Documentation of StateFate

(Estimate the Fate of Surface Water Return and Drain Flows)

FINAL

To: File

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Subject: RGDSS Ground Water – Documentation of **StateFate**, a pre processing program used to develop Surface Water Return and Drain use data for **StateCU** and summarize deep percolation for **StatePP**

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StateFate (Fate of Surface Water Returns and Drain Flows) is a preprocessor which routes water between **StateCU** and **StatePP**. It handles the complex task of routing drain flows and tail water that are potential surface water sources for some ditches. It also provides the interface between the **StateCU** program which performs the consumptive use calculations and the **StatePP** preprocessor that distributes the **StateCU** data to model cells in the **MODFLOW** model. **StateFate** was developed from the **ModFate** preprocessor that was initially developed as part of RGDSS Phase 4. This document includes the following sections:

0.0 Disclaimer

1.0 Acknowledgment

Ray R. Bennett P.E. of the Colorado Division of Water Resources developed the ModFate program as part of the Rio Grande Decision Support System. Willem A Schreüder of Principia Mathematica developed the **StateFate** program using funding provided by the Colorado Division of Water Resources and the Rio Grande Water Conservation District. Algorithms implemented in **StateFate** were developed by Jim Slattery, Jim Brannon and James Heath.

2.0 Introduction

The **StateFate** program is a preprocessor to **StateCU** and **StatePP**. The initial version of **StateFate** was called **ModFate**. During RGDSS Phase 4 **ModFate** was developed to route drain flows calculated by the groundwater model and tail water calculated by **StateCU** to other ditches if it served as a source of surface water to another ditch, to streams where the returns contribute to the flow in surface streams, or to deep percolation where the flows serve as recharge. The data used to route these flows were obtained from interviews with water commissioners as part of the data collection efforts in RGDSS Phase 4 and subsequent interviews with water commissioners and ditch company representatives completed in RGDSS Phase 6.

During RGDSS Phase 6, the program was enhanced in order to accommodate refinements to the data processing and to streamline the flow of information. The program was renamed **StateFate** to signify this change.

In order to allow finer grained access to the calculations from **StateCU**, the **StateCU** program was enhanced by Jim Brannon to save the results in the **4WB** format. This file format provides finer details of the values summarized in the **DWB** (Ditch Water Budget) file. In particular, spray losses, deep percolation resulting from the application of surface and groundwater and surface water applied to recharge are quantified separately in the **4WB** file.

The **StateFate** program reads the **4WB** file written by **StateCU** and the **DRN** file written by the **mksum** postprocessor to **MODFLOW** to determine how much surface water needs to be routed. Based on the routing information, the program then determines the fate of that water. The output is written to the **Xdi** file where it is routed to another ditch, or the **Xdr** file if it is routed to a drain, the **Xst** file if it is routed to a surface stream, or the **Xgw** if it is recharged to groundwater.

In order to determine how the additional surface supplies change the consumptive use calculations, **StateCU** is rerun using the **Xdi** file as input. This, of course, changes the output of **StateCU**. Therefore **StateCU** and **StateFate** are run iteratively until the results converge.

The **Xst** (returns to streams) and **Xdr** (returns to drains) are then used as inputs to build the stream network for the groundwater model. The **Xgw** (returns to groundwater) is used by **StatePP** to compute groundwater recharge.

The **StateFate** program also summarizes the **StateCU** results in a format that is expedient for **StatePP** to use. In particular, in the **StateCU** calculations, spray losses are lumped in with deep percolation as water that does not go to satisfy the crop consumptive use. From the **StatePP** perspective, spray losses are lumped in with consumptive use as water that enters the atmosphere and does not return to the groundwater flow system. **StateFate** therefore produces the **Xpp** file which summarizes the components of the **StateCU** budget as needed by **StatePP**. Specifically **StateFate** summarizes total groundwater pumping, deep percolation resulting from ditch losses, surface water applied to recharge, surface water applied to irrigation, and groundwater applied to irrigation. The **Xpp** file also contains the net consumption of surface water and groundwater which is used in evaluating the recharge decrees. Finally, the **Xpp** file lists the maximum potential subirrigation for meadow, alfalfa and other crops, which are the shortages calculated in **StateCU**.

StatePP uses the **StateFate** output to produce input files to **MODFLOW**. The **MODFLOW** program is used with **PEST** to calibrate aquifer parameters and in turn provide new drain flow predictions. These drain flow predictions are then used as inputs to **StateFate**. Fortunately, the drain flow predictions depend only weakly on this feedback loop, so that the drain flows predicted by a previous **MODFLOW** iteration provides an adequate input data set for the current iteration as part of the iterative procedure which is used to calibrate the groundwater model.

In this memorandum, for consistency between sections, "pumping" is used to describe groundwater withdrawals whether the withdrawal is by a mechanical pump or if the well flows under artesian pressure.

3.0 Program Description

The program **StateFate** is a preprocessor to **StateCU** and **StatePP**. Since **StatePP** requires that the user provide data for the study period, **StateFate** always produces monthly data for the same period as the StateCU data.

StateFate was written in Perl because it provides convenient data structures called hashes which are essentially arrays indexed using strings. This makes it easy to merge data from multiple files. The data from each file is read into a hash. During the processing phase, the data is then referenced using the WDID and year. The Perl code was compiled into an executable for ease of use in a Windows environment.

StateFate performs the following functions:

- Determines the files to process from parameters supplied on the command line or passed via a batch file.
- Reads the spray loss fraction for every ditch and year from the spray loss file. This file is typically named *.los.
- Reads a data file that describes the fate of water that originated from a surface water return or drain flow. This file is maintained as an Excel spreadsheet and saved as a CSV file for use by **StateFate**. The routing is further described in Section 3.2.
- Reads drain flows calculated by **mksum** from the **MODFLOW** output for each of the drains that has flow that are used in **StateCU**.
- Optionally reads subirrigation calculated from the **MODFLOW** output. This is an experimental feature in **StateFate** that is not currently used.
- Reads **StateCU** outputs from the **4WB** file.

- Performs the calculations described in Section 3.1.
- Writes the groundwater components to the *.Xpp file.
- Applies routing to the surface water.
- Writes water that is tailwater that accumulates down-ditch to another ditch to the .Xdi file.
- Writes water that returns to a stream to the .Xst file.
- Writes water that returns to a drain to the .Xdr file.
- Writes water that returns to the groundwater system to the .Xgw file.
- **StateFate** provides no output to the screen other than warnings or error messages.

Table 1 describes the input files used by the program. The files are specified on the **StateFate** command line.

Table 1
Input File Descriptions

#	File Description
1	Spray loss file (*.los) contains spray loss by ditch and year
2	Fate data (*.csv) contains flow routing information
3	Drain file (*.drn) contains monthly drain flows from MODFLOW
4	File root of subirrigation contains optional monthly subirrigation amounts. An extension of .sub1, .sub2 and .sub3 is automatically added. Specify "–" in this position to omit reading these files.
5	4WB file root. The extension .4wb will be added to read StateCU output. Output files will use this as the file root also.

Table 2 describes the output files.

The **StateFate** program does not produce a log file of calculations. The only outputs to the screen are warnings and error messages. All output files use the same file root as the 4WB file, but adds a new file extension, and saves them to the folder that contains the **StateFate** executable.

Table 2
Output File Descriptions

#	Extension	File Description	Target Program
1	**.Xdi**	Flows going to another ditch	StateCU
2	**.Xdr**	Flows going to a drain	Stream Package
3	**.Xst**	Flows returning to a surface stream	Stream Package
4	**.Xgw**	Flows returning to groundwater	StatePP
5	**.Xpp**	Budget inputs to StatePP	StatePP

3.1 Description of Calculations

StateFate reads the following values for every ditch and every month from the **4WB** file:

- Flood and sprinkler acreage using only surface water, or surface and groundwater;
- Diversions from the river;
- Diverted amount after canal losses;
- Surface water applied to recharge;
- Total surface water not consumed;
- Farm headgate deliveries by sprinkler/flood and surface/groundwater lands;
- Surface water CU by sprinkler/flood and surface/groundwater lands;
- Groundwater pumping by sprinkler/flood lands;
- Groundwater not consumed by sprinkler/flood lands;
- Change in soil moisture on groundwater lands;

StateFate then perform the following calculations:

- Ditch loss is the difference in diversions before and after canal losses;
- Surface water for recharge is subtracted from total surface water not consumed;
- The remaining surface water not consumed and change in soil moisture is partitioned to surface/groundwater and flood/sprinkler lands proportional to the difference between surface water applied and surface water consumed.
- Decrease/increase in soil moisture on lands irrigated by groundwater is added to groundwater applied/groundwater not consumed proportional to flood/sprinkler acreage.
- If applied water is less than what was not consumed, set it not consumed equal to applied water for each flood/sprinkler/surface/groundwater lands.
- The application rate for flood irrigated land is calculated for surface/groundwater irrigated lands.
- Runoff is calculated using the Helton and Williamsen formula:
  Runoff Fraction = 0.1*Rate, for application rates less than 1 foot per acre;
  0.5-0.4/Rate, for higher application rates;
- Runoff is calculated as surface/groundwater applied multiplied by the runoff fraction for surface/groundwater irrigated lands;
- Runoff is limited to no more than the amount not consumed;
- Spray loss is the specified fraction of application;
- Recharge is calculated as amount not consumed minus spray loss and runoff;
- Pumping is total pumping on flood/sprinkler land;
- Surface irrigation return flow is summed over flood/sprinkler and surface/groundwater land;
- Groundwater irrigation return flow is summed over flood/sprinkler land;
- Runoff and spray loss is summed over all lands;
- Net surface water use and net groundwater use is calculated as applied water minus groundwater recharge.

The results of the calculations are saved to the output files as described in Section 5.

3.2 Description of Routing

The routing performed as described in the routing input file. This file is maintained as an Excel spreadsheet which is then exported as a CSV file to be read by **StateFate**. The flows to be routed are the runoff calculated as described in Section 3.1 or flows read from the drain flow file.

The routing can be specified for a specific ditch by specifying the source WDID, the fate type and a fraction. The fate type must be **River**, **Ditch**, **Drain**, **Groundwater** or **Loss**. Multiple lines listing a fraction to each fate type may occur, but the fraction of each fate type for a given source must sum to 100%. If not, **StateFate** will abort with an error message.

If the fate type is **Loss**, the water is removed from the surface and groundwater systems. The water is assumed to be lost to evaporation or transpiration.

If the fate type is **Groundwater**, the water must be recharged to groundwater, and is written to the **Xgw** file.

If the fate type is **Drain**, the water returns to a drain. The input file must contain the name of a drain to which the water returns. The volume and drain are written to the **Xdr** file.

If the fate type is **Ditch**, the water returns to another ditch at a point below its measuring device. The input file must contain the name of the ditch to which the water returns. The volume and ditch are written to the **Xdi** file.

If the fate type is **Stream**, the water returns to a stream. The input file must contain the name of the stream to which the water returns, the word above or below and a WDID or gage name, indicating that the water returns to the stream **Above** or **Below** the identified location. The volume, stream and location are written to the **Xst** file.

In addition to routing information for specific source WDIDs, the user should also specify a default set of routing information for every water district as the water district number followed by an asterisk. This will be used to route runoff from ditches not specifically named in the routing file.

The drain flows calculated by the groundwater model using the monthly transient model run starts in 1970. However the study period and hence the **StateCU** calculations start in 1950. For the years 1950-1969, monthly volumes of drain flows should be estimated. These monthly values should be specified as lines in the routing file starting with an asterisk, the drain name and a set of 12 monthly values to use for the period 1950-1969.

4.0 Input File Description

Several input files are required to run **StateFate** (see **Table 1**, above). Comments may be contained to separate different sections of each file if indicated by a '#' in column 1. Following is a description of each.

4.1 Spray Loss File

The spray loss file (*.los) contains the spray loss as a fraction by ditch for every year. Each line represents a year and ditch. The order in which the years and WDIDs are specified are not important.

4.2 Fate Routing Data

The fate file is a comma separated values (CSV) file that is exported from an Excel spreadsheet. The routing is described in Section 3.2 above. Lines in the file that are not comments (i.e. does not start with a #) contain the following fields:

1. **Sequence number:** This number is not used in the processing, but a sequence number of * is used to identify monthly drain flow values to be used for the period 1950-1969.
2. **Source ID:** This is the seven digit WDID of the source of the water to be routed. A WDID may use a wildcard. For example, a WDID of 35* would apply to any source of water in water district 35 that is does not have a routing entry for that particular WDID.
3. **Source Name**: Name of the source ID. This field is provided for readability and is not used in processing.
4. **Fate Type:** Must be *Groundwater*, *River*, *Ditch*, *Drain* or *Loss*. These key words are not case sensitive.
5. **Fate %:** Fraction of the water to route to this fate as a percentage. When there are multiple fates, each entry will be a separate line in the file. The percentages must sum to 100.
6. **Destination:** When the fate is *loss* or *groundwater*, this field is ignored. If the fate is *ditch*, this field must specify the WDID of the destination ditch. If the fate is *drain*, this field must be the name of the destination drain. If the fate is *river*, this field must be the name of a stream in the stream package. In addition for a fate of *river*, the stream name must be followed by a field containing *above/below* followed by a WDID or gage name above or below where the water should be added to the stream.
7. The remainder of the fields on the line are generally ignored, but are typically used to record the name of the destination ditch and the source of the routing information.

The **StateFate** program does not validate the target streams or ditches. Invalid entries will be flagged in subsequent processing.

The order in which lines appear in the file are not important. When water from one source goes to multiple fates, these lines do not have to be contiguous, although doing so improves readability.

Line listing the drain flows for the years 1950-1969 have the following format:

1. Must be a * to designate the drain data

2. Name of the drain
3. Drain flow for January in acre-feet
4. Drain flow for February in acre-feet
5. Drain flow for March in acre-feet
6. Drain flow for April in acre-feet
7. Drain flow for May in acre-feet
8. Drain flow for June in acre-feet
9. Drain flow for July in acre-feet
10. Drain flow for August in acre-feet
11. Drain flow for September in acre-feet
12. Drain flow for October in acre-feet
13. Drain flow for November in acre-feet
14. Drain flow for December in acre-feet

The annual total may be included at the end of the line, but will not be processed..

4.3 Drain Flow File

The drain flow file contains stream and drain flow data by month for every drain for which the outflow must be rerouted. This file is created by **mksum**, a postprocessor to **MODFLOW** which is used to summarize the stream flows simulated by the groundwater model. The file format is the standard stream flow format used by **StateMod** and other CDSS tools.

4.4 Subirrigation Files

StateFate provides for the possibility to adjust the potential subirrigation quantities specified in the 4WB file. If a subirrigation file is specified, StateFate will read a monthly subirrigation adjustment in acre-feet for each ditch from the specified file.

A separate subirrigation file must be provided for each of the subirrigation types. The root is specified on the command line, and StateFate will append *-subX.stm* to that file root where X=1 represents meadow, X=2 represents alfalfa and X=3 represents other types of subirrigation. The file format is the standard STM file format used by the CDSS.

The subirrigation adjustment is optional. When a hyphen ("-") is specified as the file root, no subirrigation adjustment is read.

No subirrigation adjustment was made during Phase 6 of the RGDSS.

4.5 Detailed Water Budget Report by Land Category (*.4WB) File

The detailed water budget by land category (*.4WB) file contains detailed water budget information for each structure for each month within the study period. This file is created by **StateCU**, a preprocessor to **StatePP** and **MODFLOW**. Only the specific data from this file are utilized as described in Section 3.1 above.

5.0 Output file description

StateFate produces five output files (see **Table 2**, above). The output files for flows routed to ditches, drains, streams and groundwater all have the same standard CDSS format, except that the files contain the source of the water as a comment at the end of each line. The **Xpp** flow summary output file has a unique format.

The file name for the output files are determined by the **4WB** input file name. The file root is reused and the appropriate extension (.Xdi, .Xdr, .Xst, .Xgw or .Xpp) is appended.

5.1 .Xdi Ditch output file.

The ditch output file lists the flow to be added to a ditch as an available surface water supply not included in the historical diversion records. The file is in the standard CDSS stream flow file format, except that for informational purposes the source of the water is also shown. The ditch receiving the flow is listed as the second field on each line. The source from which the water is derived is shown in the last field on each line.

Note that a ditch may receive water from multiple sources, which will cause there to be multiple lines for a given year and ditch.

5.2 .Xdr Drain output file.

The format of the drain output file is identical to the ditch output file. The receiving structure is the name of a drain instead of a WDID because this information is used to build the stream package.

5.3 ,Xgw Groundwater output file.

The format of the groundwater output file is the same as the ditch output file. Note that in many instances, the destination and source WDIDs are the same. This is because when there is a return to groundwater, the return is mapped over the ditch service area of the ditch that is the source. Also note that in many instances, the source is a wildcard such as 20*. In these instances, the destination is actually the source, but there was no specific rule in the fate file that matched that particular ditch. Therefore the default (wildcard) rule was applied by **StateFate**.

5.4 .Xst Stream output file.

The format of the stream output file is identical to the ditch output file. Note however that the receiving structure is a specific location on a stream. This is designated as a four letter abbreviation of the stream (Alam for Alamosa, Cone for Conejos, LaJa for La Jara Creek, etc) followed by a plus or minus sign and a WDID or gage name. The plus or minus sign designates the location as above (+) or below (-) the WDID or gage. The flow is added to the stream at that location.

5.5 .Xpp Budget output file

The budget output file format is unique. Each line contains the budget values for a specific ditch for a specific month. All volumes are in acre-feet for that month. The fields contain the following values:

1. WDID of the structure;
2. Year;
3. Month;
4. Ditch loss in acre-feet;
5. Gross irrigation pumping;
6. Surface water applied to recharge;
7. Recharge from surface water application;
8. Recharge from groundwater irrigation;
9. Runoff;
10. Spray loss;
11. Net use of surface water;
12. Net use of groundwater;
13. Maximum potential subirrigation for meadow lands;
14. Maximum potential subirrigation for alfalfa lands;
15. Maximum potential subirrigation for other lands.

The runoff and spray loss values are not used by any subsequent program and are for informational purposes only. The net use of surface water and groundwater represents the net water use including consumptive use, runoff and spray losses. The net use values are used by the **mkrc** program to calculate the amount of pumping and recharge that would match the consumption permitted under the recharge decrees.

6.0 Comments

Following are comments associated with **StateFate.**

- **StateFate** greatly assists in preparing data for any study period.
- **StateFate** is specific to the RGDSS as it deals with the unique routing challenges of the San Luis Valley.

7.0 References

Ray R. Bennett *Documentation of ModFate* April 22, 2004.