MODULE – 7: Conservation Operation

7.1. Probable Flow Estimation

Derivation of initial rule curves for a reservoir requires probable inflows corresponding to different reliabilities for different months. The monthly inflow series for all the reservoirs was analyzed using the statistical approach. Since for all the reservoirs, If more than 25 years of inflow data are available at a site, then the reliable monthly flows can be computed using statistical techniques. The power transformation approach is a standard technique that is extensively used for statistical analysis of flow data.

In the present module, provisions have been made to carry out the analysis for all the months of a water year in one go using the three analysis methods: Rank analysis, Log-transform analysis, and Power-transform analysis. Earlier, such analysis was required to be repeated for each month separately. The results are also presented in two files: detailed results are presented month-by-month with all the three methods in ****.pfo*** file while the abstract of results containing the probable flows corresponding to 6 specified reliability levels for all months with all methods are presented in ****.pfg*** file. To avoid error while using the log-transform method, any zero inflow value in the given series is taken as 1 cubic meter.

7.1.1. Assumptions

Some of the assumptions are as follows:

a) Starting value of inflow series corresponds to beginning month of a water year.

b) Metric system of units has been adopted and the desirable units of data sequence are specified in the column header. Inflow sequences are to be specified in million cubic meter (MCM).

c) The inflow series need to be specified for all 12 months of a water year.

d) If 40% or more of the monthly flow values in a particular month (say, April) are less than 1 hectare.m (= 10000 cubic meter), the log-transform and power-transform analysis are not performed for such month so as to avoid errors in the computations.

7.1.2. Input Data Description

The file extension for input files is *.***pfi*** and file extension for detailed output is *.***pfo*** and for abstract output is *.***pfg***. Various items that are input to the module are described below:

Title of the problem

Specify the title of the data file containing general details of the analysis for remembrance at a later date (not more than 100 characters).

Number of years of flow series

Specify the number of years for which inflow sequence is available. Using this number, the form for inflow entry will automatically generate the specified number of empty cell rows for entry of monthly flows in different years.

Starting month of flow series

Specify the starting month (numeric) of the flow series. The first value of inflow sequence may correspond to the starting month of a water year.

Reliability Level – 1 (%)

Specify the first reliability level (say, 50 meaning thereby 50% reliable inflow) for which inflow series data is being analyzed.

Reliability Level - 2 (%)

Specify the second reliability level (say, 60 meaning thereby 60% reliable inflow) for which inflow series data is being analyzed.

Reliability Level - 3 (%)

Specify the third reliability level (say, 70 meaning thereby 70% reliable inflow) for which inflow series data is being analyzed.

Reliability Level - 4 (%)

Specify the fourth reliability level (say, 75 meaning thereby 75% reliable inflow) for which inflow series data is being analyzed.

Reliability Level - 5 (%)

Specify the fifth reliability level (say, 80 meaning thereby 80% reliable inflow) for which inflow series data is being analyzed.

Reliability Level - 6 (%)

Specify the sixth reliability level (say, 90 meaning thereby 90% reliable inflow) for which inflow series data is being analyzed.

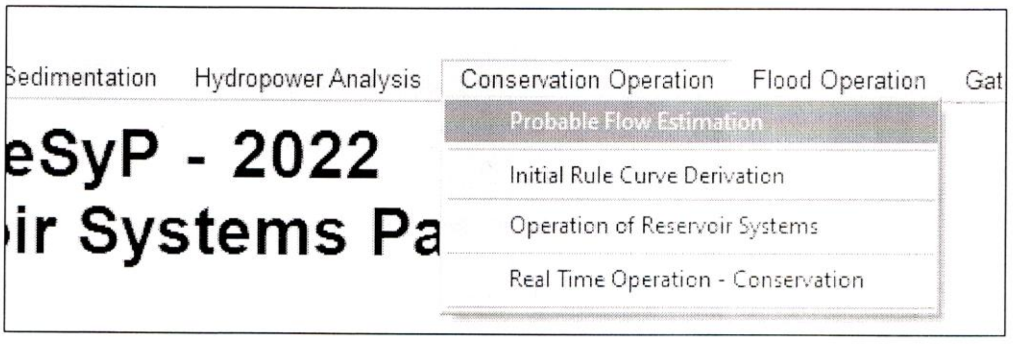
Inflow Series (MCM)

Enter the year and the monthly inflow values for different months in the year. It is also possible to prepare the table in MS-Excel and copy-paste the same in the specified table in the module.

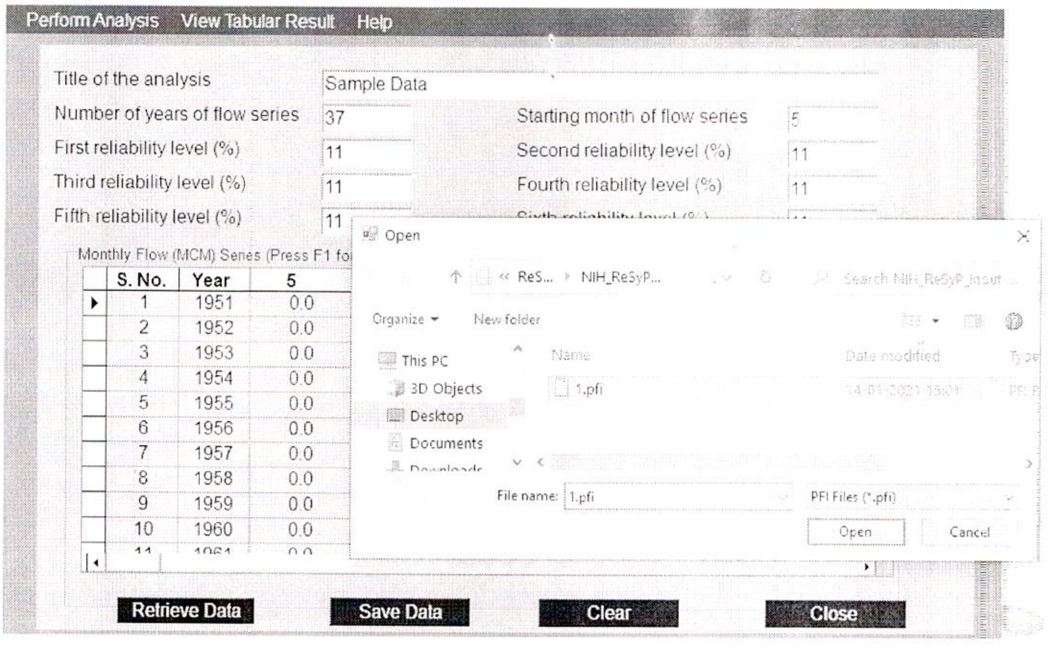
7.1.3. Steps of Analysis

Following steps are used for Probable Flow Estimation module:

a) From Conservation Operation module, select the ***Probable Flow Estimation*** module. The module will open along with the form for entry of its general data and tabular data.



b) Either retrieve an already existing data file by clicking on the ***Retrieve Data*** button or generate a new file by clearing the default data (by clicking on the ***Clear*** button) in the opening data form and fill all the data cells.

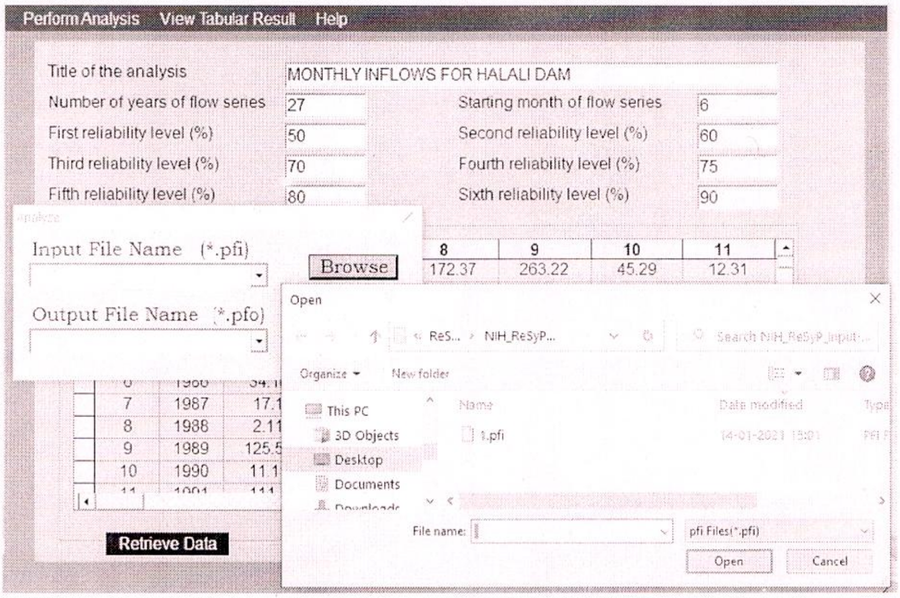


c) After entry of all data cells in the general data section, fill the years and monthly flow values **<u>in specified units</u>** in those years.

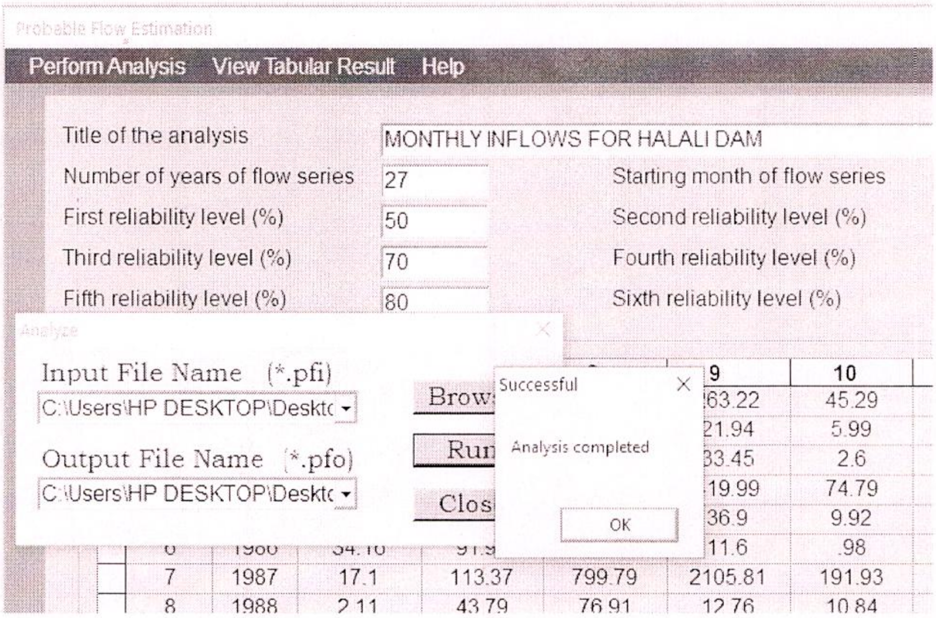
In tabular data, it is also possible to ***Copy-Paste*** the data of all columns from MS-Excel. In that case, copy the data of all columns together from MS-Excel and bring the cursor to the first row in the table and press F1 (function key). Data will get pasted in all columns in the table. Check that data are present in all cells of the table.

d) After entry of all data cells in the general data section and the tabular data, click on the ***Save Data*** button. A separate window for saving the data file will appear. First select the desired directory and then specify the desired filename for the data file. The file will be saved as .pfi file. There is no need to specify the extension in the filename. It will be automatically attached with the filename.

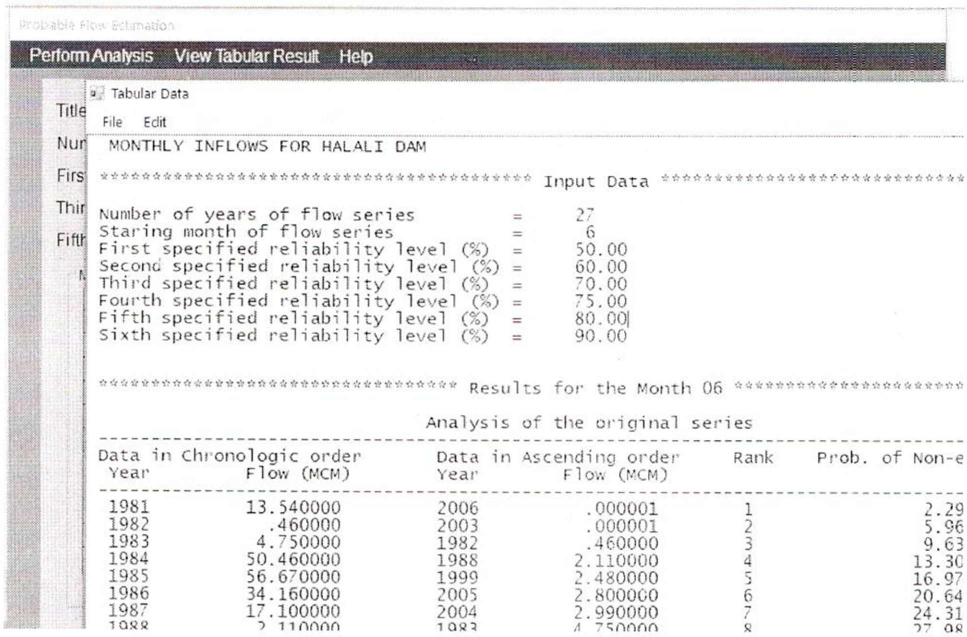
e) Click on the ***Perform Analysis*** button which will open-up a form for the specification of input and output files before the execution of the related program. First click on the ***Input File Name*** cell and then click on the ***Browse*** button. This will open a window for selecting the input file. Go to the desired directory and select the requisite data file. Click on the ***Open*** button to select the file. The file along with the path will appear in the ***Input File Name*** cell. Next, click on the ***Output File Name*** cell and repeat above steps. The filename along with the path will appear in the ***Output File Name*** cell.



f) <u>After specifying the input and output filenames along with their location, the ***Run*** button gets **activated**</u>. Click on the ***Run*** button to execute the related program with the specified input and output filenames. The program runs (in a window which closes automatically after the program execution is complete).



g) Click on the ***View Tabular Results*** button. To view data/results in tabular form, click on the ***Tabular*** button which will invoke the ***Notepad***. Click on the ***File*** and then ***Open*** and a window for file selection will appear. Go to the desired directory and select the requisite Input/Output filenames to see Input/Output files. It needs to be mentioned here that in this window, only files with extension ***.pfi*** or ***.pfo*** (for detailed results) or ***.pfg*** (for abstract results) will be displayed. Select the desired filename and click on the ***Open*** button. The file will be displayed in the **Notepad**.



MONTHLY INFLOWS FOR HALALI DAM

*** Input Data ***********************************

Number of years of flow series	=	27
Staring month of flow series	=	6
First specified reliability level (%)	=	50.00
Second specified reliability level (%)	=	60.00
Third specified reliability level (%)	=	70.00
Fourth specified reliability level (%)	=	75.00
Fifth specified reliability level (%)	=	80.00
Sixth specified reliability level (%)	=	90.00

************************************ Results for the Month 06 ************************

Analysis of the original series

Data in Chronologic order Year	Flow (MCM)	Data in Ascending order Year	Flow (MCM)	Rank	Prob. of Non-e
1981	13.540000	2006	.000001	1	2.29
1982	.460000	2003	.000001	2	5.96
1983	4.750000	1982	.460000	3	9.63
1984	50.460000	1988	2.110000	4	13.30
1985	56.670000	1999	2.480000	5	16.97
1986	34.160000	2005	2.800000	6	20.64
1987	17.100000	2004	2.990000	7	24.31

h) Close the ***Probable Flow Estimation*** module by clicking on the ***Close*** button.

7.2. Initial Rule Curve Derivation

A rule curve or a rule level specifies the storage or empty space to be maintained in a reservoir during different times of a year. Here the assumption is that a reservoir can best satisfy its purposes if the storage specified by the rule curve are maintained at different times. The rule curve, as such, does not give the amount of water to be released from the reservoir. This amount will depend upon the inflows to the reservoir, the storage space available in the reservoir and the demands from the reservoir. The rule curves are generally derived by operation studies using historic or generated flows. The operation of a reservoir by strictly following the rule curves becomes quite rigid. Often, to provide flexibility in operation, different rule curves are followed in different circumstances.

In India, the reservoirs are constructed to serve conservation purposes like water supply for domestic and industrial use, maintenance of environmental flows in the downstream channel, irrigation and hydropower generation demands. Therefore, in the present module, provision has been made to derive five rule curves: a) Upper rule curve for spilling, b) Rule curve for meeting all conservation demands, c) Rule curve for meeting irrigation/hydropower demands (based on priority), d) Rule curve for meeting environmental flow requirements and e) Rule curve for meeting domestic/industrial supply demands. Five monthly inflow series corresponding to different reliability (say 50%, 60%, 70%, 80%, and 90%) are input to the module which are used for computation of five different rule curve levels.

Various demands from the reservoir have been specified in terms of their priority rather than their purpose. Based on the priorities between irrigation and hydropower, exclusive water requirements for power generation are determined which are used to derive the rule curve levels.

7.2.1. Assumptions

Some of the assumptions are as follows:

a) Metric system of units has been adopted and the desirable units of data sequence are specified in the column header. Inflow and demand sequences are to be provided in million cubic meter (MCM) while hydropower demands are provided monthly in million units (million KwH).

b) A maximum of four rule curves for various demands (corresponding to different inflow sequence) and one upper rule curve can be derived at a time. If more such combinations are required, repeated runs of the module can be taken with revised data files.

7.2.2. Data Checks

Some of the checks performed by the module include:

a) Elevation-Area-Capacity (EAC) table of reservoir is checked. If the area (or capacity) at any reservoir level decreases with rising elevation, the program aborts and flags the line number in the EAC table for correction.

b) The capacity at each level of EAC table above the lowest level is checked by using the prismoidal formula. If the difference in the computed and specified capacity is greater than 10%, a message is flagged at the screen and in the result file after the presentation of Elevation-Area-Capacity Table in the Input Data section. The program does not abort in this case.

7.2.3. Input Data Description

Input data form for this module showing general data section and tabular input section is shown in Figures – 1, 2 and 3. The file extension for input files is **.rci*** and file extension for output file is ****.rco*** and the same for plotting of graphs in MS-Excel is ****.rcg***. Various items that are input to the module are described below:

Title of the analysis

Specify the title of the data file containing general details of the analysis for remembrance at a later date (not more than 100 characters).

Full reservoir level (m)

Specify the full reservoir level (FRL). This is the maximum level of conservation zone beyond which water is spilled from the reservoir.

Minimum Draw Down level (m)

Specify the minimum draw down level (m) up to which water is released for meeting various demands. This is the minimum level of conservation zone beyond which water is not released for conservations demands except for emergency highest priority demands.

Number of levels in EAC table

Specify the number of elevations for which corresponding water spread areas and cumulative storage capacity from reservoir bottom are available in the EAC table. Based on the entered value, the form for entry of EAC table will automatically generate the specified number of empty cell rows for input of elevation, area, and capacity.

Initial month of wet season

Specify the initial month of wet season (or monsoon season or filling season). Since it may vary for different regions of India depending on climate patterns, it has been kept as a variable. It is considered as the first month of the water year and it is assumed that the water reaches the minimum draw down level (plus specified carry-over storage) by the end of a water year.

Final month of wet season

Specify the final month of wet season (or monsoon season or filling season). During wet season, upper rule levels are kept at FRL and these are sequentially lowered in various months by carrying out the simulation analysis such that some room can be created in the reservoir for flood absorption without compromising the operational performance of reservoir for meeting various conservation demands.

Carry-over storage (MCM)

Specify the carry-over storage (MCM) to be maintained at the end of a water year. The rule curves are derived such that the specified carry-over storage may remain as balance at the end of a water year so as to manage either the late start of the wet season or the deficient wet season.

Method of supply of water through power plant

This option provides information about the passage of water for various demands either through the power plant (PP) or by-passing the PP. Hydropower production affects the water demand. Further, it is not constant and depends on the available net head at any time. However, since it is non-consumptive demand, the method of supply through PP affects the total water demands from a reservoir. Different methods are specified in terms of an integer as given below:

0- No power plant at a reservoir

1- Release for all purposes (except env. flow) pass through the PP.

2- Only highest priority demand (say domestic supply) pass through the PP.

3- Only third priority demand (say irrigation) pass through the PP.

4- No release pass through PP.

Irrigation demand is bifurcated in two demand series – one passing through the PP and another by-passing through PP. Environmental flow always by-pass PP.

Installed capacity of power plant (MW)

This refers to the maximum capacity of the power plant (MW). This will restrict the maximum power that can be generated at a time. This option will be active always and the default value of the method of supply through power plant is 0.

Tail water elevation (m)

Average tail water elevation of the PP is specified so as to compute the net head. Though it may vary with discharge, it is taken as constant here. This option will be active always and the default value of the tail water elevation is 0.

Minimum level for power generation (m)

Specify the minimum reservoir level for power generation (m). If the reservoir goes below this level, hydropower cannot be generated. This option will be active always and the default value of minimum reservoir level for power generation is 0.

Efficiency of power plant (%)

Every power plant has its own efficiency (say, 85% or 90% or so). It is used to compute the water demands for generating hydropower from net effective head. This option will be active always and the default value of efficiency of power plants is 0.

Average head loss (m)

Specify the average head loss (m) that may occur in the conveyance system so as to compute the net head for hydropower production. This option will be active always and the default value of average head loss through conveyance system is 0.

Priority between irrigation and hydropower

Though generally irrigation is accorded higher priority in comparison to the hydropower production, it is possible to analyze opposite scenarios also. If irrigation is assigned higher priority (specified by 0), it is assigned Priority – 3 followed by hydropower (Priority – 4). If hydropower is assigned higher priority (specified by 1), it is assigned Priority – 3 followed by irrigation (Priority – 4). This option will be active always and the default value of priority between irrigation and hydropower is 0.

E-A-C table

Clicking on the ***E-A-C Table*** button opens a table for entry of elevation, area, and storage capacity of the reservoir. The number of cells depends on the data specified in the cell corresponding to number of levels in EAC table.

Inflow series

Clicking on the ***Inflow Series*** button opens a table containing columns for entry of dependable flows to be considered for derivation of rule curves for different priority demands. First column represents the monthly inflows to be considered for upper rule curve derivation (may be corresponding to 50% reliability in different months). Subsequent columns represent the monthly inflows to be considered for deriving rule curve levels for different priority demands (may be corresponding to 60%, 70%, 80%, and 90% reliability for priority-4, priority-3, priority-2, and priority-1 demands respectively). It is to mention that higher is the priority of a demand, higher reliable inflow sequence should be considered. Monthly inflows corresponding to different reliability are computed using the ***Probable Flow Estimation*** module using the long-term inflow sequence in different months.

Demand series

Clicking on the ***Demand Series*** button opens a table for entry of water and hydropower demands with different priority. First and second columns represent the demands (MCM) corresponding to the highest priority (say, domestic/industrial supply) and second highest priority (say, environmental flow) respectively. Third and fourth columns represent the irrigation demands (MCM) passing through the PP and by-passing the PP respectively. Fifth column represents the monthly hydropower energy demands (MKwH) in million units. The relative priority between irrigation and hydropower is specified through a separate factor as mentioned above.

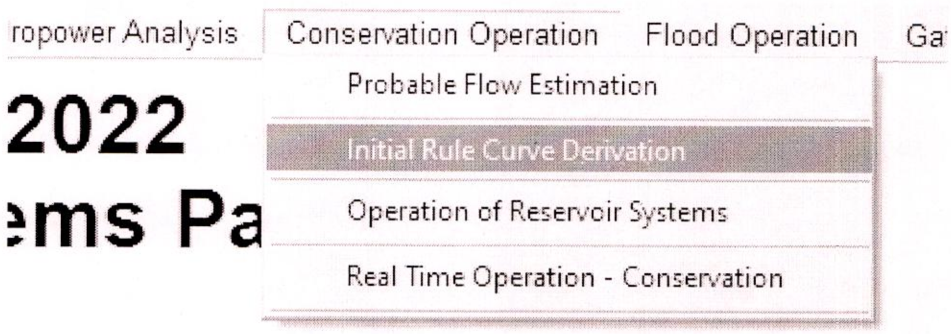
Evaporation depths (mm)

Clicking on the ***Evaporation depths*** button opens a table for entry of evaporation depths (mm) in different months of a year.

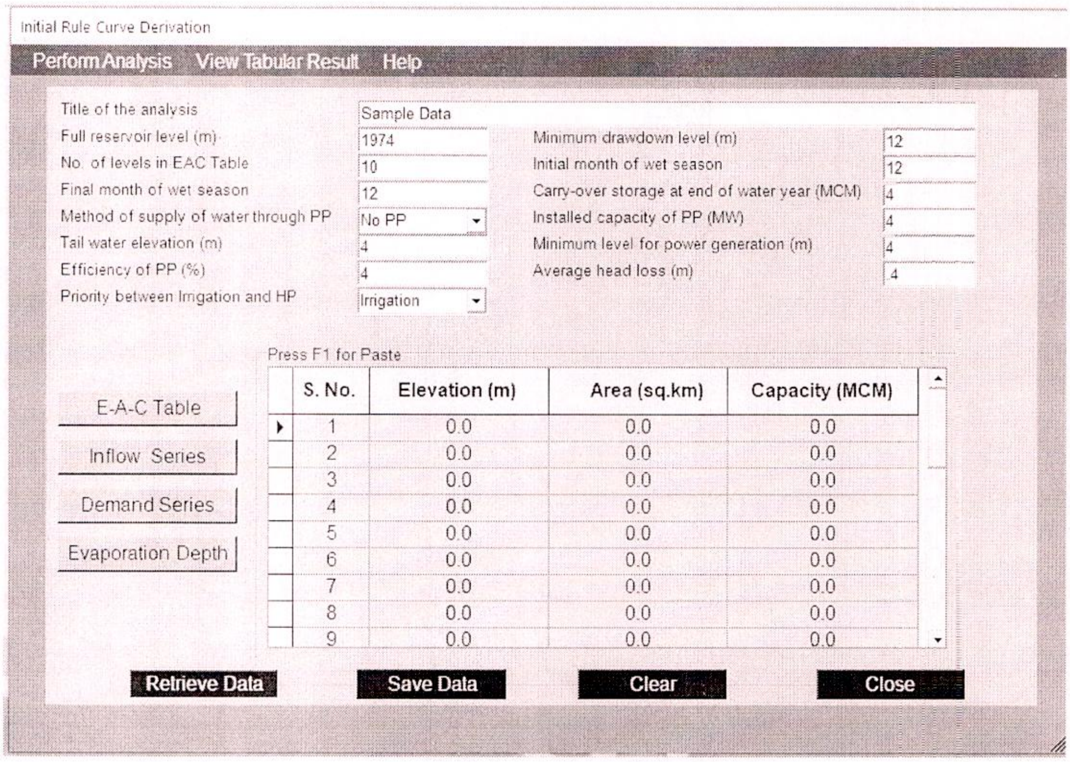
7.2.4. Steps of Analysis

The following are the steps for using the ***Initial Rule Curve Derivation*** module:

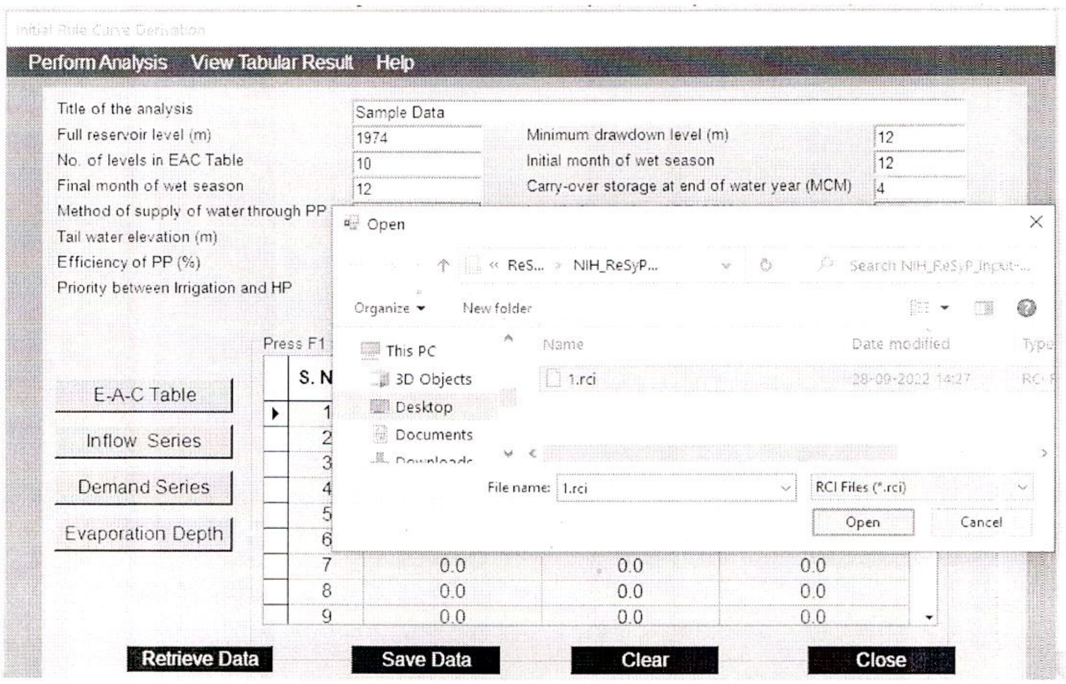
a) Invoke the ***Initial Rule Curve Derivation*** option from ***Conservation Operation*** module.



b) The data form will be displayed for entry of general details and tabular data.



c) Either retrieve an already existing data file by clicking on the ***Retrieve Data*** button or generate a new file by clearing the default data (by clicking on the ***Clear*** button) in the opening data form and fill all the data cells.



d) After entry of all data cells in the general data section, a blank **E-A-C Table** form appears in the lower part of the form for input of elevation, area, and storage capacity values. Click on the ***E-A-C Table*** button and fill all the values in the table **in specified units**.

e) Click on the ***Inflow Series*** button. A blank table appears in the lower part of the form for input of monthly inflow values (in MCM) that are to be considered for deriving the upper rule curve levels and other rule curve levels for demands of different priority. In a run, rule curve levels can be derived for a maximum of four demands (domestic supply, environmental flow, irrigation, and hydropower in the order of priority). If a particular demand does not exist at a reservoir, the inflow series for this demand is considered the same as for its next higher priority demand (say, if environmental flow demand does not exist, then inflow series is considered the same as for domestic supply demand).

f) Click on the ***Demand Series*** button. A blank table appears in the lower part of the form for input of monthly demand values (in MCM) that are to be considered for deriving the upper rule curve levels and other rule curve levels. In a run, rule curve levels can be derived for a maximum of four demands (domestic supply, environmental flow, irrigation, and hydropower in the order of priority). If a particular demand does not exist at a reservoir, the demand series for this demand is considered the "0".

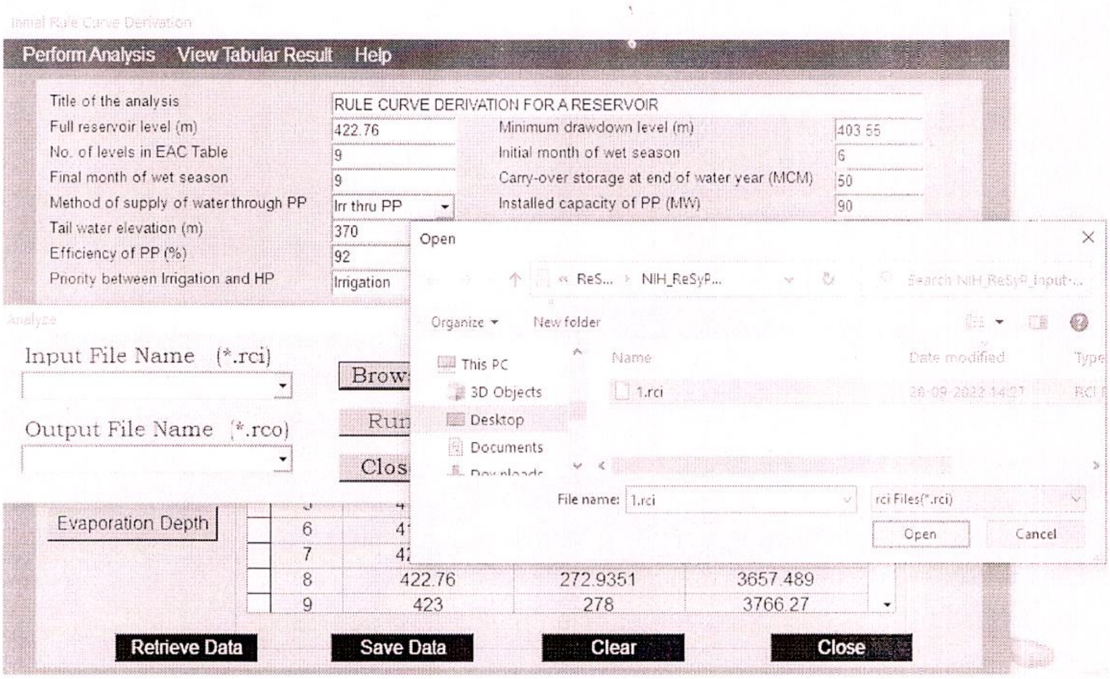
g) Click on the ***Evaporation Depth*** button. A blank table appears in the lower part of the form for input of monthly evaporation depths (in mm).

In various tabular data, it is also possible to ***Copy-Paste*** the data of all columns from MS-Excel. In that case, copy the data of all columns together from MS-

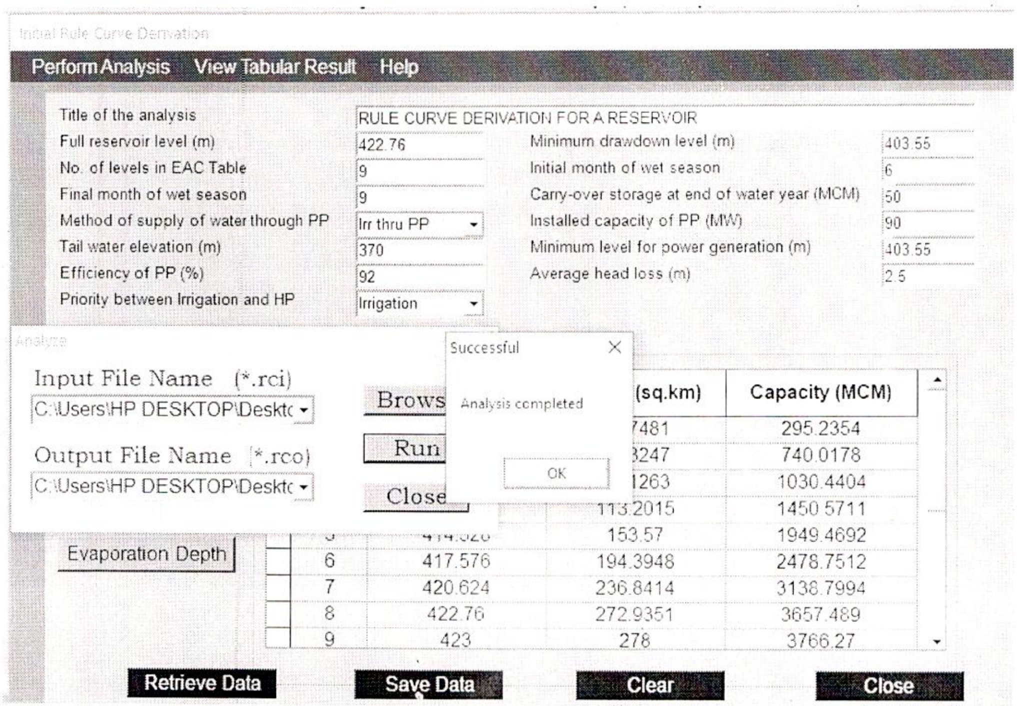
Excel and bring the cursor to the first row in the table and press F1 (function key). Data will get pasted in all columns in the table. Check that data are present in all cells of the table **in specified units**.

h) After entry of all data cells in the form, click on the ***Save Data*** button. A separate window for saving the data file will appear. First select the desired directory and then specify the desired filename for the data file. The file will be saved as ***.rci*** file. The extension will be automatically attached with the filename.

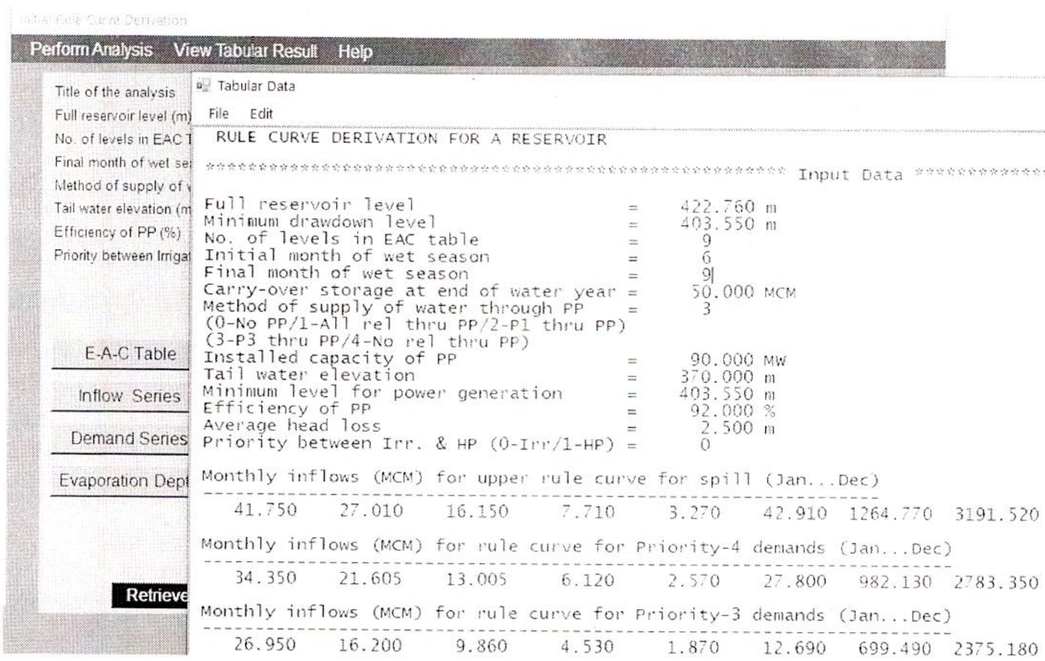
i) Click on the ***Perform Analysis*** button which will open-up a form for the specification of input and output files before the execution of the related program. First click on the ***Input File Name*** cell and then click on the ***Browse*** button. This will open a window for selecting the input file. Go to the desired directory and select the requisite data file. Click on the ***Open*** button to select the file. The file along with the path will appear in the ***Input File Name*** cell. Next, click on the ***Output File Name*** cell and repeat above steps. The filename along with the path will appear in the ***Output File Name*** cell.

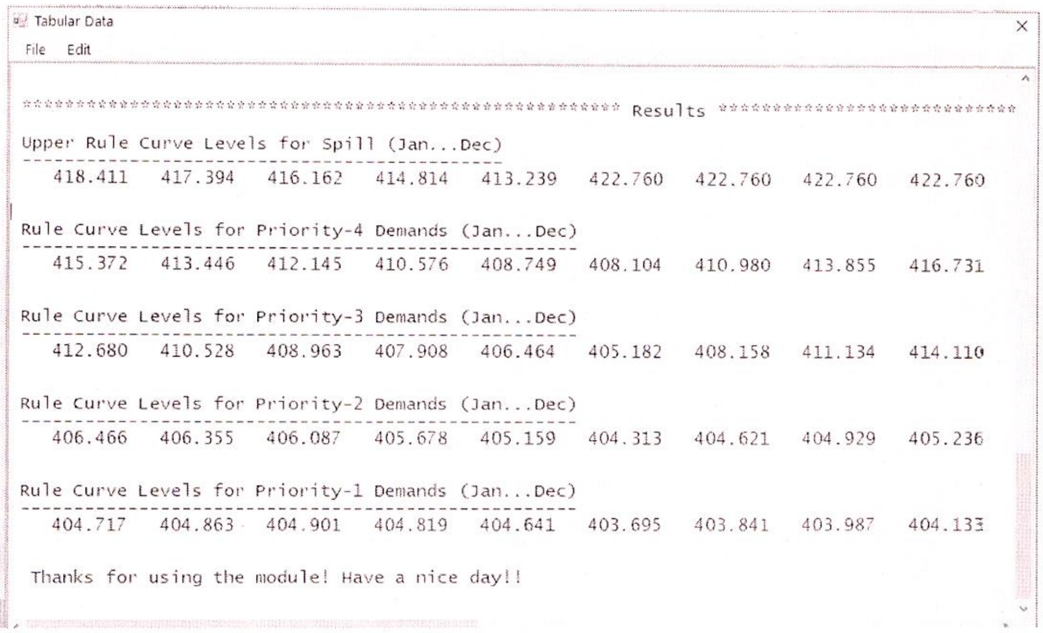


j) <u>After specifying the input and output filenames along with their location, the ***Run*** button gets **activated**</u>. Click on the ***Run*** button to execute the related program with the specified input and output filenames. The program runs (in a window which closes automatically after the program execution is complete).



k) Click on the ***View Tabular Results*** button. To view data/results in tabular form, click on the ***Tabular*** button which will invoke the ***Notepad***. Click on the ***File*** and then ***Open*** and a window for file selection will appear. Go to the desired directory and select the requisite Input/Output filenames to see Input/Output files. It needs to be mentioned here that in this window, only files with extension ***.rci*** or ***.rco*** will be displayed. Select the desired filename and click on the ***Open*** button. The file will be displayed in the **Notepad**.





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Tabular Data
File   Edit

************************************************************ Results ****************************

Upper Rule Curve Levels for Spill (Jan...Dec)
-----------------------------------------------
   418.411   417.394   416.162   414.814   413.239   422.760   422.760   422.760   422.760

Rule Curve Levels for Priority-4 Demands (Jan...Dec)
------------------------------------------------------
   415.372   413.446   412.145   410.576   408.749   408.104   410.980   413.855   416.731

Rule Curve Levels for Priority-3 Demands (Jan...Dec)
------------------------------------------------------
   412.680   410.528   408.963   407.908   406.464   405.182   408.158   411.134   414.110

Rule Curve Levels for Priority-2 Demands (Jan...Dec)
------------------------------------------------------
   406.466   406.355   406.087   405.678   405.159   404.313   404.621   404.929   405.236

Rule Curve Levels for Priority-1 Demands (Jan...Dec)
------------------------------------------------------
   404.717   404.863   404.901   404.819   404.641   403.695   403.841   403.987   404.133

 Thanks for using the module! Have a nice day!!
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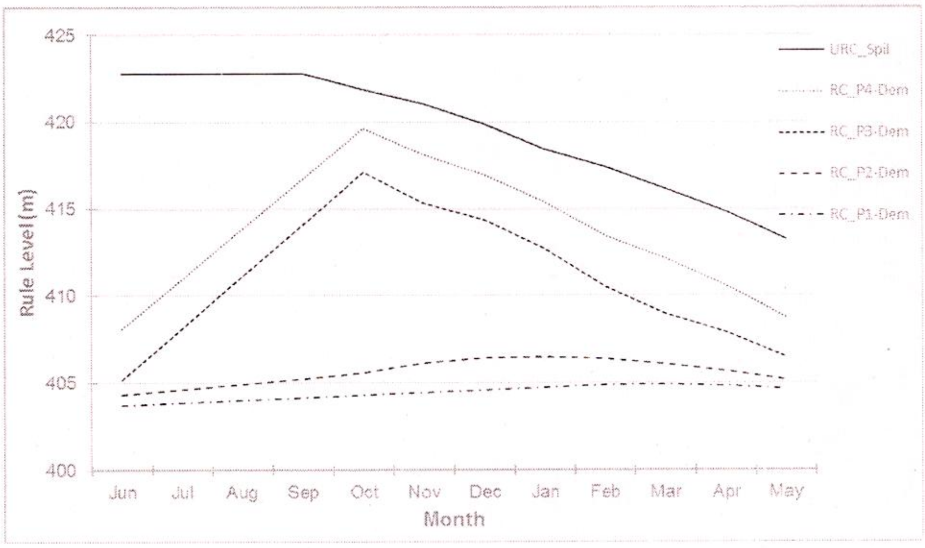
l) It is also possible to prepare the graphs in MS-Excel with specific requirements. For this purpose, ready-made graphs have been prepared in MS-Excel which can be modified. Open the graphical file (*.rcg) in MS-Excel as ***"Delimited"*** file with ***"Space"*** delimiters and with column data format as ***"General"***. The file will open in a separate MS-Excel sheet. Select and copy the whole worksheet and paste it in ***"Input"*** worksheet of ***"RC_Graph.xlsx"*** file of MS-Excel which is already built in. The graphs can be copied and pasted anywhere in a document. The graph for the sample analysis are shown in Figure below.



m) Close ***Initial Rule Curve Derivation*** module by clicking on the ***Close*** button.

7.3. Operation of Reservoir Systems

7.3.1. Conservation Operation of a Multi-Reservoir System

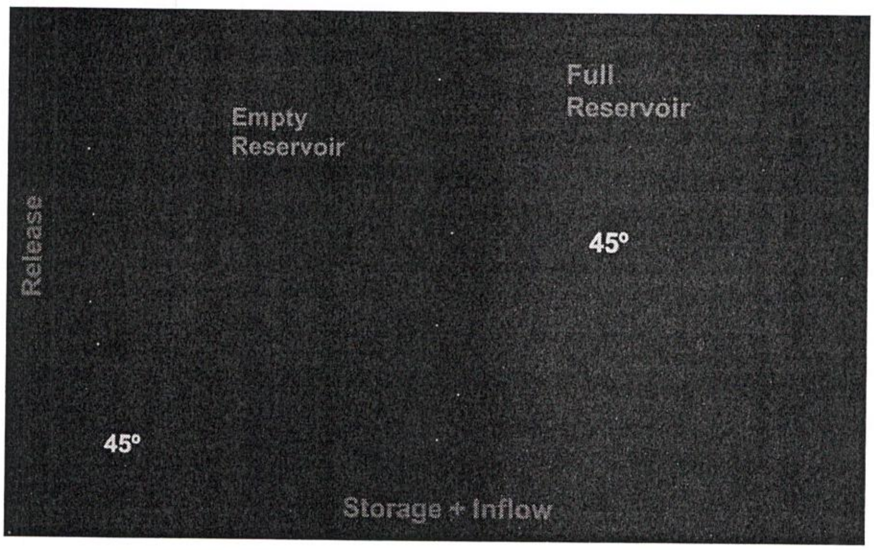
This module can be used to simulate the operation of a multipurpose multi-reservoir system for conservation operation. The various conservation purposes considered in the module include water supply for domestic and industrial purposes, irrigation, hydropower generation and minimum flow in the downstream river channel. The module can help in finalizing the optimum operation policies for each storage location. It is also possible to consider scenarios for inter-basin water transfer or water transfer among various hydraulic structures.

7.3.2. Techniques of reservoir operation considered in this module

A reservoir is operated according to a set of rules or guidelines for storing and releasing water depending upon the purposes it is required to serve. The decisions are made regarding releases in different time periods in accordance with the demands. Various policies of reservoir operation for conservation purposes that have been used in the present module are briefly discussed below.

a) Standard Linear Operating Policy

The simplest of the reservoir operation policies is the standard linear operating policy (SLOP). According to this policy, if in a particular period, the amount of water available in storage is less than the target demand, whatever quantity is available is released. If the water available is more than the target but less than target demand plus available storage capacity, then a release equal to the target demand is made and the excess water is stored in the reservoir. In case, even after making releases equal to the target demands, there is no space to store the excess water, all the water in excess of maximum storage capacity is released. The SLOP is graphically represented in Figure below.



The SLOP is a one-time operation policy without relation to the release of water at any other time. This type of time isolated releases of water is neither beneficial nor desirable. The water beyond the target output in any period has no economic value. This policy is not used in day-to-day operation due to its rigidness and above drawbacks. It is however, extensively used in planning studies.

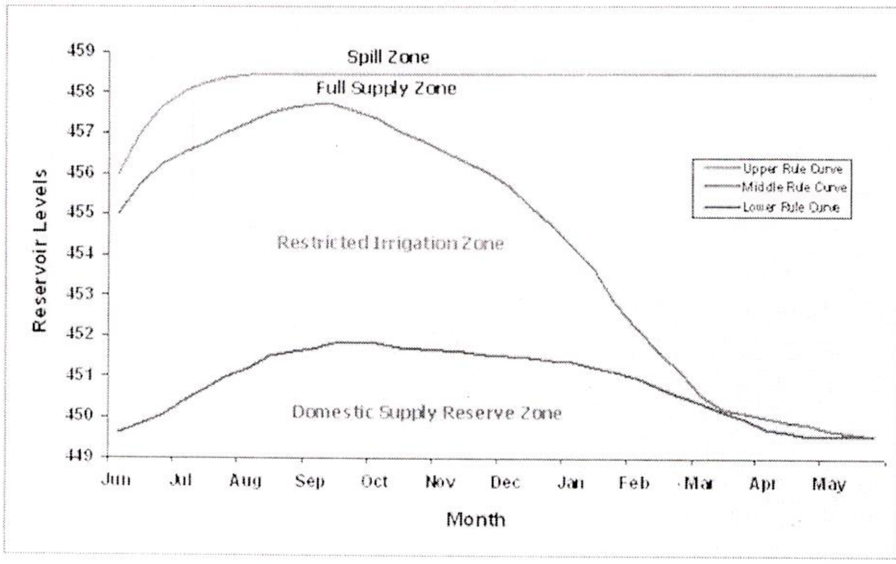
b) Rationing policy

In this policy, the entire reservoir storage space is conceptually divided in a number of zones with imaginary planes at various elevations. The sizes of these zones may vary with time. The percentage of demands to be met in these different zones is specified which reduces as the reservoir zones move from FRL (Full Reservoir Level) towards the MDDL (Minimum Draw Down Level). The percentage reduction for different purposes demands may change depending on the priority. Thus, this policy is also referred to as "Rationing Policy". During the operation analysis, the supply for different purposes is decided based on the actual reservoir level and finally, the reliability of meeting different demands can be estimated. Repeated runs of the module can help in finalizing the reduction percentages and zone sizes and levels for different demands so as to obtain acceptable performance in the long-run.

c) Rule curves based policy

A rule curve or rule level (or warning level) specifies the storage or empty space to be maintained in a reservoir during different times of the year. Here the implicit assumption is that a reservoir can best satisfy its purposes if the storage levels specified by the rule curve are maintained in the reservoir at different times. The rule curve as such does not give the amount of water to be released from the reservoir. This amount will depend upon the inflows to the reservoir, or sometimes it is specified in addition to rule curves.

The rule curves are generally derived by operation studies using historic or generated flows. Many times due to various conditions like low inflows, minimum requirements for demands etc., it is not possible to stick to the rule with respect to storage levels. It is possible to return to the rule levels in several ways. One can be to return to the rule curve by curtailing the release if the deviation is negative. However, in this concept, different rule curves are derived for different purposes (say, for domestic supply, environmental flows, irrigation, hydropower generation etc.). Below a rule curve for a specified purpose, only the curtailed demands for the purpose and other higher priority demands are met. A figure showing rule curves for different purposes for a reservoir is shown in figure below.



7.3.3. Methodology Adopted for Conservation Operation

For each storage location, the model operates the reservoir or diversion project (with/without storage) in accordance with the given rule curves (given for each reservoir for each purpose) and carries out the reliability analysis. Correspondingly, it calculates the time and volume reliability for each demand of the project at different time steps (daily/10-daily/monthly/annual) for the specified operation policy and for the given period of operation. Detailed simulation table is also prepared for each project. Based on the observation from the simulation tables, the specified operation policy can be modified till optimum results are achieved.

The model can operate for three time steps: daily, 10-daily, or monthly. For daily time step, inflows from free catchment areas in each project and precipitation depths over the project need to be provided at daily time step while for 10-daily time step, they are provided at 10-daily time step (1-10 of a month as first step, 11-20 of a month as second step, and remaining number of days in the month (8, 9, 10, or 11 as the third time step). For daily/10-daily operation, all demands, normal evaporation depths etc. are provided at 10-daily time step. The highest priority is given to the water supply demand for domestic and industrial purposes followed by minimum flow demand (environmental flow) in the downstream channel. The demands for irrigation and hydropower are given lower priority as compared to the water supply and minimum flow demand. The priority between hydropower or irrigation is user specified and may change from one period (month/ten-daily) to another. The amount of water required to produce hydropower depends on the head of water available which keeps on changing. This amount is calculated based on the mean elevation of reservoir level during a time step.

The operation of a system can be simulated with any of the three operation policies as specified above. Five different rule levels or rationing levels need to be specified for each month. For rule curve based operation, lowest level represents the warning level for highest priority demand (say, domestic supply). Next higher level represents warning level for next priority demand (say, environmental flow) along with domestic supply. Next higher level represents warning level for next priority demand (say, irrigation/hydropower) along with other higher priority demands while fourth higher level represents warning level for next priority demand (say, hydropower/irrigation) along with all other higher priority demands. Fifth highest level represents the upper rule curve level above which water can be spilled from reservoir. If we want to simulate the reservoir with SLOP, then highest rule level can be taken as FRL while all other lower levels can be taken as MDDL. Similarly, for the rationing policy, full demands for different purposes can be met above the highest level while for other zones, different supply percentages for different purposes (say, 90%, 80%, 75% etc.) need to be specified.

The data requirements of the module are quite modest and such type of data are generally available with the dam authorities. Some data pertain to the information about each structure viz. full reservoir level, dead storage level, elevation-area-capacity table, various conservation demands from the reservoir like water supply for domestic and industrial purposes, irrigation, hydropower demands (in million units), environmental flow requirements in the downstream channel, normal evaporation depths, local inflows from the intermediate/free catchment area and precipitation depths over the project area. If the concerned location is to meet some demands of a downstream structure also, then the number of the node whose demands are to be met and the percentage of demands is also specified in the input data. Some data defining the configuration of the system and the trial operation policy levels are specified by the user. In the present form, the model can be used for a system having 100 nodes and analysis can be carried out for 40 years of daily record.

For defining initial conditions at each location, data in the form such as initial year, initial month and initial storage in each storage is specified. For structures operated for hydropower generation, details regarding the method of supply through the power plants, installed capacity of the plants, minimum level for power generation, tail level elevation and efficiency of the plants are to be specified. Tables for tail water rating and head loss rating also need to be specified. To account for the situation where a part of irrigation water is passed through the power plant while another part bypasses the power plant, two irrigation canals have been taken to emerge from a dam (LBC and RBC) and irrigation release from LBC always pass through the PP while irrigation release from RBC always by-passes the PP. Four methods of supply of water through the PP are considered as mentioned below:

0 - No power plant at a reservoir
1 - Release for all purposes (except env. flow) pass through the PP.
2 - Only highest priority demand (say domestic supply) pass through the PP.
3 - Only third priority demand (say irrigation) pass through the PP.
4 - No release pass through PP.

It is generally a healthy practice to prepare the line diagram of the system under study. Line diagram should highlight the location of reservoir and diversion weirs/barrages and the location and direction of the connecting rivers and streams. For defining the system configuration in the model, node numbers must be assigned to each structure starting from the upstream structure. The node numbers are assigned in numeric starting from 1. The model recognizes each structure by its node number. Those structures that are contributing to a given structure is recognized from the node numbers of control points just upstream of the present location. For each node, computation number is assigned so that the computations during a time step proceed from upstream towards the downstream locations. For each location, the model reads the name of structure, its node number, number of nodes immediately upstream of the present node and their node numbers. Factor for reducing various demands in case of scarcity of water is also to be specified for each structure.

The model simulates the operation of the system for specified period. Based on the trial operation policy, it calculates time and volume reliability for different time steps for each structure. Further, reliability achieved for various demands in different months is also computed which can be used to fine-tune the operation policy. It also calculates the number of months when the release from the reservoir is less than a specified percentage of the total demands. In addition to calculating the reliability, a detailed operation table for each structure is prepared. For each period, the table gives the year, month and period of operation, the initial storage, flow from upstream structure (if any), flow from intermediate catchment, evaporation, various demands and releases, hydropower details, power generated, spill from the structure, and end level. Based on the observations from working table, operation levels and percent reduction factors can be fine-tuned till the acceptable operation performance is achieved.

7.3.4 Steps for application

The recommended steps to be performed for applying this module to a reservoir system are as follows:

1. Prepare the diagram of the system showing the name of reservoirs and diversion weirs/barrages, their location and the length and direction of the rivers and tributaries along with average lag times for flow movement.

2. Give node numbers in numeric form to all the control points (storage reservoir, diversion weir, barrage etc.) starting from the upstream node.

3. Get general details about the operation like the number of control locations in the system, initial month, initial year, total number of periods of operation, whether operation is to be carried out daily/10-daily/monthly time step.

4. Get general details about each structure like the name of the structure, node number, computational number in the system (from u/s to d/s), number of nodes

immediately upstream, their node numbers, method of supply of water through the power plants (if non, write 0), minimum supply for different demands.

5. If a reservoir location is operated for hydropower, get power production details which include installed capacity of power plant, tail water elevation, minimum level for power production, efficiency of the power plant, priority between irrigation and power in all periods of water year, power demands for all periods, and rating tables for tail water level and head-loss through PP.

6. Get further details about each structure like the maximum capacity up to the full reservoir level, capacity up to the intake of water supply outlet, initial storage, number of points in the elevation-area-capacity table (1 in case of diversion weir/ barrage and >1 for storage structures), downstream location whose demand is to be satisfied (if any) and the percentage of demands to be satisfied, irrigation demands (LBC and RBC separately), domestic supply demands, minimum flow demands in the downstream channel, hydropower demands, trial operation rule levels (5 rule levels at monthly time step), normal 10-daily/monthly evaporation depths, increments for evaporation and demands in various years, sediment trapped in a reservoir in different years, type of reservoir, river bed level etc.

7. For each structure, calculate the local flow coming from the free catchment area at that structure for all the periods of operation. If inflow is to be obtained by multiplying the inflow data of some other structure by some number, then the node number whose data are to be used for calculation of local inflow at present structure and the multiplication factor needs to be mentioned in the data file.

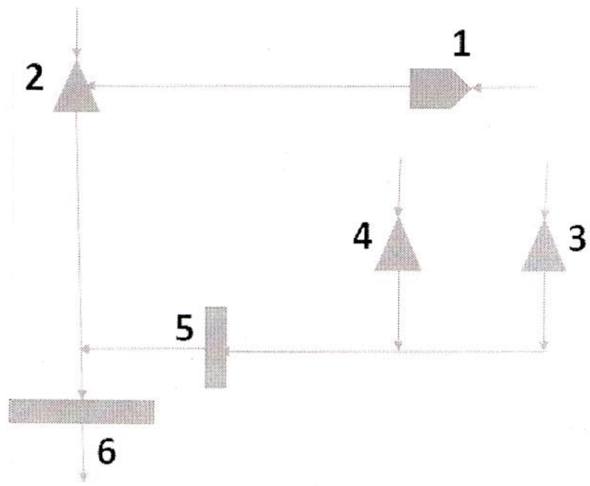
8. Prepare the data file, node-by-node for all the locations. The data must be entered in correct units as specified.

9. Keep the upper rule level at FRL and the middle and lower rule level as derived and operate the system. Find the failure months and reliability of demands in the order of their priority. First, adjust the lower rule level such that water supply failure months are reduced to the least possible. After finalizing the lower rule levels, modify the next priority demand rule levels and keep on updating till acceptable performance is achieved.

10. After optimizing the four lower rule levels, lower the upper rule levels, especially in the monsoon months, till the reliability of the system is not affected.

7.3.5. Miscellaneous Other Considerations in Conservation Operation Analysis

The present module simulates the conservation operation of a multi-reservoir system. Let us consider a system of three hydraulic structures: a reservoir with Node (1) without hydropower generation, a reservoir (2) without hydropower but it meets the demands of Node (6), a reservoir without hydropower which meets the partial demands of Node (5), a reservoir with hydropower which also meets the partial demands of Node (5), a diversion structure (5), and terminal diversion barrage (6) with some storage as shown in figure below. Miscellaneous considerations in the system that can be simulated with the current module are briefly described below using the given system as example.



a) Metric system of units has been adopted. Elevation, area, and volume are computed in the units of m, sq. m, and cubic meter.
b) A maximum of 100 hydraulic structures can be simulated for 35 years of daily data series (~ 13000 time steps). Same time step length is used for all structures while simulating a system. Further, all structures are simulated for the same number of time steps.
c) Two types of structures can be simulated: storage reservoir or diversion barrage/weir (with or without a specified storage). The type of structure is defined by the number of values in the Elevation-Area-Capacity-Seepage rate-Discharge capacity through PP (EACSD) table. If the number of levels in EACSD table is 1 (with all '0' values), it represents a diversion structure while if the number of levels are more than 1 and less than 500, then it represents a storage reservoir. Seepage rate (which increases with depth of water) is used to find the seepage loss from the reservoir from the prevailing water spread area. Discharge capacity through the PP also varies with depth of water depth above and is used to limit the possible flow of water from the PP.
d) It is not mandatory to increase the node numbers from upstream to downstream and any node number can be assigned to any structure. However, computation number is specified for each structure for sequencing the computations from upstream towards the downstream structures. All upstream structures should have computation number lower than the downstream structures.
e) While defining the node numbers of upstream structures of a node, only the <u>immediately upstream</u> structures of a node are specified. For example, in given example, there are 2 structures in the upstream of node 6 and their node numbers are 2 and 5 (specified as 2 5 in data file).
f) A system can be simulated with three operation policies: i) SLOP, ii) Rationing policy, and iii) Rule curve based policy. SLOP is a special case of rule curve

based policy in which all upper rule levels are set to FRL and all intermediate and lower rule levels (warning levels defined for different purposes) are set to MDDL.

g) The inflow series from intermediate free catchments of various structures and the precipitation depths over the projects are specified for complete water years (from June 1 to May 31 next year for India). 29 February in a leap year also needs to be accounted for separately. It is to mention that various demands and normal evaporation depths are specified at 10-daily time step (for daily and 10-daily analysis) while all such variables are specified at monthly time step for monthly analysis. For daily operation analysis, 10-daily demands and evaporation depths are equally distributed in various days of the 10-daily time step. Operation policy levels in all time steps are specified at monthly time steps. The operation levels for a reservoir can either remain constant for a month or they can be linearly interpolated for various intermediate days/10-days within a month by using an option.

   Precipitation input over the prevailing waterspread is added to the reservoir inflow. Further, if the reservoir water spread is less than that at FRL in any time step, then a proportion of the precipitation around the periphery is also converted to runoff (by using specified runoff factor) and added to the inflow.

h) To account for the variation of different demands in various years, annual demand multiplication factors are specified for all demands for different years of simulation period and the demand in any particular day/10-day/month is worked out accordingly. Thus, it is possible to consider variability of demands during the simulation period.

i) At the hydropower plants (PP), rating tables have been introduced for tail water rating as well as head-loss rating with respect to discharge through the power plant. One part of the irrigation demand [through Left Bank Canal (LBC)] passes through the PP while another part of the irrigation demand [through Right Bank Canal (RBC)] always by-passes the PP. Environmental flow always by-passes the PP. The outflow from the PP can either flow towards the d/s structure or it can join any other structure in the system [through a tunnel with specified lag time (in multiples of time step)]. The outflow from PP can also be routed out of the basin. However, only one PP can be considered at a dam site.

j) If the demands of a d/s structure are met by the releases from its immediately u/s structures, then the percent of d/s demands to be met from the structure needs to be specified. Further, the lag time from the u/s structure to the d/s structure is required so that release from u/s structure can be suitably timed to meet the d/s demands. If more than one structure (in parallel projects) are located above a d/s structure which can meet the demands of d/s structure, the release from u/s structure can also be based on the relative storage (above the all-demand rule curve level) of various structures for equitable operation of u/s structures. Otherwise, the specified percent of d/s structure can be released. These different policies of d/s demand satisfaction can be selected by using suitable options.

k) The environmental flow demand can be specified in two ways: either as the fixed demands at 10-daily/monthly time step or as the percent of inflow at a time step. Suitable option can be used.

l) The water can be diverted from any structure through a link transfer. In this case, the amount of water to be transferred at 10-daily/monthly time step is required. Further, the minimum level for link transfer, lag time of transfer, and the node to which link transfer is made also needs to be defined. Link transfer can be made to a node from multiple links also.

m) A notable addition in the present version of the software is related to the revision of EAC table due to reservoir sedimentation with time. If such an option is selected, then the annual volume of sediments trapped in the reservoir, type of reservoir, river bed level, and the amount of sedimentation (% of storage) after which revision computations are invoked, are required. If such option is selected, then EAC table is revised as soon as the specified sedimentation occurs in a reservoir and the revised EAC table is used in the operation analysis. Such revision also results in the increment of rule curve levels for various purposes which is also carried out internally.

n) Return flows from the domestic supply, and usage of water for left bank canal irrigation and the right bank canal irrigation can be considered at specified percent rates. For such flows, the node number of projects where the return flow will be received and the lag time (in multiple of time step) of return flows are need to be provided.

o) The losses (in percent) of water transfer from the d/s river reach of a project or in the link canal can be considered separately.

p) Below the rule curve level (warning level) for a particular demand, the supply for that demand is curtailed. There are two possibilities of level of curtailment. First is based on the fixed (specified) level of curtailment till next lower rule level is achieved while second is based on the linear increment in curtailment with the reduction in reservoir level up to a specified minimum supply percent which is defined separately for various water demands. In addition, critical supply percent is specified for various demands which is used for computing the reliability of water use for meeting the critical supplies.

q) Minimum release levels can be specified for various demands separately from a reservoir such that below such levels, the supply for a demand is stopped.

r) Maximum storage at a dam corresponds to the FRL (top of conservation pool) while the minimum storage refers to the Dead Storage Level (DSL) of a reservoir. It is mandatory to provide the EACSD table for a reservoir (in ascending or descending elevation order) from DSL to FRL and may be beyond. A specified storage at a diversion structure (without any level) can also be defined which can be used to temporarily store the excess water whenever available. If a reservoir reaches FRL, all the extra water is spilled in the d/s. Similarly, no release is made from reservoir for meeting any demand below DSL.

s) If the inflow series for a structure is not available, the same can be adopted from any other structure after multiplication with a specified factor.

t) Detailed working tables of all the projects are presented in the output file (*.coo) at the chosen time step. It also contains the input data for all projects along with their description. After the working tables, time reliabilities of various demands at different time steps and the volume reliability are specified. Further, time reliability for different levels of demands for various satisfaction levels for different months are presented separately.

Basic purpose of this module is to analyze the operation of a multi-reservoir system for conservation demands and assess the reliability of the system in meeting specified demands with historic inflows as inputs. It can help finalize the operation policies of projects and also design the demands/configuration of various projects.

4. Data Checks

In the module, several checks have been introduced to detect the likely errors while preparing the input data. Some of the checks performed by the module include:

d) After reading a group of data items, the program displays a message on the screen showing that the corresponding data items have been read properly. This facility is helpful in tracking the possible error as the user knows that for which structure and at which group of data, the error is encountered. The program reads in the entire data for a structure at a time.

e) E-A-C-S-D table of reservoir is checked. If the area (or storage capacity) at any reservoir level decreases with rising elevation, the program aborts and flags the line number in the E-A-C-S-D table for correction.

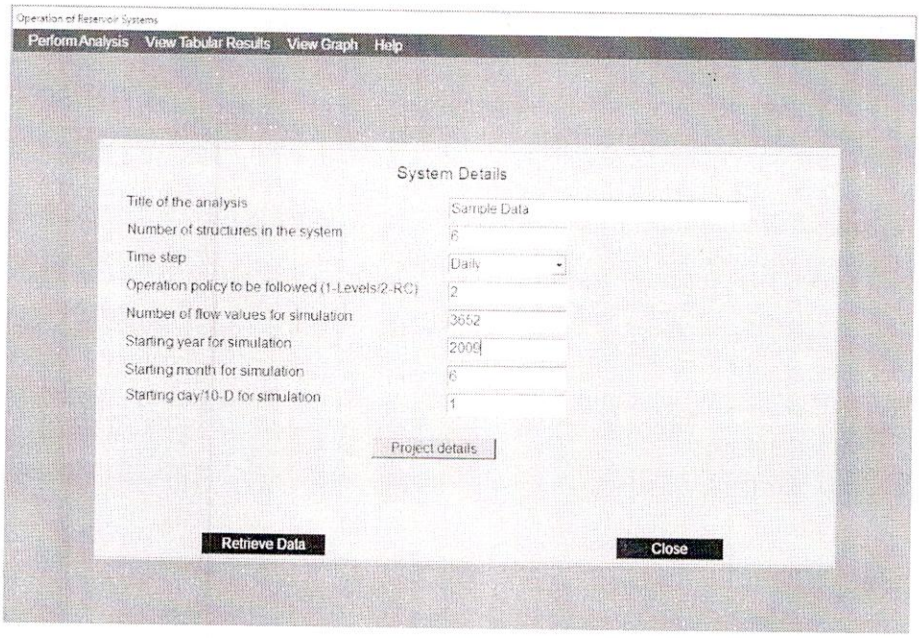
f) The storage capacity at each level in E-A-C-S-D table above the lowest level is checked by using the prismoidal formula. If the difference in the computed and specified storage capacity is greater than 10%, a message is flagged at the screen and in the result file after the presentation of Elevation-Area-Capacity-Seepage-Discharge capacity through PP table in the Input Data section. The program does not abort in this case.

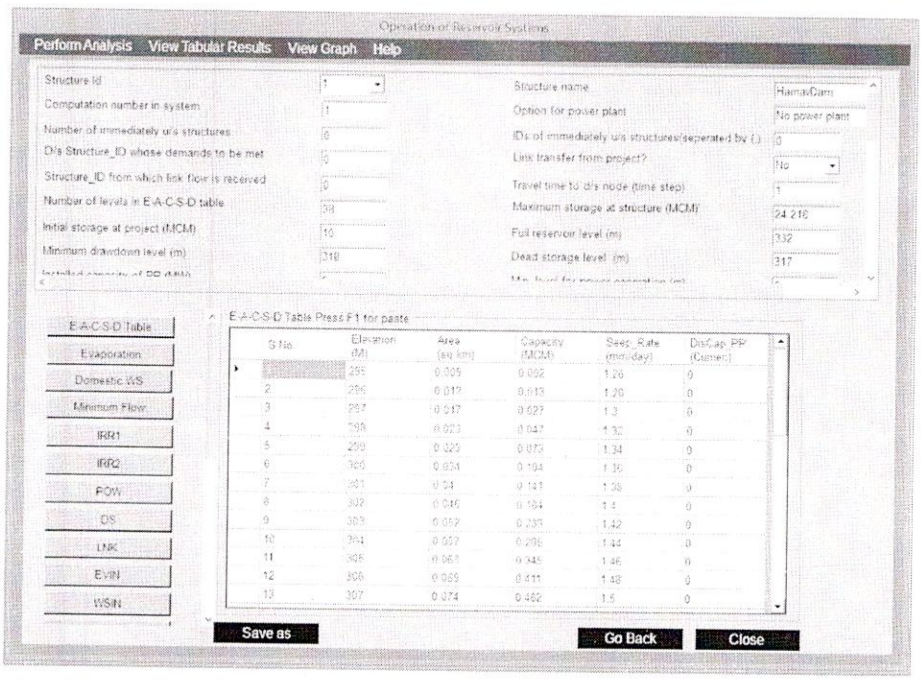
g) Node ID for any structure should be within 1 and the number of structures in the system, otherwise, a message is flagged.

5. Input Data Description

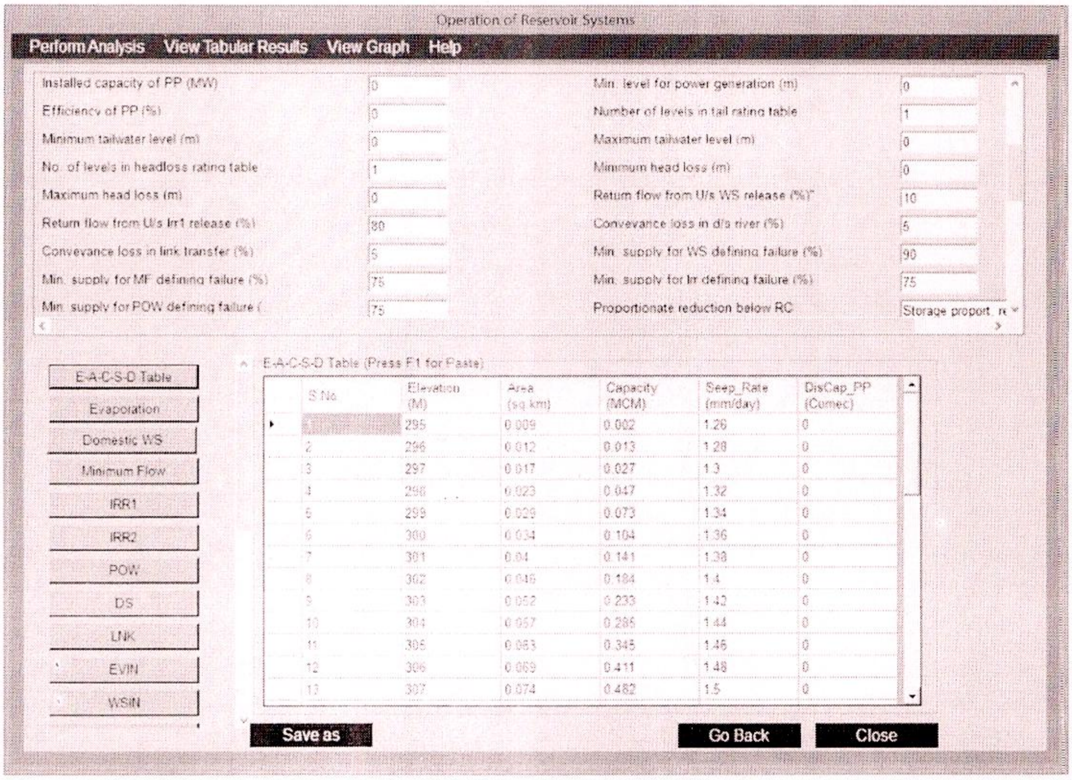
In this module, lots of data for each structure is required to be entered. Therefore, first the opening form appears in which general details of simulation and total number of structures in the system is entered. Then, each structure ID (or node number) is selected one-by-one and whole data related to a structure is entered. After entering all the data related to a structure, another structure ID (or node number) is selected for entry of its data.

The form for input of general data section of simulation analysis is shown in figure below. After filling general details of the system, general and tabular data for each structure is entered in another form as shown in next figure. The file extensions for the input and output files and for graphics files are ***.coi, *.coo, and *.cog*** respectively. In addition, some more output files are generated. One result file (*.eac) is generated which shows the periodic revised EAC tables for all reservoirs after specified sedimentation deposition. Another result file (*.wbp) is generated which shows the water balance for all projects in the basin at annual time step. Another result file (*.wbb) is generated which shows the average annual water balance components of the whole basin. Various inputs to the program are described below:

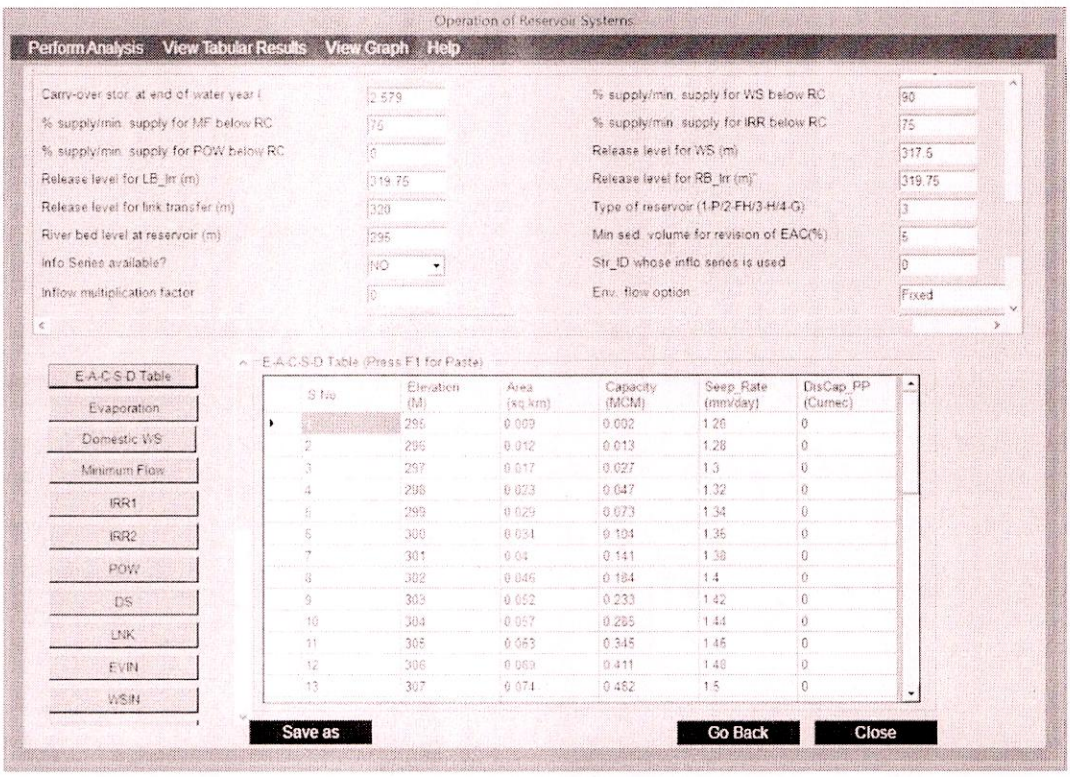




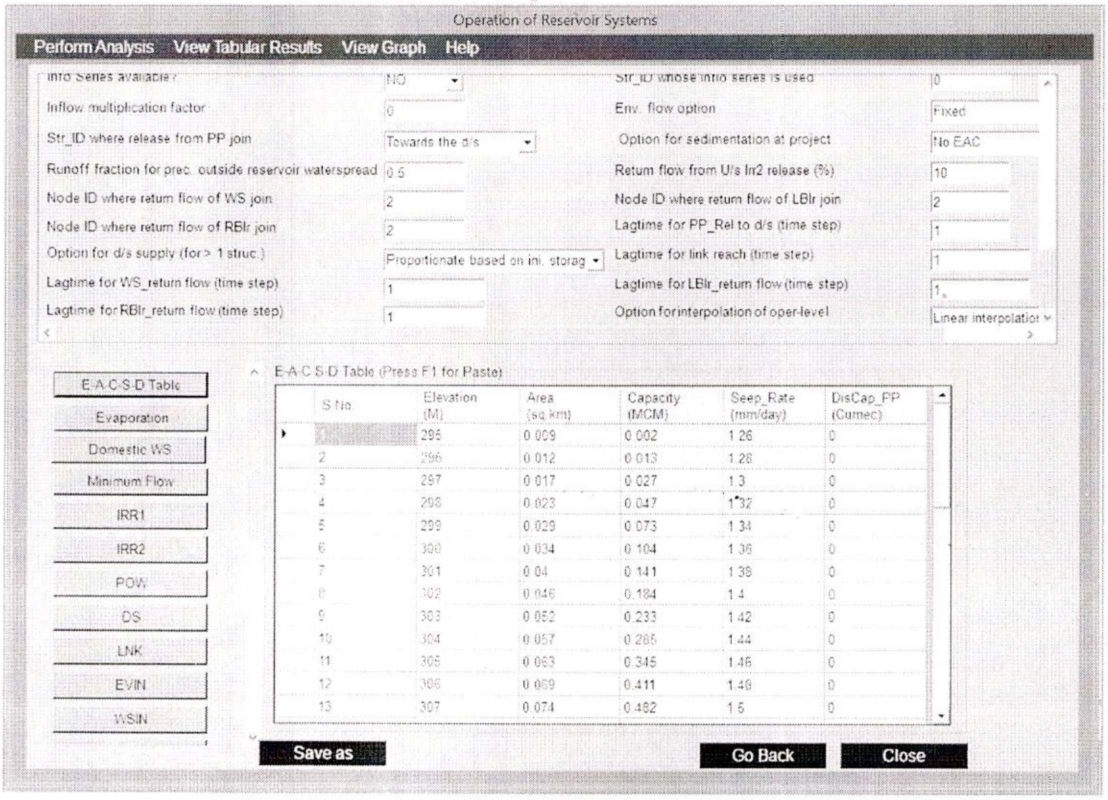
General and tabular data entry form for a structure in the system



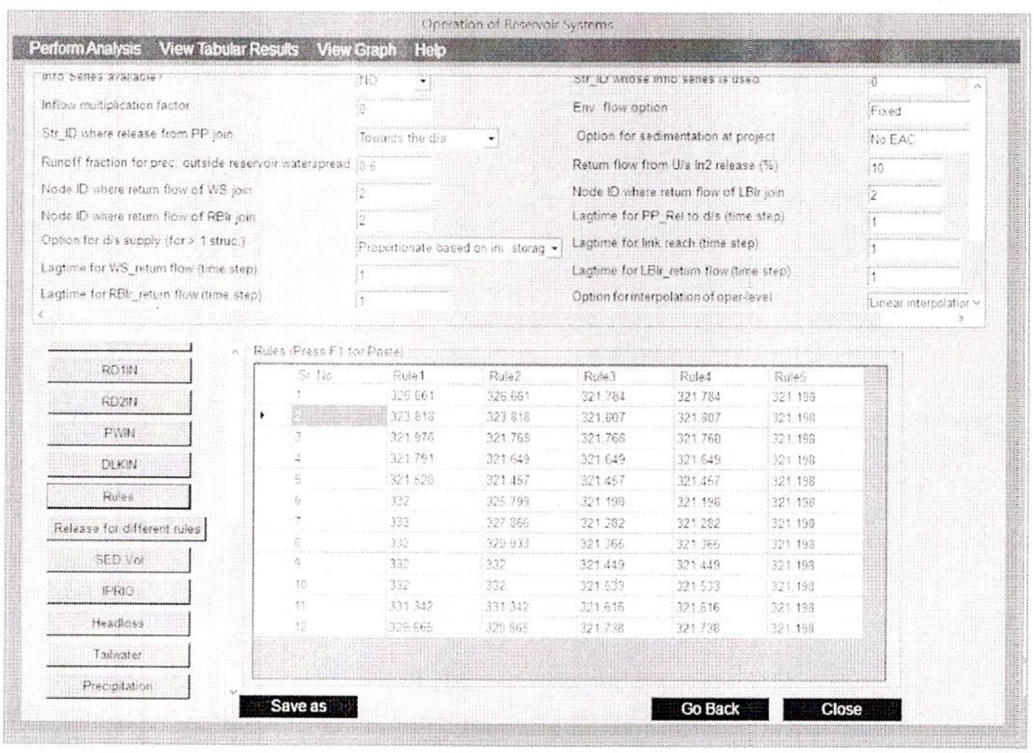
General and tabular data entry form for a structure in the system



General and tabular data entry form for a structure in the system



General and tabular data entry form for a structure in the system



Specification of rule curves in tabular data form for a structure

Title of the analysis

Specify the title of the data file containing general details of the analysis for remembrance at a later date (not more than 100 characters).

Number of structures in the system

Specify the total number of control structures in the system for which simulation analysis is to be carried out. Based on this information, corresponding number of numeric IDs can be opened for data entry of each structure. A maximum of 100 structures can be considered in a simulation analysis.

Operation policy to be followed

Specify the operation policy to be followed: '1' represents rationing policy while '2' represents policy of rule curves. SLOP can be simulated as a special case of rule curves as mentioned earlier.

Time step size (hour)

Conservation operation analysis can be carried out at daily or 10-daily or monthly time step. Select the appropriate time step based on the availability of inflow and precipitation data.

Number of time steps of simulation

Specify the number of time steps of simulation. Inflow values from the intermediate free catchments of all projects and the precipitation depths over the project waterspread areas would be required at all structures for the specified number of time steps.

Starting year of simulation

Specify the starting year (numeric) of the inflow sequence and precipitation at all structures. It is helpful in identifying a leap year and accounting for the extra day in February for daily time step analysis.

Starting month of simulation

Specify the starting month (numeric) of the simulation. Based on the day in the time sequence, the month is changed which also affects the rule curve levels and demands for a structure.

Starting day of simulation

Specify the starting day (numeric) of the simulation. Based on the day in the time sequence for daily time-step analysis, the months and years are changed which affects the rule curve levels and the demands for a structure.

After entry of these general details of the simulation, data for each hydraulic structure is entered as specified below:

Node number of structure

First, the node number of the structure (numeric) is specified. Its value should lie between 1 and the total number of structures in the system.

Name of structure

Specify the name of the structure in alphabetic.

Computation number in system (u/s-d/s)

Specify the computation number for each structure in the system. This is introduced such that analysis may proceed from u/s to d/s. Thus, data of various structures in the system can be specified in any order in the data form but the computation number helps in sequencing the simulation analysis from u/s to d/s.

Option of HP & flow through power plant

This option provides info about the hydropower production in a reservoir and the method of water supply through the power plant (PP). Hydropower production affects the total water demand at a time step. Further, it depends on the available head at any time. Since it is non-consumptive demand, the method of supply of other demands (say for domestic supply and left bank irrigation) through the PP affects the total required release from a reservoir in any time step. For example, if irrigation and domestic supply is passed through the power plant, then the required reservoir release will be maximum of the release either for producing hydropower or for left bank irrigation + domestic supply. Following options are specified in the combo box:

0 - No PP

1 - All release (domestic supply + LB irrigation) pass through PP

2 - Domestic supply only pass through PP

3 - Left bank irrigation only pass through PP

4 - Release for all demands bypass through PP

Select the suitable option for the reservoir. If there is no power plant and option (0) is selected, still, all data entry cells related to hydropower need to be filled.

Str_ID where release from PP join

Specify the node ID of the structure where the outflow from the PP will join. If it is '0' or the node ID of the d/s structure, then it will be released in the d/s natural river and will join the d/s structure. Otherwise, it will join the node ID of the specified structure. If it is specified as 101, then release through the PP will be sent out of the basin.

Lag time for PP release to d/s (time step)

Specify the lag time (in multiple of time step) required by the release through the PP to join specified structure. If it joins in the same time step, it is taken as '0'.

Number of immediately upstream structures

Specify the number of structures that are located immediately upstream of the present structure. The environmental flow, spill and the release through the PP from these upstream structures (if it is sent in d/s river) will be routed up to the d/s structure after specified lag time.

IDs of immediately upstream structures (space-separated)

Specify the IDs (node numbers) of the structures that are located immediately upstream of the present structure. **These must be space-separated** and their number depends on the number of immediately upstream structures.

D/s Str_ID whose demands to be met

If the present structure is required to meet the full/partial demands of any d/s structure (in addition to its own demands), then specify the ID (node number) of the d/s structure whose full/partial demands are to be met. **If there is no such d/s structure, enter 0.** D/s structure demands are given low priority as compared to the individual demands of present structure and the water for these demands is released only when the reservoir level exceeds the rule curve level for all demands. The amount of d/s demands to be met could either be a fixed percentage specified for different 10-daily or monthly time steps or it could depend on the available storage above the rule curve level for all demands. This is specified through following option.

Option for d/s supply (for > 1 structure)

If there are more than 1 immediately upstream structures (structures in parallel), then this option specifies whether a fixed proportion (say 20% in a time step) of d/s structure demands are to be met from present structure (select option as '1') or the amount of release from any immediately u/s structure depends on the relative storage in all immediately u/s structures (in parallel) above their corresponding rule curve levels for all demands (select option as '0'). In the second case, equitable release can be maintained in a better way from various immediately u/s parallel reservoirs.

Lag time to d/s node (time step)

If the present structure is required to meet the full/partial demands of any d/s structure, then specify the lag time of water transfer in the river reach in multiple of time step (say, 1-day or 2-day in case of daily time step and so on). If it joins in the same time step, it is taken as '0'. This lag time is used to plan the release from the u/s structure in advance for timely meeting the d/s demand.

Environmental flow option

Environmental flow can be specified either as a fixed volume for each 10-daily or monthly time step or it can be taken as a specified percentage of the inflow at a time step. If this option is taken as '0', then it represents specified % of inflow, and if it is taken as '1', then it represents fixed volume of water specified for each 10-daily or monthly time step.

Link transfer from project

Specify whether any link project is planned from the present structure (0-No;

1-Yes).

Str_ID to which link flow is sent

If a link is planned from the present structure, then specify the node ID of the structure where the link flow will be received. If it is '0', then link flow will not supplement the flow at any structure though water will be diverted from the present structure for specified link water demands at 10-daily or monthly time step.

Lag time for link transfer (time step)

If the present structure is required to meet the link demands, then specify the lag time of water transfer in the link reach in multiple of time step (say, 1-day or 2-day in case of daily time step and so on). If it joins in the same time step, it is taken as '0'. This lag time is used to plan the release from the present structure in advance for timely meeting the link demands.

Option for sedimentation at project

Specify whether sedimentation is to be considered at present project or not? If it is taken as '0', then No EAC change is considered due to sedimentation. However, if it is taken as '1', then EAC change due to sedimentation is duly considered as per the specified annual time series of sediment deposition.

Runoff fraction for precipitation outside reservoir waterspread up to periphery

Specify the runoff fraction to convert the precipitation on the periphery area of the reservoir (from outer periphery of waterspread at any time step up to the reservoir boundary at FRL). It is assumed that significant portion of this precipitation will find its way into the reservoir in the form of inflow. If it is not required to be considered, it may be taken as '0'.

Number of levels in E-A-C-S-D table

Specify the number of elevations for which corresponding water spread areas, cumulative storage capacity, seepage rate, and the discharge capacity through the PP are available in the E-A-C-S-D table. Based on the entered value, the form for entry of E-A-C-S-D table will automatically generate the specified number of empty cell rows for input of elevation, area, capacity, seepage rate, and the discharge capacity through the PP. For diversion structure, it is taken as '1' and all values of elevation, area, capacity, seepage rate, and discharge capacity are taken as '0'.

Maximum storage capacity (MCM)

Specify the storage capacity at FRL of the reservoir in MCM. As and when the reservoir storage rises above this value, water is spilled from the reservoir so as to bring it back to FRL or the upper rule curve level. It can also be specified for a diversion structure with a marginal storage but with no EACSD table.

Initial storage capacity at start of simulation (MCM)

Specify the initial storage of the reservoir in MCM at the start of simulation analysis. This can be taken as at FRL, MDDL or in-between FRL and MDDL.

Full reservoir level (m)

Specify the full reservoir level (FRL) of the reservoir (m). This is the maximum level of conservation zone beyond which water is spilled from the reservoir.

Minimum draw down level

Specify the minimum draw down level (MDDL) of the reservoir (m). This is the minimum level of conservation zone up to which various conservation demands (except for the highest priority domestic demand) can be met. Below this level, water is released only for the domestic demands.

Dead storage level

Specify the dead storage level (DSL) of the reservoir (m). This is the minimum level of conservation zone below which water is not released for any demand.

Installed capacity of power plant (MW)

Specify the maximum capacity of the power plant (MW). This will restrict the maximum energy that can be generated at a time.

Minimum reservoir level for power generation (m)

Specify the minimum reservoir level for power generation (m). This level is based on the minimum head for power generation. If the reservoir reaches below this level, hydropower is not generated.

Efficiency of power plants (%)

Every PP has some specified power generation efficiency (say 90% or so). This data is used to compute the actual hydropower production once the potential production is computed from the available net water head and turbine discharge.

Number of levels in tail rating table

Specify the number of discharge values through the power plant for which corresponding tail water levels (m) are available in the tail rating table. Based on this value, the form for entry of tail rating table will automatically generate the specified number of empty cell rows for the input of discharge (cumec) and tail water level (m).

Minimum tail water level

Specify the minimum tail water elevation (m) in the tail rating table. For discharges lower than the discharge corresponding to minimum tail water elevation, this value is used to compute the effective head for hydropower generation.

Maximum tail water level

Specify the maximum tail water elevation (m) in the tail rating table. For discharges higher than the discharge corresponding to maximum tail water elevation, this value is used to compute the effective head for hydropower generation.

Number of levels in head-loss rating table

Specify the number of discharge values from the power plant for which corresponding head-loss in the conveyance system are available in the head-loss rating table. Based on this value, the form for entry of head-loss rating table will automatically generate the specified number of empty cell rows for the input of discharge (cumec) and head-loss (m).

Minimum head loss

Specify the minimum head loss (m) in the head-loss rating table. For discharges lower than the discharge corresponding to minimum head-loss, this value is used to compute the net effective head for hydropower generation.

Maximum head loss

Specify the maximum head loss (m) in the head-loss rating table. For discharges higher than the discharge corresponding to maximum head loss, this value is used to compute the net effective head for hydropower generation.

Return flow from WS release (%)

Specify the percent return flow from domestic/industrial water supply from the reservoir. Generally, it is around 80%.

Return flow from left bank irrigation release (%)

Specify the percent return flow from the left bank irrigation release from the reservoir. Generally, it is of the order of 10 – 20%.

Return flow from right bank irrigation release (%)

Specify the percent return flow from the right bank irrigation release from the reservoir. Generally, it is of the order of 10 – 20%. It is specified separately so that different values of return flows for left and right bank canal commands could be considered.

Conveyance loss (%) in d/s river

It signifies enroute diversion or conveyance losses in percent in the d/s river section up to the d/s project. This component is added to the intended water demands so that the envisaged amount of water could be sent to meet the demands of the d/s project after accounting for the intermediate losses.

Conveyance loss (%) in link canal

It signifies the conveyance losses in percent up to the end of link canal. This component is added to the intended water demands of the link so that the envisaged amount of link demand could be met after accounting for the intermediate losses.

ID where return flow from WS join

It is quite possible that the return flow for the domestic supply from a project node does not join at the d/s node but some other location in the system. For this reason, this option has been added and one needs to specify the node ID where the return flow from the domestic supply is likely to supplement the river flows.

Lag time of return flow from WS

It is quite possible that the return flow for the domestic supply from a project node does not join in the same time step but after some lag time. For this reason, this option has been added to specify the lag time of return flow from the domestic supply to the specified node ID based on which the river flow is supplemented.

ID where return flow from left bank irrigation join

It is quite possible that the return flow for the left bank irrigation supply from a project node does not join at the d/s node but some other location in the system. For this reason, this option has been added and one needs to specify the node ID where the return flow from the left bank irrigation is likely to supplement the river flows.

Lag time of return flow from left bank irrigation

It is quite possible that the return flow for the left bank irrigation from a project node does not join in the same time step but after some lag time. For this reason, this option has been added to specify the lag time (in multiple of time step) of return flow from the left bank irrigation to the specified node ID based on which the river flow is supplemented.

ID where return flow from right bank irrigation join

It is quite possible that the return flow for the right bank irrigation supply from a project node does not join at the d/s node but some other location in the system. For this reason, this option has been added and one needs to specify the node ID where return flow from the right bank irrigation is likely to supplement the river flows.

Lag time of return flow from right bank irrigation

It is quite possible that the return flow for the right bank irrigation from a project node does not join in the same time step but after some lag time. For this reason, this option has been added to specify the lag time (in multiple of time step) of return flow from the right bank irrigation to the specified node ID based on which the river flow is supplemented.

Minimum supply for WS below rule curve and defining critical failure (%)

Generally, below the rule curve for a particular purpose, supply is reduced so the reduced supplies can be maintained throughout the water year. Minimum supply refers to the fixed minimum percent of domestic demands which are met below the corresponding rule curve level. Further, minimum supply percent also defines the critical failure condition such that if the supply at any time reduces below the specified percent, then it is considered as a critical failure time step which is never desirable. Therefore, while optimizing the rule curve levels for various purposes, it is always tried to have as less critical failures as possible.

Minimum supply for env. flow below rule curve and defining critical failure (%)

As mentioned earlier, minimum supply for env. flow refers to the fixed minimum percent of environmental flow demand which is met below corresponding rule curve level. However, if the reservoir level goes below the domestic supply rule curve level, then release for environmental flow is completely curtailed. Similarly, it also defines the critical failure condition for environmental flow demand.

Minimum supply for irrigation below rule curve and defining critical failure (%)

As mentioned earlier, minimum supply for irrigation refers to the fixed minimum percent of irrigation demand which is met below corresponding rule curve level. However, if the reservoir level goes below the environmental flow rule curve level, then release for irrigation is completely curtailed. Similarly, it also defines the critical failure condition for irrigation demand.

Min. supply for hydropower below rule curve and defining critical failure (%)

As mentioned earlier, minimum supply for hydropower refers to the fixed minimum percent of hydropower demand which is met below all demands rule curve level. However, if the reservoir level goes below the irrigation rule curve level, then release exclusively made for hydropower generation is completely curtailed. Similarly, it also defines the critical failure condition for hydropower demand.

Option for interpolation of operation levels or rule curve levels

As mentioned earlier, rule curve levels or the operation levels for different demands are specified for all 12 months. For a particular month, either we can take them constant for the whole month or we can linearly interpolate them in between the month for daily/10-daily operations. This option specifies whether we want linear interpolation in the intermediate time steps (select option with value '0') or fixed levels for the whole month (select option with value '1').

Option for proportionate reduction below RC

Below the rule curve level for a particular demand, the supply for the demand is curtailed so that reduced supplies can be maintained throughout the water year. There are two options of reduction in supply below a rule curve: either we reduce the supply in proportion to the available storage within two rule curve levels or we apply fixed curtailment. This option specifies whether we want proportionate reduction in accordance with available storage within two rule curve levels under consideration (select option with value '0') or fixed specified curtailment for any reservoir level within two rule curve levels under consideration (select option with value '1'). In the proportionate reduction case also (with option value '0'), the minimum supply for a demand is maintained till the reservoir level drops to the lower rule curve level (for next higher priority demand) after which supply for demand is completely curtailed.

Carry-over storage at end of water year

Specify the carry-over storage which is required to be maintained at the end of a water year. With sedimentation, the EACSD table is revised which results in the revision of specified rule curve levels for various demands. The specified carry-over storage is used to revise the rule curve levels.

Release level (m) for WS

There could be different off-take structures for different structures. To account for such variability, this option has been added. Specify the release level (m) for the domestic supply such that below the specified level, water may not be sent for domestic/industrial purpose.

Release level (m) for left bank irrigation

Specify the release level (m) for the left bank canal such that below the specified level, water may not be sent for left bank irrigation purpose.

Release level (m) for right bank irrigation

Specify the release level (m) for the right bank canal such that below the specified level, water may not be sent for right bank irrigation purpose.

Release level (m) for link transfer

Specify the release level (m) for the link canal such that below the specified level, water may not be sent for link transfer.

Type of reservoir

Select the type of reservoir (1 - Plain/2 - Foot-hill/3 - Hill/4 - Gorge) after finding its classification as per Elevation – Capacity plot on log-log scale.

River bed level (m)

Specify the original river bed level (m) at the dam site. The EACSD table should be specified from river bed level up to FRL for sedimentation analysis.

Minimum sedimentation for revision of EACSD (% of gross storage at FRL)

Specify minimum sediment volume as percent of gross storage at FRL which should deposit in reservoir for initiating the revision of EACSD table.

Inflow series available (0-Yes; 1-No)

This option is used to specify whether inflow series is available at a project or it is to be computed from inflow series of other structure (after multiplying the same with inflow modification factor).

Str_ID whose inflow series to be used

Specify the ID (node number) of the structure whose inflow series is to be used for computation of inflow series for the present structure.

Inflow multiplication factor

Specify the inflow modifying factor (multiplication factor) with which the inflows of the structure (with known inflows) are to be multiplied to get the inflow series for the present structure.

After the presentation of these general details of a structure (reservoir/diversion), tabular data are specified for the structure as mentioned below. It is again to mention that if the selected time step is daily or 10-daily, then the time steps of evaporation and various demands is 10-daily whereas if the selected time step is monthly, then the time steps of evaporation and various demands is monthly. The increments/decrements for different demands and the sedimentation volume are always specified for different years of the simulation period.

Normal evaporation depths (mm/day)

Specify the normal evaporation depth rates (mm/day) from the surface of a reservoir for each 10-daily/monthly time step of a water year. It is used to estimate the evaporation losses from the reservoir during each time step of simulation period.

Domestic supply demands (MCM)

Specify the base values of domestic supply demands from a reservoir for each 10-daily/monthly time step of a water year. These base values are multiplied with the annual increment/decrement to find the actual domestic supply demand in any time step of a year. This way, we can account for the variability of demands in various years. Generally, it is accorded the highest priority demand and water for this demand only can be supplied below MDDL up to DSL.

Minimum flow demand (in MCM or percent) in d/s channel

Specify the minimum flow demand (also called environmental flow demand) in the d/s reach of a structure for each 10-daily/monthly time step of a water year. It can be specified either in volume terms (MCM) or in percent terms for each time step of a water year. When specified in percent term, the minimum flow demand is calculated by multiplying the percent fraction of the time step with the inflow value at the time step. Generally, it is accorded the next-lower level priority in comparison to the domestic demand but higher priority in comparison to irrigation/hydropower demands. Water for this demand is supplied only up to MDDL and not below.

Left bank irrigation demand (MCM)

Specify the left bank irrigation demand which is assumed to pass through the hydropower plant. If there is no PP, this demand can be kept as '0' and all irrigation demand can be specified as the right bank irrigation demand. Generally, it is accorded the next-lower level priority in comparison to the environmental flow demand. Further, since it may have lower or higher priority in comparison to the hydropower demand, a time series is required (as mentioned later) to specify the relative priority between irrigation and hydropower in each time step of a water year. However, within the left bank and right bank irrigation, left bank irrigation is accorded higher priority as some incidental power also gets generated. Water for this demand is supplied only up to MDDL (or environmental flow rule curve level, whichever is higher) and not below.

Right bank irrigation demand (MCM)

Similarly, specify the right bank irrigation demand which is assumed to by-pass the hydropower plant. If there is no PP, all irrigation demand is specified as the right bank irrigation demand. Priority levels for this demand have been detailed above. Water for this demand is supplied only up to MDDL (or environmental flow rule curve level, whichever is higher) and not below.

Hydropower demand (MU)

Specify the hydropower demand (in million units) for various 10-daily/monthly time steps of a water year. If there is no PP, this demand is specified as '0'. Generally, it is accorded the next-lower level priority in comparison to the environmental flow demand. Further, since it may have lower or higher priority in comparison to the irrigation demand, a time series is required (as mentioned later) to specify the relative priority between irrigation and hydropower in each time step of a water year. Water for this demand is supplied only up to MDDL [or environmental flow rule curve level (if it has higher priority in comparison to irrigation), whichever is higher] and not below. However, if it has lower priority in comparison to irrigation, then water for this demand is supplied up to MDDL (or irrigation rule curve level, whichever is higher).

Priority between irrigation and hydropower demand

Specify the priority between irrigation and hydropower for various 10-daily/monthly time steps of a water year. '0' refers to higher priority for irrigation while '1' refers to higher priority for hydropower. This relative priority decides the applicable rule curve levels for operation of irrigation and hydropower demands. It is to mention that higher is the priority, lower is the applicable rule curve level and vice versa.

Demand percent for d/s demands

Specify the percent of d/s demands to be met from the present structure for various 10-daily/monthly time steps of a water year. While operating any u/s structure at a time step, the net demand of the d/s structure is determined (after accounting for the storage and intermediate flows at the d/s structure) and the specified percent at the time step is multiplied with the net demand to estimate the d/s demand to be met from the u/s structure. However, if there are two or more u/s structures in parallel and option is selected for equitable distribution of release for d/s demand in accordance with their relative storages above all-demand rule curve levels, then the demand percent information is not utilized. It is to mention that d/s demands are accorded the next-lower level priority in comparison to all individual demands of the present structure. However, they are accorded higher priority in comparison to link demands. Water for d/s demands is supplied only when the reservoir level exceeds the all-demand rule curve level and in no case below the MDDL.

Link transfer demand

Specify the link transfer demands to be met from the present structure for various 10-daily/monthly time steps of a water year. Link transfer demands are accorded the next-lower level priority in comparison to all individual demands of the present structure and the demands of d/s structure. Water for link demands is supplied only when the reservoir level exceeds the all-demand rule curve level and in no case below the MDDL.

Annual percent change in Evaporation depths

It is very difficult to specify the evaporation/demands at daily time step as it would increase the dimensions of the module to unmanageable proportions. Annual percent change for evaporation and various other demands has been introduced to account for the variable evaporation depths and demands in different years. Thus, actual evaporation/demand in a time step is estimated by modifying the base evaporation/demand with the annual percent change of the year of time step. Specify the annual percent change for evaporation for different years of the simulation period. Annual percent change variables for evaporation and demands can also be used to visualize the effects of climate changes on operation of reservoir systems.

Annual percent change in WS demand

Specify the annual percent change for domestic demand for different years of the simulation period. It can account for the increase in human and cattle populations and industrial development resulting in increased demands.

Annual percent change in minimum flow demand

Specify the annual percent change for minimum flow demand for different years of the simulation period. It can account for the increase in environmental flow demands of the habitat.

Annual percent change in left bank irrigation demand

Crop water demands are largely affected by the meteorological variables which may modify with changing climate and time. Specify the annual percent change for the left bank irrigation demands for different years of the simulation period. It can account for the increase in crop water demands in the command area.

Annual percent change in right bank irrigation demand

Since different commands may respond differently to various variables affecting the crop water demands, separate variables have been defined for the left bank and right bank canal irrigation. Specify the annual percent change for the right bank irrigation demands for different years of the simulation period.

Annual percent change in power demand

Similarly, the hydropower demands may increase with time because of population rise, social and industrial development, and changing climate. Specify the annual percent change for hydropower demands for different years of simulation.

Annual percent change in link demand

As mentioned above for various demands, link demands may change with time. Specify the annual percent change for the link demands for different years of the simulation period.

Upper rule curve levels (m)

Specify the upper rule curve levels (m) for a reservoir for each month of a water year. Above the upper rule curve level, water is spilled from the reservoir. It also represents the maximum limit of reservoir storage.

All-demand rule curve levels (m)

Specify the all-demand rule curve levels (m) for a reservoir for each month of a water year. Above the all-demand rule curve level in a time step, water can be released in full to meet all demands of the reservoir. Further, above this rule level, water can be released to meet the demands of d/s structure as well as the link demands. However, below this rule curve level, releases for the fourth priority demand (hydropower/irrigation) are curtailed while full supply is made for other three higher priority demands (irrigation/hydropower, environmental flow, and domestic demand).

Rule curve levels (m) for irrigation/hydropower demands

If irrigation has higher priority than hydropower, then these rule curve levels represent the rule curve levels for irrigation, otherwise for hydropower. Specify these rule curve levels (m) for each month of a water year. Above this rule curve level in a time step, curtailed release for the fourth priority demand and full release for the third priority demand are made. However, below this rule curve level and up to next higher priority demand rule curve level, supply for fourth priority demand (say, hydropower) is completely stopped while partial releases are made for the third priority demand (say, irrigation) and full supply is made for other two higher priority demands (environmental flow and domestic demand).

Rule curve levels (m) for minimum flow demands

These rule curve levels represent the rule curve for the second priority minimum flow demand (or environmental flow demand). Specify these rule curve levels (m) for each month of a water year. Above this rule curve level in a time step, curtailed release for the third priority demand (say, irrigation) and full release for the second priority demand (say environmental flow) are made. However, below this rule curve level and up to next higher priority demand rule curve level, supply for third priority demand (say, irrigation) is completely stopped while partial releases are made for the second priority demand (say, environmental flow demand) and full supply is made for other higher priority demand (domestic demand).

Rule curve levels (m) for domestic demands

These rule curve levels represent the rule curve for the top priority domestic/ industrial demands. Specify these rule curve levels (m) for each month of a water year. Above this rule curve level in a time step, curtailed release for the second priority demand (say, environmental flow) and full release for the top priority demand (say, domestic supply) are made. However, below this rule curve level up to DSL, supply for second priority demand (say, environmental flow) is completely stopped while partial releases are made for the top priority demand (say, domestic supply).

Sediment volume deposited in reservoir (MCM)

Specify the annual sediment volume (MCM) that would deposit in the reservoir storage. Once the specified volume of sediments get accumulated in the reservoir storage, the empirical area reduction method is invoked which revises the EACSD table for further computations. for which new zero elevation and sediment deposition profile are to be estimated by empirical area reduction method.

Original E-A-C-S-D table

Clicking on the ***E-A-C-S-D Table*** button opens a table for entry of elevation, area, capacity, seepage rate, and discharge capacity through the power plant of the reservoir. The number of cells depends on the data specified in the cell corresponding to number of data points in E-A-C-S-D table.

Tail-water rating table

Clicking on the ***Tail-water Rating Table*** button opens a table for entry of discharge (cumec) through the power plant and the corresponding tail water elevation (m). The number of cells depends on the data specified in the cell corresponding to number of levels in tail-water rating table.

Head-loss rating table

Clicking on the ***Head-loss Rating Table*** button opens a table for entry of discharge (cumec) through the power plant and the corresponding head-loss (m) through the conveyance system of hydropower plant. The number of cells depends on the data specified in the cell corresponding to number of levels in head-loss rating table.

Successive supply curtailment table

Clicking on the ***Supply Curtailment Table*** button opens a table for the entry of percent release for different demands (domestic supply, environmental flow, left-bank irrigation, right-bank irrigation, hydropower, d/s structure demands, and link transfer demands) at/below the specified rule curve or operation levels. This table is used when the rationing policy is used for the operation of a reservoir rather than the rule curve based policy.

Inflow Time Series

Clicking on the ***Inflow Time Series*** button opens a table for entry of inflow values in various time steps of analysis period. Number of cells in the table depends on the data specified for number of time steps of simulation.

Precipitation Time Series

Clicking on the ***Precipitation Time Series*** button opens a table for entry of precipitation depths over the reservoir area in various time steps of analysis period. Number of cells in the table depends on the data specified for number of time steps of simulation.

7.3.6. Steps of Analysis

The following are the steps for using the conservation operation module:

i) Go to the ***Conservation Operation*** module. The data form will be displayed for entry of general details about the simulation as shown in figure of system shown above. Fill the form and then click on the ***'Project Details'*** button for entry of data for individual structures in the system.

j) It is also possible to retrieve an already existing data file by clicking on the ***Retrieve Data*** button or generate a new file by clearing the default data (by clicking on the ***Clear*** button) in the opening data form and fill all the data cells.

k) Next, select the ***Structure ID*** and then enter all the general details and tabular data for the selected structure. It is important to fill all the values in the form cells **in specified units**.

In various tabular data, it is also possible to ***Copy-Paste*** the data of all columns from MS-Excel. In that case, copy the data of all columns together from MS-Excel and bring the cursor to the first row in the table and press F1 (function key). Data will get pasted in all columns in the table. Check that data are present in all cells of the table **in specified units**.

l) After entry of all data cells in the form for a structure, click on the ***Save Data*** button. A separate window for saving the data file will appear. First select the desired directory and then specify the desired filename for the data file. The file will be saved as ***.coi*** file. The extension will be automatically attached with the filename. If one wants to add the data for another structure, then he/she can select the Structure_ID. This will also automatically save the entered data for the previous structure.

m) After entering the data for all structures in a system, click on the ***Perform Analysis*** button which will open-up a form for the specification of input and output files before the execution of the related program. First click on the ***Input File Name*** cell and then click on the ***Browse*** button. This will open a window for selecting the input file. Go to the desired directory and select the requisite data file. Click on the ***Open*** button to select the file. The file along with the path will appear in the ***Input File Name*** cell. Next, click on the ***Output File Name*** cell and repeat above steps. The filename along with the path will appear in the ***Output File Name*** cell.

n) After specifying the input and output filenames along with their location, the ***Run*** button gets **activated**. Click on the ***Run*** button to execute the related program with the specified input and output filenames.

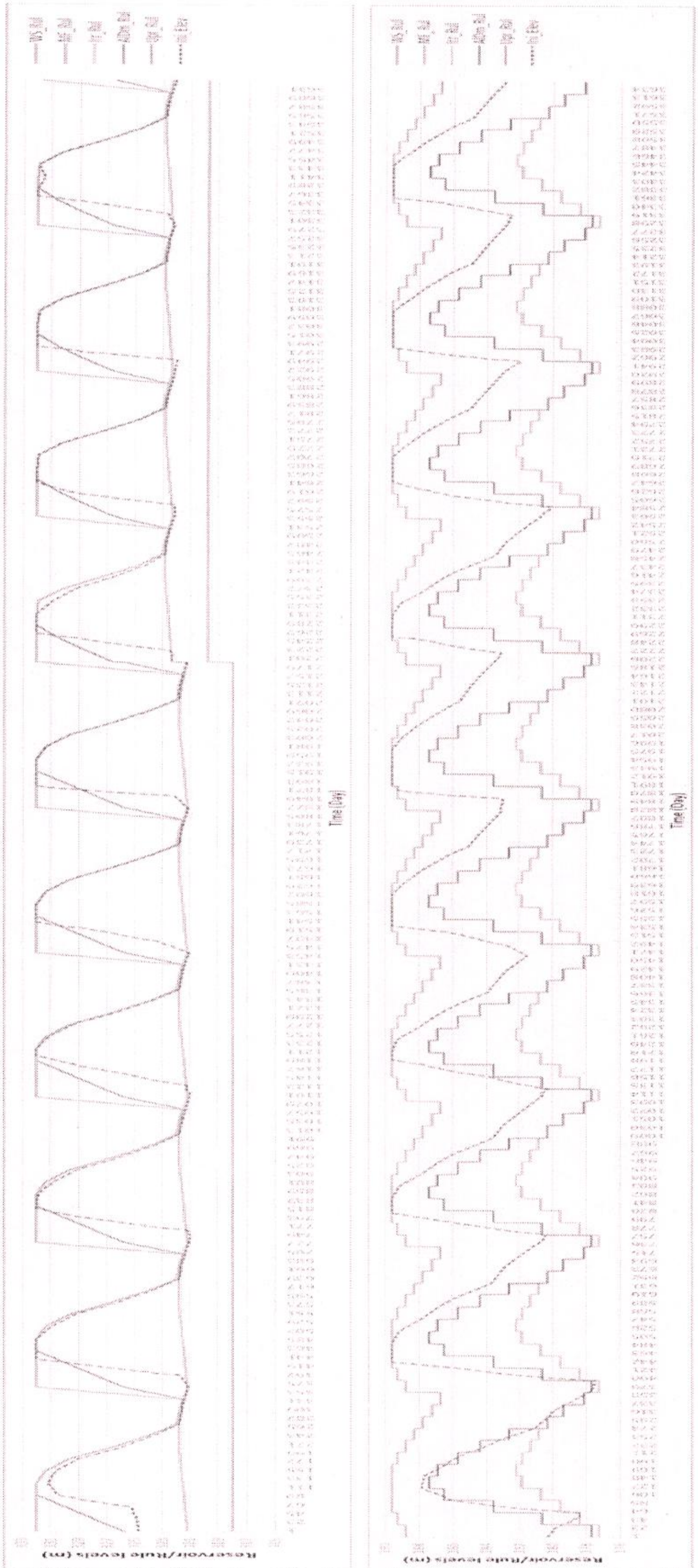
o) The program runs in a window which closes automatically after the program execution is complete and the results of simulation analysis are saved in the output file.

p) Click on the ***View Tabular Results*** button. To view data/results in tabular form, click on the ***Tabular*** button which will invoke the ***Notepad***. Click on the ***File*** and then ***Open*** and a window for file selection will appear. Go to the desired directory and select the requisite Input/Output filenames to see Input/Output files. It needs to be mentioned here that in this window, only files with extension ***.coi, *.coo, *.eac, *.wbp, and *.wbb*** will be displayed. Select the desired filename and click on the ***Open*** button. The file will be displayed in the **Notepad**.

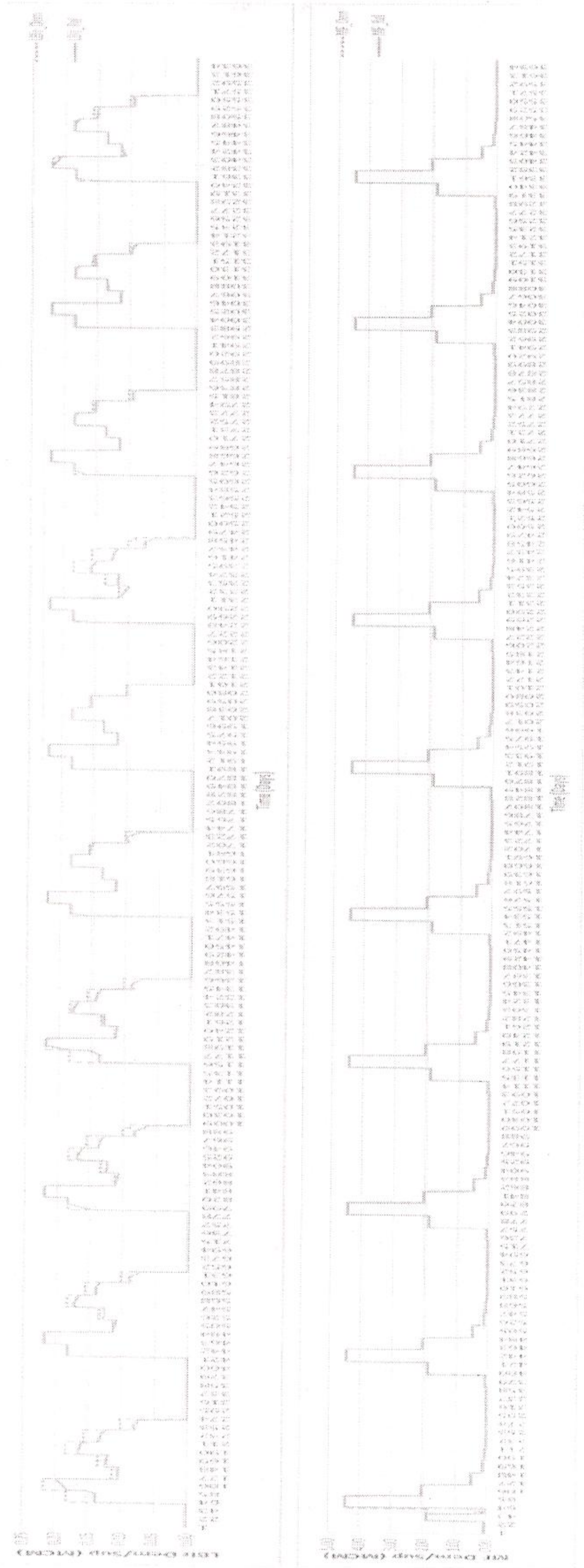
q) Since the varied results of a number of structures are involved in the output file, the presentation of results in the software in graphical form is avoided. However, built-in graphs have been prepared in MS-Excel for presentation of various outcomes for different structures which can be modified as per the requirement. Open the graphical file (*.cog) in MS-Excel as ***"Delimited"*** file with ***"Space"*** delimiters and with column data format as ***"General"***. The file will open in a separate MS-Excel sheet. Select and copy the whole worksheet and paste it in ***"Input"*** worksheet of ***"CONS_Graph.xlsx"*** file of MS-Excel which is already built in. The graphs can be copied and pasted anywhere in a document. The graph for the sample analysis are shown in figure below. Following graphs can be prepared for a reservoir:

- Plot of rule curve levels and variation of reservoir level with time
- Demand v/s release for domestic supply
- Demand v/s release for environmental flow
- Demand v/s release for irrigation
- Demand v/s release for hydropower
- Demand v/s release for link transfer

r) Close the ***Conservation Operation*** module by clicking on the ***Close*** button.



Plot of rule/reservoir levels for two reservoir with/without interpolation



Plot of different demands and their releases

7.4. *Real-Time Conservation Operation*

When a reservoir is operated as per the rule curve based operation policy, the release from the reservoir for various demands depends on the current day, month, and year, finalized rule curve levels for various purposes, and the current water level in the reservoir. As specified in the *help* file associated with the *"Initial Rule Curve Derivation"* module, different rule curve levels are derived for different demands depending on their relative priority. Though the release for various demands can be manually decided on the basis of specified rule curve based operation policy, it becomes a cumbersome daily exercise.

The basic purpose of this module is to help the operator in deciding the releases from the reservoir for various purposes as per the finalized rule curve based operation policy and depending on the current year, month, day and the current water level in the reservoir. The current year info is used to find the number of days in the month of February (if it is leap year, then 29, otherwise 28). Based the current day of a month, rule curve levels (specified at the beginning and end of the month) are linearly interpolated and corresponding storages are worked out. Thus linear variation of different rule curve levels within a month is taken into account while deciding the release for different purposes.

7.4.1. Data Checks

Some of the checks performed by the module include:

a) EAC table of reservoir is checked. If the area (or storage capacity) at any reservoir level decreases with rising elevation, the program aborts and flags the line number in the EAC table for correction.
b) The storage capacity at each level in EAC table above the lowest level is checked by using the prismoidal formula. If the difference in the computed and specified storage capacity is greater than 10%, a message is flagged at the screen and in the result file after the presentation of Elevation-Area-Capacity Table in the Input Data section. The program does not abort in this case.
c) If there is error in the entered current Year, Month, or Day, a message is flagged and the program aborts. Maximum limits of year, month and day are 2100, 12, and 31 respectively. If the day exceeds the maximum number of days in the specified month, the program aborts. In leap year, maximum number of days in February month is 29 while in non-leap year, it is 28.
d) If there is error in the entered current reservoir level for the day, a message is flagged and the program aborts. The reservoir level must be within the MDDL and the FRL.

7.4.2. Input Data Description

The form for input in general data section and tabular data is shown in Figure – 1. The file extensions for the input and output files are ***.cri*** and ***.cro*** respectively.

Title of the analysis

Specify the title of the data file containing general details of the analysis for remembrance at a later date (not more than 100 characters).

Full reservoir level

Specify the full reservoir level (FRL) of the reservoir (m). This is the maximum level of conservation zone beyond which water is spilled from the reservoir.

Minimum Draw Down level (m)

Specify the minimum draw down level (MDDL) in m up to which water is released for meeting various demands. This is the minimum level of conservation zone beyond which water is not released for conservations demands except for emergency highest priority demands.

Number of levels in EAC table

Specify the number of elevations for which corresponding water spread areas and cumulative storage capacity are available in the EAC table. Based on the entered value, the form for entry of EAC table will automatically generate the specified number of empty rows for input of EAC values.

Option of reducing demands below rule curve levels

Two options have been specified for reducing demands below the rule curve levels: a) Proportionate reduction (specified with 0), and b) Reduction by a fixed percent (specified with 1). In the proportionate reduction, if the reservoir level on any day falls below the specified rule curve level for a particular demand, then the release for the demand is reduced in proportion to the available storage in the reservoir (above the rule curve level for the next higher priority demand) in comparison to the total storage between the rule curve level for the demand under consideration and the rule curve level for the next higher priority demand.

On the other hand, in fixed percent reduction, a fixed percentage is specified for various demands and the release reduction is made only by the specified fixed percent till the storage content for a particular demand gets exhausted.

Method of supply of water through power plant

This option provides information about the passage of water for various demands either through the power plant (PP) or by-passing the PP. Hydropower production affects the water demand. Further, it is not constant and depends on the available net head at any time. However, since it is non-consumptive demand, the method of supply through PP affects the total water demands from a reservoir. Different methods are specified in terms of an integer as given below:

0 - No power plant at a reservoir

1 - Release for all purposes (except env. flow) pass through the PP.

2 - Only highest priority demand (say domestic supply) pass through the PP.

3 - Only third priority demand (say irrigation) pass through the PP.

4 - No release pass through PP.

Irrigation demand is bifurcated in to two demand series – one passing through the PP and another by-passing through PP. Environmental flow always by-passes the PP.

Installed capacity of power plant (MW)

This refers to the maximum capacity of the power plant (MW). This will restrict the maximum power that can be generated at a time. This option will be active only if the cell corresponding to method of supply through power plant is greater than 0.

Tail water elevation (m)

Average tail water elevation of the PP is specified so as to compute the net head. Though it may vary with discharge, it is taken as constant here. This option will be active only if the method of supply through PP is greater than 0.

Minimum level for power generation (m)

Specify the minimum reservoir level for power generation (m). If the reservoir goes below this level, hydropower cannot be generated. This option will be active only if the method of supply through power plant is greater than 0.

Efficiency of power plant (%)

Every power plant has its own efficiency (say, 85% or 90% or so). It is used to compute the water demands for generating hydropower from net effective head. This option will be active only if the method of supply through PP is greater than 0.

Average head loss (m)

Specify the average head loss (m) that may occur in the conveyance system so as to compute the net head for hydropower production. This option will be active only if the cell corresponding to method of supply through PP is greater than 0.

Priority between irrigation and hydropower

Though generally irrigation is accorded higher priority in comparison to the hydropower production, it is possible to analyze opposite scenarios also. If irrigation is assigned higher priority (specified by 0), it is assigned Priority – 3 followed by hydropower (Priority – 4). If hydropower is assigned higher priority (specified by 1), it is assigned Priority – 3 followed by irrigation (Priority – 4). This option will be active if the cell corresponding to method of supply through power plant is greater than 0.

E-A-C table

Clicking on the ***E-A-C Table*** button opens a table for entry of elevation, area, and storage capacity of the reservoir. The number of cells depends on the data specified in the cell corresponding to number of levels in EAC table.

Demand series

Clicking on the ***Demand Series*** button opens a table for entry of water and hydropower demands with different priority. First and second columns represent the demands (MCM) corresponding to the highest priority (say, domestic/industrial supply) and second highest priority (say, environmental flow) respectively. Third and fourth columns represent the irrigation demands (MCM) passing through the PP and by-passing the PP respectively. Fifth column represents the monthly hydropower energy demands (MKwH) in million units. The relative priority between irrigation and hydropower is specified through a separate factor as mentioned in general section.

Rule curve levels (m) for different purposes

Clicking on the ***Rule Curve Levels*** button opens a table containing columns for entry of different rule curve levels for different purposes. The second column represents the rule curve levels for highest priority (Priority-1) demands while subsequent three columns represent rule curve levels for subsequent lower priority demands (say, third Column for Priority-2 demands, fourth Column for Priority-3 demands, and fifth Column for Priority-4 demands). Final column represents the upper rule curve levels (for spilling). It is to mention that higher is the priority of demand, lower will be the rule curve level for a particular month.

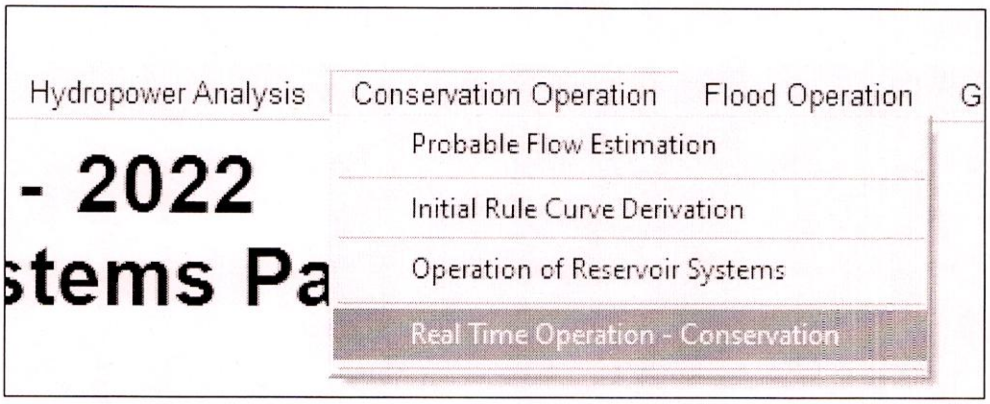
Evaporation depths (mm)

Clicking on the ***Evaporation depths*** button opens a table for entry of evaporation depths (mm) in different months of a year.

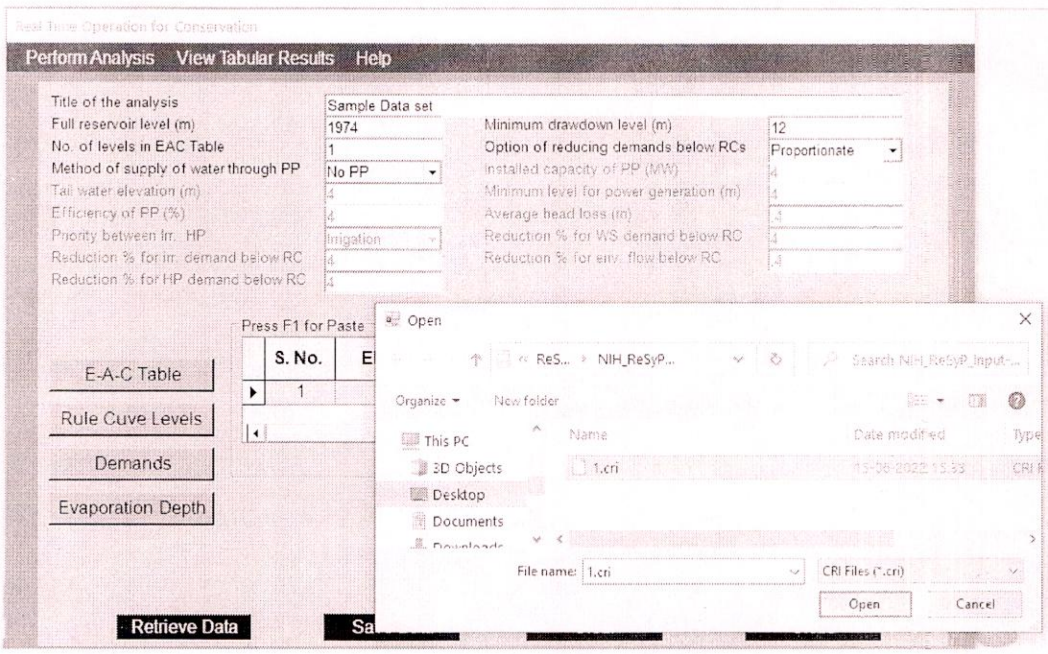
7.4.3. Steps of Analysis

The following are the steps for using the real-time conservation operation module:

a) Select the ***Real-Time Conservation Operation*** from ***Conservation Operation*** module. The data form will be displayed for entry of general details and tabular data.



b) Either retrieve an already existing data file by clicking on the ***Retrieve Data*** button or generate a new file by clearing the default data (by clicking on the ***Clear*** button) in the opening data form and fill all the data cells.



c) After entry of all data cells in the general data section, a blank **E-A-C Table** form appears in the lower part of the form for input of elevation, area, and storage capacity values. Click on the ***E-A-C Table*** button and fill all the values in the table **<u>in specified units</u>**.

d) Click on the ***Demands*** button. A blank table appears in the lower part of the form for input of monthly demand values (in MCM) that are to be considered for deriving various rule curve levels. In a run, rule curve levels can be derived for a maximum of four demands (domestic supply, environmental flow, irrigation, and hydropower in the order of priority). If a particular demand does not exist at a reservoir, the demand series for this demand is considered the "0".

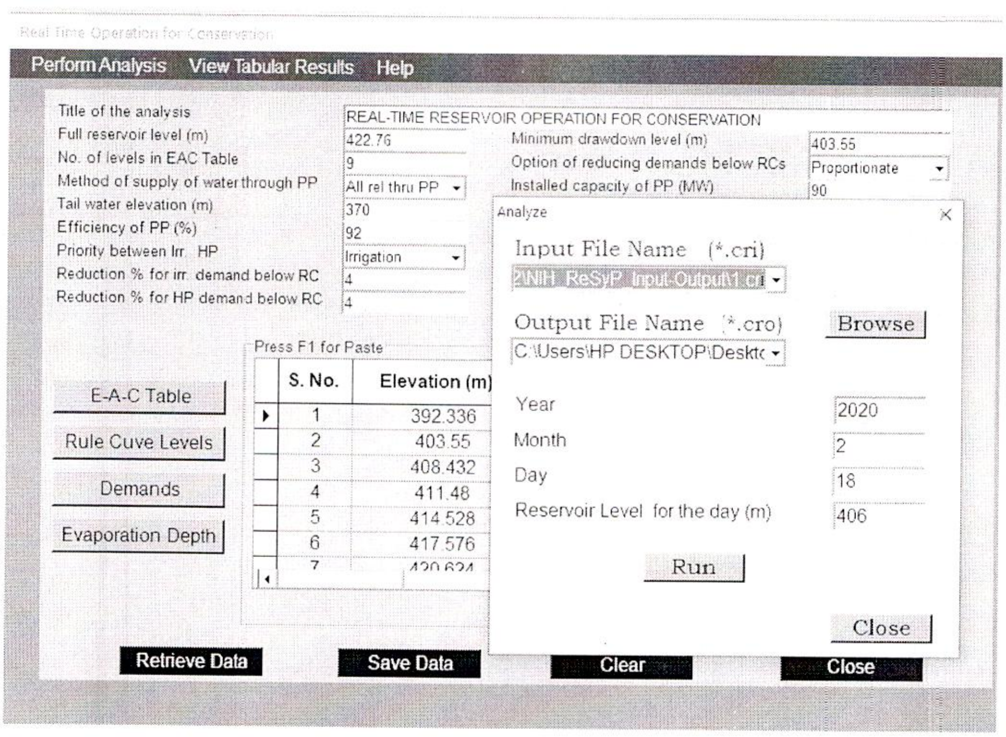
e) Click on the ***Rule Curve Levels*** button. A blank table appears in the lower part of the form for input of monthly rule curve levels for different purposes with different priorities. A maximum of five rule curve levels (m) can be specified: Four rule curves for four demands (water supply, environmental flow, irrigation, and hydropower in the decreasing order of priority) and finally the upper rule curve (for spilling). If a particular demand does not exist at a reservoir, the rule curve level for this demand is considered the same as for its next higher priority demand.

f) Click on the ***Evaporation Depth*** button. A blank table appears in the lower part of the form for input of monthly evaporation depths (in mm).

   In various tabular data, it is also possible to ***Copy-Paste*** the data of all columns from MS-Excel. In that case, copy the data of all columns together from MS-Excel and bring the cursor to the first row in the table and press F**1** (function key). Data will get pasted in all columns in the table. Check that data are present in all cells of the table **in specified units**.

g) After entry of all data cells in the form, click on the ***Save Data*** button. A separate window for saving the data file will appear. First select the desired directory and then specify the desired filename for the data file. The file will be saved as ***.cri*** file. The extension will be automatically attached with the filename.

h) Click on the ***Perform Analysis*** button which will open-up a form for the specification of input and output files before the execution of the related program. First click on the ***Input File Name*** cell and then click on the ***Browse*** button. This will open a window for selecting the input file. Go to the desired directory and select the requisite data file. Click on the ***Open*** button to select the file. The file along with the path will appear in the ***Input File Name*** cell. Next, click on the ***Output File Name*** cell and repeat above steps. The filename along with the path will appear in the ***Output File Name*** cell.

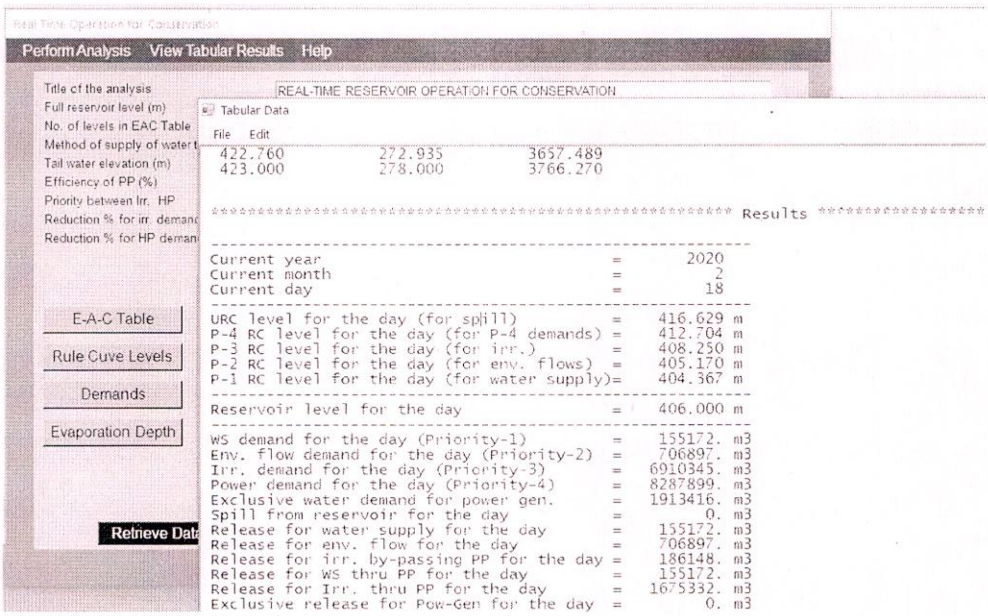


Next, enter the empty cells corresponding to the Year, Month, and Day and the Reservoir elevation (m) for the day. The form for entry of instantaneous values is displayed in a window as shown in Figure above.

i) After specifying the input and output filenames along with their location and after filling the details of Year, Month, and Day and the reservoir elevation (m) for the day, the ***Run*** button gets **activated**. Click on the ***Run*** button to execute the related program with the specified input and output filenames.

j) The program runs in a window which closes automatically after the program execution is complete and the instantaneous values of release for various demands is displayed in a window.

k) Click on the ***View Tabular Results*** button. To view data/results in tabular form, click on the ***Tabular*** button which will invoke the ***Notepad***. Click on the ***File*** and then ***Open*** and a window for file selection will appear. Go to the desired directory and select the requisite Input/Output filenames to see Input/Output files. It needs to be mentioned here that in this window, only files with extension ***.cri*** or ***.cro*** will be displayed. Select the desired filename and click on the ***Open*** button. The file will be displayed in the **Notepad**.



l) Close the ***Real-Time Conservation Operation*** module by clicking on the ***Close*** button.