

WRAP Additions and Revisions

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Introduction

The Water Rights Analysis Package (WRAP) has evolved since the late 1980's with continual additions and improvements to the software package. The modifications are described by this report as information for model-users whose applications may have spanned over timeframes involving multiple versions of the model. Maintaining a record of modifications is also useful in the continuing endeavor to improve and expand the modeling system. More recent modifications are described here in greater detail than those occurring earlier. Many additional update sections have been periodically added to this *Additions and Revisions Report* since the initial September 2006 version.

The development of WRAP is described in the *Acknowledgements* and *Chapter 1* of the *Reference Manual*. The model dates back to a 1986-1988 research project at Texas A&M University sponsored by a cooperative federal-state research program administered by the U.S. Department of the Interior and the Texas Water Resources Institute (TWRI). In 1997, the Texas Natural Resource Conservation Commission (TNRCC) incorporated WRAP in the Water Availability Modeling (WAM) System implemented pursuant to the 1997 Senate Bill 1. The TNRCC was renamed the Texas Commission on Environmental Quality (TCEQ) in 2002. WRAP has been greatly expanded and improved during 1997-2003 and 2005-2019 at Texas A&M University under the auspices of the TCEQ. Other sponsors have also contributed to the research and development effort at various times. Improvements are continuing to be made.

WRAP Documentation

WRAP is documented by the following *Reference, Users, Fundamentals, Daily, Hydrology, Salinity, and Programming Manuals* which are published as Texas Water Resources Institute (TWRI) technical reports (TRs).

Water Rights Analysis Package (WRAP) Modeling System Reference and Users Manuals, by R. Wurbs, TWRI TR-255 and TR-256, First Edition Aug 2003, 2nd Ed. Apr 2005, 3rd Ed. Sep 2006, 4th Ed. Mar 2008, 5th Ed. Aug 2008, 6th Ed. Jan 2009, 7th Ed. Jul 2010, 8th Ed. Sep 2011, 9th Ed. Aug 2012, 10th Ed. Aug 2013, 11th Ed. August 2015, 12th Edition May 2018, 13th Edition, January 2021.

Fundamentals of Water Availability Modeling with WRAP, by R. Wurbs, TWRI TR-283, First Edition April 2005, 2nd Ed. Sep 2006, 3rd Ed. May 2007, 4th Ed. Mar 2008, 5th Ed. July 2010, 6th Ed. September 2011, 7th Ed. August 2013, 8th Ed. July 2018, 7th Ed. May 2019.

Water Rights Analysis Package (WRAP) Daily Modeling System, by R. Wurbs and R. Hoffpauir, TWRI TR 430, 1st Ed. Aug 2012, 2nd Ed. Aug 2013, 3rd Ed. May 2019, 4th Ed. Jan 2021.

Water Rights Analysis Package (WRAP) River System Hydrology, by R. Wurbs, TWRI TR-431, First Edition November 2012, Second Edition August 2013, Third Edition May 2019.

Salinity Simulation with WRAP, by R. Wurbs, TWRI TR-317, First (and only) Edition, July 2009.

Water Rights Analysis Package (WRAP) Programming Manual, by R. Wurbs and R. Hoffpauir, TWRI TR-388, First Edition July 2010, 2nd Edition August 2012, 3rd Edition August 2013, 4th Edition August 2015, 6th Edition May 2019, 7th Edition January 2021.

Prior to being replaced by the set of manuals listed above, WRAP was documented by the following versions of a single manual and later an additional supplemental manual.

Water Rights Analysis Program (TAMUWRAP), Model Description and Users Manual, R.A. Wurbs and W.B. Walls, Texas Water Resources Institute, June 1988.

Water Rights Analysis Package (TAMUWRAP), Model Description and Users Manual, R. Wurbs, D.D. Dunn, and W.B. Walls, TWRI TR-146, March 1993, Revised October 1996.

Water Rights Analysis Package (WRAP), Model Description and Users Manual, R.A. Wurbs, TWRI TR-180, First Ed. Aug 1999, 2nd Ed. Oct 2000, 3rd Edition July 2001.

WRAP Computer Programs

The model documented by the June 1988 manual was a single Fortran program called *TAMUWRAP*. The 1993 and 1996 TR-146 describes a package of three Fortran programs called *WRAP2*, *WRAP3*, and *TABLES*. *WRAP2* and *TABLES* replaced *TAMUWRAP*. *WRAP3* is an expanded version of *WRAP2*. A network flow programming version called *WRAPNET* was also developed during the early 1990's. *WRAPNET* reads the same input files and creates the same simulation results as *WRAP2* but performs computations with a network flow linear programming algorithm that had been adopted for other river/reservoir system models developed by the Texas Water Development Board and other model developers. Although *WRAPNET* worked fine, the model-specific *WRAP2* algorithms were concluded to be advantageous for various reasons.

The WRAP software package is now composed of the following Fortran programs.

SIM simulates the river/reservoir water allocation/management/use system for input sequences of monthly naturalized flows and net evaporation rates.

SIMD (*D* for daily) is an expanded daily computational time step version of *SIM* that adds flow disaggregation, flow forecasting and routing, environmental pulse flows, and flood control operations along with all of the capabilities of *SIM*.

TABLES develops frequency relationships, reliability indices, and various user-specified tables for organizing, summarizing, and displaying simulation results.

HYD assists in developing and updating monthly naturalized stream flow and reservoir net evaporation-precipitation depth data for the *SIM* hydrology input files.

DAY and *DAYH* assist in calibrating routing parameters and otherwise developing daily time step hydrology input for *SIMD*.

SALT reads a *SIM* or monthly *SIMD* output file and a salinity input file and tracks salt constituents through the river/reservoir/water use system.

WinWRAP is an interface that facilitates execution of the *WRAP* programs within *Microsoft Windows* along with *Microsoft* programs and *HEC-DSSVue*.

The program *SIM* was developed by building upon and expanding *WRAP3*. The name *SIM* replaced the name *WRAP3* in 1998. *SIM* has been greatly expanded since that time. *TABLES* has also grown continuously since its initial creation in 1991-1992. *WinWRAP* was added in October 2002. Developmental versions of *SIMD* and *DAY* were included in the August 2012 *WRAP*.

The TCEQ WAM System hydrology datasets was essentially completed when *HYD* became available in 2000. Major modifications to *HYD* dealing with extensions to the hydrologic periods-of-analysis of the existing TCEQ WAM System hydrology datasets occurred during 2007-2008, 2011-2013, and 2017-2018.

The program *SALT* documented by the *Salinity Manual* was publicly released in 2009. *SALT* reads the main *SIM* simulation results output file and a salinity input file and tracks salt constituent loads and concentrations through the river/reservoir system. Addition of salinity simulation capabilities to WRAP required essentially no modifications to *SIM*. Salinity features were added to *TABLES*. *SALT* has not been significantly modified since 2009.

The daily version of the WRAP modeling system is documented by the *Daily Manual* and consists of the programs *SIMD*, *DAY*, *DAYH*, and the daily features of *TABLES*. The sub-monthly (daily) features of WRAP have been under development for several years with various developmental test versions of the software being continually improved and expanded. The August 2012 WRAP included developmental versions of *SIMD* and *DAY*. *SIMD* is an expanded version of *SIM* that includes daily time step and flood control features along with all of the simulation capabilities of *SIM*. The daily modeling system continued to be refined in the 2018 and 2019 versions of WRAP.

The expanded *SIMD* contains all the capabilities of the monthly time step *SIM*, plus options related to flood control, environmental pulse flows, flow forecasting and routing, sub-monthly targets, and disaggregation of naturalized flows. At some future time, *SIMD* could possibly be declared to replace *SIM*. However, *SIM* is currently maintained as a separate program. *SIM* is complex, and addition of expanded modeling capabilities to *SIMD* adds significantly more complexity. *SIM* has been applied extensively as a component of the TCEQ WAM System. As a safeguard, maintenance of *SIM* allows ongoing applications of the WAM System that do not need the expanded modeling capabilities to continue with the basic *SIM* software. All modifications to *SIM* are also incorporated in *SIMD*.

Conditional reliability modeling (CRM) described in Chapter 8 of the *Reference Manual* has evolved over several years. Major improvements were added during 2013-2015. Although the modifications to *SIM* and *SIMD* required to add conditional reliability modeling are significant, most of the new CRM computational routines are contained in *TABLES*.

The WRAP program *TABLES* consists of routines for organizing, displaying, summarizing, and analyzing *SIM*, *SIMD*, and *SALT* simulation results. *TABLES* contains routines that date back to the initial versions of WRAP. *TABLES* also contains major newer features dealing with *SIM* input data, conventional monthly *SIM* simulation results, *SIM* or *SIMD* conditional reliability modeling results, *SIMD* daily time step and flood control simulation results, *SALT* salinity simulation results,. The *TABLES* Fortran program is modular with separate modules or subroutines for developing tables and data listing associated with organizing the various types of *SIM*, *SIMD*, and *SALT* simulation results. The modular organization of *TABLES* facilitates adding new features.

As of May 2019, the latest publically released versions of the programs are as follows: *SIM* (May 2019), *SIMD* (May 2019), *TABLES* (May 2018), *HYD* (August 2015), *DAY* (July 2018), *DAYH* (August 2013), *SALT* (July 2010), and *WinWRAP* (May 2019).

WRAP Modifications

This report documents additions and revisions to the WRAP programs *SIM*, *TABLES*, *HYD*, and *WinWRAP* and accompanying manuals that have occurred during various time periods since the 1996 WRAP documented by the October 1996 revised TR-146 *Reference/User Manual*. The later sections of this report also include discussions of the *SIMD* and *DAY* programs and the *Daily Manual*.

Modifications Between the October 1996 and August 1999 Versions

Several revised versions of WRAP with interim documentation were distributed in conjunction with the TCEQ WAM System implementation project between the revised TR-146 dated October 1996 and the first edition of TR-180 dated August 1999. *SIM* replaced *WRAP3* and then continued to be expanded. *TABLES* was expanded. The new *HYD* was added. Major new features in the August 1999 WRAP that were not in the 1996 version include the following.

- a set of routines for adjusting gaged streamflows to determine naturalized flows
- methods for distributing naturalized streamflows from gaged (known-flow) to ungaged (unknown-flow) control points
- options to facilitate compilation of sequences of net evaporation-precipitation rates
- an adjusted net evaporation-precipitation option to account for the previous precipitation runoff from the land area now covered by a reservoir
- capabilities for modeling channel losses
- a set of optional capabilities for modeling instream flow requirements
- a drought index feature allowing instream flow, diversion, and hydropower targets to be expressed as a function of reservoir storage content
- expanded options for modeling return flows
- capabilities for developing streamflow and storage frequency relationships
- improved techniques for dealing with negative incremental naturalized streamflows
- options for adding sets of inflows and/or outflows to the naturalized streamflows
- an optional routine for assigning water right priorities by type of use
- water rights options associated primarily with off-channel reservoirs involving diversions from multiple locations and annual and monthly limits on streamflow depletions
- a backup right feature with diversion shortages for a water right supplied by other rights
- an option for modeling seasonal rule curve reservoir operations
- features for finding errors in the input data
- improvements in input data format, file organization, and input/output data management
- refinements in the structure and organization of the Fortran code

Modifications Between the August 1999 and July 2001 Versions

Additions and revisions to WRAP between the versions documented by the August 1999 first edition and July 2001 third edition of the TR-180 manual were as follows. Input data records used to activate new features are shown in parenthesis. The changes between October 2000 and July 2001 were relatively minimal compared to the changes between the August 1999 and October 2000 versions. Most of the following additions were included in the October 2000 as well as July 2001 versions. The July 2001 version also reflects addition of negative incremental flow option 5, expansion of *TO* record options, further increases in dimension limits, and other relatively small refinements made after the October 2000 version.

Modifications Applicable to both SIM and HYD (August 1999 – July 2001)

- The system for detecting errors in the input data was improved and expanded. Significantly more error checks were added.
- A new naturalized streamflow distribution option allows channel loss computations to be combined with the NRCS curve number method. (*CP* record field 6, new option 8)
- The adjustment of evaporation-precipitation depths for runoff from reservoir land was restructured for greater flexibility. (*JD* record field 10, *JC* record field 13, *CP* record field 9)
- A new negative incremental flow adjustment feature allows control points with synthesized flows to be optionally included or excluded in the negative incremental flow adjustments. (*JD* record field 8, *JC* record field 11)
- Various computational algorithms and the organization of the Fortran code were refined. Inconsistencies and errors were corrected. Improvements in certain routines reduce run times. Modifications facilitate compiling the code with different Fortran compilers. Restructuring in some cases makes the code easier to understand.
- Dimension limits were increased to allow more control points, water rights, reservoirs, and drought indices.
- Input data optionally may be in a comma-delimited format as an alternative to fixed field widths for most input records for all three programs.

SIM Modifications (August 1999 – July 2001)

- New features were added to provide greater flexibility for specifying water right requirements. A new option allows diversion, instream flow, and hydropower targets to be entered as a time series covering the entire hydrologic period-of-analysis, with monthly targets varying from year to year or repeated for any number of years. (new *TS* record)
- Another new set of options allow diversion and instream flow targets to be defined as a function of: naturalized, regulated, and/or unappropriated streamflow at multiple locations; reservoir storage and/or drawdown; and/or streamflow depletions incurred by other water rights. A new drought index feature further facilitates use of a drought index in combination with these options for defining water use targets. With the target building features, an option allows selection of the stage of the target for which the target and shortages are recorded in the output. (new target options *TO* record, *DI* record field 3, *SO* record field 9)

- Monthly and/or annual limits may be placed on the amount of water a right may withdraw from reservoir storage. (*SO* fields 7-8)
- Several water districts, cities, and other water supply entities may each control certain portions of the storage capacity of a reservoir. A reservoir evaporation-precipitation allocation routine was developed to facilitate modeling of storage capacity shared by multiple water right holders. This feature was later restructured and expanded. (new *EA/EF* records)
- New hydropower features were added to provide greater modeling flexibility. Power generation may be limited to releases from reservoir storage and by turbine elevation and discharge capacity. A tailwater rating curve may be entered as an option to a constant tailwater elevation. Releases may increase downstream flows either the next month or same month. Computational algorithms were refined. (*WS* fields 9, 12, 13; new *TQ/TE* records)
- A natural priority option was added that overrides the water rights priorities with rights being considered in upstream to downstream order. (*JD* record field 11 and later *JO* record 8)
- Negative incremental flow option 5 previously developed by HDR, Inc. for *WRAP* applications in specific river basins was added to the generic model. (*JD* record field 8)

HYD Modifications (*August 1999 – July 2001*)

- A new optional columnar table format was added to facilitate transfer of streamflows and evaporation-precipitation depths to and from spreadsheet programs such as *Microsoft Excel*. (restructured *JC* record)
- Tables displaying intermediate computational results were added for reservoir adjustments, incremental watershed parameters, and negative incremental flows. (*JC* and *RS* records)
- Regression equations were added to facilitate adjusting streamflows by combining the results of a precipitation-runoff model with *HYD*. (new *EQ* record)
- Tables displaying intermediate computational results were added for reservoir adjustments, incremental watershed parameters, and negative incremental flows.

TABLES Modifications (*August 1999 – July 2001*)

- A new option allows tables of naturalized flows, regulated flows, unappropriated flows, streamflow depletions, diversions, diversion shortages, instream flow shortages, channel losses, and/or reservoir storage to be developed in a columnar format. This facilitates data manipulation and plotting in spreadsheet or graphics software such as *Microsoft Excel*. (*2NAT*, *2REG*, *2UNA*, *2DEP*, *2DIV*, *2SHT*, *2IFS*, *2CLO*, *2CLC*, *2STO* records)
- A new *2DIV* record was added to develop tables for diversions in the same optional formats as the other variables noted above. (new *2DIV* record)
- A new option allows the computation of period reliabilities to either include or exclude months with zero demand. (*2REL* record)
- The format of the reliability table was changed to replace the shortage summary with the corresponding percentage-of-time demand targets are met. Messages are also printed in the reliability table whenever demand targets are zero. (*2REL* record)

- Job Type 3 routines were restructured for better clarity and flexibility. A new option allows regulated streamflows to be converted to input records to be read by *SIM* as *TS* record instream flow target series. (*3NAT*, *3REG*, *3UNA*, *3DEP*, *3U+D* records)
- The input format was restructured for the percentage storage and drawdown-duration tables and multiple-reservoir system release tables. (*2PER*, *4SWR*, *4SGP* records)
- File management changes included allowing the *TABLES* output filename to have a different root than the input filename. More input error checks/messages were added. The format of various output tables was revised.
- Other modifications in *TABLES* were made to deal with improvements in *SIM* including new input records, changes in format of water rights identifiers, and changes in dimension limits.

Modifications Between the July 2001 and January 2003 Versions

Improvements to *SIM*, *TABLES*, and *HYD* made between July 2001 and January 2003 are listed as follows. The user interface program *WinWRAP* was first introduced with the October 2002 release of *WRAP*.

***SIM* Modifications** (*July 2001 – January 2003*)

- The *FY* record routine for computing a yield-reliability and firm yield table was added.
- The *WR* record field 6 type 7 right and *SO* record *RETURN* options were added to allow prioritization of return flows. The type 7 right was later changed to type 4.
- The *WR/SO* record backup right routine was modified to ignore intervening *IF* record rights.
- An annual limit on diversions was added to the *SO* record.
- The *SO* record monthly and annual diversions limits were extended to include type 3 rights.
- The *TO* record lower and upper limits on targets were restructured.
- The multiplier factor and parameter limit *XL* record and associated options were added primarily to provide improved flexibility for conversion factors.
- An *XL* record option was added for placing upper and lower bounds on the *CN* and *MP* used in applying the curve number method to distribute flows from gaged to ungaged sites.
- The system (*SO* field 9) for selecting targets and shortages to output was improved.
- Flexibility was added to sequencing of backup right. This feature was later restructured.
- The flow input filename (root.INF) extension *INF* was changed to *FLO* because Windows uses the extension *INF* for a designated type of file. Several new error messages were added.
- Read statements were modified to automatically remove trailing blanks so that alphanumeric identifiers do not have to be right justified.
- Programs were restructured to initialize variables without Fortran data statements, which were removed, greatly reducing storage size.

TABLES Modifications (July 2001 – January 2003)

- The diversion and instream flow target tables (2TAR and 2IFT records) were added.
- A routine was added for performing a frequency analysis for the total monthly storage in any selected group of reservoirs, with the output provided at the bottom of a 2FRE record table for reservoir storage.
- The supplemental 2RET table was added to the 2REL table for use particularly when target building options complicate the interpretation of reliabilities. Later in the August 2006 version, this feature was integrated into the 2REL record, with the 2RET record deleted.
- The UNIT record was added for specifying units in table headings.
- A water right group summary was added to the 1SUM record table.
- Modifications were made to the 1SUM and 1SRT tables to reflect revisions to *SIM*.
- Read statements were modified to automatically remove trailing blanks so that alphanumeric identifiers do not have to be right justified.
- Several new error checks were added. A few headings were refined. Several dimension limits were increased. The program no longer reads past the ENDF record.

HYD Modifications (July 2001 – January 2003)

- The multiplier factor and parameter limit *XL* record and associated options were added.
- The monthly factor *MF* record was added.

Modifications Between the January 2003 and August 2003 Versions

The August 2003 *SIM*, *TABLES*, *HYD*, and *WinWRAP* are documented by the August 2003 first edition of the TR-255 *Reference Manual* and TR-256 *Users Manual*. Features in the August 2003 *WRAP* that were added or revised after the January 2003 version are noted as follows.

SIM Modifications (January 2003 – August 2003)

- Major restructuring of the code included adoption of dynamic dimensioning. The size of the datasets are no longer limited, and memory requirements are set dynamically by the actual size of the data sets. Array types are declared and the dimension shapes set at the beginning of the program or subroutines, with array sizes being allocated later after an initial pass reading the input file to count the number of various types of records. The dimension limit *DL* record was also created but was later removed.
- Other major restructuring of the code included revising several key arrays and creating new arrays. Data handling for multiple-reservoir system and hydropower rights was reorganized. All scratch files and data statements and most common blocks were removed. New error and warning messages were added.
- The *WR* record type 7 right feature was expanded to include use with *RF* records and to output inflows as negative diversions. Right type 7 was later revised and replaced as type 4.

- Errors were corrected that caused the $IFMETH = 2$ option on the *IF* record to result in second pass computations that were essentially a repeat of first pass computations. With the errors, the $IFFLAG = 2$ option results were basically the same as with the default option 1.
- Additional optional features were added to the instream flow computation options selected on the *IF* record. New options include those activated by $IFMETH = -2$ or -4 and the new $IFFLAG2$ on the *IF* record and the new $PASS2$ on *JD* record field 14 that was later moved to *JO* record field 10.
- The multiple-reservoir system operation rules were expanded to include new factors entered as input in *OR* record fields 7 and 8. The monthly release limit in *OR* record field 9 was also added.
- The new input parameters $LM(wr,1)$ and $LM(wr,2)$ entered in *SO* record fields 11 and 12 allow seasonal limits to be placed on streamflow depletions, diversions, and withdrawals from reservoir storage. An option was also added allowing seasonal or annual limits on regulated flows to be placed on instream flow requirements.
- The new input parameter $NOTFLAG$ in *SO* record field 13 activates new options to flag a water right such that (1) channel losses are not applied to its return flows or (2) the right is not constrained by instream flow requirements.
- The new *FY* record entry MFY activates a new option for distributing yield between water rights based on priorities along with the old alternative method based on fixed proportions.
- The set of beginning-ending storage (BES) options activated by *JD* record field 15 (later moved to *JO* record field 5) was added. The addition was motivated by allowing storage content of all reservoirs at the beginning of the simulation to be conveniently set equal to the storage content at the end of the simulation but may be applied in other ways as well.
- The variables included in the simulation results OUT file are listed in tables in the *Reference* and *Users Manuals*. Return flows were added to the water right output record. Reservoir releases at a control point from upstream reservoirs released to meet requirements further downstream were added to the control point output record.

TABLES Modifications (January 2003 – August 2003)

- The new *ICPT* record activates a set of options for developing listings of control point information in upstream-to-downstream sequencing.
- The new *2RFR*, *2RRE*, *2EVA*, *2RET*, *2ASF*, *2ROR*, *2HPS*, *2HPE*, *2RID*, *2RIR*, *2RAH*, and *2RNA* records along with previously available records result in a standard set of tables for all data included in the *SIM* simulation results output file. These time series records were again expanded in the later August 2006 version.

WinWRAP Modifications (January 2003 – August 2003)

- The new tables added to *TABLES* were also added to the *WinWRAP* feature for building *TABLES* input files. The instructions menu was refined and expanded. Refinements were made to the menus and features for specifying file names.

Modifications Between the August 2003 and May 2004 Versions

The first and second editions of the TR-255/TR-256 *Reference/Users Manuals* are dated August 2003 and April 2005, respectively. Modifications to *SIM* and *TABLES* between their August 2003 and May 2004 versions are listed below. Modifications during May 2004 through April 2005 are covered in the next section.

- Dynamic dimensioning was expanded to include all major array dimensions in *SIM*. The dimension limit *DL* record was removed. The methodologies for dimensioning arrays and transmitting data between modules in *TABLES* were likewise revised.
- A number of new error and warning messages were added to *SIM*.
- The *SIM* dual simulation options activated by *SO* record field 14 were added.
- The streamflow depletion limit option was added to the *TS* record.
- ADD, SUB, and DIV options were added to *TO* record field 4.
- The NOTFLAG options in *SO* record field 13 were expanded.
- Adjusted evaporation depth was added to the *SIM* output file and *TABLES* tables.
- The number of digits to right of decimal point was revised for several variables in the *SIM* output file and *TABLES* tables.
- The limit options activated by *TABLES ICPT* record fields 4 and 5 were revised.
- The options activated by *UNIT* record fields 4 and 5 were added.
- Additional corrections were made related to the *SIM* second pass instream flow options.
- An error that precluded use of *SIM TO* record field 2 target options 11 and 12 was corrected.
- An error related to *SIM* beginning-ending storage option 4 was corrected.
- New *JD* record beginning-simulation-storage table was later replaced *JO* record BRS table.
- *SIM* options associated with the target series repeat *TSR* record were added.
- Problems were addressed related to *SIM* and *TABLES* precision in defining shortages in computing reliabilities.
- Precision for recording net evaporation depths was increased.
- Warning messages were added citing any simulation results amount that exceeds format limits for *SIM* output file.

Modifications Between the May 2004 and April 2005 Versions

The following significant modifications are also reflected in the April 2005 second edition of the TR-255/TR-256 *Reference and Users Manuals*. An array of other minor improvements to better organize the *SIM* and *TABLES* Fortran code, error/warning checks, monitor messages, and message file messages are not listed.

SIM Modifications (May 2004 – April 2005)

- The file options record is obsolete in the April 2005 and later versions of *SIM*. *SIM* performs an initial pass through the DAT file to obtain record counts allowing the setting of dimension limits and determination of files to be opened. The HRR and BES file parameters from the old *FO* record are also now included on the new *JO* record.
- Additional warning messages were added. *JD* record ICHECK option 9 was added allowing many of the warning checks to be deactivated.
- Additional *JD* record field 4 options were added providing greater flexibility in selection of water rights to be included in the simulation results output file.
- The new job options *JO* record was added for new features and some old *JD* record features.
- New options activated by *JO* record field 2 allow greater flexibility in sequencing of *IN* and *EV* records. In prior versions of *SIM*, the *IN* and *EV* records for all control points were read for a given year, and the simulation was performed for that year. The *IN* and *EV* records had to be grouped by year in the input files. New options allow the *IN* and *EV* records to be grouped by control point. All records for the entire simulation are read at the beginning of the simulation.
- The beginning reservoir storage (BRS) file activated by *JO* field 6 was added. The *BRS* file addition was motivated by the need to have beginning-of-simulation storage volumes as input for *SALT*. However, the new *SIM* BRS table may be useful for other purposes as well.
- The input data format has been restructured for the feature for setting water right priorities based on type of use. The use priority *UP* record was added and *UC* record revised with priority input moved from the *UC* to the new *UP* record.
- The *UC*, *RF*, and *CI* records were revised to allow either 12 or 6 entries per record formats. Flexibility is added for format of the input data, but simulation computations are not affected.
- The transient water right feature was added along with a new dual simulation options and transient water right options *DT* record. The transient right option represents significant new simulation computation capabilities. The *DT* record is deleted in the August 2006 *SIM* with features moved to a new *PX* record with new features in addition to old *DT* record options.
- Reservoir storage and hydroelectric power input data were restructured with addition of the new hydroelectric power *HP* record and revisions to the *WS* record. Defaults are set internally by the program such that the *HP* record is not required if all defaults are adopted.
- A new parameter in *HP* record field 6 sets a maximum limit on secondary hydroelectric energy production.
- Defaults are set internally for all variables on the operating rules *OR* record. *OR* records are no longer required if all the defaults are adopted.
- The *SD* record defining an old type 4 water right and all related computational routines were removed from *SIM*. The *SD* record type 4 water right record dates back to *WRAP3* in the early 1990's. However, the *SD* record option was superseded by the drought index *DI* record option in 1999 and has never been used in actual WAM System applications.

- In defining water right types in *WR* record field 6, the type 7 stream inflow right added in the January 2003 version was renamed in the April 2005 version as a type 4 water right.
- An error was corrected related to use of *TO* record field 2 target options 6 and 7 in combination with the second-pass instream flow option. In setting the target, the previously accumulated streamflow depletion at the beginning of the second pass was erroneously assumed to be zero in previous versions of *SIM*.
- A problem was corrected related to the second pass when the iterative *FY* record firm yield computations were applied in combination with the second-pass instream flow option.
- A problem was corrected that prevented use of a flow adjustment FAD file. The problem had been introduced by previous revisions related to new array size allocation and deallocation features in the Fortran code.
- The maximum length of filenames was increased from 30 to 50 characters.
- Conditional reliability modeling options activated by the *CR* record were first introduced in the April 2005 *SIM* and are further refined in the August 2006 *SIM*.

TABLES Modifications (*May 2004 – April 2005*)

- Beginning with the April 2005 *TABLES*, the time series records include an option for creating Hydrologic Engineering Center Data Storage System (HEC-DSS) files.
- *TABLES* now writes a message file with filename extension TMS. The error and warning messages are restructured and expanded.
- The new parameter *MONTH* added to the 2REL, 2FRE, 2FRQ, and 2RES records allow reliability and frequency tables to be developed for a specified month of the year.
- The old 2PER record was replaced with the new 2RES record which activates a new reservoir reliability table as well as the old percent storage and storage drawdown tables.
- A new 3EPD record was added for adjusted net evaporation-precipitation depths.
- Comment records may now begin with **** or ** as well as COMM.
- The format of the cover page created with the PAGE record was revised.
- The new 1LEN record revises a DAT file with all records limited to 128 characters. This removes comments to facilitate printing.
- The 1REC record routines were updated to reflect new *SIM* input record types.
- The new TEST record activates a series of error checks of the *SIM* output file for use in rare cases in which *TABLES* can not read a *SIM* output file for some unknown reason.

WinWRAP Modifications (*May 2004 – April 2005*)

- Addition of the *WRAP Files* menu allows activation of an editor such as WordPad by browsing and clicking the filename of the data file.
- A feature was added allowing activation of *HEC-DSSVue* directly from *WinWRAP*.

Modifications Between the April 2005 and September 2006 Versions

The TCEQ is sponsoring continuing improvements and additions to WRAP during 2005–2008. *SIMD*, *DAY*, *SALT* and associated *TABLES* features described in the September 2006 First Edition of *Supplemental Manual* are introduced in the September 2006 WRAP. The Display software tool developed for use with ArcGIS to display WRAP simulation results is also described in the September 2006 *Supplemental Manual*.

The September 2006 *WinWRAP*, *SIM*, *SIM*-related features of *TABLES*, and *HYD* are documented by:

Reference Manual for the Water Rights Analysis Package (WRAP) Modeling System,
TWRI TR–255, Third Edition, September 2006.

Users Manual for the Water Rights Analysis Package (WRAP) Modeling System,
TWRI TR–256, Third Edition, September 2006.

The September 2006 Third Edition of the *Reference* and *Users Manuals* reflects thorough editing to improve clarity and detail in documenting old modeling capabilities as well as to incorporate the new features addressed below. Modifications to *SIM*, *SIM*-related *TABLES* features, and *WinWRAP* since completion of the April 2005 version of the software and accompanying April 2005 Second Edition of the *Reference* and *Users Manuals* are noted as follows.

WinWRAP Modifications (April 2005 – September 2006)

- *SIMD*, *SALT*, and *DAY* activation buttons were added. A new monitor message was added.
- The TIN file editor was updated to reflect the revisions to *TABLES* input records. The *HEC-DSSVue* activation menu was updated to access the August 2005 version of *HEC-DSSVue*.
- A problem was corrected which caused *WinWRAP* to occasionally hang-up when extremely large datasets were run on older relatively slow computers.

Modifications Common to Multiple Programs (April 2005 – September 2006)

- A feature has been incorporated in *SIM*, *TABLES*, *HYD*, *SIMD*, and *SALT* to facilitate their execution independently of *WinWRAP*. *WinWRAP* should still be routinely used, but model-users may occasionally prefer to save a mouse click by activating a program directly. Without the new feature, the programs exit upon completion of execution, losing the messages written to the monitor. Now the programs are not exited until the user presses enter or any other key, thus allowing messages on the monitor to be read before exiting.
- All error checks resulting in error messages and program termination now call a common subroutine that prints a new common message to the monitor as well as the error-specific message printed in the message file and then stops the program. This feature is incorporated in all of the programs. Error and warning checks and messages have also been revised for consistency in all programs. A number of new checks have been added along with the restructuring of the overall system for checking input data as it is read and other checks.

SIM Modifications (April 2005 – September 2006)

The following new input records have been added to *SIM*.

- BU Record – Backup Right
- FS Record – Flow Switch for Adjusting Targets
- PX Record – Priority Sequence Circumvention Options
- AX Record – Monthly Streamflow Availability Multiplier Factors
- AF Record – Streamflow Availability Allocation Factors

The *DT* record is deleted, and its features are incorporated in the new *PX* record along with other new capabilities. *SIM* writes an error message and terminates if a *DT* record is read.

Most of the modifications reflected in the September 2006 *SIM* are new additions. Additional input may be required to activate new capabilities, but old datasets generally still run fine with the April 2005 and September 2006 versions providing essentially identical results. However, the following modifications may affect simulation results from existing input datasets.

1. As explained later, the restructuring of the *EA* record evaporation allocation routine included both error corrections and changing certain aspects of the general modeling strategy and input parameters. Simulation results will change in most situations.
2. The *TO* record field 2 revision described below could affect simulation results unless the appropriate option is selected. Selection of a different option may be required.
3. Corrections to *UP* and *TSR* record options corrected problems that previously caused termination of model execution.
4. As noted above, the *DT* record has been deleted, with its features incorporated in the new expanded *PX* record.

The September 2006 *SIM* also includes various Fortran code refinements to better organize the program that are not necessarily associated with an individual new or revised modeling feature. Some of the code refinements were made to prevent potential problems that could materialize in certain uncommon situations but may or may not have actually occurred in the past.

Significant modifications to *SIM* between the April 2005 and September 2006 versions include the following revisions and additions.

- Conditional reliability modeling options activated by the *CR* record were first introduced in the April 2005 *SIM* and are further refined in the September 2006 *SIM*.
- An error message is activated if a *SIMD* input record is read that is not relevant to *SIM*.

Evaporation Allocation Features for Multiple-Owner Reservoirs

The *SIM* evaporation allocation routines activated by *EA* and *EF* records were restructured, corrected, and expanded. Simulation results from the September 2006 *SIM* may be

different in many cases than the April 2005 and earlier versions. The code was rewritten to be easier to follow. Errors were corrected. New features were added. Revisions are as follows.

1. NEAF option 4 in *EA* record field 3 and EAO options 3 and 4 in *EF* record field 2 have been added.
2. Errors in the code related to use of beginning-of-month versus latest end-of-month storage in various situations were corrected.
3. The feature was corrected in which allocation method 3 automatically switches the computations to the method 2 algorithm if one or more reservoirs are empty.
4. The following change was made to assure that the total sum of evaporation in all component reservoirs is precisely correct for the actual reservoir they represent. In previous versions of *SIM*, the evaporation allocated to the component reservoirs did not precisely sum to the correct total. The evaporation computations are necessarily approximate since the end-of-month storage is the latest value computed in the water rights priority loop. NEAF options 2 and 3 are based on factors computed from beginning-of-period storage and the *EF* record, respectively. In previous versions, the factors were applied to all component reservoirs. In the September 2006 version, the factors are applied to all but the last component reservoir. The evaporation allocated to the last reservoir is the actual total evaporation minus the evaporation allocated to the other reservoirs. This ensures that the total evaporation is correct each month even if the allocation is not exactly in proportion to the factors.
5. With addition of NEAF option 4, the factors on the *EF* record are now applied directly. Previously, each factor was divided by the total to obtain fractions summing to 1.0.
6. The streamflow availability allocation feature activated by the new *AF* record was added for use with the *EA* record. The similar new *AX* record is connected to the *PX* record.

Expanded Backup Right BU Record Feature

An expanded backup right feature is activated by the new *BU* record. Previously, the backup right activated by *SO* record field 6 could be applied only to diversion targets. The expanded backup right may be applied to diversion, instream flow, or hydropower targets. Previously, the backup was applied to the preceding *WR* record in the *DAT* file. The new *BU* record field 4 allows specification of any other water right, with the default (blank field 4) being the preceding *WR* record. The new *BU* record field 5 allows specification of a water right group identifier. The summation of shortages for all rights with that group identifier is added to the diversion, instream flow, or hydropower target of the backup right. The backup rights can also still be stacked allowing backup rights to backup other backup rights. Though superseded by the *BU* record, the old *SO* record field 6 option still works.

Expanded Target Setting Capabilities

- A flow switch feature used in setting targets has been added, which is activated by the new *FS* record. Instream flow, diversion, and hydropower targets can be switched on/off or otherwise adjusted depending on whether accumulated regulated flow, naturalized flow, unappropriated flow, streamflow depletions, diversions, or control point inflows in the

current and/or any number of preceding periods at a specified control point fall within a specified range. A primary motivation for this new feature is flexibility in modeling instream flow requirements that are expressed as a function of whether current and/or accumulated past flows fall within a specified range. Other applications are likely as well.

- A revision related to *TOTARGET* in *TO* record field 2 may affect simulation results for datasets that base targets on other junior rights. The revisions have no effect on targets based on other senior rights. Options 7, 8, 9, 11, and 12 activated by *TO* record field 2 allow targets to be adjusted as a function of streamflow depletions, reservoir withdrawals, or diversions. Options -7, -9, and -12 have been added primarily to deal with problems related to setting targets based on junior rights with or without second pass options in effect. Monthly depletions, withdrawals, or diversions are now the latest computed in the priority sequence which will be same-month for senior rights, preceding-month for junior rights, and preceding-pass for second pass simulations. The new -7, -9, and -12 options allow the user to decide whether or not the current month is included in the annual accumulation.
- A problem with using multiple sequential *TO* records to set a target was corrected.
- The new water right type 7 added to *WR* record field 6 allows target setting options to be applied to set reservoir storage targets in the same manner as a diversion target. Additional flexibility is provided for modeling reservoir operating rules.
- Entering a 4 in *WR* record field 6 now selects a type 4 right which is an inflow to the stream. The old type 7 inflow right has been reassigned as type 4. In the past, type 4 was associated with the now obsolete *SD* record.
- The new *XMONTH* option added to *WR* record field 4 allows the target entered in *WR* field 3 to be a monthly rather than annual amount.

Priority Circumvention Features

The new priority sequence circumvention options *PX* record and accompanying streamflow availability factors *AX* record replace the *DT* record and add two new modeling features. The *DT* record is deleted with its two features being incorporated by the *PX* record along with addition of the following two other new features.

The *PX* record downstream control point water availability limit feature is designed for modeling subordination agreements but may be applied for other purposes as well.

The *PX/AX* record streamflow availability allocation options provide a scheme for the model-user to define rules for allocating available streamflow between two or more rights that share the same priority. An alternative to the priority system is provided. The new *AF* record serves the same purpose but is connected to the *EA* record for use specifically in modeling multiple-owner reservoirs where the owners share the same priority.

An error was corrected in the *DT* record transient priority option computations introduced in the April 2005 version of *SIM*. The *DT* record was subsequently deleted with the transient priority options being transferred to the new *PX* record.

New Variables

- A new feature allows reservoir water surface elevations to be computed. The water surface elevations are automatically written to *SIM* reservoir/hydropower output records for all reservoirs that have *PE/PV* input records and are tabulated by a *TABLES 2WSE* record. If a reservoir is selected for output on the *RO* record, the water surface elevation will automatically be included in the output if the reservoir has a storage-elevation table defined by *PE/PV* records.
- A new variable called control point inflows was created. Control point inflow was added as one of the six options that may be selected in *FS* record field 2. A new option activated by *TO* record fields 5 and 6 allows control point inflows to be used as upper limits on targets. Control point inflows are tabulated by the new *TABLES 2CPI* record.
- Net evaporation-precipitation depths reflecting adjustments controlled by *JD* record field 10 and *CP* record fields 8 and 9 were previously included in the simulation results recorded on reservoir output records. Net evaporation-precipitation depths from *EV* records prior to adjustments have been added to the output.
- The new priority sequence circumvention options *PX* input record activates an option which results in a new variable called "*increase in available flow*" being written to the *OUT* file.

Other SIM Modifications

- In previous versions of *SIM*, the drought index was always based on beginning-of-month storage. Options activated by *JO* record field 8 were added to base the drought index on either beginning-of-month storage, end-of-month storage, or an average of the two.
- An option has been added allowing a maximum reservoir release rate to be set on the monthly storage limit *MS* record.
- A parameter added in the new field 10 of the *JO* record allows the user to increase the maximum limit on the number of entries in *SV/SA*, *PV/PE*, and *TQ/TE* record tables to any number. Previously, the tables were limited to a maximum of 12 pairs of values.
- Linear interpolation is applied to the *SV/SA*, *PV/PE*, and *TQ/TE* record tables. In previous versions of *SIM*, an error message was printed and the program terminated if a storage volume exceeded the range covered by the input tables. The error routine has been replaced with a warning message with the program execution not being terminated.
- A blunder had been introduced into an earlier version of *SIM* that prevented the optional *HRR* file from being created. The error in the code has been corrected.
- A problem was corrected that had prevented use of the *USEADD* option in *UP* record field 4.
- A problem was corrected that had prevented use of other than defaults on the *TRS* record.

- The *SIM* output OUT file record length has been lengthened from 100 to 136 characters to allow an 11-character field width with more digits to the right of the decimal. All read format statements in *TABLES* have been revised for the new OUT file format. This allows greater precision in transferring simulation results from *SIM* to *TABLES*. The potential for other problems with extremely large or extremely small numbers is also reduced.

TABLES Modifications (April 2005 – September 2006)

Since the *SIM* output OUT file and associated *TABLES* read format statements have been changed, the September 2006 version of *TABLES* reads a *SIM* OUT file only if it is created with the September 2006 version of *SIM*. Most of the type 2 *TABLES* input records have been changed and, depending on options selected, old versions of the input records likely will not work with the new *TABLES*. The 2CPI, 2XAV, 2EVR, 2WSE, 2BUD, and IDEN records are new. The old 2RET record has been deleted.

A number of new subroutines have been added to *TABLES* to support the expanded modeling capabilities associated with *SIM* and *SIMD* conditional reliability modeling results, *SIMD* sub-monthly time step and flood control simulation results, and *SALT* salinity simulation results. These routines are covered in the *Supplemental Manual* but are not addressed here.

Modifications reflected in the September 2006 *TABLES* of features covered in the basic *Reference* and *Users Manuals* made since the April 2005 version are listed as follows.

General Revisions throughout *TABLES*

- The *SIM* output OUT file was revised to express *SIM* simulation results with greater precision. All *TABLES* format statements for reading data from the *SIM* OUT file were revised accordingly. The increased precision may affect the results slightly.
- A refined scheme for consistently organizing error and warning checks and messages in all of the WRAP programs has been adopted that included adding a message file to *TABLES*. New error and warning checks and messages in *TABLES* have been added and old data checking routines have been refined.
- The new IDEN record associated with the time series, reliability, and frequency tables was added in conjunction with a refined system for specifying identifiers for control points, water rights, reservoirs, and water right groups that may be used in common by multiple records.
- The *TABLES* Fortran code has been revised in several other respects to improve its organization and facilitate continued additions.

New Features Added to the Time Series Tables

- Moving average, moving total, and multiplier/addition factor features have been added to the time series tables and the 2FRE frequency table. These arithmetic operations allow the *SIM* simulation results variables to be either adjusted or transformed to other related variables.

- New features of the *TABLES* time series records include the new parameter *DECIMAL* in field 7 which allows the model-user to set the number of digits to the right of the decimal.
- The 2CPI (control point inflow), 2EVR (unadjusted evaporation-precipitation depth), 2XAV (increase in available flow due to *PX* record option), and 2WSE (reservoir water surface elevation) time series records are new variables added to the *SIM* simulation results.

New Features Added to the Frequency Tables

- Moving average, moving total, and multiplier/addition factor features have been added to the 2FRE frequency tables as well as to the time series tables.
- Options have been added to the 2FRE record to assign frequencies based on the normal and log-normal probability distributions. Previously, only the relative frequency option was provided for assigning frequencies.
- The 2FRE and 2FRQ frequency record variable options have been expanded to include reservoir water surface elevation (option 6) and storage (option 7). Instream flow shortage is now option 8.

New Water Budget Tables

- A major new computational routine is activated by the new 2BUD record. Detailed monthly water budgets are developed for individual control points. A period-of-analysis budget is developed for the entire river basin. The 2BUD routine provides a complete tabulation of all inflows and outflows previously unavailable that may be useful for various purposes.

Other *TABLES* Modifications

- An error associated with KK options 5 and 6 activated by 1CPT record field 2 was corrected.
- The columns of the 2SBA record table have been rearranged slightly.
- The 2REL reliability as well as the 2FRE frequency and time series records have been restructured using the new IDEN record. This allowed the 2RET record to be deleted with the supplemental reliability table now being specified directly on the 2REL record.
- As previously noted, the major new *TABLES* features associated with conditional reliability modeling, daily time step simulation results, flood control, and salinity are described in Appendix E of the *Supplemental Manual* but are not further addressed here.

Modifications Between the September 2006 and May 2007 Versions

The May 2007 version of *WinWRAP*, *SIM*, *HYD*, and *SIM*-related features of *TABLES* are documented by:

Reference Manual for the Water Rights Analysis Package (WRAP) Modeling System, TWRI TR-255, Revised Third Edition, May 2007.

Users Manual for the Water Rights Analysis Package (WRAP) Modeling System, TWRI TR-256, Revised Third Edition, May 2007.

Modifications to *SIM*, *SIM*-related *TABLES* features, and *WinWRAP* since completion of the September 2006 version of the software and accompanying September 2006 Third Edition of the *Reference* and *Users Manuals* are noted as follows. Most of the modifications described here are to *SIM*. They were developed in conjunction with intermediate December 2006, February 2007, and March 2007 versions as well as with the May 2007 *SIM*. The program *HYD* has not been revised since 2002. Modifications to the programs documented in the *Supplemental Manual* are not addressed here. *SIMD* has also been updated with the *SIM* revisions. Other modifications to *SIMD* and *SALT* are not included in the following descriptions of modifications.

WinWRAP Modifications (*September 2006 – May 2007*)

The *WRAP Files* menu of *WinWRAP* was revised to reflect the addition of the new *SIM* SOU and DSS output files and the change in the *TABLES* output filename extension from the fixed TAB to a user-specified extension with a default of TOU. The *All Files* and *DSS Files* menu selections were added and other menu items were revised.

TABLES Modifications (*September 2006 – May 2007*)

- The user now has the option of specifying any filename extension for the main *TABLES* output file, with TOU being the default. The *TABLES* output file is the only WRAP file for which the user can assign a filename extension along with entering the filename root. TOU is used for the default filename extension rather than the previous standard extension TAB because Microsoft Visual Studio 2005 uses TAB as one of its defined filename extensions.
- The tables of sorted water rights created by the 1SRT record were expanded to include additional information regarding reservoirs, and an option was added allowing inclusion of instream flow rights. The format of the 1SUM record summary tables was also reorganized slightly. The KK=4 listings by water right group is now applicable to 1SRT as well as 1SUM tables.

Minor Improvements Common to SIM and TABLES (*September 2006 – May 2007*)

- A feature was added to write the date and time in the *SIM* and *TABLES* message files.
- A carriage control feature for the direct access OUT file was added that is transparent to the model-user but simplifies the compilation of *SIM* and *TABLES* a little.

SIM Modifications (*September 2006 – May 2007*)

Modifications Made in Conjunction with Updating to the New Intel Compiler

A compiler converts a Fortran program, with a filename extension FOR or variation thereof, to an executable program with filename extension EXE, static library with filename extension LIB, or dynamic library with extension DLL, and also links the program with library

routines. Compilers are typically applied within an Integrated Development Environment (IDE) which provides editing, file management, and other utility functions. Many different Fortran compiler/IDE packages are sold by various companies. The compiler, linker, and development environment used with WRAP over the past ten years is a popular Fortran software development package that has evolved through various versions as ownership passed from Microsoft to Digital to Compaq to Intel as follows.

- Digital Visual Fortran combined with a version of the Microsoft Visual Studio IDE replaced Microsoft Power Station in the early 1990's.
- Compaq Visual Fortran replaced Digital Visual Fortran in the late 1990's. The software package was similar under ownership of the two different companies and continued to combine the compiler/linker with its own version of the Microsoft IDE.
- Intel acquired Compaq Visual Fortran in the early 2000's. Intel marketed its Intel version of the 2000 Compaq Visual Fortran Version 6.5 which still continued to be combined with the Microsoft Visual Studio IDE.
- The 2006 Intel Visual Fortran 9.1 replaced Compaq Visual Fortran. Intel Visual Fortran 9.1 is used with the Microsoft Visual Studio 2005 IDE.

As the Fortran compiler/linker software transferred between companies from Microsoft to Digital to Compaq and now to Intel, it continued to be applied within the Microsoft Integrated Development Environment (IDE). The Digital and Compaq software products were sold as integrated packages that included then current versions of the Microsoft IDE along with the compiler and linker software. The Microsoft IDE was significantly expanded in 2002 and subsequently progressed through other versions, with the current version now being Microsoft Visual Studio 2005. The Microsoft Visual Studio 2005 IDE is used to develop programs in Visual Basic, C#, J#, C++, Fortran, and/or other programming languages. Components of a program may be written in different languages. Intel Visual Fortran 9.1 is sold as a separate product that requires and is implemented within the Microsoft Visual Studio 2005 Integrated Development Environment.

Standard versions of the Fortran programming language are officially approved by the American National Standards Institute (ANSI). The most recent versions of Fortran were formally adopted in 2003, 1995, 1990, and 1977. Fortran 2008 is under preparation. Marketing of compiler software implementing the improved versions of the Fortran language typically lag a couple of years behind official ANSI approval of the language standard. Compaq Visual Fortran 6.5 is based on Fortran 95. Intel Visual Fortran 9.1 is updated to Fortran 2003. The WRAP programs are compatible with both the 1995 and 2003 Fortran standards.

The two versions of the software currently used to develop/modify the Fortran source code and convert it to executable WRAP programs are as follows.

- Compaq Visual Fortran 6.5 and Microsoft IDE with copyright date of 2000. This is the Compaq Visual Fortran Professional Edition V 6.5, Intel Version.
- Intel Visual Fortran 9.1 Professional Edition with copyright date of 2006 with 2007 updates combined with Microsoft Visual Studio 2005 IDE.

SIM was updated for compatibility with the new 2006 Intel compiler. Several relatively minor changes to the Fortran code were made initially that were necessary to allow *SIM* to be compiled with the new Intel compiler without crashing. However, versions of *SIM* compiled with the new Intel compiler were found to yield small differences in simulation results for several of the TCEQ WAM System datasets than if *SIM* is compiled with the old Compaq compiler. Simulation results were also affected by whether *SIM* was compiled by the new compiler in debug or release mode (sets of configuration property settings). The variations were found to be caused primarily by problems occurring with the new Intel compiler applied in the release mode. These problems have been corrected in the current *SIM* primarily with Fortran code changes supplemented with choices of compiler configuration property settings.

Many of the problems could have been handled solely with optional compiler settings. However, code changes allow the Fortran program to be compiled with either default or other settings with either the Compaq or Intel compilers, without having to be concerned with compiler settings which can be tricky. The rules of Fortran were followed correctly with or without the modifications. The issues were related to the manner in which the alternative compilers implemented Fortran and defined default configuration property settings. The problems involved several issues ranging from simple to quite complex that were solved with various code revisions. The root causes of the more significant problems were very subtle. The greatest culprit was found to be problems with the new Intel compiler in release mode caused by the effects on conditional if statements of preciseness inconsistencies associated with floating point real number operations within the computer. These problems were corrected with a number of Fortran code revisions along with adoption of the *improve preciseness consistency* setting in the configuration properties which deactivates certain memory and run-time optimizations. The preciseness consistency problems occurred primarily within the iterative reservoir routines discussed below.

Refinements to the Reservoir and Hydropower Routines

Reservoir and hydropower computations are performed in the main program and Subroutines RELEASE, RESCAL, and POWER. The main program organizes the computational procedures based on the water right type specified on the *WR* record. Subroutine RELEASE is called for multiple-reservoir system rights to determine releases following multiple-reservoir operating rules defined by *WS* and *WR* records. Subroutine POWER is called for hydropower computations. The main program and Subroutines RELEASE and POWER call Subroutine RESCAL to perform reservoir calculations. Subroutine RESCAL computes end-of-month storage, net evaporation, and outflow volumes for each water right that has reservoir storage. Interdependencies between end-of-month storage, evaporation, and releases necessitate an iterative simulation algorithm. The algorithm stops at a maximum of 50 iterations with a warning message if stop criteria are not satisfied.

Subroutine RESCAL performs computations for each reservoir. Multiple-reservoir release decisions are made within Subroutine RELEASE, which calls Subroutine RESCAL one or multiple times as each system water right is considered. Subroutine POWER implements an iterative hydropower algorithm in which the iterative RESCAL reservoir calculations are embedded within an iterative hydropower release algorithm.

These iterative algorithms in subroutines RESCAL, RELEASE, and POWER contain a number of conditional if statements that were revised in conjunction with dealing with the preciseness consistency issues discussed in the preceding section. These routines were also improved in general to make them easier to understand and more robust. The subroutines were reorganized to facilitate reading the code and understanding the computations. Refinements were also made to make the algorithms more robust in efficiently covering every type of situation that could possibly occur during the multitude of iterative computations.

New SIM Input and Output Options and Connections to HEC-DSS

TABLES has since 2004 provided options for writing *SIM* simulation results as DSS files to be read by HEC-DSSVue for plotting or other purposes. The *TABLES* time series records allow any of the *SIM* simulation results time series data to be written to a DSS file. However, in previous versions, *SIM* was not directly connected to HEC-DSS. The following new features activated by the new optional output files *OF* record are incorporated in the May 2007 *SIM*.

- Hydrology Input DSS File
 1. A new feature of *SIM* allows naturalized flows and evaporation-precipitation depths from the *IN* and *EV* records of FLO and EVA files to be converted to a DSS file with the filename rootHYD.DSS.
 2. Naturalized flows and evaporation-precipitation depths can be read by *SIM* from a DSS file as option 6 specified in *JO* record field 2 as a new alternative to FLO and EVA files.
- Simulation Results Output DSS and SOU Files
 3. *SIM* simulation results can be written to a DSS file with filename root.DSS to be read with HEC-DSSVue.
 4. *SIM* simulation results can be written to a text file with filename extension SOU in a new columnar format that can be read with any editor or transported to Microsoft Excel.

In addition to DSS input and output files, the new SOU output file provides a columnar table that is much easier for people to read than the OUT file. The DSS and SOU output files controlled by the new *OF* record contain the same simulation results as the OUT file read by *TABLES*. The DSS and SOU file options require much more computer memory than the conventional OUT file because the water right, control point, and reservoir output data are stored in memory as arrays and then written to files at the end of the simulation.

EA Record Evaporation Allocation Routines with Multiple

Rights and Right Types at the Same Component Reservoir

EA records are used to model situations where multiple entities (owners) share the storage capacity of the same reservoir. The actual real-world reservoir is divided into multiple computational reservoirs. Without the complication of a nonlinear storage-area relationship used in the reservoir evaporation computations, *SIM* could handle this component reservoir modeling strategy with no special features required. The *EA* record feature was added originally solely to allocate net evaporation-precipitation between the component reservoirs representing the multiple owners. The *AF* record feature was added with the September 2006 *SIM* for use in

combination with an *EA* record to allocate streamflow inflows between the component reservoirs. The following routines are applied in the water rights simulation sequence when considering a water right located at a *computational component* reservoir listed on an *EA* record.

1. For type 1 and 7 rights (*WR* record field 6), the net evaporation volume is computed based on evaporation allocation methods activated by the *EA* record field 3 options. The evaporation allocation methods are applied only to type 1 and 7 rights.
2. For hydropower rights, the head used in the hydropower computations corresponds to the summation of the storage contained in all the component reservoirs listed on the *EA* record. Likewise, the elevation of the bottom of the power pool refers to total storage capacity summed for all the reservoirs. However, the *EA* record evaporation allocation routines are not applied for hydropower rights. Evaporation is determined by the conventional *SIM* computation routine.
3. The streamflow availability allocation routine activated by the *AF* record is applied to all water rights associated with all reservoirs listed on the *EA* record. Storage and evaporation are not relevant to the *AF* record streamflow availability routine.

The *EA* record evaporation allocation routines are activated within *SIM* only for type 1 and 7 rights. However, with caution, any number of water rights of any of the types can be applied at *EA* record reservoirs. Applying the *EA* record routines with multiple water rights of various types at the same component reservoir caused problems in the past from the perspectives of both problems in the Fortran code and inconsistencies regarding the requirements for developing input datasets. Previous versions of *SIM* worked correctly with some datasets but not others. The May 2007 code has been refined and corrected, and the *Reference and Users Manuals* have been expanded to better clarify how the *EA* record features can and can not be applied. The rules for combining *EA* records with multiple rights at the same component reservoir are outlined in detail in the May 2007 *Reference and Users Manuals*.

New EA Record NEAF Options

Variations of the NEAF options 2 and 3 activated by *EA* record field 3 have been added as options 22 and 33. The only difference is that the option 2 and 3 feature described below is not applied with the new options 22 and 33. All component reservoirs listed on the *EA* record are treated the same with options 22 and 33.

The evaporation allocation computations occur in the water rights priority sequence. Thus, end-of-month storage for junior rights has not yet been computed when a particular more senior right is considered and thus must be estimated. The resulting approximations mean that the evaporation volumes allocated to the component reservoirs typically do not sum to the correct total evaporation volume for the actual reservoir. With NEAF options 2 and 3, in order to address this problem, the evaporation allocated to the last reservoir listed on the *EA* record is computed as the difference between the correct total evaporation and the sum of evaporation volumes for all the other reservoirs listed on the *EA* record. This forces the evaporation for the component reservoirs to sum to the correct total. The new options 22 and 33 omit this feature.

Dual Simulation Option Default

A new feature activated by the new *JO* record field 11 sets a default dual simulation option which is applied to all water rights, subject to being over-ridden by *PX* record field 2 or *SO* record field 14.

New Dual Simulation Cumulative Depletion Limit Options

With dual simulation options 3 and 5 (*JO* record field 11, *PX* field 2, *SO* field 14), streamflow depletions each month for a right determined during the first simulation serve as a maximum limit on streamflow depletions during the second simulation. The streamflow depletion for a given month during the second simulation is not allowed to exceed the depletion for that month occurring during the initial simulation. Options 33, 333, 55, and 555 are variations of options 3 and 5 that were added with the May 2007 *SIM* to allow the depletion constraints to be relaxed somewhat by allowing flexibility in the timing of the depletions.

Dual options 33 and 55 are similar to options 3 and 5 except the limits are based on cumulative depletions rather than depletions in each individual month. For any month, for a particular right, the total cumulative depletions since the beginning of the second simulation can not exceed the corresponding cumulative depletions occurring in the initial simulation.

With options 333 and 555, for type 1 and 7 rights (*WR* record field 3) with reservoir storage, the limit during the second simulation is the accumulative streamflow depletions since the reservoir was last full. The accumulative depletions are zeroed whenever the reservoir is full to capacity. For water right types other than types 1 and 7 with storage, the options 333 and 555 limits applied during the second simulation are the first simulation depletion for the current month plus any excess depletion from the immediately preceding month. Unused depletions are carried into the next month but no further.

PX Record Priority Circumvention Features in Combination with Negative Incremental Option 5

The downstream control point flow availability limit options are activated by *PX* record fields 4 and 5 previously could be used only in combination with *JD* field 8 negative incremental flow options 1, 2, 3, and 4, not with option 5. The May 2007 *SIM* has been modified to allow the *PX* record options to be used in combination with negative incremental flow option 5.

Improved Computational Efficiency for Negative Incremental Option 4

Negative incremental option 4 (*JD* record field 8) previously required an excessive amount of execution time for datasets with a very large number of control points. The code has been revised to be much more efficient. Option 4 now has negligible effect on run times.

TL Limit Parameter for Number of Values in *IS/IP* Record Table

By default, a maximum of 12 pairs of values may be entered on *SA/SV*, *PV/PE*, *TQ/TE*, and *IS/IP* records. The TL parameter in *JD* record field 11 allows this maximum limit to be

increased to any number above 12. The TL parameter was added with the September 2006 version of *SIM*, but applied only to *SA/SV*, *PV/PE*, and *TQ/TE* record tables. *SIM* has now been revised such that TL is also applicable to the *IS/IP* records. Thus, any number of values may be included in a *IS/IP* record table defining a drought index by raising the maximum limit above the default of 12 using *JD* record field 11.

Drought Index Interpolation Error Check

A drought index is defined by a pair of *IS* and *IP* records. Linear interpolation is applied to the *IS/IP* record table for a given storage to determine the drought index multiplier factor. The linear interpolation routine for the drought index *IS/IP* record table is different than the linear interpolation routine applied to the *SA/SV*, *PV/PE*, and *TQ/TE* record tables discussed in the next section. Whereas values in *SA/SV*, *PV/PE*, and *TQ/TE* record tables must progress sequentially from small to large, such restrictions are not imposed on a drought index. A drought index may exhibit essentially any configuration of linear segments. Extrapolation is not included in the drought index linear interpolation routine. The storage must fall within the range defined by the smallest and largest storage values on the *IS* record. An error check was already in *SIM* that activates an error message if the storage exceeds the highest storage value on the *IS* record. However, there was no error check for the storage following below the lowest value on the *IS* record. The interpolation routine in the May 2007 *SIM* has been revised to include such a check.

Linear Extrapolation Warning Message

Subroutine LINEAR applies linear interpolation to *SA/SV*, *PV/PE*, and *TQ/TE* record tables. Values in *SA/SV*, *PV/PE*, and *TQ/TE* record tables must progress from small to large. If a storage volume computed during the simulation exceeds the highest value in the table being interpolated, the highest value in the table is adopted. If a simulation storage falls below the lowest value in the table, interpolation is applied based on automatically inserting the zero-zero point.

SIM already wrote a warning message any time the highest value in an interpolated table is exceeded. A new warning message was added that is activated if a simulated value falls below the range covered by the interpolated table. *SV* and *PV* records typically begin with zero storage, and *TQ* records typically begin with zero discharge, in which case, the new warning message is never activated. However, if the tables begin with non-zero values and computed storage falls below this lowest value in the table, the warning message is activated.

Obsolete *FO* and *DT* Record Messages

The files options *FO* record is obsolete in the April 2005 and later versions of *SIM*. Several files are activated by the *JO* record, and *SIM* automatically determines which other files to activate. A warning message was added in the May 2007 *SIM* which is activated if a *FO* record is read indicating that the record is no longer needed.

The *DT* record is obsolete in the September 2006 and later versions of *SIM*, having been replaced by the *PX* record. An error message was added which is activated if a *DT* record is read.

TO Record TOTARGET Options 7, 9, and 12

Options 7, 9, and 12 activated by *TO* record field 2 adjust targets based on cumulative annual depletions, withdrawals, or diversions. However, the Fortran code never actually activated these annual options unless the water right also had a *SO* record. *SIM* has now been corrected such that *TO* record TOTARGET options 7, 9, and 12 work even if the water right has no *SO* record. None of the TCEQ WAM System datasets actually include these options to date.

SO record fields 4, 8, and 10 activate options based on cumulative annual or seasonal amounts. A season is defined by beginning and ending months entered in *SO* record fields 11 and 12, with defaults of months 1 and 12. *TO* record TOTARGET options 7, 9, and 12 use the year or season defined by the *SO* record. Before the correction, no year or season was defined without an *SO* record. The correction sets defaults of months 1 and 12 which are in effect even without an *SO* record for the water right. However, if a season is defined on a *SO* record, that season also applies to *TO* record TOTARGET options 7, 9, and 12 for that water right.

TO record field 2 TOTARGET options 6, 7, 8, 9, 11, and 12 require that a water right identifier TOWR be entered in *TO* record field 9. If field 9 is blank, an error message is activated. Previously, the error check was performed only with options 6, 7, 8, and 9. The code was revised to perform the TOWR error check with TOTARGET options 11 and 12 as well.

TO and TS Record Subtraction Options

The *TO* record field 4 subtraction option consists of subtracting the amount computed in accordance with *TO* record specifications from the previously computed target amount. The *TS* record field 2 also has a subtraction option. These subtractions may result in a negative value for the target amount. The *SIM* code was revised to set a negative result equal to zero.

MS Record Combined with TO Record Field 2 Option 5

TO record TOTARGET option 5 sets targets based on reservoir draw-down. The *MS* record specifies seasonal rule curve reservoir operations with the storage capacity varying monthly. Previously, *TO* record TOTARGET options 5 and -5 draw-downs were based solely on the storage capacity specified on the *WS* record without consideration of *MS* record monthly maximum storage limits. The code has been revised to include consideration of *MS* record storage limits in computing draw-downs for TOTARGET options 5 and -5.

Backup Water Right

The September 2006 *SIM* included expanded backup right features associated with the new *BU* record that replaced the old backup feature activated by *SO* record field 6. The intent was for the old *SO* field 6 option to continue to work, though it is superseded by the new *BU* record. However, the old *SO* record feature was not maintained correctly. The BUX multiplier factor entered in *BU* record field 3 should default to 1.0 if the *SO* field 6 is used instead of the *BU* record, but did not. This coding error was corrected in the December 2006 version of *SIM*.

Summation of Diversion Targets at Control Points

Simulation results include the control point summation of the diversion targets and shortages for all water rights located at each control point. The summations are performed each month at the end of the simulation computations and affect no other simulation results. The control point summary data are used by *TABLES* in developing control point and basin (2SCP and 2SBA) summary tables. Previously, water rights were excluded from the summation if the annual target amount entered in *WR* record field 3 was zero, even if a non-zero target was established during the simulation computations by *TS* or *TO* record options. This has been corrected to include all diversion targets in the control point summaries, even if the target amount in *WR* record field 3 is zero. The parameter *ISHT* in *SO* record field 9 can be used to select which intermediate diversion target is included in the recorded simulation results.

Modifications between the May 2007 and November 2007 Versions

Modifications to the *SIM* and *TABLES* programs between the May 2007 and November 2007 versions are noted as follows. The modifications are included in a December 2007 draft fourth edition of the *Users and Reference Manuals*. The draft manual updates have been refined throughout as well as updated with the new software features.

Modifications Common to SIM and TABLES (May 2007 – November 2007)

Unformatted Output File Option

A new option has been added to *SIM* and *TABLES* to allow *SIM* simulation results to be recorded in the OUT or CRM output file in "unformatted" binary machine language. *SIM* simulation results have always been recorded in the OUT file in a "formatted" text file format which can be read by any editor as well as read by *TABLES*. With the new option, the OUT file can be read only with *TABLES*. The advantages of the new option are a significant reduction in the size of the OUT file and for simulations with large amounts of output a significant reduction in computer execution time. Also, since simulation results are stored on the hard drive in the same form as computed by the processor, there is no loss in precision. The standard formatted text file of the past remains the default with the new option requiring activation by the *JD* field 7 in *SIM* and the new SOUT record in *TABLES*.

The *JD* record has been modified to allow the new binary machine language output file option to be activated by the new switch *OUTFILE* in *JD* record field 7. The seldom-used parameter *IDSET* previously occupying field 7 is moved to the end of the *JD* record as field 12. The new machine language form of OUT or CRM file is flagged by entering a SOUT record any place in the *TABLES* input TIN file. The SOUT record has no input parameters. An error message is printed if *TABLES* reads an unformatted binary OUT file but has no SOUT record in its TIN file or reads a formatted text OUT file while having a SOUT record in the TIN file.

Miscellaneous Program Updates and Refinements

SIM and *TABLES* are fully compatible with Fortran 95 and Fortran 2003 standards. The Fortran programs compile correctly with either the Compaq Version 6.1 (copyright 2000), Intel

Version 9.1 (copyright 2006), or Intel Version 10.0 (June 2007 update) compilers, with minimal required concern with selection of compiler options. The May 2007 *SIM* incorporated revisions making *SIM* fully compatible with the latest versions of the Fortran language and Intel compiler. The September 2007 *TABLES* reflects revisions made during July-September 2007 to update to latest Fortran language standards. Various minor revisions were also made throughout the *TABLES* code to more concisely and systematically organize the Fortran program. Several new error checks were added, and minor refinements to various table formats were also made.

Another minor refinement to both *SIM* and *TABLES* consisted of expanding the standard error routine. *SIM* and *TABLES* both have an array of error checks. Each error check has its own individual message followed by activating a subroutine which writes a standard message and terminates program execution. The standard error message routine has been expanded a little to provide more information when Fortran IOSTAT errors occur.

SIM Modifications (May 2007 – November 2007)

New Instream Flow Target Feature

A new feature for defining instream flow requirements is activated by a new parameter entered in *IF* record field 6. The new feature is pertinent only if more than one *IF* record (optionally with their associated *FS*, *TO*, *TS*, *SO*, and *WS* records) set a target for the same control point. As the multiple *IF* records (with auxiliary *FS*, *TO*, *TS*, *SO*, *WS* records) connected to the same control are activated in the water rights priority sequence each month, the new *IF* record field 6 parameter controls the combination of *IF* record minimum instream flow targets. With the default option 1, the current *IF* record target replaces the preceding target set at the control point by a more senior *IF* record right. With option 2, the largest of the new versus preceding target is adopted. With option 3, the *IF* record instream flow target is adopted only if it is smaller than the target already set by the preceding more senior *IF* right.

In past versions of *SIM*, if more than one *IF* record referred to the same control point, the latest target computed in the water rights priority sequence always replaced the preceding target. This is still the default option 1. However, the new added feature now allows each *IF* record target to be compared with the latest preceding target, with adoption of either the largest (option 2) or smallest (option 3) of the two. This new feature allows any number of *IF* record rights with their supporting *FS*, *TO*, *TS*, *SO*, and *WS* record features to be combined at the same control point to model multiple-tiered instream flow requirements.

New Naturalized Flow and Evaporation-Precipitation Features Accessed on CP Record

A new option 9 has been added for the parameter *INMETHOD(cp)* in control point *CP* record field 6. A new *NEXT* option has been added for the parameter *CPEV(cp)* in *CP* record field 8. These options allow a control point to have no naturalized flows and/or to repeat the evaporation-precipitation rates from the next downstream control point.

CP record field 6 specifies the manner in which naturalized flows are provided for the control point. The new option 9 allows control points to be included in the model with no assigned naturalized flows, which is different from flows of zero. *SIM* simulation computations

to determine the amount of streamflow available to a water right consider flows at the control point of the water right and all downstream control points except now the new option 9 control points. Any control point assigned option 9 is skipped (not considered) in determining flow availability for water rights. In simulation computations dealing only with that option 9 control point, the naturalized, regulated, and unappropriated flows are zero, but this has no effect on flow availability for water rights. Flows available to water rights at an option 9 control point are controlled only by flows at other control points.

CP record field 6 specifies the manner in which net evaporation-precipitation rates are assigned to the control point. In past versions of *SIM*, net evaporation-precipitation rates from another control point are repeated by entering a control point identifier. With the new modification, if the term *NEXT* is entered, net evaporation-precipitation rates from the next downstream control point that has net evaporation-precipitation rates are repeated.

New Message with Second IF Pass Count

An optional feature that activates a second pass through the water rights simulation under certain conditions is controlled by parameters entered in instream flow *IF* record field 7 and *JO* record field 10. A new counting feature was added that counts the number of months during which the second pass simulation is performed. The count is written to the message *MSS* file. The new message provides a quick check of whether or not and the frequency that conditions occurred that activate the second pass through the water rights simulation loop.

Negative Streamflow Depletions with Multiple Rights at Same Reservoir

SIM was modified to better deal with negative streamflow depletions generated by multiple *WR* record water rights at the same reservoir that refill to different storage capacities. Previously, all of the multiple storage refilling rights at the same reservoir could generate negative streamflow depletions. *SIM* has been modified to allow only the most junior storage refilling right at a reservoir to generate negative streamflow depletions. In most cases, the correction has little or no impact on simulation results. It is pertinent only in months in which a reservoir is full to capacity and precipitation on the reservoir water surface exceeds evaporation in an amount that also exceeds diversion demands.

A negative streamflow depletion can occur if a negative net evaporation-precipitation depth from an *EV* record occurs concurrently with a full reservoir. A negative net evaporation-precipitation depth means simply that the precipitation depth exceeded the evaporation depth during that month. Streamflow is depleted to refill storage and supply net evaporation and diversion requirements. For a negative streamflow depletion to occur in a particular month, a negative net evaporation-precipitation volume must be greater than the reservoir refilling and diversion volume. A negative streamflow depletion increases streamflow below the reservoir.

With multiple water rights with different storage capacities at the same reservoir, total cumulative net evaporation-precipitation volumes are recomputed for each water right in the priority sequence. The net evaporation-precipitation volumes have always been handled correctly, without double-counting. However, the generation of negative streamflow depletions could previously be "double-counted". The basic problem dates back to the initial versions of

WRAP, but is further complicated when a multiple-right reservoir is also an *EA* record component reservoir. In the past, multiple rights at the same reservoir were treated the same in regard to generating negative streamflow depletions. *SIM* has been revised to allow only the most junior right at the reservoir to generate negative streamflow depletions.

SO record field 13 provides options to switch-off the application of specified modeling features to a particular water right. The NONSFD option was added that activates a feature that sets all negative streamflow depletions generated by a right to zero. Thus, negative streamflow depletions are switched off and not allowed to increase streamflow. The new NEGSFD option in *SO* record field 13 is applicable only to multiple rights at the same reservoir. It allows each of the rights to generate negative depletions. As discussed above, without the NEGSFD switch activated, *SIM* has been modified to allow only the most junior right to increase streamflow with negative streamflow depletions.

Minor *BU* Record Problem Potentially Terminating Program Execution

The *BU* record allows specification of a water right identifier in field 4 and a water right group identifier in field 5. Leaving either field 4 and 5 blank or neither or both the fields blank should all be fine. However, in some cases the previous version of *SIM* could terminate execution if a group identifier was entered in field 5 while field 4 was left blank. The problem was related to lack of robustness of the program in handling a water right integer identifier of zero. The problem has been corrected.

Error Message Correction

An invalid record identifier or blank record in the DAT input file activates an error message routine. In the previous version of *SIM*, the first part of the error message was written correctly followed by abrupt termination of the program. The error routine has been corrected to write the entire message and then terminate execution in the standard manner.

Evaporation-Precipitation Depth Output Correction

Evaporation-precipitation rates read from *EV* records or a DSS file may be included in the OUT file to be read by a *TABLES* 2EVR record. An error was corrected that allowed *SIM* to write depths to the OUT file for the wrong control points. *SIM* computations are not affected.

TABLES Modifications (May 2007 – November 2007)

Several features described in the May 2007 revised *Users Manual* were not actually implemented in *TABLES* until July-November 2007. If users attempt to activate these features associated with the 2FRE record in the May 2007 version of *TABLES*, a message is activated stating that the feature is still under construction. These features have been completed in the November 2007 *TABLES*. The new features are as follows.

- A frequency table option activated by 2FRE record field 5 allows frequency tables to be created in a tabular format with ten more frequencies than the old standard table which is in

row format. Data also are printed with more digits to right of the decimal than in the standard table which has limited space.

- Frequency method options activated by 2FRE record field 6 allow use of the normal and log-normal probability distributions.
- Moving average and moving total options are activated by 2FRE record fields 7 and 8. This feature was added to the time series records in the May 2007 version and the 2FRE record routine in the November 2007 version.
- The addition factor AF in field 11 of time series records and field 10 of the 2FRE record is also first implemented in the November 2007 *TABLES*.

All the capabilities described in the draft May 2007 *Users Manual* are fully operational in the November 2007 *TABLES*. However, the 5CRM, 5CR1, 5CR2, and 5COR records documented in the *Supplemental Manual* also have not yet been implemented in *TABLES* and still activate a "feature under construction" message.

Various refinements were also made throughout the *TABLES* program to update to the latest Fortran language features and better organize the code. Several new error checks were added. Table formats were refined.

Modifications between the November 2007 and March 2008 Versions

The March 2008 WRAP includes an expanded and refined Fourth Edition of the *Reference*, *Users*, and *Fundamentals Manuals* as well as the new software features described below that are incorporated in programs *SIM*, *SIMD*, *TABLES*, *HYD*, and *WINWRAP*. The modifications described here are limited to those modeling features covered in the *Reference* and *Users Manuals*, excluding modeling capabilities covered in the *Supplemental Manual*. Thus, additional improvements to *SIMD* that are not also included in *SIM* and improvements to *SALT* are not addressed in this *WRAP Additions and Revisions Report*.

The feature described below for assessing stream flow availability in the water rights priority sequence was added to *SIM* and *TABLES* between the November 2007 and March 2008 versions. The other major set of modifications consisted of extensively updating, refining, and expanding program *HYD*. *WinWRAP* was also updated primarily for consistency with revisions to *TABLES*. Other minor software improvements are also noted in the following.

The software improvements are incorporated in the March 2008 Fourth Edition of the *Users and Reference Manuals* along with a general editorial rewrite of the manuals. Documentation of new model features and editorial refinements are reflected throughout all of the chapters of the March 2008 Fourth Edition of the *Reference*, *Users*, and *Fundamentals Manuals*. Chapters 6 and 7 of the *Reference Manual* are new chapters added in the fourth edition. Chapter 5 of the *Users Manual* dealing with program *HYD* has been rewritten and expanded along with significant revisions in Chapter 3 of the *Reference Manual*.

SIM and TABLES Modifications (November 2007 – March 2008)

Flow Availability in the Water Rights Priority Sequence

A new *SIM* and *TABLES* feature described in the new Chapter 6 of the *Reference Manual* is designed to facilitate assessments of the effects of each individual water right on regulated and available stream flows at specified control points. The *SIM ZZ* input record and *ZZZ* output file and *TABLES 4ZZF* and *4ZZZ* input records are added to implement the new modeling capability. Regulated flows, available flows, and upstream reservoir releases at specified control points are tabulated by *SIM* in a *ZZZ* file as each water right is simulated in the priority loop. These three stream flow variables have always been computed and recorded at the completion of the simulation each month. However, the new *SIM* feature tracks the flows at the beginning of the water rights loop and the intermediate flows after each individual water right is simulated in the priority sequence.

The *ZZZ* file table may be read directly with any editor. The new *TABLES 4ZZF* and *4ZZZ* records activate *TABLES* options for reading a *ZZZ* file and organizing the simulation results in optional time series formats or developing frequency tables. The *4ZZF* record builds frequency tables similar to the *2FREQ* record. The *4ZZZ* record organizes the flows as tables in the *TOU* file or as *DSS* file records in a manner similar to the type 2 time series records.

New Water Rights Priority Options

Two new options as well as the one previous option for assigning water right priorities are activated by the parameter *NPOPT* in *JO* record field 9. Previously *JO* field 9 activated only the option for automatically assigning priorities in upstream-to-downstream order. This feature remains as option 1. The two new options 2 and 3 assign water right priorities based on the sequence that the water right *WR* and *IF* records (option 2) and control point *CP* records (option 3) are placed in the *DAT* input file.

New and Revised Warning Messages

SIM has always included error and warning checks associated with reading *IN* and *EV* records from *FLO* and *EVA* files. However, this set of checks has been refined and expanded. The primary type of input data error addressed by the revisions was the error of including *IN* or *EV* records in the *FLO* or *EVA* file for a control point while the *CP* record indicates that the flows or evaporation rates will be determined by other alternative means, not read from *IN* or *EV* records. Warning messages associated with reading data from the recently added stream flow allocation *AF* record were also revised.

WinWRAP Update (November 2007 – March 2008)

The last previous update of *WinWRAP* was the May 2007 version. The *TABLES* input *TIN* file editor in *WinWRAP* has been updated to reflect new or revised *TABLES* input records added or revised since May 2007. Other relatively minor refinements are also incorporated in the March 2008 *WinWRAP*. The update included an intermediate version of *WinWRAP* dated March 2008 that included all revisions except the updating of the *TIN* file editor. The banner

included a message that work was in progress on updating the TIN file editor. A final March 2008 *WinWRAP* includes all modifications.

HYD Modifications (November 2007 – March 2008)

The WRAP program *HYD* is a set of routines designed to facilitate developing the hydrology input data for *SIM*. Improvements described here are the first significant revisions to *HYD* since its original development during 1999-2001. *HYD* has been applied very little to date because the hydrology datasets of naturalized flows (*IN* records) and net evaporation-precipitation depths (*EV* records) incorporated in the Texas WAM System were completed prior to completion of the *HYD* program. The March 2008 WRAP includes a comprehensive update of *HYD*. New modeling features added to *HYD* are described in the rewritten Chapter 5 of the *Users Manual* and expanded Chapter 3 and added Chapter 6 of the *Reference Manual*.

Extensive modifications were made to upgrade the *HYD* Fortran code to a level of refinement comparable to *SIM* and *TABLES*. New features activated by the new *OI* and *AN* records were added. New features associated with old input records were also added. Significant modifications reflected in the new March 2008 *HYD* are as follows.

- The *HYD* file options *FO* and dimension limits *DL* records were removed along with automation of file activation and array dimensioning. File organization was revised. The Fortran code was restructured and refined.
- DSS input and output file capabilities were added.
- Several existing computational features were refined.
- The parameters entered on the job control *JC* record were restructured and expanded.
- New features allow *HYD* to read a *SIM* output OUT file along with other input and use pertinent *SIM* output to adjust a flow dataset following specifications defined by parameters entered on records in the *HYD* input HIN file.
- The new *OI* record converts *SIM* OUT file simulation results to *SIM* or *HYD* input records.
- The new *AN* record applies alternative methods for defining a representative annual set of flows and/or net evaporation-precipitation rates that can be repeated for multiple years.

Modifications between the March 2008 and January 2009 Versions

The Fifth Edition of the *Reference* and *Users Manuals* dated August 2008 incorporates modifications to *SIM*, *HYD*, and *TABLES* made since the March 2008 version of the software and accompanying March 2008 Fourth Edition of the *Reference* and *Users Manuals*. Chapters 6 and 7 were added to the *Reference Manual* with the March 2008 Fourth Edition. A proposed new procedure for extending the hydrologic period-of-analysis is outlined on pages 206-209 of the Chapter 6. The flow extension procedure was introduced with the March 2008 Fourth Edition and refined in the August 2008 Fifth Edition of the *Reference Manual*. Most of the modifications to *SIM*, *HYD*, and *TABLES* occurring between the March 2008 and August 2008 versions are new additions created to facilitate the flow extension procedure. However, these additions are generic new features that can also be adopted for other types of applications.

New Features Shared by SIM, HYD, and/or TABLES (March 2008 – August 2008)

Storage Capacity and Drawdown

Reservoir storage capacity was added to the reservoir/hydropower output record written to the *SIM* output OUT, SOU, and DSS files. The reservoir storage capacity for a reservoir recorded in the OUT file is the lesser of the (1) largest *WS* record storage capacity defined by one or multiple water rights connected to the reservoir, (2) capacity limit entered on a monthly storage *MS* record, and (3) capacity limit entered on the new observed storage *OS* record described below. Programs *TABLES* and *HYD* read storage capacity along with the other variables in the *SIM* output OUT file.

TABLES now includes the storage capacity and storage drawdown on the time series tables activated by the new 2RSC and 2RSD records. Reservoir storage drawdown (2RSD record) is storage capacity (2RSC) minus end-of-month storage volume (2STO).

HYD now includes the storage capacity and storage drawdown in the variables selected by *OI* record field 2 and flow adjustments selected by *AS* record field 6. These *HYD* features are designed for using *SIM* simulation results in developing *SIM* input datasets.

Diversion targets and shortages were also added to the list of variables in the *HYD* output/input *OI* records field 4 and adjustment specification *AS* record field 6. These variables were already included in the *TABLES* time series records.

New Flow Distribution Option 10

The new flow distribution option 10 in *SIM* and *HYD* computes naturalized flows at an ungaged control point as a linear function of flows at one, two, three, or four gaged control points. The new methodology is motivated by flow extension applications. The methodology can be applied for the extension period with the coefficients in the flow distribution equation determined as the means of the naturalized flows for the original period-of-analysis. The methodology is applicable for other types of applications as well. Flow distribution methods are selected by *INMETHOD(cp)* on the control point *CP* record and parameters are entered on DIS file *FD*, *FC*, and *WP* records.

The new flow distribution option 10 is covered in Chapters 3 and 5 of the August 2008 *Users Manual* and in the August 2008 *Reference Manual*, which also contains a related new section entitled *Control Point Ordering and Allowable Source Control Points*.

HYD Modifications (March 2008 – January 2009)

The March 2008 version of *HYD* incorporated a variety of major improvements and new features. The August 2008 version reflects further refinements and additions. The addition of reservoir storage capacity, storage drawdown, diversion target, and diversion shortage to the variables available to the *OI* and *AS* record features was noted above. The new flow distribution option 10 is also discussed in the preceding paragraphs. *EQ* record features have been expanded and refined. Modifications also include a number of new error and warning checks throughout

the program and various other refinements. The new option 7 activated by JC(8) on the JC record was added to develop RU records for a RUF file from SIM simulation results.

SIM Modifications (March 2008 – January 2009)

The new flow distribution option 10 and addition of storage capacity to the simulation results output files are noted above. Other modifications are as follows.

Addition of Observed Storage (OS) Record Feature

The new OS record feature added to the August 2008 version of SIM is described near the end of Chapter 4 of the *Reference Manual* and in Chapter 5 of the *Users Manual*. The new Example 18 (originally 16) the July 2010 *Reference Manual* Appendix C illustrates incorporation of OS records in the flow extension procedure outlined on pages 210-213 of Chapter 6.

Reservoir storage capacity limits may be entered in the SIM input DAT file as observed storage OS records. Sequences of actual observed storage volumes or alternatively storage volumes computed in a prior simulation are entered on the OS records. Storage volumes are specified for each month of the hydrologic period-of-analysis for a particular reservoir. In each month of the simulation, as each water right is considered in the priority sequence, the storage capacity of the reservoir is the lesser of the storage capacity specified for the water right on its WS record and the volume specified for the reservoir on its OS record. The reservoir is filled to the capacity defined by the WR/WS and OS records subject to being constrained to the amount of stream flow available for filling. The end-of-month storage volume contained in the reservoir is limited to not exceed its capacity. Excess storage is released as a spill which is cascaded downstream just as a return flow or hydropower release.

Revision to PX Record Downstream Control Point Flow Availability Limit Option

This correction made in June 2008 is not related to any of the other modifications. The revision deals with the downstream control point flow availability limit option activated by fields 4 and 5 of the priority sequence circumvention options PX record. The PX record connects to a water right. The XCP(px) options selected in PX record field 4 for limiting stream flow availability for the water right apply to the stream flow availability computations at the control point XCPID identified in PX record field 5 and downstream control points. Previously, the feature was not activated if XCPID entered in PX record field 5 happened to be the control point located immediately downstream of the water right control point. The feature was activated only if one or more control points were located between the water right control point and the PX record field 5 XCPID control point. The control point immediately below the water right location can now be adopted as XCPID just like any other downstream control point.

Error Messages for Missing SV and SA Records

Error checks and messages have been refined in regard to situations in which SV and/or SA records are missing from the DAT file. The new error messages are more helpful in tracking the missing SV and SA records than the original messages. JD record field 4 ICHECK option 5

has also been expanded to include a list of reservoirs requiring *SV* and *SA* records along with the listing of *SV* and *SA* records.

RUF File with *RU* Records Activated by *RUFIN* and *RUF* on *JO* Record

The new regulated-unappropriated flow (RUF) file containing sequences of *RU* records is used by a set of options activated by the parameters *RUFIN* and *RUF* added as *JO* record fields 12 and 13. The new feature with *RU* records stored in a *SIM* RUF input file is designed to incorporate regulated flows in a condensed dataset by applying flow adjustments consisting of regulated flows less unappropriated flows. The concept of a condensed dataset was introduced in Chapter 6 of the August 2008 Fifth Edition of the *Reference Manual* and further refined in the January 2009 Sixth Edition. Although addition of the *RU* record and RUF file was motivated by this specific type of application, the new feature may also be used for other types of applications.

The flow volumes stored in a RUF file are applied within *SIM* to adjust stream flows. The *RU* record adjustments are somewhat similar to but distinctly different than the old flow adjustment *FA* and constant inflow *CI* records. The *RU* record adjustments are not cascaded downstream accounting for channel losses like the *FA* and *CI* record adjustments. The *RU* record monthly volumes are optionally added to naturalized flows or unappropriated flows at alternative stages of the *SIM* simulation as specified by the new parameters *RUFIN* and *RUF* on the *JO* record. Thus, the *RU* record flow adjustments may be applied within the *SIM* simulation in alternative ways controlled by the *JO* record *RUFIN* and *RUF* option selections.

The *SIM* input RUF file was designed specifically for incorporating regulated flows in a condensed dataset. With this type of application, the *RU* records containing regulated less unappropriated flows are created with *HYD* from *SIM* simulation results. However, as a generic feature, RUF files may be developed and applied in various other ways for different applications.

Addition of Target Options *TO* Record Options 13 and 14

The parameter *TOTARGET* in *TO* record field 2 specifies which variable in the *SIM* simulation the targets are computed based upon. New *TOTARGET* options 13 and 14 have been added for computing the target for the water right of the *WR* or *IF* record to which the *TO* record is connected based on the instream flow target (option 13) or instream flow shortage (option 14) for the water right specified as *TOWR*(n) in *JO* record field 9.

With option 13, the computed target is based upon the last target computed for the water right specified as *TOWR*(n) in *JO* record field 9. Addition of option 13 was motivated by applications in which a diversion or instream flow target is computed based on the target of another instream flow right. However, option 13 simply applies the last target computed for the *TOWR*(n) water right which may be either an *IF* record or *WR* record right. If the *TOWR*(n) water right is senior to the water right for which the target is being computed in accordance with the *TO* record, the target for the *TOWR*(n) water right for the same month is applied. If the *TOWR*(n) water right is junior, the target for the preceding month is applied.

Option 14 is designed for computing targets as a function of instream flow shortages. However, this particular instream flow shortage is defined within the water rights priority

sequence simulation by comparing a target for the TOWR(n) water right with an estimated regulated flow at the control point of the TOWR(n) water right as follows. The target for option 14 is identically same target as defined for option 13. The regulated flow is the flow at the control point of the TOWR(n) right at the point (priority) in the priority sequence at which the target is being computed for the *WR* or *IF* record right to which the *TO* record is connected.

Control Point Summations with Dual Options 1 and 4

At the completion of the simulation for each month, *SIM* sums values for various variables for all water rights and reservoirs associated with each control point. These summations are recorded on the control point output records in the output file. Dual simulation options 1 and 4 in *PX* record field 2 specify that water rights be included in the first simulation but omitted in the second simulation of a dual simulation. Thus, reservoirs connected to these water rights may be included in the initial simulation without necessarily also being included in the final simulation. However, reservoir storage contents and net evaporation-precipitation volumes for all reservoirs were previously summed for the control point output.

The control point summations for a dual simulation were modified such that storage and net evaporation-precipitation volumes are included for only reservoirs connected to at least one water right included in the second simulation. Thus, reservoirs connected to only dual option 1 and 4 water rights are excluded from these summations. Since the control point summations occur at the completion of the simulation each month, no other simulation results are affected.

Dual Simulation Option Combined with *FY* and *CR* Record Options

Problems have been corrected that prevented using the dual simulation option activated by the *PX* record in combination with either the firm yield *FY* record or conditional reliability *CR* record. These three different optional *SIM* features all involve repetitive simulations. The cycles would not execute together in certain situations. The problems have been corrected.

Monthly Storage Capacity *MS* Record Feature Correction

The *MS* record is designed for modeling reservoir operations with seasonally varying storage capacities. An error was introduced in the *MS* record computational routine in the August 2008 version of *SIM* in the process of adding the new observed storage *OS* record feature which also involves monthly varying storage capacity limits. In the August 2008 *SIM*, the new *OS* record worked correctly, but the old *MS* record no longer worked correctly. The problem has been corrected in the January 2009 *SIM*.

ZZZ File Tabulations for *IF* Record Second Pass Option

The *ZZ* record activates a feature that records regulated and available stream flows in water rights priority sequence in the *ZZZ* file. *IF* record *IFMETH* options 2 and 4 or *PASS2* on the *JO* record specify a second pass through the water rights priority loop. With the second pass option activated, simulation results are recorded in the *ZZZ* file for both the first and second pass. As discussed below, a problem was corrected in program *TABLES* which prevented *TABLES* from developing *4ZZF* and *4ZZZ* tables from a *SIM ZZZ* file in which both first and

second pass simulation results are recorded. A minor revision was also made to *SIM* in which the notation **** Beginning *** in the *ZZZ* file is changed to **** Beginning 2P* to indicate the beginning of the second pass results.

TABLES Modifications (*August 2008 – January 2009*)

1REC Record Correction

The 1REC record provides two options for selecting the records from the *SIM* input DAT file to be copied to the *TABLES* output file. The first option consists of listing the record types to be included, and the second option consists of listing the record types to be excluded. However, the second option was always activated even if the first option was specified on the 1REC record. This error has been corrected.

4ZZF and 4ZZZ Tables for Second Pass SIM Simulation Results

As noted above, the *ZZ* record activates a *SIM* option in which regulated and available flows are written to the *ZZZ* file. *IF* record *IFMETH* options 2 and 4 or *PASS2* on the *JO* record specify a second pass through the *SIM* water rights priority loop simulation if instream flow requirements are not met during the first simulation. Simulation results are recorded in the *ZZZ* file for both the first and second pass. The *TABLES* 4ZZF and 4ZZZ records develop tables that organize the data in a *ZZZ* file. *TABLES* was previously unable to read a *ZZZ* file that included both first and second pass simulation results. *TABLES* has been corrected such that the results from the first pass are skipped, and the second pass results in the *ZZZ* file are included in the 4ZZF and 4ZZZ record tables. Although results from both simulations are included in the *SIM* output *ZZZ* file, only the final simulation results (second pass) are included in the *TABLES* 4ZZF and 4ZZZ record tables.

Modifications between the January 2009 and July 2010 Versions

Salinity Modeling Capabilities

Salinity modeling capabilities were added to WRAP effective July 2009 with completion of the program *SALT* and accompanying manual. The program *SALT* became operational in July 2009 after development efforts extending over several years. *SALT* is documented by the July 2009 *Salinity Manual: Salinity Simulation with WRAP*, TWRI TR-317, July 2009.

SIM Modifications (*January 2009 – July 2010*)

The following minor revisions to *SIM* made during the period January through August 2009 involve options that happen to not be activated in any of the existing TCEQ WAM System datasets.

- A problem with FSV option 6 activated by *FS* record field 2 was corrected.
- A problem in combining INMETHOD option 2 in *CP* record field 6 with INEV option 2 in *JO* record field 2 was corrected.

Any number of *TO* records can be connected to the same water right. However, a warning message was erroneously added in the July 2010 version of *SIM* indicating that a *WR* or *IF* record can have only one *TO* record with TOTARGET options -1, -2, and -3 selected in *TO* record field 2. This warning message is not correct and is removed in the January 2011 *SIM*.

Flow Switch *FS* Record Capabilities

New modeling capabilities controlled by the *SIM FS* record and new *TABLES* 2FSV and 2FSC records were added. The primary *SIM* and *TABLES* additions related to the *FS* record are summarized as follows.

- The *FS* record previously activated a criteria based on comparing cumulative flow volume to a specified range. This feature is still intact in the July 2010 *SIM*. A second alternative option has been added in which the number of months in which flow volumes fall into a specified range is counted.
- Flow volumes and counts for instream flow *IF* record rights have been added to the *SIM* OUT, SOU, and DSS output files. 2FSV and 2FSC records are added to *TABLES* time series records to tabulate these new simulation results variables.
- A *FS* record can now be applied to a reservoir release capacity specified in *OR* record fields 9 and 10 as well as to water right targets.
- Any number of *FS* records can be connected to the same water right. Any number of water rights can be connected to the same *FS* record. Previously, each water right was limited to one *FS* record, and each *FS* record was limited to one water right.
- *FS*, *OR*, *WR*, and *IF* records have been revised to accommodate the expanded flow switch capabilities. Revisions to the *OR* and *WR* records will not affect old input datasets. The *IF* record is slightly revised by relocating the seldom-used IFFLAG2 to make room for a *FS* identifier. Old *FS* records must be updated. Old versions of the *IF* record with non-zero IFFLAG2 and old *FS* records generate warning messages in the July 2010 *SIM*.

Features for Modeling Reservoir Operations

A flow switch *FS* record can now be connected to the maximum release limit entered in operating rules *OR* record field 9. This added new field does not affect old datasets.

A multiple-reservoir system operation feature described on *Reference Manual* pages 114-115 was corrected. The revision has no effect in the normal situation in which multiple reservoirs supply a common diversion located downstream of all the system reservoirs. The revision deals with system reservoirs that are not located upstream of the diversion site. Example 9 was added to Appendix B. The corrected feature allows reservoir Res-D in Example 9 to participate in multiple-reservoir system operations, as explained in Example 9, even though the reservoir is not located upstream of the diversion and the conveyance option is not activated.

The type 7 water right activated by *WR* record field 6 allows reservoir storage capacity to be set as a water right target. All target setting features on *TO*, *SO*, *FS*, *TS*, and other record types are applicable to the storage refilling target. This new feature was initially added in an

earlier version of SIM documented by the January 2009 *Users Manual* but was not fully implemented until the July 2010 version of *SIM*. Prior to the July 2010 *SIM*, an error message was activated if water right type 7 was specified on the *WR* record.

Hydropower and Reservoir Release HRR File and 4HRR Record

The format of the *SIM* output HRR file was significantly revised. The new 4HRR record replaces the old 4SWR and 4SGP records and reorganizes the resulting *TABLES* output tables, including adding hydropower. Also, an error has been corrected that prevented the HRR file from being developed when the dual simulation option was activated.

Water Right Group *RG* Record

A water rights group *RG* record was added. Various optional criteria are activated to define a group of water rights. Dual simulation and downstream control point limit parameters associated with the *PX* record can be assigned to each right in the group.

Flow Adjustment *FA* Record and FAD File

Two new options for organizing and applying the flow adjustment *FA* records in the FAD file are described on pages 108-109 of the July 2010 *Users Manual*.

Cascading of Negative *CI* Record Constant Inflows

A problem related to cascading downstream of negative entries on constant inflow *CI* records was corrected. Typically, only positive inflows are entered on *CI* records. However, *SIM* was refined to handle negative inflows as well.

Water Rights Output for Hydropower Rights

Option 5 was added to OUTWR in *JD* record field 6 specifying that all hydropower rights be included in the *SIM* output file.

Priority Sequence Circumvention *PX* Record Options

A problem has been corrected dealing with combining the XCP(px) feature activated by *PX* record field 4 with the MONDEP(wr) or ANNDEP(wr) features activated by *SO* record fields 3 and 4 with the same water right. Both of these options involve limiting stream flow availability. With the previous *SIM*, incompatibilities in some cases result in incorrect simulation results. The problem has been corrected in the July 2010 *SIM*.

XP(px) option 1 activated by *PX* record field 6 allows return flows to occur later in the priority sequence than the corresponding diversion. The program was refined to preclude potential problems related to the control point location of the delayed return flow.

TABLES Modifications (January 2009 – July 2010)

New 2FSV and 2FSC Records

As previously noted, flow volumes and counts for instream flow *IF* record rights have been added to the *SIM* OUT, SOU, and DSS output files. 2FSV and 2FSC records are added to *TABLES* time series records to tabulate these new simulation results variables.

New Format Options for Frequency Tables

Options 3 and 4 were added to parameter TABLE in 2FRE record field 5 providing additional format options for frequency tables.

Improved Filename Restrictions for All WRAP Programs

Prior to the July 2010 version of the programs, the pathname included in a filename could not include blank spaces. Thus, input data files could not be stored in a folder different than the folder storing the executable programs if the folders had a blank in their names. This restriction is removed in the July 2010 version of the programs. However, although any number of blank spaces can be included in a pathname (folder names) in the July 2010 version, there still cannot be three or more adjacent blanks. Also, prior to the July 2010 version of the programs, a filename including complete pathname could not exceed 50 characters in length. The filename length limit has been increased to 120 characters. These refinements apply to all of the WRAP programs (*WinWRAP*, *SIM*, *SIMD*, *TABLES*, *DAY*, and *SALT*).

Modifications between the July 2010 and September 2011 Versions

SIM Modifications (July 2010 – September 2011)

RG Record Field 3 Group Identifier and BU Record Field 5 Group Identifier

The new water right group *RG* record feature was added with the July 2010 version of *SIM*. The January 2011 *SIM* has been corrected to address the following problem which is relevant only when both *RG* record field 3 and backup *BU* record field 5 are used in combination. *RG* record field 3 allows group identifiers to be assigned to any number of water rights. A water right group identifier entered in *BU* record field 5 allows specification of a group of water rights to be backed up. A problem occurred in the previous version of *SIM* if *BU* record field 5 referenced a water right group identifier assigned to water rights by *RG* record field 3 because, in reading the DAT file, *BU* record error checks occurred prior to *RG* record operations. *SIM* terminated with an error message indicating the group identifier referenced by the *BU* record was not found on any *WR* record. The *SIM* Fortran program has been corrected to allow completion of the *RG* record operations prior to the *BU* record error check.

Target Options TO Record TOTARGET Option 13

TOTARGET option 13 in *TO* record field 2 previously actually applied only to instream flow targets even though the *Users Manual* indicated that option 13 applied to either instream flow or diversion targets. Option 13 has been expanded in the *SIM* program to include diversion targets as well as instream flow targets.

Conflict between Modeling a Subordination Agreement with *PX/BU* Records and Applying Depletion Limit Features of *SO, ML, TS,* and *PX* Record Options

The *PX* record XCP feature is designed to be used in combination a *BU* record in modeling a subordination agreement. *SIM* has been modified to address the issue described below which is relevant only when the *PX* record XCP feature is combined with both a backup *BU* record and certain *SO, TS,* or other *PX* record features are activated for the same water right that has the *PX* record XCP feature activated. It is likely that this situation has not actually occurred in a dataset to date.

The downstream control point flow availability routine activated by the parameter XCP in *PX* record field 4 includes a feature in which the resulting increases in available stream flow and resulting stream flow depletions are treated the same as shortages that can be added to the targets of backup *BU* record rights. The problem in the previous version of *SIM* occurred in the computation of the volume to be added to the backup right target in situations in which the streamflow depletion was constrained by streamflow depletion limits specified by supplemental options *SO* record fields 3 and 4, monthly limits *ML* records, SDL option in target series *TS* record field 2, or DUAL options 3 and 5 in *PX* record field 2. The effects of these stream flow depletion limit options on stream flow availability conflicted with the effects of the *PX* record XCP options on stream flow availability. This problem has been corrected.

Over-Writing versus Replacing *SIM* Output Files

This modification consists of revising the routine for replacing *SIM* output files to be consistent in all situations. Actual *SIM* simulation results as accessed through *TABLES* are not changed by this *SIM* modification. Input and output files are activated at the beginning of a *SIM* execution. Output files with the same filename root may already exist from previous executions of *SIM*. The file activation routine replaces the old output files that have the same filename. In the current *SIM*, old output files are deleted and new output files are created. This was also this case in previous versions of *SIM* with the following exception.

Output files always have the same filename root as the DAT input file. In the July 2010 and previous versions of *SIM*, if the hydrology (FLO, EVA, DIS) input files were assigned a different filename root than the DAT input file and the output files, old existing output files were overwritten rather than deleted/replaced. If the old and new output files had the same number of lines of output data (same file size) or if the new output file was larger than the old file, over-writing versus deleting/replacing the file results in identically the same new output file. However, if the new file is shorter than the old file, over-writing leaves extraneous old data at the end of the file in the portion of the file not overwritten. Since *TABLES* never reads this portion of the file, simulation results viewed by the model user are not affected. However, the output file may be unnecessarily large. *SIM* has been revised to consistently delete and replace existing relevant output files at the beginning of the *SIM* execution.

New Error Message for Hydropower Rights

In all past and present versions of *SIM*, a reservoir must be specified on a *WS* record if hydroelectric power is specified on a water right *WR* record. In past versions, *SIM* terminates

without an explanation if a reservoir is not specified for a hydropower right. An error message has now been added for this situation.

New Negative Incremental Flow ADJINC and NEGINC Options

Options for dealing with negative incremental flows are selected using the parameter ADJINC in *JD* record field 8. NEGINC in *JD* record field 9 writes information in the message file regarding negative incremental flows. The new ADJINC options 6, 7, and 8 and NEGINC options 4 and 5 were added. The new ADJINC option 6 yields the same simulation results as the old option 4, but computer execution time is reduced. The new ADJINC option 7 was motivated by daily *SIMD* simulations but is also applicable to monthly *SIM* simulations. NEGINC options 4 and 5 add summary tables.

OR Record Connection to FS and CV Records

The *OR* record defines reservoir operating rules. Parameter FSOR in *OR* record field 10 references a *FS* or the new *CV* record for use in setting a maximum reservoir release limit. With the expanded structure noted below, the *FS* or *CV* record computations may occur at any place in the priority sequence. An *OR* record referencing a *FS* or *CV* record which references a *WR* record can incorporate *UC*, *TO*, *TS*, *SO*, *DI/IS/IP*, and *BU* record options in developing reservoir operating rules.

New Cumulative Volume CV Record

The new *CV* record is similar to the *FS* record but applies a different set of options to develop targets and other quantities. The cumulative volume variable CVV selected in *CV* record field 3 and flow switch variable FSV selected in *FS* record field 3 are defined identically the same, and the cumulative volume of the selected variable is summed over time periods in the same manner. However, the *CV* record has a different set of options for applying the CVV cumulative volume than the options employed by the *FS* record using the FSV cumulative volume. The *CV* record provides an expanded set of optional manipulations of the selected *CVV/FSV* variable that can be accumulated (summed) over any number of time steps in developing *IF* record instream flow targets, *WR* record diversion, hydropower, and storage targets, *LO* record stream flow depletion limits, and *OR* record reservoir release limits. These options are defined by *CV* record fields 5, 6, 7, 8, 9, and 10. As noted in the next section, five additional *CVV/FSV* variables have been added to the previous six *FSV* variables.

New FS Record Flow Switch Variables

A flow switch variable FSV is selected in *FS* record field 3. Previously, six FSV options were available, with all six options referenced to control points. The following five new FSV options are referenced to the water right specified in the new *FS* record field 17.

- 7 stream flow depletion
- 8 total diversion
- 9 diversion from reservoir storage
- 10 *WR* or *IF* record water right target
- 11 instream flow shortage for *IF* record right

FSV option 10 allows the flow switch variable to be defined as the target computed for the water right specified in *FS* record field 17. The computed quantity is used as a flow switch variable rather than a water right target. Thus, the flow switch variable can be computed using the target setting features provided by combining *WR*, *UC*, *TO*, *TS*, *SO*, *DI/IS/IP*, *BU*, and *FS* records entered with any other *IF* or *WR* record right including type 8 *WR* record rights. The new type 8 *WR* record water right is described below. The *FS* record flow switch is then applied along with other *UC*, *TO*, *TS*, *SO*, *DI/IS/IP*, and *BU* records for the current *IF* or *WR* record water right to develop an instream flow, diversion, hydropower, or storage target. This is one of several ways of *stacking* sets of target setting records.

New Water Right Type 8

Water right types are specified in *WR* record field 6. The new type 8 right only creates a target with no other computations performed for that water right. Water right targets can be developed using *UC*, *TO*, *TS*, *SO*, *DI/IS/IP*, *BU*, *CV*, and *FS* records along with the *WR* record target setting features. However, the target for a type 8 water right is not used by that right, and the right is not further simulated.

The only reason for a type 8 right is to allow its target to be used by one or more other *WR* or *IF* record water rights in assigning or adjusting their instream flow, diversion, hydropower, or storage targets, reservoir release limits, or stream flow depletion limits. The *WR* record water right may be referenced directly by a *FS* or *CV* record or a *FS* or *CV* record entered with the right may be referenced by an *IF*, *WR*, or *OR* record. *TO* and *LO* records can also reference any water right including type 8 rights.

Expanded Framework for Water Rights to Access and Apply *FS* and *CV* Records

CV and *FS* records can be applied in the following alternative modes.

1. *CV* and *FS* records can be included in the set of *UC*, *SO*, *TO*, *LO*, *TS*, *BU*, *PX*, *DI/IS/IP*, and *WS/HP/OR* records that follow a *WR* or *IF* record. *CV* and *FS* records are attached to the preceding *WR* or *IF* record in the same manner as the *UC*, *SO*, *TO*, *LO*, *TS*, *BU*, *PX*, and *WS/HP/OR* records. Quantities are computed in the priority sequence simulation at the priority specified by the *WR* or *IF* record.
2. A *WR* or *IF* record can reference a *CV* or *FS* record that is located with the records for some other *WR* or *IF* record water right by entering the *CV* or *FS* integer identifier in *WR* record field 10 or *IF* record field 9. The same *CV* or *FS* record results developed at the same priority sequence can thus be applied for any number of water rights. The product provided by the *CV* record is a monthly target volume. The *FS* record optionally provides either a monthly target volume or a flow switch.
3. A *CV* or *FS* record can be used in setting a maximum release limit for a reservoir by entering the integer identifier of the *CV* or *FS* record in *OR* record field 10. The product of the referenced *CV* or *FS* record is either a release limit volume or flow switch.
4. *TO* and *LO* records for the current right can access a target computed for another right (*WR* or *IF* record) using *CV*, *FS*, *UC*, *SO*, *TO*, *LO*, *TS*, *BU*, *PX*, *WS/HP/OR*, and *DI/IS/IP* records.

The *CV* record is new as noted earlier. The *FS* record was applied in the first mode described above in January 2011 and earlier versions of *SIM*. The other modes have been restructured and expanded in the September 2011 *SIM*.

Water right type is specified in *WR* record field 6. The new water right type 8 is designed for water rights created solely to be referenced by *TO*, *LO*, *CV*, and *FS* records as noted above. A type 8 right does nothing but compute a target and by itself has no effect on the simulation. However, its target can be used in *TO*, *LO*, *CV*, and *FS* record operations performed for other water rights.

New *TO* Record TOTARGET Option 15

The new option 15 in *TO* record field 2 sets the target equal to the factor in field 3. Thus, a user-specified number can be incorporated in the target setting procedures.

New Stream Flow Depletion Limit Options *LO* Record

The new *LO* record has identically the same format as the target options *TO* record. However, the *LO* record produces maximum limits on stream flow depletions rather than *TO* record diversion, instream flow, hydropower, or storage targets. The *LO* record instream flow limits are computed using the same *TO* record options that are available for developing targets.

Supplemental Options *SO* Record Modifications

IF record instream flow targets and *WR* record diversion, hydropower, and storage targets are developed in a series of 12 steps which are outlined on pages 69-70 of the *Users Manual*. The final target is used in the simulation. However, the intermediate target after each step and associated shortage can be recorded in the simulation results output OUT file. The intermediate target development step for which the target and associated shortage are written in the OUT file is selected by parameter ISHT(wr) in *SO* record field 9. The number of ISHT(wr) choices has increased from 8 to 12.

Several new error checks/messages have been added to the *SIM* routine that reads the supplemental options *SO* record. The *SO* record now has the same level of input data error checking as all the other input records.

The seldom-used parameter NOTFLAG in *SO* record field 13 provides options for switching off selected features. The NOCLWR option has been revised to apply to only stream flow depletions, not return flows. A note has been added to the *Users Manual* that the NORFCL option should not be applied to next month return flow options.

Constant Naturalized Flow Replacement Added to *CP* Record

Naturalized flow options are specified by INMETHOD(cp) in control point *CP* record field 6 and CPIN(cp) in field 7. The new fields 11 and 13 of the *CP* record allow naturalized flows at a control point in all months to be replaced with a constant flow CPF(cp) entered in the new *CP* record field 13. If flows have not been otherwise entered, option 2 in field 6 with zero in field 7 can be used in combination with the replacement flow in field 13. An F16.0 format is

provided to allow an extremely large number to be entered in modeling an accounting (artificial) control point with unlimited flow.

Return Flow Method Default Added to *JO* Record

A new input parameter *RFD* has been added as *JO* record field 11 that sets a default for the return flow method specified by *RFMETH* in *WR* record field 7. A blank *WR* field 7 previously meant default return flow option 1. A blank *WR* field 7 now results in adoption of *RFD* from *JO* field 11, which is no change if *JO* field 11 is blank (zero).

Seasonal Drought Index Defined by New *IM* Record

A drought index is defined by a set of *DI*, *IS*, and *IP* records for use in developing instream flow, water supply diversion, hydropower, and storage targets as a function of reservoir storage contents. Previously, the drought (storage) index was updated each time step during the simulation with changing reservoir contents storage and applied the same throughout the year. The new optional *IM* record provides a set of 12 switches for the 12 months of the year. The drought index determined for a particular month can continue to be applied in future months rather than being reset each month as storage changes. The drought index can also be switched completely off-or-on each month.

New *IF* Record Option Assigning Instream Flow Target to Multiple Control Points in a Reach

The new parameter *CP2* added as *IF* record field 12 defines a stream reach extending from the control point specified in *IF* record field 2 downstream to *CP2*. This reach may contain any number of control points. *CP2* in the new field 12 is a control point identifier, with the exception that *OUT* entered in field 12 assigns *CP2* as the outlet. The instream flow target defined by the *IF* record and its auxiliary records is repeated at all control points between the control points entered in *IF* record fields 2 and 12.

Instream Flow Target Recorded on Control Point Output Record in *OUT*, *SOU*, and *DSS* Files

Instream flow targets and shortages are recorded on water right (instream flow) output records in past and current versions of *SIM*. The August 2011 *SIM* has been expanded to include instream flow targets on control point output records in the *OUT* file and instream flow targets and shortages in the *SOU* and *DSS* output files. *TABLES* computes instream flow shortages from the targets and regulated flows read from the *OUT* file.

Instream flow targets and shortages are tabulated by *TABLES* *2IFT* and *2IFS* records. Multiple *IF* records may assign instream flow targets at the same control point in *SIM*. A new *SIM* feature noted above allows an instream flow target to be assigned to all of the control points in a specified stream reach by a single *IF* record. The instream flow target recorded in the *SIM* *OU* file for an *IF* record right is the target set in the priority sequence at the priority of the right.

The new feature records instream flow targets by control point in the *OUT*, *SOU*, and *DSS* output files at the completion of the priority sequence. Shortages are determined within *SIM* (*SOU* and *DSS* files) or *TABLES* (*OUT* file) by combining targets and regulated flows.

TABLES Modifications (July 2010 – September 2011)

Earlier versions of *TABLES* had the following error that had been introduced in expanding *TABLES* to include sub-monthly time steps. The water right group option for the time series tables created by 2STO, 2EVA, 2DEP, 2TAR, 2SHT, and 2DIV records would not work with either monthly or daily simulation results. Time series tables could be created for control points, reservoirs, or water rights, but not water right groups. The group option is now working.

A warning message has been added related to the parameter MORE entered in field 4 of the time series records that controls the adding of more columns in building of columnar tables with multiple time series records. The last record must have a zero (blank) entry for MORE indicating completion of the table. Otherwise, the table is not created. The new warning message reminds the user that the table was not created because of this wrong entry for MORE.

2IFT and 2IFS Records for Control Points

As noted above, 2IFT and 2IFS records can now be applied to control points as well as *IF* record water rights. The instream flow target at the completion of the priority simulation each month is now included in the *SIM* simulation results for control points. *TABLES* determines instream flow shortages as the target minus regulated flow.

Instream Flow Shortages at Control Points Added to 2FRE and 2FRQ Records

Instream flow shortages at control points have also been included as an additional option on 2FRE and 2FRQ frequency records.

New Table of Simulation Means Added to Time Series Records

A new type of table which includes only the totals or means for the entire simulation for each control point, water right, or reservoirs has been added to the time series records as field 3 PT option 6. The following three numbers are written at the end of the tabulation: summation of total amount, mean, and count of the number of control points, water rights, or reservoirs included in the tabulation.

Storage Totals in 2FRE Tables

Options 4, 5, and 6 in 2FRE record field 2 create storage frequency tables for reservoirs with the last line at the bottom of the table being frequency statistics of the total storage in all of the reservoirs in the table. Options -4, -5, and -6 create tables with only the bottom totals line, without the individual reservoirs. Options 4, 5, and 6 have always worked fine with the correct totals line at the bottom of the table. However, options -4, -5, and -6 for most situations incorrectly created totals tables with all zeros. Options -4, -5, and -6 have been corrected.

Annual Means for 2RSC, 2RSD, and 2WSE Records

Annual amounts are provided for the various types of time series tables. However, annual totals were replaced with annual means for the 2RSC, 2RSD, and 2WSE records since means are appropriate rather than totals for reservoir storage and elevation variables.

Addition of New DATA Record

The new DATA record represents a significant expansion of *TABLES* capabilities. The DATA record converts *SIM* or *SIMD* simulation results to other variables that are used in lieu of the original simulation results by the *TABLES* type 2 (monthly) time series, type 6 (daily) time series, 2FRE, 2FRQ, 6FRE, and 6FRQ record routines. The DATA record is applicable to either monthly or daily simulation results but is particularly useful in organizing/analyzing daily data. Annual data series can be developed from either monthly or daily simulation results. Addition of the DATA record feature was motivated by environmental instream flow studies, but the new feature is applicable in other areas as well.

The DATA record reads and manipulates any of the *SIM* or *SIMD* simulation results variables to develop a dataset for a user-formulated variable of interest derived from the simulation results. An entire simulation results time series or optionally only periods (days or months) falling within a specified season (months) of the year may be adopted. Multiple-period totals, moving averages, moving totals, annual minimums, and annual maximums are computed. For example, the minimum 7-day volume found in each year of a long daily series could be recorded and used with a 2FRE or 2FRQ record to assign probabilities to 7-day low flows.

The product of the DATA record is an array stored in computer memory of either an annual, monthly, or daily time series dataset for a user-formulated variable. The data series developed by a DATA record is organized and analyzed using daily or monthly time series and/or 2FRE, 2FRQ, 6FRE, and 6FRQ records in the same manner that these records are applied directly to simulation results.

Modifications between the September 2011 and August 2012 Versions

WRAP Manuals

The August 2012 version of WRAP is documented by the following manuals.

Water Rights Analysis Package (WRAP) Modeling System Reference Manual, TWRI TR-255, 9th Edition, August 2012. (*Reference Manual*)

Water Rights Analysis Package (WRAP) Modeling System Users Manual, TWRI TR-256, 9th Edition, August 2012. (*Users Manual*)

Fundamentals of Water Availability Modeling with WRAP, TWRI TR-283, 6th Edition, September 2011. (*Fundamentals Manual*)

Salinity Simulation with WRAP, TWRI TR-317, July 2009. (*Salinity Manual*)

Water Rights Analysis Package (WRAP) Daily Modeling System, TWRI TR-430, August 2012. (*Daily Manual*)

Water Rights Analysis Package (WRAP) River System Hydrology, TWRI TR-431, November 2012. (*Hydrology Manual*)

Water Rights Analysis Package (WRAP) Programming Manual, TWRI TR-388, 2nd Edition, August 2012. (*Programming Manual*)

The *Reference, Users, and Fundamentals Manuals* document the programs *WinWRAP*, *SIM*, and *TABLES*. The *Hydrology Manual* covers the program *HYD*. The *Daily Manual* covers *SIMD*, *DAY*, and the *SIMD*-related features of *TABLES*. The *Salinity Manual* documents program *SALT* and the *SALT*-related features of *TABLES*. The *Programming Manual* facilitates modifications to any of the Fortran programs but is not needed in applying the modeling system.

The *Daily Manual* and *Hydrology Manual* are new manuals added with the August 2012 WRAP. The old *Supplemental Manual* is now obsolete and no longer used. The conditional reliability modeling material in the old *Supplemental Manual* is now found in the *Reference* and *Users Manuals*. The sub-monthly features previously covered in the *Supplemental Manual* are now covered in the *Daily Manual* along with additional new *SIMD* modeling features. The *Hydrology Manual* covers features of *HYD* previously covered in the *Reference* and *Users Manuals* along with new features of *HYD* introduced in the August 2012 WRAP.

Fortran Compiler Update

Versions of the WRAP programs released prior to August 2012 were compiled with the Compaq Visual Fortran Version 6.5 (2000 copyright) within Microsoft Visual Studio 2008. The August 2012 publicly released versions of the WRAP programs are compiled with the Visual Fortran Composer XE 2011 released by Intel in 2011 which is also implemented within the 2008 or 2010 Microsoft Visual Studio IDE.

A compiler converts a Fortran program, with the filename extension FOR or some variation thereof, to an executable program with filename extension EXE, along with linking the Fortran program to library routines. Compilers are applied within an Integrated Development Environment (IDE) which provides editing, file management, and other utility functions. Intel acquired Compaq Visual Fortran in 2005. The Fortran compiler and IDE used with the WRAP programs has since evolved through several versions since 2005 under the auspices of Intel.

A comparative investigation during 2006-2007 of the 2000 Compaq compiler versus initial versions of the Intel compiler is noted on pages 20-21. Although the evolving versions of the Intel compiler have continued to be investigated for use with the WRAP programs, all publicly released versions of the WRAP programs prior to the August 2012 WRAP were compiled with the 2000 Compaq compiler or its predecessors.

Dealing with certain types of computational issues varies between compilers and between settings in a particular compiler. Compiler issues with the WRAP programs were found to most often be related to precision and/or the manner in which the computer handles the digits of real numbers to the right of those digits that actually contribute to precision. These issues affect decisions within the code that are based on comparing real numbers. For example, a certain logical decision in a computational algorithm may be based on whether or not the computed value of the variable X is equal to zero, and at a certain step in the computations X equals 0.00000000010. Other issues are related to combining integer and real numbers and handling of undefined arithmetic operations such as dividing by zero.

Changes to the WRAP programs made during 2006-2007 to enhance compiler compatibility are discussed on pages 20-21. An additional series of small changes to the *SIM*

and *SIMD* Fortran code during 2012 was likewise motivated by changing from Compaq Visual Fortran Version 6.5 to the Intel Visual Fortran Composer XE 2011. Alternative settings in the 2011 version of the compiler were also explored. The WRAP programs compile fine with either compiler, though the old Compaq compiler will not work with the latest versions of Microsoft Windows. A primary objective of the enhancements to the *SIM* and *SIMD* Fortran code was to obtain consistent *SIM* simulation results with either the old Compaq or new Intel compilers while taking advantage of the features of the updated Intel compiler.

Although simulation results for most of the TCEQ WAM System datasets are not affected at all, a few small changes in simulation results occur in some of the WAM datasets with adoption of the updated compiler and selection of compiler settings. Choice of compiler and compiler settings also affects the results of the optimization algorithms in the recently developed program *HYD* flow extension routine. Results from any of the WRAP programs may potentially be affected minimally though numbers do not vary to a significant magnitude.

Daily Modeling System

The simulation model *SIMD* is an expanded version of *SIM*. All of the monthly simulation capabilities of *SIM* are also included by *SIMD*. *SIMD* allows use of a sub-monthly (daily) computational time step and also includes features for simulating reservoir operations for flood control. Modeling with a sub-monthly (daily) time step including disaggregation of monthly flows to daily flows, flow forecasting, routing, reverse routing and disaggregation of water use targets to a daily time step. *TABLES* works with either *SIM/SIMD* monthly or *SIMD* sub-monthly simulation results. *DAY* is used to calibrate routing parameters for *SIMD*.

Developmental test versions of *SIMD*, *DAY*, and the daily routines in *TABLES* have been under development for several years. *SIMD*, *DAY* and the daily routines of *TABLES* were greatly improved between the September 2011 and August 2012 versions. However, since the daily features of WRAP have been in a developmental stage rather than routinely applied in practice, improvements have not been tracked in this *Additions and Revisions Report*.

The major focus of WRAP improvements between September 2011 and August 2012 has been on testing and improving *SIMD*. Major improvements include adding the pulse flow environmental flow target setting features specified with the *PF* and *PO* records. Computational algorithms related to primarily to forecasting have been rewritten to reduce computer execution time, resulting in typical runtime reductions of more than 50 percent. A number of other improvements and corrections are also incorporated in the daily features of *SIMD*. All of the *SIM* modifications noted in the next section are also reproduced in *SIMD*.

***SIM* Modifications** (September 2011 – August 2012)

New Hydrologic Index *HI* Record and Hydrologic Index Series HIS File

TO record TOTARGET option 16, *FS* record FSV option 12, and *CV* record CVV option 12 have been added. These new target setting options reference a hydrologic index entered on *HI* records in a hydrologic index series HIS file. The addition of the *HI* record and HIS file were motivated by application of the Palmer hydrologic drought index in setting environmental

instream flow targets but can also be used with other quantities in the target setting procedures. This new target setting feature was designed primarily for use with *SIMD* daily simulations but can also be applied in *SIM* monthly simulations.

Other New *FS*, *CV*, and *TO* Record Options

A new *FS/CV* record feature is activated by the parameter FSI(*FS*,14) added as the last entry on the *FS* and *CV* records. The new feature is activated only if the new field is non-zero (not blank). FSI(*FS*,14) may be 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, or 12. FSI(*FS*,14) is the month in which the FSV cumulative volume and count of occurrences are set to zero at the beginning of the month. A FSI(*FS*,14) of 1 limits the criteria upon which the flow switch or other *FS/CV* record decisions are based to consideration of only flows occurring within the calendar year.

FSV and CVV option -1 was added to *FS* and *CV* record field 3. The new option -1 is the same as the existing default option 1 except reservoir releases are excluded from the regulated flows. Likewise, TOTARGET options 22 and -22 were added to *TO* record field 2. The new options 22 and -22 are the same as the existing options 2 and -2 except reservoir releases are excluded from the regulated flows.

New ICHECK Option

ICHECK option 12 activated by *JD* record field 4 was added. This new option records in the message MSS file the instream flow targets of selected rights in priority order for each month of the simulation. This provides a detailed tracking of the changing instream flow targets computed throughout the priority sequence in each month of the simulation.

Corrections to *CV* and *FS* Record Features

The *CV* record was added in the September 2011 *SIM*, and the *FS* record features were expanded in the September 2011 *SIM*. Several refinements and corrections to computational algorithms activated by *CV* and *FS* record options have been incorporated in the August 2012 version of *SIM* that may affect simulation results in some cases.

Corrections to Features Controlled by *PX* Record Fields 3, 4, and 5

A problem related to initial values assigned for stream flow depletions resulted in incorrect simulation results, in some cases, when the feature controlled by XCP and XCPID in *PX* record fields 4 and 5 was activated. The problem has been corrected.

Previously, *SIM* would crash with an error message if the control point representing the basin outlet was entered for XCPID in *PX* record field 5. This has been corrected. Another refinement was made to the *PX* record XCPID feature to deal with months in which the available amount of stream flow is computed to be a small negative number.

The *PX* record XCPID option results in the variable XAV being recorded in the OUT file in the last field of the water right output record for the water right with the *PX* record. *SIM* erroneously recorded the last *PX* record XAV in the last field of the water right output records

for all water rights without *PX* records. The error did not affect simulation results other than adding unused data in OUT file fields that were not read by *TABLES* anyway.

Extremely Large Numbers Exceeding Output Specifications of OUT File

SIM simulation results are recorded in an output OUT file in either text or binary format or as a DSS file in binary format. There are no size limits for numbers recorded in binary format. However, the default OUT file in text format is essentially always used and does limit the size of the numbers recorded in the text file. Many of the monthly simulation results variables are limited to not exceed 9,999,999 acre-feet, and others are limited to not exceed 999,999 acre-feet. The size limits are not exceeded in most applications of most WAM datasets. However, the size limits are sometimes exceeded.

SIM has included the following safeguard for many years. If the size limit for a particular variable is exceeded in a particular month, the number -1.0 is written to the OUT file, and the correct number is written along with a warning message in the MSS file. Several minor refinements to maximize the utility of this feature are reflected in the August 2012 *SIM*.

Other Revisions

Prior to the January 2011 *SIM*, the NOCLWR option for NOTFLAG in *SO* record field 13 included both return flows and streamflow depletions, but was revised in the January 2011 *SIM* to include only streamflow depletions and revised back in the August 2012 *SIM* to include both return flows and flow depletions. This appears to affect only the Rio Grande WAM.

Previously, a type 4 water right could not be combined with *CV* and *BU* records. This has been corrected. The type 4 right is for a discharge into the stream rather than a diversion, is relatively new, and has been seldom if ever used to date.

Previously, a HRR file could not be created if the second pass option was activated by PASS2 in *JO* record field 10 or IFMETH on *IF* record field 8. This has been corrected.

A warning message activated by incorrect use of *CO*, *WO*, *RO*, and *GO* records has been changed to an error message accompanied by program termination.

The format of *IN* and *EV* records is specified by INEV in *JO* record field 2. With the default INEV option 1, the simulation period specified by NYRS on the *JD* record can be shorter than the number of years for which *IN* and *EV* records are provided. However, previously, the NYRS could not be shortened for INEV option 2. This has been corrected.

TABLES Modifications (September 2011 – August 2012)

2RFR and 6RFR record tables had been inadvertently omitted from the *TABLES* feature that allows *TABLES* to read a *SIM* output OUT file created in binary format. This has been corrected. The option that allows the *SIM* output file to be recorded in binary format has actually been seldom if ever used.

The application of the *2DIV* record to water right groups previously did not work correctly but has now been fixed.

Time series records include an option for printing time series data in columns. The column headings cannot exceed 11 characters. Previously, 16-character water right identifiers were truncated to 11 characters. *TABLES* has been revised to print the entire 16-character water right identifiers using two lines rather than a single line.

Several modifications were made to *TABLES* for compatibility with the daily features of *SIMD*. Essentially all of the routines in *TABLES* handle *SIMD* sub-monthly (daily) simulation results as well as *SIM* daily simulation results.

HYD Modifications (*September 2011 – August 2012*)

A major new capability has been added to program *HYD* to extend the hydrologic period-of-analysis of existing *SIM* hydrology input datasets using precipitation and evaporation datasets maintained by the Texas Water Development Board. Naturalized stream flow sequences are synthesized by relating naturalized flows to precipitation and evaporation. A hydrologic model is calibrated to reproduce the existing period-of-analysis naturalized flows and then applied to synthesize flows for the extension period. The new naturalized flow and net evaporation-precipitation extension methodologies are documented in the new *Hydrology Manual*.

Modifications between the August 2012 and August 2013 Versions

The programs *WinWRAP*, *HYD*, *SIMD*, *DAY*, *SIM*, and *TABLES* were revised between the August 2012 and August 2013 versions of *WRAP*. *SALT* is the only *WRAP* program that was not modified during this period. The latest versions of program *SALT* and the *Salinity Manual* are dated August 2010 and July 2009, respectively. The other *WRAP* programs and manuals have been revised since the August 2012 version and are dated August 2013.

The August 2013 *Reference*, *Users*, *Fundamentals*, *Hydrology*, *Daily*, and *Programming Manuals* have been updated to include new features added to the programs and otherwise edited and refined. Refinements include expanding or clarifying explanations of certain older features as well as incorporating the new software features described in the listing of software revisions and additions provided by this document. Pulse flow *PF* and pulse flow options *PO* records covered in the *Daily Manual* may require revisions in existing daily *SIMD* input datasets. Otherwise, the previous versions of all of the manuals are still fine to use unless the new features added to the programs as described in this document are of interest.

Refinements to the August 2013 *Fundamentals Manual* include updating the hydrologic period-of-analysis of the example from 1940-1997 to 1940-2012, addition of Appendix E dealing with input errors, and expanding the instructions for using *WinWRAP*. The *Reference*, *Hydrology*, *Daily* and *Salinity Manuals* contain examples that build upon and expand the *Fundamentals Manual* example. The only change to the example in the *Fundamentals Manual* is extending the simulation period to include 1998-2012. Simulations can be performed with alternative periods-of-analysis of 1940-1997 or 1940-2012 simply by changing *NYRS* in *JD* record field 2. Thus, the *Fundamental Manual* dataset is easily used to reproduce either 1940-1997 or 1940-2012 simulation results for the examples in the other manuals.

WinWRAP Modifications (August 2012 to August 2013)

The August 2012 WRAP was the first publicly released version compiled with the new Intel compiler that replaced the old Compaq compiler. All of the August 2012 WRAP programs except *WinWRAP* were compiled with the Intel compiler. A problem prevented *WinWRAP* from compiling with the new compiler. An incompatibility issue was later discovered that causes the Compaq-compiled *WinWRAP* to sometimes hang-up with the Intel-compiled programs. Additional code has since been obtained that allows *WinWRAP* to be compiled with the Intel compiler. The problem with occasional hanging-up is resolved in the Intel-compiled *WinWRAP*.

The *TABLES* input file editor in the August 2013 *WINWRAP* contains the following minor update related to entering values in the optional fields 7-12 of time series input records. The first six fields are not affected. The dialog box had not been updated for the previous addition of the parameter INPUT as field 7 of the time series records. Omitting the new field 7 also caused incorrect placement of entries in the optional fields 8, 9, 10, 11, and 12. The August 2013 revised built-in editor still does not include the parameter INPUT, but the other fields are no longer affected. Values for INPUT still must be added manually outside of the built-in editor. WordPad or other editors are commonly used rather than the *TABLES* editor contained within WinWRAP, and these optional fields of the time series records have seldom been used.

HYD Modifications (August 2012 to August 2013)

A major new capability has been added to *HYD* to extend the hydrologic period-of-analysis of existing *SIM* hydrology input datasets using precipitation and evaporation datasets maintained by the Texas Water Development Board. Naturalized stream flow sequences are synthesized by relating naturalized flows to precipitation and evaporation. A hydrologic model is calibrated to reproduce the existing period-of-analysis naturalized flows and then applied to synthesize flows for the extension period. The new naturalized flow and net evaporation-precipitation extension methodologies were explained in the November 2012 first edition of the *Hydrology Manual* and demonstrated in a Brazos WAM case study documented in an October 2012 report. The flow extension methodologies were applied during 2013 to the Colorado WAM and Trinity WAM. Most but not all of the features for extending the hydrologic period-of-analysis were introduced in the August 2012 *HYD*. Additional features have since been completed. Most of the capabilities were described in the November 2012 *Hydrology Manual*, but other options and refinements were added during 2013.

The old *HYD* output-input *OI* record activates a routine that reads simulation results from a *SIM* or monthly *SIMD* output OUT file and uses these data to create input records for a *SIM* input file. Options 17 and 18 have been added to the variable selection parameter in *OI* record field 2 to read instream flow targets for either water rights or control points. The motivation for this addition is to allow target series *TS* records to be created for a *SIM* input file that contain aggregated monthly sums of daily instream flow targets computed in a daily *SIMD* simulation.

JC record field 21 has been added with the new parameter CDO which is an optional alternative record identifier that replaces *IN* on flow records read and created by *HYD*. This new option allows the operations designed for flows on *IN* records to be applied to quantities on records other types of record such as flow adjustment *FA* records. *HYD* can now read and create spring flow or other flow adjustments on *FA* records.

EQ record field 13 has been added with the new parameter ID2 designed to allow flows at a particular control point to be computed as a function of flows at another control point.

SIMD Modifications (*August 2012 to August 2013*)

New pulse flows options have been added that are activated by new parameters in new fields added to the pulse flow *PF* record and pulse flow options *PO* record as well as some reorganization of existing *PF/PO* record entries. The option allowing reservoir releases to be excluded from the regulated flows used to define pulse events and the option to limit pulse flow targets to not exceed the flow trigger have been moved from the *PO* record to the *PF* record. A new option was added to the *PO* record to allow event volume credit to be given to larger pulses when a smaller pulse was being tracked prior to a larger pulse initiation. New options are added to accommodate the use of hydrologic condition as a criterion for initiating pulse flow events. An optional *PF* record identifier is added to improve the readability of the SMM output file and for linking to *PO* record options.

The *SIMD* forecasting algorithm was revised to improve the accuracy of the computations. Another different revision consisted of adding a day to the default forecast period.

JU record parameter FRMETH was removed. FRMETH previously controlled the selection for placing flood control flow changes either before or within the priority sequence. WRMETH now controls placement of flow changes for both normal and flood control rights.

Parameter WRMETH was changed to control placement of flow changes for the final current day non-forecast simulation only. Parameter WRFCST was added in the field previously occupied by FRMETH. Parameter WRFCST controls placement of flow changes during the forecast simulation. With forecasting enabled, the user may select the same or different methods for placing flow changes either before or within the priority sequence.

A feature was added to the subroutine that constructs the routing factor array (RFA) to reduce the attenuation by remove leading and trailing days containing small flow volumes. The small quantities removed from the edges are added to the quantities in remaining days. The user may accept the default parameters on the *RT* record or enter a value to control the amount of attenuation reduction.

Flood control modeling options are refined to allow flexibility in adopting both *FF* record and *FV/FQ* record operations for the same flood pool or overlapping pools. The operational feature resulting in the smallest release controls.

DAY Modifications (*August 2012 to August 2013*)

The routing calibration algorithm automatically minimizes the value of attenuation to a value of 1.0 day when the lag and attenuation parameter pair results in outflow that only spans two days. This new feature removes the problem of non-unique lag and attenuation pairs that result in the same calibrated objective function. The lag parameter is adjusted automatically by the algorithm to create a lag and attenuation pair which has the same routing effect.

SIM Modifications (August 2012 to August 2013)

Addition of a Target Series TSF File

Target series *TS* records can be inserted in the DAT file within the group of records that follow a water right *WR* or instream flow *IF* record. In the past, this placement in the DAT file was the only means for applying *TS* records. The new target series file, with filename extension TSF, provides an alternative option for storing *TS* records. A single *TS* record following an *IF* or *WR* record in the DAT file, references a set of *TS* records in the TSF file with quantities for each month of the period-of-analysis. Addition of the TSF file was motivated by the application in which daily environmental instream flow targets computed in a *SIMD* simulation are aggregated to monthly target volumes within *SIMD* for input to *SIM* on *TS* records. Program *HYD* is used to read the monthly flows from the *SIMD* OUT file and create a *SIM* TSF input file. However, although addition of the TSF file was motivated by daily-to-monthly environmental flow target conversions, *TS* records in a TSF file may be applicable for a variety of modeling applications.

New Options on Target Options *TO* Record

New options have been added to those activated by the parameter TOTARGET in *TO* record field 2. The new options activated by the new TOTARGET entries -6, -8, -11, -13, -14, and -16 are the same as options 6, 8, 11, 13, 14, and 16 except the values of the specified variables (flow depletion, storage withdrawal, diversion, target, shortage, or hydrologic index) in the preceding month rather than the current month are used in the target setting routines.

Zero Streamflow Depletion Limit on Limit Options *LO* Record

The *LO* record is identical in format to the *TO* record but creates a maximum streamflow depletion limit rather than a target. Previously, the *LO* record would set only positive non-zero limits but has now been modified to also set a maximum streamflow depletion limit of zero.

Constant Monthly Naturalized Flow Repeated at a Control Point

The August 2012 *SIM* allows the naturalized flow at the control point to be replaced with a constant volume entered as CPF(cp) in field 13 of the control point *CP* record. INMETHOD option 2 in *CP* record field 6 allows naturalized flows to be repeated from the control point specified as CPIN(cp) in *CP* record field 7. However, in the August 2012 *SIM*, CPF(cp) entered for a control point could not be repeated for another control point using INMETHOD option 2. The August 2013 *SIM* has been modified to allow the CPF(cp) naturalized flow to be repeated for other control points using INMETHOD option 2.

Error Messages for Monthly Return Flow Factors

RFMETH options 3 and 4 in *WR* record field 6 specify use of monthly return flow multipliers on *RF* records with the connecting identifier RFIDWR in *WR* record field 8. Error checks/messages were added to ensure that RFIDWR is specified and does correspond to an identifier on a *RF* record if RFMETH option 3 or 4 is specified.

Drought Index Interpolation Problem

A problem related to computational precision could occasionally and randomly occur when the drought index (*DI*, *IS*, *IP* records) feature was applied with reservoirs with large storage capacities, if the storage capacity was entered as the largest storage volume on the *IS* record. The problem did not occur if the largest storage volume on the *IS* record exceeded the reservoir storage capacity. During months of the simulation with the reservoir full to capacity, the computed storage contents could be a small fraction of an acre-foot greater than storage capacity, causing an interpolation out-of-range error message to be activated by the *DI* record drought index routine. This problem typically did not occur but sometimes could occur. The problem has been corrected.

FY Record Period Reliability with Second Pass Option

The *FY* record computations of firm yield and volume reliabilities were correct without this modification. However, obviously incorrect period reliabilities were tabulated in the YRO table for simulations in which the second pass option is activated by PASS2 option 2 in *JO* record field 10 or IFMETH field 8. This problem has been corrected.

ZZ Record Junior Water Right Limit

ZZWR entered in *ZZ* record field 4 is the identifier of the most junior water right to be included in the *ZZZ* file. With a blank *ZZ* record field 4, all water rights are included in the *ZZZ* file. Water right identifiers *WRID*(wr) are specified in *WR* record field 12. Typically, identifiers are assigned to all rights in a dataset. However, *SIM* functions fine if *WR* record field 12 is blank for one or more water rights. However, previously a blank *ZZ* record field 4 would match with a blank *WR* record field 12. The water right with a blank *WRID*(wr) would be treated as the most junior water right to be included in the *ZZZ* file. This has been corrected.

FS and CV Record Accumulation Computations Early in the Simulation

The flow switch *FS* and cumulative volume *CV* records are used to compute targets as a function of the cumulative volume of a variable defined in *FS* or *CV* record field 3 over the preceding specified number of months specified as *FSI*(FS,5). Volume accumulation computations have been modified for those months of the simulation before *FSI*(FS,5) months.

For example, the variable could be regulated flows and *FSI*(FS,5) could be 6 months. After the 6th month, the total volume of regulated flows over the preceding 6 months is computed in both the August 2013 *SIM* and previous versions. However, the issue is the accumulation computations in those months before the sixth month. For example, in the third month, only two preceding months have been simulated. In previous versions of *SIM*, with a *FSI*(FS,5) of 6 months entered on the *FS* or *CV* record, in the third month of the simulation, the cumulative volume of the selected variable includes the total volume in the first and second months which is added to the volume in the current month. In the August 2013 *SIM*, in the third month of the simulation, the total volume in the first and second months is multiplied by 6/2 to obtain an approximate 6-month equivalent volume.

CV Record FSI(FS,2) Option 4

Option 4 selected in CV record field 4 applies bounds on a target based on the ratio of the value of the CVV variable in the month preceding the current month to the value in the month preceding the preceding month. In the August 2013 *SIM*, the total cumulative volumes of the CVV variable in the two months are used to compute this ratio. In the August 2012 and earlier versions, the volumes reflected in the ratio were defined differently depending on values for other parameters entered on the CV record. The objective of the modification is to have a clear consistent definition of the ratio being computed. Option 4 is not included on the FS record, and thus this revision affects only the CV record.

Specifying Output and Assigning Group Identifiers by Water Use Type

A new feature activated by the new parameter GOUC on the GO record allows use type identifiers on UC and WR records to be treated as group identifiers. The group output GO record can now use water use type identifiers along with water right groups for specifying output. With the new feature activated, the use type identifiers are recorded as the second group identifier on the output records read by TABLES for use in grouping water rights.

TABLES Modifications (August 2012 to August 2013)

2REL or 6REL Reliability Table Water Rights Group Option

Previously, in creating reliability tables for water right groups, NUM in 2REL or 6REL record field 5 had to be non-zero, and the NUM water right groups had to be listed on IDEN records. A new feature is now activated if NUM is zero (default blank field 5) that consists of automatically including all water right groups defined on WR record fields 13 and 14 in the reliability table, up to a maximum of the first 80 groups defined by water rights sequenced in priority order. The new TABLES feature first reads through the water right output records in the SIM output OUT file to compile a list of group identifiers. These group identifiers are applied in the construction of the reliability table in identically the same manner as if they are read from IDEN records in the TABLES input TIN file. This new TABLES 2REL and 6REL feature also provides an additional table that supplements the reliability table with a count of the number of water rights in each group.

Water right groups are defined in the optional WR record fields 13 and 14. As noted above, the new SIM feature added to the GO record allows water use identifiers to also be treated as group identifiers. Thus, a reliability table also can be created that contains diversions aggregated by type of water use as defined by WR and UC records.

Time Series Headings for Column Format

The time series tables created by PT option 2 in field 3 of the time series records are in columnar format with the control point, reservoir, or water right identifiers printed in the column headings. The 16-character water right identifiers were truncated to 8 characters when included in the same table as control point or reservoir identifiers. The program has been revised to include the full 16-character water right identifiers.

Instream Flow Targets and Shortages

Option -9 has been added to 2FRE or 6FRE tables to develop frequency tables for instream flow targets at a control point (ID=0). 2FRE or 6FRE tables previously could not be created for instream flow shortages at a control point (ID=0) for default TABLE option 1.

2IFS or 6IFS record instream flow shortages at a control point are the differences between targets and regulated flows which previously could be either positive or negative numbers. Negative numbers are now set equal to zero.

2BUD Volume Budget

The volume budget computations activated by the 2BUD record would terminate without explanation for a dataset with more than 3,700 control points due to an array management problem. This problem has been corrected.

Modification to WRAP Programs in General (August 2012 to August 2013)

The programs end with an exit message. *WinWRAP* automatically signals the programs to close all open files. Previously if executed without *WinWRAP*, all active input and output files were automatically closed when the user pressed the enter key to leave the program. A feature was added to the August 2013 versions of the programs to automatically close all active files at the completion of program execution without waiting for the user to leave the program. Thus, an output file now can be read by another program prior to leaving the program that created the output file. For example, the *SIMD* output file can be read by *TABLES* prior to the user quitting *SIMD*. This added capability will probably provide no practical utility for most typical situations but can be useful if the programs are executed remotely.

Modifications between the August 2013 and August 2015 Versions

The August 2015 Version of WRAP includes expanded versions of *SIM*, *SIMD*, and *TABLES*. *HYD* has been recompiled in 64-bit configuration. *WinWRAP*, *DAY*, and *SALT* have not been changed since the August 2013 package. The August 2015 versions of the *Reference*, *Users*, *Daily*, and *Programming Manuals* incorporate the new software features and have been further edited for clarity. The *Fundamentals*, *Hydrology*, and *Salinity Manuals* require no revisions for the August 2015 expanded version of WRAP.

The revisions to *SIM* do not affect the results obtained from executing *SIM* with the TCEQ WAM System monthly input datasets or example datasets in the manuals. The monthly WAMs for all of the river basins have been run with the August 2013 version and August 2015 test version for comparison. There are no differences in simulation results. The latest *SIM* contains new capabilities not yet incorporated in the existing monthly datasets.

Conversion from 32-Bit to 64-Bit Computing (August 2013 to August 2015)

The WRAP programs have been converted from 32-bit to 64-bit word size. They are now compiled with the Intel Fortran XE2013 compiler in 64-bit mode. A 64-bit version of the HEC-DSS static library linked to the WRAP programs during compilation was obtained from the

USACE Hydrologic Engineering Center to replace the 32-bit version. The WRAP programs can also still be compiled in 32-bit mode if needed for older computers. Software with 64-bit virtual memory addresses can take advantage of newer 64-bit computer architecture, buses, memory and CPUs, allowing programs to execute faster. Most personal computers and operating systems marketed in recent years use 64-bit architecture. Both 32-bit and 64-bit application software can be executed with a 64-bit operating system. However, a 64-bit operating system is required to execute 64-bit application programs.

Expansion of Conditional Reliability Modeling (CRM) Capabilities (Aug 2013 to Aug 2015)

The following new features have been added to the CRM routines of *SIM* and *TABLES*. All revisions to *SIM* have also being transported to *SIMD*. *Reference Manual* Chapter 7 entitled "Short-Term Conditional Reliability Modeling" and relevant pages of the *Users Manual* have been expanded to cover the new features.

An old feature designed to reduce computer execution time was previously activated by parameter CR5 on the *CR* record. This option was not needed and was an unnecessary complication that has not actually been used. Thus, the old CR5 feature has been removed.

A new capability allows the *SIM* CRM simulations to be performed without repeating any of the months of the long-term hydrologic period-of-analysis. The new feature allows hydrologic sequences of any length to be simulated using the hydrologic sequences from the FLO, EVA, and FAD files without repetition or alteration. This new option is activated by parameter CR5 on the *CR* record and is illustrated by Example 8.3 in the *Reference Manual*.

The length of CRM simulation sequences can be any integer number of months. A new feature activated by CR3 on the *CR* record is designed for CR2 simulation periods of greater than 12 months. The new CR3 feature allows all months of the simulation sequences to be included in the CRM, SOU, and DSS files or optionally limits the simulation results output file records to any selected 12-month sub-period of the longer simulation. The default is to include the last 12 months in the CRM simulation results file read by *TABLES*. These features are illustrated by Examples 8.2 and 8.3 in the *Reference Manual*.

The SOU and DSS file simulation results output created by *SIM* were originally designed for conventional long-term simulations. The SOU and DSS files have been expanded to include CRM. Unlike *TABLES* time series routines, these new features place no limits on the length of the CRM simulation sequences. Unlike the DSS files created with *TABLES*, the multiple CRM sequences are treated as individual records in the new DSS file created directly by *SIM*. HEC-DSSVue can be used to plot the multiple sequences of simulation results on the same graph or different graphs, tabulate the sequences, or convert the data to a MS Excel file.

A new table of CRM sequencing information is added to the SOU file and replaces the ICHECK option 10 tabulation in the message MSS file.

A new feature has been added to the *TABLES* probability array CRM methodology that allows the storage-flow-frequency (SFF) and incremental probability (IP) arrays used to assign probabilities to CRM simulation sequences to be developed based on change in storage during

any number of preceding months. This new capability is controlled by the new parameters CRS on the 5CR1 record and CSVO and CSV on the 5CR2 record.

The SFF and IP arrays used to assign probabilities to the hydrologic simulation sequences are based on applying regression to compute the predicted or expected value of naturalized flow volume based on preceding storage or storage change. One of four alternative regression equations is selected by the parameter FIT on the 5CR1 and 5CR2 records. A new FIT option 5 has been added that allows the predicted (expected) value to be set equal to the long-term mean of the flow volume for CR1 months without consideration of preceding storage. With this new option activated, the SFF array method becomes equivalent to the FF array method.

The new parameter QX in 5CR2 record field 15 allows the expected value of flow from the calibrated regression model to be adjusted to reflect other considerations such as teleconnections related to climate cycles such as the El Nino-Southern Oscillation (ENSO). QX can be combined with either the FIT regression options or the new FIT option 5.

The *IM* record allows drought indices set in any specified months to be applied in any number of subsequent months. A drought index DIFACT can now be entered in *IM* record field 14 that resets the drought index at the beginning of each CRM simulation sequence. Although motivated by CRM, the new generic feature can also be used in a conventional long-term simulation to set the drought index in the initial months of the simulation.

All revisions to *SIM* are also incorporated in *SIMD*. *SIMD* was also modified to allow CRM to be applied to aggregated monthly totals from a daily simulation. Other refinements to the *SIM*, *SIMD*, and *TABLES* CRM routines include new or refined error and warning messages, table headings, and output options.

Other SIM and SIMD Modifications (August 2013 to August 2015)

The simulation output (SOU) and data storage system (DSS) files are activated by the optional output files *OF* record input in the DAT file. The SOU and DSS files were originally developed for use with conventional monthly non-CRM simulations. The DSS file created by *SIM* and *SIMD* was recently expanded to include both daily simulation results and monthly CRM simulation results. The SOU file was modified to include monthly CRM simulation results.

As discussed in the new *Reference* and *Users Manuals*, simulation results can be recorded in a DSS file either directly by *SIM* or *SIMD* or by *TABLES*, with either alternative approach providing certain advantages. HEC-DSSVue provides flexible convenient capabilities for managing, plotting, and analyzing the large datasets generated by either daily *SIMD* or monthly CRM simulations as well as conventional monthly simulations.

The required *JD* record and optional *JO*, *CR*, *FY*, *OF*, *XL*, *ZZ*, *RG*, *CO*, *RO*, *WO*, and *GO* records are placed at the beginning of the input DAT file. In the past, these records had to be in a certain sequential order following the rules explained in the *Users Manual*. These sequencing rules have been removed in the August 2015 *SIM* and *SIMD* allowing these records to be placed in any order. The *Users Manual* has also been edited throughout from the perspective of improving clarity in the explanation of logistical mechanics of input records.

A problem was corrected that limited the number of water rights that could be included in the ZZZ file activated by the ZZ record under certain circumstances.

The natural priority option activated by NOPT in JO record field 9 places water rights in upstream-to-downstream priority order based on control points in water right WR record field 2. This has been refined to also include locations set by the alternative control point ACPID option in SO record field 5.

OF and DT records were deleted in the April 2005 and August 2006, respectively, versions of SIM. Since then, if OF and DT records are read, SIM has generated messages that these records are obsolete. These special messages have been removed in the August 2015 SIM. OF and DT records now generate error messages just like any other incorrect record identifier.

Other minor revisions to SIM and SIMD are related to file handling and error and warning checks. All revisions to SIM are also included in SIMD. Several other additional revisions to SIMD are not applicable to SIM.

New Options Added to TABLES Time Series Routines (August 2013 to August 2015)

The new PT option 7 in field 3 of the time series records creates a summary containing only the total and mean. The new TOTALS option added as field 9 creates a time series of totals for all control points, water rights, or reservoirs. For example, a time series table or DSS record of the summation of storage contents of all selected reservoirs for each month of the simulation can be created. In addition to plotting the storage contents of individual reservoirs with HEC-DSSVue, the total storage contents of the perhaps several hundred or more reservoirs in the dataset or some subset thereof can be plotted, tabulated, and statistically analyzed.

The new parameters XUL and XLL allow upper and lower limits to be specified to limit quantities included in the tabulations specified by the time series records.

Modifications between the August 2015 and July 2018 Versions

The July 2018 WRAP is documented by the following manuals.

Water Rights Analysis Package (WRAP) Modeling System Reference Manual, TWRI TR-255, 12th Edition, 458 pages, July 2018. (*Reference Manual*)

Water Rights Analysis Package (WRAP) Modeling System Users Manual, TWRI TR-256, 12th Edition, 266 pages, July 2018. (*Users Manual*)

Fundamentals of Water Availability Modeling with WRAP, TWRI TR-283, 8th Edition, 116 pages, July 2018. (*Fundamentals Manual*)

Water Rights Analysis Package (WRAP) Daily Modeling System, TWRI TR-430, 3rd Edition, July 2018. (*Daily Manual*)

Water Rights Analysis Package (WRAP) River System Hydrology, TWRI TR-431, Second Edition, 120 pages, August 2013. (*Hydrology Manual*)

Salinity Simulation with WRAP, TWRI TR-317, 87 pages, July 2009. (*Salinity Manual*)

The July 2018 editions of the *Reference*, *Users*, *Fundamentals*, and *Daily Manuals* reflect major revisions since the 2015 editions. The following descriptions of modifications to the WRAP programs reference these most recent editions of the manuals. The *Hydrology* and *Salinity Manuals* were not modified during the period from August 2015 to July 2018 and are not included in the following discussion. An update of the *Hydrology Manual* is planned. Further revisions to DSS options and daily environmental flow standard features are being incorporated since a preliminary May 2018 version of the programs and manuals.

HEC-DSS and HEC-DSSVue (August 2015 – July 2018)

HEC-DSS and HEC-DSSVue have been applied to a limited extent with previous versions of WRAP and have been fully integrated into the July 2018 WRAP. The WRAP programs have been modified to fully incorporate DSS management of time series input data and simulation results. DSS files and HEC-DSSVue have been integrated throughout the July 2018 *Reference*, *Users*, *Fundamentals*, and *Daily Manuals*. A new chapter entitled "*Chapter 6 HEC-DSS Data Storage System and HEC-DSSVue*" has been added to the *Users Manual* to explain WRAP applications of DSS and HEC-DSSVue.

The Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers (USACE) maintains a suite of generalized simulation models that are applied extensively by numerous agencies and consulting firms throughout the United States and abroad. The HEC-DSS (Data Storage System) is used routinely with HEC simulation models and is also used with other non-HEC modeling systems including WRAP. Multiple simulation models share the same data management and graphics software. Data are stored in DSS files in a direct access binary format. DSS files can be created, written to, and read only with software with DSS capabilities. Capabilities for creating and accessing DSS files are incorporated in the WRAP programs by linking during compilation to routines from a HEC-DSS library of computer code developed by the Hydrologic Engineering Center. HEC-DSS and HEC-DSSVue are designed for efficiently working with datasets of time series data, including extremely large datasets.

The HEC-DSS Visual Utility Engine (HEC-DSSVue) is a graphical user interface program for managing, viewing, editing, and graphing data in DSS files and performing statistical analyses and mathematical operations. HEC-DSSVue is explained in detail by a user's manual available at the HEC website along with the software. <http://www.hec.usace.army.mil/>

DSS input and output files and HEC-DSSVue capabilities serve the following roles in the WRAP/WAM modeling system.

1. HEC-DSS facilitates more efficient WAM hydrology updates and improvements.
2. All of the *SIM* and *SIMD* time series input can be stored in a single DSS input file that facilitates convenient and effective data management, analysis, and display.
3. All of the *SIM* and *SIMD* simulation results can be recorded in a single DSS output file that facilitates convenient and effective data management, analysis, and display.
4. HEC-DSSVue provides flexible capabilities for managing WRAP input datasets and simulation results that include cataloging and searching data records, viewing and comparing, plotting graphs, data tabulation, mathematical operations, and statistical analyses.

5. Information incorporated in the July 2018 WRAP manuals explain HEC-DSSVue capabilities expected to be routinely applied in WRAP/WAM modeling. HEC-DSSVue provides extensive additional capabilities explained in its 490-page user's manual that could also be employed in future WRAP/WAM applications not yet envisioned.

All existing input/output features of the WRAP programs are completely preserved with the full integration of DSS. The new DSS-based capabilities described here are added as alternative options, while still maintaining all existing text file capabilities. Options can be combined using DSS files for selected input and/or output and conventional text files for other data or using both DSS and text files to store the same time series data in the alternative formats.

DSS-Based Improvements in Managing *SIM* Time Series Input Data

Modifications to the WRAP programs to improve features for managing time series input data include (1) storage of any or all time series input data in a single DSS input file rather than separate text files and (2) various refinements to the individual types of time series records. *SIM* and *SIMD* time series input data consists of:

- monthly naturalized flows on *IN* records
- monthly evaporation-precipitation depths on *EV* records
- monthly adjustments to naturalized flows on *FA* records
- monthly regulated-unappropriated flow adjustments on *RU* records
- monthly environmental flow standard hydrologic index sequences on *HI* records
- monthly water right target series and streamflow depletion limits on *TS* records
- daily flow pattern hydrographs on *DF* records (*SIMD* only)

New options added to *SIM* and *SIMD* allowing these time series to be input in a single hydrology DSS input file rather than in separate FLO, EVA, FAD, RUF, HIS, TSF, DAT, and DCF text files. The new DSS input features are optional. All of the old options for storing *IN*, *EV*, *FA*, *RU*, *HI*, *TS*, and *DF* records are still available. New options activated by parameters on the *JO*, *JU*, and *OF* records allow time series to be read from FLO, EVA, FAD, RUF, HIS, DAT, TSF, and/or DCF files and converted to DSS records in a DSS file.

The new DSS time series input options are covered on the following pages of the July 2018 *Users Manual*: pages 42-44 (additions to *JO* record), pages 45-47 (new *OF* record), page 48 (new *FA*, *RU*, *HI* identifier records), pages 122, 127-134 (*FA*, *RU*, *FA*, and *TS* time series records), pages 171-172 (daily flow *DF* records), and pages 237-252 (new Chapter 6 on DSS).

The reorganized target series record is described on pages 122 and 132-133 of the *Users Manual*. *IF* or *WR* record water right targets or streamflow depletion limits can now be input on target series *TS* records in any combination of DAT, TSF, and/or DSS files. The TSID identifier was changed from a 3-character to 6-character format and now defaults to the control point of the water right. *TS* record options are explained on pages 132-133 of the *Users Manual*.

SIM Simulation Results DSS Output File

The primary WRAP/WAM application of DSS in the past has been plotting simulation results with HEC-DSSVue from a DSS file created by *TABLES* from output records read by

TABLES from a *SIM* output OUT file. Significant enhancements to conditional reliability modeling (CRM) during 2014-2015 included recording multiple sequences of CRM simulation results directly to a *SIM* output DSS file as described in Chapter 8 of the *Reference Manual*. The multiple sequences of CRM simulation results recorded on DSS records can be of any length.

The July 2018 versions of *SIM* and *SIMD* can output all simulation results to a DSS output file. The 42 simulation results time series variables that can be included in the DSS file are listed on page 47 of the July 2018 *Users Manual*. All or any subset of the 42 variables can be selected for inclusion in the output DSS file. Optional files *OF* record parameters for selecting variables are described on pages 45-46 of the *Users Manual*.

SIM and *SIMD* have always recorded monthly simulation results in an OUT or CRM output file and daily results in a separate SUB file. The same simulation results can now be recorded in a single DSS file. With the latest *SIM/SIMD*, the OUT or CRM, SUB, and DSS output files can be employed in a single execution of the simulation model. The WRAP program *TABLES* reads *SIM* output OUT files. HEC-DSSVue reads the simulation results from the DSS file. *SIMD* daily simulation results otherwise recorded in a SUB file can also be recorded in the same DSS file as the monthly simulation results.

TABLES creates reliability tables and various other tables that cannot be created with HEC-DSSVue and thus remains an essential component of WRAP. Frequency tables can be created with either *TABLES* or HEC-DSSVue. HEC-DSSVue develops frequency plots as well as frequency tables for any of the variables. HEC-DSSVue has various other statistical and mathematical features not available in *TABLES*.

A comparison of WRAP uses of HEC-DSSVue versus *TABLES* is presented on pages 39-40 of the *Fundamentals Manual*. The most beneficial capabilities added by HEC-DSSVue in managing, analyzing, and displaying *SIM* simulation results are perhaps the: (1) very convenient capabilities for quickly searching through massive simulation results datasets to find any number of output data records of interest and (2) comprehensive, flexible capabilities for preparing high-quality time series plots

Various *SIM* DSS output control parameters on the new optional files *OF* record are described on pages 45-47 of the July 2018 *Users Manual*. Control points, water rights, and reservoirs are selected for inclusion in the OUT and CRM text files and binary DSS file in exactly the same manner. All simulation results variables are included in the OUT or CRM files for each control point, water right, and reservoir selected. However, new options on the *OF* record allow user selection of variables to include in the DSS file.

Any or all of the 42 variables listed on page 47 of the *Users Manual* can be selected for inclusion in the DSS output file for selected control points (variables 1-16), water rights (variables 17-30), and reservoirs (variables 31-42). Ten of the water right variables are for both *WR* and *IF* record rights, and four are associated with only instream flow *IF* record rights. The single DSS output file can contain monthly or daily quantities or both monthly and daily quantities for any of the variables for any number of selected control points, water rights, and/or reservoirs. All DSS files are accessible with HEC-DSSVue.

New Methodology for Modeling SB3 Environmental Flow Standards

A new approach for simulating SB3 environmental flow standards has been developed that is designed to replicate the format of the SB3 flow standards, as published in the Texas Administrative Code, as closely as possible. The previous approach for incorporating SB3 flow standards into monthly *SIM* and daily *SIMD* simulations has been based on adapting existing *SIM/SIMD* capabilities within the existing modeling framework to the full extent possible. The new approach based on replicating the actual format of the SB3 flow standards is designed to be much easier for model users to understand and implement.

The newly created environmental standard *ES* record and hydrologic condition *HC* record are applicable to both monthly *SIM* and daily *SIMD* simulations. The old pulse flow *PF* and pulse flow options *PO* records have been revised. The *PF* and *PO* records are still applicable only for a daily *SIMD* simulation. The new *ES* record provides capabilities for modeling subsistence, base, and high flow components of flow standards. *PF* records model high pulse flows. The new *HC* record defines hydrologic conditions for both *ES* and *PF* record flow targets.

Both the overall framework and the details of individual exiting options have been revised along with addition of the new methods. The new methodologies are described on the following sections of the new manuals.

- Section entitled "*Environmental Flow Standards*" (pages 111-118) added to Chapter 4 of the *Reference Manual*.
- New "*Chapter 6 Environmental Flow Standards*" and "*Chapter 8 Environmental Flow Examples*" of the *Daily Manual*.
- *ES* and *HC* record explanations on pages 74-79 and *PF* and *PO* record explanations on pages 155-161 of the *Users Manual*.

A strategy for developing monthly environmental instream flow targets from a daily simulation has been proposed and is being further investigated. Features controlled by *ES* and *HC* records can be employed directly in a monthly *SIM* simulation. However, a more accurate monthly simulation can be achieved as follows. *ES*, *HC*, *PF*, and *PO* record features are employed in a daily *SIMD* simulation, with daily targets summed to monthly and stored in a DSS file. The monthly *SIM* simulation reads *TS* record monthly instream flow targets from the DSS input file along with time series of *IN*, *EV*, and other records. This strategy is continuing to be explored and refined.

Other SIM Modifications (August 2015 – July 2018)

Addition of Safe Yield Criteria to the *FY* Record

The new safe yield is a more complicated form of firm yield providing greater flexibility in defining water supply capabilities. Parameters *FYC*(1), *FYC*(2), *FYC*(3), and *FYIN*(6) have been added as the new fields 10, 11, 12, and 13 of the *FY* record described on pages 55-57 of the *Users Manual*. If these new fields are blank, the *YRO* file yield-reliability table is created and firm yield is computed as in the past, without any change. The new fields 10-13 provide criteria

for defining a "safe yield" to be adopted as an alternative to "firm yield". An explanation and example of applying the new feature are presented on pages 194-204 of the *Reference Manual*.

Two alternative strategies, (1) storage reserve and (2) allowable shortages, are provided for defining safe yield. The new *FY* record parameter FYC(2) provides four options for defining a reservoir storage reserve representing FYC(3) months of water supply. FYC(1) provides flexibility in defining allowable water supply shortages.

Addition of Hydropower and Instream Flow Targets to the *FY* Record

As noted in the preceding section, the modeling capabilities activated by the firm yield *FY* record are described on pages 55-57 of the July 2018 *Users Manual* and pages 194-204 of the July 2018 *Reference Manual*. In the past, the *FY* record was applicable to only *WR* record water supply diversions. The *FY* record is now also applicable to *WR* record hydroelectric energy generation and *IF* record instream flow targets. For purposes of the *FY* record computations, instream flow shortages are zero if regulated flow exceeds the target and otherwise the difference of regulated flow less the instream flow target.

Options for Distributing Naturalized Flows from Primary to Secondary Control Points

Several improvements in the methods for computing naturalized flows at secondary control points are described as follows. Chapter 3 of the *Reference Manual* has been edited for improved clarity in explaining the original methods as well as the addition of new features.

Options for obtaining naturalized flows are selected using parameter INMETHOD(cp) in *CP* record field 2 as described on pages 67-68 of the *Users Manual*. Option 2 allows flows at control point CPIN(cp) to be repeated at control CPID(cp,1). In past versions of *SIM*, CPIN(cp) had to be a primary control point with naturalized flows input on *IN* records since the repetition occurred as the flows were read from the *FLO* input file. The modification consists of allowing CPIN(cp) to be any control point including secondary or primary control point. The option 2 routine is repeated again at the end of the flow distribution routine. This means either secondary or primary control points can serve as source control points for INMETHOD(cp) option 2.

Flow distribution parameters are read from *FD*, *FC*, and *WP* records described on the revised pages 120-121 of the *Users Manual*, which are stored in a *DIS* file. Flow distribution options 2 through 8 selected with parameter INMETHOD(cp) in *DAT* file *CP* record field 6 require a *FD* record in the *DIS* file with a source control point identifier that matches the control point identifier on the *CP* record in the *DAT* file. A warning message routine, dating back many years to the early versions of *SIM*, that checks that the control point identifiers appropriately match had not been functioning but has now been corrected.

CP record INMETHOD(cp) option 10 is based on an equation proportioning flows at multiple other control points using factors input on *FC* records in the *DIS* file. The old INMETHOD option 10 was based on *FC* record coefficients at a maximum of three control points, was awkward to understand, and could cause *SIM* to terminate when reading *FC* records under some conditions. The new revised option 10 has no limit on the number of control points included on *FC* records and has been revised to remedy the other problems. Modifications to

option 10 also motivated an overall reorganization of the Fortran routine that reads the DIS file. The new INMETHOD(cp) option 10 is described on page 121 of the *Users Manual* and pages 64-65 of the *Reference Manual*. The new Example 4 added on pages 405-409 of Appendix C of the *Reference Manual* illustrates the flow distribution methods including the new option 10.

Revised CO, RO, WO, and GO Records

CO, *RO*, *WO*, and *GO* records for selecting simulation results to be included in output files are described on pages 49-51 of the *Users Manual*. These four records have been revised to provide greater flexibility and convenience. Any number of identifiers can now be listed on any number of records essentially unrestricted by any rules. The number of identifiers does not have to be specified. *IF* record water rights can now also be included on the *GO* record groupings. Files with old records are still fine. Automation simply adds greater flexibility and simplicity.

Output option selection parameter GOUC on the group output *GO* record now activates five options rather than the previous single option of using *UC* record identifiers as group identifiers. Output option selection parameter NREOUT on the *RO* record now activates four options rather than the previous binary option of including all or none of the reservoirs.

The *CO* and *WO* records now serve dual purposes. They are used to specify which control points and water rights to include in the output files as in the past. The *CO* and *WO* records are now also used for designating control points, water rights, and reservoirs as artificial.

Artificial Control Points, Water Rights, and Reservoirs

A new scheme has been added for designating control points, water rights, and reservoirs as being artificial, which is explained on page 51 of the *Users Manual* and page 159 of the *Reference Manual*. The new feature is activated by the new parameter ARTIF on the *CO* and *WO* records described on pages 49-50 of the *Users Manual*.

Designation of control points, water rights, and reservoirs as being "*artificial*" does not affect the *SIM* simulation computations. The sole purpose of the artificial classification scheme is to exclude certain quantities from the simulation results output OUT, CRM, SOU, and DSS files. Quantities for artificial control points, water rights, and reservoirs are included in the output files only if certain output options entered on *JD* and *RO* records are selected. The primary motivation for the artificial classification feature is devised or "dummy" control points, water rights, and reservoirs that have been incorporated in several of the WAM input datasets for purposes of various accounting computations. Accounting diversions and storage serve computational purposes but do not represent actual physical facilities.

Addition of IF Record Water Right Group Identifiers

The water right *WR* record has always included two water right group identifiers WRIDS(wr,1) and WRIDS(wr,2), but the instream flow *IF* record had no group identifiers. The two group identifiers have been added to the *IF* record as described on pages 71-73 of the *Users Manual*. A new instream flow parameter array was added to the *SIM* Fortran code to deal with differences between *IF* record and *WR* record water rights that motivated exclusion of *IF* record group identifiers in the past.

Additions to Water Right Group *RG* Record

The water rights group *RG* record is described on pages 59-62 of the July 2018 *Users Manual* and pages 160-161 of the July 2018 *Reference Manual*. The new RGI(I,1) options activated by entering -9 or -99 in *RG* record field 2 result in all water rights in the defined group being omitted from the simulation. The priority option activated by *RG* record field 4 is also a new feature that has been added in the July 2018 *SIM*.

JO Record Dual Simulation Deactivation Option

The default dual simulation option is activated by the parameter DUALD on the *JO* record. A new DUALD option allows all dual simulation specifications on *PX* records for any and all water rights to be deactivated. The purpose of this new feature is to allow the *SIM* dual simulation feature to be easily switched on and off by changing a single parameter entry.

Multiple Target Options *TO* Records

Field 10 has been removed from the *TO* record. Any number of *TO* records may be included in the set of records following a *WR* or *IF* record. In the past, with multiple *TO* records, the parameter CONT in *TO* record field 10 was required to instruct *SIM* to read the next *TO* record. A routine has been added for *SIM* to automatically count the number of *TO* records. There is no field 10 on the *TO* record described on *Users Manual* page 94, but old DAT files with *TO* records with an entry in that field still function fine. The old field 10 is simply not read.

Combining *TO* record TOTARGET Option 5 with a *MS* Record

The target options *TO* record TOTARGET option 5 drawdown does not consider monthly storage *MS* record seasonal storage rule curve reservoir operations in the pre-2018 *SIM*. The drawdown is computed from the original *WS* record storage capacity even if the storage capacity is seasonally varied by the optional monthly storage *MS* record. The *MS* record monthly variations in storage capacity are recognized by the July 2018 *SIM* in computing *TO* record TOTARGET option 5 drawdowns (*Users Manual* pages 94 and 114).

Addition of LDAYS Option

The parameter USE in field 4 of the *WR* and *IF* records is described on pages 69-73 of the *Users Manual*. The NDAYS option distributes the annual target amount evenly over the 12 months of the year assuming each month has 28 (February), 30, or 31 days, ignoring the one day difference that occurs in leap years. The new LDAYS alternative is otherwise identical to the NDAYS option but correctly accounts for leap years having 29 rather than 28 days in February.

New *DI* Record Option for Assigning Drought Index Identifiers

In the past, integer drought index identifiers were automatically assigned by *SIM* in sequential order as *DI* records were read. A new drought index identifier DIID(DI) has been added as *DI* record field 2 (*Users Manual* page 115) that allows the user to assign any integer

identifiers in any order. If *DI* record field 2 is left blank, the drought index identifier is automatically assigned in the same manner as in past versions of *SIM*.

New *OR* Record Option for Multiple-Reservoir System Operations

The operating rules *OR* record is described on pages 84-86 of the *Users Manual* and pages 140-142 of the *Reference Manual*. The new option 2 activated by the rank parameter in *OR* field 6 is a new feature for controlling multiple-reservoir system release decisions in which the rank is based on water surface elevation drawdown in feet. This new option requires a *PV/PE* record table of volume versus elevation for each reservoir in the multiple-reservoir system. The framework for managing *PV/PE* record volume-relationships has been reorganized to facilitate inclusion of reservoir water surface elevations in simulation results for information as well as supporting hydropower computations and the new multiple-reservoir system operations option.

New *WS* Record Option for Specifying Empty Beginning Reservoir Storage

The beginning-of-simulation storage contents is specified by *BEGIN* in *WS* record field 8 (*Users Manual* page 82-83). A blank field 8 or *BEGIN*=0.0 defaults to the reservoir being full to capacity at the beginning of the simulation. In the past, an empty reservoir was modeled entering a very small number for *BEGIN* that had to be greater than zero. A new *BEGIN* option allows zero beginning storage to be specified by entering a -1.0 for *BEGIN*.

Interpolation Exceeding Maximum Storage on *SV/SA*, *PV/PE*, and *IS/IP* Records

An error message accompanied by termination of program execution has been added to the linear interpolation routine that reads the reservoir storage-area (*SV/SA* records), storage-elevation (*PV/PE* records), and drought index (*IS/IP* records) tables that is activated if the simulated quantity exceeds the maximum value in the table being interpolated. In pre-2018 versions of *SIM*, the interpolated quantity is set equal to the maximum value in the interpolation table, a warning message is written, and program execution continues.

In the July 2018 *SIM*, a warning message is written to the message *MSS* file any time the maximum value in an interpolated table is exceeded at all, but the error message with program termination occurs only if the maximum value in the table is exceeded by more than 1.0 percent. Thus, the iterative computational algorithms are allowed to continue if the computed quantity slightly exceeds the highest value in the table in a particular iteration. The interpolated quantity is set equal to the maximum value in the interpolation table. An error message is written to the *MSS* file and program execution is terminated if the maximum value in the table is exceeded by more than 1.0 percent.

Like many *SIM* warning and error checks, the warning and error checks described in the preceding paragraph are activated only if the standard *ICHECK* option 1 is selected in *JD* record field 4. In the July 2018 *SIM*, if an interpolated table is exceeded by more than 1.0% and *ICHECK* option 1 is activated in *JD* record field 4, *SIM* is terminated with an error message. Changing *ICHECK* to 9 results in the maximum value in the table being adopted and a warning message being recorded in the *MSS* file without terminating execution of *SIM*.

A small modification was also added to the drought index *DI* record routine which interpolates a storage versus index table input on *IS* and *IP* records. An error message is activated if the interpolation exceeds the limits of the *IS/IP* records. A situation was found in which a small negative storage volume, such as -0.0000001 acre-feet, could activate the error message and terminate *SIM* execution. The code was modified to change negative storage volumes to zero in the drought index interpolation routine.

SIM Iterative Algorithm for Computing Storage and Evaporation-Precipitation Volumes

End-of-month reservoir storage contents, net evaporation-precipitation volume during the month, diversions, and releases are computed by an iterative algorithm for given beginning-of-month storage, available streamflow, preceding withdrawals/releases for senior water rights, diversion targets, and active and inactive reservoir storage capacities. The computed end-of-month storage volume depends upon the net evaporation less precipitation volume during the month which depends on both the beginning-of-month and end-of-month storage volumes and associated water surface areas. The inter-dependence of end-of-month storage contents, net evaporation-precipitation volumes during the month, and the other variables necessitates an iterative algorithm that can cover a variety of situations.

The iterations stop when two sequential estimates of end-of-month storage satisfy the following criteria: the change between the two estimates is both less than 0.1 acre-feet and less than of 0.01 percent of beginning-of-month storage. A warning message is generated if a maximum limit of 50 iterations is reached without satisfying the stop criteria. The warning message has the following format and typically occurs when reservoirs are almost empty.

```
WARNING: Reservoir storage and evaporation computations did not converge to within
         stop criteria in 50 iterations for water right 3226A1
         Reservoir: PAYNE1; CP: 3226N ; Year: 1948; Month: 8; Final Evap: 0.91
         Begin Storage: 2.55; 49th End Storage: 0.12; 50th End Storage adopted: 0.00
```

The net evaporation less precipitation volume is computed as the average water surface area during the month in acres multiplied by the net evaporation-precipitation (EP) depth in feet read from the *EV* records. EP depths are positive in months with evaporation exceeding precipitation and negative in months with precipitation exceeding evaporation. EP volumes should be positive if EP depths are positive. Likewise, EP volumes should be negative if EP depths are negative. However, this does not always happen in the iterative algorithm described in the preceding paragraph as the storage contents approaches zero. The following warning message is generated if the final value of EP from the iterative algorithm has the wrong sign.

```
WARNING: Evaporation volume has wrong sign. 1940 1 CORWHT Volume = -71.9 depth = 0.003
```

The larger WAMs have hundreds of reservoirs which during the hundreds of months of a *SIM* simulation provide many opportunities for the two warning messages noted above to be generated. These MSS file warning messages are recorded numerous times by some of the WAM datasets. The iteration *SIM* simulation algorithms were reviewed to determine whether improvements are feasible. The following two refinements are adopted in the October 2017 *SIM*.

1. Wrong-sign net evaporation-precipitation volumes are set equal to zero.

2. The next-iteration estimated change in end-of-month storage volume is reduced by half for the 35th through 50th iterations to prevent an infinite repetitive cycle.

Most if not all of the wrong sign warning messages occur when reservoirs are almost empty. For example, the iterative algorithm might result in a very small end-of-month storage volume of 0.845 acre-feet in a reservoir with a capacity of 100,000 acre-feet and very small EP volume of -0.0002431 acre-feet in a month with a positive evaporation-precipitation depth read from the *EV* record. With a positive EP depth on the *EV* record, the computed EP volume should be positive or zero. Thus, the wrong sign warning message is recorded in the MSS file.

The July 2018 *SIM* has been modified as follows. If the computed net evaporation less precipitation (EP) volume has a negative or positive sign that is not the same as the *EV* record EP depth, the net EP volume is set equal to zero. *JD* record ICHECK options 13 and 14 have been added. With ICHECK option 13 selected in *JD* record field 4, a warning message is written in the MSS file each time a wrong sign EP volume is changed to zero. With ICHECK option 14 selected, the new feature described here is not activated and the simulation results should be identical to the results generated with the August 2015 and earlier versions of *SIM*.

In some cases, setting the EP volume to zero can result in a negative end-of-month storage volume. The negative end-of-month storage volume is set equal to zero. With ICHECK option 13 activated, a warning message in the MSS file warns that the negative storage volume was changed to zero.

The iterative algorithms for simultaneously computing end-of-month reservoir storage contents, net evaporation less precipitation volumes, diversions, and reservoir releases must cover a variety of situations and thus are necessarily complex. The modification described in the preceding two paragraphs apply to standard type 1 water rights. The wrong sign warning message can still be generated in other cases such as multiple-owner reservoirs modeled with evaporation allocation *EA* records.

Another component of the refinements to the iterative reservoir volume balance algorithm in the July 2018 *SIM* consists of assigning the next estimate of the end-of-month storage differently after the 35th iteration. The computations in the pre-2018 and 2018 versions of *SIM* are the same for a particular reservoir in months that require 35 or fewer iterations. The projected storage change is reduced to half for iterations 36 through 50 in the 2018 *SIM* to address the complexity described in the next paragraph.

The following observations are derived from experimentation with the WAM simulations. The stop criteria are more than adequately stringent and should not be changed. Simulation results for the WAMs are not changed by increasing the maximum number of iterations from 50 to 100. The warning message that the maximum limit of 50 iterations is reached usually occurs in months in which a reservoir is almost empty. A key problem resulting in the 50 iteration limit being reached is as follows. In some cases, within about ten to twenty iterations the computational algorithm goes into a repetition cycle which alternates between only two values of the end-of-month storage. With the original algorithm, the iterations would not advance past these two values with an unlimited number of iterations. The modification incorporated in the 2018 *SIM* is designed to "unstick" this infinite cycle after 35 iterations by

reducing the next-iteration change in end-of-month storage volume by 50 percent. This modification improves accuracy and reduces the number of warning messages recorded in the message file.

Hydroelectric power generation computations also interact with the algorithm for computing reservoir storage and net evaporation. The iterative hydropower computational algorithm has also been refined.

TABLES Additions and Improvements (August 2015 – July 2018)

Type 1 input records activate *TABLES* routines that read water right, reservoir, and control point data from a *SIM* input DAT file and develop tables that organize and summarize the simulation input. Types 2 and 6 records control routines that read the *SIM* monthly output OUT and *SIMD* daily output SUB files and develop tables that organize and analyze the simulation results. The July 2018 version of *TABLES* has major new and improved type 1 capabilities for analyzing *SIM* input data and significantly refined and expanded types 2 and 6 features for organizing and analyzing simulation results. A new chapter entitled "*Chapter 7 Program TABLES Analyses of Simulation Input and Results*" has been added to the *Reference Manual*. Examples of applying the new and improved features are found in the new chapter.

New and Revised TABLES Type 1 Tables

The 1REC, 1RCT, 1SRT, 1SUM, 1RES, and 1CPT records are described on pages 190-195 of the *Users Manual* and pages 217-223 of the *Reference Manual*. The old 1LEN record is removed with its function moved to the 1REC record in the July 2018 *TABLES*. The new 1RCT and 1RES records are added. The 1SRT, 1SUM, and 1CPT records are significantly expanded and improved.

The purpose of the *TABLES* routines activated by these TIN file input records is to summarize and organize selected input data from the *SIM/SIMD* input DAT file. The 1REC feature simply allows *SIM* input records of any record type to be copied to the *TABLES* output TOU file. The 1RCT counts the number of records of each of the 58 types of records possible in a *SIM* input DAT file and 17 additional record types possible in a *SIMD* DAT file.

The 1SRT record allows the user to list all water rights in priority order without grouping or to categorize the water rights into groups and list the water rights within each group in priority order. The 1SUM record routine uses the same data read from the *SIM* input DAT file as the 1SRT record but sums the quantities by defined group rather than listing each individual reservoir in the table. The recent improvements consist mainly of adding a set of criteria controlled by eight new input parameters that define a user-selected sub-set of water rights to include in the 1SRT and 1SUM tables. The new criteria parameters are the same on both the 1SRT and 1SUM tables. The format of two tables created by the 1SRT and 1SUM records have been refined and a new optional table has been added to the 1SRT record.

The newly created 1RES record tabulates additional information regarding the reservoirs associated with the water rights. Each line in the 1RES record represents a *WS* record read from the DAT file. A *WS* record is required for any water right with reservoir storage capacity. Multiple

rights can be associated with the same reservoir and multiple reservoirs with the same water right. Each line in the 1RES table represents a *WS* record with its associated *WR* or *IF* record information. Multiple *WS* records for the same reservoir are grouped together in the 1RES table. The 1RES tables provides basic information about each reservoir and each water right associated with each reservoir. An option allows the table to be limited to only those reservoirs with storage capacities exceeding a specified minimum limit.

The 1CPT records lists control points in upstream-to-downstream order and tabulates specified data for each control point. A new KK option 7 has been added which tabulates channel loss factors, delivery factors, and cumulative deliver factors.

TABLES Type 2 Record Selection of Control Points, Water Rights, and/or Reservoirs

The following records have similar schemes for specifying control points, water rights, reservoirs, and/or water right groups for inclusion in the tables: time series records for the 34 variables listed on page 199 of the July 2018 *Users Manual*, 2REL (page 208), 2FRE (page 212), 2SCP (page 217), 2SWR (page 217), 2SGP (page 218), 2SRE (page 218), and the corresponding daily type 6 records (page 234). The scheme has been revised to improve convenience and consistency. The selection process is controlled by options specified by the parameter NUM on the records listed above and optional IDEN records. The new scheme is described on page 203 of the *Users Manual*.

Control point, water right, reservoir, and/or water right group identifiers can be listed on IDEN records. The strict rules governing use of IDEN records have been removed analogously to the previously discussed modifications to the *SIM CO*, *WO*, *RO*, and *GO* records. Any number of identifiers can now be listed on any number of IDEN records essentially unrestricted by any rules. Blanks are allowed. Since *TABLES* now automatically counts the identifiers, the number of identifiers does not have to be specified by NUM in the referencing records.

2REL Record Criteria for Defining Water Rights to Include in Reliability Table

The new parameters FAMT, XAMT, XPS, XPJ, XCP, XGROUP, and XUSE are added to the 2REL record described on pages 208-211 of the *Users Manual* to define a subset of water rights for inclusion in the reliability table. The selection criteria are based on minimum limits on annual diversion targets, priority ranges, control point location, type of water use, and group identifiers as explained on page 235 of the new *TABLES* chapter in the *Reference Manual*.

The larger WAM datasets contain many hundreds of water rights. A 2REL table containing all water rights may be extremely long. This new feature is designed to provide convenient flexible options for delineating a set of water rights of interest for inclusion in the reliability table.

New 2IFF Record

A new time series record was added to tabulate the portion of the instream flow target that is supplied. The new 2IFF record is described on pages 198-202 of the *Users Manual*.

TABLES 2FRE Record Additions

The variable for which the frequency metrics are computed is selected from 18 options by the entry in 2FRE field 2 described on pages 212-213 of the *Users Manual*. The following new variables were added to the selection list.

Option 10 instream flow shortage as percentage of target for control points.

Option 11 instream flow target for *IF* record rights.

Option 13 instream flow shortage as percentage of target for *IF* record rights.

The numbering for instream flow options 10 through 15 in 2FRE record field 2 has changed. Thus, old 2FRE records in old TIN files may develop the frequency tables for the wrong variable which should be obvious from the table heading.

The parameter XLIMIT was added as the last field of the 2FRE record to facilitate limiting the length of the frequency table. Time series are excluded from the frequency table if their mean exceeds XLIMIT.

Addition of Unit Conversion Feature to Time Series and Frequency Records

A new option on the time series and 2FRE record activated by the input parameter CFS converts the SIM simulation time series from acre-feet to cubic feet per second (cfs). The different number of days (28, 29 in leap years, 30, and 31) are reflected in the unit conversions.

Developmental Daily WRAP Modeling System (August 2015 – July 2018)

The WRAP modeling system including the SIM simulation model employs a monthly computational time step. The new daily version of WRAP modeling system consists of the daily simulation model *SIMD*, daily features of *TABLES*, and the daily flow programs *DAY* and *DAYH*. The programs *SIMD* and *DAY* are still in a developmental testing status. The July 2018 Draft *Daily Manual* supplements the Reference and Users Manuals in documenting the daily modeling system. The daily features of WRAP are designed to supplement and extend, not replace, the basic monthly modeling system.

SIMD Modifications (August 2015 – July 2018)

A new feature was added to *SIM* that allows *SIM* to be executed with an input dataset designed for a daily *SIMD* simulation. The records that are applicable only to a daily simulation are skipped over in the monthly *SIM* simulation. Messages are recorded in the message MSS file indicating which daily records were found but not read. Any other invalid record identifiers activate error messages and program termination. Unlike *SIM*, *SIMD* has no features for skipping daily-only DAT file input records. *SIMD* as well as *SIM* can perform a monthly simulation with a DAT file designed for a monthly simulation (no daily-only records), with both models providing the same simulation results.

With the exception of the new feature noted in the preceding paragraph, all *SIM* modeling capabilities are replicated in *SIMD*. The *SIM* modifications described on the preceding pages are included in both *SIM* and *SIMD*. As previously noted, the *SIMD* environmental pulse flow *PF*

and *PO* record features have been revised along with the new *SIM/SIMD* environmental standard *ES* and hydrologic condition *HC* records. The new SB3 environmental flow modeling strategy includes a general framework shared by *SIM* and *SIMD* and high pulse flow features applicable only to *SIMD*. The following additional modifications to daily modeling features of *SIMD* are not relevant to *SIM*.

A new "*Chapter 4 SIMD Modeling System*" was added to the July 2018 *Users Manual*. The *Daily Manual* has been significantly revised throughout since the August 2015 version, and several chapters and an appendix are essentially totally new. The examples presented in the *Daily Manual* are new or significantly revised. The *SIMD* Fortran program has been significantly restructured and refined throughout since the August 2015 version.

The July 2018 version of *SIMD* requires the *JT* record to be in the format outlined in Chapter 4 of the *Users Manual*. Format changes and additional new options on the *JT* record result in old input datasets not working with the latest version of *SIMD*.

Handling of daily flow pattern hydrographs in *SIMD* has been significantly revised. The only option for storing daily flow input datasets in the past was *DF* records in the DCF file which was very awkward for large datasets. The new strategy of storing the *DF* records in the hydrology DSS input file is much more convenient and is the recommended standard. The option of *DF* records in the DCF file is also still retained.

DF record daily flow pattern hydrographs are provided in the input dataset for selected control points and repeated within *SIMD* at many other control points. The routine for automatically repeating *DF* record flows at many other control points has been refined.

Both the revised July 2018 *SIMD* and the new *DAY* include routines that read *DF* records from a DCF file and write the data to a DSS file. The *Daily Flows (DAY)* program converts the flows directly from the DCF file to the DSS file. *SIMD* includes options for repeating flows and other adjustments that are applied prior to writing the resulting flows to the DSS file.

Flood control reservoir operations are comprised of two sets of operating rules: (1) single or multiple reservoir system operations based on channel capacities at any number of downstream control points as specified by *FR* and *FF* records and (2) outlet structure capacities as specified by *FV* and *FQ* records. The routines for simulating operation of flood control reservoirs have been refined to better combine components of the operating rules.

Several Fortran code corrections deal with problems encountered with the occurrence of various combinations of conditions in the forecast simulation computations. The forecast computations functioned correctly in most applications but problems were encountered in some situations, particularly with large complex WAMs with long forecast periods.

New Daily Flows (DAY) Program (*August 2015 – July 2018*)

The new program *Daily Flows (DAY)* provides a set of routines for (1) compiling and manipulating daily flow data, (2) converting datasets between text and DSS files, (3) performing statistical analyses of flows and flow changes, (3) computing lag and attenuation metrics for use

in estimating values for routing parameters, and (4) disaggregating monthly flows to daily. The program provides a general framework that facilitates adding more capabilities in the future.

Program *Daily Flows (DAY)* reads input files of observed, naturalized, or simulated regulated or unappropriated daily stream flows, performs statistical, lag/attenuation, flow disaggregation, and other analyses using these datasets, and creates output files containing datasets of daily stream flows and the results of the various computations. DSS is the *DAY* default for managing data, but *DAY* includes optional features for converting files between DSS and other standard WRAP text file formats.

"*Appendix A Program Daily Flows (DAY)*" was added to the *Daily Manual* to document the new WRAP program *DAY*. The new routing parameter calibration methodology is covered in Chapter 4 of the *Daily Manual*.

The old program *DAY* has been renamed *Daily Hydrographs (DAYH)* and is documented in *Daily Manual* Appendix B. The new *DAY* was created from scratch and is very different than the old program but is designed to essentially replace the old program for most applications. The old *DAYH* (Appendix B) is retained in the WRAP package of computer programs since most of its features are not replicated in the new *DAY* (Appendix A) and vice versa.

A completely new methodology for estimating values for the daily lag and attenuation routing parameters has been developed and incorporated in the new program *DAY* (*Daily Manual* Chapter 4). The new routing parameter calibration methodology is based on identifying flow changes in daily flow records based on specified criteria, computing lag and attenuation for each flow change, and performing statistical frequency analyses of the resulting lag and attenuation datasets. The DSS-based data management methods incorporated in the new *DAY* are much more efficient and easier to use than the text files employed by the old program *DAYH*. The new program *DAY* incorporates statistical analysis capabilities as well as routines for defining flow changes and computing lag and attenuation.

Modifications between the July 2018 and May 2019 Versions

The May 2019 WRAP is documented by the following manuals.

Water Rights Analysis Package (WRAP) Modeling System Reference Manual, Texas Water Resources Institute (TWRI) Technical Report (TR) 455, 12th Edition, 464 pages, May 2019.

Water Rights Analysis Package (WRAP) Modeling System Users Manual, TWRI TR-256, 12th Edition, 270 pages, May 2019.

Fundamentals of Water Availability Modeling with WRAP, TWRI TR-283, 8th Edition, 116 pages, May 2019.

Water Rights Analysis Package (WRAP) Daily Modeling System, TWRI TR-430, 3rd Edition, 342 pages, May 2019.

Water Rights Analysis Package (WRAP) River System Hydrology, TWRI TR-431, Second Edition, 120 pages, August 2013. (*Hydrology Manual*)

Salinity Simulation with WRAP, TWRI TR-317, 87 pages, July 2009. (*Salinity Manual*)

The May 2019 editions of the manuals have been updated to reflect modifications to the computer programs *SIM*, *SIMD*, *TABLES*, and *WinWRAP*. The manuals have also been generally edited throughout for accuracy, clarity, conciseness, and completeness. HEC-DSS and HEC-DSSV have been fully integrated into WRAP. The examples in the *Fundamentals* and *Daily Manuals* have been revised. Input datasets for the examples in all of the manuals are included with the WRAP package of software and documentation.

WinWRAP Update (August 2013 – May 2019)

The latest version of *WinWRAP* prior to the May 2019 version is dated August 2013. The May 2019 *WinWRAP* reflects various updates. The lists of files include recently added files. The information menu now contains updated information. Obsolete features have been removed.

SIM and SIMD Additions and Improvements (July 2018 – May 2019)

All modifications to *SIM* are also incorporated in *SIMD*. Many daily modeling features of *SIMD* are not relevant to the monthly *SIM*. However, most of the new expanded *SIM/SIMD* improvements since July 2018, described as follows, are applicable to both monthly *SIM/SIMD* and daily *SIMD* simulations. Modifications to *SIMD* daily features are described later.

New Features of Multiple-Reservoir System Operating Rules

The latest version of the reservoir system operating rules are described on pages 139-149 of the May 2019 *Reference Manual* and pages 84-86 of the May 2019 *Users Manual*.

The upper and lower sub-pool options activated by *OR* record fields 8, 9, 10, and 11 are new features (*Users Manual* pages 84-85). Up to four conservation pool components can now be combined with three different strategies for ranking reservoirs for release decisions.

A new DSS output file feature created for tracking multiple-reservoir system operations is activated by DSS(2) in *OF* record field 3 (*Users Manual* pages 45-46 and *Reference Manual* page 149). For each system water right of interest, the following variables are recorded in the DSS file for each reservoir for each month of the simulation: reservoir releases in acre-feet, storage contents in acre-feet, storage contents as a percentage of capacity, and water surface elevation and drawdown in feet for reservoirs with *PV/PE* records. *HEC-DSSVue* can be employed to plot or tabulate these variables and perform other comparative analyses.

Recording of Targets for Individual Instream Flow Rights

This new feature is relevant only for two or more *IF* record instream flow rights located at the same control point. This new addition was motivated by previous constraints in separating SB3 environmental flow standards from other instream flow rights at the same control point and the inability to separate *PF* record pulse flow targets and *ES* record subsistence and base flow targets in the recording of *SIMD* simulation results. However, the new feature is generically applicable in *SIM* and *SIMD* modeling of all types of instream flow targets. *IF* record field 7 IFM(IF,2) options for combining two *IF* record targets at the same control point include adopting the (1) junior, (2) largest, or (3) smallest. Previously, only the final combined instream flow

target was included in the output file for each water right. A new variable, the individual pre-combined instream flow target, has been added to the *SIM* and *SIMD* simulation results output file. This new variable is labeled TIF on *Reference Manual* pages 173 and 179 and the list of output variables on page 47 of the *Users Manual*. The new *TABLES* 2TIF and 6TIF time series records are added for the individual water right target.

PF record pulse flows require an *ES* record even with addition of the new TIF individual water right target described in the preceding paragraph. A new option labeled PFES has been added for ESF in *ES* record field 2 (*Users Manual* page 75). The new PFES option was created to facilitate treating the *PF* record pulse flow component of an environmental flow standard as a separate *IF* record water right for output recording purposes. The environmental flow standards at a control point can now be modeled as a single *IF* record water right (as before) or divided into any number of *IF* record water rights.

Listing of Water Rights, Control Points, and Reservoirs in Output OUT File

The new DSS(1) option 2 in *OF* record field 2 activates a recently added routine to list water rights, control points, and reservoirs in the OUT file (*Users Manual* pages 45-46 and 245-246) without including the actual simulation results. The list of selected water rights includes water right and control point identifiers, annual target, priority, and group identifiers. The control point list includes the identifiers of each control point and its next downstream control point. The reservoir list includes reservoir identifiers, control points, and storage capacities. *SIM* input options control selection of water rights, control points, and reservoirs included in the OUT file. These lists provide general information that may be useful for various purposes. The new *TABLES* DSSM or DSSD record routines discussed later can read either form of *SIM* OUT file.

Type 8 Water Right Priorities

A water right with type option 8 specified in *WR* record field 6 computes a target which has no effect on the simulation unless the type 8 right is referenced by another water right. Water rights may include *TO* or *LO* records that reference another water right, including type 8 rights. Previous versions of *SIM* allowed referencing of any type 8 rights including those junior to the referencing right (with targets from the preceding month). An error check (execution termination and message) was added that requires that type 8 water rights be senior to the water right that connects to the type 8 right through *TO* or *LO* records.

New Feature Activated by DSS(7) in *OF* record field 8

The new input parameter DSS(7) in *OF* record field 8 activates an option that omits output records from the DSS file that contain zeros for all time periods. Other minor refinements were made in options controlling writing *SIMD* simulation results to the DSS output file.

Linear Interpolation Tracking Messages

SIM and *SIMD* include a variety of computations that call the same linear interpolation subroutine to interpolate *SV/SA*, *PV/SE*, or other tables. Warning messages generated by the linear interpolation routine were modified to a combination of warning and error messages, and a

tracking mechanism was added. The original messages lacked information regarding which computations and table caused the problem. The new tracking system allows warning and error messages to identify the computations and table that generated the interpolation problem.

Change of *SIM* Output SOU File Activation Parameter

The SOU output file activation parameter has been moved from DSS(2) on the *OF* record to SOUF in *JD* record field 7 (*Users Manual* page 39). SOUF options 1 and 2 refer to the sets of simulation results variables listed on page 47 of the *Users Manual*. Several other minor refinements to the *SIM/SIMD* output SOU file were also made.

Other Modifications Applicable to Both *SIM* and *SIMD*

Several old error and warning checks and messages have been revised. Several new error and warning checks have been added. DSS conventions have been refined for consistency in all of the WRAP programs.

Other Modifications Applicable Only to *SIMD*

The modifications common to both *SIM* and *SIMD* described in the preceding paragraphs consist of addition of new or expanded optional modeling capabilities. Performing monthly simulations with *SIM* with old versions of *SIM* is still fine as long as new optional features are not employed. However, modifications to the daily simulation components of *SIMD* also included several corrections to computational routines and changes in input parameters. Problems in the flood control and pulse flow routines were detected and corrected. Depending on options selected, some modifications can affect daily simulation results. Thus, for daily simulations, the May 2019 *SIMD* should replace all preceding developmental versions of *SIMD*.

SIMD previously always automatically created a daily output SUB file with each daily simulation. A SUB file is now created only if specified by the new parameter SUBFILE in *JT* record field 13. The default is to create only the DSS output file. DSS does not limit the size of the output file. However, without limiting selected output data, a SUB file may be created that is so large that *SIMD* execution is terminated. The modification deals with this issue by simply not creating a SUB file if the output dataset is extremely large or not relevant.

Hydrologic index sequences on *HI* records were previously automatically uniformly disaggregated from monthly to daily in a daily *SIMD* simulation. The *HI* record sequences are now by default not disaggregated. The new parameter DHMETHOD in *JU* record field 11 provides the option of uniformly disaggregating *HI* record sequences.

Flood control *FR*, *FF*, and *FQ* records include maximum flow rate limits. *FF* record flood flow limits previously were entered in acre-feet/year and *FR* and *FQ* flood control release limits were entered in acre-feet/day. These flow rates are now entered by default in units of cfs. The new not-cfs parameter NCFS in *JT* record field 15 allows these flows to optionally be entered in acre-feet/day or other units.

TABLES Additions and Improvements (July 2018 – May 2019)

The addition of routines for reading and analyzing data from a DDS file represents a major expansion of *TABLES* capabilities and WRAP modeling capabilities in general. The recent modifications to *TABLES* also include various other improvements.

Addition of Capabilities for Accessing and Analyzing Data from a DSS Input File

TABLES previously included options for recording time series output in a DSS file but had no capabilities for reading DSS files. New features were introduced in May 2019 *TABLES* that read essentially any daily, monthly, or annual time series data from any DSS file (*Users Manual* pages 190-191, 206, 236, 239-240). This includes all time variables in *SIM* and *SIMD* input and output DSS files and any other time series other variables. New *TABLES* input TIN file records noted in the following discussion include DSSM, DSSD, 2DSS, 6DSS, and 7DSS.

The recently created DSSM and DSSD record routines allow *TABLES* to read monthly or daily time series data from a DSS file which are stored by *TABLES* in computer memory as arrays. This time series arrays are employed by *TABLES*, similarly to *SIM* or *SIMD* simulation results read by *TABLES* from OUT or SUB files, in the following alternative ways (*Users Manual* pages 190-191, 205-206, 209-212, and 247-250).

- The DSSM record includes an option for writing the monthly time series dataset to the TOU file as a set of records in standard *SIM* hydrology input record format. For example, datasets of *IN* record naturalized flows and *EV* record evaporation-precipitation rates can be quickly and easily converted from a DSS file to FLO and EVA files (*Users Manual* pages 190-191).
- The DSSD record includes an option for creating daily time series tables in the TOU file in a format in which each row has 28, 29 (leap year February), 30, or 31 daily values.
- Entering 2DSS or 6DSS in field 1 of the time series records (*Users Manual* pages 205-206) activates an option in which the array created by a DSSM or DSSD record is treated in the same manner as if the data series had been read from a *SIM/SIMD* output OUT or SUB file.
- Variable ID option 16 in 2FRE, 2FRQ, 6FRE, 6FRQ record field 2 reads the array created by a DSSM or DSSD record and performs frequency analyses in the same manner as if the data series had been read from an OUT or SUB file (*Users Manual* pages 213-216).
- ID option 5 in 2REL and 6REL record field 4 reads the array created by a DSSM or DSSD record and performs reliability analyses in the same manner as if the data series had been read from a *SIM* or *SIMD* output OUT or SUB file (*Users Manual* pages 209-212).

The new 7DSS file described on pages 239-240 of the *Users Manual* reads any annual series data from any DSS file for purposes of performing statistical frequency analyses based on the log-Pearson type III or log-normal probability distribution functions and relative frequency formulas. Several examples of the many annual times series variables that are relevant for 7DSS record analyses include minimum 7-day, 15-day, or any period stream flow volumes in each year, peak daily flood flows in each year, minimum or maximum daily or monthly reservoir storage volumes in each year, minimum or maximum monthly precipitation or evaporation depths in each year, or total annual volumes, depths, or mean flow rates of any variable.

OUT/SUB text-format output files are over-written with each execution of *SIM/SIMD* and thus can contain simulation results for only one simulation. DSS allows results for any number of *SIM/SIMD* simulations or from any other source to be recorded in the same DSS file for convenient comparative analyses. Results for alternative simulations and/or other data may be with-versus-without a particular component of interest can be easily compared or combined. Thus, the new *TABLES* feature allows concurrent access to results from multiple simulations.

Other Additions to *TABLES*

2TIF and 6TIF time series records (*Users Manual* pages 206-207) are added to allow the individual water right targets to be recorded in the *SIM* and *SIMD* simulation results for two or more *IF* record water rights at the same control point as noted earlier in this progress report.

The Weibull formula [$P=(m/(N+1))100\%$] has been added as METHOD 4 activated in field 6 of the 2FRE, 2FRQ, 6FRE, and 6FRQ records (*Users Manual* pages 213-216).

Recent *TABLES* modifications also include other minor refinements in various new and refined error and warning checks, table headings, and organization of data management. For example, the term OUT is now appended to the root of the *TABLES* output DSS file to differentiate between input and output DSS files with the same filename root. DSS conventions have been revised for consistency throughout the programs.

HYD Additions and Improvements (July 2018 – May 2019)

HydSeries (hydrologic series) described in the new Chapter 2 of the May 2019 *Hydrology Manual* is a new "subprogram" of the WRAP program *HYD* that can be used either in combination with or independently of the other *HYD* capabilities covered in Chapters 3 through 8 of the *Hydrology Manual*. *HydSeries* is controlled by a new *HS* record inserted in the *HYD* input HIN file along with one or more time series identifier *SI* records. *HydSeries* is designed primarily to be used with *HEC-DSSVue* and other components of *HYD* to develop monthly hydrology input datasets for the simulation model *SIM*. *HydSeries* and *HEC-DSSVue* can also be applied with *TABLES* in the analysis of *SIM* simulation results.

HydSeries reads a dataset consisting of any number of time series data sequences covering each month of a period-of-analysis covering any number of years. The monthly time series can be essentially any variable (observed flows, naturalized flows, any of the *SIM* simulation results variables, precipitation, evaporation, net evaporation less precipitation, etc.). The following time series data management and analysis capabilities are provided by *HydSeries*.

- Conversions between file formats.
- Efficient access to TWDB quadrangle precipitation and evaporation databases.
- Computation of annual series from the daily monthly series that may be annual totals or means or minima or maxima of monthly moving averages in each year.
- Linear regression trend analysis.
- Computation of basic statistics.

Modifications between the May 2019 and September 2019 Versions of SIM and SIMD

The only modifications to *SIM* and *SIMD* between the May 2019 and September 2019 versions are refinements to the routine controlled by the hydrologic condition *HC* record, which is the same in both *SIM* and *SIMD*. The modifications are applicable only to *HC* record field 4 HCV(wr) options RF, RR, NF, and ST. An error in which the reservoir storage for the HCV option ST was always zero was corrected. The routine for summing flows at multiple control points for HCV options RF, RR, and NF and storage for option ST was improved.

Modifications between the September 2019 and January 2021 Versions of SIM and SIMD

The January 2021 versions of *SIM* and *SIMD* replace the September 2019 versions described in the May 2019 *Reference, Users, and Daily Manuals*. The revisions described in numbered paragraphs 3 and 4 on the next page may affect *SIM* simulation results if the new features controlled by the environmental standards *ES* record added in the May 2019 versions of *SIM* and *SIMD* are employed. A problem with a seldom if ever used option in the use priority adjustment *UP* record noted in numbered paragraph 2 also affects both *SIM* and *SIMD* results. For a *SIM* input dataset without *ES* or *UP* records, the revisions described here will not affect simulation results if the *SIM* input dataset is perfectly correct with no blunders or irregularities. However, errors in *SIM* input datasets may be easier to detect and correct pursuant to these revisions, in some cases perhaps much easier. In addition to those revisions noted in this paragraph, several of the other revisions described in the numbered following paragraphs affect *SIMD* simulation results and also make *SIMD* easier to apply.

Revisions to the WRAP *Users Manual* are described later in this section. The revisions affect *SIM* input data in the DAT file only if the ESAF option in *ES* record field 16 (revision paragraph 4 on the next page) or if certain options are selected in *RO* record field 2 (paragraph 5). *SIMD C2, C3, W2, G2, and R2* input records have been removed as discussed in revision paragraph 7 below. New options have been added to the *SIMD JT* and *JU* records. The *Reference* and *Daily Manuals* have also been updated and edited.

New error and warning checks and messages and trace messages were added and existing checks and messages revised in conjunction with the revisions summarized in the following paragraphs. Other checks and message refinements are independent of these *SIM* and *SIMD* revisions. Most of the revisions to error, warning, and trace messages are reflected only in *SIMD*, but some are also included in *SIM*.

Revisions to Both SIM and SIMD

1. A linear interpolation subroutine is called at many different places in the *SIM* and *SIMD* simulation computations to interpolate *SV/SA, PV/PE, and TE/TQ* record tables. *SIMD* also uses this subroutine to interpolate *FV/FQ* record quantities. Many interpolations are performed for each water right in each month of a *SIM* or each day of a *SIMD* simulation. If the maximum value in a table is exceeded by more than 1.0 percent in an interpolation, the simulation is terminated with an error message that includes replication of the table being interpolated. Warning messages result from smaller exceedances. Switching from ICHECK option 1 to option 9 deactivates the error check (which terminates execution) allowing

warning messages all exceedances of the interpolated table. It was discovered that irregularities in input datasets not directly related to the input table identified in the interpolation error or warning message could terminate program execution and generate a misleading interpolation error message. The problem was caused by complexities in storing quantities from multiple arrays in the same computer memory. This problem was corrected similarly in both *SIM* and *SIMD* by revising the strategy for organizing and storing *SV/SA*, *PV/PE*, *TE/TQ*, and *FV/FQ* record arrays in computer memory. Error and warning messages associated with the linear interpolation issues have also been refined.

2. The USEFAC option in use priority adjustment *UP* record field 6 did not function. This has been corrected in the January 2021 versions of both *SIM* and *SIMD*.
3. Environmental flow standards (EFS) may be specified by environmental standard *ES* and hydrologic condition *HC* records introduced in the May 2019 versions of *SIM* and *SIMD*. Subsistence (SUBS or SF50), base (BASE), and high (HAnn & HSnn) flow components of EFS are specified by ESF(wr,es) in *ES* record field 2. Option SUBS components of EFS instream flow targets were computed incorrectly in some cases replicating the SF50 option. The problem is corrected in the January 2021 versions of *SIM* and *SIMD*.
4. By default, the ESQ minimum instream flow limits are entered in *ES* record fields 4 through 15 in units of cubic feet per second. *ES* record field 16 originally contained a parameter ESAF(ws,es) that allowed the ESQ limits to be entered in acre-feet rather than cfs. ESAF(ws,es) has been removed from the *ES* record and replaced with the new ESAF added to *SIM* as *JD* record field 14. NCFS in *JT* record field 15 serves the same purpose in *SIMD* but applies to *PF*, *FF*, *FR*, and *FQ* records, not included in *SIM*, as well as *ES* records included in both *SIM* and *SIMD*. Replacement of *ES* record ESAF(ws,es) with *JD* record ESAF means that the default units of cfs can still be replaced with the option of acre-feet, but the choice of units must be applied consistently to all *ES* records.
5. The revisions described in the following paragraph 6 deal with revising the system for selecting control points, water rights, and reservoirs for which to include simulation results in output files. Most of these revisions involve only *SIMD*. Options controlling output of *SIMD* daily and aggregated monthly simulation results are integrated into options controlling output of *SIM* monthly simulation results. However, revisions to options controlled by reservoir output *RO* records affect selection of *SIM* as well as *SIMD* simulation results.

Revisions Applicable Only to *SIMD*

6. The framework of options for selecting control points, water rights, and reservoirs for which to include simulation results in the *SIMD* OUT, SUB, CRM, AFF, and DSS output files was revised as follows. The *C2*, *C3*, *W2*, *G2*, and *R2* input records have been removed in the January 2021 *SIMD*. Likewise, parameters OUTCP2 and OUTWR2 are removed from the *JT* record. *JT* record AFF options have also been simplified. Previously, separate computer routines implemented output selections of control points, water rights, and reservoirs for daily and aggregated monthly results from a daily simulation versus monthly results from a monthly simulation. The *CO*, *WO*, *GO*, and *RO* records were previously applicable to essentially only *SIM* monthly simulations results. The *CO*, *WO*, *GO*, and *RO* records now

control daily and monthly *SIMD* simulation results as well as monthly *SIM* results. *JT* record OUTCP2 option 5 and OUTWR2 option 6 have been added to the *JD* record OUTCP and OUTWR options. The output file options controlled by the *OF* record are still fully functional for both *SIM* and *SIMD* simulation results. No flexibility is lost by these changes. The objective was to simplify the selection of simulation results to be included in the *SIMD* output files. Several nonfunctional combinations of output options were also corrected.

7. The pulse flow component of EFS instream flow targets are defined in *SIMD* by *PF* records. Negative incremental flow options for *SIM* and *SIMD* are selected with NEGINC in *JD* record field 10. Pulse flow targets were incorrectly computed with NEGINC option 4. With NEGINC option 4 selected, *PF* record components of EFS instream flow targets were computed treating negative incremental flows in the same manner as NEGINC option 3. This has been corrected.
8. The new input parameter NORT (no *RT* record routing) has been added as the new field 9 of the *JU* record. Routing is activated by inclusion of *RT* records in the daily input DIF file. Simulation studies may include alternative simulations with versus without routing. This was previously achieved by inserting and or not inserting (removing) the set of *RT* records. With activation of the new NORT option, the *RT* records are automatically skipped over in reading the DIF file. The NORT option also skips over unnecessary computations in the simulation resulting in improved computational efficiency than achieved by the absence of *RT* records in the DIF file.
9. The message MSS file shared by *SIM* and *SIMD* includes counts of system components counted from the input data. Although tabulation of these counts has been refined slightly for *SIM*, the following revisions deal almost entirely with counts associated only with *SIMD*. These refinements affect only the information presented in the message MSS file, with no effects on actual simulation results. The counts for *FS* records previously included *CV*, *FR*, and *FF* as well as *FS* records, though labeled incorrectly in the MSS file count tabulation as "total flow switches (*FS* records)". Counts of the total numbers of *FR* records and *FF* records have been added both to the computations and the MSS file count tabulations. Several computational loops are now a little more efficient, but simulation results other than MSS file counts are not affected.
10. Target options *TO* record field 2 TOTARGET option -7 did not update the daily target for the month of December. This *SIMD* problem has been corrected.
11. DHMETHOD in *JU* record field 11 specifies whether or not *HI* record hydrologic series are disaggregated. The default is no disaggregation. An entry of 9 specifies uniform monthly-to-daily disaggregation. However, the default no disaggregation occurred even if 9 was entered in *JU* record field 11. This *SIMD* problem has been corrected.
12. *DF* record daily flows by default (DFFILE=0,1) are read from the hydrology DSS input file. DFFILE option 2 in *JU* record field 3 allows the *DF* record daily flows to be read in text format from the DIF file. DFFILE option 2 was not working but has now been corrected. DFFILE option 1, meaning reading *DF* record daily flows from a DSS file, is the much preferred recommended option.

Revisions to the WRAP Manuals

The January 2021 *WRAP Users Manual* contains a variety of editorial corrections and clarifications and additional explanations that are not listed here. The revisions that directly change entries on input records are listed as follows.

- OUTCP option 5 and OUTWR option 7 have been added to the *JD* record fields 5 and 6 on page 39.
- The new input parameter ESAF has been added as *JD* record field 14 on page 40.
- Parameter NROUT has been renamed RESOUT and the options have been slightly revised in *RO* record field 2 on page 49.
- ESAF in *ES* record field 16 on page 75 has been removed.
- The new input parameter NORT has been added as *JU* record field 9 on page 143.
- The old parameters OUTCP2 and OUTWR2 in fields 2 and 3 of the *JT* record on page 139 have been removed. The old OUTCP2 option 5 has been added to OUTCP and the old OUTWR2 option 7 have been added to OUTWR in *JD* record fields 5 and 6 on page 39.
- The *C2*, *W2*, *G2*, *R2*, and *C3* records on the old pages 147-148 have been removed. This causes the page numbers to change for the remainder of the manual.

The January 2021 *Daily Manual* and *Reference Manual* have been updated to reflect the revisions to *SIM* and *SIMD*. Editorial updates and clarifications are scattered through these manuals.