

README FILE FOR LMT8 for MODFLOW

[Version 8.1: 02/03/2017]

INTRODUCTION

LMT8 is updated version of the LMT7 package for MODFLOW that enables simulation of transport in packages that are not supported by MT3DMS. LMT8 produces the information needed by MT3D-USGS for multi-species mass transport modeling in the unsaturated zone (new UZT package), streams (new SFT package), and lakes (new LKT package), among other new packages. The LMT Package was originally documented in the USGS Open-File Report 01-82 (Zheng and others, 2001), available from <http://water.usgs.gov/nrp/gwsoftware/modflow2000/ofr01-82.pdf>.

REVISION HISTORY

Version 8.1: 02-03-2017

Added writing of SWR flows to flow-transport link file. At the time of release, MT3D-USGS was not yet capable of processing these flows.

Implemented check for the Seawater Intrusion (SWI2) Package. LMT8 will terminate with an error if SWI2 is active for the flow simulation.

Version 8.0: 09-30-2016

Initial release.

Notes on the LMT Input File for MODFLOW

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The data in the MODFLOW input file for LMT8 are the same as for the original LMT6 version of LMT (see above Internet link to the documentation for LMT6), with a new optional line (shown last in the example below) when solute transport in the unsaturated zone, streams, and lakes is to be simulated. The LMT8 input file must have the following records:

```
OUTPUT_FILE_NAME      [***.FTL]
OUTPUT_FILE_UNIT      [333]
OUTPUT_FILE_HEADER    [extended]
OUTPUT_FILE_FORMAT    [unformatted]
```

The following line is required when the user wants to simulate unsaturated zone transport, streamflow transport, lake transport, or some combination of these.

```
PACKAGE_FLOWS          [ALL]
```

The first item in each line is a keyword (shown in all uppercase) that must be specified exactly as shown except that either uppercase or lowercase can be used. The 2nd item in each line is shown in brackets, which indicates the items are optional. If an optional item is specified, do not include the brackets.

When any of the optional items are omitted, default values as shown above are assigned. Note that the placeholder [***] is replaced by the same root name of the LMT input file.

For the new optional item `PACKAGE_FLOWS`, acceptable arguments to follow are either `ALL` or some combination of `UZF`, `SFR`, or `LAK`. The order of `UZF`, `SFR`, or `LAK` does not matter. When specified, flows associated with the respective package (e.g., `UZF`, etc.) will be written to the `FTL` package. Otherwise, only those fluxes interacting with the groundwater (saturated) system are written, which in the case of `UZF` include recharge, groundwater ET, and spring discharge.

The MODFLOW Name File must include the name of an LMT input file to activate the `LMT8` package and cause MODFLOW to create the flow-transport link file used by MT3D-USGS. The file type in the Name file remains as `LMT6`, because the file is backward compatible. To ensure backward compatibility, the line starting `PACKAGE_FLOWS` is optional. If not specified and the `UZF`, `SFR`, and/or `LAK` package is active, then calculated fluxes between these packages and the groundwater system will be written to the Flow-Transport Link (`FTL`) file and used by the Source-Sink Mixing (`SSM`) package within MT3D-USGS. Commonly, a file extension of ".LMT" is used for the input file. The following is a sample LMT line in the MODFLOW Name File for a file named "test.lmt".

```
LMT6      45   test.lmt
```

The second item is an unused file unit that MODFLOW will use to read the LMT input file. In this example, 45 is used for the unit number.

Notes on the Implementation of LMT8 in MODFLOW

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The source code for the `LMT8` package is found in a Fortran file named `lmt8.f`. To implement `LMT8` in MODFLOW, do the following:

a) Insert the keyword '`LMT8`' (all capital) in the 49th element of the `CUNIT` array in the MODFLOW-NWT main program and b) put the LMT source file (`lmt8.f`) in the same directory as the other MODFLOW source files and recompile.

Notes on the Flow-Transport Link File

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The flow-transport link file produced by MODFLOW through the `LMT8` package can be saved in either an unformatted (binary) file or an ASCII text file with free format. MODFLOW will write one of two headers to the beginning of the `FTL` file that reads either '`MTGS1.00.00`' or '`MT3D4.00.00`' depending on whether the `UZF1`, `SFR2`, or `LAK3` package is active in the simulation. Regardless of whether `PACKAGE_FLOWS` appears in the `LMT8` input file, MT3D-USGS will always write the header as `MTGS1.00.00` when `UZF1`, `SFR2`, `LAK3` or `SWR1` is active to accommodate these packages, either as boundary conditions to the groundwater system or for writing fluxes within their respective domains (e.g., cell-to-cell fluxes within the unsaturated zone, or reach-to-reach within the streams).

The header `MT3D4.00.00` can be read by either MT3D-USGS or MT3DMS while the latter,

MTGS1.00.00, can only be read by MT3D-USGS version 1.0 or later. Because an ASCII text file requires much more disk space than an equivalent unformatted (binary) file, the ASCII text file option is intended mainly for debugging purposes when the unformatted (binary) option fails to work properly.

The structure of unformatted (binary) files used in MODFLOW-NWT is controlled by a number of "specifiers" in the file 'openspec.inc' as part of MODFLOW-NWT distribution files. These specifiers are used in the OPEN statement to open the flow-transport link file along with other input/output files. If non-standard specifiers are used, such as FORM = 'BINARY', it may be necessary to use the same OPEN statement specifiers in the MT3D-USGS code for the flow-transport link file to be read by MT3D-USGS correctly. For MT3D-USGS version 1.0 or later, the structure of unformatted files is specified in the source file 'filespec.inc', similar to 'openspec.inc' used by MODFLOW-NWT.

MODFLOW Internal Flow and Sink/Source Packages Supported in LMT

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LMT8 supports the following MODFLOW Internal Flow and Sink/Source Packages: BCF7, LPF7, HUF7; RIV7, RCH7, WEL7, DRN7, EVT7, GHB7, STR7, RES7, FHB7, MNW, ETS7, DRT7, UZF1, SFR2, LAK3 and [SWR1](#).

Format of the FTL file with header MTGS1.00.00

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MT3D-USGS simulates transport in the structured finite-difference grid of the aquifer domain, but can also simulate transport in other coupled domains, such as a stream network, lake cells, and/or the unsaturated zone. The FTL file, therefore, may contain flows for these additional domains as well as exchanges between these domains.

In order to support new functionality in MT3D-USGS, a new alternative structure of the Flow-Transport Link (FTL) is available for simulating solute transport within or between domains not historically supported by MT3DMS and the groundwater system (unsaturated zone, streams, and lakes). However, to ensure backward compatibility, the old format will be used when transport problem does not include interaction with one of the aforementioned domains.

For details of the original FTL file format, see Appendix C of the MT3DMS manual. The following describes the contents of the FTL file when the header MTGS1.00.00 is used.

FOR EACH SIMULATION:

F0. VERSION, MTWEL, MTDNR, MTRCH, MTEVT, MTRIV, MTGHB, MTCHD, MTISS, MTNPER

Explanation of variables

- VERSION (character*11)—a character string used by MT3D-USGS to identify FTL file generated by MODFLOW-NWT version 1.1 or later. LMT8 will set VERSION as either 'MT3D4.00.00' or 'MTGS1.00.00' depending on whether UZF1, SFR2, or LAK3 is present in the flow model. MT3D-USGS will use FTL files with either header, but appropriate flags are set for reading the FTL based on what information is provided based on the variable VERSION.

- MTWEL—an integer flag indicating whether wells (the WEL package) are included in the MODFLOW simulation:
 - MTWEL>0, wells are included in the MODFLOW simulation;
 - MTWEL=0, wells are not included in the MODFLOW simulation.
- MTDNR—an integer flag indicating whether drains (the DRN package) are included in the MODFLOW simulation. The convention is the same as that for MTWEL.
- MTRCH—an integer flag indicating whether recharge (the RCH package) is included in the MODFLOW simulation. The convention is the same as that for MTWEL.
- MTEVT—an integer flag indicating whether evapotranspiration (the EVT package) is included in the MODFLOW simulation. The convention is the same as that for MTWEL.
- MTRIV—an integer flag indicating whether rivers, as simulated by the RIV package, are included in the MODFLOW simulation. The convention is the same as that for MTWEL. Note that for the standard header option (MT3D4.00.00), MTRIV can represent either the RIV package or the Stream (STR) package since only one of these two packages can be present in the same simulation. For the new header option, a separate entry MTSTR is used to indicate the STR package.
- MTGHB—an integer flag indicating whether general-head-dependent boundaries (the GHB package) are included in the MODFLOW simulation. The convention is the same as that for MTWEL.
- MTCHD—an integer flag indicating whether any constant-head boundary cells are included in the MODFLOW simulation. The convention is the same as that for MTWEL.
- MTISS—an integer flag indicating whether the flow simulation is steady-state or transient: MTISS>0, the flow simulation is steady-state. MTISS=0, the flow simulation is transient in one or more stress periods.
- MTNPER—the number of stress periods used in the flow simulation.

F1. NPCKGTX

- NPCKGTX—an integer used by MT3D-USGS to determine the number of flow package text entries that are to be read next.

(If NPCKGTX>0, there must be NPCKGTX records of F2)

F2. PCKGTX

- PCKGTX—(character*20)—a character string used by MT3D-USGS to signify the type of information that is contained in the flow-transport link file. Values for PCKGTX include:
 - "STR"
 - "RES"
 - "FHB"
 - "DRT"
 - "ETS"
 - "MNW"
 - "MNW FLOWS" (not supported yet)
 - "UZP"
 - "UZP FLOWS"
 - "LAK"
 - "LAK FLOWS"
 - "SFR"
 - "SFR FLOWS"

- “SWR” (added in LMT8 version 8.1)
- “SWR FLOWS” (not supported yet)
- “CONNECT SFR LAK”
- “CONNECT SFR UZF”
- “CONNECT LAK UZF”
- and others that may be added in the future.

FOR EACH TIME STEP OF THE FLOW SOLUTION:

F3. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F4. THKSAT(NCOL,NROW,NLAY)

- KPER—the stress period at which the cell saturated thicknesses are saved.
- KSTP—the time step at which the cell saturated thicknesses are saved.
- NCOL, NROW, NLAY—the numbers of columns, rows and layers, respectively.
- LABEL(character*16)—a character string equal to ‘THKSAT’, the identifier for the saturated cell thickness array.
- THKSAT—Saturated thickness of unconfined cells. For inactive cells, the value must be set equal to 1.E30. For confined cells, the value must be set to –111.

(If NCOL=1, skip F5 and F6)

F5. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F6. QX(NCOL,NROW,NLAY)

- LABEL(character*16)—a character string equal to ‘QXX’, the identifier for the QX array.
- QX—volumetric flow rates (L3T-1) between cells at cell interfaces along rows (or the x- axis). Positive in the direction of increasing J indexes. Start at the right face of column 1.

(If NROW=1, skip F7 and F8)

F7. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F8. QY(NCOL,NROW,NLAY)

- LABEL(character*16)—a character string equal to ‘QYY’, the identifier for the QY array.
- QY—volumetric flow rates (L3T-1) between cells at cell interfaces along columns (or the y-axis). Positive in the direction of increasing I indexes. Start at the lower face of row 1.

(If NLAY=1, skip F9 and F10)

F9. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F10. QZ(NCOL,NROW,NLAY)

- LABEL(character*16)—a character string equal to ‘QZZ’, the identifier for the QZ array.
- QZ—volumetric flow rates (L3T-1) between cells at cell interfaces along layers (or the z axis). Positive in the direction of increasing K indexes. Start at the bottom face of layer 1.

(If MTOSS>0, skip F11 and F12)

F11. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F12. QSTO(NCOL,NROW,NLAY)

- LABEL(character*16)—a character string equal to ‘STO’, the identifier for the QSTO array.
- QSTO—volumetric flow rates (L3T-1) released from or accumulated in transient groundwater storage. Positive for release and negative for accumulation.

F13. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NCNH

- LABEL(character*16)—a character string equal to 'CNH', the identifier for constant-head boundaries.
- NCNH—total number of constant-head boundary cells.

(If NCNH>0, there must be NCNH records of F14)

F14. KCNH, ICNH, JCNH, QCNH

- KCNH, ICNH, JCNH—cell indices of each constant-head boundary cell.
- QCNH—volumetric net flow rate (L3T-1) out of or into each constant-head cell, including the exchange between neighboring constant-heads cells. Positive if the flow is out of the constant-head cell, negative otherwise.

(If wells are not present in the flow model, skip F15 and F16)

F15. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NWEL

- LABEL(character*16)—a character string equal to 'WEL', the identifier for wells.
- NWEL—total number of wells.

(If NWEL>0, there must be NWEL records of F16)

F16. KWEL, IWEL, JWEL, QWEL

- KWEL, IWEL, JWEL—cell indices of each well.
- QWEL—volumetric flow rate (L3T-1) of each well. Positive if the flow is into the cell, negative otherwise. (The same convention is followed by the rest of sink/source terms).

(If drains are not present in the flow model, skip F17 and F18)

F17. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NDRN

- LABEL(character*16)—a character string equal to 'DRN', the identifier for drains.
- NDRN—total number of drains.

(If NDRN>0, there must be NDRN records of F18)

F18. KDRN, IDRN, JDRN, QDRN

- KDRN, IDRN, JDRN—cell indices of each drain.
- QDRN—volumetric flow rate (L3T-1) of each drain.

(If recharge is not present in the flow model, skip F19, F20 and F21)

F19. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F20. IRCH(NCOL,NROW)

F21. RECH(NCOL,NROW)

- LABEL(character*16)—a character string equal to 'RCH', the identifier for recharge.
- IRCH—layer indices of the recharge flux.
- RECH—volumetric recharge rate (L3T-1).

(If evapotranspiration is not present in the flow model, skip F22, F23, and F24)

F22. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F23. IEVT(NCOL,NROW)

F24. EVTR(NCOL,NROW)

- LABEL(character*16)—a character string equal to 'EVT', the identifier for evapotranspiration.
- IEVT—layer indices of the evapotranspiration flux.

- EVTR—volumetric evapotranspiration rate (L3T-1).

(If rivers are not present in the flow model, skip F25 and F26)

F25. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NRIV

- LABEL(character*16)—a character string equal to 'RIV', the identifier for rivers.
- NRIV—total number of rivers.

(If NRIV>0, there must be NRIV records of F26)

F26. KRIV, IRIV, JRIV, QRIV

- KRIV, IRIV, JRIVN—cell indices of each river (or stream) cell.
- QRIV—volumetric flow rate (L3T-1) of each river (or stream) cell.

(If general-head-dependent boundaries are not present in the flow model, skip F27 and F28)

F27. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NGHGB

- LABEL(character*16)—a character string equal to 'GHB', the identifier for general-head-dependent boundaries.
- NGHGB—total number of GHB cells.

(If NGHGB>0, there must be NGHGB records of F28)

F28. KGHB, IGHGB, JGHGB, QGHGB

- KGHB, IGHGB, JGHGB—cell indices of each general-head-dependent boundary cell.
- QGHGB—volumetric flow rate (L3T-1) of each general-head-dependent boundary cell.

(If "STR" is present in PCKGTX, read F29 and F30)

F29. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NSTR

LABEL (character*16)—a character string equal to 'STR', the identifier for streams.

NSTR—total number of STR cells.

(If NSTR>0, there must be NSTR records of F30)

F30. KSTR, ISTR, JSTR, QSTR

- KSTR, ISTR, JSTR—cell indices of each stream cell.
- QSTR—volumetric flow rate (L3T-1) of each stream cell.

(If "RES" is present in PCKGTX, read F31 and F32)

F31. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NRES

- LABEL(character*16)—a character string equal to 'RES', the identifier for reservoirs.
- NRES—total number of reservoir cells.

(If NRES>0, there must be NRES records of F32)

F32. KRES, IRES, JRES, QRES

- KRES, IRES, JRES—cell indices of each reservoir cell.
- QRES—volumetric flow rate (L3T-1) of each reservoir cell.

(If "FHB" is present in PCKGTX, read F33 and F34)

F33. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NFHB

- LABEL(character*16)—a character string equal to 'FHB', the identifier for the FHB flow term.
- NFHB—total number of transient specified-flow cells.

(If NFHB>0, there must be NFHB records of F34)

F34. KFHB, IFHB, JFHB, QFHB

- KFHB, IFHB, JFHB—cell indices of each transient specified-flow cell.
- QFHB—volumetric flow rate (L3T-1) of each transient specified-flow cell.

(If “DRT” is present in PCKGTX, read F35, F36 and F37)

F35. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NDRTCL+NDRTFLOW

- LABEL(character*16)—a character string equal to ‘DRT’, the identifier for the DRT flow term.
- NDRTCL—total number of drain-with-return-flow cells.
- NDRTFLOW—total number of recipient cells that receive return flow.

(If NDRTCL>0, there must be NDRTCL records of F36 alternating with NDRTFLOW records of F37)

F36. KDRT, IDRT, JDRT, QDRT, MHOST, QSW

(If this drain-with-return-flow cell has a recipient cell, then read F35)

F37. KRCF, IRCP, JRCF, QRCF, MHOST, QSW

- KDRT, IDRT, JDRT—cell indices of each drain-with-return-flow cell.
- QDRT—volumetric flow rate (L3T-1) of each drain-with-return-flow cell.
- MHOST—is the node number ($NCOL * NROW * (KDRT - 1) + NCOL * (IDRT - 1) + JDRT$) of the host cell.
- QSW—is zero.
- KRCF, IRCP, JRCF—cell indices of the recipient cell.
- QRCF—volumetric flow rate (L3T-1) for the recipient cell. QRCF may be less than QDRT.

(If “ETS” is present in PCKGTX, read F38, F39, F40)

F38. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F39. IETS(NCOL,NROW)

F40. ETSR(NCOL,NROW)

- LABEL(character*16)—a character string equal to ‘ETS’, the identifier for segmented recharge.
- Layer indices of the segmented ET flux

(If “MNW1” or “MNW2” packages are present in PCKGTX, skip F41 and F42)

F41. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NMNW

- LABEL(character*16)—a character string equal to ‘MNW’, the identifier for the MNW flow term.
- NMNW—total number of multi-node well cells, which will be greater than or equal to the number of individual multi-node wells.

(If NMNW>0, there must be NMNW records of F42)

F42. KMNW, IMNW, JMNW, QMNW, IDMNW, QSW

- KMNW, IMNW, JMNW—cell indices of each multi-node well cell.
- QMNW—volumetric flow rate (L3T-1) of each multi-node well cell.
- IDMNW—is the id for the MNW well.
- QSW—is zero.

(If “UF” is present in PCKGTX, read F43 through F48. Note that when “UF FLOWS” is present in PCKGTX, “UF” will not be present)

F43. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F44. IUZFRCH(NCOL,NROW)

F45. UZFLWT(NCOL,NROW)

- LABEL (character*16)—a character string equal to 'UZF RECHARGE', the identifier for UZF-calculated recharge to the saturated zone.
- IUZFRCH – layer indices of the UZF-calculated recharge flux
- UZFLWT – volumetric UZF-calculated recharge rate (L3T-1)

F46. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F47. IGWET(NCOL,NROW)

F48. GWET(NCOL,NROW)

- LABEL (character*16)—a character string equal to 'GW-ET', the identifier for UZF-calculated groundwater evapotranspiration from the saturated zone.
- IGWET – layer indices of the UZF-calculated groundwater evapotranspiration flux
- GWET – volumetric UZF-calculated groundwater evapotranspiration rate (L3T-1)

(If "UZF FLOWS" is present in PCKGTX, read F49 through F59. Note that when "UZF" is present in PCKGTX, "UZF FLOWS" will not be present)

F49. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F50. RTSOLWC(NCOL,NROW,NLAY)

- LABEL (character*16)—a character string equal to 'WATER CONTENT', the identifier for UZF average water content in the unsaturated zone encompassed by that cell. Owing to the internal discretization used by the UZF package for routing wetting and drying waves through the unsaturated zone, only the average water content over the grid cell is reported in the FTL file.
- RTSOLWC – layer indices of the UZF-calculated groundwater evapotranspiration flux

F51. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F52. RTSOLFL(NCOL,NROW,NLAY)

- LABEL (character*16)—a character string equal to 'UZ FLUX', the identifier for vertical unsaturated-zone fluxes across layer interfaces.
- RTSOLFL(NCOL,NROW,NLAY) – volumetric flow rates (L3T-1) of unsaturated-zone flow along layers. As with QZ, RTSOLFL is positive in the direction of increasing K indexes and start at the bottom face of layer 1.

F53. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F54. RTSOLDS(NCOL,NROW,NLAY)

- LABEL (character*16)—a character string equal to 'UZQSTO', the identifier for unsaturated-zone change in storage.
- RTSOLDS(NCOL,NROW,NLAY) – volumetric flow rates (L3T-1) released from or accumulated in transient unsaturated-zone storage. Positive for release and negative for accumulation.

F57. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F58. GRIDET(NCOL,NROW,NLAY)

- LABEL (character*16)—a character string equal to 'UZ-ET', the identifier for evapotranspiration originating from the unsaturated-zone.
- GRIDET – volumetric unsaturated-zone evapotranspiration rates (L3T-1) Unlike GWET, unsaturated-zone evapotranspiration may occur from multiple layers at the same row/column index.

F57. KPER, KSTP, NCOL, NROW, NLAY, LABEL

F58. IGWET(NCOL,NROW)

F59. GWET(NCOL,NROW)

- LABEL (character*16)—a character string equal to 'GW-ET', the identifier for UZF-calculated groundwater evapotranspiration from the saturated zone.
- IGWET and GWET – see items F47 and F48, respectively.

(If "LAK" or "LAK FLOWS" is present in PCKGTXT, read F60 through F61)

F60. KPER, KSTP, NCOL, NROW, NLAY, LABEL, LKNODE

- LABEL (character*16) – a character string equal to either 'LAK' or 'LAK FLOWS' depending on which label appears in PCKGTXT.
- LKNODE – number of lake-groundwater cell interactions that will be listed in item F61

(If LKNODE>0, there must be LKNODE records of F61)

F61. IL, IR, IC, FLOB, LAKE, 0

- IL, IR, IC – cell indices of each LAK cell.
- FLOB – Flow through the lakebed for the cell at location IL, IR, and IC (L3T-1).
- LAKE – LAK number interacting with cell IL, IR, and IC.
- 0 – An unused place holder required by the read utility in MT3D-USGS. The same read utility is used in different places.

(If "LAK FLOWS" is present in PCKGTXT, read F62 through F64. Note that when "LAK" is present in PCKGTXT, F62 through F64 will not be written)

F62. KPER, KSTP, TEXT, NLAKES, NLKFLWTYP, NLAKCON

F63. LAKFLOWTYPE(NLKFLWTYP)

- TEXT (character*16) – a character string equal to 'LAK FLOWS', an identifier for LAK-specific fluxes (i.e., evaporation and/or precipitation occurring directly on a LAK surface).
- NLAKES – Number of lakes simulated in the LAK package and number of lines that will be read in item F63
- NLKFLWTYP – Number of lake-specific state variables and fluxes that will be listed in F63 depending on what is simulated. 1 column of data will appear for each of the following variables when required by the simulation: 1) lake volume; 2) change in lake volume; 3) precipitation; 4) evaporation; 5) overland runoff specified by the user in the LAK input file (runoff generated by the UZF1 package is written in the CONNECT LAK UZF section; and 6) a user-specified withdraw from a lake and removed from the model.
- NLAKCON – Number of lake-to-lake flows. Because MT3D-USGS does not currently support coalescing lakes, this value will always be zero until functionality is added to support coalescing lakes.
- LAKFLOWTYPE – Column headers identifying which values are present F64. Header values correspond to the flows described in NLKFLWTYP and are 'VOLUME', 'DELVOL', 'PRECIP', 'EVAP', 'RUNOFF', and/or 'WITHDRAW'. Only values that are simulated are printed. So if precipitation is zero, this column of data will be omitted from the linker file.

(If NLKFLWTYP>0, there must be NLAKES records of F64)

F64. VOLOLD, DELVOLLAK, PRECIP, EVAP, RUNF, WTHDRW

- VOLOLD – Total lake volume at the beginning of the time step (L3).
- DELVOLLAK – Change in lake volume during the time step (L3T-1).

- PRECIP – Precipitation occurring on the surface of the lake (L3T-1).
- EVAP – Evaporation occurring from the surface of the lake (L3T-1).
- RUNF – User-specified runoff into the lake (L3T-1).
- WTHDRW – User-specified withdraw from the lake. Water is removed from the model (L3T-1).

(If “SFR” or “SFR FLOWS” is present in PCKGTX, read F65 through F66.

F65. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NSTRM

- LABEL (character*16) – a character string equal to either ‘SFR’ or ‘SFR FLOWS’ depending on which label appears in PCKGTX.
- NSTRM – number of stream-groundwater cell interactions that will be listed in item F66. Also, equal to the total number of stream reaches in the simulation.

(If NSTRM>0, there must be NSTRM records of F66)

F66. IL, IR, IC, STRM, STRLEN

- IL, IR, IC – cell indices of each SFR cell.
- STRM – Flow through the streambed for the cell at location IL, IR, and IC (L3T-1).
- STRLEN –Length of stream within cell IL, IR, and IC (L).

(If “SFR FLOWS” is present in PCKGTX, read F67 through F69. Note that when “SFR” is present in PCKGTX, “SFR FLOWS” will not be present)

F67. KPER, KSTP, LABEL, NSTRM, NFLOWTYPE, NINTOT

F68. FLOWTYPE(NFLOWTYPE)

- LABEL (character*16) – a character string equal to ‘SFR FLOWS’, an identifier for SFR-specific fluxes (e.g., evaporation and/or precipitation occurring directly on a SFR surface)
- NFLOWTYPE – Number of stream (SFR2) specific state variables and fluxes that will be listed in F68 depending on what is simulated. One column of data will appear for each of the following variables when required by the simulation: 1) volume of water in the stream reach; 2) SFR reach length within the cell; 3) precipitation; 4) evaporation; and 5) overland runoff specified by the user in the SFR input file (runoff generated by the UZF1 package is written in the CONNECT SFR UZF section).
- NINTOT – Number of stream reach-to-stream reach fluxes. Reach-to-reach flows may include confluence and diversion flows, headwater flows (i.e., user-specified inflow to a segment), network sink flow (i.e., flow exiting the model), and one-to-one reach flow within a segment. Stream flows interacting with lakes are written in the CONNECT SFR LAK section.

(If NSTRM>0, there must be NSTRM records of F68)

F69. VOL, RCHLEN, PRECIP, EVAP, RUNOF

- VOL – Total volume of water in a stream reach (L3).
- RCHLEN – Length of channel within a grid cell (L).
- PRECIP – Precipitation occurring on the surface of the stream (L3T-1).
- EVAP – Evaporation occurring from the surface of the stream (L3T-1).
- RUNOF – User-specified runoff into the stream reach (L3T-1). Note that this runoff value will only be a fraction of the total user-specified runoff, which is apportioned to each stream reach within a segment in direct relation to the fraction of the total length of the stream channel within the segment that is present in each reach.

(If NINTOT>0, there must be NINTOT records of F70. NINTOT may be greater than NSTRM to account for confluences, diversions, and user-specified stream-network sources and sinks)

F70. I, L, IDISP, FLOWIN, XSA

- I, L – Node from which flow is leaving and entering, respectively. Node numbers are assigned based on their position within the list of reach data in the SFR2 input file. Thus, the first entry in this list is 1, the last entry is number NSTRM. -999 appearing in either I or L signifies a stream network source (I) or sink (L); that is, user-specified inflow to the stream network will result in -999 being written in position I, whereas internally calculated exit flows after accounting for all upstream interactions will result in -999 being written in position J.
- IDISP – A flag for indicating whether or not dispersion should be simulated in the reach-to-reach transport calculation.
- FLOWIN – Flow rate from I to L (L3T-1).
- XSA – Cross-sectional area through which FLOWIN travels from I to L (L2).

(If "SWR" is present in PCKGTX, read Fswr1 through Fswr4.)

Fswr1. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NQAQCONN

- LABEL (character*16) – a character string equal to either 'SWRQAQ'.
- NQAQCONN – number of SWR reach-groundwater cell interactions that will be listed in item Fswr2. Also, equal to the total number of surface water routing reaches in the simulation.

(If NQAQCONN>0, there must be NQAQCONN records of Fswr2)

Fswr2. IL, IR, IC, QSWR

- IL, IR, IC – cell indices of each SFR cell.
- QSWR – Volumetric flow from SWR to the aquifer for the cell at location IL, IR, and IC (L3T-1).

Fswr3. KPER, KSTP, NCOL, NROW, NLAY, LABEL, NSWRGWET

- LABEL (character*16) – a character string equal to either 'SWRGWET'.
- NSWRGWET – number of SWR reach GWET values that will be listed in item Fswr4.

(If NSWRGWET >0, there must be NSWRGWET records of Fswr4)

Fswr4. IL, IR, IC, QSWRGWET

- IL, IR, IC – cell indices of each SFR cell.
- QSWRGWET – SWR groundwater ET for the cell at location IL, IR, and IC (L3T-1).

(If "CONNECT SFR LAK" is present in PCKGTX, read F71 through F72)

F71. KPER, KSTP, LABEL, NSFRLAK

- LABEL (character*16) – A character string equal to 'CONNECT SFR LAK', an identifier for SFR-LAK interaction fluxes (e.g., streams pouring into lakes and/or outflow from a lake into a stream, natural or managed [specified] release)
- NSFRLAK – Number of SFR-LAK connections

(If NSFRLAK>0, there must be NSFRLAK records of F72)

F72. J, LAKSFR, SWLAK, 0

- J – Is the index of the SFR reach, based on where it appears in the reach input section of the SFR input file, from which flow leaves and enters a lake
- LAKSFR – Is the index of the LAK receiving flow from reach J. LAKSFR is based upon the order of which lakes are specified within the LAK input file.

- SWLAK – The flowrate between reach J and lake with index number LAKSFR. The sign convention for SWLAK is positive where the direction of flow is from SFR to LAK and negative where the direction of flow is from LAK to SFR.
- 0 – A dummy placeholder expected by the MT3D-USGS read utility. Because the same reader is used for 'CONNECT SFR LAK', 'CONNECT SFR UZF', and 'CONNECT LAK UZF', the value appearing in this position is needed in 'CONNECT SFR UZF', for example, but not 'CONNECT SFR LAK'.

(If "CONNECT SFR UZF" is present in PCKGTX, read F73 through F74)

F73. KPER, KSTP, LABEL, NSFRCON

- LABEL (character*16) – A character string equal to 'CONNECT SFR UZF', an identifier for UZF-calculated runoff entering streams.
- NSFRCON – The number of connections between grid cells with simulated runoff and SFR reaches.

(If NSFRCON >0, there must be NSFRCON records of F74)

F74. CT, N, Q, VALUE

- CT – Is the index of the SFR reach, based on where it appears in the reach input section of the SFR input file, amended with UZF-calculated runoff flow.
- N – Is the index number of the cell from which UZF-calculated runoff is originating. The cell index number is calculated as $(L-1)*NROW*NCOL + (R-1)*NCOL + C$, where L, R, and C are the layer, row, and column numbers, respectively, of the cell generating runoff, and NROW and NCOL are the total number of rows and columns, respectively, in the model grid.
- Q – Is the runoff from cell N to stream reach CT (L3T-1).
- VALUE – An integer value equal to either 1, 2, or 3 that indicates the nature of the runoff. A value of 1 is assigned to groundwater discharge (i.e., spring flow) runoff. A value of 2 is assigned to runoff resulting from rejected infiltration rooted in saturation excess. A value of 3 is assigned to runoff resulting from infiltration rates in excess of the vertical hydraulic conductivity of that cell.

(If "CONNECT LAK UZF" is present in PCKGTX, read F75 through F76)

F75. KPER, KSTP, LABEL, NLAKCON

- LABEL (character*16) – A character string equal to 'CONNECT LAK UZF', an identifier for UZF-calculated runoff entering lakes.
- NLAKCON – The number of connections between grid cells with simulated runoff and lakes.

(If NLAKCON >0, there must be NLAKCON records of F76)

F76. LK, N, Q, VALUE

- LK – Is the index of the lake, based on the order it appears in the LAK input file, amended with UZF-calculated runoff flow.
- N – Is the index number of the cell from which UZF-calculated runoff is originating. The cell index number is calculated as $(L-1)*NROW*NCOL + (R-1)*NCOL + C$, where L, R, and C are the layer, row, and column numbers, respectively, of the cell generating runoff, and NROW and NCOL are the total number of rows and columns, respectively, in the model grid.
- Q – Is the runoff from cell N to lake LK (L3T-1).
- VALUE – An integer value equal to either 1, 2, or 3 that indicates the nature of the runoff. A value of 1 is assigned to groundwater discharge (i.e., spring flow) runoff. A value of 2 is assigned to runoff resulting from rejected infiltration rooted in saturation excess. A value of 3 is assigned to runoff resulting from infiltration rates in excess of the vertical hydraulic conductivity of that cell.

to runoff resulting from infiltration rates in excess of the vertical hydraulic conductivity of that cell.

(If "CONNECT SNK UZF" is present in PCKGTXT, read F77 through F78)

F77. KPER, KSTP, LABEL, NSNKCON

- LABEL (character*16) – A character string equal to 'CONNECT LAK UZF', an identifier for UZF-calculated runoff that is removed from the simulation.
- NSNKCON – The number of UZF cells with runoff that is removed from the simulation.

(If NSNKCON >0, there must be NSNKCON records of F78)

F78. SNK, N, Q, VALUE

- SNK – Always equal to -999 which signifies that the UZF-calculated runoff flow is removed from the simulation.
- N – Is the index number of the cell from which UZF-calculated runoff is originating. The cell index number is calculated as $(L-1)*NROW*NCOL + (R-1)*NCOL + C$, where L, R, and C are the layer, row, and column numbers, respectively, of the cell generating runoff, and NROW and NCOL are the total number of rows and columns, respectively, in the model grid.
- Q – Is the runoff from cell N that is removed from the simulation (L3T-1).
- VALUE – An integer value equal to either 1, 2, or 3 that indicates the nature of the runoff. A value of 1 is assigned to groundwater discharge (i.e., spring flow) runoff. A value of 2 is assigned to runoff resulting from rejected infiltration rooted in saturation excess. A value of 3 is assigned to runoff resulting from infiltration rates in excess of the vertical hydraulic conductivity of that cell.