations accurately simulate the movement of water from bank storage into the channel while the continuity equation overestimates stream discharge.

The Bear River valley case study illustrates the need for using kinematic-wave theory in models of stream-aquifer systems. The kinematic equations give reasonably accurate estimates of streamflow without significantly increasing computational effort over that required for models using only the continuity equation. The ability of models using kinematic equations to accurately simulate declining limbs of hydrographs and low-flow periods means that water managers can more accurately evaluate the effects of ground-water pumpage or streamflow. If a model using only the continuity equation was used by water managers, the quantity of water available during periods of declining streamflow would be overestimated. Consequently, any effects of ground-water pumpage on streamflow could be masked by overestimates of streamflow.

Selected model input and output data for the simulation using kinematic equations are presented in this report as an aid to future users of the program. Data-input formats are given in table 2. The input data used for the kinematic simulation are given in table 3 and model output for a single time step are given in table 4.

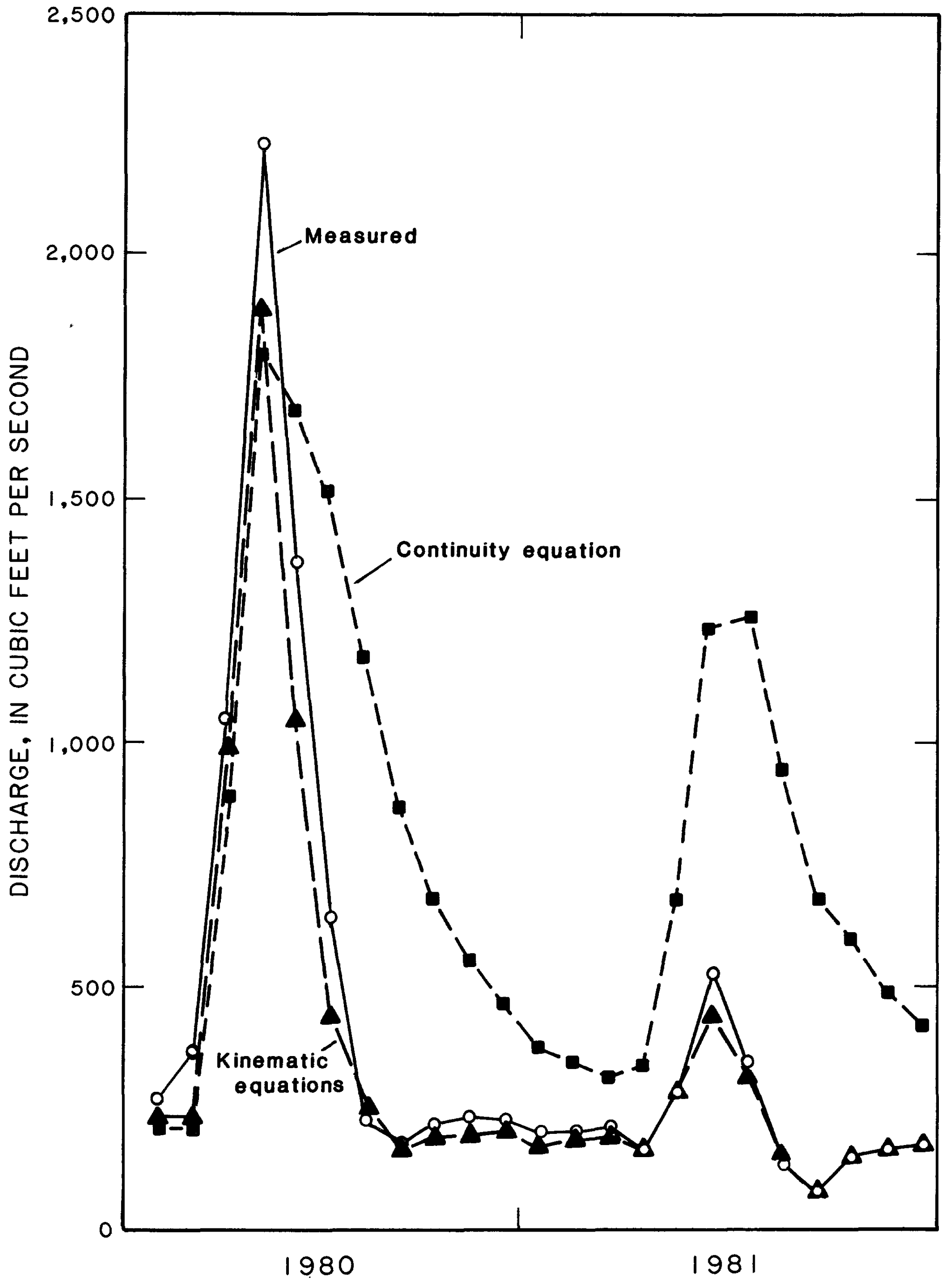

Figure 6.--Measured streamflow in the Bear River at Border, Wyoming and streamflow calculated by the model using the kinematic and continuity equations.

SUMMARY

Water managers and hydrologists often are faced with the problem of evaluating the effects of ground-water pumpage on streamflow. This report documents a model that is useful for predicting changes in streamflow as a result of ground-water pumpage and that was developed to simulate the hydrologic system of the Bear River in western Wyoming. The stream-aquifer model is especially useful for simulating streams that flow intermittently due to leakage to the aquifer or diversion for irrigation or become perched due to declining hydraulic head in the aquifer. Previous models of hydraulic interchange between ground water and surface water either have given inadequate consideration to stream hydraulics or have simulated streamflow in such detail as to be computationally cumbersome when applied to large heterogeneous aquifers.

The model couples the equation describing two-dimensional ground-water flow with the kinematic equations of one-dimensional open-channel flow. Darcy's law for vertical flow through a semipermeable streambed is used to couple the ground-water flow and streamflow equations. The equations of flow in the stream-aquifer system are approximated numerically by the finite-element method. The Fortran program that solves the equations of flow is listed in the report. Data-input formats are described, and input and output for a sample simulation are given as an aid to model users. A description of the program design also is given to help model users plan a finite-element grid. The model procedure used to enter aquifer and stream-channel properties is flexible.

Several options were added to the program to simulate a variety of hydrologic features. These features include perched streams, streamflow diversions, springs, recharge from irrigated acreage, and evapotranspiration from the water table and from phreatophytes. Time-dependent boundary conditions can be simulated. Program modifications for simulating unconfined aquifers and aquifers with variable directions of anisotropy also are described.

The stream-aquifer model was evaluated for numerical accuracy by comparing model results with results from an analytical method. Model results for a simulation of streamflow depletion due to pumping nearby wells compared favorably with results obtained by an analytical solution technique. Simulations using various stream-node spacings and time steps showed that numerical dispersion can be significant when modeling streamflow. A case study of the stream-aquifer system in the Bear River valley of western Wyoming showed that stream-aquifer leakage is more accurately calculated when using kinematic equations to simulate streamflow than when using the continuity equation. A simulation using the kinematic equations more accurately reproduced stream-aquifer leakage during periods of base flow as well as periods of large streamflow.

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page 35 follows

SUPPLEMENTAL DATA

page 37 followi

Table 1.--*Program listing*

```
C
C     A FINITE ELEMENT PROGRAM FOR THE SOLUTION OF TRANSIENT FLOW
C     OF GROUND WATER COUPLED WITH KINEMATIC SURFACE-WATER FLOW.
C     GROUND-WATER FLOW IS TWO-DIMENSIONAL,CONFINED WITH
C     STREAM LEAKAGE. SURFACE-WATER FLOW IS ONE-DIMENSIONAL WITH
C     TRIBUTARIES, DIVERSIONS, AND IRRIGATION RECHARGE. STREAMS
C     MAY BE MODELED AS HYDRAULICLY CONNECTED TO THE GROUND
C     WATER, PERCHED, DRY, OR A COMBINATION.
C
C     GUIDELINES FOR DIMENSIONS OF ARRAYS
C        ISW(NUMNP),NPBC(NUMNP),XORD(NUMNP),YORD(NUMNP),PHI(NUMNP),
C        ISWARR(NSWELM,3),PHITMP(NUMNP),Q(NUMNP),
C        IDFLD(NUMEL),MAT(NUMEL),TRAN(NUMEL),STOR(NUMEL),QRE(NUMEL),
C        IDSTM(NUMSN),UI(NUMSN),YBED(NUMSN),SLOPE(NSWELM),
C        TOP(NSWELM),RMAN(NSWELM),RLEAK(NSWELM),H(NUMSN),HTMP(NUMSN),
C        SWFAC(NUMSN),QS(NUMSN),GRND(NUMNP),NODELU(NUMSN),QSOLD(NUMSN)
C        RX(NUMAT),RY(NUMAT),RC(NUMAT),QXY(NUMAT),
C        SLP(NUMCHN),TP(NUMCHN),RM(NUMCHN),RS(NUMCHN),
C        RHSFAC(NUMNP),THICK(NUMCHN),IDACT(NUMCHN),
C        IHEAD(NDIV),ISNDN(NDIV),QADJ(NDIV),QMIN(NDIV),ISMIN(NDIV),
C        TOTARE(NFLD),IFLDAC(NFLD),IDIVND(NFLD),ICJUN(NJUNC),
C        QFLD(NFLD),CURATE(NFLD),QEND(NFLD),
C        DNDX(3),DNDY(NNPE),QE(NNPE),C(NNPE,NNPE),
C        S(3,NNPE),RE(NNPE,NNPE),
C        QSAVE(NUMSN),NP(NUMEL,3),TITLE(20),
C        RJAC(2,2),RJACI(2,2),WT(2,1),SF(5,3,1),NUMQPT(2),
C        SK(IDIM,JDIM),DQ(IDIM),
C        NSPFLD(NFLD),QPUMP(NFLD)
C        QGW(NSWELM,3/3+1),NODSUP(NFLD,NSUP),PERSUP(NFLD,NSUP)
C
C     CURRENT DIMENSIONS ARE :
C        NUMNP=320,NUMEL=535,NUMSN=100,NUMAT=10,NUMCHN=10,NDIV=20,
C        NSWELM=100,NFLD=20,IDIM=320,JDIM=50,NSUP=10,NJUNC=20
C
      DIMENSION
     $   ISW(320),NPBC(320),XORD(320),YORD(320),PHI(320),STRT(320),
     $   PHITMP(320),Q(320),
     $   IDFLD(535),MAT(535),TRAN(535),STOR(535),QRE(535),
     $   IDSTM(100),H(100),UI(100),YBED(100),SLOPE(100),
     $   QSAVE(100),TOP(100),RMAN(100),RLEAK(100),HTMP(100),
     $   SWFAC(100),QS(100),GRND(320),NODELU(100),QSOLD(100),
     $   RX(10),RY(10),RC(10),QXY(10),
     $   SLP(10),TP(10),RM(10),RS(10),
     $   RHSFAC(100),THICK(10),IDACT(10),
     $   IHEAD(20),ISNDN(20),QADJ(20),QMIN(20),ISMIN(20),
     $   TOTARE(20),IFLDAC(20),IDIVND(20),ICJUN(20),
     $   QGW(100,2),NODSUP(20,10),PERSUP(20,10),NSPFLD(20),QPUMP(20),
     $   QFLD(20),CURATE(20),QEND(20),TITLE(20),
     $   DNDX(3),DNDY(3),QE(3),C(3,3),
     $   RE(3,3),S(3,3),
     $   NP(535,3),ISWARR(100,3),
     $   RJAC(2,2),RJACI(2,2),WT(2,1),SF(5,3,1),NUMQPT(2)
C
```

```
      REAL*8 SK,DQ
      COMMON /LDUBLK/SK(320,35),DQ(320)
C
C     SET IDIM>NUMNP, JDIM>BAND WIDTH OF GW MATRIX (IB), KDIM>NUMEL
C     ITOL IS THE CLOSURE CRITERIUM, IN FEET.
C
      IDIM=320
      JDIM=35
      KDIM=535
      TOL=0.01
C
C     OPEN DATA INPUT AND PRINT FILES
C
      OPEN (UNIT=5,FILE='SAMPLE.DATA',STATUS='OLD')
      OPEN (UNIT=6,FILE='PRTFILE')
C
C     FORMATS
C
1     FORMAT ('1  #EL  #NP  #SE  #SN #MAT #CHN #JUN NFLD  #PP ITMAX',
     $        'IPUNCH')
2     FORMAT (11I5)
3     FORMAT ('0NODE  ISW NPBC      XORD      YORD       PHI         Q',
     $        '      GRND')
4     FORMAT (3I5,5F10.2)
5     FORMAT ('0  EL IDFLD   NP ARRAY')
6     FORMAT (8I5)
7     FORMAT ('0  EL  MAT      TRAN      STOR       QRE')
8     FORMAT (2I5,3G10.3)
9     FORMAT ('0  SN         HI        UI      YBED     ')
10    FORMAT (I5,3F10.3)
11    FORMAT ('0 MAT         RX        RY        RC       QXY')
12    FORMAT (I5,4G10.3)
13    FORMAT ('0ICHN       SLP        TP        RM        RS',
     $        '     THICK')
14    FORMAT (I5,5G10.3)
15    FORMAT ('1PUMPING PERIOD INPUT DATA'/'  NTS     TIMAX     DTIME',
     $        '     DELTA   NN NDIV INCPR IPLT     SCALE    CONINT')
16    FORMAT (I5,3G10.3,4I5,2G10.3)
17    FORMAT ('0  NP NPBC          Q       PHI        QS')
18    FORMAT (2I5,3G10.3)
19    FORMAT ('0ACTIVE STREAM ARRAY')
20    FORMAT (16I5)
21    FORMAT (' ISN IHEAD ISNDN    QADJ      QMIN ISMIN')
22    FORMAT (3I5,2G10.3,I5)
23    FORMAT ('  NP IFLDAC IDIVND CURATE NSPFLD')
24    FORMAT (3I5,G10.3,I5)
25    FORMAT ('1SOLUTION AT TIME =',G12.5,' DAYS =',G12.5/' NODE',
     $        '       XORD        YORD         PHI   DRAWDOWN',
     $        ' STREAM HEAD STREAMFLOW')
26    FORMAT (I5,2E12.5,4(1X,F11.4))
27    FORMAT (' WARNING! DETERMINATE FOR ELEMENT',I5,', QUADRATURE ',
     $        'POINT',I5,' IS ',G12.5)
28    FORMAT (' AVERAGE SLOPE FOR STREAM NODE',I5,' SHOULD BE ',E14.7)
```

```
29    FORMAT (' SUPPLIMENTAL PUMPING RATES'/' FIELD   RATE
     $        'RECHARGE')
30    FORMAT (I5,2E14.7)
31    FORMAT ('0IB=',I5)
32    FORMAT ('0SOLUTION FAILED TO CONVERGE AT TIME STEP',I5)
33    FORMAT (2G10.0)
34    FORMAT (' THETA = ',F5.2,' ETDEEP = ',F5.2)
35    FORMAT ('0ISWEL ISWARR ARRAY  IDSTRM     SLOPE       TOP',
     $        '          RMAN      RLEAK')
36    FORMAT (5I5,4G10.3)
37    FORMAT ('0DIVERSION',I5,'FLOW RATE ',G12.5)
38    FORMAT (' INITIAL HEAD OR VELOCITY AT STREAM NODE',I5,
     $        ' IS ZERO.'/5X,' NO CHECK OF CHANNEL CHARACTERISTICS IS
     $        'POSSIBLE.')
39    FORMAT (' SUPPLIMENTAL PUMPING'/' NFLD NSUP NODE  PERCENT')
40    FORMAT (3I5,G10.3)
41    FORMAT (20A4)
42    FORMAT (' ETMAX = ',E14.7)
43    FORMAT (' SOLUTION AT TIME STEP',I5,' CONVERGED IN',I5,
     $        ' ITERATIONS')
44    FORMAT (' STREAM JUNCTION NODES')
C
C     INPUT DATA
C
      DO 102 I=1,3
      READ (5,41) TITLE
      WRITE (6,41) TITLE
102   CONTINUE
      WRITE(6,1)
      READ(5,2)NUMEL,NUMNP,NSWELM,NUMSN,NUMAT,NUMCHN,NJUNC,NFLD,NUMPP,
     $         ITMAX,IPUNCH
      WRITE(6,2)NUMEL,NUMNP,NSWELM,NUMSN,NUMAT,NUMCHN,NJUNC,NFLD,NUMPP,
     $          ITMAX,IPUNCH
      READ (5,33) THETA,ETDEEP
      WRITE (6,34) THETA,ETDEEP
      IF (ITMAX.LE.0) ITMAX=1
      WRITE(6,3)
      READ(5,4) (I,ISW(I),NPBC(I),XORD(I),YORD(I),PHI(I),Q(I),GRND(I),
     $          I1=1,NUMNP)
      WRITE (6,4)(I,ISW(I),NPBC(I),XORD(I),YORD(I),PHI(I),Q(I),GRND(I),
     $           I=1,NUMNP)
      WRITE(6,5)
      DO 110 I1=1,NUMEL
      READ (5,6) I,IDFLD(I),(NP(I,J),J=1,3)
      WRITE (6,6)I,IDFLD(I),(NP(I,J),J=1,3)
110   CONTINUE
      WRITE (6,7)
      DO 112 I1=1,NUMEL
      READ (5,8) I,MAT(I),TRAN(I),STOR(I),QRE(I)
      WRITE (6,8) I,MAT(I),TRAN(I),STOR(I),QRE(I)
112   CONTINUE
      WRITE (6,9)
      READ (5,10) (I,H(I),UI(I),YBED(I),I1=1,NUMSN)
```

```
      WRITE (6,10) (I,H(I),UI(I),YBED(I),I=1,NUMSN)
      READ (5,20) (ICJUN(I),I=1,NJUNC)
      WRITE (6,44)
      WRITE (6,20) (ICJUN(I),I=1,NJUNC)
      WRITE (6,35)
      READ (5,36) (I,ISWARR(I,1),ISWARR(I,2),ISWARR(I,3),
     $            IDSTM(I),SLOPE(I),TOP(I),RMAN(I),RLEAK(I),I1=1,NSWELM)
      WRITE (6,36) (I,ISWARR(I,1),ISWARR(I,2),ISWARR(I,3),
     $            IDSTM(I),SLOPE(I),TOP(I),RMAN(I),RLEAK(I),I=1,NSWELM)
      WRITE (6,11)
      READ (5,12) (I,RX(I),RY(I),RC(I),QXY(I),I1=1,NUMAT)
      WRITE (6,12)(I,RX(I),RY(I),RC(I),QXY(I), I=1,NUMAT)
      WRITE (6,13)
      READ (5,14) (I,SLP(I),TP(I),RM(I),RS(I),THICK(I),I1=1,NUMCHN)
      WRITE (6,14)(I,SLP(I),TP(I),RM(I),RS(I),THICK(I), I=1,NUMCHN)
C
      CALL SHAFAC(SF,WT,NUMQPT)
C
      J1=3/3+1
      DO 120 I=1,NUMSN
      TPK=0.0
      DO 118 J=1,NSWELM
      ISMAT=IDSTM(J)
      DO 116 K=2,3
      NPS=ISWARR(J,K)
      NPS=ISW(NPS)
      IF (NPS.NE.I) GO TO 116
      IF (TOP(J)*TP(ISMAT).LE.TPK) GO TO 116
      RMK=RMAN(J)*RM(ISMAT)
      TPK=TOP(J)*TP(ISMAT)
      SLPK=SLOPE(J)*SLP(ISMAT)
116   CONTINUE
      DO 117 JJ=1,J1
      QGW(J,JJ)=0.0
117   CONTINUE
118   CONTINUE
      HTMP(I)=H(I)
      IF (IPUNCH.EQ.-1) QS(I)=UI(I)
      IF (IPUNCH.NE.-1) QS(I)=UI(I)*H(I)*TPK
      IF (UI(I).EQ.0.0.OR.H(I).EQ.0.0) GO TO 119
      IF (IPUNCH.EQ.-1) UI(I)=UI(I)/H(I)/TPK
      RHSFAC(I)=UI(I)*TPK/H(I)**(2.0/3.0)
      SLPK=(RHSFAC(I)/TPK*RMK/1.486)**2
      WRITE (6,28) I,SLPK
      GO TO 120
119   RHSFAC(I)=1.486*SLPK**0.5*TPK/RMK
      WRITE (6,38) I
120   CONTINUE
      DO 122 I=1,NUMNP
      PHITMP(I)=PHI(I)
      STRT(I)=PHI(I)
122   CONTINUE
      IB=0
```

```
      NNM1=3-1
      DO 123 I=1,NUMEL
      DO 123 J=1,NNM1
      JP1=J+1
      NPJ=NP(I,J)
      DO 123 K=JP1,3
      NPK=NP(I,K)
      J1=NPK-NPJ
      J1=IABS(J1)
      IF (J1.GT.IB) IB=J1
123   CONTINUE
      IB=IB+1
      IDIAG=1
      WRITE (6,31) IB
      IF (IB.GT.JDIM) STOP
      NUMEQ=NUMNP
      TIME=0.0
      IPP=0
C
C     COMPUTE TOTAL AREA OF EACH IRRIGATION FIELD
C
      IF (NFLD.LE.0) GO TO 130
      DO 124 I=1,NFLD
      TOTARE(I)=0.0
124   CONTINUE
      DO 129 I=1,NUMEL
      IF (IDFLD(I).LE.0) GO TO 129
      IDF=IDFLD(I)
      AREA=0.0
      JEND=NUMQPT(1)
      DO 128 J=1,JEND
      RJAC(1,1)=0.0
      RJAC(1,2)=0.0
      RJAC(2,1)=0.0
      RJAC(2,2)=0.0
      DO 126 K=1,3
      NPK=IABS(NP(I,K))
      RJAC(1,1)=RJAC(1,1)+SF(2,K,J)*XORD(NPK)
      RJAC(1,2)=RJAC(1,2)+SF(3,K,J)*XORD(NPK)
      RJAC(2,1)=RJAC(2,1)+SF(2,K,J)*YORD(NPK)
      RJAC(2,2)=RJAC(2,2)+SF(3,K,J)*YORD(NPK)
126   CONTINUE
      DETJ=RJAC(1,1)*RJAC(2,2)-RJAC(2,1)*RJAC(1,2)
      IF (DETJ.LE.0.0) GO TO 7001
      DO 127 K=1,3
      DO 127 L=1,3
      AREA=AREA+WT(1,J)*SF(1,K,J)*SF(1,L,J)*DETJ
127   CONTINUE
128   CONTINUE
      TOTARE(IDF)=TOTARE(IDF)+AREA
129   CONTINUE
C
C
```

Table 1.--*Program listing*--Continued

```
C     BEGIN NEW PUMPING PERIOD
C
130   WRITE (6,15)
      READ (5,16)NTS,TIMAX,DTIME,DELTA,NN,NDIV,INCPR,IPLT,SCALE,CONINT
      DT=DTIME
      TM=0.0
      DO 137 I=1,NTS
      TM=TM+DT
      IF (TM.GE.TIMAX) GO TO 138
      DT=DT*DELTA
137   CONTINUE
      GO TO 139
138   DTIME=TIMAX/TM*DTIME
      NTS=I
139   WRITE(6,16)NTS,TIMAX,DTIME,DELTA,NN,NDIV,INCPR,IPLT,SCALE,CONINT
      READ (5,33) ETMAX
      WRITE (6,42) ETMAX
      DO 131 I=1,NUMSN
      QSAVE(I)=0.0
      NODELU(I)=0
131   CONTINUE
      IF (NN.LE.0) GO TO 133
      WRITE (6,17)
      DO 132 I1=1,NN
      READ (5,18) I,NPBC(I),Q(I),TMP,TMP1
      IF (ISW(I).LE.0) WRITE (6,18) I,NPBC(I),Q(I),TMP
      IF (ISW(I).GT.0) WRITE (6,18) I,NPBC(I),Q(I),TMP,TMP1
      IF (NPBC(I).EQ.-1) PHI(I)=TMP
      IF (ISW(I).LE.0) GO TO 132
      NPS=ISW(I)
      QSAVE(NPS)=TMP1
132   CONTINUE
133   DTIME=DTIME/DELTA
      INCR=0
      ITS=0
      IPP=IPP+1
      LU=1
C
C     READ FLAGS FOR ACTIVE STREAMS
C
      WRITE (6,19)
      READ (5,20) (IDACT(I),I=1,NUMCHN)
      WRITE (6,20)(IDACT(I),I=1,NUMCHN)
C
C     READ DIVERSION DATA
C
      IF (NDIV.LE.0) GO TO 134
      WRITE (6,21)
      READ(5,22)(I,IHEAD(I),ISNDN(I),QADJ(I),QMIN(I),ISMIN(I),I1=1,NDIV)
      WRITE(6,22)(I,IHEAD(I),ISNDN(I),QADJ(I),QMIN(I),ISMIN(I),I=1,NDIV)
C
C     READ IRRIGATION FIELD DATA
C
```

Table 1.--*Program listing*--Continued

```
134   IF (NFLD.LE.0) GO TO 250
      WRITE (6,23)
      READ (5,24) (I,IFLDAC(I),IDIVND(I),CURATE(I),NSPFLD(I)
     $             ,I1=1,NFLD)
      WRITE(6,24) (I,IFLDAC(I),IDIVND(I),CURATE(I),NSPFLD(I)
     $            ,I=1,NFLD)
      NSUP=0
      DO 136 I=1,NFLD
      NSUP=NSUP+NSPFLD(I)
136   CONTINUE
      IF (NSUP.EQ.0) GO TO 250
      WRITE (6,39)
      READ (5,40) (I,J,NODSUP(I,J),PERSUP(I,J),K=1,NSUP)
      WRITE (6,40) (I,J,NODSUP(I,J),PERSUP(I,J),K=1,NSUP)
C
C     BEGIN NEW TIME STEP
C
250   CONTINUE
C
      DTIME=DTIME*DELTA
      ITS=ITS+1
      DO 252 I=1,NUMSN
      QSOLD(I)=QS(I)
252   CONTINUE
      DO 450 ITER=1,ITMAX
      ITSTOP=0
      IF (IPP.EQ.1.AND.ITS.EQ.1.AND.ITER.EQ.1) GO TO 162
      DO 254 I=1,NUMSN
      QS(I)=QSAVE(I)
254   CONTINUE
C
C     ROUTE STREAMFLOW
C
      DO 160 I=1,NUMSN
      DO 158 J=1,NSWELM
      J1=IDSTM(J)
      THK=THICK(J1)
      TPK=TOP(J)*TP(J1)
      IF (IDACT(J1).EQ.0) GO TO 158
      DO 156 K=2,3
      NPK=ISWARR(J,K)
      NPSK=ISW(NPK)
      IF (I.NE.NPSK) GO TO 156
      DO 154 L=2,3
      IF (K.EQ.L) GO TO 154
      NPL=ISWARR(J,L)
      NPSL=ISW(NPL)
      IF (NPSL.LE.NPSK) GO TO 154
C     GW LEAKAGE
      GWTMP=0.0
      HK=YBED(NPSK)+(1.0-THETA)*H(NPSK)+THETA*HTMP(NPSK)
      HL=YBED(NPSL)+(1.0-THETA)*H(NPSL)+THETA*HTMP(NPSL)
      PHIK=PHI(NPK)*(1.0-THETA)+PHITMP(NPK)*THETA
```

```
      PHIL=PHI(NPL)*(1.0-THETA)+PHITMP(NPL)*THETA
      IF (PHIK.GE.YBED(NPSK).AND.HK.GT.YBED(NPSK)) GO TO 142
      IF (PHIK.LT.YBED(NPSK)-THK) PHIK=YBED(NPSK)-THK
      IF (NODELU(NPSK).EQ.0) LU=1
      NODELU(NPSK)=1
      IF (HK.EQ.YBED(NPSK).AND.PHIK.LT.YBED(NPSK)) HK=PHIK
      GO TO 143
142   IF (NODELU(NPSK).EQ.1) LU=1
      NODELU(NPSK)=0
143   IF (PHIL.GE.YBED(NPSL).AND.HL.GT.YBED(NPSL)) GO TO 144
      IF (PHIL.LT.YBED(NPSL)-THK) PHIL=YBED(NPSL)-THK
      IF (NODELU(NPSL).EQ.0) LU=1
      NODELU(NPSL)=1
      IF (HL.EQ.YBED(NPSL).AND.PHIL.LT.YBED(NPSL)) HL=PHIL
      GO TO 145
144   IF (NODELU(NPSL).EQ.1) LU=1
      NODELU(NPSL)=0
145   KM1=K-1
      LM1=L-1
      GWTMP=GWTMP+QGW(J,KM1)*(PHIK-HK)
      GWTMP=GWTMP+QGW(J,LM1)*(PHIL-HL)
C     SOLVE FOR STREAM DISCHARGE
      RLENG=((XORD(NPK)-XORD(NPL))**2+(YORD(NPK)-YORD(NPL))**2)**0.5
      DECIDE=0.0
      IF (H(NPSL).GT.0.0) DECIDE=(5.0/3.0)*(DTIME/RLENG)*QSOLD(NPSL)
     $                    /H(NPSL)/TPK
      CJFACK=1.0
      DO 141 KK=1,NJUNC
      ICJ=ICJUN(KK)
      IF (IABS(ICJ).NE.NPSK) GO TO 140
      DECIDE=2.0
      IF (ICJ.LT.0) CJFACK=0.5
      GO TO 148
140   IF (IABS(ICJ).NE.NPSL) GO TO 141
      DECIDE=2.0
      GO TO 148
141   CONTINUE
148   IF (DECIDE.LT.1.0) GO TO 146
      QTMP=QS(NPSK)+GWTMP-RLENG/DTIME*TPK*(HTMP(NPSK)
     $     -H(NPSK))
      QTMP=QTMP*CJFACK
      GO TO 147
146   QTMP=H(NPSL)+(GWTMP*DTIME/RLENG+DTIME*(QSOLD(NPSK)-
     $     QSOLD(NPSL))/RLENG)/TPK
      IF (QTMP.LT.0.0) QTMP=0.0
      QTMP=RHSFAC(NPSL)*QTMP**(5.0/3.0)
147   IF (NDIV.LE.0) GO TO 153
C     DIVERSIONS
      DO 152 M=1,NDIV
      NPM=IHEAD(M)
      IF (NPSL.NE.ISW(NPM)) GO TO 152
      NPSMIN=ISMIN(M)
      TMP=QTMP-QMIN(M)
```

Table 1.--*Program listing*--Continued

```
      IF (QS(NPSMIN).LE.QMIN(M)) TMP=0.0
      IF (TMP.GT.QADJ(M)) TMP=QADJ(M)
      QTMP=TMP
      NPS=ISNDN(M)
      NPS=ISW(NPS)
      QS(NPS)=QS(NPS)-TMP
      GO TO 153
152   CONTINUE
C     ROUTING COMPLETE FROM NODE K TO NODE L
153   QS(NPSL)=QS(NPSL)+QTMP
154   CONTINUE
156   CONTINUE
158   CONTINUE
C     CALCULATE STREAM HEAD FROM MANNING'S EQUATION AND CHECK
C     FOR CONVERGENCE
      IF (QS(I).LT.0.0) QS(I)=0.0
      TMP=(QS(I)/RHSFAC(I))**(3.0/5.0)
      IF (TMP.LT.0.0) TMP=0.0
      IF (ABS(TMP-HTMP(I)).GT.TOL) ITSTOP=1
      HTMP(I)=TMP
160   CONTINUE
162   DO 261 I=1,NUMEQ
      DQ(I)=Q(I)
      IF (LU.EQ.0) GO TO 261
      DO 260 J=1,IB
      SK(I,J)=0.0
260   CONTINUE
261   CONTINUE
C
C     COMPUTE DISCHARGE TO IRRIGATION FIELDS
C
      IF (NFLD.LE.0) GO TO 300
      DO 290 I=1,NFLD
      QEND(I)=0.0
      QFLD(I)=0.0
      QPUMP(I)=0.0
      IF (IFLDAC(I).EQ.0) GO TO 290
      NPK=IDIVND(I)
      NPS=ISW(NPK)
      QEND(I)=RHSFAC(NPS)*((1.0-THETA)*H(NPS)+THETA*HTMP(NPS))
     $         **(5.0/3.0)
      NSUP=NSPFLD(I)
      IF (NSUP.EQ.0) GO TO 290
      DO 266 K=1,NSUP
      TMP=(QEND(I)/TOTARE(I)-CURATE(I))*TOTARE(I)*PERSUP(I,K)
      IF (TMP.GT.0.0) TMP=0.0
      QPUMP(I)=TMP
      N=NODSUP(I,K)
      IF (N.GT.0) DQ(N)=DQ(N)+TMP
266   CONTINUE
290   CONTINUE
C
C     ELEMENT INTEGRATION FOR AQUIFER
```

```
C
300   DO 304 J=1,NSWELM
      DO 304 K=1,2
      QGW(J,K)=0.0
304   CONTINUE
      DO 390 I=1,NUMEL
      MATI=MAT(I)
      DO 306 J=1,3
      QE(J)=0.0
      DO 306 K=1,3
      C(J,K)=0.0
      S(J,K)=0.0
      RE(J,K)=0.0
306   CONTINUE
C
C     BEGIN VOLUME QUADRATURE FOR AQUIFER
C
      JEND=NUMQPT(1)
      DO 340 J=1,JEND
      RJAC(1,1)=0.0
      RJAC(1,2)=0.0
      RJAC(2,1)=0.0
      RJAC(2,2)=0.0
      GRNDJ=0.0
      PHIJ=0.0
      DO 310 K=1,3
      NPK=NP(I,K)
      RJAC(1,1)=RJAC(1,1)+SF(2,K,J)*XORD(NPK)
      RJAC(1,2)=RJAC(1,2)+SF(3,K,J)*XORD(NPK)
      RJAC(2,1)=RJAC(2,1)+SF(2,K,J)*YORD(NPK)
      RJAC(2,2)=RJAC(2,2)+SF(3,K,J)*YORD(NPK)
      GRNDJ=GRNDJ+SF(1,K,J)*GRND(NPK)
      PHIJ=PHIJ+SF(1,K,J)*(PHI(NPK)*(1.0-THETA)+PHITMP(NPK)*THETA)
310   CONTINUE
      IF (GRNDJ.LE.0.0) GRNDJ=1.0E+20
      DETJ=RJAC(1,1)*RJAC(2,2)-RJAC(2,1)*RJAC(1,2)
      IF (DETJ.LE.0.0) GO TO 7001
      RJACI(1,1)=+RJAC(2,2)/DETJ
      RJACI(1,2)=-RJAC(1,2)/DETJ
      RJACI(2,1)=-RJAC(2,1)/DETJ
      RJACI(2,2)=+RJAC(1,1)/DETJ
      DO 315 K=1,3
      DNDX(K)=RJACI(1,1)*SF(2,K,J)+RJACI(2,1)*SF(3,K,J)
      DNDY(K)=RJACI(1,2)*SF(2,K,J)+RJACI(2,2)*SF(3,K,J)
315   CONTINUE
      DO 330 K=1,3
      NPK=NP(I,K)
      QE(K)=QE(K)+WT(1,J)*SF(1,K,J)*QXY(MATI)*QRE(I)*DETJ
      AREA=0.0
      IF (PHIJ.GE.GRNDJ) QE(K)=QE(K)-WT(1,J)*SF(1,K,J)*ETMAX*DETJ
      IF (PHIJ.GT.GRNDJ-ETDEEP.AND.PHIJ.LT.GRNDJ) QE(K)=QE(K)+
     $   WT(1,J)*SF(1,K,J)*ETMAX*(GRNDJ-ETDEEP)/ETDEEP*DETJ
      DO 329 L=1,3
```

```
      RXJ=TRAN(I)*RX(MATI)
      RYJ=TRAN(I)*RY(MATI)
      S(K,L)=S(K,L)+WT(1,J)*(DNDX(K)*RXJ*DNDX(L)+DNDY(K)*RYJ*DNDY(L))
     $       *DETJ
      AREA=AREA+WT(1,J)*SF(1,K,J)*SF(1,L,J)*DETJ
      C(K,L)=C(K,L)+WT(1,J)*SF(1,K,J)*RC(MATI)*STOR(I)*SF(1,L,J)*DETJ
      IF (PHIJ.GT.GRNDJ-ETDEEP.AND.PHIJ.LT.GRNDJ) S(K,L)=S(K,L)+
     $    WT(1,J)*SF(1,K,J)*ETMAX/ETDEEP*SF(1,L,J)*DETJ
329   CONTINUE
      IF (NFLD.EQ.0) GO TO 330
      I1=IDFLD(I)
      IF (I1.LE.0) GO TO 330
      IF (IFLDAC(I1).EQ.0) GO TO 330
      TMP=QEND(I1)/TOTARE(I1)-CURATE(I1)
      IF (TMP.LE.0) GO TO 330
      QFLD(I1)=QFLD(I1)+AREA*TMP
      QE(K)=QE(K)+AREA*TMP
330   CONTINUE
340   CONTINUE
C
C     LINE QUADRATURE FOR LEAKAGE TERM
C
      DO 354 KK=1,NSWELM
      ISE=KK
      IF (ISWARR(KK,1).EQ.I) GO TO 356
354   CONTINUE
      ISE=0
      GO TO 379
356   ISMAT=IDSTM(ISE)
      IF (IDACT(ISMAT).EQ.0) GO TO 379
      DO 380 J=1,3
      L1=(J-1)+1
      IF (ISWARR(ISE,2).NE.NP(I,L1)) GO TO 380
      KEND=NUMQPT(2)
      DO 375 K=1,KEND
      DXDXI=0.0
      DYDXI=0.0
      YK=0.0
      HK=0.0
      RSK=0.0
      RTMP=0.0
      THK=0.0
      PHIK=0.0
      DO 368 L=1,2
      L1=(J-1)+L
      IF (L1.GT.3) L1=1
      NPL=NP(I,L1)
      NPS=ISW(NPL)
      IF (NPS.EQ.0) GO TO 368
      DXDXI=DXDXI+SF(5,L,K)*XORD(NPL)
      DYDXI=DYDXI+SF(5,L,K)*YORD(NPL)
      YK=YK+SF(4,L,K)*YBED(NPS)
      RSK=RSK+SF(4,L,K)*RLEAK(ISE)*RS(ISMAT)/THICK(ISMAT)
```

```
     $         *TOP(ISE)*TP(ISMAT)
      HK=HK+SF(4,L,K)*(HTMP(NPS)*THETA+H(NPS)*(1.0-THETA))
      THK=THK+SF(4,L,K)*THICK(ISMAT)
      PHIK=PHIK+SF(4,L,K)*(PHITMP(NPL)*THETA+PHI(NPL)*(1.0-THETA))
368   CONTINUE
      IF (PHIK.LT.YK.AND.HK.LE.0.0) RSK=0.0
      IF (PHIK.LT.YK-THK) RTMP=YK-THK
      DETJS=SQRT(DXDXI**2+DYDXI**2)
      DO 370 L=1,2
      L1=(J-1)+L
      IF (L1.GT.3) L1=1
      NPL=NP(I,L1)
      NPS=ISW(NPL)
      QE(L1)=QE(L1)+WT(2,K)*SF(4,L,K)*RSK*(YK+HK-RTMP)*DETJS
      QGW(ISE,L)=QGW(ISE,L)+WT(2,K)*SF(4,L,K)*RSK*DETJS
      IF (RTMP.NE.0.0) GO TO 370
      DO 369 M=1,2
      M1=(J-1)+M
      IF (M1.GT.3) M1=1
      RE(L1,M1)=RE(L1,M1)+WT(2,K)*SF(4,L,K)*RSK*SF(4,M,K)*DETJS
369   CONTINUE
370   CONTINUE
375   CONTINUE
380   CONTINUE
C
C     FILL LARGE COEFFICIENT MATRICES FOR AQUIFER
C
379   DO 386 J=1,3
      NPJ=NP(I,J)
      DQ(NPJ)=DQ(NPJ)+QE(J)
      DO 384 K=1,3
      NPK=NP(I,K)
      NPS=ISW(NPK)
      DQ(NPJ)=DQ(NPJ)+(C(J,K)/DTIME-(1.0-THETA)*S(J,K))*PHI(NPK)
      IF (NPS.LE.0) GO TO 382
      DQ(NPJ)=DQ(NPJ)-(1.0-THETA)*RE(J,K)*PHI(NPK)
382   IF (LU.EQ.0) GO TO 384
      IF (NPK.LT.NPJ) GO TO 384
      K1=NPK-NPJ+IDIAG
      SK(NPJ,K1)=SK(NPJ,K1)+C(J,K)/DTIME+THETA*S(J,K)
      IF (NPS.LE.0) GO TO 384
      SK(NPJ,K1)=SK(NPJ,K1)+THETA*RE(J,K)
384   CONTINUE
386   CONTINUE
390   CONTINUE
C
C     HEAD BOUNDARY CONDITIONS FOR AQUIFER
C
      DO 430 I=1,NUMNP
      IF (NPBC(I).GE.0) GO TO 430
      IF (LU.EQ.1) SK(I,IDIAG)=1.0D+50
      DQ(I)=PHI(I)*1.0D+50
430   CONTINUE
```

Table 1.--*Program listing*--Continued

```
C
C     SOLVE FOR AQUIFER HEAD
C
      CALL UDU (LU,NUMEQ,IB)
      LU=0
C
C     CHECK FOR CONVERGENCE
C
      DO 442 I=1,NUMNP
      IF (ABS(PHITMP(I)-DQ(I)).GT.TOL) ITSTOP=1
      PHITMP(I)=DQ(I)
442   CONTINUE
      IF (ITSTOP.EQ.0.AND.ITER.GT.1) GO TO 452
450   CONTINUE
      IF (ITMAX.GT.1) WRITE (6,32) ITS
452   IF (ITSTOP.EQ.0) WRITE (6,43) ITS,ITER
      DO 460 I=1,NUMNP
      NPS=ISW(I)
      PHI(I)=DQ(I)
      IF (NPS.EQ.0) GO TO 460
      H(NPS)=HTMP(NPS)
460   CONTINUE
C
C     WRITE STATEMENTS
C
      TIME=TIME+DTIME
      INCR=INCR+1
      IF (ITS.EQ.NTS) INCR=INCPR
      IF (INCR.LT.INCPR) GO TO 520
      INCR=0
      DAYS=TIME/86400.0
      WRITE (6,25) TIME,DAYS
      DO 510 I=1,NUMNP
      NPS=ISW(I)
      DDOWN=STRT(I)-PHI(I)
      IF (NPS.GT.0) GO TO 505
      WRITE (6,26) I,XORD(I),YORD(I),PHI(I),DDOWN
      GO TO 510
505   WRITE (6,26) I,XORD(I),YORD(I),PHI(I),DDOWN,H(NPS),QS(NPS)
510   CONTINUE
      IF (NFLD.LE.0) GO TO 520
      WRITE (6,29)
      WRITE (6,30) (I,QPUMP(I),QFLD(I),I=1,NFLD)
C
520   CONTINUE
      IF (ITS.LT.NTS) GO TO 250
      IF (IPLT.GT.0) CALL TOPO (NP,STRT,PHI,XORD,YORD,CONINT,SCALE,
     $                          NUMNP,NUMEL,IDIM,KDIM,IPLT,DAYS)
      IF (IPP.LT.NUMPP) GO TO 130
      IF (IPUNCH.EQ.0) STOP
      OPEN (UNIT=7,FILE='PUNFILE')
      WRITE (7,4) (I,ISW(I),NPBC(I),XORD(I),YORD(I),PHI(I),Q(I),GRND(I)
     $             ,I=1,NUMNP)
```

```
      WRITE (7,10) (I,H(I),QS(I),YBED(I),I=1,NUMSN)
      STOP
C
C     ERROR MESSAGES
C
7001  WRITE (6,27) I,J,DETJ
C
999   STOP
      END
C
      SUBROUTINE SHAFAC (SF,WT,NUMQPT)
C
C     SHAPE FACTOR SF (FUNCTION, NODAL POINT,QUADRATURE POINT)
C
      DIMENSION
     $         SF(5,3,1),WT(2,1),NUMQPT(2)
C
C     VOLUME QUADRATURE
C
120   WT(1,1)=0.5
      NUMQPT(1)=1
      SF(1,1,1)=1.0/3.0
      SF(1,2,1)=1.0/3.0
      SF(1,3,1)=1.0-SF(1,1,1)-SF(1,2,1)
      SF(2,1,1)=-1.0
      SF(2,2,1)=+1.0
      SF(2,3,1)=0.0
      SF(3,1,1)=-1.0
      SF(3,2,1)=0.0
      SF(3,3,1)=+1.0
C
500   NUMQPT(2)=1
      WT(2,1)=1.0
      SF(4,1,1)=0.5
      SF(5,1,1)=-1.0
      SF(4,2,1)=0.5
      SF(5,2,1)=1.0
C
      RETURN
C
      END
C
      SUBROUTINE UDU(LU,NUMEQ,IB)
C
C     AN LDU DECOMPOSITION FOR BANDED SYMETRIC MATRICES
C
      COMMON /LDUBLK/ SK(320,35),DQ(320)
      REAL*8 SK,DQ,FAC
C
      NEM1=NUMEQ-1
      DO 450 I=1,NEM1
      JEND=NUMEQ-I+1
      IF(JEND.GT.IB) JEND=IB
```

```
C
      DO 440 J=2,JEND
      J1=I+J-1
      IF(LU.EQ.0) GO TO 435
C
      FAC=SK(I,J)/SK(I,1)
C
429   K1=0
      DO 430 K=J,JEND
C
      K1=K1+1
      SK(J1,K1)=SK(J1,K1)-SK(I,K)*FAC
  430 CONTINUE
      SK(I,J)=FAC
C
  435 CONTINUE
      DQ(J1)=DQ(J1)-DQ(I)*SK(I,J)
  440 CONTINUE
  450 CONTINUE
C
C     BACK SUBSTITUTION
C
      DQ(NUMEQ)=DQ(NUMEQ)/SK(NUMEQ,1)
C
      DO 470 I=1,NEM1
      I1=NUMEQ-I
      DQ(I1)=DQ(I1)/SK(I1,1)
      JEND=NUMEQ-I1+1
      IF(JEND.GT.IB) JEND=IB
      DO 460 J=2,JEND
      J1=I1+J-1
      DQ(I1)=DQ(I1)-SK(I1,J)*DQ(J1)
  460 CONTINUE
  470 CONTINUE
C
      RETURN
      END
C
      SUBROUTINE TOPO (NP,STRT,PHI,XORD,YORD,CONINT,SCALE,NUMNP,
     $                  NUMEL,IDIM,KDIM,IPLT,DAYS)
C
C     MAP PLOT FOR ZETA 8 PLOTTER
C
      DIMENSION NP(KDIM,3),XORD(IDIM),YORD(IDIM),PHI(IDIM),
     $          STRT(IDIM),X(2),Y(2),IROT(4)
      DATA IROT /1,2,3,1/
C
      OPEN (UNIT=9,FILE='PLTFILE')
      CALL PLOTS (53,0,-9)
C
      XMIN=XORD(1)
      XMAX=XMIN
      YMIN=YORD(1)
```

Table 1.--*Program listing*--Continued

```
      YMAX=YMIN
      DO 210 J=2,NUMNP
      IF (XORD(J).LT.XMIN) XMIN=XORD(J)
      IF (XORD(J).GT.XMAX) XMAX=XORD(J)
      IF (YORD(J).LT.YMIN) YMIN=YORD(J)
      IF (YORD(J).GT.YMAX) YMAX=YORD(J)
210   CONTINUE
      XMIN=XMIN/SCALE
      XMAX=XMAX/SCALE-XMIN
      YMIN=YMIN/SCALE
      YMAX=YMAX/SCALE-YMIN
      YMAX=YMAX-0.5
      CALL NUMBER (XMAX,YMAX,0.40,DAYS,0.0,1)
C
      DO 300 I=1,NUMEL
      TMP=0.0
      IF (IPLT.EQ.2) TMP=STRT(NP(I,1))
      J1=NP(I,1)
      PMIN=PHI(J1)-TMP
      PMAX=PMIN
      DO 220 J=2,3
      TMP=0.0
      J1=NP(I,J)
      IF (IPLT.EQ.2) TMP=STRT(J1)
      IF (PMAX.LT.PHI(J1)-TMP) PMAX=PHI(J1)-TMP
      IF (PMIN.GT.PHI(J1)-TMP) PMIN=PHI(J1)-TMP
220   CONTINUE
      IF (IPLT.EQ.2) PMAX=-PMAX
      IF (IPLT.EQ.2) PMIN=-PMIN
      CHK=(PMAX-PMIN)/CONINT
      IF (CHK.GT.10.0) GO TO 7001
      INT=PMIN/CONINT
      C=INT*CONINT
240   CONTINUE
      J3=0
      DO 280 K=1,3
      J1=IROT(K)
      J2=IROT(K+1)
      J1=NP(I,J1)
      J2=NP(I,J2)
      PHI1=PHI(J1)
      PHI2=PHI(J2)
      IF (IPLT.EQ.2) PHI1=STRT(J1)-PHI1
      IF (IPLT.EQ.2) PHI2=STRT(J2)-PHI2
      SLOPE=PHI2-PHI1
      IF (SLOPE.EQ.0.0) GO TO 270
      PT=(C-PHI1)/SLOPE
      IF (PT.LT.0.0.OR.PT.GT.1.0) GO TO 280
      J3=J3+1
      X(J3)=XORD(J1)+PT*(XORD(J2)-XORD(J1))
      Y(J3)=YORD(J1)+PT*(YORD(J2)-YORD(J1))
      IF (J3.EQ.2) GO TO 281
      GO TO 280
```

Table 1.--*Program listing*--Continued

```
270    CONTINUE
       IF (PHI1.NE.C) GO TO 280
       X(1)=XORD(J1)
       Y(1)=YORD(J1)
       X(2)=XORD(J2)
       Y(2)=YORD(J2)
       J3=2
       GO TO 281
280    CONTINUE
281    CONTINUE
C
       IF (J3.NE.2) GO TO 285
       X1=X(1)/SCALE-XMIN
       X2=X(2)/SCALE-XMIN
       Y1=Y(1)/SCALE-YMIN
       Y2=Y(2)/SCALE-YMIN
       CALL PLOT (X1,Y1,+3)
       CALL PLOT (X2,Y2,+2)
C
285    CONTINUE
       C=C+CONINT
       IF (C.LE.PMAX) GO TO 240
300    CONTINUE
C
       CALL PLOT (XMAX,YMIN,999)
       RETURN
7001   WRITE (6,1) I
       GO TO 300
1      FORMAT ('0 TOO MANY CONTOURS IN ELEMENT ',I5)
       END
```

Table 2.--*Data-input formats*

Group 1: Title and problem setup.

Card	Columns	Format	Variable	Definition
1,2,3	1-80	20A4	TITLE	A three line problem title.
4	1-5	I5	NUMEL	Number of aquifer elements.
	6-10	I5	NUMNP	Number of aquifer nodes.
	11-15	I5	NSWELM	Number of stream elements.
	16-20	I5	NUMSN	Number of stream nodes.
	21-25	I5	NUMAT	Number of aquifer-element zones.
	26-30	I5	NUMCHN	Number of stream-element zones.
	31-35	I5	NJUNC	Number of stream-channel junctions.
	36-40	I5	NFLD	Number of fields irrigated by stream diversions.
	41-45	I5	NUMPP	Total number of pumping periods.
	46-50	I5	ITMAX	Maximum number of iterations permitted for each time step.
	51-55	I5	IPUNCH	Code 1 to punch results at the end of a simulation. Data are punched in the format of input groups 2 and 5. Code -1 to continue a simulation using data punched from a previous run.
5	1-10	F10.0	THETA	A value greater than 0.0 but less than or equal to 1.0. THETA indicates the point during a time step where the finite-element integration is performed. For steady-state problems, code 1.0. For transient problems, coding 1.0 is equivalent to using an implicit-solution method while 0.5 is equivalent to a Crank-Nicolson method.
	11-20	F10.0	ETDEEP	Effective depth of evapotranspiration, in feet.

Group 2: Aquifer nodes. Code one card for each aquifer node.

Card	Columns	Format	Variable	Definition
--	1-5	I5	I	Aquifer-node number.
	6-10	I5	ISW(I)	Stream-node number. Code 0 if not a stream.
	11-15	I5	NPBC(I)	Nodal boundary condition. Code -1 to simulate a known hydraulic head of the aquifer.
	16-25	F10.0	XORD(I)	X coordinate (feet).
	26-35	F10.0	YORD(I)	Y coordinate (feet).
	36-45	F10.0	PHI(I)	Initial hydraulic head in the aquifer (feet).
	46-55	F10.0	Q(I)	Point recharge (+) or discharge (-) in the aquifer (cubic feet per second).
	56-65	F10.0	GRND(I)	Land-surface altitude (feet).

Table 2.--*Data-input formats*--Continued

Group 3: Aquifer elements. Code one card for each aquifer element.

Card	Columns	Format	Variable	Definition
--	1-5	I5	I	Aquifer-element number.
	6-10	I5	IDFLD(I)	Identification number for field irrigated by stream diversion. If the element is not part of an irrigated field, code 0.
	11-40	6I5	NP(I,J), J=1,3	Aquifer nodes associated with element I. Code nodes in a counterclockwise direction, when viewed from above, beginning with any node.

Group 4: Aquifer properties. Code one card for each aquifer element.

Card	Columns	Format	Variable	Definition
--	1-5	I5	I	Aquifer-element number.
	6-10	I5	MAT(I)	Aquifer-zone number.
	11-20	F10.0	TRAN(I)	Transmissivity (feet squared per second).
	21-30	F10.0	STOR(I)	Storage coefficient (dimensionless).
	31-40	F10.0	QRE(I)	Distributed recharge (+) or discharge (-) for the aquifer (feet per second).

Group 5: Stream nodes. Code one card for each stream node.

Card	Columns	Format	Variable	Definition
--	1-5	I5	I	Stream-node number.
	6-15	F10.0	H(I)	Initial depth of water (feet).
	16-25	F10.0	UI(I)	Initial stream velocity (feet per second) if IPUNCH was coded as 0 or 1 (input group 1). Stream discharge (cubic feet per second) if IPUNCH was coded as -1.
	26-35	F10.0	YBED(I)	Altitude of the stream channel (feet).

Note: Stream nodes must be numbered so that water will flow from nodes with small numbers to nodes with larger numbers. One way to ensure correct stream-node numbering is to number stream nodes in downstream order, a procedure similar to that used in numbering stream gages. After all stream nodes are numbered, diversion-canal nodes can be numbered from headgates to irrigation fields.

Table 2.--*Data-input formats*--Continued

Group 6: Stream-junction nodes.

Card	Columns	Format	Variable	Definition
--	1-80	16I5	ICJUN(I), I=1, NJUNC	Stream nodes that represent channel junctions. Junctions can occur where a tributary flows into a main channel or where a main channel splits. If the stream splits into two channels, code ICJUN as the node number * -1. Code junctions in downstream order.

Group 7: Stream elements. Code one card for each stream element.

Card	Columns	Format	Variable	Definition
--	1-5	I5	I	Stream-element number.
	6-10	I5	ISWARR (I,1)	Aquifer-element corresponding to stream element I.
	11-15	I5	ISWARR (I,2)	Aquifer-node number corresponding to stream element I.
	16-20	I5	ISWARR (I,3)	Second aquifer-node number corresponding to stream element I.
	21-25	I5	IDSTM(I)	Stream-zone number.
	26-35	F10.0	SLOPE(I)	Slope of the stream channel (feet per foot).
	36-45	F10.0	TOP(I)	Width of the stream channel (feet).
	46-55	F10.0	RMAN(I)	Manning's coefficient of roughness (dimensionless).
	56-65	F10.0	RLEAK(I)	Vertical hydraulic conductivity of the streambed (feet per second).

Note: Aquifer nodes coded as ISWARR(I,2) and ISWARR(I,3) must be coded in the counterclockwise order given in group 3.

Group 8: Aquifer zone. Code one card for each aquifer zone.

Card	Columns	Format	Variable	Definition
--	1-5	I5	I	Aquifer-zone number.
	6-15	F10.3	RX(I)	Multipliation factor for transmissivity in the X direction.
	16-25	F10.3	RY(I)	Multiplication factor for transmissivity in the Y direction.
	26-35	F10.3	RC(I)	Multiplication factor for storage coefficient.
	36-45	F10.3	QXY(I)	Multiplication factor for distributed recharge or discharge.

Table 2.--*Data-input formats*--Continued

Group 9: Stream zone. Code one card for each stream zone.

Card	Columns	Format	Variable	Definition
--	1-5	I5	I	Stream-zone number.
	6-15	F10.0	SLP(I)	Multiplication factor for channel slope.
	16-25	F10.0	TP(I)	Multiplication factor for channel width.
	26-35	F10.0	RM(I)	Multiplication factor for Manning's coefficient of roughness.
	36-45	F10.0	RS(I)	Multilplication factor for streambed hydraulic conductivity.
	46-55	F10.0	THICK(I)	Thickness of the streambed (feet).

Note: The remaining card groups are coded once for each pumping period.

Group 10: Pumping-period information.

Card	Columns	Format	Variable	Definition
1	1-5	I5	NTS	Number of time steps in the pumping period.
	6-15	F10.0	TIMAX	Maximum length of pumping period (seconds).
	16-25	F10.0	DTIME	Initial time step (seconds).
	26-35	F10.0	DELTA	Multiplication factor for each successive time step.
	36-40	I5	NN	Number of aquifer nodes where boundary conditions change from the previous pumping period.
	41-45	I5	NDIV	Number of stream diversions active this pumping period.
	46-50	I5	INCPR	Number of time steps between printouts. Results of the last time step are always printed.
	51-55	I5	IPLT	Code 1 to plot hydraulic head in the aquifer. Code 2 to plot drawdown. Code 0 for no plot.
	56-65	F10.0	SCALE	Map scale for plot, given as map units (feet) per plotter inch.
	66-75	F10.0	CONINT	Contour interval (feet) for plot.

Note: To simulate a given number of time steps, set TIMAX to a value larger than the expected simulation period. The program will use DTIME, DELTA, and NTS as coded. To simulate a given pumping period, set NTS larger than the number required for the simulation period. The program will compute the exact DTIME (which will be less than or equal to DTIME coded) and NTS to arrive exactly at TIMAX on the last time step.

Table 2.--*Data-input formats*--Continued

Group 10: Pumping-period information.--Continued

Card	Columns	Format	Variable	Definition
2	1-10	F10.0	ETMAX	Maximum rate of evapotranspiration (feet per second) from the water table.

Group 11: New boundary conditions. Code one card for each node where boundary conditions change.

Card	Columns	Format	Variable	Definition
--	1-5	I5	I	Aquifer-node number.
	6-10	I5	NPBC(I)	New boundary condition. Code -1 if the hydraulic head in the aquifer is known, otherwise code 0.
	11-20	F10.0	Q(I)	New point recharge (+) or discharge (-). If a well was used in the previous pumping period but not the current one, it must be turned off by coding 0.0.
	21-30	F10.0	PHI(I)	New hydraulic head in the aquifer (feet). This value is ignored unless NPBC(I) is -1.
	31-40	F10.0	QS(I)	New stream discharge (cubic feet per second). If a stream flows in the previous pumping period but not the current one, code 0.0. If no stream node is defined for aquifer node I, this value is ignored.

Group 12: Active stream zones.

Card	Columns	Format	Variable	Definition
--	1-80	16I5	IDACT(I), I=1, NUMCHN	Code 1 if stream zone I is considered to be active during the pumping period. Twenty stream zones are coded per card. If more than 16 zones are defined, a second card is coded.

Table 2:--*Data-input formats*--Continued

Group 13: Stream diversions. Code one card for each diversion.

Card	Columns	Format	Variable	Definition
--	1-5	I5	I	Diversion number.
	6-10	I5	IHEAD(I)	Aquifer-node number of first node on the diversion channel.
	11-15	I5	ISNDN(I)	Aquifer-node number on main channel immediately downstream from the diversion.
	16-25	F10.0	QADJ(I)	Maximum diversion rate permitted (cubic feet per second).
	26-35	F10.0	QMIN(I)	Minimum streamflow (cubic feet per second) that must pass stream node ISMIN(I) (diversion headgate) before diversion of water can begin.
	36-40	I5	ISMIN(I)	See the definition of QMIN(I).

Group 14: Irrigated fields. Code one card for each field.

Card	Columns	Format	Variable	Definition
--	1-5	I5	I	Irrigated-field number.
	6-10	I5	IFLDAC(I)	Code 1 if the field is considered to be active during the pumping period.
	11-15	I5	IDIVND(I)	Aquifer-node number at the downstream end of the diversion channel. Stream discharge at this node supplies the irrigated field with water.
	16-25	F10.0	CURATE(I)	Consumptive-use requirement of the field (feet per second).
	26-30	I5	NSPFLD(I)	Number of wells considered as supplying supplemental water for the field.

Group 15: Supplemental wells. Code one card for each well considered as a supplemental water right.

Card	Columns	Format	Variable	Definition
--	1-5	I5	I	Number of the irrigated field associated with this well.
	5-10	I5	J	Sequence number for wells associated with field I.
	11-15	I5	NODSUP(I)	Aquifer node where supplemental pumping occurs.
	16-25	F10.0	PERSUP(I,J)	Percent of the total irrigated field that is irrigated by supplemental pumping, expressed as a decimal fraction.

Table 3.--*Input data for kinematic simulation of the Bear River valley*

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NORTHERN BEAR RIVER STREAM-AQUIFER SYSTEM, WYOMING

TRANSIENT SIMULATION FROM FEBRUARY 1980 THROUGH FEBRUARY 1982
INPUT DATA FOR FEBRUARY 1980 THROUGH JUNE 1980
  535  318   87   91    9    9    9   12    5   30   -1
       0.5       10.0
    1    0   -1      0.00  36221.00  6203.00     0.00  9999.00
    2    0    0   2750.00  35680.00  6202.23     0.00  9999.00
    3    0    0   5630.00  41423.00  6202.08     0.00  6217.00
    4    0   -1   2728.00  42545.00  6203.00     0.00  6217.00
    5    0    0   5282.00  35141.00  6201.39     0.00  9999.00
    6    0    0   8263.00  40460.00  6201.23     0.00  6210.00
    7    2    0   6584.00  42844.00  6201.98     0.00  6210.00
    8    1   -1   3581.00  44442.00  6203.00     0.00  6212.00
    9   71   -1   4010.00  45707.00  6203.00     0.00  6215.00
   10    0    0   6608.00  48230.00  6202.72     0.00  9999.00
   11    3    0   6960.00  32810.00  6200.72     0.00  9999.00
   12    0    0   9400.00  35280.00  6200.28     0.00  9999.00
   13    0    0  13466.00  35157.00  6199.05     0.00  9999.00
   14    4    0   8459.00  37291.00  6200.78     0.00  6225.00
   15    0    0  10739.00  39288.00  6200.36     0.00  6210.00
   16    5    0   9691.00  41087.00  6200.91     0.00  6210.00
   17   72    0   9023.00  45156.00  6201.66     0.00  6215.00
   18    0    0  11674.00  47467.00  6201.62     0.00  9999.00
   19    0   -1   6998.00  52610.00  6203.00     0.00  9999.00
   20    0    0  13295.00  32412.00  6198.87     0.00  9999.00
   21    0    0  16735.00  34244.00  6197.85     0.00  6205.00
   22    0    0  15370.00  35940.00  6198.51     0.00  6208.00
   23   74    0  13477.00  37638.00  6199.32     0.00  6210.00
   24    6    0  13327.00  39487.00  6199.59     0.00  6205.00
   25   73    0  11023.00  43669.00  6200.93     0.00  6212.00
   26    0    0  16042.00  44385.00  6199.31     0.00  9999.00
   27    0    0  15114.00  49353.00  6201.87     0.10  9999.00
   28    0    0  18038.00  30384.00  6196.84     0.00  6205.00
   29    9    0  19518.00  30905.00  6196.43     0.00  6200.00
   30    8    0  20376.00  33700.00  6196.57     0.00  6200.00
   31    7    0  16378.00  36991.00  6198.30     0.00  6202.00
   32    0    0  16767.00  41204.00  6198.78     0.00  6208.00
   33    0    0  19837.00  42942.00  6198.24     0.00  9999.00
   34    0    0  23600.00  46040.00  6197.76     0.00  9999.00
   35    0    0  25730.00  26864.00  6194.95     0.00  6200.00
   36    0    0  23781.00  27876.00  6194.78     0.00  6200.00
   37   10    0  23416.00  28934.00  6195.00     0.00  6199.00
   38    0    0  22373.00  31790.00  6195.71     0.00  6200.00
   39    0    0  21434.00  34223.00  6196.35     0.00  6201.00
   40    0    0  20024.00  37661.00  6197.34     0.00  6205.00
   41    0    0  23202.00  39864.00  6196.84     0.00  9999.00
   42    0    0  26647.00  42700.00  6196.54     0.00  9999.00
   43    0   -1  25493.00  21004.00  6218.00     0.00  9999.00
   44   79   -1  25028.00  23382.00  6218.00     0.00  9999.00
   45   80    0  26355.00  24907.00  6195.69     0.00  9999.00
   46   76    0  27842.00  26802.00  6192.85     0.00  6200.00
```

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

47	12	0	27586.00	28704.00	6193.37	0.00	6198.00
48	11	0	25581.00	28818.00	6194.31	0.00	6198.00
49	0	0	25010.00	30933.00	6194.77	0.00	6199.00
50	0	0	24466.00	35200.00	6195.58	0.00	9999.00
51	0	0	26011.00	37938.00	6195.49	0.00	9999.00
52	0	0	29820.00	39397.00	6194.95	0.10	9999.00
53	0	-1	26534.00	16076.00	6218.00	0.00	9999.00
54	0	0	27723.00	21403.00	6208.21	0.00	9999.00
55	0	0	27688.00	24940.00	6196.20	0.00	9999.00
56	77	0	30596.00	25665.00	6191.62	0.00	6200.00
57	13	0	31086.00	28566.00	6191.93	0.00	6196.00
58	0	0	31514.00	29831.00	6192.05	0.00	6198.00
59	75	0	27248.00	31965.00	6194.19	0.00	6199.00
60	0	0	30114.00	34749.00	6193.97	0.00	6203.00
61	0	0	33282.00	34786.00	6193.84	0.00	9999.00
62	0	0	33357.00	39115.00	6195.77	0.00	9999.00
63	0	0	29064.00	15218.00	6207.70	0.00	9999.00
64	0	0	30571.00	20754.00	6200.97	0.00	9999.00
65	0	0	34051.00	19892.00	6194.50	0.00	9999.00
66	78	0	35021.00	23742.00	6189.35	0.00	6198.00
67	14	0	35717.00	25692.00	6189.43	0.00	6194.00
68	0	0	36464.00	27061.00	6189.46	0.00	6194.00
69	0	0	37744.00	29694.00	6189.59	0.00	6198.00
70	0	0	33271.00	32727.00	6192.01	0.00	6199.00
71	0	0	37080.00	34080.00	6194.59	0.00	9999.00
72	0	0	36206.00	38837.00	6198.39	0.00	9999.00
73	0	0	32491.00	14198.00	6198.65	0.00	9999.00
74	0	0	37839.00	17075.00	6189.76	0.00	9999.00
75	0	0	39183.00	21873.00	6186.98	0.00	6193.00
76	81	0	40459.00	23661.00	6186.94	0.00	6193.00
77	0	0	41258.00	24925.00	6186.95	0.00	6193.00
78	15	0	42322.00	26556.00	6186.92	0.00	6192.00
79	0	0	39018.00	31008.00	6189.43	0.00	6200.00
80	0	0	41818.00	31311.00	6192.42	0.00	9999.00
81	0	0	41035.00	33163.00	6195.91	0.00	9999.00
82	0	0	39267.00	38504.00	6205.13	0.10	9999.00
83	0	0	38083.00	13113.00	6188.96	0.00	9999.00
84	0	0	38934.00	14323.00	6188.10	0.00	9999.00
85	0	0	42220.00	16894.00	6184.32	0.00	9999.00
86	0	0	41808.00	18955.00	6185.00	0.00	6190.00
87	0	0	43728.00	22694.00	6185.43	0.00	6190.00
88	0	0	44157.00	24065.00	6185.59	0.00	6191.00
89	16	0	44796.00	25065.00	6185.57	0.00	6195.00
90	0	0	44170.00	26547.00	6186.20	0.00	6197.00
91	0	0	44079.00	29504.00	6190.52	0.00	9999.00
92	0	0	43983.00	31405.00	6194.11	0.00	9999.00
93	0	0	43996.00	33940.00	6200.55	0.00	9999.00
94	0	4	44344.00	40010.00	6230.11	1.29	9999.00
95	0	0	42506.00	10715.00	6187.58	0.10	9999.00
96	0	0	42943.00	13564.00	6183.85	0.00	9999.00
97	0	0	45160.00	13606.00	6183.69	0.00	9999.00
98	0	0	44596.00	16776.00	6184.03	0.00	9999.00

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

99	0	0	44238.00	19101.00	6184.46	0.00	6190.00
100	0	0	46312.00	21995.00	6184.30	0.00	6190.00
101	17	0	47796.00	23096.00	6183.94	0.00	6190.00
102	0	0	50757.00	24032.00	6182.77	0.00	6190.00
103	0	0	50398.00	26145.00	6184.72	0.00	9999.00
104	0	0	49466.00	29688.00	6189.18	0.00	9999.00
105	0	0	49642.00	33277.00	6194.14	0.00	9999.00
106	0	0	49614.00	38082.00	6202.61	0.00	9999.00
107	0	0	45357.00	10700.00	6183.56	0.00	9999.00
108	0	0	47009.00	13596.00	6183.49	0.00	9999.00
109	0	0	47077.00	16658.00	6183.58	0.00	6192.00
110	0	0	46826.00	19299.00	6183.82	0.00	6189.00
111	0	0	51900.00	20330.00	6182.15	0.00	6186.00
112	18	0	52330.00	21806.00	6181.88	0.00	6188.00
113	82	0	53231.00	22435.00	6181.56	0.00	6190.00
114	0	0	54189.00	24067.00	6181.08	0.00	9999.00
115	0	0	55054.00	27970.00	6183.00	0.00	9999.00
116	0	0	56027.00	32506.00	6185.95	0.00	9999.00
117	0	0	54568.00	36209.00	6192.13	0.00	9999.00
118	0	0	48684.00	10842.00	6183.30	0.00	9999.00
119	0	0	49912.00	13423.00	6183.13	0.00	9999.00
120	0	0	51032.00	15688.00	6182.69	0.00	6193.00
121	0	0	51732.00	18324.00	6182.27	0.00	6186.00
122	19	0	54165.00	19157.00	6181.26	0.00	6185.00
123	83	0	56072.00	20467.00	6180.67	0.00	6190.00
124	0	0	56241.00	22473.00	6180.59	0.00	9999.00
125	0	0	57584.00	27060.00	6180.04	0.00	9999.00
126	0	0	59517.00	33439.00	6182.45	0.00	9999.00
127	0	0	53073.00	12140.00	6183.38	5.88	9999.00
128	0	0	52286.00	13094.00	6183.08	0.00	9999.00
129	0	0	53298.00	14832.00	6182.17	0.00	6192.00
130	0	0	53786.00	17363.00	6181.59	0.00	6187.00
131	20	0	56000.00	16560.00	6180.75	0.00	6184.00
132	0	0	56010.00	18461.00	6180.71	0.00	6186.00
133	0	0	58549.00	19609.00	6179.93	0.00	6188.00
134	0	0	58829.00	22618.00	6179.87	0.00	9999.00
135	0	0	61542.00	26723.00	6179.26	0.00	9999.00
136	0	0	63685.00	32784.00	6180.14	0.00	9999.00
137	0	0	53860.00	11027.00	6182.44	0.00	9999.00
138	0	0	55399.00	12656.00	6181.61	0.00	9999.00
139	0	0	55512.00	14187.00	6181.31	0.00	6188.00
140	21	0	58057.00	16233.00	6179.99	0.00	6183.00
141	0	0	58330.00	17921.00	6179.96	0.00	6183.00
142	0	0	62127.00	17110.00	6178.74	0.00	6181.00
143	0	0	61561.00	20070.00	6179.08	0.00	6190.00
144	0	0	62208.00	22654.00	6179.02	0.00	9999.00
145	0	0	64163.00	22855.00	6178.54	0.00	9999.00
146	0	0	65448.00	26333.00	6178.42	0.00	9999.00
147	0	0	68010.00	31970.00	6178.83	0.00	9999.00
148	0	0	58505.00	10792.00	6180.03	0.10	9999.00
149	0	0	58405.00	11954.00	6180.09	0.00	9999.00
150	0	0	58203.00	13698.00	6180.13	0.00	6186.00

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

151	22	0	62435.00	15261.00	6178.47	0.00	6181.00
152	0	0	65762.00	15455.00	6177.64	0.00	6180.00
153	0	0	66204.00	19254.00	6177.84	0.00	6190.00
154	0	0	68115.00	21251.00	6177.50	0.00	9999.00
155	0	0	68606.00	24522.00	6177.47	0.00	9999.00
156	0	0	71944.00	26670.00	6176.73	0.10	9999.00
157	0	0	62462.00	10192.00	6178.43	0.00	9999.00
158	0	0	62574.00	11458.00	6178.44	0.00	9999.00
159	0	0	62528.00	12937.00	6178.47	0.00	6183.00
160	23	0	65377.00	12500.00	6177.36	0.00	6180.00
161	24	0	68076.00	13542.00	6176.90	0.00	6178.00
162	0	0	68244.00	15548.00	6177.09	0.00	6179.00
163	0	0	68412.00	17501.00	6177.21	0.00	6183.00
164	0	0	70640.00	19443.00	6176.87	0.00	9999.00
165	0	0	71236.00	22555.00	6176.86	0.00	9999.00
166	0	0	75742.00	26017.00	6176.10	0.00	9999.00
167	0	0	65522.00	9648.00	6177.51	0.00	9999.00
168	0	0	65739.00	10808.00	6177.49	0.00	9999.00
169	0	0	67700.00	12277.00	6177.02	0.00	6180.00
170	25	0	71711.00	11993.00	6176.10	0.00	6178.00
171	0	0	71930.00	13576.00	6176.21	0.00	6177.00
172	0	0	72203.00	15370.00	6176.31	0.00	6178.00
173	0	0	72637.00	17532.00	6176.38	0.00	6183.00
174	0	0	74923.00	20636.00	6176.10	0.00	9999.00
175	0	0	78780.00	20986.00	6175.43	0.00	9999.00
176	0	0	79435.00	25418.00	6175.43	0.00	9999.00
177	0	0	67896.00	9319.00	6176.92	0.10	9999.00
178	0	0	67848.00	10375.00	6176.96	0.00	9999.00
179	0	0	71277.00	9672.00	6176.21	0.00	9999.00
180	0	0	76140.00	10650.00	6175.54	0.00	6177.00
181	26	0	75887.00	12869.00	6175.54	0.00	6175.00
182	0	0	75785.00	13715.00	6175.61	0.00	6175.00
183	0	0	75952.00	15245.00	6175.68	0.00	6178.00
184	0	0	76224.00	16933.00	6175.72	0.00	6183.00
185	0	0	79926.00	18182.00	6175.14	0.00	9999.00
186	0	0	83793.00	20485.00	6174.53	0.00	9999.00
187	0	0	84130.00	24655.00	6174.57	0.00	9999.00
188	0	0	71112.00	8405.00	6176.20	0.00	9999.00
189	0	0	75707.00	8593.00	6175.60	0.00	9999.00
190	0	0	80358.00	9573.00	6175.15	0.00	6176.00
191	0	0	79949.00	12268.00	6175.07	0.00	6174.00
192	27	0	79587.00	13695.00	6175.08	0.00	6174.00
193	0	0	79913.00	15542.00	6175.08	0.00	6180.00
194	0	0	84042.00	17686.00	6174.43	0.00	9999.00
195	0	0	87169.00	20046.00	6173.89	0.00	9999.00
196	0	0	87612.00	24109.00	6173.92	0.00	9999.00
197	0	0	75490.00	7538.00	6175.60	0.00	9999.00
198	0	0	80771.00	7776.00	6175.19	0.00	9999.00
199	0	0	83573.00	8448.00	6175.01	0.00	6178.00
200	0	0	84376.00	10609.00	6174.54	0.00	6173.00
201	28	0	84126.00	13356.00	6174.36	0.00	6173.00
202	0	0	84348.00	15519.00	6174.34	0.00	6180.00

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

203	0	0	86783.00	16616.00	6173.91	0.00	9999.00
204	0	0	89647.00	19189.00	6173.38	0.00	9999.00
205	0	0	90356.00	23620.00	6173.37	0.00	9999.00
206	0	0	81029.00	6402.00	6175.19	0.00	9999.00
207	0	0	83936.00	7021.00	6177.26	0.00	9999.00
208	0	0	87002.00	7850.00	6185.22	0.00	9999.00
209	0	0	87067.00	10226.00	6174.20	0.00	6172.00
210	29	0	85493.00	12029.00	6174.17	0.00	6172.00
211	0	0	86454.00	14242.00	6173.97	0.00	6178.00
212	0	0	88942.00	15602.00	6173.49	0.00	9999.00
213	0	0	92230.00	18436.00	6172.82	0.00	9999.00
214	0	0	92835.00	23185.00	6172.85	0.00	9999.00
215	0	0	84090.00	6122.00	6177.78	0.00	9999.00
216	0	0	87102.00	6582.00	6188.86	0.00	9999.00
217	32	0	89113.00	7522.00	6199.42	0.00	9999.00
218	33	0	89653.00	10001.00	6174.00	0.00	6171.00
219	30	0	87921.00	11964.00	6173.76	0.00	6171.00
220	0	0	88454.00	13017.00	6173.63	0.00	6171.00
221	0	0	90943.00	14536.00	6173.05	0.00	9999.00
222	0	0	93216.00	14999.00	6172.49	0.00	9999.00
223	0	0	95031.00	18792.00	6172.23	0.00	9999.00
224	0	0	94893.00	22858.00	6172.41	0.00	9999.00
225	31	0	89053.00	6203.00	6218.28	3.55	9999.00
226	0	0	92803.00	6342.00	6179.41	0.00	9999.00
227	0	0	92704.00	7715.00	6177.86	0.00	9999.00
228	0	0	93188.00	9508.00	6172.45	0.00	6171.00
229	35	0	93668.00	10350.00	6172.20	0.00	6170.00
230	34	0	90455.00	11845.00	6173.28	0.00	6170.00
231	0	0	93411.00	11830.00	6172.31	0.00	6170.00
232	39	0	96319.00	12555.00	6171.33	0.00	9999.00
233	0	0	95541.00	15252.00	6171.93	0.00	9999.00
234	0	0	98722.00	17876.00	6171.49	0.00	9999.00
235	0	0	97571.00	20046.00	6171.75	0.00	9999.00
236	0	0	97213.00	22318.00	6171.88	0.00	9999.00
237	0	0	96922.00	6585.00	6170.60	0.00	9999.00
238	36	0	97509.00	7691.00	6168.82	0.00	9999.00
239	37	0	98044.00	9061.00	6170.33	0.00	6183.00
240	38	0	98685.00	10536.00	6170.50	0.00	6180.00
241	0	0	99326.00	12064.00	6171.02	0.00	6175.00
242	43	0	98917.00	14601.00	6171.38	0.00	6168.00
243	44	0	100614.00	16176.00	6171.18	0.00	6167.00
244	45	0	102257.00	17382.00	6170.84	0.00	6166.00
245	0	0	101582.00	19551.00	6170.88	0.00	9999.00
246	0	0	100645.00	22301.00	6171.09	0.00	9999.00
247	0	0	101728.00	6667.00	6171.13	0.00	9999.00
248	85	0	102899.00	8509.00	6171.96	0.00	9999.00
249	0	0	103120.00	10567.00	6171.78	0.00	9999.00
250	42	0	102183.00	13106.00	6171.57	0.00	6180.00
251	0	0	103036.00	14844.00	6171.19	0.00	6180.00
252	0	0	103731.00	16530.00	6170.74	0.00	6173.00
253	46	0	105860.00	19899.00	6169.67	0.00	6164.00
254	0	0	105185.00	22067.00	6169.88	0.00	6170.00

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

255	84	0	106707.00	9757.00	6192.94	0.00	9999.00
256	41	0	104290.00	12198.00	6171.89	0.00	9999.00
257	0	0	105412.00	14726.00	6170.96	0.00	9999.00
258	0	0	106055.00	16571.00	6170.23	0.00	6170.00
259	50	0	108026.00	20046.00	6168.76	0.00	6163.00
260	0	0	107930.00	22000.00	6169.11	0.00	6170.00
261	40	0	109348.00	10113.00	6218.59	4.19	9999.00
262	0	0	108305.00	12547.00	6171.60	0.00	6198.00
263	48	0	107679.00	14081.00	6170.91	0.00	6190.00
264	49	0	107533.00	16617.00	6169.75	0.00	6180.00
265	52	0	108538.00	16928.00	6168.96	0.00	6180.00
266	53	0	109240.00	20093.00	6167.86	0.00	6162.00
267	87	0	111145.00	10368.00	6184.03	0.00	9999.00
268	47	0	109361.00	12594.00	6171.13	0.00	6200.00
269	51	0	109213.00	14760.00	6169.51	0.00	6190.00
270	0	0	110599.00	17287.00	6166.42	0.00	6175.00
271	54	0	110825.00	20138.00	6165.54	0.00	6161.00
272	88	0	114684.00	10561.00	6166.82	0.00	9999.00
273	86	0	111739.00	12952.00	6167.84	0.00	9999.00
274	0	0	112174.00	15537.00	6165.10	0.00	9999.00
275	0	0	113242.00	17908.00	6162.23	0.00	6165.00
276	55	0	112884.00	20180.00	6162.29	0.00	6160.00
277	0	0	117117.00	11446.00	6162.24	0.00	9999.00
278	0	0	115013.00	13041.00	6163.34	0.00	9999.00
279	58	0	115661.00	15836.00	6158.84	0.00	6163.00
280	57	0	116571.00	18419.00	6155.88	0.00	6150.00
281	56	0	115631.00	20377.00	6157.56	0.00	6162.00
282	59	0	119940.00	16290.00	6146.93	0.00	6140.00
283	60	0	120265.00	17872.00	6145.58	0.00	6135.00
284	0	0	118797.00	19992.00	6152.12	0.00	6140.00
285	0	0	125064.00	16897.00	6120.35	0.00	6130.00
286	61	0	124914.00	18377.00	6118.79	0.00	6130.00
287	0	0	123870.00	20811.00	6111.92	0.00	6120.00
288	0	0	123034.00	22663.00	6110.79	0.00	9999.00
289	89	0	127021.00	17521.00	6114.44	0.00	6130.00
290	62	0	126458.00	21062.00	6110.34	0.00	6117.00
291	0	0	125522.00	23865.00	6108.73	0.00	6115.00
292	0	0	130196.00	18772.00	6107.36	0.00	9999.00
293	0	0	129150.00	20890.00	6106.90	0.00	6120.00
294	63	0	127789.00	23220.00	6106.56	0.00	6110.00
295	0	0	127851.00	24962.00	6105.28	0.00	6110.00
296	0	0	134911.00	21917.00	6098.22	0.00	9999.00
297	64	0	130803.00	24102.00	6101.64	0.00	6105.00
298	65	0	130814.00	26161.00	6099.64	0.00	6100.00
299	0	0	139255.00	24851.00	6090.17	0.00	9999.00
300	0	0	137098.00	26341.00	6091.42	0.00	6090.00
301	66	0	135519.00	27405.00	6092.38	0.00	6090.00
302	90	0	133203.00	28842.00	6093.52	0.00	6095.00
303	0	0	141748.00	27162.00	6084.95	0.00	9999.00
304	0	0	140067.00	28755.00	6085.51	0.00	6088.00
305	67	0	137964.00	30613.00	6086.77	0.00	6085.00
306	0	0	136070.00	31943.00	6088.17	0.00	6090.00

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

307	0	0	144029.00	29157.00	6079.21	0.00	9999.00
308	0	0	142504.00	30379.00	6080.24	0.00	6083.00
309	68	0	141138.00	31653.00	6081.32	0.00	6080.00
310	91	0	140034.00	32662.00	6082.68	0.00	6080.00
311	0	0	145832.00	30732.00	6073.63	0.00	9999.00
312	0	0	145469.00	31896.00	6073.08	0.00	6080.00
313	69	0	144999.00	33059.00	6072.63	0.00	6075.00
314	0	0	143737.00	34069.00	6073.69	0.00	6075.00
315	0	-1	151811.00	33183.00	6061.00	0.00	9999.00
316	0	-1	150342.00	35039.00	6062.00	0.00	9999.00
317	70	-1	148874.00	37053.00	6063.00	0.00	6065.00
318	0	-1	147982.00	38113.00	6063.00	0.00	6070.00
1	0	1	2	3			
2	0	1	3	4			
3	0	2	5	3			
4	0	5	6	3			
5	0	3	6	7			
6	0	3	7	4			
7	0	4	7	8			
8	0	5	11	14			
9	0	11	12	14			
10	0	5	14	6			
11	0	14	15	16			
12	0	14	16	6			
13	0	6	16	7			
14	0	7	16	17			
15	0	7	17	8			
16	0	8	17	9			
17	0	9	17	10			
18	0	17	18	10			
19	0	10	18	19			
20	0	9	10	19			
21	0	11	20	12			
22	0	12	20	13			
23	2	20	21	13			
24	2	13	21	22			
25	0	13	22	23			
26	2	12	13	23			
27	2	12	23	14			
28	0	14	23	15			
29	0	15	23	24			
30	0	15	24	16			
31	0	16	24	25			
32	0	16	25	17			
33	0	17	25	18			
34	1	25	26	17			
35	1	18	26	27			
36	0	18	27	19			
37	0	20	28	21			
38	0	28	29	21			
39	0	29	30	21			
40	0	21	30	31			

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

41	0	21	31	22
42	0	22	31	23
43	0	23	31	24
44	0	24	31	32
45	0	24	32	25
46	1	25	32	26
47	1	32	33	26
48	0	26	33	34
49	0	26	34	27
50	0	28	36	37
51	0	28	37	29
52	0	29	37	38
53	0	29	38	30
54	0	30	38	39
55	0	30	39	40
56	0	30	40	31
57	0	31	40	32
58	1	32	40	33
59	1	40	41	33
60	0	33	41	34
61	0	41	42	34
62	3	45	46	35
63	0	35	45	48
64	0	48	46	47
65	0	36	35	48
66	0	36	48	37
67	0	37	48	49
68	0	37	49	38
69	1	38	49	50
70	0	38	50	39
71	0	39	50	40
72	0	40	50	41
73	0	50	51	41
74	0	41	51	42
75	0	51	52	42
76	0	43	53	54
77	0	43	54	44
78	0	44	54	45
79	3	45	54	55
80	3	45	55	46
81	3	46	55	56
82	0	46	56	57
83	0	46	57	47
84	0	47	57	58
85	4	47	58	59
86	0	48	47	59
87	0	48	59	49
88	1	49	59	50
89	1	50	59	60
90	1	50	60	51
91	0	51	60	52
92	0	60	62	52
93	0	60	61	62
94	0	53	63	54
95	0	54	63	64
96	3	54	64	55
97	3	55	64	56
98	3	64	66	56
99	3	64	65	66
100	0	56	66	67
101	0	56	67	57
102	0	57	67	68
103	0	57	68	58
104	4	58	68	69
105	4	58	69	70
106	4	58	70	59
107	0	59	70	60
108	0	60	70	61
109	0	70	71	61
110	0	61	71	72
111	0	61	72	62
112	0	63	73	64
113	0	73	65	64
114	0	73	74	65
115	5	65	74	75
116	5	65	75	66
117	0	66	75	76
118	0	66	76	67
119	0	67	76	77
120	0	67	77	78
121	0	67	78	68
122	4	68	78	69
123	0	69	78	79
124	0	69	79	70
125	0	70	79	71
126	0	71	79	81
127	0	79	80	81
128	0	71	81	82
129	0	71	82	72
130	0	73	83	84
131	0	73	84	74
132	0	74	84	85
133	5	74	85	86
134	5	74	86	75
135	0	75	86	76
136	0	76	86	87
137	6	76	87	77
138	6	77	87	88
139	0	77	88	78
140	0	78	88	89
141	0	78	89	90
142	0	78	90	79
143	4	79	90	91
144	4	79	91	80

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

145	0	80	91	92
146	0	80	92	93
147	0	80	93	81
148	0	81	93	82
149	0	82	93	94
150	0	83	95	84
151	0	84	95	96
152	0	84	96	85
153	8	96	98	85
154	8	96	97	98
155	5	85	98	99
156	5	85	99	86
157	0	86	99	87
158	0	99	100	87
159	6	87	100	88
160	6	88	100	101
161	0	88	101	89
162	0	89	101	102
163	0	89	102	90
164	0	90	102	103
165	0	90	103	91
166	0	91	103	104
167	0	91	104	92
168	0	92	104	105
169	0	92	105	93
170	0	93	105	106
171	0	93	106	94
172	0	95	107	96
173	0	96	107	97
174	0	107	108	97
175	8	97	108	98
176	8	108	109	98
177	5	98	109	110
178	5	98	110	99
179	0	99	110	100
180	6	110	111	100
181	6	100	111	112
182	6	100	111	101
183	0	101	112	102
184	0	102	112	113
185	0	102	113	114
186	0	102	114	103
187	0	103	114	115
188	0	103	115	104
189	0	104	115	116
190	0	104	116	105
191	0	105	116	117
192	0	105	117	106
193	0	107	118	108
194	0	118	119	108
195	0	108	119	109
196	0	109	119	120
197	0	109	120	121
198	0	109	121	110
199	0	110	121	111
200	6	121	122	111
201	6	111	122	112
202	0	112	122	113
203	0	122	123	113
204	0	113	123	124
205	0	113	124	114
206	0	114	124	125
207	0	114	125	115
208	0	115	125	116
209	0	125	126	116
210	0	118	127	128
211	0	118	128	119
212	0	119	128	120
213	8	120	128	129
214	0	120	129	130
215	0	120	130	121
216	6	121	130	122
217	6	130	131	122
218	0	122	131	132
219	0	122	132	123
220	7	132	133	123
221	7	123	133	134
222	7	123	134	124
223	0	124	134	125
224	0	125	134	135
225	0	125	135	126
226	0	135	136	126
227	8	127	137	138
228	8	127	138	128
229	8	128	138	129
230	8	129	138	139
231	0	129	139	131
232	0	129	131	130
233	0	139	140	131
234	0	131	140	132
235	7	140	141	132
236	7	132	141	133
237	7	141	142	133
238	7	133	142	143
239	7	133	143	134
240	7	134	143	144
241	0	134	144	135
242	0	144	145	135
243	0	135	145	146
244	0	135	146	136
245	0	146	147	136
246	8	137	148	138
247	8	138	148	149
248	8	138	149	150

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

249	8	138	150	139
250	0	139	150	140
251	0	150	151	140
252	7	140	151	142
253	7	140	142	141
254	7	151	152	142
255	7	142	152	153
256	7	142	153	143
257	0	143	153	144
258	0	144	153	145
259	0	145	153	154
260	0	145	154	155
261	0	145	155	146
262	0	146	155	147
263	0	155	156	147
264	0	148	157	158
265	0	148	158	149
266	8	149	158	159
267	8	149	159	150
268	0	150	159	151
269	0	159	160	151
270	7	160	152	151
271	7	160	161	152
272	7	152	161	162
273	7	152	162	163
274	7	152	163	153
275	0	153	163	154
276	0	154	163	164
277	0	154	164	165
278	0	154	165	155
279	0	155	165	156
280	0	165	166	156
281	0	157	167	168
282	0	157	168	158
283	8	158	168	169
284	8	158	169	159
285	8	168	169	160
286	0	160	169	161
287	0	169	170	161
288	0	161	170	171
289	7	161	171	162
290	7	162	171	172
291	7	162	172	173
292	7	162	173	163
293	0	163	173	164
294	0	164	173	174
295	0	164	174	165
296	0	165	174	166
297	0	174	175	166
298	0	175	176	166
299	0	167	177	178
300	0	167	178	168
301	8	168	178	169
302	8	178	170	169
303	8	178	179	170
304	8	179	180	170
305	0	170	180	181
306	0	170	181	171
307	0	171	181	182
308	7	171	182	172
309	7	172	182	183
310	7	172	183	173
311	7	173	183	184
312	0	173	184	174
313	0	174	184	185
314	0	174	185	175
315	0	175	185	186
316	0	175	186	187
317	0	175	187	176
318	0	177	188	179
319	0	177	179	178
320	0	188	189	179
321	8	179	189	180
322	8	189	190	180
323	0	180	190	191
324	0	180	191	181
325	0	181	191	192
326	0	181	192	182
327	7	182	192	183
328	7	183	192	193
329	7	183	193	184
330	0	184	193	185
331	0	193	194	185
332	0	185	194	186
333	0	194	195	186
334	0	186	195	196
335	0	186	196	187
336	0	188	197	189
337	0	197	198	189
338	8	189	198	190
339	8	198	199	190
340	0	190	199	200
341	0	190	200	191
342	0	191	200	201
343	0	191	201	192
344	7	192	201	202
345	7	192	202	193
346	0	193	202	194
347	0	202	203	194
348	0	194	203	195
349	0	203	204	195
350	0	195	204	205
351	0	195	205	196
352	0	197	206	198

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

353	0	206	207	198
354	8	198	207	199
355	8	207	208	199
356	8	199	208	209
357	8	199	209	200
358	0	200	209	210
359	0	200	210	201
360	7	201	210	211
361	7	201	211	202
362	0	202	211	203
363	0	211	212	203
364	0	203	212	204
365	0	212	213	204
366	0	204	213	214
367	0	204	214	205
368	0	206	215	207
369	0	215	216	207
370	0	207	216	208
371	0	216	217	208
372	8	217	218	208
373	8	208	218	209
374	0	209	218	219
375	0	209	219	210
376	7	210	219	211
377	7	219	220	211
378	0	211	220	212
379	0	220	221	212
380	0	212	221	213
381	0	221	222	213
382	0	222	223	213
383	0	213	223	214
384	0	223	224	214
385	0	216	225	217
386	8	225	226	217
387	8	226	227	217
388	8	217	227	218
389	8	218	227	228
390	0	218	228	229
391	0	218	229	230
392	0	218	230	219
393	0	219	230	220
394	0	220	230	221
395	0	230	231	221
396	0	231	222	221
397	0	231	232	222
398	0	232	233	222
399	0	222	233	223
400	0	233	234	223
401	0	223	234	235
402	0	223	235	224
403	0	235	236	224
404	8	226	237	227
405	8	237	238	227
406	8	227	238	228
407	8	238	239	228
408	0	228	239	229
409	0	229	239	240
410	0	229	240	232
411	0	229	232	231
412	0	229	231	230
413	0	240	241	232
414	0	232	241	242
415	0	232	242	233
416	0	233	242	234
417	0	242	243	234
418	0	243	244	234
419	0	234	244	245
420	0	234	245	235
421	0	235	245	246
422	0	235	246	236
423	8	247	248	238
424	8	238	248	239
425	8	239	248	249
426	8	239	249	240
427	9	240	249	241
428	9	241	249	250
429	0	241	250	242
430	0	242	250	251
431	0	242	251	243
432	0	243	251	252
433	0	243	252	244
434	9	244	252	253
435	0	244	253	245
436	0	245	253	254
437	0	245	254	246
438	8	248	255	249
439	8	249	255	256
440	9	249	256	250
441	0	250	256	251
442	0	256	257	251
443	9	251	257	252
444	9	257	258	252
445	9	252	258	253
446	9	258	259	253
447	0	253	259	260
448	0	253	260	254
449	8	255	261	256
450	0	256	261	262
451	0	256	262	263
452	0	256	263	257
453	0	257	263	258
454	0	263	264	258
455	9	258	264	259
456	0	264	265	259

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

457	0	265	266	259
458	0	259	266	260
459	10	261	267	268
460	0	261	268	262
461	0	262	268	263
462	0	268	269	263
463	0	263	269	264
464	0	269	265	264
465	0	269	270	265
466	0	265	270	266
467	0	270	271	266
468	10	267	272	273
469	10	267	273	268
470	10	268	273	269
471	10	273	274	269
472	9	269	274	270
473	9	270	274	275
474	9	270	275	271
475	9	271	275	276
476	10	272	277	278
477	10	272	278	273
478	10	273	278	279
479	10	273	279	274
480	9	274	279	275
481	9	275	279	280
482	9	275	280	281
483	9	275	281	276
484	10	277	282	278
485	10	278	282	279
486	0	279	282	280
487	0	280	282	283
488	0	280	283	284
489	0	280	284	281
490	0	282	285	283
491	0	283	285	286
492	0	285	289	286
493	0	286	289	290
494	0	286	290	287
495	0	287	290	291
496	0	287	291	288
497	0	289	292	293
498	11	289	293	290
499	11	290	293	294
500	0	290	294	291
501	0	291	294	295
502	0	292	296	293
503	0	293	296	297
504	11	293	297	294
505	0	294	297	295
506	0	295	297	298
507	11	296	299	300
508	11	296	300	297

509	0	297	300	301
510	0	297	301	298
511	0	298	301	302
512	0	299	303	304
513	0	299	304	300
514	0	300	304	301
515	0	301	304	305
516	12	301	305	306
517	12	301	306	302
518	0	303	307	308
519	0	303	308	304
520	0	304	308	309
521	0	304	309	305
522	0	305	309	310
523	0	305	310	306
524	0	307	311	308
525	0	308	311	312
526	0	308	312	309
527	0	309	312	313
528	0	309	313	314
529	0	309	314	310
530	0	311	315	316
531	0	311	316	312
532	11	312	316	313
533	0	313	316	317
534	0	313	317	318
535	0	313	318	314

1	8	1.0	1.0	1.0
2	8	1.0	1.0	1.0
3	8	1.0	1.0	1.0
4	8	1.0	1.0	1.0
5	8	1.0	1.0	1.0
6	8	1.0	1.0	1.0
7	8	1.0	1.0	1.0
8	8	1.0	1.0	1.0
9	8	1.0	1.0	1.0
10	8	1.0	1.0	1.0
11	8	1.0	1.0	1.0
12	8	1.0	1.0	1.0
13	8	1.0	1.0	1.0
14	8	1.0	1.0	1.0
15	8	1.0	1.0	1.0
16	8	1.0	1.0	1.0
17	8	1.0	1.0	1.0
18	8	1.0	1.0	1.0
19	1	1.0	1.0	1.0
20	8	1.0	1.0	1.0
21	8	1.0	1.0	1.0
22	8	1.0	1.0	1.0
23	8	1.0	1.0	1.0
24	8	1.0	1.0	1.0
25	8	1.0	1.0	1.0

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

26	8	1.0	1.0	1.0	78	6	1.0	1.0	1.0
27	8	1.0	1.0	1.0	79	6	1.0	1.0	1.0
28	8	1.0	1.0	1.0	80	6	1.0	1.0	1.0
29	8	1.0	1.0	1.0	81	6	1.0	1.0	1.0
30	8	1.0	1.0	1.0	82	8	1.0	1.0	1.0
31	8	1.0	1.0	1.0	83	8	1.0	1.0	1.0
32	8	1.0	1.0	1.0	84	8	1.0	1.0	1.0
33	8	1.0	1.0	1.0	85	8	1.0	1.0	1.0
34	8	1.0	1.0	1.0	86	8	1.0	1.0	1.0
35	1	1.0	1.0	1.0	87	8	1.0	1.0	1.0
36	1	1.0	1.0	1.0	88	8	1.0	1.0	1.0
37	8	1.0	1.0	1.0	89	8	1.0	1.0	1.0
38	8	1.0	1.0	1.0	90	8	1.0	1.0	1.0
39	8	1.0	1.0	1.0	91	8	1.0	1.0	1.0
40	8	1.0	1.0	1.0	92	1	1.0	1.0	1.0
41	8	1.0	1.0	1.0	93	1	1.0	1.0	1.0
42	8	1.0	1.0	1.0	94	6	1.0	1.0	1.0
43	8	1.0	1.0	1.0	95	6	1.0	1.0	1.0
44	8	1.0	1.0	1.0	96	6	1.0	1.0	1.0
45	8	1.0	1.0	1.0	97	6	1.0	1.0	1.0
46	8	1.0	1.0	1.0	98	6	1.0	1.0	1.0
47	8	1.0	1.0	1.0	99	6	1.0	1.0	1.0
48	1	1.0	1.0	1.0	100	8	1.0	1.0	1.0
49	1	1.0	1.0	1.0	101	8	1.0	1.0	1.0
50	8	1.0	1.0	1.0	102	8	1.0	1.0	1.0
51	8	1.0	1.0	1.0	103	8	1.0	1.0	1.0
52	8	1.0	1.0	1.0	104	8	1.0	1.0	1.0
53	8	1.0	1.0	1.0	105	8	1.0	1.0	1.0
54	8	1.0	1.0	1.0	106	8	1.0	1.0	1.0
55	8	1.0	1.0	1.0	107	8	1.0	1.0	1.0
56	8	1.0	1.0	1.0	108	1	1.0	1.0	1.0
57	8	1.0	1.0	1.0	109	1	1.0	1.0	1.0
58	8	1.0	1.0	1.0	110	1	1.0	1.0	1.0
59	8	1.0	1.0	1.0	111	1	1.0	1.0	1.0
60	1	1.0	1.0	1.0	112	6	1.0	1.0	1.0
61	1	1.0	1.0	1.0	113	6	1.0	1.0	1.0
62	6	1.0	1.0	1.0	114	6	1.0	1.0	1.0
63	8	1.0	1.0	1.0	115	6	1.0	1.0	1.0
64	8	1.0	1.0	1.0	116	6	1.0	1.0	1.0
65	8	1.0	1.0	1.0	117	8	1.0	1.0	1.0
66	8	1.0	1.0	1.0	118	8	1.0	1.0	1.0
67	8	1.0	1.0	1.0	119	8	1.0	1.0	1.0
68	8	1.0	1.0	1.0	120	8	1.0	1.0	1.0
69	8	1.0	1.0	1.0	121	8	1.0	1.0	1.0
70	8	1.0	1.0	1.0	122	8	1.0	1.0	1.0
71	8	1.0	1.0	1.0	123	8	1.0	1.0	1.0
72	8	1.0	1.0	1.0	124	8	1.0	1.0	1.0
73	8	1.0	1.0	1.0	125	1	1.0	1.0	1.0
74	1	1.0	1.0	1.0	126	1	1.0	1.0	1.0
75	1	1.0	1.0	1.0	127	1	1.0	1.0	1.0
76	6	1.0	1.0	1.0	128	1	1.0	1.0	1.0
77	6	1.0	1.0	1.0	129	1	1.0	1.0	1.0

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

130	6	1.0	1.0	1.0	182	8	1.0	1.0	1.0
131	6	1.0	1.0	1.0	183	8	1.0	1.0	1.0
132	6	1.0	1.0	1.0	184	8	1.0	1.0	1.0
133	6	1.0	1.0	1.0	185	4	1.0	1.0	1.0
134	6	1.0	1.0	1.0	186	2	1.0	1.0	1.0
135	8	1.0	1.0	1.0	187	2	1.0	1.0	1.0
136	8	1.0	1.0	1.0	188	2	1.0	1.0	1.0
137	8	1.0	1.0	1.0	189	2	1.0	1.0	1.0
138	8	1.0	1.0	1.0	190	2	1.0	1.0	1.0
139	8	1.0	1.0	1.0	191	2	1.0	1.0	1.0
140	8	1.0	1.0	1.0	192	2	1.0	1.0	1.0
141	8	1.0	1.0	1.0	193	9	1.0	1.0	1.0
142	8	1.0	1.0	1.0	194	9	1.0	1.0	1.0
143	1	1.0	1.0	1.0	195	9	1.0	1.0	1.0
144	1	1.0	1.0	1.0	196	9	1.0	1.0	1.0
145	1	1.0	1.0	1.0	197	8	1.0	1.0	1.0
146	1	1.0	1.0	1.0	198	8	1.0	1.0	1.0
147	1	1.0	1.0	1.0	199	8	1.0	1.0	1.0
148	1	1.0	1.0	1.0	200	8	1.0	1.0	1.0
149	1	1.0	1.0	1.0	201	8	1.0	1.0	1.0
150	6	1.0	1.0	1.0	202	8	1.0	1.0	1.0
151	6	1.0	1.0	1.0	203	8	1.0	1.0	1.0
152	6	1.0	1.0	1.0	204	4	1.0	1.0	1.0
153	9	1.0	1.0	1.0	205	4	1.0	1.0	1.0
154	9	1.0	1.0	1.0	206	4	1.0	1.0	1.0
155	8	1.0	1.0	1.0	207	2	1.0	1.0	1.0
156	8	1.0	1.0	1.0	208	2	1.0	1.0	1.0
157	8	1.0	1.0	1.0	209	2	1.0	1.0	1.0
158	8	1.0	1.0	1.0	210	9	1.0	1.0	1.0
159	8	1.0	1.0	1.0	211	9	1.0	1.0	1.0
160	8	1.0	1.0	1.0	212	9	1.0	1.0	1.0
161	8	1.0	1.0	1.0	213	9	1.0	1.0	1.0
162	8	1.0	1.0	1.0	214	8	1.0	1.0	1.0
163	8	1.0	1.0	1.0	215	8	1.0	1.0	1.0
164	2	1.0	1.0	1.0	216	8	1.0	1.0	1.0
165	2	1.0	1.0	1.0	217	8	1.0	1.0	1.0
166	2	1.0	1.0	1.0	218	8	1.0	1.0	1.0
167	2	1.0	1.0	1.0	219	8	1.0	1.0	1.0
168	2	1.0	1.0	1.0	220	8	1.0	1.0	1.0
169	2	1.0	1.0	1.0	221	4	1.0	1.0	1.0
170	2	1.0	1.0	1.0	222	4	1.0	1.0	1.0
171	2	1.0	1.0	1.0	223	4	1.0	1.0	1.0
172	6	1.0	1.0	1.0	224	4	1.0	1.0	1.0
173	9	1.0	1.0	1.0	225	2	1.0	1.0	1.0
174	9	1.0	1.0	1.0	226	2	1.0	1.0	1.0
175	9	1.0	1.0	1.0	227	9	1.0	1.0	1.0
176	9	1.0	1.0	1.0	228	9	1.0	1.0	1.0
177	8	1.0	1.0	1.0	229	9	1.0	1.0	1.0
178	8	1.0	1.0	1.0	230	8	1.0	1.0	1.0
179	8	1.0	1.0	1.0	231	8	1.0	1.0	1.0
180	8	1.0	1.0	1.0	232	8	1.0	1.0	1.0
181	8	1.0	1.0	1.0	233	8	1.0	1.0	1.0

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

234	8	1.0	1.0	1.0	286	8	1.0	1.0	1.0
235	8	1.0	1.0	1.0	287	8	1.0	1.0	1.0
236	8	1.0	1.0	1.0	288	8	1.0	1.0	1.0
237	8	1.0	1.0	1.0	289	8	1.0	1.0	1.0
238	8	1.0	1.0	1.0	290	8	1.0	1.0	1.0
239	4	1.0	1.0	1.0	291	8	1.0	1.0	1.0
240	4	1.0	1.0	1.0	292	8	1.0	1.0	1.0
241	4	1.0	1.0	1.0	293	4	1.0	1.0	1.0
242	4	1.0	1.0	1.0	294	4	1.0	1.0	1.0
243	4	1.0	1.0	1.0	295	4	1.0	1.0	1.0
244	2	1.0	1.0	1.0	296	3	1.0	1.0	1.0
245	2	1.0	1.0	1.0	297	3	1.0	1.0	1.0
246	9	1.0	1.0	1.0	298	3	1.0	1.0	1.0
247	8	1.0	1.0	1.0	299	8	1.0	1.0	1.0
248	8	1.0	1.0	1.0	300	8	1.0	1.0	1.0
249	8	1.0	1.0	1.0	301	8	1.0	1.0	1.0
250	8	1.0	1.0	1.0	302	8	1.0	1.0	1.0
251	8	1.0	1.0	1.0	303	8	1.0	1.0	1.0
252	8	1.0	1.0	1.0	304	8	1.0	1.0	1.0
253	8	1.0	1.0	1.0	305	8	1.0	1.0	1.0
254	8	1.0	1.0	1.0	306	8	1.0	1.0	1.0
255	8	1.0	1.0	1.0	307	8	1.0	1.0	1.0
256	8	1.0	1.0	1.0	308	8	1.0	1.0	1.0
257	4	1.0	1.0	1.0	309	8	1.0	1.0	1.0
258	4	1.0	1.0	1.0	310	8	1.0	1.0	1.0
259	4	1.0	1.0	1.0	311	8	1.0	1.0	1.0
260	4	1.0	1.0	1.0	312	4	1.0	1.0	1.0
261	4	1.0	1.0	1.0	313	4	1.0	1.0	1.0
262	2	1.0	1.0	1.0	314	4	1.0	1.0	1.0
263	2	1.0	1.0	1.0	315	4	1.0	1.0	1.0
264	8	1.0	1.0	1.0	316	3	1.0	1.0	1.0
265	8	1.0	1.0	1.0	317	3	1.0	1.0	1.0
266	8	1.0	1.0	1.0	318	8	1.0	1.0	1.0
267	8	1.0	1.0	1.0	319	8	1.0	1.0	1.0
268	8	1.0	1.0	1.0	320	8	1.0	1.0	1.0
269	8	1.0	1.0	1.0	321	8	1.0	1.0	1.0
270	8	1.0	1.0	1.0	322	8	1.0	1.0	1.0
271	8	1.0	1.0	1.0	323	8	1.0	1.0	1.0
272	8	1.0	1.0	1.0	324	8	1.0	1.0	1.0
273	8	1.0	1.0	1.0	325	8	1.0	1.0	1.0
274	8	1.0	1.0	1.0	326	8	1.0	1.0	1.0
275	4	1.0	1.0	1.0	327	8	1.0	1.0	1.0
276	4	1.0	1.0	1.0	328	8	1.0	1.0	1.0
277	4	1.0	1.0	1.0	329	8	1.0	1.0	1.0
278	4	1.0	1.0	1.0	330	4	1.0	1.0	1.0
279	3	1.0	1.0	1.0	331	4	1.0	1.0	1.0
280	3	1.0	1.0	1.0	332	4	1.0	1.0	1.0
281	8	1.0	1.0	1.0	333	4	1.0	1.0	1.0
282	8	1.0	1.0	1.0	334	3	1.0	1.0	1.0
283	8	1.0	1.0	1.0	335	3	1.0	1.0	1.0
284	8	1.0	1.0	1.0	336	8	1.0	1.0	1.0
285	8	1.0	1.0	1.0	337	8	1.0	1.0	1.0

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

338	8	1.0	1.0	1.0	390	8	1.0	1.0	1.0
339	8	1.0	1.0	1.0	391	8	1.0	1.0	1.0
340	8	1.0	1.0	1.0	392	8	1.0	1.0	1.0
341	8	1.0	1.0	1.0	393	8	1.0	1.0	1.0
342	8	1.0	1.0	1.0	394	4	1.0	1.0	1.0
343	8	1.0	1.0	1.0	395	4	1.0	1.0	1.0
344	8	1.0	1.0	1.0	396	4	1.0	1.0	1.0
345	8	1.0	1.0	1.0	397	4	1.0	1.0	1.0
346	4	1.0	1.0	1.0	398	4	1.0	1.0	1.0
347	4	1.0	1.0	1.0	399	4	1.0	1.0	1.0
348	4	1.0	1.0	1.0	400	4	1.0	1.0	1.0
349	4	1.0	1.0	1.0	401	3	1.0	1.0	1.0
350	3	1.0	1.0	1.0	402	3	1.0	1.0	1.0
351	3	1.0	1.0	1.0	403	3	1.0	1.0	1.0
352	8	1.0	1.0	1.0	404	5	1.0	1.0	1.0
353	5	1.0	1.0	1.0	405	5	1.0	1.0	1.0
354	5	1.0	1.0	1.0	406	5	1.0	1.0	1.0
355	5	1.0	1.0	1.0	407	5	1.0	1.0	1.0
356	5	1.0	1.0	1.0	408	8	1.0	1.0	1.0
357	5	1.0	1.0	1.0	409	8	1.0	1.0	1.0
358	8	1.0	1.0	1.0	410	8	1.0	1.0	1.0
359	8	1.0	1.0	1.0	411	8	1.0	1.0	1.0
360	8	1.0	1.0	1.0	412	8	1.0	1.0	1.0
361	8	1.0	1.0	1.0	413	8	1.0	1.0	1.0
362	4	1.0	1.0	1.0	414	8	1.0	1.0	1.0
363	4	1.0	1.0	1.0	415	4	1.0	1.0	1.0
364	4	1.0	1.0	1.0	416	4	1.0	1.0	1.0
365	4	1.0	1.0	1.0	417	4	1.0	1.0	1.0
366	3	1.0	1.0	1.0	418	3	1.0	1.0	1.0
367	3	1.0	1.0	1.0	419	3	1.0	1.0	1.0
368	5	1.0	1.0	1.0	420	3	1.0	1.0	1.0
369	5	1.0	1.0	1.0	421	3	1.0	1.0	1.0
370	5	1.0	1.0	1.0	422	3	1.0	1.0	1.0
371	5	1.0	1.0	1.0	423	5	1.0	1.0	1.0
372	5	1.0	1.0	1.0	424	5	1.0	1.0	1.0
373	5	1.0	1.0	1.0	425	5	1.0	1.0	1.0
374	8	1.0	1.0	1.0	426	5	1.0	1.0	1.0
375	8	1.0	1.0	1.0	427	8	1.0	1.0	1.0
376	8	1.0	1.0	1.0	428	8	1.0	1.0	1.0
377	8	1.0	1.0	1.0	429	8	1.0	1.0	1.0
378	4	1.0	1.0	1.0	430	8	1.0	1.0	1.0
379	4	1.0	1.0	1.0	431	8	1.0	1.0	1.0
380	4	1.0	1.0	1.0	432	8	1.0	1.0	1.0
381	4	1.0	1.0	1.0	433	8	1.0	1.0	1.0
382	4	1.0	1.0	1.0	434	8	1.0	1.0	1.0
383	3	1.0	1.0	1.0	435	3	1.0	1.0	1.0
384	3	1.0	1.0	1.0	436	3	1.0	1.0	1.0
385	5	1.0	1.0	1.0	437	3	1.0	1.0	1.0
386	5	1.0	1.0	1.0	438	5	1.0	1.0	1.0
387	5	1.0	1.0	1.0	439	5	1.0	1.0	1.0
388	5	1.0	1.0	1.0	440	8	1.0	1.0	1.0
389	5	1.0	1.0	1.0	441	8	1.0	1.0	1.0

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

442	8	1.0	1.0	1.0	494	7	1.0	1.0	1.0
443	8	1.0	1.0	1.0	495	7	1.0	1.0	1.0
444	8	1.0	1.0	1.0	496	7	1.0	1.0	1.0
445	8	1.0	1.0	1.0	497	7	1.0	1.0	1.0
446	8	1.0	1.0	1.0	498	7	1.0	1.0	1.0
447	8	1.0	1.0	1.0	499	7	1.0	1.0	1.0
448	3	1.0	1.0	1.0	500	7	1.0	1.0	1.0
449	5	1.0	1.0	1.0	501	7	1.0	1.0	1.0
450	5	1.0	1.0	1.0	502	7	1.0	1.0	1.0
451	8	1.0	1.0	1.0	503	7	1.0	1.0	1.0
452	8	1.0	1.0	1.0	504	7	1.0	1.0	1.0
453	8	1.0	1.0	1.0	505	7	1.0	1.0	1.0
454	8	1.0	1.0	1.0	506	7	1.0	1.0	1.0
455	8	1.0	1.0	1.0	507	7	1.0	1.0	1.0
456	8	1.0	1.0	1.0	508	7	1.0	1.0	1.0
457	8	1.0	1.0	1.0	509	7	1.0	1.0	1.0
458	8	1.0	1.0	1.0	510	7	1.0	1.0	1.0
459	5	1.0	1.0	1.0	511	7	1.0	1.0	1.0
460	5	1.0	1.0	1.0	512	7	1.0	1.0	1.0
461	8	1.0	1.0	1.0	513	7	1.0	1.0	1.0
462	8	1.0	1.0	1.0	514	7	1.0	1.0	1.0
463	8	1.0	1.0	1.0	515	7	1.0	1.0	1.0
464	8	1.0	1.0	1.0	516	7	1.0	1.0	1.0
465	8	1.0	1.0	1.0	517	7	1.0	1.0	1.0
466	8	1.0	1.0	1.0	518	7	1.0	1.0	1.0
467	8	1.0	1.0	1.0	519	7	1.0	1.0	1.0
468	5	1.0	1.0	1.0	520	7	1.0	1.0	1.0
469	5	1.0	1.0	1.0	521	7	1.0	1.0	1.0
470	8	1.0	1.0	1.0	522	7	1.0	1.0	1.0
471	8	1.0	1.0	1.0	523	7	1.0	1.0	1.0
472	8	1.0	1.0	1.0	524	7	1.0	1.0	1.0
473	8	1.0	1.0	1.0	525	7	1.0	1.0	1.0
474	8	1.0	1.0	1.0	526	7	1.0	1.0	1.0
475	8	1.0	1.0	1.0	527	7	1.0	1.0	1.0
476	5	1.0	1.0	1.0	528	7	1.0	1.0	1.0
477	5	1.0	1.0	1.0	529	7	1.0	1.0	1.0
478	5	1.0	1.0	1.0	530	7	1.0	1.0	1.0
479	8	1.0	1.0	1.0	531	7	1.0	1.0	1.0
480	8	1.0	1.0	1.0	532	7	1.0	1.0	1.0
481	8	1.0	1.0	1.0	533	7	1.0	1.0	1.0
482	8	1.0	1.0	1.0	534	7	1.0	1.0	1.0
483	8	1.0	1.0	1.0	535	7	1.0	1.0	1.0
484	5	1.0	1.0	1.0	1	0.893	57.500	6201.001	
485	5	1.0	1.0	1.0	2	0.897	57.858	6200.039	
486	8	1.0	1.0	1.0	3	0.327	9.760	6200.406	
487	8	1.0	1.0	1.0	4	0.327	9.760	6200.476	
488	8	1.0	1.0	1.0	5	1.188	67.639	6200.655	
489	8	1.0	1.0	1.0	6	1.188	67.616	6197.596	
490	8	1.0	1.0	1.0	7	0.980	67.965	6196.322	
491	8	1.0	1.0	1.0	8	0.984	68.470	6194.599	
492	7	1.0	1.0	1.0	9	0.987	68.753	6194.457	
493	7	1.0	1.0	1.0	10	0.990	69.174	6193.024	

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

11	1.205	69.361	6192.323
12	0.993	69.536	6191.371
13	0.996	69.883	6189.917
14	1.215	70.377	6187.383
15	1.004	70.942	6185.010
16	1.006	71.194	6183.688
17	1.009	71.505	6182.045
18	1.230	71.943	6179.643
19	1.021	73.041	6179.368
20	1.029	74.056	6178.831
21	1.034	74.735	6178.043
22	1.045	76.206	6176.521
23	1.056	77.527	6175.402
24	1.063	78.469	6174.944
25	1.072	79.729	6174.164
26	1.082	81.010	6173.666
27	1.085	81.367	6174.271
28	1.088	81.798	6172.476
29	1.092	82.358	6172.240
30	1.098	83.176	6171.634
31	0.344	10.000	6218.973
32	0.334	9.489	6200.064
33	0.311	8.378	6174.986
34	1.386	92.270	6171.011
35	1.170	92.750	6170.164
36	0.000	0.000	6168.431
37	0.480	1.347	6169.381
38	0.631	3.055	6169.341
39	1.484	99.728	6169.299
40	1.082	80.090	6218.400
41	0.691	36.133	6172.347
42	0.670	34.236	6172.107
43	1.649	133.092	6169.395
44	1.434	133.340	6168.699
45	1.436	133.675	6168.326
46	1.441	134.426	6167.093
47	0.789	38.294	6171.463
48	0.459	17.410	6171.531
49	0.429	15.457	6170.423
50	1.737	148.741	6167.015
51	0.460	17.469	6170.130
52	0.433	15.731	6169.629
53	1.830	163.232	6166.019
54	1.608	163.377	6162.758
55	1.610	163.746	6159.536
56	1.613	164.229	6154.824
57	1.615	164.608	6153.132
58	0.000	0.000	6156.630
59	0.926	1.482	6143.760
60	1.630	167.235	6142.655
61	1.989	168.418	6116.071
62	1.640	169.113	6107.627
63	1.644	169.786	6103.854
64	1.646	170.212	6099.967
65	1.646	170.231	6097.948
66	2.000	170.094	6090.648
67	1.645	170.005	6085.027
68	2.001	170.244	6078.837
69	1.650	170.903	6070.172
70	1.656	172.047	6060.500
71	0.000	0.000	6214.000
72	0.000	0.000	6213.000
73	0.000	0.000	6212.000
74	0.000	0.000	6197.500
75	0.000	0.000	6192.200
76	0.000	0.000	6192.200
77	0.000	0.000	6192.100
78	0.000	0.000	6192.000
79	0.000	0.000	6231.000
80	0.000	0.000	6230.000
81	0.000	0.000	6187.300
82	0.000	0.000	6179.600
83	0.000	0.000	6179.500
84	0.000	0.000	6210.000
85	0.000	0.000	6208.000
86	0.000	0.000	6170.800
87	0.000	0.000	6201.000
88	0.000	0.000	6200.000
89	0.000	0.000	6115.900
90	0.000	0.000	6090.600
91	0.000	0.000	6078.800

5	34	39	-40	43	-47	50	53	60
1	15	8	7	1	0.0002015	1.0	1.0	1.0
2	14	7	16	1	0.0002015	1.0	1.0	1.0
3	31	16	24	1	0.0002015	1.0	1.0	1.0
4	44	24	31	1	0.0002015	1.0	1.0	1.0
5	56	31	30	1	0.0003416	1.0	1.0	1.0
6	39	29	30	1	0.0003416	1.0	1.0	1.0
7	52	29	37	1	0.0003416	1.0	1.0	1.0
8	67	37	48	1	0.0003416	1.0	1.0	1.0
9	86	48	47	1	0.0009073	1.0	1.0	1.0

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

10	84	47	57	1	0.0009073	1.0	1.0	1.0
11	102	57	67	1	0.0004128	1.0	1.0	1.0
12	121	67	78	1	0.0004128	1.0	1.0	1.0
13	140	89	78	1	0.0003469	1.0	1.0	1.0
14	161	101	89	1	0.0003469	1.0	1.0	1.0
15	183	101	112	1	0.0003469	1.0	1.0	1.0
16	202	112	122	2	0.0003469	1.0	1.0	1.0
17	218	122	131	2	0.0002291	1.0	1.0	1.0
18	234	131	140	2	0.0002291	1.0	1.0	1.0
19	251	151	140	2	0.0002291	1.0	1.0	1.0
20	270	151	160	2	0.0002291	1.0	1.0	1.0
21	271	160	161	2	0.0002291	1.0	1.0	1.0
22	288	161	170	2	0.0002291	1.0	1.0	1.0
23	306	170	181	2	0.0002291	1.0	1.0	1.0
24	326	181	192	2	0.0002291	1.0	1.0	1.0
25	344	192	201	2	0.0002291	1.0	1.0	1.0
26	360	201	210	2	0.0002291	1.0	1.0	1.0
27	376	210	219	2	0.0002291	1.0	1.0	1.0
28	393	219	230	2	0.0002291	1.0	1.0	1.0
29	412	230	229	3	0.0002291	1.0	1.0	1.0
30	411	229	232	3	0.0003954	1.0	1.0	1.0
31	415	232	242	3	0.0003954	1.0	1.0	1.0
32	417	242	243	3	0.0003954	1.0	1.0	1.0
33	418	243	244	3	0.0003954	1.0	1.0	1.0
34	435	244	253	3	0.0003954	1.0	1.0	1.0
35	447	253	259	3	0.0003954	1.0	1.0	1.0
36	458	259	266	3	0.0003954	1.0	1.0	1.0
37	467	271	266	3	0.0003954	1.0	1.0	1.0
38	475	276	271	3	0.0003954	1.0	1.0	1.0
39	483	281	276	3	0.0040601	1.0	1.0	1.0
40	489	281	280	3	0.0040601	1.0	1.0	1.0
41	488	280	283	3	0.0023780	1.0	1.0	1.0
42	491	286	283	4	0.0023780	1.0	1.0	1.0
43	494	286	290	4	0.0022797	1.0	1.0	1.0
44	500	290	294	4	0.0022797	1.0	1.0	1.0
45	504	297	294	4	0.0022797	1.0	1.0	1.0
46	506	297	298	4	0.0020980	1.0	1.0	1.0
47	511	298	301	4	0.0020980	1.0	1.0	1.0
48	515	305	301	4	0.0020980	1.0	1.0	1.0
49	522	305	309	4	0.0020980	1.0	1.0	1.0
50	528	309	313	4	0.0012168	1.0	1.0	1.0
51	534	313	317	4	0.0012168	1.0	1.0	1.0
52	9	14	11	5	0.0032584	1.0	1.0	1.0
53	11	16	14	5	0.0032584	1.0	1.0	1.0
54	385	225	217	6	0.0049758	1.0	1.0	1.0
55	372	217	218	6	0.0049758	1.0	1.0	1.0
56	392	218	230	6	0.0049758	1.0	1.0	1.0
57	424	239	238	8	0.0004000	1.0	1.0	1.0
58	426	240	239	8	0.0004000	1.0	1.0	1.0
59	413	232	240	8	0.0004000	1.0	1.0	1.0
60	449	261	256	7	0.0028793	1.0	1.0	1.0
61	441	250	256	7	0.0028793	1.0	1.0	1.0

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

```
 62  430  242  250     7 0.0028793        1.0        1.0        1.0
 63  459  268  261     7 0.0034481        1.0        1.0        1.0
 64  461  268  263     7 0.0034481        1.0        1.0        1.0
 65  454  263  264     7 0.0034481        1.0        1.0        1.0
 66  455  264  259     7 0.0034481        1.0        1.0        1.0
 67  470  269  268     7 0.0037613        1.0        1.0        1.0
 68  465  265  269     7 0.0037613        1.0        1.0        1.0
 69  466  266  265     7 0.0037613        1.0        1.0        1.0
 70  485  282  279     3 0.0004000        1.0        1.0        1.0
 71  490  283  282     3 0.0004000        1.0        1.0        1.0
 72   17    9   17     9    0.0020        1.0        1.0        1.0
 73   33   17   25     9    0.0020        1.0        1.0        1.0
 74   29   23   24     9    0.0020        1.0        1.0        1.0
 75   87   48   59     9    0.0020        1.0        1.0        1.0
 76   81   56   46     9    0.0020        1.0        1.0        1.0
 77   98   66   56     9    0.0020        1.0        1.0        1.0
 78   78   45   44     9    0.0020        1.0        1.0        1.0
 79  119   67   76     9    0.0020        1.0        1.0        1.0
 80  184  112  113     9    0.0020        1.0        1.0        1.0
 81  204  113  123     9    0.0020        1.0        1.0        1.0
 82  438  248  255     9    0.0020        1.0        1.0        1.0
 83  470  268  273     9    0.0020        1.0        1.0        1.0
 84  468  267  272     9    0.0020        1.0        1.0        1.0
 85  492  289  286     9    0.0020        1.0        1.0        1.0
 86  517  302  301     9    0.0020        1.0        1.0        1.0
 87  529  310  309     9    0.0020        1.0        1.0        1.0
  1 0.0319411 0.0319411       0.15        0.0
  2 0.0319411 0.0319411       0.15        0.0
  3 2.1353250 2.1353250       0.15        0.0
  4 2.1353250 2.1353250       0.15        0.0
  5 0.0731491 0.0731491       0.15        0.0
  6 0.0169116 0.0169116       0.15        0.0
  7 1.5395794 1.5395794       0.15        0.0
  8 2.1353250 2.1353250       0.15        0.0
  9 2.1353250 2.1353250       0.15        0.0
  1         1.0        60.0    0.025 1.6300E-06        1.0
  2         1.0        60.0    0.025 6.0300E-06        1.0
  3         1.0        60.0    0.025 2.5800E-06        1.0
  4         1.0        60.0    0.025 4.1472E-06        1.0
  5         1.0        10.0    0.050    1.0E-10        1.0
  6         1.0        15.0    0.050 2.5721E-05        1.0
  7         1.0        25.0    0.050 2.8125E-05        1.0
  8         1.0        10.0    0.025 2.1199E-04        1.0
  9         1.0        10.0    0.025    1.0E-06        1.0
 60 2419200.0       300.0       1.2     4     0  100     0          0.0        0.0
   0.0
  8   -1       0.00     6203.0     140.0       0.0
 11    0        0.0        0.0      9.02       0.0
225    0       3.55        0.0      10.0       0.0
261    0       4.19        0.0      74.0       0.0
  1    1    1    1    1    1    1    1    0
  1    0   25        0.0    0
```

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

2	0	23	0.0	0					
3	0	45	0.0	0					
4	0	59	0.0	0					
5	0	66	0.0	0					
6	0	76	0.0	0					
7	0	123	0.0	0					
8	0	248	0.0	7					
9	0	274	0.0	0					
10	0	272	0.0	0					
11	0	289	0.0	0					
12	0	302	0.0	0					
8	1	96	0.03571						
8	2	97	0.06015						
8	3	128	0.02444						
8	4	149	0.03947						
8	5	168	0.02820						
8	6	208	0.03008						
8	7	217	0.05075						
60	2678400.0	300.0	1.2	4	0	100	0	0.0	0.0
0.0									
8	-1	0.00	6203.0	138.	0.0				
11	0	0.0	0.0	14.5	0.0				
225	0	3.55	0.0	10.0	0.0				
261	0	4.19	0.0	56.0	0.0				
1	1	1	1	1	1	1	1	0	
1	0	25	0.0	0					
2	0	23	0.0	0					
3	0	45	0.0	0					
4	0	59	0.0	0					
5	0	66	0.0	0					
6	0	76	0.0	0					
7	0	123	0.0	7					
8	0	248	0.0	0					
9	0	274	0.0	0					
10	0	272	0.0	0					
11	0	289	0.0	0					
12	0	302	0.0	0					
8	1	96	0.03571						
8	2	97	0.06015						
8	3	128	0.02444						
8	4	149	0.03947						
8	5	168	0.02820						
8	6	208	0.03008						
8	7	217	0.05075						
60	2592000.0	300.0	1.2	8	9	100	0	0.0	0.0
1.961E-08									
8	-1	0.00	6203.0	532.	0.0				
11	0	0.0	0.0	254.	0.0				
225	0	3.55	0.0	50.0	0.0				
261	0	4.19	0.0	225.	0.0				
9	-1	0.0	6203.0	0.0	0.0				
44	-1	0.0	6218.0	0.0	0.0				

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

```
 255    0        0.0        0.0       35.0        0.0
 267    0        0.0        0.0       15.0        0.0
   1    1    1    1    1    1    1    1    1
   1   23   31        0.0        0.0
   2   59   47        0.0        0.0
   3   46   47        0.0        0.0
   4   76   78        0.0        0.0
   5  113  122        4.8        0.0
   6  273  265       7.50        0.0
   7  289  290       18.0        0.0
   8  302  305        0.0        0.0
   9  310  313        0.0        0.0
   1    2   25        0.0    0
   2    1   23        0.0    0
   3    1   45        0.0    0
   4    1   59        0.0    0
   5    1   66        0.0    0
   6    1   76        0.0    0
   7    1  123        0.0    0
   8    1  248        0.0    7
   9    1  274        0.0    0
  10    1  272        0.0    0
  11    1  289        0.0    0
  12    1  302        0.0    0
   8    1   96    0.03571
   8    2   97    0.06015
   8    3  128    0.02444
   8    4  149    0.03947
   8    5  168    0.02820
   8    6  208    0.03008
   8    7  217    0.05075
  60 2678400.0     300.0        1.2   16    9  100    0       0.0       0.0
 9.489E-08
   8   -1       0.00     6203.0       991.        0.0
  11    0        0.0        0.0       149.        0.0
 225    0       3.55        0.0      100.0        0.0
 261    0       4.19        0.0       849.        0.0
   9   -1        0.0     6203.0       0.77        0.0
  44   -1        0.0     6218.0        0.0        0.0
 255    0        0.0        0.0       22.7        0.0
 267    0        0.0        0.0        4.5        0.0
 119    0    -0.4195        0.0        0.0        0.0
 114    0    -0.5568        0.0        0.0        0.0
 145    0    -0.3168        0.0        0.0        0.0
 185    0    -0.3711        0.0        0.0        0.0
 257    0    -0.0807        0.0        0.0        0.0
 291    0        0.0        0.0        0.0        0.0
 292    0    -0.1291        0.0        0.0        0.0
 293    0    -0.3872        0.0        0.0        0.0
   1    1    1    1    1    1    1    1    1
   1   23   31       0.27        0.0
   2   59   47       56.2        0.0
```

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

3	46	47		1.90		0.0						
4	76	78		22.9		0.0						
5	113	122		22.7		0.0						
6	273	265		29.5		0.0						
7	289	290		29.0		0.0						
8	302	305		2.2		0.0						
9	310	313		0.0		0.0						
1	1	25		5.787E-08	0							
2	1	23		5.787E-08	0							
3	1	45		5.787E-08	0							
4	1	59		5.787E-08	0							
5	1	66		5.787E-08	0							
6	1	76		5.787E-08	0							
7	1	123		5.787E-08	0							
8	1	248		5.787E-08	7							
9	1	274		5.787E-08	0							
10	1	272		5.787E-08	0							
11	1	289		5.787E-08	0							
12	1	302		5.787E-08	0							
8	1	96		0.03571	0							
8	2	97		0.06015								
8	3	128		0.02444								
8	4	149		0.03947								
8	5	168		0.02820								
8	6	208		0.03008								
8	7	217		0.05075								
60		2592000.0		300.0		1.2	16	9	100	0	0.0	0.0
1.566E-07												
8	-1		0.00		6203.0		644.		0.0			
11	0		0.0		0.0		52.2		0.0			
225	0		3.55		0.0		36.0		0.0			
261	0		4.19		0.0		569.		0.0			
9	-1		0.0		6203.0		38.1		0.0			
44	-1		0.0		6218.0		0.0		0.0			
255	0		0.0		0.0		77.0		0.0			
267	0		0.0		0.0		35.6		0.0			
119	0		-0.8879		0.0		0.0					
114	0		-1.1786		0.0		0.0		0.0			
145	0		-0.6706		0.0		0.0		0.0			
185	0		-0.7855		0.0		0.0		0.0			
257	0		-0.1708		0.0		0.0		0.0			
291	0		0.0		0.0		0.0		0.0			
292	0		-0.2732		0.0		0.0		0.0			
293	0		-0.8196		0.0		0.0		0.0			
1	1	1	1	1	1	1	1	1				
1	23	31		2.40		0.0	7					
2	59	47		112.		0.0	12					
3	46	47		1.7		0.0	12					
4	76	78		33.2		0.0	15					
5	113	122		41.5		0.0	19					
6	273	265		37.3		0.0	52					
7	289	290		60.0		0.0	62					

Table 3.--*Input data for kinematic simulation of the Bear River valley*--Continued

8	302	305	6.80		0.0	67
9	310	313	35.2		0.0	69
1	1	25	1.225E-07	0		
2	1	23	1.225E-07	0		
3	1	45	1.225E-07	0		
4	1	59	1.225E-07	0		
5	1	66	1.225E-07	0		
6	1	76	1.225E-07	0		
7	1	123	1.225E-07	0		
8	1	248	1.225E-07	7		
9	1	274	1.225E-07	0		
10	1	272	1.225E-07	0		
11	1	289	1.225E-07	0		
12	1	302	1.225E-07	0		
8	1	96	0.03571			
8	2	97	0.06015			
8	3	128	0.02444			
8	4	149	0.03947			
8	5	168	0.02820			
8	6	208	0.03008			
8	7	217	0.05075			

Table 4.--*Selected output for kinematic simulation of the Bear River valley*

SOLUTION AT TIME = 0.12960E+08 DAYS = 150.00

NODE	XORD	YORD	PHI	DRAWDOWN	STREAM HEAD	STREAMFLOW
1	0.00000E+00	0.36221E+05	6202.9990	0.0010		
2	0.27500E+04	0.35680E+05	6202.5146	-0.2842		
3	0.56300E+04	0.41423E+05	6202.5781	-0.4980		
4	0.27280E+04	0.42545E+05	6202.9990	0.0010		
5	0.52820E+04	0.35141E+05	6201.9590	-0.5693		
6	0.82630E+04	0.40460E+05	6202.1660	-0.9355		
7	0.65840E+04	0.42844E+05	6202.6748	-0.6943	3.8063	643.5004
8	0.35810E+04	0.44442E+05	6202.9990	0.0010	3.8052	644.0000
9	0.40100E+04	0.45707E+05	6202.9990	0.0010	1.2411	38.1000
10	0.66080E+04	0.48230E+05	6202.9258	-0.2061		
11	0.69600E+04	0.32810E+05	6201.4512	-0.7314	0.8943	52.2000
12	0.94000E+04	0.35280E+05	6201.2793	-0.9990		
13	0.13466E+05	0.35157E+05	6200.6709	-1.6211		
14	0.84590E+04	0.37291E+05	6201.6875	-0.9072	0.8943	52.2000
15	0.10739E+05	0.39288E+05	6201.6895	-1.3291		
16	0.96910E+04	0.41087E+05	6202.1670	-1.2568	4.8068	694.9070
17	0.90230E+04	0.45156E+05	6202.7178	-1.0576	1.2389	37.9871
18	0.11674E+05	0.47467E+05	6202.9346	-1.3145		
19	0.69980E+04	0.52610E+05	6202.9990	0.0010		
20	0.13295E+05	0.32412E+05	6200.5088	-1.6387		
21	0.16735E+05	0.34244E+05	6199.9609	-2.1113		
22	0.15370E+05	0.35940E+05	6200.4580	-1.9482		
23	0.13477E+05	0.37638E+05	6201.0088	-1.6885	0.2362	2.4000
24	0.13327E+05	0.39487E+05	6201.4434	-1.8535	4.8042	694.0514
25	0.11023E+05	0.43669E+05	6202.5801	-1.6504	1.2378	37.9313
26	0.16042E+05	0.44385E+05	6202.6650	-3.3555		
27	0.15114E+05	0.49353E+05	6205.9121	-4.0420		
28	0.18038E+05	0.30384E+05	6199.2764	-2.4365		
29	0.19518E+05	0.30905E+05	6199.6172	-3.1875	3.9449	692.0757
30	0.20376E+05	0.33700E+05	6199.8779	-3.3076	3.9416	691.7769
31	0.16378E+05	0.36991E+05	6200.4756	-2.1758	3.9420	691.4644
32	0.16767E+05	0.41204E+05	6201.8730	-3.0928		
33	0.19837E+05	0.42942E+05	6202.0967	-3.8564		
34	0.23600E+05	0.46040E+05	6192.5381	5.2217		
35	0.25730E+05	0.26864E+05	6199.9336	-4.9834		
36	0.23781E+05	0.27876E+05	6199.7969	-5.0166		
37	0.23416E+05	0.28934E+05	6200.0488	-5.0488	3.9450	692.8488
38	0.22373E+05	0.31790E+05	6199.8965	-4.1865		
39	0.21434E+05	0.34223E+05	6200.1670	-3.8174		
40	0.20024E+05	0.37661E+05	6200.6797	-3.3398		
41	0.23202E+05	0.39864E+05	6200.9395	-4.0996		
42	0.26647E+05	0.42700E+05	6192.4043	4.1357		
43	0.25493E+05	0.21004E+05	6217.9990	0.0010		
44	0.25028E+05	0.23382E+05	6217.9990	0.0010	0.0000	0.0000
45	0.26355E+05	0.24907E+05	6199.4658	-3.7754	0.0000	0.0000
46	0.27842E+05	0.26802E+05	6200.9443	-8.0947	0.0000	0.0000
47	0.27586E+05	0.28704E+05	6201.4277	-8.0576	3.5542	582.3784
48	0.25581E+05	0.28818E+05	6200.5195	-6.2100	4.7966	693.4612
49	0.25010E+05	0.30933E+05	6200.8867	-6.1172		
50	0.24466E+05	0.35200E+05	6201.1396	-5.5596		

Table 4.--*Selected output for kinematic simulation of the Bear River valley*--Continued

51	0.26011E+05	0.37938E+05	6200.9541	-5.4639		
52	0.29820E+05	0.39397E+05	6200.6016	-5.6514		
53	0.26534E+05	0.16076E+05	6217.9990	0.0010		
54	0.27723E+05	0.21403E+05	6207.7998	0.4102		
55	0.27688E+05	0.24940E+05	6196.4785	-0.2783		
56	0.30596E+05	0.25665E+05	6200.4023	-8.7822	0.0598	0.2431
57	0.31086E+05	0.28566E+05	6202.2295	-10.2998	3.5635	584.8816
58	0.31514E+05	0.29831E+05	6204.1533	-12.1035		
59	0.27248E+05	0.31965E+05	6202.5273	-8.3369	2.3701	112.0000
60	0.30114E+05	0.34749E+05	6202.3174	-8.3477		
61	0.33282E+05	0.34786E+05	6194.9414	-1.1016		
62	0.33357E+05	0.39115E+05	6190.5654	5.2041		
63	0.29064E+05	0.15218E+05	6209.3760	-1.6758		
64	0.30571E+05	0.20754E+05	6195.4453	5.5244		
65	0.34051E+05	0.19892E+05	6191.1641	3.3359		
66	0.35021E+05	0.23742E+05	6197.7949	-8.4453	0.0989	0.5622
67	0.35717E+05	0.25692E+05	6198.7012	-9.2715	4.3465	588.8837
68	0.36464E+05	0.27061E+05	6200.4717	-11.0117		
69	0.37744E+05	0.29694E+05	6202.9551	-13.3652		
70	0.33271E+05	0.32727E+05	6204.7607	-12.7510		
71	0.37080E+05	0.34080E+05	6191.7969	2.7930		
72	0.36206E+05	0.38837E+05	6198.4961	-0.1064		
73	0.32491E+05	0.14198E+05	6203.9736	-5.3232		
74	0.37839E+05	0.17075E+05	6185.7568	4.0029		
75	0.39183E+05	0.21873E+05	6193.6445	-6.6641		
76	0.40459E+05	0.23661E+05	6194.0234	-7.0830	1.1427	33.2000
77	0.41258E+05	0.24925E+05	6194.6494	-7.6992		
78	0.42322E+05	0.26556E+05	6195.4834	-8.5635	3.4682	560.0100
79	0.39018E+05	0.31008E+05	6202.7871	-13.3574		
80	0.41818E+05	0.31311E+05	6206.8916	-14.4717		
81	0.41035E+05	0.33163E+05	6195.3359	0.5742		
82	0.39267E+05	0.38504E+05	6206.2236	-1.0938		
83	0.38083E+05	0.13113E+05	6187.8730	1.0869		
84	0.38934E+05	0.14323E+05	6185.3584	2.7412		
85	0.42220E+05	0.16894E+05	6189.6328	-5.3125		
86	0.41808E+05	0.18955E+05	6190.3018	-5.3018		
87	0.43728E+05	0.22694E+05	6192.0225	-6.5928		
88	0.44157E+05	0.24065E+05	6192.6416	-7.0518		
89	0.44796E+05	0.25065E+05	6192.6768	-7.1064	3.4739	561.6703
90	0.44170E+05	0.26547E+05	6194.0576	-7.8574		
91	0.44079E+05	0.29504E+05	6216.8467	-26.3271		
92	0.43983E+05	0.31405E+05	6198.2217	-4.1113		
93	0.43996E+05	0.33940E+05	6198.6523	1.8975		
94	0.44344E+05	0.40010E+05	6230.5010	-0.3906		
95	0.42506E+05	0.10715E+05	6186.3594	1.2207		
96	0.42943E+05	0.13564E+05	6189.1357	-5.2861		
97	0.45160E+05	0.13606E+05	6189.0410	-5.3506		
98	0.44596E+05	0.16776E+05	6189.1123	-5.0820		
99	0.44238E+05	0.19101E+05	6189.8281	-5.3682		
100	0.46312E+05	0.21995E+05	6190.1953	-5.8955		
101	0.47796E+05	0.23096E+05	6189.7227	-5.7822	3.4813	563.3210
102	0.50757E+05	0.24032E+05	6187.5361	-4.7666		

Table 4.--*Selected output for kinematic simulation of the Bear River valley*--Continued

103	0.50398E+05	0.26145E+05	6177.2803	7.4395		
104	0.49466E+05	0.29688E+05	6184.9141	4.2656		
105	0.49642E+05	0.33277E+05	6193.0654	1.0742		
106	0.49614E+05	0.38082E+05	6203.8379	-1.2275		
107	0.45357E+05	0.10700E+05	6188.6934	-5.1338		
108	0.47009E+05	0.13596E+05	6188.8105	-5.3203		
109	0.47077E+05	0.16658E+05	6189.3467	-5.7666		
110	0.46826E+05	0.19299E+05	6190.1777	-6.3574		
111	0.51900E+05	0.20330E+05	6188.3643	-6.2139		
112	0.52330E+05	0.21806E+05	6187.6611	-5.7813	4.2360	565.0331
113	0.53231E+05	0.22435E+05	6186.4336	-4.8740	1.3064	41.5000
114	0.54189E+05	0.24067E+05	6185.3525	-4.2725		
115	0.55054E+05	0.27970E+05	6184.6016	-1.6016		
116	0.56027E+05	0.32506E+05	6186.9043	-0.9541		
117	0.54568E+05	0.36209E+05	6192.3389	-0.2090		
118	0.48684E+05	0.10842E+05	6188.7832	-5.4834		
119	0.49912E+05	0.13423E+05	6187.9102	-4.7803		
120	0.51032E+05	0.15688E+05	6189.3525	-6.6621		
121	0.51732E+05	0.18324E+05	6186.5801	-4.3105		
122	0.54165E+05	0.19157E+05	6186.1162	-4.8564	3.3439	527.5715
123	0.56072E+05	0.20467E+05	6185.5234	-4.8535	1.3097	41.6755
124	0.56241E+05	0.22473E+05	6184.9170	-4.3271		
125	0.57584E+05	0.27060E+05	6183.8584	-3.8184		
126	0.59517E+05	0.33439E+05	6178.9033	3.5469		
127	0.53073E+05	0.12140E+05	6189.2295	-5.8496		
128	0.52286E+05	0.13094E+05	6188.5439	-5.4639		
129	0.53298E+05	0.14832E+05	6190.2119	-8.0420		
130	0.53786E+05	0.17363E+05	6185.5459	-3.9561		
131	0.56000E+05	0.16560E+05	6185.3760	-4.6260	3.3589	531.9398
132	0.56010E+05	0.18461E+05	6187.0068	-6.2969		
133	0.58549E+05	0.19609E+05	6184.3076	-4.3779		
134	0.58829E+05	0.22618E+05	6183.9385	-4.0684		
135	0.61542E+05	0.26723E+05	6182.5684	-3.3086		
136	0.63685E+05	0.32784E+05	6178.2500	1.8896		
137	0.53860E+05	0.11027E+05	6188.8926	-6.4521		
138	0.55399E+05	0.12656E+05	6188.0557	-6.4453		
139	0.55512E+05	0.14187E+05	6184.9219	-3.6123		
140	0.58057E+05	0.16233E+05	6183.8018	-3.8115	3.3671	534.6777
141	0.58330E+05	0.17921E+05	6184.9932	-5.0332		
142	0.62127E+05	0.17110E+05	6183.0205	-4.2803		
143	0.61561E+05	0.20070E+05	6182.9453	-3.8652		
144	0.62208E+05	0.22654E+05	6182.6230	-3.6035		
145	0.64163E+05	0.22855E+05	6181.6816	-3.1416		
146	0.65448E+05	0.26333E+05	6181.1504	-2.7305		
147	0.68010E+05	0.31970E+05	6176.1416	2.6885		
148	0.58505E+05	0.10792E+05	6186.0576	-6.0273		
149	0.58405E+05	0.11954E+05	6186.0830	-5.9932		
150	0.58203E+05	0.13698E+05	6186.8691	-6.7393		
151	0.62435E+05	0.15261E+05	6182.8467	-4.3770	3.3817	539.5481
152	0.65762E+05	0.15455E+05	6181.0703	-3.4307		
153	0.66204E+05	0.19254E+05	6181.1719	-3.3320		
154	0.68115E+05	0.21251E+05	6180.3262	-2.8262		

Table 4.--*Selected output for kinematic simulation of the Bear River valley*--Continued

155	0.68606E+05	0.24522E+05	6179.9756	-2.5059		
156	0.71944E+05	0.26670E+05	6178.9814	-2.2510		
157	0.62462E+05	0.10192E+05	6183.2646	-4.8350		
158	0.62574E+05	0.11458E+05	6183.0771	-4.6367		
159	0.62528E+05	0.12937E+05	6182.6572	-4.1875		
160	0.65377E+05	0.12500E+05	6180.8477	-3.4873	3.3954	543.0437
161	0.68076E+05	0.13542E+05	6180.5420	-3.6416	3.4014	545.2297
162	0.68244E+05	0.15548E+05	6180.4736	-3.3838		
163	0.68412E+05	0.17501E+05	6180.4453	-3.2354		
164	0.70640E+05	0.19443E+05	6179.5947	-2.7246		
165	0.71236E+05	0.22555E+05	6179.2920	-2.4316		
166	0.75742E+05	0.26017E+05	6178.2441	-2.1445		
167	0.65522E+05	0.96480E+04	6181.8496	-4.3398		
168	0.65739E+05	0.10808E+05	6182.0107	-4.5205		
169	0.67700E+05	0.12277E+05	6181.0654	-4.0459		
170	0.71711E+05	0.11993E+05	6179.4199	-3.3203	3.4076	547.9110
171	0.71930E+05	0.13576E+05	6179.2539	-3.0439		
172	0.72203E+05	0.15370E+05	6179.2549	-2.9453		
173	0.72637E+05	0.17532E+05	6179.0986	-2.7188		
174	0.74923E+05	0.20636E+05	6178.4258	-2.3262		
175	0.78780E+05	0.20986E+05	6177.5449	-2.1152		
176	0.79435E+05	0.25418E+05	6177.4873	-2.0576		
177	0.67896E+05	0.93190E+04	6181.0869	-4.1670		
178	0.67848E+05	0.10375E+05	6181.1191	-4.1592		
179	0.71277E+05	0.96720E+04	6179.9336	-3.7236		
180	0.76140E+05	0.10650E+05	6178.7998	-3.2598		
181	0.75887E+05	0.12869E+05	6178.2617	-2.7217	3.4153	550.2296
182	0.75785E+05	0.13715E+05	6178.3564	-2.7461		
183	0.75952E+05	0.15245E+05	6178.3232	-2.6436		
184	0.76224E+05	0.16933E+05	6178.2334	-2.5137		
185	0.79926E+05	0.18182E+05	6177.2705	-2.1309		
186	0.83793E+05	0.20485E+05	6176.5576	-2.0273		
187	0.84130E+05	0.24655E+05	6176.5742	-2.0039		
188	0.71112E+05	0.84050E+04	6179.9707	-3.7705		
189	0.75707E+05	0.85930E+04	6179.2207	-3.6211		
190	0.80358E+05	0.95730E+04	6178.2305	-3.0801		
191	0.79949E+05	0.12268E+05	6177.6221	-2.5518		
192	0.79587E+05	0.13695E+05	6177.5117	-2.4316	3.4183	550.9038
193	0.79913E+05	0.15542E+05	6177.4023	-2.3223		
194	0.84042E+05	0.17686E+05	6176.5439	-2.1143		
195	0.87169E+05	0.20046E+05	6175.9346	-2.0449		
196	0.87612E+05	0.24109E+05	6175.9121	-1.9922		
197	0.75490E+05	0.75380E+04	6179.1328	-3.5332		
198	0.80771E+05	0.77760E+04	6178.5293	-3.3389		
199	0.83573E+05	0.84480E+04	6178.3799	-3.3701		
200	0.84376E+05	0.10609E+05	6177.0703	-2.5303		
201	0.84126E+05	0.13356E+05	6176.6211	-2.2607	3.4185	551.3402
202	0.84348E+05	0.15519E+05	6176.5703	-2.2305		
203	0.86783E+05	0.16616E+05	6176.0352	-2.1250		
204	0.89647E+05	0.19189E+05	6175.4395	-2.0596		
205	0.90356E+05	0.23620E+05	6175.3789	-2.0088		
206	0.81029E+05	0.64020E+04	6178.5547	-3.3643		

Table 4.--*Selected output for kinematic simulation of the Bear River valley*--Continued

207	0.83936E+05	0.70210E+04	6181.8857	-4.6260		
208	0.87002E+05	0.78500E+04	6192.5586	-7.3389		
209	0.87067E+05	0.10226E+05	6176.7549	-2.5547		
210	0.85493E+05	0.12029E+05	6176.5420	-2.3721	3.4191	551.8828
211	0.86454E+05	0.14242E+05	6176.2061	-2.2363		
212	0.88942E+05	0.15602E+05	6175.6182	-2.1279		
213	0.92230E+05	0.18436E+05	6174.8896	-2.0693		
214	0.92835E+05	0.23185E+05	6174.8896	-2.0400		
215	0.84090E+05	0.61220E+04	6182.0605	-4.2803		
216	0.87102E+05	0.65820E+04	6193.8721	-5.0117		
217	0.89113E+05	0.75220E+04	6202.0410	-2.6211	0.7480	36.3796
218	0.89653E+05	0.10001E+05	6176.2490	-2.2490	0.7604	37.1791
219	0.87921E+05	0.11964E+05	6176.0410	-2.2813	3.4205	552.6832
220	0.88454E+05	0.13017E+05	6175.8438	-2.2139		
221	0.90943E+05	0.14536E+05	6175.1836	-2.1338		
222	0.93216E+05	0.14999E+05	6174.6094	-2.1191		
223	0.95031E+05	0.18792E+05	6174.3115	-2.0811		
224	0.94893E+05	0.22858E+05	6174.4629	-2.0527		
225	0.89053E+05	0.62030E+04	6220.0977	-1.8174	0.7419	36.0000
226	0.92803E+05	0.63420E+04	6192.4111	-13.0010		
227	0.92704E+05	0.77150E+04	6189.5342	-11.6738		
228	0.93188E+05	0.95080E+04	6175.0615	-2.6113		
229	0.93668E+05	0.10350E+05	6174.5850	-2.3848	3.5541	590.9421
230	0.90455E+05	0.11845E+05	6175.4336	-2.1533	4.2221	590.6586
231	0.93411E+05	0.11830E+05	6174.5400	-2.2305		
232	0.96319E+05	0.12555E+05	6173.3936	-2.0635	4.3762	604.7798
233	0.95541E+05	0.15252E+05	6174.0225	-2.0928		
234	0.98722E+05	0.17876E+05	6173.5781	-2.0879		
235	0.97571E+05	0.20046E+05	6173.8320	-2.0820		
236	0.97213E+05	0.22318E+05	6173.9541	-2.0742		
237	0.96922E+05	0.65850E+04	6176.4355	-5.8359		
238	0.97509E+05	0.76910E+04	6170.7842	-1.9639	0.0000	0.0000
239	0.98044E+05	0.90610E+04	6171.6602	-1.3301	1.1020	5.3816
240	0.98685E+05	0.10536E+05	6172.0674	-1.5674	1.2751	9.8671
241	0.99326E+05	0.12064E+05	6172.9307	-1.9111		
242	0.98917E+05	0.14601E+05	6173.5029	-2.1230	5.1394	885.0693
243	0.10061E+06	0.16176E+05	6173.2803	-2.1006	4.4639	884.9043
244	0.10226E+06	0.17382E+05	6172.9170	-2.0771	4.4635	884.9426
245	0.10158E+06	0.19551E+05	6172.9600	-2.0801		
246	0.10065E+06	0.22301E+05	6173.1670	-2.0771		
247	0.10173E+06	0.66670E+04	6182.7412	-11.6113		
248	0.10290E+06	0.85090E+04	6183.9102	-11.9502	1.8912	76.8841
249	0.10312E+06	0.10567E+05	6175.0352	-3.2549		
250	0.10218E+06	0.13106E+05	6173.8340	-2.2637	2.3782	282.7661
251	0.10304E+06	0.14844E+05	6173.2871	-2.0967		
252	0.10373E+06	0.16530E+05	6172.7568	-2.0166		
253	0.10586E+06	0.19899E+05	6171.7266	-2.0566	4.4643	885.0436
254	0.10519E+06	0.22067E+05	6171.9092	-2.0293		
255	0.10671E+06	0.97570E+04	6202.1670	-9.2266	1.8929	77.0000
256	0.10429E+06	0.12198E+05	6174.2295	-2.3398	2.3794	283.7083
257	0.10541E+06	0.14726E+05	6173.0840	-2.1240		
258	0.10606E+06	0.16571E+05	6172.2549	-2.0244		

Table 4.--*Selected output for kinematic simulation of the Bear River valley*--Continued

259	0.10803E+06	0.20046E+05	6170.9844	-2.2246	5.5292	1024.5630
260	0.10793E+06	0.22000E+05	6171.1523	-2.0420		
261	0.10935E+06	0.10113E+05	6221.6162	-3.0264	3.5087	569.0000
262	0.10831E+06	0.12547E+05	6174.0508	-2.4512		
263	0.10768E+06	0.14081E+05	6173.1230	-2.2129	1.6176	142.0914
264	0.10753E+06	0.16617E+05	6171.8623	-2.1123	1.6223	141.8829
265	0.10854E+06	0.16928E+05	6171.2070	-2.2471	1.3562	105.4747
266	0.10924E+06	0.20093E+05	6170.2461	-2.3857	5.8369	1128.1243
267	0.11115E+06	0.10368E+05	6199.6045	-15.5742	1.1916	35.6000
268	0.10936E+06	0.12594E+05	6174.0029	-2.8730	2.6271	284.3100
269	0.10921E+06	0.14760E+05	6172.1914	-2.6816	1.6191	142.2712
270	0.11060E+06	0.17287E+05	6169.2217	-2.8018		
271	0.11083E+06	0.20138E+05	6168.1553	-2.6152	5.1256	1127.9573
272	0.11468E+06	0.10561E+05	6188.6377	-21.8174	1.1900	35.5224
273	0.11174E+06	0.12952E+05	6172.8496	-5.0098	1.2254	37.3000
274	0.11217E+06	0.15537E+05	6168.9541	-3.8545		
275	0.11324E+06	0.17908E+05	6165.3525	-3.1221		
276	0.11288E+06	0.20180E+05	6165.1211	-2.8311	5.1254	1128.0815
277	0.11712E+06	0.11446E+05	6183.4092	-21.1689		
278	0.11501E+06	0.13041E+05	6182.0938	-18.7539		
279	0.11566E+06	0.15836E+05	6162.6885	-3.8486	0.0000	0.0000
280	0.11657E+06	0.18419E+05	6158.9238	-3.0439	5.1263	1128.5122
281	0.11563E+06	0.20377E+05	6160.6572	-3.0977	5.1265	1128.3047
282	0.11994E+06	0.16290E+05	6150.3311	-3.4014	1.5834	3.6236
283	0.12027E+06	0.17872E+05	6149.1768	-3.5967	5.1385	1133.4602
284	0.11880E+06	0.19992E+05	6155.2207	-3.1006		
285	0.12506E+06	0.16897E+05	6126.8350	-6.4854		
286	0.12491E+06	0.18377E+05	6126.4531	-7.6631	6.2533	1136.3550
287	0.12387E+06	0.20811E+05	6121.4727	-9.5527		
288	0.12303E+06	0.22663E+05	6117.7598	-6.9697		
289	0.12702E+06	0.17521E+05	6123.9092	-9.4688	1.6298	60.0000
290	0.12646E+06	0.21062E+05	6119.2539	-8.9141	4.9903	1080.5667
291	0.12552E+06	0.23865E+05	6118.4756	-9.7451		
292	0.13020E+06	0.18772E+05	6117.8359	-10.4756		
293	0.12915E+06	0.20890E+05	6118.5342	-11.6338		
294	0.12779E+06	0.23220E+05	6115.9883	-9.4287	5.0034	1085.1880
295	0.12785E+06	0.24962E+05	6115.3975	-10.1172		
296	0.13491E+06	0.21917E+05	6112.2168	-13.9971		
297	0.13080E+06	0.24102E+05	6112.3965	-10.7568	5.0178	1090.9470
298	0.13081E+06	0.26161E+05	6107.9717	-8.3320	5.0265	1094.2122
299	0.13926E+06	0.24851E+05	6101.2100	-11.0400		
300	0.13710E+06	0.26341E+05	6101.8613	-10.4414		
301	0.13552E+06	0.27405E+05	6101.5498	-9.1699	6.1304	1100.1445
302	0.13320E+06	0.28842E+05	6102.4609	-8.9414	0.4413	6.8000
303	0.14175E+06	0.27162E+05	6091.5127	-6.5625		
304	0.14007E+06	0.28755E+05	6091.9268	-6.4170		
305	0.13796E+06	0.30613E+05	6092.8818	-6.1123	5.0347	1096.8528
306	0.13607E+06	0.31943E+05	6094.6592	-6.4893		
307	0.14403E+06	0.29157E+05	6083.9287	-4.7188		
308	0.14250E+06	0.30379E+05	6085.0156	-4.7754		
309	0.14114E+06	0.31653E+05	6085.7744	-4.4541	6.1240	1098.2830
310	0.14003E+06	0.32662E+05	6087.6299	-4.9502	1.1835	35.2000

Table 4.--*Selected output for kinematic simulation of the Bear River valley*--Continued

311	0.14583E+06	0.30732E+05	6077.3906	-3.7607		
312	0.14547E+06	0.31896E+05	6076.8379	-3.7578		
313	0.14500E+06	0.33059E+05	6076.2549	-3.6250	4.9432	1064.0339
314	0.14374E+06	0.34069E+05	6077.1895	-3.4990		
315	0.15181E+06	0.33183E+05	6060.9990	0.0010		
316	0.15034E+06	0.35039E+05	6062.0000	0.0000		
317	0.14887E+06	0.37053E+05	6063.0000	0.0000	4.9387	1063.0969
318	0.14798E+06	0.38113E+05	6063.0000	0.0000		

IRRIGATION RECHARGE AND SUPPLEMENTAL PUMPING RATES

FIELD	PUMPING	RECHARGE
1	0.0000000E+00	0.2916928E+02
2	0.0000000E+00	0.3215232E+00
3	0.0000000E+00	0.0000000E+00
4	0.0000000E+00	0.1058258E+03
5	0.0000000E+00	0.0000000E+00
6	0.0000000E+00	0.2908117E+02
7	0.0000000E+00	0.2588240E+02
8	0.0000000E+00	0.5827027E+02
9	0.0000000E+00	0.0000000E+00
10	0.0000000E+00	0.3000324E+02
11	0.0000000E+00	0.5592099E+02
12	0.0000000E+00	0.5536435E+01

GPO 857-984