ATTACHMENT 2.—DOCUMENTATION OF PROGRAMS STLK1 AND STWT1

PROGRAM STLK1

Narrative

Program STLK1 calculates ground-water levels, seepage rates, and bank-storage changes for arbitrarily changing stream-stage and/or recharge stresses applied to confined and leaky aquifers bounded by a fully penetrating stream. The program reads input data provided by the user and then calculates aquifer responses based on the convolution technique. A description of the numbered steps in the code follows:

Main program:

1. Call subroutine OFILE to open input (variable IN), result (variable IO), and plot (variable IP) files.
2. Call subroutine DATAIO to read input data from input file and write input data to result file.
3. Define dimensionless and other program parameters.
4. Call subroutine LINVST to calculate coefficients used for the Stehfest (1970) algorithm.
5. Initialize response and other arrays. These arrays hold the head, seepage, and bank-storage results.
6. Calculate the time rate of change of system stress.
7. Calculate heads, seepage, and bank storage using convolution. This block of instructions, up to step 9, uses the convolution technique to calculate system responses at each time step.
8. Call subroutine LTST1 to calculate dimensionless head (variable HD) and seepage (variable QD) for each value of dimensionless time (variable TD).
9. Write results of convolution for all time steps to result and plot files.
10. Close input, result, and plot files; stop program execution; and end.

Subroutine OFILE:

11. Subroutine OFILE opens input, result, and plot files.

Function LENCHR:

12. Function LENCHR calculates the length of a character string (code from R. S. Regan, USGS, written commun., 1997).

Subroutine DATAIO:

13. Subroutine DATAIO reads input data from the input file and writes this data to the result file.

Subroutine BANNER:

14. Subroutine BANNER writes a program banner to the result file.

Subroutine RDERR:

15. If an error is found in the input data in subroutine DATAIO, subroutine RDERR writes a message to the result file indicating the input line on which the error was found and then stops program execution.

Subroutine LINVST:

16. Subroutine LINVST calculates coefficients used for the Stehfest (1970) algorithm.

Subroutine LTST1:

17. Subroutine LTST1 calculates the Laplace transform solutions for heads and seepage for each dimensionless time (variable TD). A value of TD is passed to LTST1 from the Main program and values of head (variable HDT) and seepage (variable QTD) are returned to the Main program from LTST1.

List of Program Variables

Variable	Definition
AB	Saturated thickness of aquifer.
ABT	Saturated thickness of aquitard.
AK	Hydraulic conductivity of aquifer.
AKT	Hydraulic conductivity of aquitard.
AS	Specific storage of aquifer.
ASC	Storativity (storage coefficient of aquifer).
AST	Specific storage of aquitard.
ASYT	Specific yield of aquitard.
AT	Transmissivity of aquifer.
BANK	DIMENSION (IMAXX), Array of bank-storage volumes per unit stream length at each time step.
BANKV	DIMENSION (IMAXX), Array of bank-storage volumes at each time step.
C1, C2, C3, C4	Coefficients for head and seepage calculations in subroutine LTST1.
CA, CAQ	Coefficients for head and seepage calculations in subroutine LTST1.
DELT	Time-step size.
EXPMAX	Maximum allowable absolute value of exponential arguments.
FH	DIMENSION (IMAXX), Array of the time rate of change of system stresses for heads at each time step.
FQ	DIMENSION (IMAXX), Array of the time rate of change of system stresses for seepage at each time step.
FF	Coefficient for aquifer-width term for calculations of head and seepage in subroutine LTST1.
FI	Counter in subroutine LINVST.
FDEN, FNUM	Coefficients for aquifer-width term for calculations of head and seepage in subroutine LTST1.
G	DIMENSION (20), Array used in the calculation of Stehfest (1970) coefficients in subroutine LINVST.
GAMMA1	Dimensionless ratio of aquitard to aquifer hydraulic conductivity.
GAM1SQ	Square of dimensionless ratio of aquitard to aquifer hydraulic conductivity.
H	DIMENSION (IMAXX), Array of heads at the observation well.
HD	Dimensionless head at observation well at time TD in main program.
HDT	Dimensionless head at observation well at time TD in subroutine LTST1.
HINIT	Initial head at observation well at start of simulation.
HNET	DIMENSION(IMAXX), Array of total stress to system at each time step for calculations of head.
HS	DIMENSION (20), Array used in the calculation of Stehfest (1970) coefficients in subroutine LINVST.
I	Counter in main program and subroutines.
IAQ	Aquifer type: IAQ=0, confined aquifer; IAQ=1, leaky aquifer with constant head overlying aquitard; IAQ=2, leaky aquifer with impervious layer overlying aquitard; IAQ=3, leaky aquifer overlain by water-table aquitard.
ID	Counter in subroutine DATAIO.
IFNAME	Input file name.
ILINE	Integer line counter.
IMAXX	Maximum number of time steps.
IN	Input file unit number.
IO	Result file unit number.
IP	Plot file unit number.
IPLOT	Integer test as to whether or not to write results to plot file: IPLOT=0, results not written to plot file; IPLOT=1, results written to plot file.
IPRINT	Option for printing stress data to result file: IPRINT=0, stress data not printed; IPRINT=1, stress data printed.
IS	Counter in subroutine LINVST.

Variable	Definition
ISTRESS	Stress type: ISTRESS=0, stream-stage fluctuations; ISTRESS=1, recharge/ET; ISTRESS = 2, stream-stage fluctuations and recharge/ET.
IXA	Streambank code: IXA=0, semipervious streambank material absent; IXA=1, semipervious streambank material present.
IXL	Aquifer extent: IXL=0, semi-infinite aquifer; IXL=1, finite-width aquifer.
JT	Counter for upper limit of time in convolution integral.
KS, K1, K2	Counters in subroutine LINVST.
KT	Counter for time in convolution integral.
LENCHR	Length of character string.
MAX	Maximum length of character string.
N	Length of character string.
NH	One half the number of Stehfest (1970) terms.
NS	Number of Stehfest (1970) terms.
NT	Number of stress events (also equals number of time steps).
OFNAME	Result file name.
PDL, PDLQ	Coefficients for calculations of head and seepage in subroutine LTST1.
PFNAME	Plot file name.
PP	Laplace transform variable.
QD	Dimensionless seepage at streambank at time TD in main program and subroutine LTST1.
QNET	DIMENSION(IMAXX), Array of total net stress to system at each time step for calculations of seepage.
QTD	Dimensionless seepage at streambank at time TD in subroutine LTST1.
RECH	DIMENSION(IMAXX), Array of recharge amount at each time step.
RE0, RE0Q	Coefficients for calculations of head and seepage in subroutine LTST1.
SEEP	DIMENSION (IMAXX), Array of seepage per unit stream length at each time step.
SEEPT	DIMENSION (IMAXX), Array of seepage at each time step.
SIGMA1	Dimensionless ratio of aquitard to aquifer storativity.
SIGMAP	Dimensionless ratio of aquifer storativity to aquitard specific yield.
SN	Changes sign of alternating series for array V in subroutine LINVST.
SQRTM	Square root of ratio of aquitard to aquifer hydraulic properties multiplied by Laplace transform variable.
STAGE	DIMENSION (IMAXX), Array of stream-stage level at each time step.
STRING	A character string.
SUMH	Sum of head terms in convolution integral.
SUMQ	Sum of seepage terms in convolution integral.
T	Time.
TD	Dimensionless time.
TINIT	Simulation start time.
TITLE1	First line of title.
TITLE2	Second line of title.
V	DIMENSION (20), Array of Stehfest (1970) coefficients.
VAR	DIMENSION (11), Array of character data listing line-by-line input variables, in subroutine RDERR.
X	Distance to observation well from stream-channel center.
XAA	Streambank leakance.
XAAD	Dimensionless streambank leakance.
XD	Dimensionless distance to observation well.
XDEN	Denominator for seepage term for leaky aquifer overlain by water-table aquitard in subroutine LTST1.

Variable	Definition
XLL	Width of aquifer.
XLLD	Dimensionless width of aquifer.
XLN2	Logarithm of 2.
XM	Ratio of aquitard to aquifer hydraulic properties multiplied by Laplace transform variable.
XNUM	Numerator for seepage term for leaky aquifer overlain by water-table aquitard in subroutine LTST1.
XP, XPQ	Sum of head (XP) and seepage (XPQ) terms in Laplace transform solution.
XSTREAM	Length of stream reach.
XTIME	DIMENSION (IMAXX), Array of times for each stream stage or recharge event.
XZERO	Stream half width.
XZEROD	Dimensionless stream half width.
XZEROSQ	Square of stream half width.

PROGRAM STWT1

Narrative

Program STWT1 calculates ground-water levels, seepage rates, and bank-storage changes for arbitrarily changing stream-stage and/or recharge stresses applied to water-table (or confined) aquifers bounded by a fully penetrating stream. The program reads input data provided by the user and then calculates aquifer responses based on the convolution technique. A description of the numbered steps in the code follows:

Main program:

1. Call subroutine OFILE to open input (variable IN), result (variable IO), and plot (variable IP) files.
2. Call subroutine DATAIO to read input data from input file and write input data to result file.
3. Define dimensionless and other program parameters.
4. Call subroutine LINVST to calculate coefficients used for the Stehfest (1970) algorithm.
5. Initialize response and other arrays. These arrays hold the head, seepage, and bank-storage results.
6. Calculate the time rate of change of system stress.
7. Calculate heads, seepage, and bank storage using convolution. This block of instructions, up to step 9, uses the convolution technique to calculate system responses at each time step.

8. If aquifer is confined, call subroutine LTST1 to calculate dimensionless head (variable HD) and seepage (variable QD) for each value of dimensionless time (variable TD). If aquifer is unconfined, call subroutine LTST2 to calculate dimensionless head and seepage for each value of dimensionless time.
9. Write results of convolution for all time steps to result and plot files.
10. Close input, result, and plot files; stop program execution; and end.

Subroutine OFILE:

11. Subroutine OFILE opens input, result, and plot files.

Function LENCHR:

12. Function LENCHR calculates the length of a character string (code from R.S. Regan, USGS, written commun., 1997).

Subroutine DATAIO:

13. Subroutine DATAIO reads input data from the input file and writes this data to the result file.

Subroutine BANNER:

14. Subroutine BANNER writes a program banner to the result file.

Subroutine RDERR:

15. If an error is found in the input data in subroutine DATAIO, subroutine RDERR writes a message to the result file indicating the input line on which the error was found and then stops program execution.

Subroutine LINVST:

16. Subroutine LINVST calculates coefficients used for the Stehfest (1970) algorithm.

Subroutine LTST1:

17. Subroutine LTST1 calculates the Laplace transform solutions for heads and seepage for confined aquifers for each dimensionless time (variable TD). A value of TD is passed to LTST1 from the Main program and values of head (variable HDT) and seepage (variable QTD) are returned to the Main program from LTST1.

Subroutine LTST2:

18. Subroutine LTST2 calculates the Laplace transform solutions for heads and seepage for water-table aquifers for each dimensionless time (variable TD). A value of TD is passed to LTST2 from the Main program and values of head (variable HD) and seepage (variable QWT) are returned to the Main program from LTST2.

List of Program Variables

Many of the variables used in program STWT1 are equivalent in name and definition to those in program STLK1. For brevity, only those variables that differ in meaning from those of program STLK1 or are only used in program STWT1 are listed here. Definitions for variables in STWT1 that are not listed here can be found in the List of Variables for program STLK1.

Variable	Definition
A1, A2	Coefficients in Newton-Raphson technique in subroutine LTST2.
AKX	Horizontal hydraulic conductivity of aquifer.
ASY	Specific yield of aquifer.
BETA	Product of ratio of vertical to horizontal hydraulic conductivity of aquifer and square of ratio of distance to observation well to saturated thickness of aquifer.
BETA0	Product of ratio of vertical to horizontal hydraulic conductivity of aquifer and square of dimensionless stream half-width.
EPS, EPS0	Current (EPS) and previous (EPS0) values of epsilon in subroutine LTST2.
ERR, ERRQ	Relative error terms for infinite summations of head (ERR) and seepage (ERRQ) in subroutine LTST2.
F, FP	Function (F) and first derivative of function (FP) in Newton-Raphson technique in subroutine LTST2.
FDEN, FNUM	Coefficients for aquifer-width term for calculations of head and seepage in subroutine LTST1 and for head only in subroutine LTST2.
FDENQ, FNUMQ	Coefficients for seepage calculations in subroutine LTST2.
FN	Coefficient for aquifer-width term for calculations of head in subroutine LTST2.
FNQ	Coefficient for seepage term in subroutine LTST2.
HWT	Dimensionless head at observation well at time TD in subroutine LTST2.
IAQ	Aquifer type: IAQ=0, confined aquifer; IAQ=1, water-table aquifer.
IOWS	Type of observation well: IOWS=0, partially penetrating observation well; IOWS=1, fully penetrating observation well; IOWS=2, observation piezometer.
NN	Maximum (integer) number of terms for finite summations in Laplace transform solutions for head and seepage in subroutine LTST2.
NNR	Upper bound on number of Newton-Raphson iterations (100) in subroutine LTST2.
PDL, PDLQ	Coefficients for calculations of head and seepage in subroutines LTST1 and LTST2.

Variable	Definition
PI	The number pi.
QN, QNXD	Terms in the head and seepage Laplace transform solutions in subroutine LTST2.
QWT	Dimensionless seepage at streambank at time TD in subroutine LTST2.
RE0, RE0Q	Coefficients for calculations of head (RE0) and seepage (RE0Q) in subroutines LTST1 and LTST2.
RERRNR	Relative error for Newton-Raphson iteration and summation in subroutine LTST2.
RHS	Right-hand side of function in Newton-Raphson technique in subroutine LTST2.
SIGMA	Ratio of aquifer storativity to specific yield.
SINE	Sine of variable epsilon in subroutine LTST2.
SUMM, SUMT	Summation terms for head in Laplace transform solution in subroutine LTST2.
SUMMQ, SUMTQ	Summation terms for seepage in Laplace transform solution in subroutine LTST2.
XAD	Product of dimensionless streambank leakance and hyperbolic tangent function in Laplace transform solutions for head and seepage in subroutine LTST2.
XDEN	Term in the head and seepage Laplace transform solutions in subroutine LTST2.
XKD	Ratio of vertical to horizontal hydraulic conductivity of aquifer.
XN	Counter for finite summations in Laplace transform solutions for head and seepage in subroutine LTST2.
XN_MAX	Maximum (real) number of terms for finite summations in Laplace transform solutions for head and seepage in subroutine LTST2.
XNUM, XNUMQ	Terms in the head (XNUM) and seepage (XNUMQ) Laplace transform solutions in subroutine LTST2.
XTRMS	Factor used to determine number of terms in the finite summations for Laplace transform solutions for head and seepage in subroutine LTST2.
ZP	Vertical distance from bottom of aquifer to observation piezometer.
Z1	Vertical distance from bottom of aquifer to bottom of screened interval of observation well.
Z2	Vertical distance from bottom of aquifer to top of screened interval of observation well.
ZD	Dimensionless position of observation piezometer.
ZD1	Dimensionless position of bottom of screened interval of observation well.
ZD2	Dimensionless position of top of screened interval of observation well.