II.4-RES-SNGL SINGLE RESERVOIR REGULATION OPERATION

Introduction

The Single Reservoir Regulation Operation allows for the simulation of a single independently operated reservoir. It was developed as a means for forecasting releases from a reservoir when the user is not provided with future releases from the operating agency.

In the real world of reservoir regulation a single independently operated reservoir is rare. Operation of systems of reservoirs for optimization of objectives (such as flood control or power generation) is more common.

The input for this Operation consists of:

- Operation components
- Reservoir Control Language (RCL)

Operation Components

The Operation allows the user to select the components needed for simulation. The components are known as Schemes and Utilities.

A Scheme is an algorithmized operating rule that will generate outputs (discharge, pool elevation and storage contents).

A Utility is a simulation aid that does not compute output variables.

The following list describes the Schemes and Utilities.

Schemes:

1. Fill and spill (FILLSPILL) - no discharge occurs until the pool elevation reaches a specified level - the inflow is passed until maximum discharge is reached and outing occurs at that point

2. Flash board control (FLASHBDS) - a type of uncontrolled gated spillway - flash boards provide additional storage until elevation tops the boards and the boards flip - requires new routing regulations as additional boards flip

3. Induced surcharge (INDSRCHGE) - used during flood situations this operation mode provides additional storage above normal top of pool level

4. Discharge minimization (MINQ) - a release is determined to try to prevent flooding at a downstream location by using forecasted inflows (non-iterative solution)

5. Inflow passage (PASSFLOW) - none of the inflow volume is retained thereby maintaining the pool elevation

6. Power generation (POWERGEN) - the generation (turbine) discharge is computed as influenced by various conditions including inflow, rule curve, minimum discharge requirement, diurnal and weekly fluctuations in generation schedules and maximum generation discharge among others - not to be accounted for are forecasted weather conditions and power pool activities

7. Pool elevation controlled discharge (POOLQ) - release is controlled solely by the pool elevation

8. Rule curve (RULECURVE) - the pool elevation is specified by a table of elevations for each day of the year and discharge is computed based on the designated elevation

9. Daily rate of change of pool elevation (SETDH) - ramp up pool elevation or to ramp down pool elevation or to put a limit on the maximum rate of change pool elevation

10. Daily rate of change of reservoir release (SETDQ) - ramp up reservoir release or to ramp down reservoir release or to put a limit on the maximum rate of change of reservoir release

11. Prescribed elevation (SETH) - the elevation for the time period is specified and the discharge is computed

12. Prescribed discharge (SETQ) - the discharge from the reservoir for the time period is known beforehand and the pool elevation is the only computed quantity

13. Uncontrolled spillway (SPILLWAY) - no discharge occurs until the pool elevation reaches a specified level - all spilled inflow is then routed

14. Stage and pool elevation controlled discharge (STPOOLQ) - the reservoir release is controlled by the stage at a downstream point and the current pool elevation

Utilities:

1. Adjust model results (ADJUST) - modify simulated values using observed values to create an adjusted value

2. Back-computed inflow (BACKFLOW) - utilize observed pool elevations and discharges to adjust simulated inflow

3. Entry into induced surcharge (ENTERISC) - check to see if induced surcharge Scheme is to be used

4. Entry into flashboard Scheme (GOFLASH) - check to see if flashboard Scheme is to be used

5. Maximum dam outflow (MAXQ) - determine maximum possible discharge at a given pool elevation

6. Rainfall/evaporation on reservoir (RAINEVAP) - add influence of meteorological inputs to changes in pool elevations

7. Rule curve adjustment (RULEADJ) - determine the amount of deviation the operator keeps the pool from elevation specified by the rule curve

8. Set minimum element (SETMIN) - use minimum value of already computed outputs

9. Set maximum element (SETMAX) - use maximum value of already computed outputs

10. Inflow summation (SUMINF) - sum inflows over a specified time interval - for use in power generation and minimize discharge Schemes

Reservoir Control Language

Operation RES-SNGL can be used to duplicate the operating plans of a reservoir.

Operating plans are instructions linked together and triggered by logical checks on hydrologic and other conditions. The instructions are carried out by the Schemes.

The links and checks are provided by the Reservoir Control Language (RCL). The RCL consists of IF blocks for making conditional checks and DO statements for specifying enactment of the Schemes.

A description of the RCL is in Chapter II.4-RES-SNGL-RCL.

Application of Single Reservoir Operation

Although Operation RES-SNGL provides the capabilities for complete simulation of a reservoir's regulation the Schemes prescribed discharge and prescribed elevation expect reservoir behavior to be known beforehand particularly when values are given in an observed time series. In this case the Operation is not truly simulating the reservoir's operation but in essence is monitoring a known mode of operation. In the case of prescribed discharge (with the discharge values provided via time series with no missing values) unless a pool elevation graph needs to be displayed the Operation is not needed. Instead the known discharge time series can be input to a routing Operation to move the water downstream.

Also the prescribed operation Schemes can be used to follow the behavior of reservoir systems if good cooperation and data exchange exist between an user and the operating agency. The prescribed discharge Scheme can be used for pool elevation computations if discharge data are provided and discharges can be computed if observed and forecasted pool elevations are received by the user.

The RCL allows the user to specify what and when Schemes and utilities are to be utilized in the regulation simulation. However there is a set order of execution for utilities that are not executed by an RCL statement and a set order of actions within the run period. The run time outline is shown in Figure 1.

The pre-loop tasks represent those optional utilities that are not activated by an RCL DO statement and are executed only once during the course of a forecast run. (All Schemes require a DO statement to start computations; the only utilities that need a DO statement and therefore are embedded within the RCL are: entry into induced surcharge, entry into flashboards, select minimum element and select maximum element.) The values generated from these pre-loop actions remain intact for the entire run period. If selected the pre-loop tasks are conducted in the order: inflow adjustment, rule curve adjustment, inflow summation. The inflow adjustment uses mean daily observed discharges and observed pool elevations to back-compute 'observed' inflows using the continuity equation:

$$\overline{I} - \overline{O} = \frac{\Delta S}{\Delta t}$$

During testing it has been evident that often bad readings of either discharge or more likely pool elevation result in negative values of 'observed' inflow. These faulty inflows then lead to further errors. If observed inflows are reported they can be used with an ADJUST-Q Operation to adjust the simulated hydrograph prior to Operation RES-SNGL. The method the operator usually uses to 'observe' the inflows is the same technique employed by the inflow adjustment Utility but is often times done on a more frequent basis which leads to more reasonable averaged inflow values. A close look at the individual data situation will help the user in selecting the proper arrangement for adjusting inflows.

If specified the rule curve is adjusted here and is influenced by the inflow values in a check for ignoring elevation differences if the inflow value is too large.

If the inflow summation Utility is specified it is executed at this point in the run using the inflow values either passed to Operation RES-SNGL or modified by the inflow adjustment Utility.

Upon completion of the pre-loop computations Operation RES-SNGL enters the major execution loops. There can be as many as four of them. The most outside loop is passed through at least once and twice at most. The first pass is to compute values from the start-up carryover without benefit of any observed values and is known as the simulation pass. If the adjust Utility is specified it constitutes the second pass of this first loop. In this second pass whatever observations of discharge and pool elevations that are available are used to compute adjusted flows out through the last period of observation according to the methods outlined in the adjust Utility.

The next innermost loop cycles once per time period within the run. At the beginning of each time period if the rain on reservoir Utility

has been set up for use initial estimates are made for the additions/subtractions to inflow volumes by the direct meteorological influences.

The innermost loop (the one that is executed most in a forecast run) is the RCL analysis loop. For each time period the RCL is analyzed to decide what specified actions need to be taken so that at the end of each period the four output variables (mean and instantaneous discharge, pool elevation and storage contents) have been filled by the execution of at least one Scheme. With the ability of conditional execution within the RCL it is conceivable that during a time period no conditions may have been met leading to execution of no Schemes. If this event occurs the Operation will execute the pass inflow Scheme so that outputs will be present for each time period. The user is notified of this occurrence by a warning message in the forecast program output.

At the end of each time period a check is made for the need to save carryover. Carryover is saved only for the following situation:

- Forecast run is a carryover save run.
- The time period is a date for which carryover is to be saved.
- The run is in the last pass of the outermost loop (i.e. simulated pass for no adjustments and adjusted pass if adjustments to outputs are to be made).

A number of Schemes and utilities require carryover at a period's start for proper execution. Therefore carryover must be updated at the end of each time period for those Schemes/utilities needing carryover. With the conditional execution ability of RCL all defined Schemes/utilities are not necessarily executed within a time period. For any Scheme/Utility requiring carryover not activated within a time period carryover is updated by computing or supplying the proper values for further successful execution. The carryover updating is done at the end of each time period regardless of the need for saving carryover to the carryover file.

If the rain on reservoir Utility is being used a comparison is made between the initial estimate of period ending surface area and that resulting from the computations. If the difference is greater than a specified tolerance the Operation repeats calculations for the time period using the inflow alterations created with the new surface area value. No comparisons are made after the second iteration.

Operation Component Interactions

The Operation has been designed so that all Schemes act independently of each other. The output generated from one Scheme does not affect the execution of any other. Each Scheme will start up using the carryover from the beginning of the time period and generate its own output. In the sequence of processing the RCL the following rules are important:

1. the conditions checked by an IF statement are those resulting from the last Scheme execution

2. the outputs generated by the last Scheme during a time period are the outputs for that time period

The first rule means that even though the output of the first Scheme does not influence the computations of any subsequent Scheme the execution of the second Scheme can be controlled by values generated from the first Scheme. It also means that the results of the previous period are used for IF checks if no Schemes are executed within a time period prior to the IF block.

It should be noted that the utilities select minimum element (SETMIN) and select maximum element (SETMAX) do control output although not by computing them based on operating rules. So when references are made to Scheme outputs these two utilities can be included in the use of 'Scheme'.

The following example will illustrate rule number 1:

```
IF (QO.GT.65000.0.OR.POOL.GT.109.0) THEN DO SPILLWAY
   ELSE DO PASSFLOW
      IF (QO.GT.65000.0.OR.POOL.GT.109.0) THEN DO SPILLWAY
         ENDIF
   ENDIF
```

The manner in which the two IF statements are analyzed is:

1. The first IF statement checks the values of instantaneous discharge and pool elevation as they existed at the end of the previous period and

2. The second IF statement checks the values of the two quantities as they were computed in the pass inflow (PASSFLOW) Scheme.

Rule 2 can be illustrated by the following RCL example:

```
DO PASSFLOW
DO SETQ
```

In this case the results of the pass inflow Scheme (PASSFLOW) will be completely overridden by those generated by the prescribed discharge Scheme (SETQ). Stacking DO statements for executions of Schemes in this manner is not good utilization of the RCL.

The only time stacking DO statements makes sense is when one of the 'selecting' utilities, either select minimum result (SETMIN) or select maximum result (SETMAX), or select maximum result (SETMAX) is used. Although neither of these utilities computes output they make comparisons of previously computed outputs and choose the proper set of outputs based on the selection criteria. For example:

```
DO ENTERISC
IF (SURCHARGE) THEN DO INDSRCHGE
   ELSE DO SETQ
```

```
        DO STPOOLQ
        DO SETMIN
    ENDIF
```

In this case there are essentially two modes of operation flood control and low flow. The entry-into-surcharge Utility (ENTERISC) is used to determine if the flood situation exists. If it does not then the low flow discharge is prescribed (here it should have been set up as input through a time series) but discharge is limited by existing downstream conditions.

The discharge is not allowed to surpass the restricting flow dictated by flow at a downstream point (limiting release is computed in STPOOLQ). The minimum of the releases computed by the two successive Scheme executions is what is used as the Operation output. This is selected in the SETMIN Utility (which has been specified to select the minimum release value).

Figure 1. Run time outline

- PRE-LOOP TASKS
    - INFLOW ADJUSTMENT*
    - RULE CURVE ADJUSTMENT*
    - INFLOW SUMMATION*
- EXECUTION LOOPS
    - SIMULATED/ADJUSTED* LOOP (1)
    - TIME PERIOD LOOP (2)
    - RAIN/EVAP* LOOP (3)
    - RCL ANALYSIS LOOP (4)
    - END LOOP 4
    - END LOOP 3

  CARRYOVER SAVED*

    - END LOOP 2
    - END LOOP 1

* = Optional action