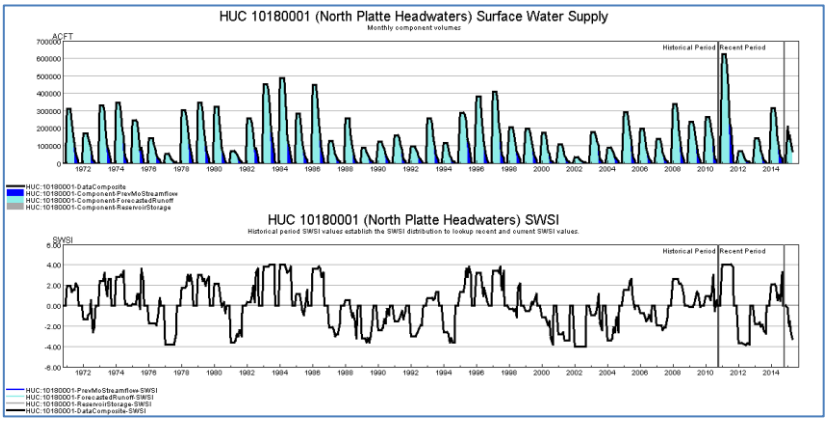

COLORADO SURFACE WATER SUPPLY INDEX (SWSI) AUTOMATION TOOL

TSTool Software Guide Version 6

June 30, 2015

PREPARED FOR

Colorado Water Conservation Board

Colorado Division of Water Resources

DEVELOPED BY

Open Water Foundation

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Definitions

AWDB	The NRCS Air and Water Database makes data available to the public through web services.
CIM	Colorado Information Marketplace
Colorado's Decision Support Systems (CDSS)	A system of databases and software tools used to help the State of Colorado make decisions about water resources.
ColoradoWaterHBGuest	HydroBase data are made available to the public from web services. ColoradoWaterHBGuest is the public account that is allowed accessed to the HydroBase web services.
ColoradoWaterSMS	The State of Colorado's Satellite Monitoring System transmits real-time hydro-meteorological data to a central storage database. While these data are made available, they are typically considered provisional and have not been quality-controlled.
Command file	A text file with a .TSTool extension that is used by TSTool and contains commands for data acquisition, analysis, and visualization.
Control file	The Excel workbook named CO-SWSI-Control.xlsx that is used to define all configuration properties and input data needed to run the Colorado SWSI analysis.
Current Period	The water year that includes the current month for which the SWSI analysis is being computed.
CWCB	Colorado Water Conservation Board
Data Composite	The sum of the SWSI component volumes (reservoir storage, previous month's streamflow, and forecasted runoff) for a HUC8 or river basin.
DWR	Colorado Division of Water Resources
Forecast SWSI Value	A SWSI value that was computed using forecasted natural flows for the forecasted runoff component.
Forecasts	Future runoff volumes predicted by the NRCS using regression equations and observed hydro-meteorological data as predictor variables. The NRCS issues these forecasts on the 1st of the month from January to June at locations throughout the West dominated by snowmelt-runoff. In Colorado, the forecasts represent future runoff volumes for a specified forecast period. The forecasts are presented as probabilistic ranges. For the purposes of the Colorado SWSI analysis, the 50th percent exceedance (expected value) forecast is used.

Historical Period

The period used to establish the distribution of SWSI and NEP values, currently defined as WY 1971-2010. In this period, historical natural flows are used for the forecasted runoff component.

Historical SWSI Value

A SWSI value that was computed using historical natural flows for the forecasted runoff component.

HUC

Hydrologic unit codes are basin boundaries established by the US Geological Survey. The length of the code indicates the relative spatial scale. For example, HUC2 represents major river basins, while HUC8 represents watersheds. In the Colorado SWSI analysis, all references to HUC refer to the 8-digit HUC.

HydroBase

The State of Colorado's official database that stores water administration data and hydro-meteorological data. These data are accessible with web services.

Native flow

For the purposes of the Colorado SWSI analysis, native flows are approximate estimates of the streamflows that would occur at a given location in the absence of human influences and that result from natural hydrologic processes such as rainfall-runoff and snowmelt-runoff:

$$Q_{native} = Q_{observed} + \Delta ReservoirStorage + \Delta Irrigation + \Delta Transbasin$$

where:

Q_{native} = the native streamflow calculated at a given location for a given time interval

$Q_{observed}$ = the streamflow observed at a given location for a given time interval

$\Delta ReservoirStorage$ = ∑(Δreservoir storage) for all reservoirs upstream of the given location for the given time interval

$\Delta Irrigation$ = ∑(diversions – return flows) for significant demands upstream of the given location for the given time interval. This term is often omitted unless observed data are available.

$\Delta Transbasin$ = ∑(transbasin exports – transbasin imports) upstream of the given location for the given time interval.

Natural flow

For the purposes of the Colorado SWSI analysis, the terms native flow and natural flow are used interchangeably and represent an approximation of the streamflows that would be in the river at a given location if not for human influences. See definition for native flow.

NEP	Non-exceedance probability, or the probability of not exceeding a given value
NRCS	Natural Resources Conservation Service
Observed flow	Streamflows in a river channel measured using a stream gage and rating curve. These flows reflect human influences to the river.
OIT	Colorado Governor's Office of Information Technology
Override	An override is a value specified by the user that is manually entered and will be used even if data for that time interval already exist in a time series.
Recent Period	The period between the historical period and the current period. In the monthly Colorado SWSI analysis, data for the recent period are not required but are helpful for comparison against current results. The recent period results are calculated the same way as the current month's SWSI: the composite volume is assessed using the historical dataset. However, the forecasted runoff component in the recent period is calculated using historical natural flows. This means that in the monthly analysis, the SWSI results for the recent period represent "historical SWSI" values. When generating historical forecasts of the Colorado SWSI (for example, because the station assignments for a HUC have been changed), the forecasted runoff component in the recent period is calculated using forecasted natural flows, same as that used in the current period. This means that in the re-forecast analysis, the SWSI results for the recent period represent "forecast SWSI" values.
RESC	A data type used by the NRCS AWDB web services to represent historical reservoir storage contents. For a monthly time step, the data values represent end-of-month storage.
SRVO	A data type used by the NRCS AWDB web services to represent historical natural flow volumes.
SRVOO	A data type used by the NRCS AWDB web services to represent historical observed flow volumes.
SWSI	The Surface Water Supply Index was developed by the NRCS and DWR for Western States that rely on snowmelt-runoff and reservoir storage for water supply (Garen, 1993).
Time series product	A text file with a .tsp extension that is used by TSTool as a template for plotting data and placing annotations on one or more graphs.

TSTool	A data acquisition, analysis, and visualization tool developed by the State of Colorado as part of the Colorado's Decision Support Systems (CDSS). TSTool processes are used to promote transparency, repeatability, and automation for complex water resources analyses.
Water Year	A water year runs from October of the previous calendar year to September of the current calendar year. For example, water year 1971 begins October 1970 and ends September 1971.
WATF	The State of Colorado's Water Availability Task Force (WATF) interprets available hydrologic information from across the State and takes action to mitigate drought effects when appropriate.

TSTool Command Summary

The following TSTool commands are used in the Colorado SWSI Automation Tool. Full documentation for each command is provided with the TSTool software.

TSTool Command	Description
Add	Add one or more time series to a time series.
AddConstant	Add a constant or monthly constants to one or more time series.
AdjustExtremes	Adjust the extreme values in a time series while conserving mass, for example to adjust for negative streamflow.
AnalyzePattern	Analyze time series for wet/average/dry conditions.
AppendTable	Append a table to another.
CalculateTimeSeriesStatistic	Calculate a statistic for time series.
ChangeInterval	Change the interval for time series to create new interval time series.
ChangePeriod	Change the period of time series, for example to extend and fill.
CheckTimeSeries	Check time series values for specific criteria and output to a table and warnings.
CheckTimeSeriesStatistic	Calculate a time series statistic and then check the statistic against criteria.
CloseExcelWorkbook	Close an Excel workbook that is being written to.
Comment	A single line #-comment to provide explanatory information.
CommentBlockEnd	Multi-line */ comment block end.
CommentBlockStart	Single line /* comment block start.
ConvertDataUnits	Convert time series data units.
Copy	Create new time series by copying a time series.
CopyFile	Create a new file by copying a file.
CopyPropertiesToTable	Copy processor properties to a table.
CopyTable	Create a new table by copying a table, with options to copy specific columns, rename columns, and filter rows.
CopyTimeSeriesPropertiesToTable	Copy time series properties to a table.
DeselectTimeSeries	Deselect time series, used to create lists of time series used with TSList=SelectedTS command parameter.
Disaggregate	Disaggregate time series from lonter interval to shorter interval data.
Divide	Divide time series by another time series.
Empty	Blank command line.
EndFor	End of For() command block.
EndIf	End of If() command block.
Exit	Exit processing, useful when testing a partial command file.
ExpandTemplateFile	Expand a FreeMarker syntax template text file into an expanded file, useful for repeating common processing.
FillConstant	Fill missing data in time series with a constant value.

TSTool Command	Description
FillFromTS	Fill missing data using values in a time series from another time series' data values.
FillHistMonthAverage	Fill missing data in monthly time series using the monthly averages from the same time series.
FillHistYearAverage	Fill missing data in yearly time series using the yearly averages from the same time series.
FillInterpolate	Fill missing data in time series by interpolating between non-missing values.
FillPattern	Fill missing data in time series by using wet/average/dry values for the same time series.
FillRegression	Fill missing data in time series using ordinary least squares regression.
FillRepeat	Fill missing data in time series by repeating values forward or backward.
For	For-loop start.
FormatDateTimeProperty	Format date/time property into a new processor string property given a format specifier, useful when a specific string version of date/time is needed.
FormatStringProperty	Format a new string processor property given other properties as input.
FormatTableDateTime	Format a date/time column in a table, for example to output a specific date/time format for output.
FormatTableString	Format a table string column using other table columns as input.
Free	Free a time series - it will no longer be available for further processing, useful when using temporary time series for processing.
FreeTable	Free a table - it will no longer be available for further processing, useful when using temporary tables for processing.
If	If block start.
InsertTableColumn	Insert a column into a table.
InsertTableRow	Insert a row into a table.
JoinTables	Join tables horizontally using one or more common columns.
ListFiles	List files in a folder.
LookupTimeSeriesFromTable	Create a new time series by looking up time series values from a table.
ManipulateTableString	Manipulate a table string in a table - see also FormatTableString() command.
Message	Generate a message for logging and user.
Multiply	Multiply one time series by another.
NewEndOfMonthTSFromDayTS	Create a new end of month time series from a daily time series, useful for determining reservoir end or month time series.

TSTool Command	Description
NewExcelWorkbook	Create a new Excel workbook that can be written to by other commands.
NewPatternTimeSeries	Create a new time series filled with an initial pattern of values and flags, useful for automated testing.
NewStatisticTimeSeries	Create a new time series containing a statistic of all similar date/times, for example average of all January 1 daily values.
NewStatisticYearTS	Create a new Time series containing a statistic of all annual values, useful to create an annual time series to compare to other time series.
NewTable	Create a new empty table.
NewTimeSeries	Create a new time series to receive results from other commands.
ProcessTSProduct	Process a time series product into views and image files.
ReadDateValue	Read time series from a "DateValue" format file, one of the primary formats used by TSTool.
ReadDelimitedFile	Read time series from a delimited file, for example a comma-separated-value (CSV) file.
ReadHydroBase	Read time series from the State of Colorado's HydroBase database.
ReadNrcsAwdb	Read time series from Natural Resources Conservation Service (NRCS) Air and Water Database web services.
ReadPatternFile	Read time series from wet/average/dry pattern file produced by AnalyzePattern() command.
ReadPropertiesFromExcel	Read processor properties from an Excel worksheet.
ReadPropertiesFromFile	Read processor properties from a text file.
ReadStateMod	Read time series from the State of Colorado's StateMod water allocation model text input files.
ReadTableCellsFromExcel	Read table cells from specific cells in an Excel worksheet, useful for transferring form input into a flat data table.
ReadTableFromDataStore	Read a table from a database datastore.
ReadTableFromExcel	Read a table from an Excel worksheet.
ReadTimeSeriesFromDataStore	Read time series from a datastore.
ReadTimeSeriesList	Read time series using a table with list of identifiers.
RemoveFile	Remove a file.
ReplaceValue	Replace values in a time series with alternate values.
RunCommands	Run a command file, used to create master command files to run larger workflows.
RunningStatisticTimeSeries	Create a running statistic time series using various methods to determine the sample size.
Scale	Scale time series by a constant value.
SelectTimeSeries	Select time series for processing, used with the TSList=SelectedTS parameter.
SetConstant	Set time series data values to a constant.
SetFromTS	Set time series data values using values from another time series.

TSTool Command	Description
SetInputPeriod	Set the global input period default when reading time series, useful for datastores that have an inconvenient default input period.
SetOutputPeriod	Set the global output period default when writing time series, useful to standardize all output to a consistent period.
SetOutputYearType	Set the global output year type (e.g., calendar, water year).
SetProperty	Set a processor property.
SetPropertyFromTable	Set a processor property from a table.
SetTableValues	Set table values based on filters.
SetTimeSeriesPropertiesFromTable	Set time series properties from a table, useful to cross-reference data from different data sources.
SetTimeSeriesProperty	Set a single time series property.
SetTimeSeriesValuesFromLookupTable	Set time series values from a lookup table, for example to set values based on a distribution.
SetTimeSeriesValuesFromTable	Set time series values from a table, similar to other commands that set time series values.
SetWorkingDir	Set the working directory for processing - generally not used given newer features to access processor ${WorkingDir} property.
ShiftTimeByInterval	Shift time series values by an interval, useful to handle time zone changes, routing, and use of previous timestep(s) as input.
SortTable	Sort a table based on one or more columns.
SortTimeSeries	Sort a list of time series based on identifier or other time series properties.
StartLog	Start a new log file for logging.
Subtract	Subtract time series from another time series.
TableMath	Calculate table column values using input table column(s) and/or constant values.
TableTimeSeriesMath	Manipulate time series values using data from a table.
TableToTimeSeries	Create new time series using values from a table.
TimeSeriesToTable	Create a table using values from time series.
WriteDateValue	Write time series to a DateValue format file.
WriteDelimitedFile	Write time series to a delimited (e.g., CSV) file.
WritePropertiesToFile	Write processor properties to a text file.
WriteTableCellsToExcel	Write table cells to cells in an Excel worksheet, useful for transferring "flat" table data into Excel forms.
WriteTableToDataStore	Write a table to a database datastore.
WriteTableToDelimitedFile	Write a table to a delimited (e.g., CSV) file.
WriteTableToExcel	Write a table to an Excel worksheet.
WriteTableToHTML	Write a table to an HTML file.
WriteTimeSeriesPropertiesToFile	Write time series properties to a file, useful for automated tests.

TSTool Command	Description
WriteTimeSeriesProperty	Write time series property to a file, replaced by WriteTimeSeriesProperiesToFile().
WriteTimeSeriesToDataStore	Write time series to a database datastore, useful for generic database designs.
WriteTimeSeriesToExcel	Write time series to an Excel worksheet, with formatting based on data values.

Introduction

The State of Colorado monitors conditions that affect water supply, including snowpack, precipitation, reservoir storage, and streamflows. The Governor of Colorado established the Water Availability Task Force (WATF) to interpret available information and to take actions to mitigate drought effects when appropriate. The WATF has the authority to activate the Colorado Drought Mitigation and Response Plan (CWCB, 2013) when drought conditions reach significant levels.

The WATF makes drought projections based on a variety of hydro-meteorological data types (i.e., snowpack, soil moisture, streamflow, reservoir levels, ground water levels, precipitation, and temperature) and drought indices (i.e., Surface Water Supply Index, Standardized Precipitation Index, and Modified Palmer Drought Index). More information about the WATF is available on the CWCB website (CWCB, 2015).

The Surface Water Supply Index (SWSI) is an index used to describe drought in mountainous areas that rely primarily on surface water supplies such as snowpack and reservoir storage. The SWSI was developed by the Soil Conservation Service (now Natural Resources Conservation Service or NRCS) and the Colorado Division of Water Resources (DWR) in 1981 for the Colorado Drought Plan. DWR has produced the original SWSI in accordance with the Colorado Drought Plan since 1981. In 1993, Dave Garen from NRCS proposed a revised SWSI calculation to improve upon the known deficiencies of the original SWSI calculation methodology (Garen, 1993). Other Western States have adopted their own version of the SWSI as well.

The Colorado Water Conservation Board (CWCB) completed a major revision to the Colorado Drought Plan in 2010. At that time, Colorado adopted a revised SWSI analysis that is calculated on a smaller geographic scale and that uses streamflow forecasts instead of the weighted precipitation, streamflow, snowpack, and reservoir storage factors used in the original SWSI. This approach is similar to what Garen proposed in 1993. The revised Colorado SWSI is computed on a monthly time step and considers three components depending on the time of year (**Table 1**).

Table 1. Colorado Revised SWSI Formulation (CWCB, 2013)

Time Period	Components
January - June	Forecasted Runoff + Reservoir Storage
July - September	Previous Month's Streamflow + Reservoir Storage
October - December	Reservoir Storage

Since 2011, the NRCS has been producing a SWSI product for the WATF similar to the revised SWSI called for in the 2010 Drought Plan. The NRCS SWSI process relies on Excel spreadsheets to compute values for selected eight-digit Hydrologic Unit Codes (HUC).

In 2015, the State of Colorado undertook the SWSI Automation Tool Enhancement project, which resulted in the development of an automated SWSI calculation tool based on the criteria set forth in the 2010 Drought Plan. The automated tool produces results that can be incorporated into DWR's

HydroBase database and made available to the public using the CDSS Platform (DNR, 2015) and the Colorado Information Marketplace. Open Water Foundation collaborated with DWR and CWCB in developing the Colorado SWSI Automation Tool. Riverside Technology, inc, provided input on the forecast data source and reviewed the implementation of the Colorado SWSI Automation Tool.

The TSTool software tool has been developed as part of the CDSS. TSTool has the advantages of being able to access many data sources, of automating data processing and visualization, and of using workflow commands that provide transparency and repeatability to the computation process.

This **Colorado Surface Water Supply Index (SWSI) Automation Tool - TSTool Software Guide** provides an overview of the concepts and procedures necessary for a practitioner to use the Colorado SWSI Automation Tool.

Colorado SWSI Methodology Overview

The Colorado SWSI is calculated for each month of the year, typically within the first ten days of the month. As noted previously in **Table 1**, the Colorado SWSI is computed using three components depending on the time of year:

- **Forecasted Runoff:** Forecasted runoff volumes are issued monthly from January through June by the NRCS. The forecasts represent probabilistic estimates of natural flow volumes for the upcoming season. They are generated using regression models and hydro-meteorological data as predictor variables (i.e., snowpack, precipitation, and streamflow). The Colorado SWSI computations use the 50th percent exceedance (expected value) forecast volumes. Complete information about the NRCS forecasts can be obtained from the NRCS website (NRCS, 2015).

  The forecasts are generated for fixed forecast periods defined by location that were selected to represent high runoff months. The Colorado SWSI Automation Tool was developed assuming the forecast period starts in April. This assumption is true for all locations except the Purgatoire River at Trinidad. At this location, from January through June, the NRCS issues a March-July forecast. Starting in April, the NRCS also issues a current month-July forecast. Until the Colorado SWSI Automation Tool can be updated to handle this case, when running the SWSI analysis in January-March, the DWR will use a regression equation that relates March-July runoff volumes with April-July runoff volumes for Purgatoire River at Trinidad.

  For the Colorado SWSI analysis, forecasts that end in September are used for locations in the Rio Grande Basin and forecasts that end in July are used for locations in other river basins. The forecasts used in May and June represent expected runoff from the current month until the end of the forecast period. See **Table 2** for a summary of the forecast period used by river basin and SWSI calculation month.

Table 2. Forecast Period by Basin and SWSI Calculation Month

SWSI Calculation Months	Forecast Period (Rio Grande Basin)	Forecast Period (Non-Rio Grande Basins)
January-April	April-September	April-July
May	May-September	May-July
June	June-September	June-July
July-December	Not used	Not used

The Colorado SWSI Automation Tool is configured to obtain forecasted streamflow data from the NRCS AWDB web services.

When the Colorado SWSI is calculated for the months of January through June, the analysis incorporates the forecasted runoff component as an indicator of future surface water supply. For the current water year's forecasted runoff values, the NRCS forecasts are used. For recent and historical water years, when the actual runoff is known, the forecasted runoff component is calculated from historical natural flow data.

- **Reservoir Storage:** The Colorado SWSI always incorporates observed reservoir storage data as an indicator of the current state of the surface water supply. For a given month's analysis, the SWSI incorporates beginning-of-month storage values. For inclusion in the Colorado SWSI analysis, DWR has selected reservoirs that are used as active storage in a HUC and that increase the available water supply volume in a HUC. Therefore, the reservoirs that are included are typically municipal and irrigation reservoirs, not reservoirs used for augmentation.

  The Colorado SWSI Automation Tool is set up to obtain observed reservoir storage data from the NRCS and the State of Colorado.
  - The NRCS AWDB web services provide access to end-of-month storage values using the RESC data type.
  - The State of Colorado has two sets of web services:
    - ColoradoWaterHBGuest services access daily reservoir storage data from HydroBase that have been quality controlled and are considered published.
    - ColoradoWaterSMS services access daily reservoir storage data for the recent period that have not been quality-controlled and are considered provisional.
    - The daily reservoir storage data from ColoradoWaterHBGuest and ColoradoWaterSMS are merged to make a continuous record, with ColoradoWaterHBGuest data taking precedence.
    - To be consistent with the NRCS AWDB data, end-of-month storage time series are computed from the daily storage values.
  - Before calculating the SWSI values, the end-of-month storage values are shifted forward by one month to represent beginning-of-month storage values for the current month's analysis.

- **Previous Month's Streamflow:** Per the State Drought Plan, in the months of July-September, the Colorado SWSI procedure incorporates a component representing the previous month's native flow volume (CWCB, 2013).

The Colorado SWSI Automation Tool is set up to obtain monthly native flow volumes from the NRCS AWDB web services. **Appendix A – NRCS Native Flow Equations** contains the equations used by the NRCS to compute native flow volumes in Colorado.

Before calculating the Colorado SWSI values, the monthly native flow volumes are shifted forward by one month to represent previous month's streamflow for the current month's analysis (see **Table 3** for an example demonstrating the data manipulation).

Table 3. Example of Data Transformation from Natural Flow to Previous Month's Streamflow Component

Date	Natural Flow (ac-ft)	SWSI Component (ac-ft)	Explanation
2015-06	3,000	0	Previous month's streamflow component is not used in June
2015-07	2,000	3,000	July SWSI analysis uses June volume to represent previous month's streamflow volume
2015-08	1,000	2,000	August SWSI analysis uses July volume to represent previous month's streamflow volume
2015-09	800	1,000	September SWSI analysis uses August volume to represent previous month's streamflow volume
2015-10	500	0	Previous month's streamflow component is not used in October

If the required native flow data are not available for the current month's analysis, the Colorado SWSI Automation Tool has been set up to use observed flows rather than native flows for the previous month's streamflow component. This option is discussed in more detail in the **Colorado SWSI Automation Tool Step-by-Step Procedure** and in **Appendix C – Colorado SWSI Automation Tool Workflow Details**.

The Colorado SWSI analysis is performed on 41 HUC8 watersheds. DWR selected natural flow locations, water supply reservoirs, and forecast locations that represent the surface water supply for each HUC8 included in the Colorado SWSI analysis (see **Appendix B – Station Assignments by HUC**). In general, all significant water supply reservoirs with storage data available in real-time are included. The natural flow and forecast locations were selected to most closely represent total flow in the HUC, whether at a single location at the HUC outlet or as multiple locations on individual tributaries.

As part of the current project, Open Water Foundation reviewed the input data being used in the Colorado SWSI analysis. Issues that were identified, solutions that were implemented, and unresolved issues are documented in the following appendices:

- **Appendix D – Historical Period Data Issues**
- **Appendix E – Current Water Year Data Issues**
- **Appendix F – Recent Period Data Issues**

After development of the Colorado SWSI Automation Tool, Riverside Technology, inc reviewed sections of the TSTool process to confirm that the implemented command logic is consistent with the calculation methodology. The review notes are included in .

The Colorado SWSI methodology includes the following steps:

- The natural flow, reservoir storage, and forecast data are downloaded for all specified stations and reservoirs.
- The raw data are analyzed for missing values.
- Missing values can be filled using automated techniques (such as regression analysis or interpolation) and/or the user can manually specify values to be used. Automated techniques can be used to fill missing values in the raw data obtained from source agencies. Manually-specified values are applied to any data value (missing or not) in the auto-filled dataset.
    - For natural flows, missing values can be filled automatically using monthly regression analysis. The user should specify a filling station that is close to the station being filled, that has data for the periods that require filling, and that has a correlation coefficient of at least 0.7 for the overlapping data with the station being filled. Filled values are denoted using a data flag of "R" for regression.
    - For reservoir storage, missing values are filled in multiple ways.
        - If the values are missing because the reservoir was not yet storing water, the storage values are set to 0. Filled values are denoted using a data flag of "Z" for zeroes.
        - If values are missing after the reservoir began storing water, the user can elect to fill based on linear interpolation between surrounding values or with historical average monthly values. Filled values are denoted using data flags of "I" for interpolation or "H" for historical monthly averages.
        - If a reservoir is decommissioned, the user can elect to fill the storage data with zeroes to the current month. Filled values are denoted using a data flag of "Z" for zeroes.
    - No automated filling options are implemented for the forecast data.
    - The user may elect to apply overrides (i.e., values determined by the user) for any time series value. Filled values are denoted using a data flag that starts with "MO" for manual overrides.
    - Any missing data in the historical period that are not filled will reduce the number of years used to establish the distribution of SWSI and NEP values.
    - Any missing data in the recent and current periods that are not filled will produce missing values in the output products.
- The filled input data are transformed to represent the SWSI components. This step includes time shifts, data accumulations, and setting component values to zero in months when the component is not used for the SWSI analysis.
- Results are computed for each station and reservoir. The results include the following values:
    - Component Volume (ac-ft)
    - Component Non-Exceedance Probability by Month (%)
- Results are computed for each HUC. The results include the following values:
    - Data Composite (ac-ft)
    - Data Composite Percent of Average (%)
    - Data Composite Non-Exceedance Probability (%)
    - Data Composite SWSI (--)
    - Reservoir Storage (ac-ft)
    - Reservoir Storage Percent of Average (%)
    - Reservoir Storage Non-Exceedance Probability (%)

  - Reservoir Storage SWSI (--)
  - Previous Month's Streamflow (ac-ft)
  - Previous Month's Streamflow Percent of Average (%)
  - Previous Month's Streamflow Non-Exceedance Probability (%)
  - Previous Month's Streamflow SWSI (--)
  - Forecasted Runoff (ac-ft)
  - Forecasted Runoff Percent of Average (%)
  - Forecasted Runoff Non-Exceedance Probability (%)
  - Forecasted Runoff SWSI (--)
  - Composite SWSI for the same month last year
  - Change in Composite SWSI from last year to this year
- Results are calculated for each major river basin in Colorado. The results include all of the results listed by HUC as well as the following values:
  - Composite SWSI for the previous month
  - Change in Composite SWSI from the previous month to the current month

For each SWSI component and the sum of the components (i.e., the data composite), the results are computed using the same methodology:

- For a given month, the component's water supply volumes are ranked over the historical period, currently defined as WY 1971-2010, to determine the Gringorten plotting position. The plotting position values range from 0.00-1.00.
  - In using the Gringorten plotting position, the analysis assumes an empirical distribution, which is to say the historical data are used without fitting a distribution to the dataset.
  - If there are ties in the water supply volumes, they receive the same plotting position value.
  - DWR expects that the historical period will be moved forward periodically in accordance with the NRCS.
- The Gringorten plotting position is multiplied by 100 to determine the non-exceedance probabilities (NEP) over the historical period. The non-exceedance probabilities range from 0% (driest in the historical record) to 100% (wettest in the historical period).
- The non-exceedance probability values are transformed to a scale of -4.16 (extreme drought conditions) to +4.16 (abundant water supply) to determine the SWSI values over the historical period. The conversion formula is shown in **Equation 1**. This range of SWSI values is consistent with that used for the Palmer Drought Index and allows users to view familiar values.

$$SWSI = \frac{NEP - 50}{12}$$

Equation 1. Converting NEP Value to SWSI Values

- For months in the recent and current periods, the component's water supply volumes are used to look up corresponding NEP and SWSI values based on the historical dataset.

Colorado SWSI Output Products

The results from the Colorado SWSI Automation Tool are produced as both tabular and graphical outputs. Tabular outputs are typically written to two file formats: DateValue files are used by TSTool to run the processing steps, while Excel files are provided to facilitate user review. HTML files can also be written to implement a website, though these commands are currently disabled in the process.

SWSI Current Summary

The main output used by DWR to import results into HydroBase and the Colorado Information Marketplace and to display results in the CDSS Map Viewer is an Excel workbook named **SWSI-Current-Summary.xlsx**, which contains three worksheets: Basin Summary, HUC Summary, and HUC Components. These worksheets can be written to HTML files to implement a website that facilitates user review or product sharing though the commands are currently disabled.

The Basin Summary results worksheet (shown in **Table 4**) includes:

- Basin name (Basin)
- Analysis date (Date)
- Composite SWSI value for the analysis date (SWSI)
- Composite NEP value for the analysis date (NEP)
- Composite SWSI value for the month prior to the analysis date (SWSI Prev Mo)
- The change in Composite SWSI values from the previous month to the current month (Chg SWSI Prev Mo)
- Composite SWSI value for the same month for the year prior to the analysis date (SWSI Prev Yr)
- The change in Composite SWSI values from the previous year to the current year (Chg SWSI Prev Yr)

Table 4. SWSI Current Summary Output - Basin Summary

Basin	Date	SWSI	NEP	SWSI Prev Mo	Chg SWSI Prev Mo	SWSI Prev Yr	Chg SWSI Prev Yr
Arkansas	2015-05	-0.07	49.18	-0.08	0.01	-0.22	0.15
Colorado	2015-05	-1.80	28.34	-1.67	-0.13	2.21	-4.01
Gunnison	2015-05	-2.33	22.07	-2.01	-0.32	1.57	-3.90
Rio Grande	2015-05					-0.66	
San Juan-Dolores	2015-05	-3.66	6.05	-3.29	-0.37	-1.53	-2.13
South Platte	2015-05	2.26	77.14	1.28	0.98	2.50	-0.24
Yampa-White	2015-05	-2.11	24.67	-2.65	0.54	0.12	-2.23

The HUC Summary results worksheet (shown in **Table 5**) includes:

- Basin name (Basin)
- HUC identifier (HUC_ID)
- HUC name (HUC_Name)

- Analysis date (Date)
- Composite SWSI value for the analysis date (SWSI)
- Composite NEP value for the analysis date (NEP)
- Composite SWSI value for the same month for the year prior to the analysis date (SWSI Prev Yr)
- The change in Composite SWSI values from the previous year to the current year (Chg SWSI Prev Yr)
- NEP value for the reservoir storage component (ReservoirStorageNEP)
- NEP value for the previous month's streamflow component (PrevMoStreamflowNEP)
- NEP value for the forecasted runoff component (ForecastedRunoffNEP)

Table 5. SWSI Current Summary Output - HUC Summary

Basin	HUC_ID	HUC_Name	Date	SWSI	NEP	SWSI Prev Yr	Chg SWSI Prev Yr	Reservoir Storage NEP	Prev Mo Streamflow NEP	Forecasted Runoff NEP
Arkansas	11020001	Arkansas Headwaters	2015-05	-0.66	42.05	0.91	-1.58	57.64		37.80
Arkansas	11020002	Upper Arkansas	2015-05	0.77	59.25	1.49	-0.72	76.99		43.93
Arkansas	11020005	Upper Arkansas-Lake Meredith	2015-05	-0.39	45.32	0.60	-0.99	78.03		39.53
Arkansas	11020006	Huerfano	2015-05	-2.91	15.08	-2.44	-0.47	12.69		25.91
…	…	…	…	…	…	…	…	…	…	…

The HUC Components results worksheet (shown in **Table 6**) includes:

- Basin name (Basin)
- HUC identifier (HUC_ID)
- HUC name (HUC_Name)
- Analysis date (Date)
- Component (reservoir storage, previous month's streamflow, or forecasted runoff) for which the station was used (Component Type)
- Station or reservoir identifier (Component ID)
- Station or reservoir name (Component Name)
- Monthly component volume in ac-ft (Component Volume)
- Monthly component NEP computed by month (Component NEP by Month)

Table 6. SWSI Current Summary Output - HUC Components

Basin	HUC_ID	HUC_Name	Date	Component Type	Component ID	Component Name	Component Volume	Component NEP by Month
Arkansas	11020001	Arkansas Headwaters	2015-05	Forecasted Runoff	07091500	ARKANSAS RIVER AT SALIDA	194000.00	38.00

Arkansas	11020001	Arkansas Headwaters	2015-05	Reservoir Storage	07007020	CLEAR CREEK RESERVOIR	8700.00	74.00
Arkansas	11020001	Arkansas Headwaters	2015-05	Reservoir Storage	07007110	TURQUOISE LAKE	62900.00	53.00
…	…	…	…	…	…	…	…	…

SWSI Summary by Basin

All of the component and result time series are written to an Excel workbook ({BasinName}-SWSI.xlsx) for each river basin. These workbooks can also be written to HTML files to implement a website that facilitates user review or product sharing though the commands are currently disabled.

The SWSI Summary by Basin results worksheet (shown in **Table 7**) includes:

- Analysis date (Date)
- Monthly component volume in ac-ft (Data Composite, Reservoir Storage, Previous Month's Streamflow and Forecasted Runoff)
- Monthly component percent of historical average computed by month (PctOfAverage for Data Composite, Reservoir Storage, Previous Month's Streamflow and Forecasted Runoff)
- Monthly component plotting position (Plotting Position for Data Composite, Reservoir Storage, Previous Month's Streamflow and Forecasted Runoff)
- Monthly component NEP value (NEP for Data Composite, Reservoir Storage, Previous Month's Streamflow and Forecasted Runoff)
- Monthly component SWSI value (SWSI for Data Composite, Reservoir Storage, Previous Month's Streamflow and Forecasted Runoff)

Table 7. SWSI Summary by River Basin

Date	Data Composite	Data Composite PctOfAverage	Data Composite Plotting Position	Data Composite NEP	Data Composite SWSI	…
1999-10	975655	229	0.99	98.51	4.04	…
1995-10	894473	210	0.96	96.02	3.83	…
1985-10	872295	205	0.94	93.53	3.63	…
1997-10	840187	197	0.91	91.04	3.42	…
1986-10	836559	196	0.89	88.56	3.21	…
…	…	…	…	…	…	…

SWSI Summary by HUC

All of the component and results time series are written to an Excel workbook ({HUC_ID}-SWSI.xlsx) for each HUC. These workbooks can also be written to HTML files to implement a website that facilitates user review or product sharing though the commands are currently disabled.

The SWSI Summary by HUC results worksheet (shown in **Table 8**) includes:

- Analysis date (Date)

- Monthly component volume in ac-ft (Data Composite, Reservoir Storage, Previous Month's Streamflow and Forecasted Runoff)
- Monthly component percent of historical average computed by month (PctOfAverage for Data Composite, Reservoir Storage, Previous Month's Streamflow and Forecasted Runoff)
- Monthly component plotting position (Plotting Position for Data Composite, Reservoir Storage, Previous Month's Streamflow and Forecasted Runoff)
- Monthly component NEP value (NEP for Data Composite, Reservoir Storage, Previous Month's Streamflow and Forecasted Runoff)
- Monthly component SWSI value (SWSI for Data Composite, Reservoir Storage, Previous Month's Streamflow and Forecasted Runoff)

Table 8. SWSI Summary by HUC

Date	Data Composite	Data Composite PctOfAverage	Data Composite Plotting Position	Data Composite NEP	Data Composite SWSI	…
1985-10	65519	291	0.99	98.51	4.04	…
1995-10	61046	271	0.96	96.02	3.83	…
1979-10	52800	235	0.94	93.53	3.63	…
1984-10	41448	184	0.91	91.04	3.42	…
…	…	…	…	…	…	…

Time Series by HUC (or Basin)

All of the input, component, and results time series are written to an Excel workbook ({HUC_ID}-TimeSeries.xlsx or ({BasinName}-TimeSeries.xlsx) for each HUC and River Basin. The Time Series summaries by HUC (or Basin) include the same time series as the SWSI summaries, with the addition of monthly volumes in ac-ft for each individual station used in the analysis (as shown in **Table 9**). These workbooks can also be written out to HTML files to implement a website that facilitates user review or product sharing though the commands are currently disabled.

In the HUC time series summaries, the term "HUC:" is prepended before the HUC identifier to make it clear where results are being presented by station identifier versus HUC identifier.

Table 9. Time Series by HUC (or River Basin)

Date	06620000 Component PrevMoStreamflow	06620000 Component ForecastedRunoff	HUC:10180001 Component ReservoirStorage	HUC:10180001 ReservoirStorage PctOfAverage	…
1970-10	0	0	0	Null	…
1970-11	0	0	0	Null	…
1970-12	0	0	0	Null	…
1971-01	0	310163	0	Null	…
1971-02	0	310163	0	Null	…
1971-03	0	310163	0	Null	…
1971-04	0	310163	0	Null	…
…	…	…	…	…	…

SWSI History Graphs by River Basin

Graphs are created for each river basin (Basin-{BasinName}-SWSI-history-graph.png) that show the time series of SWSI values since the beginning of the historical period through the current month's analysis (**Figure 1**). Red vertical lines are used on the graphs to distinguish the historical, recent, and current periods used in the analysis.

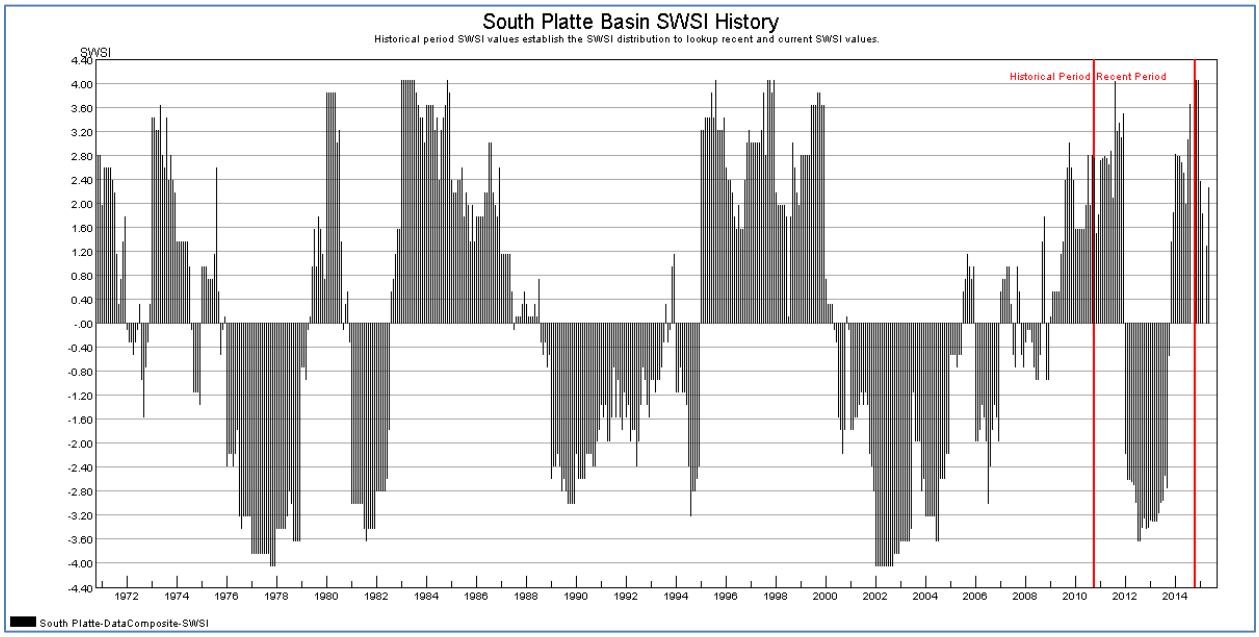

Figure 1. SWSI History Graph (River Basin)

SWSI History Graphs by HUC

Graphs are created for each HUC that show the time series of component volumes and SWSI values for the full analysis period for all months (HUC-{HUC_ID}-SWSI-history-graph.png; **Figure 2**) and for all months for the recent and current periods only (HUC-{HUC_ID}-SWSI-recent-graph.png; **Figure 3**). To change the period displayed in the recent graph, the user may change the **RecentPeriodGraphStartDate** property in the control file.

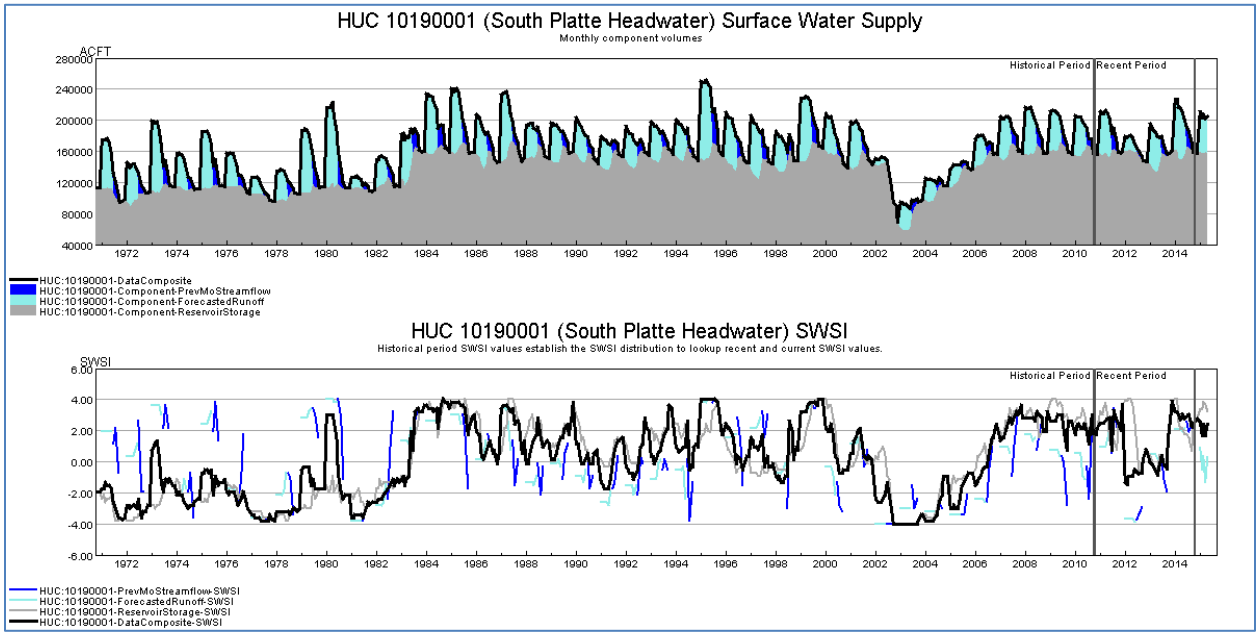

Figure 2. SWSI History Graph for the Full Analysis Period (HUC)

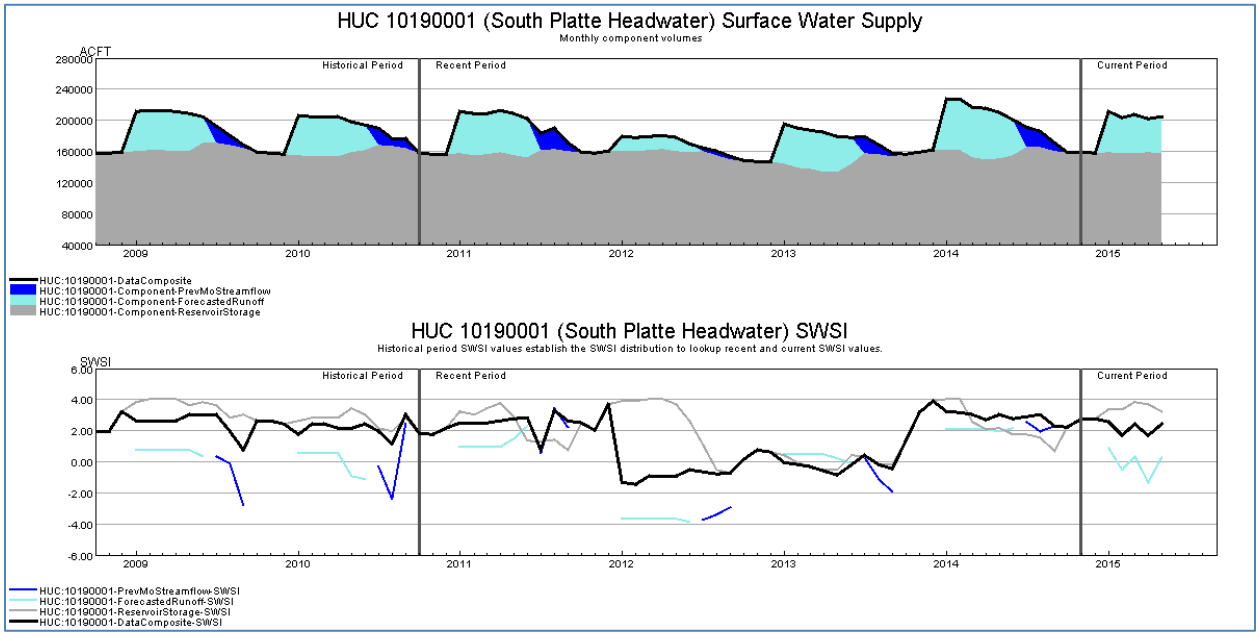

Figure 3. SWSI History Graph for the Recent and Current Periods (HUC)

SWSI History Graphs by HUC and Month

Graphs are created for each HUC and month (HUC-{HUC_ID}-SWSI-history-{Month}-graph.png) that show the time series of component volumes and SWSI values for the full analysis period (**Figure 4**).

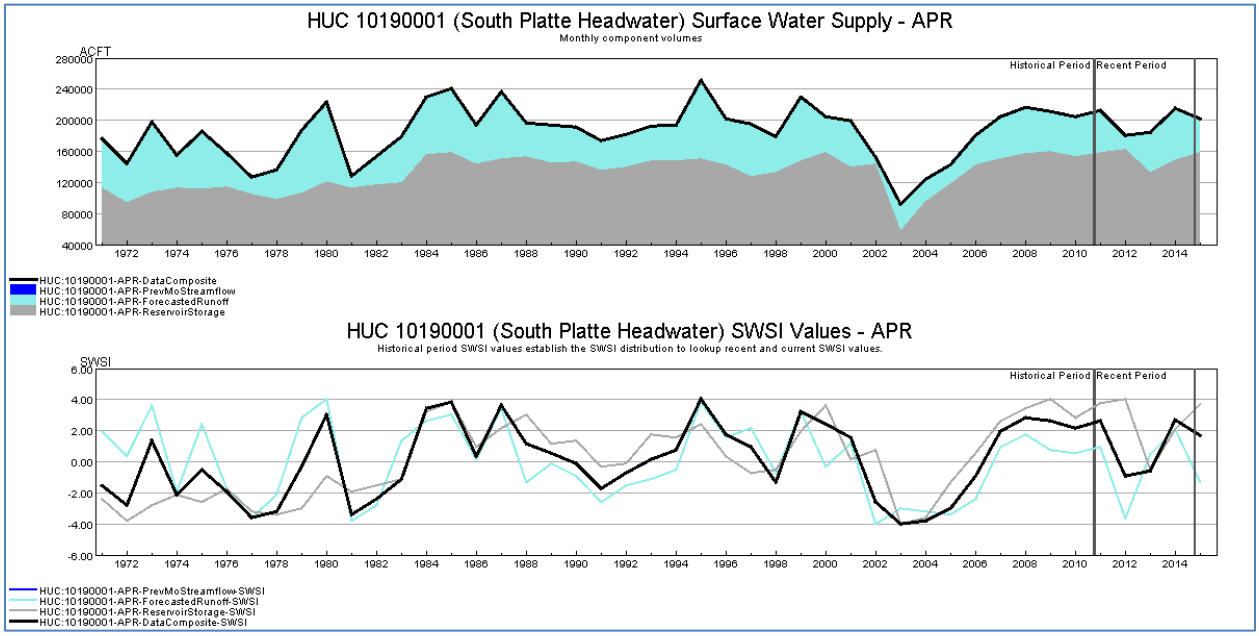

Figure 4. SWSI History Graph by Month for the Full Analysis Period (HUC)

Colorado SWSI Automation Tool Directory Structure

The files for the Colorado SWSI Automation Tool are organized into two directories: one that contains helpful documents (_Documents) and one that contains all files for one month's analysis (_2015-05). The _2015-05 directory was provided by Open Water Foundation to DWR as a master copy and a starting point for subsequent monthly analyses.

To conduct an analysis for a new month, the most recent directory should be copied and renamed to the current month and year as YYYY-MM (or something similar). As an example, the data in a 2015-05 folder would include data relevant for a May 1, 2015 SWSI analysis, including all historical, recent, and current data, as well as all intermediate files and output files generated from the TSTool process.

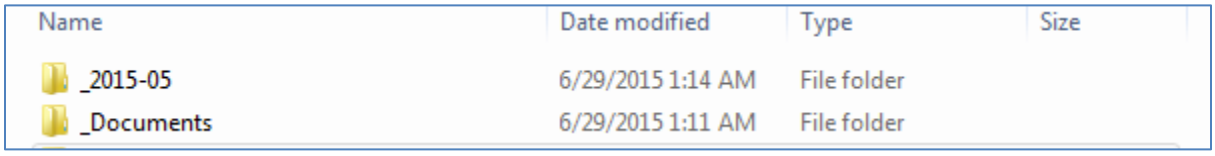

Figure 5. Highest level directory structure

The _Documents directory contains this guide to running the Colorado SWSI Automation Tool (_SWSI-TSTool-Guide), helpful background documents, and documents from the first project phase (**Figure 6**).

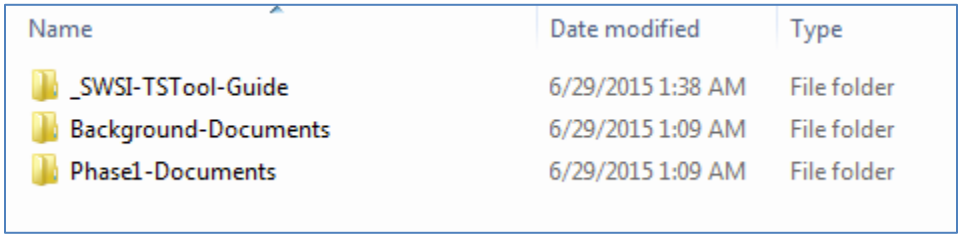

Figure 6. _Documents directory

The Colorado SWSI Automation Tool uses an Excel workbook (named CO-SWSI-Control.xlsx and referred to in this document as the control file) and TSTool command files and time series products to perform the necessary processing. All input data, intermediate data and computation artifacts, and output data and graphs are saved within the YYYY_MM folder to help the user review and archive the results.

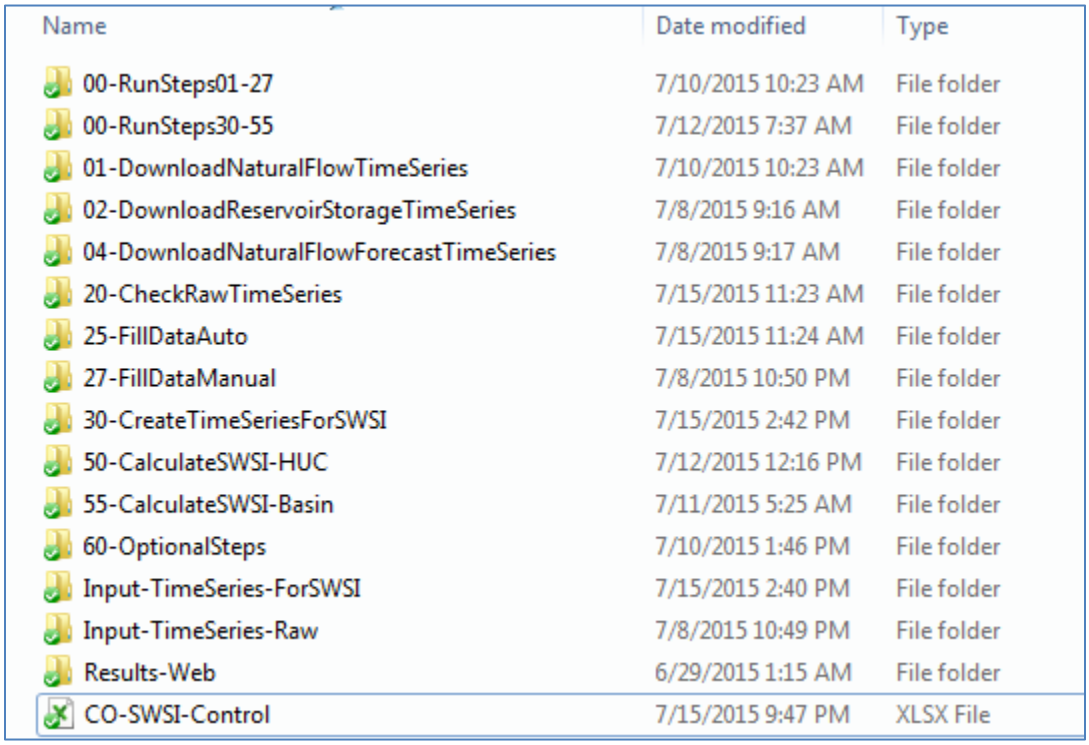

Figure 7. YYYY-MM Directory

Figure 7 shows the contents of a YYYY_MM folder, which include:

- The control file (CO-SWSI-Control.xlsx), that controls the analysis by defining the configuration properties and the stations needed to run the analysis.
- Folders whose name starts with a number (e.g., 01-DownloadNaturalFlowTimeSeries) represent TSTool processing steps. The numbers in the folder names indicate the order of the processing steps, with gaps in the numbering to allow future additions, if necessary. The folders at a minimum contain a TSTool command file with the same name as the folder.
- The Input-TimeSeries-Raw folder contains the time series data for stations and reservoirs before the data are transformed into SWSI Components. The data are available in DateValue and Excel format for three processing stages: raw data, auto-filled data, and manual-filled data.

    - The final input data are written to an Excel workbook named Final-Input-Data.xlsx that contains all data flags from the data download and filling processes. The data flags indicate data sources, data quality issues, and data manipulation, and are written to help DWR understand where the data values came from.
- The Input-TimeSeries-ForSWSI folder contains the time series data for stations and reservoirs after the data are transformed into SWSI Components.
    - The final component data are written to an Excel workbook named SWSI-Components-Data.xlsx that contains most data flags from the data download and filling processes. The exception to this is the Forecasted Runoff component, which does not include the data flags where historical natural flow data were used.
- The Results-Web directory contains all tabular and graphical output products described in **Colorado SWSI Output Products**.

Colorado SWSI Automation Tool Step-by-Step Procedures

This section presents step-by-step procedures for a practitioner running the Colorado SWSI Automation Tool. Additional details of the process are documented in **Appendix C – Colorado SWSI Automation Tool Workflow Details**.

To modify the methodology in the control file

1. Open the master version of the Excel file named "CO-SWSI-Control.xlsx".
2. The **Config** worksheet contains properties needed to run the analysis. Properties highlighted in blue are entered by the user.
    a. The **NumberOfBasins** property specifies the number of river basins that are processed. This property is used for automated error checking. If basins are added or removed, this property should be updated.
    b. The **NumberOfHUCs** property specifies the number of HUCs that are processed. This property is used for automated error checking. If HUCs are added or removed, this property should be updated.
    c. The **RecentPeriodFlowType** property determines how the forecasted runoff component is treated in the recent period. To run a typical monthly analysis and generate historical SWSI values in the recent period, this property should be set to "**NaturalFlow**." To run a re-forecast analysis and generate forecast SWSIs in the forecast period, this property should be set to "**ForecastedNaturalFlow**."
3. The **Combined Inputs** worksheet specifies all station information necessary to run the Colorado SWSI analysis by HUC and river basin.
    a. To include or exclude stations from the HUC analysis, set the **Include** column to YES or NO, respectively.
    b. To use observed flows for the previous month's streamflow for a station, set the **Include** column to YES-OBS.
        i. If the observed flow option is being used, consider whether all natural flow stations in the HUC should use observed flows.
    c. To include or exclude stations from the Basin analysis, set the **Basinwide Analysis** column to YES or NO, respectively.

   d. To change a data source for a natural flow station
      i. The only option is to set all **Datastore** options to use the NRCS AWDB web services to obtain SRVO data.
   e. To use observed flow data for a natural flow station
      i. The **Datastore** options should be retained to use the NRCS AWDB web services to obtain SRVO data. These data are used in the forecasted runoff component.
      ii. The **Datastore2** options should be set up to obtain data from the ColoradoWaterHBGuest datastore.
      iii. The **Datastore3** options can be set up to obtain data from the ColoradoWaterSMS datastore.
   f. To change a data source for a forecasted natural flow station
      i. The only option is to set all **Datastore** options to use the NRCS AWDB web services to obtain SRVO forecast data.
   g. To change a data source for a reservoir storage station
      i. The default option is to set all **Datastore** options to use the NRCS AWDB web services to obtain RESC data.
      ii. Alternatively, the **Datastore** options can be set to use the ColoradoWaterSMS web services to obtain STORAGE data.
      iii. If **Datastore** options are changed to use ColoradoWaterSMS, **Datastore2** options can be changed to use ColoradoWaterHBGuest web services to obtain ResMeasStorage data.
4. If a station is removed from the **Combined Inputs** worksheet, it should also be removed from the filling worksheets (**FlowDataFill**, **ReservoirDataFill**, and **Overrides**) to avoid processing errors. It suffices to set the **Include** column to "NO"; rows do not need to be deleted. For flow stations, this applies to both natural flow and observed flow stations.
5. In general, changes such as adding cell comments or inserting rows or columns to the control file should not disrupt the TSTool process because TSTool does not generally refer to specific cell ranges. The exceptions to this are in the Overrides and Reforecast List worksheets. However, it is very important not to disrupt named cell ranges, which are used heavily in the TSTool process. It is good practice to make a backup of the control workbook before making changes in case an error is introduced into the process.

To run the monthly SWSI analysis

Set up activities

1. **Create the current month's analysis directory by copying the previous month's directory.** The directories should be named to indicate the year and month being analyzed (YYYY-MM).
   a. Note: During the TSTool processing steps, output files are first removed so that, in the event that a step fails to create an output, the user will be able to detect this situation and not mistake old files for current results.
2. **Navigate to the new directory to open the control file (CO-SWSI-Control.xlsx) in Excel**.
   a. Go to the "Config" worksheet. Configuration properties that are entered by the user are highlighted in blue. Configuration properties that are calculated automatically are highlighted in gray.
      i. Every month, the following value should be updated:

1. CurrentMonthDate

ii. If this is the first analysis of the water year, the following values should be reviewed and changed as necessary:

1. HistoricalPeriodStartDate
2. HistoricalPeriodEndDate
3. SMSInputPeriodStartDay
4. RecentPeriodGraphStartDate

b. Go to the "Overrides" worksheet. Turn off last month's override values by setting Include=NO for any values applied to the previous month's analysis. Those data values may now be available from the source agencies.

c. Close all Excel workbooks (and any other open files in the YYYY_MM directory). The process will fail if a file is open and cannot be removed and re-written.

Run the TSTool processing steps

3. **Open the TSTool software program**.

a. The TSTool software program is installed at C:\CDSS\TSTool-XX.YY.ZZ\bin\TSTool.exe.

b. TSTool version 11.04.03 or later is required to run the Colorado SWSI Automation Tool.

c. Files with .TSTool extensions are TSTool command files that can be opened and run using TSTool. The user will need to run the TSTool command files in sequence to complete the Colorado SWSI analysis, with opportunities to review the inputs and results between steps. **Table 10** summarizes the approximate run time for each step and the overall processing time.

d. To run a TSTool command file, the user should navigate to the File – Open Command File menu option, browse to the command file, click "Open" to load the command file, and then click the "Run All Commands" button.

e. After running a TSTool processing step, all output files created by the TSTool process will be accessible from the TSTool "Output Files" tab. (Note that the control file is not created by TSTool, and therefore must be accessed through Windows Explorer.)

f. The TSTool processing steps are linear, sequential steps. When changes are made to a particular step, that step needs to be rerun along with any subsequent steps in the numbered order. This concept is particularly important to understand during the data filling steps:

i. In Step 25, the automated filling process always uses the raw data files from Steps 1-4 as input, and writes out auto-filled data files.

ii. In Step 27, the manual filling process always uses the auto-filled data from Step 25 as inputs, and writes out manual-filled data files.

Table 10. Approximate Run Times for TSTool Processing Steps

Step	Approximate Run Time (minutes)
01-DownloadNaturalFlowTimeSeries	2
02-DownloadReservoirStorageTimeSeries	2
04-DownloadNaturalFlowForecastTimeSeries	2
20-CheckRawTimeSeries	<1
25-FillDataAuto	1
27-FillDataManual	1

30-CreateTimeSeriesForSWSI	<1
50-CalculateSWSI-HUC	20
55-CalculateSWSI-Basin	5
Total Processing Time (required steps only)	**35**
60a-CompareHistSWSI-NRCS	<1
60b-GenerateCurrentSummaries	10
60c-CompareFcstSWSI-NRCS	<1
Total Processing Time (with additional steps)	47

Note: Rather than running TSTool steps 01-27 separately, the user may opt to run the aggregated version named 00-RunSteps01-27.TSTool.

4. **Download the raw input data.** All available data are downloaded to ensure that a full archive of data is kept for the month's analysis, and to minimize the need for subsequent downloads during the analysis. Input data are downloaded for each station listed in the control file on the "Combined Inputs" worksheet without consideration of which HUC or Basin will use the data. Station data are downloaded once and can then be used in multiple HUCs.
    a. **Download natural flow time series (and observed flow time series, if being used):**
        i. Load the 01-DownloadNaturalFlowTimeSeries.TSTool command file in TSTool.
            1. In the command pane, there may be a warning at the bottom of the command file indicating that the "Input file does not exist: "YYYY-MM\Input-TimeSeries-Raw\NaturalFlow\ObservedFlow-Month.dv." This file is not created if observed flow are not being used, so this warning can be disregarded.
        ii. Click "Run All Commands."
        iii. When the run is finished, click on the Problems tab.
            1. Any rows that have a Severity of "WARNING" or "FAILURE" should be reviewed. The Problem column gives details about the severity status.
            2. A Warning with a Problem of "Input file does not exist: "YYYY-MM\Input-TimeSeries-Raw\NaturalFlow\ObservedFlow-Month.dv" is OK if observed flow data are not being used in the analysis.
            3. A Warning with a Problem of "For the natural flow data type, HUC ${HUCID} is assigned a mixture of observed and natural flow stations" is OK if this situation was intentional. Otherwise, the user can go to the Combined Inputs worksheet in the control file and specify that all natural flow stations for a given HUC use observed flow data.
            4. A Warning with a Problem of "${NumStations} expected but ${NumTimeSeries} created" indicates that the number of time series created does not match the number of stations. The message will indicate if the problem is with the natural flow data from NRCS, the observed flow data from ColoradoWaterSMS, or the observed flow data from ColoradoWaterHBGuest. The data source or the data source specifications on the Combined Inputs worksheet need to be investigated.
            5. A Warning with a Problem of "No data was returned for ${NumTimeSeriesDefault} stations" indicates that the data source specified

on the Combined Inputs worksheet needs to be investigated. The message will indicate if the problem is with the natural flow data from NRCS, the observed flow data from ColoradoWaterSMS, or the observed flow data from ColoradoWaterHBGuest.

6. If changes are made in the Combined Inputs worksheet, the TSTool command file has to be re-run.

iv. The output files can be opened from the "Output Files" tab. The Flow-Month.xlsx workbook includes all the raw flow data. Missing values are denoted by blanks.

b. Download reservoir storage data:

i. Load the 02-DownloadReservoirStorageTimeSeries.TSTool command file in TSTool.
ii. Click "Run All Commands."
iii. When the run is finished, click on the Problems tab:

1. Any rows that have a Severity of "WARNING" or "FAILURE" should be reviewed. The Problem column gives details about the severity status.
2. A Warning with a Problem of ${NumTimeSeries} time series created but ${ReservoirCount} time series expected indicates that the number of time series created does not match the number of reservoirs. The message will indicate if the problem is with the data from NRCS AWDB, ColoradoWaterSMS, or ColoradoWaterHBGuest. The data source or the data source specifications on the Combined Inputs worksheet need to be investigated.
3. A Warning with a Problem of "No data was returned for ${NumTimeSeries} stations" indicates that the data source specified on the Combined Inputs worksheet needs to be investigated. The message will indicate if the problem is with the NRCS AWDB, ColoradoWaterSMS, or ColoradoWaterHBGuest data.
4. If changes are made in the Combined Inputs worksheet, the TSTool command file has to be re-run.

iv. The output files can be opened from the "Output Files" tab. The ReservoirStorage-Month.xlsx workbook includes all the end-of-month storage data. Missing values are denoted by blanks.

c. Download forecasted natural flow data:

i. Load the 04-DownloadNaturalFlowForecast.TSTool command file into TSTool.
ii. Click "Run All Commands."
iii. When the run is finished, click on the Problems tab:

1. Any rows that have a Severity of "WARNING" or "FAILURE" should be reviewed. The Problem column gives details about the severity status.
2. A Warning with a Problem of "${NumTS} time series created but ${ForecastedCount} time series expected indicates that the data source specified on the Combined Inputs worksheet needs to be investigated.
3. If changes are made in the Combined Inputs worksheet, the TSTool command file has to be re-run.

iv. The output files can be opened from the "Output Files" tab. The ForecastedNaturalFlow-Month.xlsx workbook includes all the forecasted natural flow data. Missing values are denoted by blanks.

5. **Analyze the raw data for missing values.**

a. Load the 20-CheckRawTimeSeries.TSTool command file into TSTool.
b. Click "Run All Commands."

c. When the run is finished, click on the Problems tab:
    i. Any rows that have a Severity of "WARNING" or "FAILURE" should be reviewed. The Problem column gives details about the severity status.
    ii. There will be a Warning with a Problem of "Severity for RunCommands (WARNING) is max of commands in command file that was run." This warning is OK and simply means that warnings were generated due to missing values.
    iii. There will likely be many Warnings with Type=Missing and Problems of "Time series {TS_Alias} value NaN at {YYYY-MM} is missing. These warnings are OK and simply mean that warnings were generated due to missing values.
d. Use Windows Explorer to navigate to the 20-CheckRawTimeSeries folder. Open "TimeSeriesChecks.xlsx" in Excel.
    i. On the Natural Flow, Observed Flow, Reservoir Storage, and Forecasted Natural Flow worksheets, cells that contain the missing count are highlighted in red if a station has missing data.
    ii. On the Missing Value List worksheet, missing values are listed by descending date.
    iii. Note that during the Colorado SWSI Automation Tool development, Open Water Foundation performed a significant review of the historical data and addressed most issues using the automated filling options. However, new issues may arise because of changes in data availability.
    iv. On the Natural Flow worksheet, make note of any stations with missing data, particularly in the historical period or for the previous month. (The data have not yet been shifted and transformed into component values, so the previous month's flow value is needed for the previous month's streamflow component.) The user should determine whether missing values should be filled, and if so, whether automatically using regression analysis or manually using user-determined override values.
        1. Note: if the user has specified to use observed flow data for the previous month's streamflow component for a station, the missing counts for that station's natural flow data will be too high. There is no effect on the results if the user chooses to fill unnecessary missing natural flow values; some of the filled data values will not be used where observed flow data are being used instead.
    v. On the Reservoir Storage worksheet, make note of any stations with missing data, particularly in the historical period or for the previous month. Determine whether missing values should be filled, and if so, whether automatically (using interpolation, historical monthly averages, or zeroes) or manually using user-determined override values. (Note that the data have not yet been shifted and transformed into component values, so the previous month's storage value is needed for the reservoir storage component.)
    vi. On the Forecasted Natural Flow worksheet, make note of any stations with missing data, particularly for the current month. Determine whether missing values should be filled. The only filling option currently implemented is user-determined override values.
    vii. On the Observed Flow worksheet, make note of any stations with missing data, particularly in the historical period or for the previous month. (The data have not yet been shifted and transformed into component values, so the previous month's flow value is needed for the previous month's streamflow component.) The user should determine whether missing values should be filled, and if so, whether

automatically using regression analysis or manually using user-determined override values.

viii. Open the control workbook (CO-SWSI-Control.xlsx) and enter new filling information (if needed) on the FlowDataFill, ReservoirDataFill, and Overrides worksheets. **Note: the auto-filling indicated on the FlowDataFill and ReservoirDataFill worksheets will only fill values that are missing in the raw datasets. In contrast, the manual overrides specified on the Overrides worksheet will be used regardless of whether the value in the auto-filled datasets is missing or not.**

ix. Close all workbooks. The process will fail if a file is open and cannot be removed and re-written. If the process does fail, simply close all workbooks and rerun this step. The user does not need to rerun earlier steps.

6. Fill missing values using automated filling techniques in TSTool.

a. Load the 25-FillDataAuto.TSTool command file into TSTool.
   i. In the command pane, warnings may be associated with the observed data files if they don't exist. This is OK if observed data are not being used in the analysis.

b. Click "Run All Commands."

c. When finished running, click on the Problems tab.
   i. Any rows that have a Severity of "WARNING" or "FAILURE" should be reviewed. The Problem column gives details about the severity status.
   ii. There will be a Warning with a Problem of "Severity for RunCommands (WARNING) is max of commands in command file that was run." This warning is OK and simply means that warnings were generated due to missing values.
   iii. There will likely be several Warnings with Type=Missing and Problems of "Time series {TS_Alias} value NaN at {YYYY-MM} is missing. These warnings are OK and simply mean that warnings were generated due to missing values.
   iv. A Warning with a Problem of "${StationsCount} filling stations expected, but data read for only ${NumStationsRead} stations" indicates that the filling data source information specified on the flow filling worksheet needs to be investigated. The message will indicate whether the issue is with the natural flow filling or the observed flow filling data.
      1. If changes are made on the FlowDataFill worksheet, the TSTool command file has to be re-run.

d. To review the regression statistics from the natural flow filling, go to the Tables tab and open NatFlow_RegressionStats. This table summarizes:
   i. The dependent station being filled (ID)
   ii. The independent station used for filling (Independent_ID)
   iii. Dates of available data (DependentAnalysisStart, DependentAnalysisEnd, IndependentAnalysisStart, IndependentAnalysisEnd)
   iv. Period used for filling (FillStart and FillEnd)
   v. Regression statistics for each month (where the month is denoted by suffixes of _1 to _12), such as correlation coefficient (e.g., R_1) and coefficient of determination (e.g., R2_1).

e. If observed data are being used, and filling is being performed on the observed flow data, the regression statistics will be written to ObsFlow_RegressionStats.

f. To compare the raw and filled time series, commands are provided at the end of the command file. Run the commands to read the raw and filled time series. For a given station, select the raw and filled time series to plot using a line graph.
   i. To see the data flags, right-click on the graph and select "Properties."

ii. Under Time Series Properties, select the Symbol tab.
iii. Select a symbol for the flagged data symbol and choose a symbol size larger than 0.
iv. Close the Properties window.

g. Alternatively, to review the filled data using Excel, go to the Output Files tab:
i. Open the NaturalFlow-Month-1AutoFilled.xlsx workbook to review the filled natural flow data.
ii. If observed data are being used, open the ObservedFlow-Month-1AutoFilled.xlsx workbook to review the filled observed flow data.
iii. Open the ReservoirStorage-Month-1AutoFilled.xlsx workbook to review the filled reservoir storage data.
iv. Missing values are denoted using blanks.

h. Use Windows Explorer to navigate to the 25-FillDataAuto folder. Open "TimeSeriesChecks.xlsx" in Excel.
i. Determine whether adjustments are needed to the auto-filling specifications.
1. If changes are made to the auto-filling specifications, this step needs to be re-run in TSTool, as well as all subsequent steps. Previous steps do not need to be rerun.
ii. Determine whether additional missing values should be filled using overrides.
1. Open the control workbook (CO-SWSI-Control.xlsx) and enter filling information on the Overrides worksheet. Manual overrides can be used for any date in the historical period, recent period, or current water year, for example to provide data where automated filling is difficult to perform, or for current data that may not yet be available from web services.
2. Note that at this point in the process, the data have not yet been time-shifted and transformed into component values. The manual overrides should be specified using the date stamps and data types associated with the raw data.

i. Close all workbooks. The process will fail if a file is open and cannot be removed and re-written.

7. Fill missing values using manual overrides specified by the user.

a. Load the 27-FillDataManual.TSTool command file into TSTool.
i. In the command pane, warnings may be associated with the observed data files if they don't exist. This is OK if observed data are not being used in the analysis.

b. Click "Run All Commands."

c. When finished running, click on the Problems tab.
i. Any rows that have a Severity of "WARNING" or "FAILURE" should be reviewed. The Problem column gives details about the severity status.
ii. There will be a Warning with a Problem of "Severity for RunCommands (WARNING) is max of commands in command file that was run." This warning is OK and simply means that warnings were generated due to missing values.
iii. There will likely be several Warnings with Type=Missing and Problems of "Time series {TS_Alias} value NaN at {YYYY-MM} is missing. These warnings are OK and simply mean that warnings were generated due to missing values.

d. To check that the manual overrides were applied, open a filled time series as a table. Choose to have the flags shown as a superscript. Scroll to the override dates and confirm that the values and flags were set as expected.

e. Alternatively, to review the filled data using Excel, go to the Output Files tab:

i. Open the Input-Data-Final.xlsx workbook. This workbook contains the final input data and all data flags denoting data source, quality, and manipulations. **Table 11** contains a list of the data flags that are used in the process.

Table 11. Data Flags and Definitions

Data Flag Abbreviation	Data Flag Description
R	Value filled using monthly linear regression
Z	Value filled using 0
RZ	Value filled using monthly linear regression was negative and was replaced with 0
I	Value filled using linear interpolation between surrounding values
H	Value filled using historical monthly averages
MO-*	Value filled using manual override
M	Value is missing
HB	Value obtained from the State of CO HydroBase database
SMS	Value obtained from the State of CO Satellite Monitoring System
E	Value is edited (assigned by NRCS, value can be treated the same as a value without a data flag)

ii. Missing values are denoted using blanks.

f. Use Windows Explorer to navigate to the 27-FillDataManual folder. Open "TimeSeriesChecks.xlsx" in Excel.
   i. Determine whether any additional missing values should be filled. If so, make changes to the FlowDataFill, ReservoirDataFill, and Overrides worksheets. Repeat steps 6 and 7 as needed.
   ii. Moving forward, the impacts of missing data are as follows:
      1. If data are missing in the historical period, fewer years will be used to establish the SWSI and NEP distributions, and the ranges of possible SWSI and NEP values will narrow.
      2. If data are missing in the recent period, SWSI and NEP results will also be missing in the recent period, which affects the graphical and tabular outputs.
      3. If data are missing in the current month, SWSI and NEP results will also be missing.
      4. The exception to this is stations where natural flow data are noted as missing, but are not being used because the user has elected to use observed streamflow for the previous month's streamflow component. As long as the needed observed flow data are available, the SWSI and NEP results will be calculated.

g. Close all Excel workbooks. The process will fail if a file is open and cannot be removed and re-written.

Note: Rather than running TSTool steps 30-55 separately, the user may opt to run the aggregated version named 00-RunSteps30-50.TSTool.

8. **Create the SWSI component input data**.
   a. Load the 30-CreateTimeSeriesForSWSI.TSTool command file into TSTool.

i. In the command pane, warnings may be associated with the observed data files if they don't exist. This is OK if observed data are not being used in the analysis.

b. Click "Run All Commands."

c. When finished running, click on the Problems tab.
   i. Any rows that have a Severity of "WARNING" or "FAILURE" should be reviewed. The Problem column gives details about the severity status.
   ii. There will be a Warning with a Problem of "Severity for RunCommands (WARNING) is max of commands in command file that was run." This warning is OK and simply means that warnings were generated due to missing values.
   iii. There will likely be several Warnings with Type=Missing and Problems of "Time series {TS_Alias} value NaN at {YYYY-MM} is missing. These warnings are OK and simply mean that warnings were generated due to missing values.

d. If desired, scroll to the bottom of the command file and run the commands to read the raw and transformed data.

e. From this point forward in the process, the input data have been time-shifted and transformed into component values.

f. Use Windows Explorer to navigate to the 30-CreateTimeSeriesForSWSI folder. Open "TimeSeriesChecks.xlsx" in Excel.
   i. If no observed flow data are being used, the missing value information should be the same as was obtained in Step 27, although the dates may have been time-shifted in creating the components.
   ii. If observed flow data are being used, there should be fewer missing values because the program has at this point substituted observed flow for the previous month's streamflow component.

g. On the Output Files tab, open the SWSI-Components-Data.xlsx workbook. This workbook contains the final component data by station after transformations and time shifts. Most data flags are shown, though the forecasted runoff component no longer has data flags where historical natural flow data have been used, due to data accumulations.

h. Close all workbooks. The process will fail if a file is open and cannot be removed and re-written.

9. **Calculate the SWSI results by HUC.**

   a. Load the 50-CalculateSWSI-HUC.TSTool command file into TSTool.

   b. Click "Run All Commands."

   c. When finished running, click on the Problems tab.
      i. Any rows that have a Severity of "WARNING" or "FAILURE" should be reviewed. The Problem column gives details about the severity status.
      ii. A Failure with a Problem of "ERROR - ${HUCCount} HUCs found but ${NumberOfHUCs} expected. Check HUC IDs and HUC Names in control file." Indicates that there are typos in the HUC information on the Combined Inputs worksheet, resulting in duplicates. Fix the problem and then re-run this step.
      iii. A Failure with a Problem similar to "ERROR for HUC ${HUCID} - ${SelectReservoirCount} reservoirs found but ${NumReservoirs} expected. FIX!" indicates a problem with the TSTool process and/or possibly duplicate stations assigned to a HUC for the same data type. Fix the problem and then re-run this step.

   d. Review all HUC products in the Results-Web folder, in particular the SWSI Current Summary workbook and the HUC graphical outputs, to quality control the results.

10. **Calculate the SWSI results by Basin.**

    a. Load the 55-CalculateSWSI-Basin.TSTool command file into TSTool.

b. Click "Run All Commands."
c. When finished running, click on the Problems tab.
    i. Any rows that have a Severity of "WARNING" or "FAILURE" should be reviewed. The Problem column gives details about the severity status.
    ii. A Failure with a Problem of "ERROR - ${BasinCount} Basins found but ${NumberOfBasins} expected. Check control file." Indicates that there are typos in the Basin information on the Combined Inputs worksheet, resulting in duplicates. Fix the problem and then re-run this step.
    iii. A Failure with a Problem similar to "ERROR for Basin ${Basin} - ${SelectReservoirCount} reservoirs found but ${NumReservoirs} expected. FIX!" indicates a problem with the TSTool process and/or possibly duplicate stations assigned to a Basin for the same data type. Fix the problem and then re-run this step.
d. Review all Basin products in the Results-Web folder, in particular the SWSI Current Summary workbook and the graphical outputs, to quality control the results.

Review and disseminate the output products

11. Go to the YYYY_MM\Results_Web folder to review available graphical and tabular output products.
12. Provide the SWSI-Current-Summary.xlsx file to OIT to load into HydroBase.
13. Archive the following files (at a minimum) so that the Colorado SWSI outputs can be re-generated in the future:
    a. CO-SWSI-Control.xlsx
    b. Input-TimeSeries-Raw/Input-Data-Final.xlsx (*Note: this file is not required to rerun the SWSI analysis, but it contains the final input data with all data flags that indicate data sources and filling that may be of interest to the user in deciphering results.*)
    c. Input-TimeSeries-ForSWSI/ForecastedRunoff/SWSI-Component-ForecastedRunoff.dv
    d. Input-TimeSeries-ForSWSI/ForecastedRunoff/Station-ForecastedRunoff-NEP.dv
    e. Input-TimeSeries-ForSWSI/PrevMoStreamflow/SWSI-Component-PrevMoStreamflow.dv
    f. Input-TimeSeries-ForSWSI/PrevMoStreamflow/Station-PrevMoStreamflow-NEP.dv
    g. Input-TimeSeries-ForSWSI/ReservoirStorage/SWSI-Component-ReservoirStorage.dv
    h. Input-TimeSeries-ForSWSI/ReservoirStorage/Station-ReservoirStorage-NEP.dv

    Note: With the above files saved, the user can rerun the SWSI analysis starting from Step 50 in the TSTool process.

Compare Colorado Historical SWSI Values to NRCS Historical SWSI Values (Optional)

14. Run Historical SWSI Comparison
    a. Load the 60a-CompareHistSWSI-NRCS.TSTool command file into TSTool.
    b. Click "Run All Commands."
    c. Click on the Problems tab and confirm there are no warnings or failures.
    d. On the Output Files tab, click on the results graphs to review.

To run Colorado SWSI Re-forecasts

1. **Set "RecentPeriodFlowType" property in control workbook to ForecastedNaturalFlow. Save and exit the workbook.**
2. **Follow the procedure specified above in "To run the monthly SWSI analysis."**
3. **Extend the NRCS Forecast SWSI dataset.** This process uses NRCS Forecast SWSI data contained in the Input-TimeSeries-ForSWSI/ComparisonData/NRCS-SWSI-Recent.dv file. New values can be added to this dataset in one of two ways:
    a. New values can be manually added using a text editor by copying a previous line and then updating the values. If this approach is used, the user also needs to manually update the End property in the DateValue file header.
    b. Rename the existing file and then use TSTool to read the existing file and the file containing new values, merge the time series, and write out a new file with the original file name (Input-TimeSeries-ForSWSI/ComparisonData/NRCS-SWSI-Recent.dv).
4. **Generate dated Current SWSI Summaries for each month in the recent period.**
    a. Load the 60b-GenerateCurrentSummaries.TSTool command file into TSTool.
    b. Click "Run All Commands."
    c. When finished, click on the Problems tab to ensure no warnings or failures were generated.
    d. Open the dated summary files from the Output Files tab.

Compare Colorado Forecast SWSI Values to NRCS Forecast SWSI Values (Optional)

5. **Run Forecast SWSI Comparison**
    e. Load the 60c-CompareFcstSWSI-NRCS.TSTool command file into TSTool.
    f. Click "Run All Commands."
    g. Click on the Problems tab and confirm there are no warnings or failures.
    h. On the Output Files tab, click on the results graphs to review.

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Appendix A – NRCS Native Flow Equations

Calculations completed to generate SRVO (Native Flow) data for AWDB Database

Source: Gus Goodbody, NRCS. Last updated: 7/15/2015

Basin	HUC8 ID	HUC8 Name	Station ID	Station Name	Native Flow Calculation	Component ID/Name	Component Type
South Platte	10190003	Middle South Platte- Cherry Creek. Colorado.	06707500	SOUTH PLATTE RIVER AT SOUTH PLATTE	Externally Adjusted		
South Platte	10190003	Middle South Platte- Cherry Creek. Colorado.	06710385	BEAR CREEK ABV EVERGREEN	no adjustments		
South Platte	10190003	Middle South Platte- Cherry Creek. Colorado.	06719505	CLEAR CREEK AT GOLDEN	+	06719505 - Clear Ck at Golden	Observed
					-	09021500 - Berthoud Pass Ditch nr Berthoud Pass	Diversion
					+	200540 - Church Ditch	Diversion
					+	700542 - Golden City Ditch	Diversion
					-	VIDTUNCO - Vidler Tunnel	Diversion
South Platte	10190003	Middle South Platte- Cherry Creek. Colorado.	06724000	SAINT VRAIN CREEK AT LYONS	Externally Adjusted		
South Platte	10190003	Middle South Platte- Cherry Creek. Colorado.	06727000	BOULDER CREEK NEAR ORODELL	Externally Adjusted		
South Platte	10190003	Middle South Platte- Cherry Creek. Colorado.	06729500	SOUTH BOULDER CK NR ELDORADO SPRINGS, CO	+	06729500 - South Boulder Ck nr Eldorado Springs	Observed
					+	06016130 - Gross Reservoir	Change in Storage
					-	09022500 - Moffat Water Tunnel at East Portal	Diversion
					+	BOSDELCO - South Boulder Ck Div	Diversion
South Platte	10190003	Middle South Platte- Cherry Creek. Colorado.	06738000	BIG THOMPSON R AT MOUTH, NR DRAKE, CO	Externally Adjusted		

Basin	HUC8 ID	HUC8 Name	Station ID	Station Name	Native Flow Calculation	Component ID/Name	Component Type
South Platte	10190003	Middle South Platte- Cherry Creek. Colorado.	06752000	CACHE LA POUDRE R AT CANYON MOUTH	Externally Adjusted		
Yampa/White	10180001	North Platte Headwaters. Colorado.	06620000	NORTH PLATTE R NR NORTHGATE	+	06620000 - North Platte R nr Northgate	Observed
					+	06745500 - Cameron Pass Ditch	Diversion
					+	06746000 - Michigan Ditch	Diversion
South Platte	10190001	South Platte Headwater. Colorado.	06695500	ELEVENMILE CANYON RE NEAR LAKE GEORGE	Externally Adjusted		
South Platte	10190002	Upper South Platte. Colorado.	06707500	SOUTH PLATTE RIVER AT SOUTH PLATTE	Externally Adjusted		
South Platte	10190002	Upper South Platte. Colorado.	06710385	BEAR CREEK ABV EVERGREEN	no adjustments		
South Platte	10190004	Clear. Colorado	06719505	CLEAR CREEK AT GOLDEN	+	06719505 - Clear Ck at Golden	Observed
					-	09021500 - Berthoud Pass Ditch nr Berthoud Pass	Diversion
					+	200540 - Church Ditch	Diversion
					+	700542 - Golden City Ditch	Diversion
					-	VIDTUNCO - Vidler Tunnel	Diversion
South Platte	10190005	St. Vrain. Colorado.	06724000	SAINT VRAIN CREEK AT LYONS	Externally Adjusted		
South Platte	10190005	St. Vrain. Colorado.	06727000	BOULDER CREEK NEAR ORODELL	Externally Adjusted		
South Platte	10190005	St. Vrain. Colorado.	06729500	SOUTH BOULDER CK NR ELDORADO SPRINGS, CO	+	06729500 - South Boulder Ck nr Eldorado Springs	Observed
					+	06016130 - Gross Reservoir	Change in Storage
					-	09022500 - Moffat Water Tunnel at East Portal	Diversion
					+	BOSDELCO - South Boulder Ck Div	Diversion
South Platte	10190006	Big Thompson. Colorado.	06738000	BIG THOMPSON R AT MOUTH, NR DRAKE, CO	Externally Adjusted		
South Platte	10190007	Cache La Poudre. Colorado, Wyoming.	06752000	CACHE LA POUDRE R AT CANYON MOUTH NEAR FORT COLLINS	Externally Adjusted		
South Platte	10190012	Middle South Platte- Sterling. Colorado, Nebraska.	06707500	SOUTH PLATTE RIVER AT SOUTH PLATTE	Externally Adjusted		
South Platte	10190012	Middle South Platte- Sterling. Colorado, Nebraska.	06710385	BEAR CREEK ABV EVERGREEN	no adjustments		
South Platte	10190012	Middle South Platte- Sterling. Colorado, Nebraska.	06719505	CLEAR CREEK AT GOLDEN	+	06719505 - Clear Ck at Golden	Observed
					-	09021500 - Berthoud Pass Ditch nr Berthoud Pass	Diversion

Basin	HUC8 ID	HUC8 Name	Station ID	Station Name	Native Flow Calculation	Component ID/Name	Component Type
					+	200540 - Church Ditch	Diversion
					+	700542 - Golden City Ditch	Diversion
					-	VIDTUNCO - Vidler Tunnel	Diversion
South Platte	10190012	Middle South Platte-Sterling. Colorado, Nebraska.	06724000	SAINT VRAIN CREEK AT LYONS	Externally Adjusted		
South Platte	10190012	Middle South Platte-Sterling. Colorado, Nebraska.	06727000	BOULDER CREEK NEAR ORODELL	Externally Adjusted		
South Platte	10190012	Middle South Platte-Sterling. Colorado, Nebraska.	06729500	SOUTH BOULDER CK NR ELDORADO SPRINGS, CO	+	06729500 - South Boulder Ck nr Eldorado Springs	Observed
					+	06016130 - Gross Reservoir	Change in Storage
					-	09022500 - Moffat Water Tunnel at East Portal	Diversion
					+	BOSDELCO - South Boulder Ck Div	Diversion
South Platte	10190012	Middle South Platte-Sterling. Colorado, Nebraska.	06738000	BIG THOMPSON R AT MOUTH, NR DRAKE, CO	Externally Adjusted		
South Platte	10190012	Middle South Platte-Sterling. Colorado, Nebraska.	06752000	CACHE LA POUDRE R AT CANYON MOUTH	Externally Adjusted		
Arkansas	11020001	Arkansas Headwaters. Colorado.	07091500	ARKANSAS RIVER AT SALIDA	+	07091500 - Arkansas R at Salida	Observed
					-	07081900 - Boustead Tunnel	Diversion
					-	09077500 - Busk Ivanhoe Tunnel	Diversion
					+	07007020 - Clear Creek Reservoir	Change in Storage
					-	09061500 - Columbine Ditch	Diversion
					-	CO0006 - Ewing Ditch	Diversion
					-	07081899 - Homestake Tunnel	Diversion
					+	CO0017 - Otero Pump Station	Diversion
					+	07007110 - Turquoise Lake	Change in Storage
					+	07007120 - Twin Lakes Reservoir	Change in Storage
					-	CO0033 - Twin Lakes Tunnel	Diversion
					-	CO0040 - Wurtz Ditch	Diversion
Arkansas	11020002	Upper Arkansas. Colorado.	07099400	ARKANSAS RIVER ABOVE PUEBLO	+	07099400 - Arkansas R ab Pueblo	Observed
					+	07091500 - Arkansas R at Salida	Combined Adjustments

Basin	HUC8 ID	HUC8 Name	Station ID	Station Name	Native Flow Calculation	Component ID/Name	Component Type
					+	07099375 - Bessemer Ditch	Diversion
					+	07095900 - Canon City Hydraulic	Diversion
					+	07096100 - Canon City Oil Creek Ditch	Diversion
					+	07094400 - Canon City Water Works	Diversion
					+	CO0001 - City Of Florence	Diversion
					+	09115000 - Larkspur Ditch at Marshall Pass	Diversion
					+	07096530 - Minnequa Canal	Diversion
					+	CO0018 - Pbww Municipal Outlet	Diversion
					+	07007090 - Pueblo Reservoir	Change in Storage
					-	CO0019 - Pueres Exchange Release	Diversion
					+	CO0020 - Pueres Exchange/apod Storage	Diversion
					+	CO0027 - South Canon Ditch	Diversion
Arkansas	11020005	Upper Arkansas- Lake Meredith. Colorado.	07099400	ARKANSAS RIVER ABOVE PUEBLO	+	07099400 - Arkansas R ab Pueblo	Observed
					+	07091500 - Arkansas R at Salida	Combined Adjustments
					+	07099375 - Bessemer Ditch	Diversion
					+	07095900 - Canon City Hydraulic	Diversion
					+	07096100 - Canon City Oil Creek Ditch	Diversion
					+	07094400 - Canon City Water Works	Diversion
					+	CO0001 - City Of Florence	Diversion
					+	09115000 - Larkspur Ditch at Marshall Pass	Diversion
					+	07096530 - Minnequa Canal	Diversion
					+	CO0018 - Pbww Municipal Outlet	Diversion
					+	07007090 - Pueblo Reservoir	Change in Storage
					-	CO0019 - Pueres Exchange Release	Diversion
					+	CO0020 - Pueres Exchange/apod Storage	Diversion

Basin	HUC8 ID	HUC8 Name	Station ID	Station Name	Native Flow Calculation	Component ID/Name	Component Type
					+	CO0027 - South Canon Ditch	Diversion
Arkansas	11020005	Upper Arkansas- Lake Meredith. Colorado.	07111000	HUERFANO RIVER NEAR REDWING	no adjustments		
Arkansas	11020005	Upper Arkansas- Lake Meredith. Colorado.	07114000	CUCHARAS RIVER AT BOYD RANCH NR LA VETA	no adjustments		
Arkansas	11020006	Huerfano. Colorado.	07111000	HUERFANO RIVER NEAR REDWING	no adjustments		
Arkansas	11020006	Huerfano. Colorado.	07114000	CUCHARAS RIVER AT BOYD RANCH NR LA VETA	no adjustments		
Arkansas	11020009	Upper Arkansas- John Martin Reservoir. Colorado, Kansas	07099400	ARKANSAS RIVER ABOVE PUEBLO	+	07099400 - Arkansas R ab Pueblo	Observed
					+	07091500 - Arkansas R at Salida	Combined Adjustments
					+	07099375 - Bessemer Ditch	Diversion
					+	07095900 - Canon City Hydraulic	Diversion
					+	07096100 - Canon City Oil Creek Ditch	Diversion
					+	07094400 - Canon City Water Works	Diversion
					+	CO0001 - City Of Florence	Diversion
					+	09115000 - Larkspur Ditch at Marshall Pass	Diversion
					+	07096530 - Minnequa Canal	Diversion
					+	CO0018 - Pbww Municipal Outlet	Diversion
					+	07007090 - Pueblo Reservoir	Change in Storage
					-	CO0019 - Pueres Exchange Release	Diversion
					+	CO0020 - Pueres Exchange/apod Storage	Diversion
					+	CO0027 - South Canon Ditch	Diversion
Arkansas	11020009	Upper Arkansas- John Martin Reservoir. Colorado, Kansas	07111000	HUERFANO RIVER NEAR REDWING	no adjustments		
Arkansas	11020009	Upper Arkansas- John Martin Reservoir. Colorado, Kansas	07114000	CUCHARAS RIVER AT BOYD RANCH NR LA VETA	no adjustments		
Arkansas	11020009	Upper Arkansas- John Martin Reservoir. Colorado, Kansas	07124500	PURGATOIRE RIVER AT TRINIDAD	+	07124500 - Trinidad Lake Inflow	Observed
					+	07007100 - Trinidad Lake	Change in Storage
Arkansas	11020010	Purgatoire. Colorado, New Mexico.	07124500	PURGATOIRE RIVER AT TRINIDAD	+	07124500 - Trinidad Lake Inflow	Observed

Basin	HUC8 ID	HUC8 Name	Station ID	Station Name	Native Flow Calculation	Component ID/Name	Component Type
					+	07007100 - Trinidad Lake	Change in Storage
Rio Grande	13010001	Rio Grande Headwaters. Colorado.	08220000	RIO GRANDE NEAR DEL NORTE	+	08220000 - Rio Grande nr Del Norte	Observed
					+	08219000 - Beaver Reservoir	Change in Storage
					-	09341000 - Treasure Pass Ditch	Diversion
					+	08008170 - Continental Reservoir	Change in Storage
					+	08008150 - Santa Maria Reservoir	Change in Storage
					-	CO0029 - Tabor Ditch	Diversion
					-	CO0037 - Williams Creek-Squaw Pass Ditch	Diversion
					-	09352000 - Pine River Weminuche Pass Ditch	Diversion
					+	08008130 - Rio Grande Reservoir	Change in Storage
					-	CO0036 - Weminuche Pass Ditch	Diversion
Rio Grande	13010002	Alamosa-Trinchera. Colorado, New Mexico.	08236000	ALAMOSA CREEK ABOVE TERRACE RESERVOIR	no adjustments		
Rio Grande	13010002	Alamosa-Trinchera. Colorado, New Mexico.	08240500	TRINCHERA CK	no adjustments		
Rio Grande	13010002	Alamosa-Trinchera. Colorado, New Mexico.	08241500	SANGRE DE CRISTO	+	08241500 - Sangre De Cristo Ck	Observed
					+	CO0012 - Indian Creek Diversion	Diversion
					+	3500570 - Sdc-Trinchera Canal	Diversion
Rio Grande	13010002	Alamosa-Trinchera. Colorado, New Mexico.	08242500	UTE CREEK	no adjustments		
Rio Grande	13010002	Alamosa-Trinchera. Colorado, New Mexico.	08250000	CULEBRA CREEK AT SAN LUIS	+	08250000 - Culebra Ck at San Luis	Observed
					+	08008140 - Sanchez Reservoir	Change in Storage
Rio Grande	13010004	Saguache. Colorado.	08227000	SAGUACHE CREEK NEAR SAGUACHE, CO	no adjustments		
Rio Grande	13010005	Conejos. Colorado, New Mexico.	08246500	CONEJOS RIVER NEAR MOGOTE	+	08246500 - Conejos R nr Mogote	Observed
					+	08008120 - Platoro Reservoir	Change in Storage
Colorado	14010001	Colorado Headwaters. Colorado.	09019000	COLORADO RIVER INFLOW TO LAKE GRANBY	+	09019000 - Colorado R bl Lake Granby	Externally Adjusted-BOR

Basin	HUC8 ID	HUC8 Name	Station ID	Station Name	Native Flow Calculation	Component ID/Name	Component Type
					+	09010000 - Grand River Ditch at La Poudre Pass	Diversion
Colorado	14010001	Colorado Headwaters. Colorado.	09021000	WILLOW CK INFLOW TO WILLOW CK RESERVOIR	Externally Adjusted		
Colorado	14010001	Colorado Headwaters. Colorado.	09038500	WILLIAMS FORK BLW WILLIAMS FORK RESERVOIR	+	09038500 - Williams Fk bl Williams Fk Reservoir	Observed
					+	CO0041 - August P Gumlick Tunnel	Diversion
					+	0937300 - Big Lake Ditch	Diversion
					+	09009150 - Williams Fork Reservoir	Change in Storage
Colorado	14010001	Colorado Headwaters. Colorado.	09070500	COLORADO RIVER NEAR DOTSERO	+	09070500 - Colorado R nr Dotsero	Observed
					+	09013000 - Alva B. Adams Tunnel at East Portal	Diversion
					+	0937300 - Big Lake Ditch	Diversion
					+	09009030 - Green Mountain Reservoir	Change in Storage
					+	09009020 - Dillon Reservoir	Change in Storage
					+	06702400 - Harold D. Roberts Tunnel Near Grant	Diversion
					+	09042000 - Hoosier Pass Tunnel Near Alma	Diversion
					+	09061500 - Columbine Ditch	Diversion
					+	CO0006 - Ewing Ditch	Diversion
					+	09009040 - Homestake Reservoir	Change in Storage
					+	07081899 - Homestake Tunnel	Diversion
					+	CO0040 - Wurtz Ditch	Diversion
					+	09010000 - Grand River Ditch at La Poudre Pass	Diversion
					+	09009060 - Lake Granby	Change in Storage
					+	09022500 - Moffat Water Tunnel at East Portal	Diversion
					+	09014500 - Shadow Mountain Reservoir	Change in Storage
					+	09009150 - Williams Fork Reservoir	Change in Storage
					+	09009160 - Willow Creek Reservoir	Change in Storage

Basin	HUC8 ID	HUC8 Name	Station ID	Station Name	Native Flow Calculation	Component ID/Name	Component Type
					+	09041395 - Wolford Mountain Reservoir	Change in Storage
Colorado	14010002	Blue. Colorado.	09057500	BLUE RIVER INFLOW TO GREEN MOUNTAIN RES	+	09057500 - Blue R bl Green Mountain Reservoir	Observed
					+	09009030 - Green Mountain Reservoir	Change in Storage
					+	09009020 - Dillon Reservoir	Change in Storage
					+	06702400 - Harold D. Roberts Tunnel Near Grant	Diversion
					+	09042000 - Hoosier Pass Tunnel Near Alma	Diversion
Colorado	14010003	Eagle. Colorado.	09070000	EAGLE RIVER BELOW GYPSUM	+	09070000 - Eagle R bl Gypsum	Observed
					+	09061500 - Columbine Ditch	Diversion
					+	CO0006 - Ewing Ditch	Diversion
					+	09009040 - Homestake Reservoir	Change in Storage
					+	07081899 - Homestake Tunnel	Diversion
					+	CO0040 - Wurtz Ditch	Diversion
Colorado	14010004	Roaring Fork. Colorado.	09085000	ROARING FORK AT GLENWOOD SPRINGS	+	09085000 - Roaring Fk at Glenwood Springs	Observed
					+	07081900 - Boustead Tunnel	Diversion
					+	09077500 - Busk Ivanhoe Tunnel	Diversion
					+	09009110 - Ruedi Reservoir	Change in Storage
					+	CO0033 - Twin Lakes Tunnel	Diversion
Colorado	14010005	Colorado Headwaters-Plateau. Colorado.	09095500	COLORADO RIVER NEAR CAMEO			
Gunnison	14020001	East-Taylor. Colorado.	09109209	TAYLOR RIVER BELOW TAYLOR PARK RESERVOIR	Externally Adjusted-BOR		
Gunnison	14020001	East-Taylor. Colorado.	09112500	EAST RIVER AT ALMONT	no adjustments		
Gunnison	14020002	Upper Gunnison. Colorado.	09114500	GUNNISON RIVER NEAR GUNNISON, CO	+	09114500 - Gunnison R Near Gunnison	Observed
					+	09009120 - Taylor Park Reservoir	Change in Storage
Gunnison	14020002	Upper Gunnison. Colorado.	09124500	LAKE FORK AT GATEVIEW, CO	no adjustments		
Gunnison	14020003	Tomichi. Colorado.	09119000	TOMICHI CREEK AT GUNNISON, CO	no adjustments		
Gunnison	14020004	North Fork Gunnison. Colorado.	09132500	NORTH FORK GUNNISON R NR SOMERSET	+	09132500 - NF Gunnison R nr Somerset	Observed

Basin	HUC8 ID	HUC8 Name	Station ID	Station Name	Native Flow Calculation	Component ID/Name	Component Type
					+	09009100 - Paonia Reservoir	Change in Storage
Gunnison	14020005	Lower Gunnison. Colorado.	09152500	GUNNISON RIVER NR GRAND JUNCTION	+	09152500 - Gunnison R nr Grand Junction	Observed
					+	09009010 - Blue Mesa Reservoir	Change in Storage
					+	09126000 - Crystal Reservoir	Change in Storage
					+	09127999 - Gunnison Tunnel	Diversion
					+	09009080 - Morrow Point Reservoir	Change in Storage
					+	09009100 - Paonia Reservoir	Change in Storage
					+	09147022 - Ridgway Reservoir	Change in Storage
					+	09125800 - Silverjack Reservoir	Change in Storage
					+	09009120 - Taylor Park Reservoir	Change in Storage
Gunnison	14020006	Uncompahange. Colorado.	09147500	UNCOMPAHGRE RIVER AT COLONA	+	09147500 - Uncompahgre R at Colona	Observed
					+	09147022 - Ridgway Reservoir	Change in Storage
San Juan/Dolores	14030002	Upper Dolores. Colorado.	09169000	DOLORES RIVER BELOW MCPHEE RESERVOIR	Externally Adjusted-BOR		
San Juan/Dolores	14030003	San Miguel. Colorado.	09172500	SAN MIGUEL RIVER NEAR PLACERVILLE	no adjustments		
Yampa/White	14050001	Upper Yampa. Colorado.	09239500	YAMPA RIVER AT STEAMBOAT SPRINGS	+	09239500 - Yampa R at Steamboat Springs	Observed
					+	09237495 - Stagecoach Reservoir nr Oak Creek	Change in Storage
					+	YAMRESCO - Yamcolo Reservoir	Change in Storage
Yampa/White	14050001	Upper Yampa. Colorado.	09242500	ELKHEAD RIVER NEAR MILNER			
Yampa/White	14050001	Upper Yampa. Colorado.	09246200	ELKHEAD CREEK ABOVE LONG GULCH	no adjustments		
Yampa/White	14050002	Lower Yampa. Colorado.	09251000	YAMPA RIVER NEAR MAYBELL	+	09251000 - Yampa R nr Maybell	Observed
					+	09237495 - Stagecoach Reservoir nr Oak Creek	Change in Storage
					+	YAMRESCO - Yamcolo Reservoir	Change in Storage
Yampa/White	14050003	Little Snake. Colorado.	09260000	LITTLE SNAKE RIVER NEAR LILY	+	09260000 - Little Snake R nr Lily	Observed
					+	WY0001 - City Of Cheyenne Tunnel	Diversion

Basin	HUC8 ID	HUC8 Name	Station ID	Station Name	Native Flow Calculation	Component ID/Name	Component Type
Yampa/White	14050005	Upper White. Colorado.	09304500	WHITE RIVER NEAR MEEKER	no adjustments		
San Juan/Dolores	14080101	Upper San Juan. Colorado.	09346400	SAN JUAN RIVER NEAR CARRACAS	+	09346400 - San Juan R nr Carracas	Observed
					+	08284160 - Azotea Tunnel	Diversion
San Juan/Dolores	14080101	Upper San Juan. Colorado.	09353500	LOS PINOS RIVER NEAR BAYFIELD	Externally Adjusted-BOR		
San Juan/Dolores	14080102	Piedra. Colorado.	09349800	PIEDRA RIVER NEAR ARBOLES	no adjustments		
San Juan/Dolores	14080104	Animas. Colorado.	09361500	ANIMAS RIVER AT DURANGO	no adjustments		
San Juan/Dolores	14080104	Animas. Colorado.	09363100	FLORIDA RIVER BELOW LEMON RESERVOIR NR DURANGO	Externally Adjusted-BOR		
San Juan/Dolores	14080105	Middle San Juan. Colorado.	09365500	LA PLATA RIVER AT HESPERUS	no adjustments		
San Juan/Dolores	14080107	Mancos. Colorado.	09370500	MANCOS RIVER NEAR MANCOS	Externally Adjusted-CBRFC		

Appendix B – Station Assignments by HUC

The station assignments by HUC shown in this appendix are included in the "Combined Inputs" worksheet of the control file. The following list was created on June 30, 2015 but may become out-of-date as CWCB and DWR revise the Colorado SWSI analysis.

HUC8	HUC Name	Data Type	ID	Station Name
10190003	Middle South Platte-Cherry Creek	ForecastedNaturalFlow	06707500	SOUTH PLATTE RIVER AT SOUTH PLATTE
10190003	Middle South Platte-Cherry Creek	ForecastedNaturalFlow	06710385	BEAR CREEK ABV EVERGREEN
10190003	Middle South Platte-Cherry Creek	ForecastedNaturalFlow	06719505	CLEAR CREEK AT GOLDEN
10190003	Middle South Platte-Cherry Creek	ForecastedNaturalFlow	06724000	SAINT VRAIN CREEK AT LYONS
10190003	Middle South Platte-Cherry Creek	ForecastedNaturalFlow	06727000	BOULDER CREEK NEAR ORODELL
10190003	Middle South Platte-Cherry Creek	ForecastedNaturalFlow	06729500	SOUTH BOULDER CK NR ELDORADO SPRINGS, CO
10190003	Middle South Platte-Cherry Creek	ForecastedNaturalFlow	06738000	BIG THOMPSON R AT MOUTH, NR DRAKE, CO
10190003	Middle South Platte-Cherry Creek	ForecastedNaturalFlow	06752000	CACHE LA POUDRE R AT CANYON MOUTH
10190003	Middle South Platte-Cherry Creek	ReservoirStorage	06016020	BARR LAKE
10190003	Middle South Platte-Cherry Creek	ReservoirStorage	06016230	MILTON RESERVOIR
10190003	Middle South Platte-Cherry Creek	ReservoirStorage	06016280	STANDLEY RESERVOIR
10190003	Middle South Platte-Cherry Creek	ReservoirStorage	06016370	HORSECREEK RESERVOIR
10190003	Middle South Platte-Cherry Creek	NaturalFlow	06707500	SOUTH PLATTE RIVER AT SOUTH PLATTE
10190003	Middle South Platte-Cherry Creek	NaturalFlow	06710385	BEAR CREEK ABV EVERGREEN
10190003	Middle South Platte-Cherry Creek	NaturalFlow	06719505	CLEAR CREEK AT GOLDEN
10190003	Middle South Platte-Cherry Creek	NaturalFlow	06724000	SAINT VRAIN CREEK AT LYONS
10190003	Middle South Platte-Cherry Creek	NaturalFlow	06727000	BOULDER CREEK NEAR ORODELL
10190003	Middle South Platte-Cherry Creek	NaturalFlow	06729500	SOUTH BOULDER CK NR ELDORADO SPRINGS, CO
10190003	Middle South Platte-Cherry Creek	NaturalFlow	06738000	BIG THOMPSON R AT MOUTH, NR DRAKE, CO

HUC8	HUC Name	Data Type	ID	Station Name
10190003	Middle South Platte-Cherry Creek	NaturalFlow	06752000	CACHE LA POUDRE R AT CANYON MOUTH
10180001	North Platte Headwaters	ForecastedNaturalFlow	06620000	NORTH PLATTE R NR NORTHGATE
10180001	North Platte Headwaters	NaturalFlow	06620000	NORTH PLATTE R NR NORTHGATE
10190001	South Platte Headwater	ForecastedNaturalFlow	06695500	ELEVENMILE CANYON RESV INFLOW
10190001	South Platte Headwater	ReservoirStorage	06016010	ANTERO RESERVOIR
10190001	South Platte Headwater	ReservoirStorage	06016100	ELEVENMILE CANYON RESERVOIR
10190001	South Platte Headwater	ReservoirStorage	16016025	SPINNEY MOUNTAIN RESERVOIR
10190001	South Platte Headwater	NaturalFlow	06695500	ELEVENMILE CANYON RE NEAR LAKE GEORGE
10190002	Upper South Platte	ForecastedNaturalFlow	06707500	SOUTH PLATTE RIVER AT SOUTH PLATTE
10190002	Upper South Platte	ForecastedNaturalFlow	06710385	BEAR CREEK ABV EVERGREEN
10190002	Upper South Platte	ReservoirStorage	06016080	CHEESMAN LAKE
10190002	Upper South Platte	ReservoirStorage	09009020	DILLON RESERVOIR
10190002	Upper South Platte	NaturalFlow	06707500	SOUTH PLATTE RIVER AT SOUTH PLATTE
10190002	Upper South Platte	NaturalFlow	06710385	BEAR CREEK ABV EVERGREEN
10190004	Clear	ForecastedNaturalFlow	06719505	CLEAR CREEK AT GOLDEN
10190004	Clear	NaturalFlow	06719505	CLEAR CREEK AT GOLDEN
10190005	St. Vrain	ForecastedNaturalFlow	06724000	SAINT VRAIN CREEK AT LYONS
10190005	St. Vrain	ForecastedNaturalFlow	06727000	BOULDER CREEK NEAR ORODELL
10190005	St. Vrain	ForecastedNaturalFlow	06729500	SOUTH BOULDER CK NR ELDORADO SPRINGS, CO
10190005	St. Vrain	ReservoirStorage	06016130	GROSS RESERVOIR
10190005	St. Vrain	ReservoirStorage	06016220	MARSHALL RESERVOIR
10190005	St. Vrain	ReservoirStorage	06016260	BUTTONROCK (RALPH PRICE) RESERVOIR
10190005	St. Vrain	ReservoirStorage	06016290	TERRY RESERVOIR
10190005	St. Vrain	ReservoirStorage	06016300	UNION RESERVOIR
10190005	St. Vrain	NaturalFlow	06724000	SAINT VRAIN CREEK AT LYONS
10190005	St. Vrain	NaturalFlow	06727000	BOULDER CREEK NEAR ORODELL
10190005	St. Vrain	NaturalFlow	06729500	SOUTH BOULDER CK NR ELDORADO SPRINGS, CO
10190006	Big Thompson	ForecastedNaturalFlow	06738000	BIG THOMPSON R AT MOUTH, NR DRAKE, CO
10190006	Big Thompson	ReservoirStorage	06016040	BOYD LAKE

HUC8	HUC Name	Data Type	ID	Station Name
10190006	Big Thompson	ReservoirStorage	06016060	CARTER LAKE
10190006	Big Thompson	ReservoirStorage	06016180	LAKE LOVELAND RESERVOIR
10190006	Big Thompson	ReservoirStorage	06016190	LONE TREE RESERVOIR
10190006	Big Thompson	ReservoirStorage	06016200	MARIANO RESERVOIR
10190006	Big Thompson	ReservoirStorage	09009160	WILLOW CREEK RESERVOIR
10190006	Big Thompson	ReservoirStorage	09009060	LAKE GRANBY
10190006	Big Thompson	NaturalFlow	06738000	BIG THOMPSON R AT MOUTH, NR DRAKE, CO
10190007	Cache La Poudre	ForecastedNaturalFlow	06752000	CACHE LA POUDRE R AT CANYON MOUTH
10190007	Cache La Poudre	ReservoirStorage	06016030	BLACK HOLLOW RESERVOIR
10190007	Cache La Poudre	ReservoirStorage	06016050	CACHE LA POUDRE
10190007	Cache La Poudre	ReservoirStorage	06016070	CHAMBERS LAKE
10190007	Cache La Poudre	ReservoirStorage	06016090	COBB LAKE
10190007	Cache La Poudre	ReservoirStorage	06016120	FOSSIL CREEK RESERVOIR
10190007	Cache La Poudre	ReservoirStorage	06016140	HALLIGAN RESERVOIR
10190007	Cache La Poudre	ReservoirStorage	06016150	HORSETOOTH RESERVOIR
10190007	Cache La Poudre	ReservoirStorage	06016310	WINDSOR RESERVOIR
10190007	Cache La Poudre	NaturalFlow	06752000	CACHE LA POUDRE R AT CANYON MOUTH NEAR FORT COLLINS
10190012	Middle South Platte-Sterling	ForecastedNaturalFlow	06707500	SOUTH PLATTE RIVER AT SOUTH PLATTE
10190012	Middle South Platte-Sterling	ForecastedNaturalFlow	06710385	BEAR CREEK ABV EVERGREEN
10190012	Middle South Platte-Sterling	ForecastedNaturalFlow	06719505	CLEAR CREEK AT GOLDEN
10190012	Middle South Platte-Sterling	ForecastedNaturalFlow	06724000	SAINT VRAIN CREEK AT LYONS
10190012	Middle South Platte-Sterling	ForecastedNaturalFlow	06727000	BOULDER CREEK NEAR ORODELL
10190012	Middle South Platte-Sterling	ForecastedNaturalFlow	06729500	SOUTH BOULDER CK NR ELDORADO SPRINGS, CO
10190012	Middle South Platte-Sterling	ForecastedNaturalFlow	06738000	BIG THOMPSON R AT MOUTH, NR DRAKE, CO
10190012	Middle South Platte-Sterling	ForecastedNaturalFlow	06752000	CACHE LA POUDRE R AT CANYON MOUTH
10190012	Middle South Platte-Sterling	ReservoirStorage	06016170	JULESBURG RESERVOIR
10190012	Middle South Platte-Sterling	ReservoirStorage	06016240	POINT OF ROCKS RESERVOIR
10190012	Middle South Platte-Sterling	ReservoirStorage	06016250	PREWITT RESERVOIR
10190012	Middle South Platte-Sterling	ReservoirStorage	06016160	JACKSON LAKE RESERVOIR

HUC8	HUC Name	Data Type	ID	Station Name
10190012	Middle South Platte-Sterling	ReservoirStorage	06016270	RIVERSIDE RESERVOIR
10190012	Middle South Platte-Sterling	ReservoirStorage	06016110	EMPIRE RESERVOIR
10190012	Middle South Platte-Sterling	NaturalFlow	06707500	SOUTH PLATTE RIVER AT SOUTH PLATTE
10190012	Middle South Platte-Sterling	NaturalFlow	06710385	BEAR CREEK ABV EVERGREEN
10190012	Middle South Platte-Sterling	NaturalFlow	06719505	CLEAR CREEK AT GOLDEN
10190012	Middle South Platte-Sterling	NaturalFlow	06724000	SAINT VRAIN CREEK AT LYONS
10190012	Middle South Platte-Sterling	NaturalFlow	06727000	BOULDER CREEK NEAR ORODELL
10190012	Middle South Platte-Sterling	NaturalFlow	06729500	SOUTH BOULDER CK NR ELDORADO SPRINGS, CO
10190012	Middle South Platte-Sterling	NaturalFlow	06738000	BIG THOMPSON R AT MOUTH, NR DRAKE, CO
10190012	Middle South Platte-Sterling	NaturalFlow	06752000	CACHE LA POUDRE R AT CANYON MOUTH
11020001	Arkansas Headwaters	ForecastedNaturalFlow	07091500	ARKANSAS RIVER AT SALIDA
11020001	Arkansas Headwaters	ReservoirStorage	07007020	CLEAR CREEK RESERVOIR
11020001	Arkansas Headwaters	ReservoirStorage	07007110	TURQUOISE LAKE
11020001	Arkansas Headwaters	ReservoirStorage	07007120	TWIN LAKES RESERVOIR
11020001	Arkansas Headwaters	ReservoirStorage	09009040	HOMESTAKE RESERVOIR
11020001	Arkansas Headwaters	NaturalFlow	07091500	ARKANSAS RIVER AT SALIDA
11020002	Upper Arkansas	ForecastedNaturalFlow	07099400	PUEBLO RESERVOIR INFLOW
11020002	Upper Arkansas	ReservoirStorage	07007090	PUEBLO RESERVOIR
11020002	Upper Arkansas	NaturalFlow	07099400	ARKANSAS RIVER ABOVE PUEBLO
11020005	Upper Arkansas-Lake Meredith	ForecastedNaturalFlow	07099400	ARKANSAS RIVER ABOVE PUEBLO
11020005	Upper Arkansas-Lake Meredith	ForecastedNaturalFlow	07111000	HUERFANO RIVER NEAR REDWING
11020005	Upper Arkansas-Lake Meredith	ForecastedNaturalFlow	07114000	CUCHARAS RIVER AT BOYD RANCH NR LA VETA
11020005	Upper Arkansas-Lake Meredith	ReservoirStorage	07007070	MEREDITH RESERVOIR
11020005	Upper Arkansas-Lake Meredith	ReservoirStorage	07007130	LAKE HENRY
11020005	Upper Arkansas-Lake Meredith	NaturalFlow	07099400	ARKANSAS RIVER ABOVE PUEBLO
11020005	Upper Arkansas-Lake Meredith	NaturalFlow	07111000	HUERFANO RIVER NEAR REDWING
11020005	Upper Arkansas-Lake Meredith	NaturalFlow	07114000	CUCHARAS RIVER AT BOYD RANCH NR LA VETA
11020006	Huerfano	ForecastedNaturalFlow	07111000	HUERFANO RIVER NEAR REDWING
11020006	Huerfano	ForecastedNaturalFlow	07114000	CUCHARAS RIVER AT BOYD RANCH NR LA VETA

HUC8	HUC Name	Data Type	ID	Station Name
11020006	Huerfano	ReservoirStorage	07007030	CUCHARAS RESERVOIR
11020006	Huerfano	NaturalFlow	07111000	HUERFANO RIVER NEAR REDWING
11020006	Huerfano	NaturalFlow	07114000	CUCHARAS RIVER AT BOYD RANCH NR LA VETA
11020009	Upper Arkansas-John Martin Reservoir	ForecastedNaturalFlow	07099400	ARKANSAS RIVER ABOVE PUEBLO
11020009	Upper Arkansas-John Martin Reservoir	ForecastedNaturalFlow	07111000	HUERFANO RIVER NEAR REDWING
11020009	Upper Arkansas-John Martin Reservoir	ForecastedNaturalFlow	07114000	CUCHARAS RIVER AT BOYD RANCH NR LA VETA
11020009	Upper Arkansas-John Martin Reservoir	ForecastedNaturalFlow	07124500	PURGATOIRE RIVER AT TRINIDAD
11020009	Upper Arkansas-John Martin Reservoir	ReservoirStorage	07007010	ADOBE CREEK RESERVOIR
11020009	Upper Arkansas-John Martin Reservoir	ReservoirStorage	07007060	JOHN MARTIN RESERVOIR
11020009	Upper Arkansas-John Martin Reservoir	NaturalFlow	07099400	ARKANSAS RIVER ABOVE PUEBLO
11020009	Upper Arkansas-John Martin Reservoir	NaturalFlow	07111000	HUERFANO RIVER NEAR REDWING
11020009	Upper Arkansas-John Martin Reservoir	NaturalFlow	07114000	CUCHARAS RIVER AT BOYD RANCH NR LA VETA
11020009	Upper Arkansas-John Martin Reservoir	NaturalFlow	07124500	PURGATOIRE RIVER AT TRINIDAD
11020010	Purgatoire	ForecastedNaturalFlow	07124500	PURGATOIRE RIVER AT TRINIDAD
11020010	Purgatoire	ReservoirStorage	07007100	TRINIDAD LAKE
11020010	Purgatoire	NaturalFlow	07124500	PURGATOIRE RIVER AT TRINIDAD
13010001	Rio Grande Headwaters	ForecastedNaturalFlow	08220000	RIO GRANDE NEAR DEL NORTE
13010001	Rio Grande Headwaters	ReservoirStorage	08008130	RIO GRANDE RESERVOIR
13010001	Rio Grande Headwaters	ReservoirStorage	08008150	SANTA MARIA RESERVOIR
13010001	Rio Grande Headwaters	ReservoirStorage	08008170	CONTINENTAL RESERVOIR
13010001	Rio Grande Headwaters	NaturalFlow	08220000	RIO GRANDE NEAR DEL NORTE
13010002	Alamosa-Trinchera	ForecastedNaturalFlow	08236000	ALAMOSA CREEK ABOVE TERRACE RESERVOIR
13010002	Alamosa-Trinchera	ForecastedNaturalFlow	08240500	TRINCHERA CK
13010002	Alamosa-Trinchera	ForecastedNaturalFlow	08241500	SANGRE DE CRISTO
13010002	Alamosa-Trinchera	ForecastedNaturalFlow	08242500	UTE CREEK
13010002	Alamosa-Trinchera	ForecastedNaturalFlow	08250000	CULEBRA CREEK AT SAN LUIS
13010002	Alamosa-Trinchera	ReservoirStorage	08008160	TERRACE RESERVOIR
13010002	Alamosa-Trinchera	ReservoirStorage	MTNRESCO	MOUNTAIN HOME
13010002	Alamosa-Trinchera	NaturalFlow	08236000	ALAMOSA CREEK ABOVE TERRACE RESERVOIR

HUC8	HUC Name	Data Type	ID	Station Name
13010002	Alamosa-Trinchera	NaturalFlow	08240500	TRINCHERA CK
13010002	Alamosa-Trinchera	NaturalFlow	08241500	SANGRE DE CRISTO
13010002	Alamosa-Trinchera	NaturalFlow	08242500	UTE CREEK
13010002	Alamosa-Trinchera	NaturalFlow	08250000	CULEBRA CREEK AT SAN LUIS
13010004	Saguache	ForecastedNaturalFlow	08227000	SAGUACHE CREEK NEAR SAGUACHE, CO
13010004	Saguache	NaturalFlow	08227000	SAGUACHE CREEK NEAR SAGUACHE, CO
13010005	Conejos	ForecastedNaturalFlow	08246500	CONEJOS RIVER NEAR MOGOTE
13010005	Conejos	ReservoirStorage	08008120	PLATORO RESERVOIR
13010005	Conejos	NaturalFlow	08246500	CONEJOS RIVER NEAR MOGOTE
14010001	Colorado Headwaters	ForecastedNaturalFlow	09070500	COLORADO RIVER NEAR DOTSERO
14010001	Colorado Headwaters	ReservoirStorage	09009150	WILLIAMS FORK RESERVOIR
14010001	Colorado Headwaters	ReservoirStorage	09041395	WOLFORD MOUNTAIN RESERVOIR
14010001	Colorado Headwaters	NaturalFlow	09070500	COLORADO RIVER NEAR DOTSERO
14010002	Blue	ForecastedNaturalFlow	09057500	BLUE RIVER INFLOW TO GREEN MOUNTAIN RES
14010002	Blue	ReservoirStorage	09009030	GREEN MOUNTAIN RESERVOIR
14010002	Blue	NaturalFlow	09057500	BLUE RIVER INFLOW TO GREEN MOUNTAIN RES
14010003	Eagle	ForecastedNaturalFlow	09070000	EAGLE RIVER BELOW GYPSUM
14010003	Eagle	NaturalFlow	09070000	EAGLE RIVER BELOW GYPSUM
14010004	Roaring Fork	ForecastedNaturalFlow	09085000	ROARING FORK AT GLENWOOD SPRINGS
14010004	Roaring Fork	ReservoirStorage	09009110	RUEDI RESERVOIR
14010004	Roaring Fork	NaturalFlow	09085000	ROARING FORK AT GLENWOOD SPRINGS
14010005	Colorado Headwaters-Plateau	ForecastedNaturalFlow	09095500	COLORADO RIVER NEAR CAMEO
14010005	Colorado Headwaters-Plateau	ReservoirStorage	09009140	VEGA RESERVOIR
14010005	Colorado Headwaters-Plateau	NaturalFlow	09095500	COLORADO RIVER NEAR CAMEO
14020001	East-Taylor	ForecastedNaturalFlow	09109209	TAYLOR R INF TO TAYLOR PARK RESERVOIR
14020001	East-Taylor	ForecastedNaturalFlow	09112500	EAST RIVER AT ALMONT
14020001	East-Taylor	ReservoirStorage	09009120	TAYLOR PARK RESERVOIR
14020001	East-Taylor	NaturalFlow	09109209	TAYLOR RIVER BELOW TAYLOR PARK RESERVOIR
14020001	East-Taylor	NaturalFlow	09112500	EAST RIVER AT ALMONT

HUC8	HUC Name	Data Type	ID	Station Name
14020002	Upper Gunnison	ForecastedNaturalFlow	09124500	LAKE FORK AT GATEVIEW, CO
14020002	Upper Gunnison	ForecastedNaturalFlow	09124800	GUNNISON R INF TO BLUE MESA RESERVOIR
14020002	Upper Gunnison	ReservoirStorage	09009010	BLUE MESA RESERVOIR
14020002	Upper Gunnison	ReservoirStorage	09009080	MORROW POINT RESERVOIR
14020002	Upper Gunnison	ReservoirStorage	09009330	FRUITLAND RESERVOIR
14020002	Upper Gunnison	ReservoirStorage	09009340	CRAWFORD RESERVOIR
14020002	Upper Gunnison	ReservoirStorage	09125800	SILVER JACK RESERVOIR
14020002	Upper Gunnison	NaturalFlow	09114500	GUNNISON RIVER NEAR GUNNISON, CO
14020002	Upper Gunnison	NaturalFlow	09124500	LAKE FORK AT GATEVIEW, CO
14020003	Tomichi	ForecastedNaturalFlow	09119000	TOMICHI CREEK AT GUNNISON, CO
14020003	Tomichi	ReservoirStorage	09116500	VOUGA RESERVOIR NEAR DOYLEVILLE
14020003	Tomichi	NaturalFlow	09119000	TOMICHI CREEK AT GUNNISON, CO
14020004	North Fork Gunnison	ForecastedNaturalFlow	09132500	NORTH FORK GUNNISON R NR SOMERSET
14020004	North Fork Gunnison	ReservoirStorage	09009100	PAONIA RESERVOIR
14020004	North Fork Gunnison	NaturalFlow	09132500	NORTH FORK GUNNISON R NR SOMERSET
14020005	Lower Gunnison	ForecastedNaturalFlow	09152500	GUNNISON RIVER NR GRAND JUNCTION
14020005	Lower Gunnison	NaturalFlow	09152500	GUNNISON RIVER NR GRAND JUNCTION
14020006	Uncompahgre	ForecastedNaturalFlow	09147500	UNCOMPAHGRE RIVER AT COLONA
14020006	Uncompahgre	ReservoirStorage	09147022	RIDGEWAY RESERVOIR
14020006	Uncompahgre	NaturalFlow	09147500	UNCOMPAHGRE RIVER AT COLONA
14030002	Upper Dolores	ForecastedNaturalFlow	09169000	DOLORES RIVER BELOW MCPHEE RESERVOIR
14030002	Upper Dolores	ReservoirStorage	09009170	GROUNDHOG RESERVOIR
14030002	Upper Dolores	ReservoirStorage	MPHC2000	MCPHEE RESERVOIR
14030002	Upper Dolores	NaturalFlow	09169000	DOLORES RIVER BELOW MCPHEE RESERVOIR
14030003	San Miguel	ForecastedNaturalFlow	09172500	SAN MIGUEL RIVER NEAR PLACERVILLE
14030003	San Miguel	NaturalFlow	09172500	SAN MIGUEL RIVER NEAR PLACERVILLE
14050001	Upper Yampa	ForecastedNaturalFlow	09239500	YAMPA RIVER AT STEAMBOAT SPRINGS
14050001	Upper Yampa	ForecastedNaturalFlow	09242500	ELK RIVER NEAR MILNER, CO
14050001	Upper Yampa	ForecastedNaturalFlow	09246200	ELKHEAD CREEK ABOVE LONG GULCH

HUC8	HUC Name	Data Type	ID	Station Name
14050001	Upper Yampa	ReservoirStorage	09237495	STAGECOACH RESERVOIR NR OAK CREEK
14050001	Upper Yampa	ReservoirStorage	YAMRESCO	YAMCOLO RESERVOIR
14050001	Upper Yampa	NaturalFlow	09239500	YAMPA RIVER AT STEAMBOAT SPRINGS
14050001	Upper Yampa	NaturalFlow	09242500	ELKHEAD RIVER NEAR MILNER
14050001	Upper Yampa	NaturalFlow	09246200	ELKHEAD CREEK ABOVE LONG GULCH
14050002	Lower Yampa	ForecastedNaturalFlow	09251000	YAMPA RIVER NEAR MAYBELL
14050002	Lower Yampa	NaturalFlow	09251000	YAMPA RIVER NEAR MAYBELL
14050003	Little Snake	ForecastedNaturalFlow	09260000	LITTLE SNAKE RIVER NEAR LILY
14050003	Little Snake	NaturalFlow	09260000	LITTLE SNAKE RIVER NEAR LILY
14050005	Upper White	ForecastedNaturalFlow	09304500	WHITE RIVER NEAR MEEKER
14050005	Upper White	NaturalFlow	09304500	WHITE RIVER NEAR MEEKER
14080101	Upper San Juan	ForecastedNaturalFlow	09346400	SAN JUAN RIVER NEAR CARRACAS
14080101	Upper San Juan	ForecastedNaturalFlow	09353500	LOS PINOS RIVER NEAR BAYFIELD
14080101	Upper San Juan	ReservoirStorage	09009130	VALLECITO RESERVOIR
14080101	Upper San Juan	NaturalFlow	09346400	SAN JUAN RIVER NEAR CARRACAS
14080101	Upper San Juan	NaturalFlow	09353500	LOS PINOS RIVER NEAR BAYFIELD
14080102	Piedra	ForecastedNaturalFlow	09349800	PIEDRA RIVER NEAR ARBOLES
14080102	Piedra	NaturalFlow	09349800	PIEDRA RIVER NEAR ARBOLES
14080104	Animas	ForecastedNaturalFlow	09361500	ANIMAS RIVER AT DURANGO
14080104	Animas	ForecastedNaturalFlow	09363100	FLORIDA RIVER INFLOW TO LEMON RESERVOIR
14080104	Animas	ReservoirStorage	09009070	LEMON RESERVOIR
14080104	Animas	NaturalFlow	09361500	ANIMAS RIVER AT DURANGO
14080104	Animas	NaturalFlow	09363100	FLORIDA RIVER BELOW LEMON RESERVOIR NR DURANGO
14080105	Middle San Juan	ForecastedNaturalFlow	09365500	LA PLATA RIVER AT HESPERUS
14080105	Middle San Juan	ReservoirStorage	LONRESCO	LONG HOLLOW RESERVOIR
14080105	Middle San Juan	NaturalFlow	09365500	LA PLATA RIVER AT HESPERUS
14080107	Mancos	ForecastedNaturalFlow	09370500	MANCOS RIVER NEAR MANCOS
14080107	Mancos	ReservoirStorage	09009050	JACKSON GULCH RESERVOIR
14080107	Mancos	NaturalFlow	09370500	MANCOS RIVER NEAR MANCOS

Appendix C – Colorado SWSI Automation Tool Workflow Details

Control File

An Excel workbook (CO-SWSI-Control.xlsx) is used to control the Colorado SWSI analysis. A description of the worksheets follows:

- Hist: History of the workbook. This worksheet should be used to note major changes to the control file or the Colorado SWSI Automation Tool program version.
- Notes: Descriptions of each worksheet
- Config: Worksheet where the configuration properties needed to run TSTool are specified. User-entered values are highlighted in blue. Values that are automatically calculated are highlighted in gray. The configuration properties are named to help TSTool retrieve the values.
- Combined Inputs: This worksheet defines the stations that are used in the HUC and the Basin analyses.
    - For reservoir storage, Datastore can be NrcsAwdb or ColoradoWaterSMS, while Datastore 2 can be ColoradoWaterHBGuest.
    - For natural flows, Datastore should be NrcsAwdb. For observed flow option, Datastore 2 should be ColoradoWaterHBGuest while Datastore3 can be ColoradoWaterSMS.
- FlowDataFill: Worksheet that specifies automated filling to be done on the natural flow stations.
- ReservoirDataFill: Worksheet that specifies automated filling to be done on the reservoirs.
- NatFlowCalcs: Scratch worksheet for natural flow calculations, to be modified monthly as necessary when data are not available from web services.
- Overrides: User-determined values that override any existing data.
- Lookup Tables: Tables of information needed by TSTool.
    - Month_Table is used to loop on months and to specify when different components are used in the SWSI analysis.
    - RawDataChecks Style Table and RawDataChecks Condition Table are used to highlight missing counts > 0 in red in RawDataChecks.xlsx.
    - Data Fill Date Options are used to provide validation lists for Fill Start Date and Fill End Date on the FlowDataFill worksheet.
    - The Reservoir Start Fill Methods and Reservoir End Fill Methods are used to provide validation lists on the ReservoirDataFill worksheet.
    - The Data Types List is used to provide validation lists on the Overrides worksheet.
    - The DataFlags Style Table and DataFlags Condition Table are used to highlight cells based on the data flag in the cell comment in the Input_Data_Final.xlsx.
- HUC_Reference: List of HUC ids and names for user reference only (not used by the program).

TSTool Processing

There are five conceptual processing steps in the TSTool SWSI Automation Tool:

- Data download
- Data checks and filling
- Creation of SWSI components
- SWSI calculation and products
- Optional processes

This appendix provides an overview of each component, along with detailed explanations of the TSTool processes within each component. In the process flowcharts (**Figure 8**, **Figure 9**, **Figure 10**, **Figure 12**, and **Figure 13**):

- "TS Alias" refers to the time series aliases used by TSTool to identify time series.
- "TS Properties" are time series properties used by TSTool during processing and for outputs.
- "Data Flags" are used by TSTool to indicate manipulation of data values.

The process flow charts are also provided in PowerPoint format in the _Documents\ _SWSI-TSTool-Guide directory.

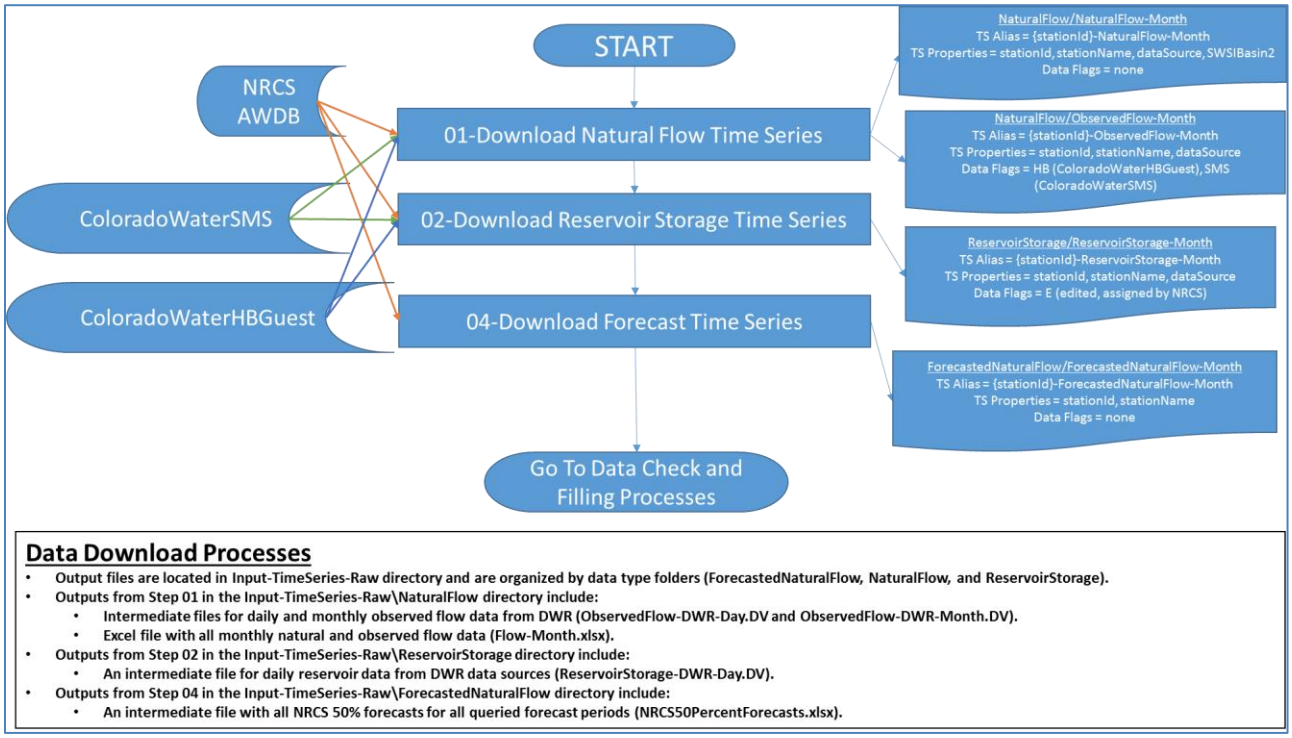

Figure 8. Flowchart of the Data Download Processes

01 - Download Natural Flow Time Series.TSTool

Purpose:

- Automatically download monthly "observed" natural flows for the full period of data availability for NaturalFlow stations identified on the Combined Inputs worksheet where the "Include" column is set to "YES". These data are used for the previous month's streamflow and forecasted runoff components in the Colorado SWSI.
- If needed, automatically download monthly observed (i.e., gaged) streamflows for the full period of data availability for NaturalFlow stations identified on the Combined Inputs worksheet

where the "Include" column is set to "YES-OBS". These data are used for the previous month's streamflow component in the Colorado SWSI in rare cases when the required natural flow data are not available. If this option is applied, observed flow data are used for the previous month's streamflow component for all periods (i.e., historical period, recent period, and current period).

Workflow Details:

- First, the command file checks to see if the user has specified that any observed flow data be used in the Colorado SWSI analysis. This case is signified by NaturalFlow stations on the Combined Inputs worksheet in the control file that have the "Include" column set to "YES-OBS".
- If the observed flow case exists, the command file checks affected HUCs to see whether all natural flow stations in the affected HUC have been assigned to use observed flow data. If not, a warning message is written out to the user. The user can choose to ignore the warnings or to set all stations to use observed flow data.
- Natural flow data are downloaded for all NaturalFlow stations on the Combined Inputs worksheet where the "Include" column is set to "YES". Natural flow data are downloaded even in the "observed flow" case because the data are used for the forecasted runoff component.
    - The command file is set up to use the NRCS AWDB web service to obtain monthly natural streamflow volumes (using the SRVO data type).
    - Stations can be associated with more than one HUC, so a unique station list is created as a table.
    - Station identifiers, station names, and the data source are set as properties to support SWSI processing and output products.
    - A time series property (SWSI Basin2) is set to differentiate stations in the Rio Grande basin from stations in other basins – this property is used in step 30 when accumulating monthly natural flows over the forecast period. Stations in the Rio Grande basin are accumulated through September, while stations in other basins are accumulated through July.
    - Automated checks are included to ensure that the number of time series matches the number of stations, and to warn the user about any time series that are completely missing.
    - The monthly natural flow data are written to a DateValue file.
- Observed flow data are downloaded for all NaturalFlow stations on the Combined Inputs worksheet where the "Include" column is set to "YES-OBS". These data are used only for the previous month's streamflow component.
    - If no stations are set to use observed flow data, this set of commands is bypassed and no observed flow output file is written.
    - The command file is set up to use the ColoradoWaterSMS and ColoradoWaterHBGuest web services to obtain historical streamflow volumes (using the DISCHRG and Streamflow data types, respectively). Typically, data from these two sources must be merged for a complete record.
    - The command files were set up assuming that all stations assigned to use observed flows will have data available from the ColoradoWaterHBGuest web service. Additional data can optionally be obtained using the ColoradoWaterSMS web service.
    - Stations can be associated with more than one HUC, so unique station lists are created as tables for each web service.
    - Processing for the ColoradoWaterSMS web service is done first.
        - The ColoradoWaterSMS web service returns daily streamflow data.

        - Calls to this service will fail if the request includes a start date before January 1, 2000. Therefore, the data call uses a start date of January 1, 2000 which is set in the control file as the SMSInputPeriodStartDayText property.
        - Station information for the ColoradoWaterSMS web service is specified in the "Datastore3" columns on the Combined Inputs worksheet.
        - Station identifiers, station names, and the data source are set as properties to support SWSI processing and output products.
        - Calls to the ColoradoWaterSMS web service do not automatically set units on the returned time series. Therefore, a "SetTimesSeriesProperty" command is used to set the units to cfs.
        - The data are converted to ac-ft/day.
        - The time series are converted from daily to monthly time series with units of ac_ft.
        - The ColoradoWaterSMS and ColoradoWaterHBGuest web services in some cases use different location IDs for the same station. For example, for the Mancos near Mancos station, the ColoradoWaterSMS service uses a station identifier of MANMANCO while the ColoradoWaterHBGuest web service uses the identifier of 09370500. To anticipate this issue, the aliases for time series returned by the ColoradoWaterSMS web service are changed to use station identifiers as the location IDs.
        - Automated checks are included to ensure that the number of time series matches the number of stations, and to warn the user about any time series that are completely missing.
    - Processing for the ColoradoWaterHBGuest web service is done second.
        - The ColoradoWaterHBGuest web service returns monthly streamflow data.
        - Station information for the ColoradoWaterHBGuest web service is specified in the "Datastore2" columns on the Combined Inputs worksheet.
        - Station identifiers, station names, and the data source are set as properties to support SWSI processing and output products.
        - Automated checks are included to ensure that the number of time series matches the number of stations, and to warn the user about any time series that are completely missing.
    - Data from the ColoradoWaterSMS and ColoradoWaterHBGuest web services are merged to produce continuous monthly time series for each station.
        - HydroBase data are given precedence since these data are published values.
        - Data flags are set to "HB" or "SMS" to indicate the data source.
        - After merging, a "Scale" time series is used with a multiplier of 1 to reset the units from ACFT to "ac_ft," consistent with other data types used later on for the SWSI analysis.
        - The daily and monthly observed flow data are written to DateValue files.
    - The monthly natural and observed flow data are written to an Excel file called "Flow-Month.xlsx."
- At times (for example, on holidays), the NRCS AWDB web services are down. If no data are returned, the user should check the NRCS website and try again when the services are running.

02 - Download Reservoir Storage Time Series.TSTool

Purpose:

- Automatically produce end-of-month reservoir time series for the full period of data availability for ReservoirStorage stations identified on the Combined Inputs worksheet.

Workflow Details:

- The command file is set up currently to use two data sources:
    - The NRCS AWDB web service.
    - The DWR ColoradoWaterSMS and ColoradoWaterHBGuest web services. If data are being obtained from DWR, Datastore 1 in the control file should be specified as ColoradoWaterSMS and Datastore 2 in the control file should be specified as ColoradoWaterHBGuest. The process will run if ColoradoWaterSMS is specified as Datastore 1, but Datastore 2 is left null (for example, because a reservoir is new and no data exist in HydroBase). Typically, data from these two sources must be merged for a complete record.
    - The NRCS and DWR data sources cannot be mixed for a given reservoir.
- Reservoirs can be associated with more than one HUC, so a unique list is created as a table.
- Unique lists are then created depending on the specified datastores so that separate data calls can be made to each data source (i.e., NRCS AWDB, ColoradoWaterSMS, ColoradoWaterHBGuest).
- Data are obtained from DWR data sources
    - Data are obtained from ColoradoWaterSMS.
        - Calls to the ColoradoWaterSMS web service will fail if the start date is prior to 2000. Therefore, before making the call to ColoradoWaterSMS, the input period is limited to begin in 2000.
        - The ColoradoWaterSMS web service returns daily data, so the start and end dates must also be specified on a daily time step.
        - Station ID, station name, and data source properties are assigned.
        - The units of the data returned from ColoradoWaterSMS are not set by default, so the units are explicitly set to ACFT.
        - Automated checks are performed to ensure that the number of time series created matches the expected number, and to warn the user about any time series that are completely missing.
    - Data are obtained from ColoradoWaterHBGuest.
        - The input period is reset to the full period.
        - The ColoradoWaterHBGuest datastore information is contained in the control workbook under Datastore2 columns on the Combined Inputs worksheet.
        - The ColoradoWaterHBGuest web service returns daily data, so the start and end dates must also be specified on a daily time step.
        - Station ID, station name, and data source properties are assigned.
        - Automated checks are performed to ensure that the number of time series created matches the expected number, and to warn the user about any time series that are completely missing.
    - ColoradoWaterSMS and ColoradoWaterHBGuest data are merged to produce continuous daily time series over the full period.
        - A new time series is created for the full period.

        - The new time series is filled first with data from ColoradoWaterHBGuest data, which takes precedence over ColoradoWaterSMS data. Data flags are set to "HB" for HydroBase to signify the data source.
        - The new time series is then filled with data from ColoradoWaterSMS data. Data flags are set to "SMS" to signify the ColoradoWaterSMS web service as the data source.
        - The merged data are multiplied by 1 and the units are set to ac_ft to be consistent with the other data components.
    - The merged, daily DWR data are converted to end-of-month time series to be consistent with the data returned from the NRCS.
        - Station ID, station name, and data source properties are assigned.
        - The data flags from the daily time series are not transferred to the monthly time series.
- Data are obtained from the NRCS AWDB web service.
    - Station ID, station name, and data source properties are assigned.
    - Automated checks are performed to ensure that the number of time series created matches the expected number, and to warn the user about any time series that are completely missing.
    - At times (for example, on holidays), the NRCS AWDB web services are down. If no data are returned, the user should check the NRCS website and try again when the services are running.
- The final data written out represent end-of-month storage values in ac-ft using time series aliases of {stationId}-ReservoirStorage-Month regardless of data source. This facilitates generic logic in following steps.

04 - Download Natural Flow Forecast.TSTool

Purpose:

- Automatically produce time series of 50th percent exceedance forecasts for the appropriate forecast period for ForecastedNaturalFlow stations identified on the Combined Inputs worksheet.

Workflow Details:

- Stations can be associated with more than one HUC, so a unique station list is created as a table.
- Separate lists of unique stations are created depending on whether the station is located in the Rio Grande basin or the other basins. The forecast period (April-September) differs in the Rio Grande basin from the forecast period (April-July) used in other basins.
- "ExpandTemplateFile" commands are used to generate strings of concatenated station identifiers separated by commas (for example: stationA,stationB,stationC). The strings are saved as properties: ForecastedNaturalFlowListUniqueRioGrandeIds and ForecastedNaturalFlowListUniqueNonRioGrandeIds. These properties are used in "ReadNrcsAwdb" commands to specify the station list.
- Six separate calls are made to the NRCS AWDB data service depending on the station location and forecast period:
    - Rio Grande: APR-SEP, MAY-SEP, and JUN-SEP.
    - Non-Rio Grande: APR-JUL, MAY-JUL, and JUN-JUL.
- The calls to the NRCS AWDB service return natural flow (SRVO) forecasts with an exceedance probability of 50%.

- The results from each call to the NRCS AWDB service are saved in separate tables, but all results are appended to the master NRCS_50PercentForecasts table.
- The forecast values are multiplied by 1000 to get units of ac-ft.
    - Note: As of June 2015, the NRCS service was returning forecast values with units of both ac-ft and kac-ft, though values indicated units solely of kac-ft. The NRCS confirmed via e-mail that all forecast values for locations in Colorado are in kac-ft and that the unit codes would be updated accordingly.
- The "TableToTimeSeries" command is used to generate time series of 50th percent exceedance forecasts by location as shown in **Table 12**.
- Properties are read from Excel to determine if the current month's analysis is using the forecasted runoff component. If so, the forecast data returned from the NRCS will extend to the current month. If not, the time series need to be explicitly extended to the current month, though the values will be missing starting in July of the current year (because the last forecast issued by the NRCS each year is published in June).
- Station id and station name properties are assigned to the time series.
- An automated check is performed to confirm that the number of time series created matches the number of stations.
- At times (for example, on holidays), the NRCS AWDB web services are down. If no data are returned, the user should check the NRCS website and try again when the services are running.

Table 12. Forecast Values by Month and Location

MONTH	RIO GRANDE BASIN	NON-RIO GRANDE BASIN
JAN	APR-SEP	APR-JUL
FEB	APR-SEP	APR-JUL
MAR	APR-SEP	APR-JUL
APR	APR-SEP	APR-JUL
MAY	MAY-SEP	MAY-JUL
JUN	JUN-SEP	JUN-JUL
JUL-DEC	Not applicable	Not applicable

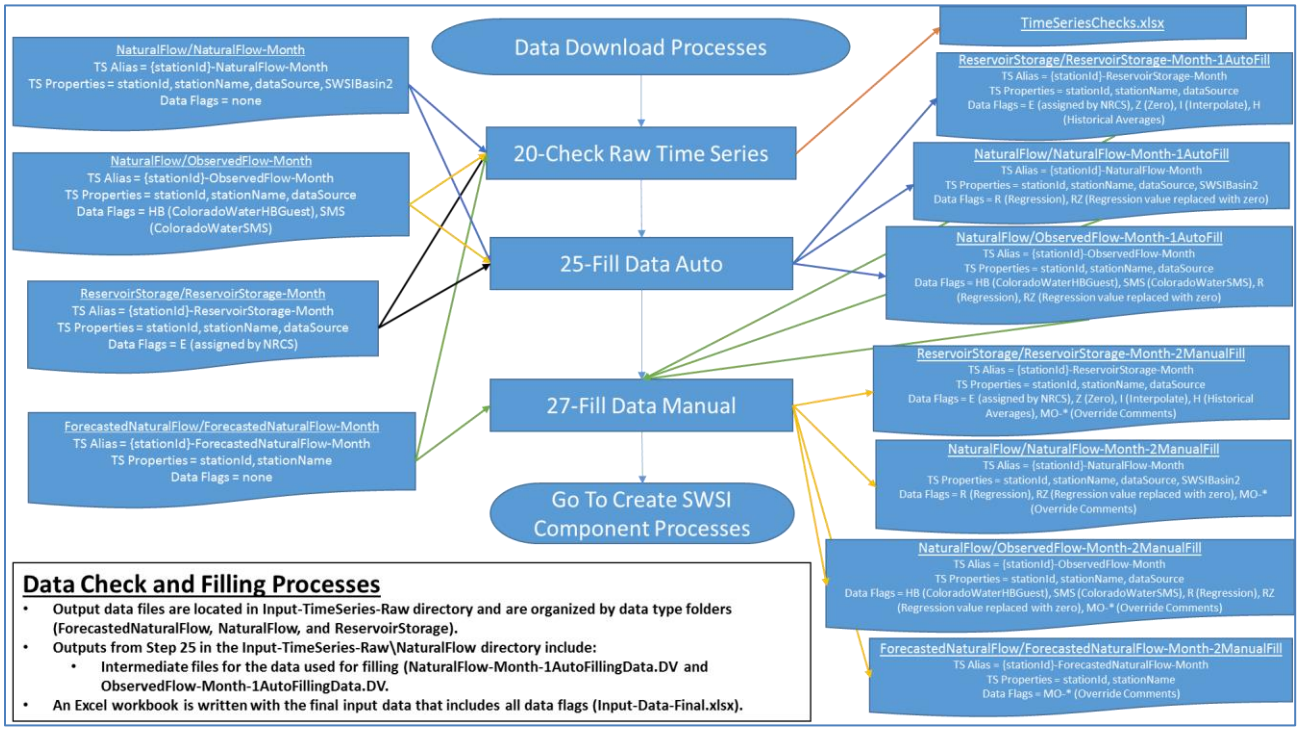

Figure 9. Flowchart of the Data Check and Filling Processes

20 – Check Raw Time Series.TSTool

Purpose:

- Summarize the number of missing values for each raw station time series for various time windows.

Workflow Details:

- The time series checks are performed by expanding a template file (Template-Check-InputTimeSeries.TSTool).
- The raw data time series are read from the start of the historical period to the current month.
- Time series properties are set to indicate the data type: natural flow, reservoir storage, or forecasted natural flow.
- The CalculateTimeSeriesStatistic command is used to count the number of missing values in each station time series and assign the value to a time series property.
- The natural flow data are used in both the previous month's streamflow and the forecasted runoff components.
    - For the previous month's streamflow component, June-August streamflow volumes are shifted forward by one month to use in July-September SWSI calculations. Therefore, raw data are needed in the months of June-August for the full analysis period through the previous month.
    - For the forecasted runoff component, April-September streamflow volumes are accumulated to represent the runoff over the forecast period.
        - Depending on the RecentPeriodFlowDataType property, the observed natural flows are used in the historical and recent periods, or just the historical period.

    - The above requirements are combined to assess the following missing count properties:
        - The number of missing values from April-September in the historical period.
        - If RecentPeriodFlowDataType=NaturalFlow, the number of missing values from April-September in the recent period.
        - If RecentPeriodFlowDataType=ForecastedNaturalFlow, the number of missing values from June-August in the recent period.
        - The number of missing values from June-August in the current water year through the previous month.
        - The number of missing values from June-August for the previous month.
- The forecasted natural flow data are used in the forecasted runoff component. Raw data values represent accumulated runoff volumes over the relevant forecast period. The forecasted runoff component is used from Jan-Jun in the SWSI analysis. These requirements are combined to assess the following missing count properties:
    - If RecentPeriodFlowDataType=ForecastedNaturalFlow, the number of missing values from Jan-Jun in the recent period.
    - The number of missing values from Jan-Jun for the current water year.
    - The number of missing values from Jan-Jun for the current month.
- The reservoir storage data are used for the reservoir storage component year-round in the SWSI analysis. The previous month's end-of-month storage value is shifted forward by one month to represent the current month's beginning-of-month storage value. These requirements are combined to assess 4 missing count properties:
    - The number of missing values in the historical period.
    - The number of missing values in the recent period.
    - The number of missing values in the current water year through the previous month.
    - The number of missing values for the previous month.
- The missing count properties are written to summary tables and sorted for output.
    - For natural flow data, the output is sorted by number of missing values in the historical period (descending) to highlight the stations with the most missing data.
    - For the forecasted runoff data, the output is sorted by the number of missing values for the current month (descending).
    - For the reservoir storage data, the output is sorted by number of missing values in the historical period (descending) to highlight the stations with the most missing data.
- If observed flow data are being used in the analysis:
    - The observed flow data are used in the previous month's streamflow component.
    - For the previous month's streamflow component, June-August streamflow volumes are shifted forward by one month to use in July-September SWSI calculations. Therefore, raw data are needed in the months of June-August for the full analysis period through the previous month.
    - The above requirements are combined to assess 4 missing count properties:
        - The number of missing values from June-August in the historical period.
        - The number of missing values from June-August in the recent period.
        - The number of missing values from June-August in the current water year through the previous month.
        - The number of missing values from June-August for the previous month.
- The results are written to an Excel workbook and conditional formatting is applied to highlight cells where the missing count is greater than 0 in red.

- Additionally, a list of missing values is created and written to Excel, assuming that the number of missing values is greater than zero.

25 – Fill Data Auto.TSTool

Purpose:

- Fill missing values in the raw time series using automated filling techniques in TSTool (i.e., regression analysis, interpolation, historical monthly averages, and zero values).

Workflow Details:

- To fill missing values in the natural flow dataset:
    - The raw natural flow data are read.
    - A property is set to indicate that these stations are needed for the SWSI analysis, to differentiate later on from stations used solely for filling data.
    - The filling table is read from the control workbook from the FlowDataFill worksheet where Flow Type = Natural and Include <> "NO".
    - A list of stations is created to indicate filling stations whose data have not yet been downloaded.
    - Data are obtained for these additional stations from the NRCS AWDB web services.
    - An automatic check is performed to confirm that data were returned for all additional stations.
    - A loop is run over the stations that need to be filled.
        - Properties are set to indicate the filling station ID, the fill start date, and the fill end date.
        - The FillRegression command is used to perform the filling using monthly regression equations. The regression statistics are written to the NatFlow_RegressionStats table.
        - Filled data are assigned a data flag of "R" to indicate regression filling.
        - To prevent cases where the filled value is negative, a ReplaceValue command is used to set negative values to zero and reset the data flag to RZ to indicate filled values were replaced with zeroes. This situation can happen when a downstream station with much larger flows is used for filling, resulting in a regression equation with a negative intercept.
    - The original or filled data are written to DateValue and Excel formats.
    - The filling data are written to DateValue format as an archive.
- If observed flow data are being used:
    - To fill missing values in the observed flow dataset:
        - The raw observed flow data are read.
        - A property is set to indicate that these stations are needed for the SWSI analysis, to differentiate later on from stations used solely for filling data.
        - The filling table is read from the control workbook from the FlowDataFill worksheet where Flow Type = Observed and Include <> "NO".
        - If any observed data filling has been specified:
            - A list of stations is created to indicate filling stations whose data have not yet been downloaded.
            - Data are obtained for these additional stations from the ColoradoWaterHBGuest web service.

- An automatic check is performed to confirm that data were returned for all additional stations.
- A loop is run over the stations that need to be filled.
    - Properties are set to indicate the filling station ID, the fill start date, and the fill end date.
    - The FillRegression command is used to perform the filling using monthly regression equations. The regression statistics are written to the ObsFlow_RegressionStats table.
    - Filled data are assigned a data flag of "R" to indicate regression filling.
    - To prevent cases where the filled value is negative, a ReplaceValue command is used to set negative values to zero and reset the data flag to RZ to indicate filled values were replaced with zeroes. This situation can happen when a downstream station with much larger flows is used for filling, resulting in a regression equation with a negative intercept.
- The original or filled data are written to DateValue and Excel formats.
- The filling data are written to DateValue format as an archive.

- To fill missing values in the reservoir storage dataset:
    - The raw reservoir storage data are read.
    - The filling table is read from the control workbook from the ReservoirDataFill worksheet.
    - The first filling loop involves filling the start of the data record with zeroes if the reservoir was not yet storing water. Filled data flags are set to Z for zeroes.
    - The second filling loop involves filling missing values by interpolating between existing values. This approach is typically selected when only a few data values are missing. Filled data flags are set to I for interpolate.
    - The third filling loop involves filling missing values using historical monthly averages. This approach is typically used when more than one year of data is missing. Filled data flags are set to H for historical monthly averages.
    - The fourth filling loop is applied to reservoirs that have been decommissioned and are no longer storing water. In this case, missing values are set to zero through the current month. Filled data flags are set to Z for zeroes.
    - The filled data are written to DateValue and Excel formats.
- A data check summary is performed on the filled natural flow data, the filled observed flow data (if used), the filled reservoir storage data, and the raw forecasted natural flow data to provide an update on the status of missing data. The time series aliases and dates with missing values are written to a summary table and to Excel.

27 – Fill Data Manual.TSTool

Purpose:

- Fill missing values (or replace existing values) in the raw time series using user-specified values.

Workflow Details:

- The override table is read from the control workbook from the Overrides worksheet.
- Conditional formatting tables are read from the control workbook on the Lookup Values worksheet.

- If observed data are being used in the analysis:
    - The auto-filled observed flow data are read.
    - The SetTimeSeriesValuesFromTable command is used to apply override values and set filled data flags based on the overrides comment column from the control workbook.
- The auto-filled natural flow data are read.
- The SetTimeSeriesValuesFromTable command is used to apply override values and set filled data flags based on the overrides comment column from the control workbook.
- The auto-filled reservoir storage data are read.
- The SetTimeSeriesValuesFromTable command is used to apply override values and set filled data flags based on the overrides comment column from the control workbook.
- The raw forecasted natural flow data are read.
- The SetTimeSeriesValuesFromTable command is used to apply override values and set filled data flags based on the overrides comment column from the control workbook.
- The manual-filled time series are written to DateValue format for use in later TSTool processing steps.
- A summary of the final input data are written to Input_Data_Final.xlsx. Cell comments are used to show where data values were filled. The cells are also color-coded based on the data fill flag to facilitate user review.
- A data check summary is performed on the manual-filled natural flow data, the manual-filled reservoir storage data, and the manual-filled forecasted natural flow data to provide an update on the status of missing data. The time series aliases and dates with missing values are written to a summary table and to Excel.

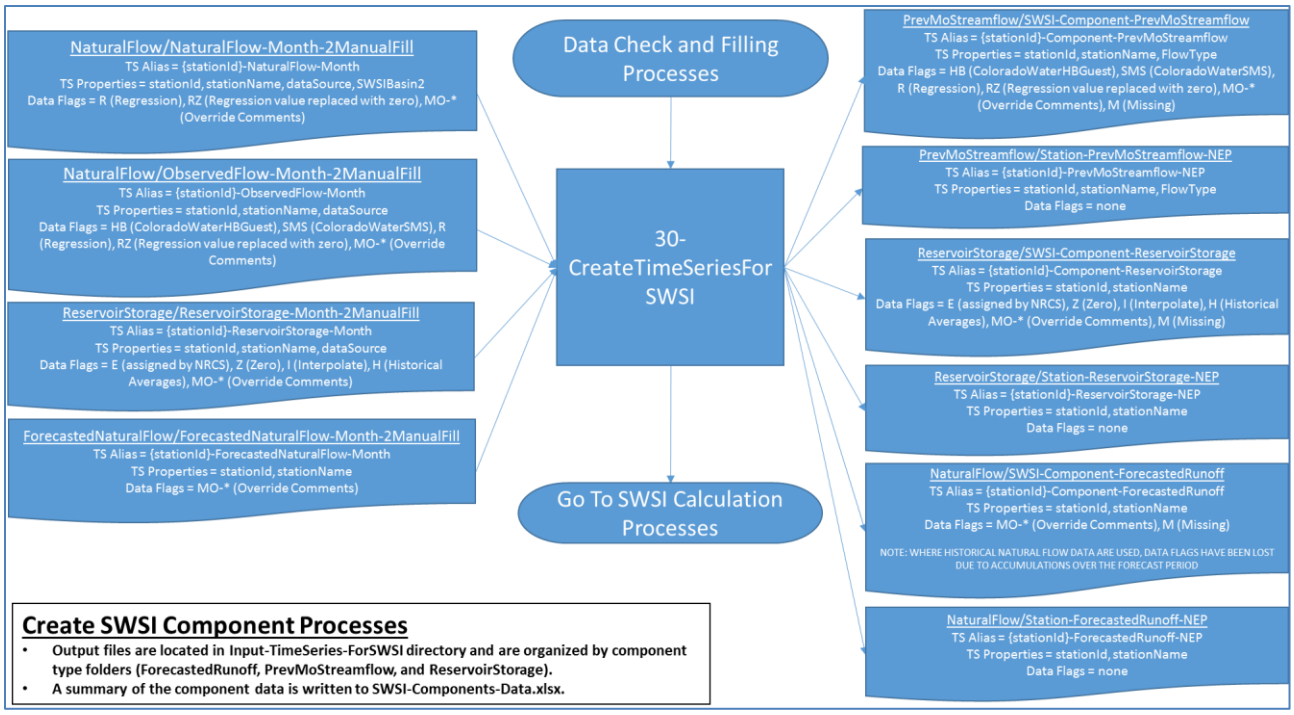

Figure 10. Flowchart of the Create SWSI Component Processes

30 – Create Time Series for SWSI.TSTool

Purpose:

- Automatically produce the component time series needed for the SWSI calculation by station so that they can be added by HUC in a later processing step.

Workflow Details:

- Reservoir storage component
  - This component is used year-round.
  - Input data are shifted forward by one month to use the previous month's end-of-month value as the current month's beginning-of-month storage value. The data shift is accomplished using the "ShiftTimeByInterval" command.
- Previous month's streamflow component (see **Table 3** for example data transformations)
  - This component is used from Jul-Sep.
  - The expected situation is that natural flow data will be used. However, the user can opt to use observed flow data for one or more stations instead.
  - The natural flow data are read and assigned a FlowType property of "NatFlow".
  - If observed data are being used:
    - The observed flow data are read.
    - For each station assigned to use observed flow data:
      - The natural flow time series is freed from memory.
      - The observed flow time series is copied to a new time series with an alias of {stationId}-Component-PrevMoStreamflow which is consistent with that used for the natural flow data.
      - The new time series is assigned a FlowType property of "ObsFlow" to help distinguish in the outputs where observed flow data were used.
  - All data are shifted forward by one month to use the previous month's volume as the current month's previous month's streamflow value. The data shift is accomplished using the "ShiftTimeByInterval" command.
  - The monthly values are set to 0 from Oct-Jun (when this component is not used) using a "SetConstant" command.
- Forecast runoff component
  - This component is used Jan-Jun.
  - The historical period is treated differently from the current period, so two component time series are generated and then merged.
    - For the historical period:
      - Historical natural flow data are accumulated over the appropriate forecast period based on month and location (see **Table 12**).
        - The SWSI Basin2 time series property is used to differentiate stations in the Rio Grande basin versus stations outside the Rio Grande basin.
        - Because of the transformations applied to the natural flow data to accumulate runoff volumes over the forecast period, the data flags are not propagated through this step.
      - Two "RunningStatisticTimeSeries" commands are used to perform the accumulation of monthly natural flows to the forecast period (one for Rio Grande stations, and one for non-Rio Grande stations).

Offset-duration notation is used to specify the start and end of the accumulation period (see **Table 13**). For example, in January for a station in the Rio Grande basin, the monthly flows need to be accumulated for APR-SEP and the offset-duration value is specified as 3-8. Relative to Jan, Apr is 3 months ahead and Sep is 8 months ahead.

Table 13. Offset notation used to accumulate monthly historical natural flows over the forecast period.

MONTH	RIO GRANDE BASIN		NON-RIO GRANDE BASIN	
	Forecast Period	**Offset-Duration Notation**	**Forecast Period**	**Offset-Duration Notation**
JAN	APR-SEP	3-8	APR-JUL	3-6
FEB	APR-SEP	2-7	APR-JUL	2-5
MAR	APR-SEP	1-6	APR-JUL	1-4
APR	APR-SEP	0-5	APR-JUL	0-3
MAY	MAY-SEP	0-4	MAY-JUL	0-2
JUN	JUN-SEP	0-3	JUN-JUL	0-1
JUL-DEC	Not applicable	Not applicable	Not applicable	Not applicable

        - The data values are set to 0 in Jul-Dec when the forecast runoff component is not used.
        - The data values are set to 0 for the current period, when forecasts are used instead of "observed" natural flows.
    - For the current period:
        - Forecasted natural flows over the forecast period are used.
        - The data values are set to 0 in Jul-Dec when the forecast runoff component is not used.
        - The data values are set to 0 for the historical, when "observed" natural flows are used instead of forecasts.
    - If the RecentPeriodFlowType = NaturalFlow, then the forecasted runoff in the recent period is computed like the historical period. This is the default case where historical natural flows are used for the forecasted runoff component.
    - If the RecentPeriodFlowType = ForecastedNaturalFlow, then the forecasted runoff in the recent period is computed like the current period. This is the re-forecast option where forecasts are used for the forecasted runoff component in the recent period.
    - The historical and current time series are merged. **Figure 11** presents an example of a merged time series to demonstrate that values are more variable in the current period (when forecasts are used) than in the historical period (when historical natural flows are used).
        - In the historical period, "observed" natural flows are accumulated from monthly natural flow values. We know what the natural flows were in past years. This fact means that for the months of Jan-Apr, when the forecast period is constant, the forecasted runoff component values are also constant from month to month. In May and June, the forecasted runoff component values decrease to reflect less time from the current month until the end of the forecast period.
        - In the current period, when forecasts are used, the forecasted runoff component is more variable because it also reflects forecast model uncertainty.

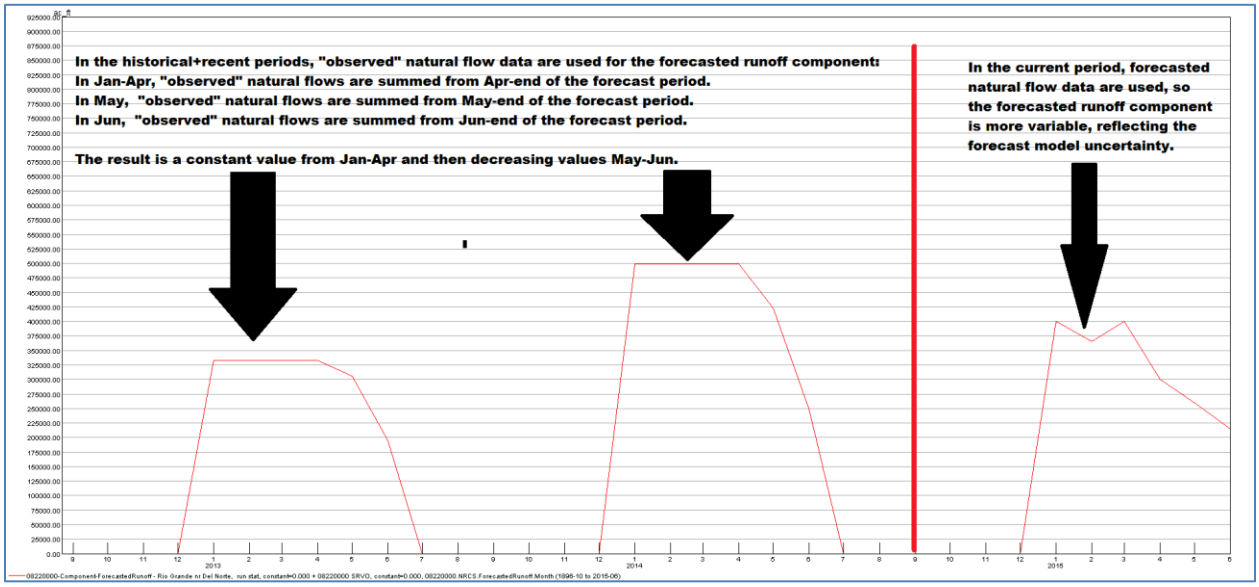

Figure 11. Example of the Forecasted Runoff Component

- NEP Values by Month are calculated for each station by first calculating the Gringorten plotting position and then multiplying the results by 100. The NEP time series are set to missing in months when the component is not being used.
- A data check summary is performed on the final component data. The time series aliases and dates with missing values are written to a summary table and to Excel.

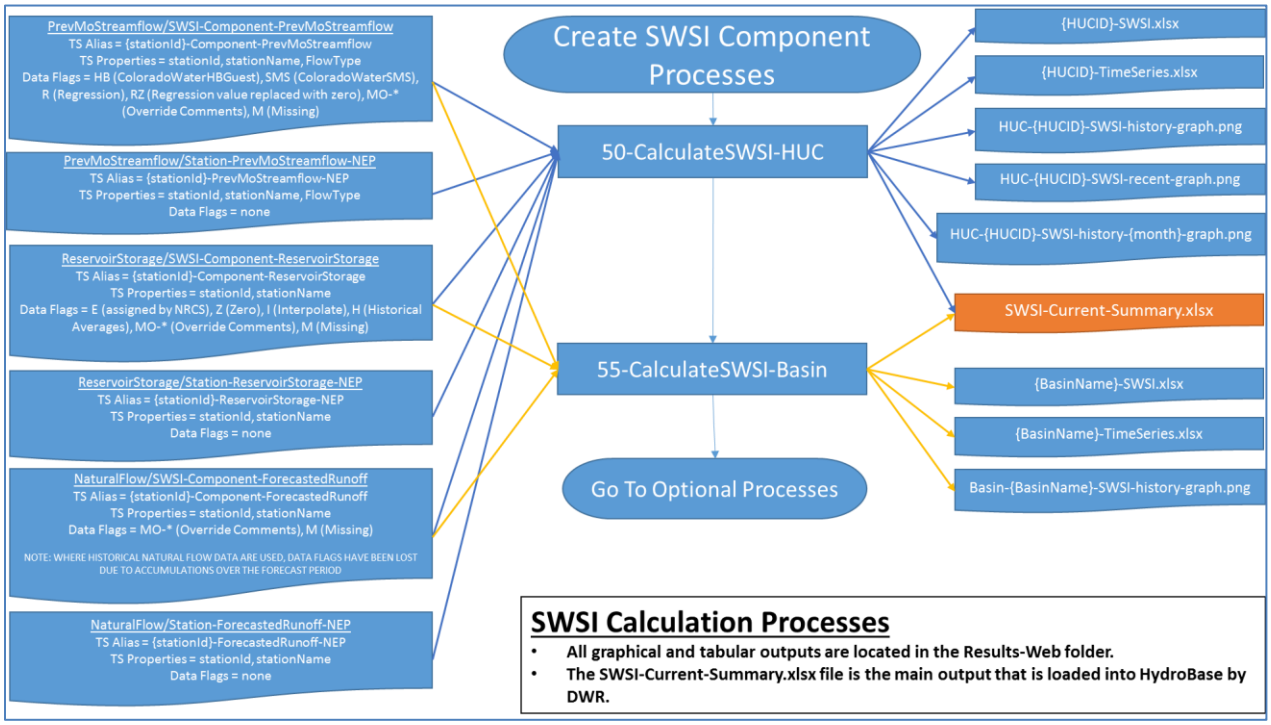

Figure 12. Flowchart of the SWSI Calculation Processes

50 – Calculate SWSI - HUC.TSTool

Purpose:

- Perform all of the SWSI-related calculations and generate all of the SWSI output products on a HUC8 basis.

Workflow Details:

- Many properties are read from the control file related to the start and end dates of the historical, recent, and current periods, as well as dates and annotation placements to support the graphical outputs.
- A lookup table of month properties is read from Excel that crosswalks month IDs (1-12) with month abbreviations (JAN-DEC). This information is used to loop on months and generate monthly outputs in graphical and tabular formats. This table is also used to set three flags that indicate which SWSI components are used in the current month: ReservoirFlag, PrevMoFlowFlag, and ForecastFlag.
- There are six station component data files read as inputs:
    - Reservoir storage component-volumes
    - Reservoir storage component-NEP by month
    - Previous month's streamflow component-volumes
    - Previous month's streamflow component- NEP by month
    - Forecasted runoff component-volumes
    - Forecasted runoff component- NEP by month
- The current month's volume and percent of average values are set as time series properties on each station time series.
- The combined inputs table is read and used to generate a list of unique HUC8 identifiers that are used to loop for the SWSI processing.
- An automated check is done to compare the number of unique HUC IDs with the expected number. This helps to identify typos in the HUC ID and name that may result in HUCs being erroneously processed multiple times. If a warning is produced, the user should review the control file to ensure the NumberOfHUCs property is correct and that the HUC and HUC Name columns on the Combined Inputs worksheet do not have any typos or inconsistencies.
- The Summary Output Table for HUCs is created based on DNR requirements as follows, with column name and data type indicated:
    - Basin, string (River Basin)
    - HUC_ID, string (8-digit HUC8 identifier)
    - HUC_Name, string (HUC Name)
    - Date, datetime (YYYY-MM of current month's analysis)
    - SWSI, double (surface water supply index value that ranges from -4.16 to +4.16)
    - NEP, double (non-exceedance probability that ranges from 0-100%)
    - SWSI_Prev_Yr, double (SWSI value for this month last year, value ranging from -4.16 to +4.16)
    - Chg_SWSI_Prev_Yr, double (calculated as SWSI – SWSI_Prev_Yr)
- The Summary Output Table for HUC Components is created based on DNR requirements as follows, with column name and data type indicated:
    - Basin, string (River Basin)
    - HUC_ID, string (8-digit HUC8 identifier)
    - HUC_Name, string (HUC Name)
    - Date, string (YYYY-MM of current month's analysis)

    - Component Type, string (Reservoir Storage, Previous Month's Streamflow, or Forecasted Runoff)
    - Component ID, string (station identifier)
    - Component Name, string (station name)
    - Component Volume, double (component volume in ac-ft)
    - Component Percent Of Average, double (percent of historical average)
- The process then enters into a loop on HUC identifiers. For the current HUC:
    - Set the hucName property to be used in outputs.
    - Set the riverBasin property to be used in outputs.
    - Create a table of the assigned previous month's streamflow stations (HUC_PrevMoStreamflowStations) and set a property of the station count (NumPrevMoStreamflowGages).
    - Create a table of the assigned reservoirs (HUC_Reservoirs) and set a property of the station count (NumReservoirs).
    - Create a table of the assigned forecasted runoff stations (HUC_ForecastedRunoffStations) and set a property of the station count (NumForecastedRunoffGages).
    - Calculate the sum of the reservoir storage component for the HUC (TS alias = HUC:${HUCID}-Component-ReservoirStorage.
        - For the reservoirs assigned to the current HUC, assign time series properties of HUC that are used to write station values to the Summary Output Table. These properties are assigned to both the station volume and percent of average time series.
        - Perform an automated check that the number of reservoirs summed for the HUC value matches the expected number. If a warning is generated, make sure that the input data files have data for all assigned reservoirs.
    - Calculate results for the HUC's reservoir storage component.
        - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
        - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
    - Calculate the sum of the previous month's streamflow component for the HUC (TS alias = HUC:${HUCID}-Component-PrevMoStreamflow.
        - For the gages assigned to the current HUC, assign time series properties of HUC that are used to write station values to the Summary Output Table. These properties are assigned to both the station volume and percent of average time series.
        - Perform an automated check that the number of gages summed for the HUC value matches the expected number. If a warning is generated, make sure that the input data files have data for all assigned gages.
    - Calculate results for the HUC's previous month's streamflow component.
        - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
        - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
    - Calculate the sum of the forecasted runoff component for the HUC (TS alias = HUC:${HUCID}-Component-ForecastedRunoff.

        - For the gages assigned to the current HUC, assign time series properties of HUC that are used to write station values to the Summary Output Table. These properties are assigned to both the station volume and percent of average time series.
        - Perform an automated check that the number of gages summed for the HUC value matches the expected number. If a warning is generated, make sure that the input data files have data for all assigned gages.
    - Calculate results for the HUC's forecasted runoff component.
        - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
        - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
    - Calculate the data composite for the HUC as the sum of the three components (reservoir storage + previous month's streamflow + forecasted runoff). The TS alias of the data composite time series is HUC:${HUCID}-DataComposite.
    - Calculate results for the HUC's data composite.
        - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
        - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
        - Assign properties (hucName and riverBasin) to the HUC data composite SWSI time series (time series alias is HUC:${HUCID}-DataComposite-SWSI) that will be output to the Summary Output Table.
    - Create an Excel workbook for the current HUC that has worksheets for each month. This workbook is named ${HUCID}-SWSI.xlsx.
    - Begin a nested loop on months to generate results and outputs. For the current month:
        - Assign the month abbreviation as a property.
        - Remove the html output file for the current HUC and month.
        - Write all of the historical results for the current month to a table named HUC:${HUCID}-${MonthAbbrev}
            - Data Composite (ac-ft)
            - Data Composite Percent of Average (%)
            - Data Composite Plotting Position (--)
            - Data Composite Non-Exceedance Probability (%)
            - Data Composite Surface Water Supply Index (--)
            - Reservoir Storage (ac-ft)
            - Reservoir Storage Percent of Average (%)
            - Reservoir Storage Plotting Position (--)
            - Reservoir Storage Non-Exceedance Probability (%)
            - Reservoir Storage Surface Water Supply Index (--)
            - Previous Month Streamflow (ac-ft)
            - Previous Month Streamflow Percent of Average (%)
            - Previous Month Streamflow Plotting Position (--)
            - Previous Month Streamflow Non-Exceedance Probability (%)
            - Previous Month Streamflow Surface Water Supply Index (--)
            - Forecasted Runoff (ac-ft)
            - Forecasted Runoff Percent of Average (%)

        - Forecasted Runoff Plotting Position (--)
        - Forecasted Runoff Non-Exceedance Probability (%)
        - Forecasted Runoff Surface Water Supply Index (--)
    - For the recent and current periods, use the current month's data composite volume and component volumes to look up NEP and SWSI results using the historical data in HUC:${HUCID}-${MonthAbbrev}.
    - Add results for the recent and current periods to the HUC:${HUCID}-${MonthAbbrev} table. Of the results listed above, all results are computed for the recent+current periods EXCEPT the plotting position. This is because the NEP and SWSI values are determined using a lookup function rather than computed from the plotting position as is done in the historical period.
    - The HUC:${HUCID}-${MonthAbbrev} table is sorted by Data Composite descending.
    - The HUC:${HUCID}-${MonthAbbrev} table is written to an HTML file and to the corresponding month worksheet in ${HUCID}-SWSI.xlsx.
    - The monthly results are used to produce monthly output graphs in Results-Web/graphs-png/${MonthId}-${MonthAbbrev}-HUC
        - The current month's values are put into yearly time series for plotting.
        - A template file is expanded for the current HUC and month. The tsp is saved to Results-Web/graphs-tsp/${MonthId}-${MonthAbbrev}-HUC
    - This is the end of the month loop.
- The ${HUCID}-SWSI.xlsx workbook is closed, which causes TSTool to write the results in memory to file.
- Results across all months are plotted for the full history and for the recent+current periods only.
    - Template files are expanded for the current HUC for both the historical graph and the recent graph. The tsp files are saved to Results-Web/graphs-tsp/ALL-HUC.
    - PNG files for the historical and the recent graphs are saved to Results-Web/graphs-png/ALL-HUC.
- All time series data for the HUC are output to Excel.
    - The existing file (${HUCID}-TimeSeries.xlsx) is removed.
    - The relevant time series are selected and written to Results-Web/ts/(${HUCID}-TimeSeries.xlsx.
- A temporary copy (Summary_Output_Table_HUC_Temp) of the Summary_Output_Table_HUC is made. This is because the TimeSeriesToTable commands always create a new table instead of appending results to an existing table.
- The HUC's current results are written to the Summary_Output_Table_HUC_temp table.
- The results are appended from Summary_Output_Table_HUC_temp to Summary_Output_Table_HUC, and the temporary table is released from memory.
- A temporary copy (Summary_Output_Table_HUC_Components_Temp) of the Summary_Output_Table_HUC_Components is made. This is because the TimeSeriesToTable commands always create a new table instead of appending results to an existing table.
- The HUC's current component results are written to the Summary_Output_Table_HUC_Components_temp table.

        - If a component is not used in the current month, neither the stations nor the accompanying data values are written.
        - If a component is used, but a station's data values are missing, the station name and identifier are written to the table but the data values are blank.
        - Data values are zero when the result is zero (for example, there is no reservoir storage).
        - Data values should never appear as NaN.
    - The results are appended from Summary_Output_Table_HUC_Components_temp to Summary_Output_Table_HUC_Components, and the temporary table is released from memory.
    - To prepare for the next HUC, all time series are deselected, the three generic tables (HUC_PrevMoStreamflowStations, HUC_Reservoirs, and HUC_ForecastedRunoffStations) are freed, and the three generic properties (NumPrevMoStreamflowGages, NumReservoirs, and NumForecastedRunoffGages) are reset to 0.
    - This is the end of the HUC loop.
- The Summary_Output_Table_HUC is finalized and output.
    - Table math is done to compute Chg_SWSI_Prev_Yr as SWSI – SWSI_Prev_Yr.
    - The table is sorted on river basin ascending and HUC ID ascending.
    - The table is written out to Results-Web/swsi-summary in Excel format (SWSI-Current-Summary.xlsx) on the HUC Summary worksheet and in HTML format (SWSI--Current-Summary-HUC.html).
- The Summary_Output_Table_HUC_Components is finalized and output.
    - The table is sorted on river basin ascending, HUC ID, Component Type, and Component ID.
    - The table is written out to Results-Web/swsi-summary in Excel format (SWSI-Current-Summary.xlsx) on the HUC Components worksheet and in HTML format (SWSI-Current-Summary-HUC-Components.html).

55 – Calculate SWSI - Basin.TSTool

Purpose:

- Perform all of the SWSI-related calculations and generate all of the SWSI outputs on a river basin basis.

Workflow Details:

- Many properties are read from the control file related to start and dates of the historical, recent, and current periods, as well as dates and annotation placements to support the graphical outputs.
- There are three station component data files read as inputs:
    - Reservoir storage component-volumes
    - Previous month's streamflow component-volumes
    - Forecasted runoff component-volumes
- The combined inputs table is read and used to generate a list of unique river basins that is used to loop for the SWSI processing.
- A lookup table of month properties is read from Excel that crosswalks month ids (1-12) with month abbreviations (JAN-DEC). This information is used to loop on months and generate monthly outputs in graphical and tabular formats.

- An automated check is done to compare the number of unique river basins with the expected number. This helps to identify typos in the basin name that may result in basins being erroneously processed multiple times.
- The Summary Output Table for basins is created based on DWR requirements as follows:
    - Basin, string (River Basin)
    - Date, datetime (YYYY-MM of current month's analysis)
    - SWSI, double (surface water supply index value that ranges from -4.16 to +4.16)
    - NEP, double (non-exceedance probability that ranges from 0-100%)
    - SWSI_Prev_Mo, double (SWSI value for last month, value ranging from -4.16 to +4.16)
    - Chg_SWSI_Prev_Mo, double (calculated as SWSI – SWSI_Prev_Mo)
    - SWSI_Prev_Yr, double (SWSI value for this month last year, value ranging from -4.16 to +4.16)
    - Chg_SWSI_Prev_Yr, double (calculated as SWSI – SWSI_Prev_Yr)
- The process then enters into a loop on basins. For the current basin:
    - Create a table of the assigned previous month's streamflow stations (Basin_PrevMoStreamflowStations) and set a property of the station count (NumPrevMoStreamflowGages).
    - Create a table of the assigned reservoirs (Basin_Reservoirs) and set a property of the station count (NumReservoirs).
    - Create a table of the assigned forecasted runoff stations (Basin_ForecastedRunoffStations) and set a property of the station count (NumForecastedRunoffGages).
    - Calculate the sum of the reservoir storage component for the Basin (TS alias = ${BasinName}-Component-ReservoirStorage).
        - For the reservoirs assigned to the current Basin, assign time series properties of Basin that are used to write station values to the Summary Output Table.
        - Perform an automated check that the number of reservoirs summed for the Basin value matches the expected number.
    - Calculate results for the Basin's reservoir storage component.
        - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
        - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
    - Calculate the sum of the previous month's streamflow component for the Basin (TS alias = ${BasinName}-Component-PrevMoStreamflow.
        - For the gages assigned to the current Basin, assign time series properties of Basin that are used to write station values to the Summary Output Table.
        - Perform an automated check that the number of gages summed for the Basin value matches the expected number.
    - Calculate results for the Basin's previous month's streamflow component.
        - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
        - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
    - Calculate the sum of the forecasted runoff component for the Basin (TS alias = ${BasinName}-Component-ForecastedRunoff.
        - For the gages assigned to the current Basin, assign time series properties of Basin that are used to write station values to the Summary Output Table

        - Perform an automated check that the number of gages summed for the Basin value matches the expected number.
    - Calculate results for the Basin's forecasted runoff component.
        - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
        - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
    - Calculate the data composite for the Basin as the sum of the three components (reservoir storage + previous month's streamflow + forecasted runoff). The TS alias of the data composite time series is ${BasinName}-DataComposite.
    - Calculate results for the Basin's data composite.
        - Calculate percent of historical average based on the WY1971-2010 period for the whole available period.
        - Establish the plotting position, non-exceedance probabilities (NEP), and the SWSI values for the historical period only (WY 1971-2010).
        - Assign properties (BasinName) to the Basin data composite SWSI time series (time series alias is ${BasinName}-DataComposite-SWSI) that will be output to the Summary Output Table.
    - Create an Excel workbook for the current Basin that has worksheets for each month. This workbook is named ${BasinName}-SWSI.xlsx.
    - Begin a nested loop on months to generate results and outputs. For the current month:
        - Assign the month abbreviation as a property.
        - Remove the html output file for the current Basin and month.
        - Write all of the historical results for the current month to a table named ${BasinName}-${MonthAbbrev}
            - Data Composite (ac-ft)
            - Data Composite Percent of Average (%)
            - Data Composite Plotting Position (--)
            - Data Composite Non-Exceedance Probability (%)
            - Data Composite Surface Water Supply Index (--)
            - Reservoir Storage (ac-ft)
            - Reservoir Storage Percent of Average (%)
            - Reservoir Storage Plotting Position (--)
            - Reservoir Storage Non-Exceedance Probability (%)
            - Reservoir Storage Surface Water Supply Index (--)
            - Previous Month Streamflow (ac-ft)
            - Previous Month Streamflow Percent of Average (%)
            - Previous Month Streamflow Plotting Position (--)
            - Previous Month Streamflow Non-Exceedance Probability (%)
            - Previous Month Streamflow Surface Water Supply Index (--)
            - Forecasted Runoff (ac-ft)
            - Forecasted Runoff Percent of Average (%)
            - Forecasted Runoff Plotting Position (--)
            - Forecasted Runoff Non-Exceedance Probability (%)
            - Forecasted Runoff Surface Water Supply Index (--)

        - For the recent and current periods, use the current month's data composite volume and component volumes to look up NEP and SWSI results using the historical data in ${BasinName}-${MonthAbbrev}.
        - Append results for the recent and current periods to the ${BasinName}-${MonthAbbrev} table. Of the results listed above, all results are computed for the recent+current periods EXCEPT the plotting position. This is because the NEP and SWSI values are determined using a lookup function rather than computed from the plotting position as is done in the historical period.
        - The ${BasinName}-${MonthAbbrev} table is sorted by Data Composite descending.
        - The ${BasinName}-${MonthAbbrev} table is written to an HTML file and to the corresponding month worksheet in ${BasinName}-SWSI.xlsx.
        - This is the end of the month loop.
    - The ${BasinName}-SWSI.xlsx workbook is closed, which prompts TSTool to write the results in memory to file.
    - Results across all months are plotted for the full period.
        - A template file is expanded for the current Basin. The tsp file is saved to Results-Web/graphs-tsp/ALL-Basin.
        - A PNG file is saved to Results-Web/graphs-png/ALL-Basin.
    - All time series data for the Basin are output to Excel.
        - The existing file (${BasinName}-TimeSeries.xlsx) is removed.
        - The relevant time series are selected and written to Results-Web/ts/${BasinName}-TimeSeries.xlsx.
    - A temporary copy (Summary_Output_Table_ Temp) of the Summary_Output_Table is made. This is because the TimeSeriesToTable commands always create a new table instead of appending results to an existing table.
    - The Basin's current results are written to the Summary_Output_Table_ temp table.
    - The results are appended from Summary_Output_Table_ temp to Summary_Output_Table, and the temporary table is released from memory.
    - To prepare for the next Basin, all time series are deselected, the three generic tables (Basin_PrevMoStreamflowStations, Basin_Reservoirs, and Basin_ForecastedRunoffStations) are freed, and the three generic properties (NumPrevMoStreamflowGages, NumReservoirs, and NumForecastedRunoffGages) are reset to 0.
    - This is the end of the Basin loop.
- The Summary_Output_Table is finalized and output.
    - Table math is done to compute Chg_SWSI_Prev_Mo as SWSI – SWSI_Prev_Mo and Chg_SWSI_Prev_Yr as SWSI – SWSI_Prev_Yr.
    - The table is sorted on river basin ascending.
    - The table is written out to Results-Web/swsi-summary in Excel format (SWSI-Current-Summary.xlsx) on the Basin Summary worksheet and in HTML format (SWSI--Current-Summary-Basin.html).

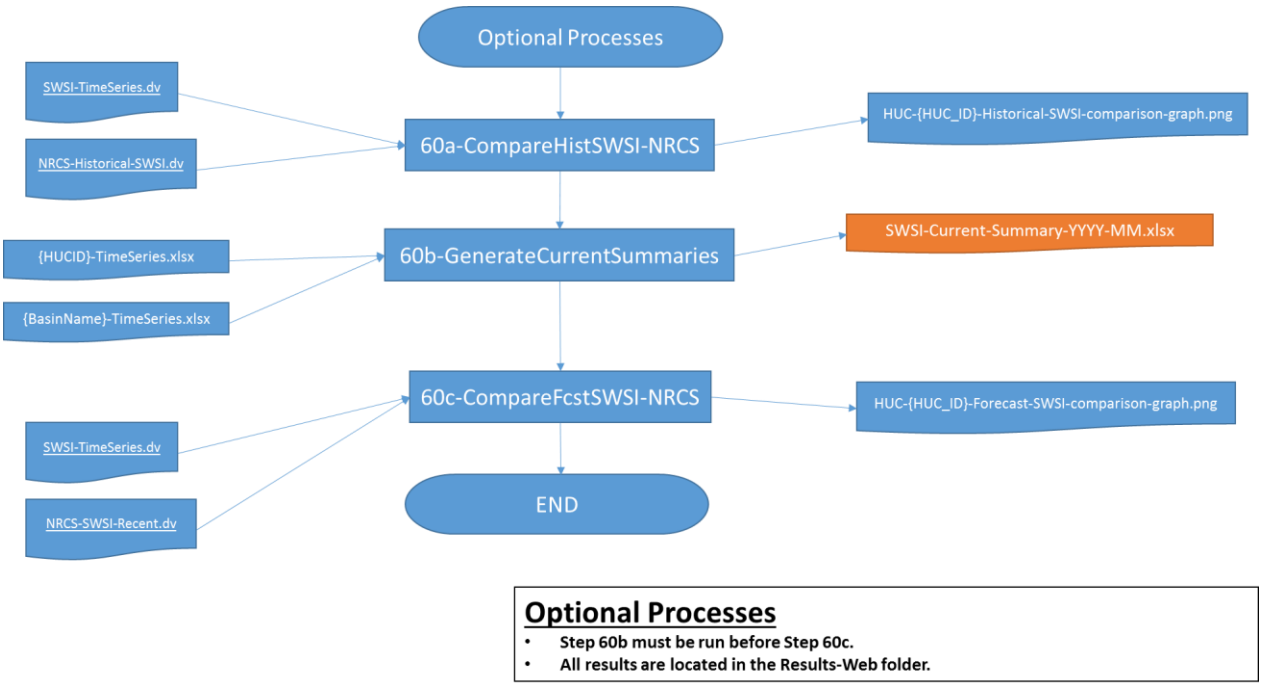

Figure 13. Flowchart of the Optional Processes

60a –CompareHistSWSI-NRCS.TSTool

Purpose:

- To compare the historical SWSI values computed using the Colorado SWSI Automation Tool to those calculated by the NRCS for the historical period.

Workflow Details:

- Properties are read from Excel for the start and the end dates of the historical period.
- Read the Combined Inputs table and make a list of unique HUCs.
- Perform an automated check on the number of HUCs.
- Read the NRCS historical SWSI values for the historical period.
- Read the Colorado historical SWSI values for the historical period.
- Loop on the HUCs.
- Expand a template to make a time series product for the HUC comparing the Colorado and NRCS SWSI values.
- Create and output a graphic based on the time series product.

60b –Generate Current Summaries.TSTool

Purpose:

- To produce dated versions of the Current SWSI Summary workbook for each month in the recent period. This step was developed primarily to support the need to produce re-forecasted SWSI values, though it can be used for historical SWSIs as well.

Workflow Details:

- Make a list of the unique river basins.
- Read in the river basin time series results.
- To avoid having a large number of extraneous time series in memories, free all basin time series from memory, except the Data Composite NEP and SWSI time series.
- Assign a BasinTS property that indicates the time series that represent basin results. This property is used later for time series selection.
- Make a list of the unique HUCs.
- Read in the HUC time series results.
- To avoid having a large number of extraneous time series in memories, free all HUC time series from memory, except the Data Composite NEP, Data Composite SWSI, and Component NEP time series.
- Assign HUC_ID, Basin, and HUC_Name time series properties to the HUC time series. These properties are later written to the HUC Summary table.
- Assign a HUCTS property that indicates the time series that represent HUC results. This property is used later for time series selection.
- Read in the component volume and NEP time series.
- Assign a StationTS property that indicates the time series that represent station results. This property is used later for time series selection.
- Assign ComponentType properties to the station time series. These properties are later written to the HUC Component Summary.
- Read a list of months to be processed from Excel. The columns contain values that will be used to set the RunMonthDate, PreviousMonthDate, and PreviousYearDate properties to be set.
- Calculate a RunMonthMM column that is used to determine which components are being used in the month's analysis.
- Begin a loop on the months to be processed.
- ReservoirFlag, PrevMoFlowFlag, and ForecastFlag properties are set to indicate which components are being used.
- Create the Basin Summary, HUC Summary, and HUC Components tables.
- Create a dated Excel workbook as SWSI-Current-Summary-RunMonthDate.xlsx.
- Copy basin properties to the Basin Summary table.
- Insert basin results into the Basin Summary table.
- Calculate Change in SWSI columns in the Basin Summary table.
- Sort the Basin Summary table by Basin name.
- Write the Basin Summary table to Excel.
- Copy HUC properties to the HUC Summary table.
- Insert HUC results into the HUC Summary table.
- Calculate Change in SWSI columns in the HUC Summary table.
- Sort the HUC Summary table by Basin name and HUC ID.
- Write the HUC Summary table to Excel.
- Begin a loop on the HUCs.
- For each HUC, create tables of the assigned stations.
- If the reservoir storage component is being used for the current month and the HUC has at least one assigned reservoir:
    - Create a temporary copy of the HUC Components table.
    - Append rows for the HUC-reservoir assignments.

    - Set the component type to ReservoirStorage.
    - Insert the reservoir storage results into the temporary HUC Components table.
    - Append results from the temporary HUC Components table to the HUC Components table.
    - Free the temporary HUC Components table.
- If the previous month's streamflow component is being used for the current month and the HUC has at least one assigned station:
    - Create a temporary copy of the HUC Components table.
    - Append rows for the HUC-station assignments.
    - Set the component type to PrevMoStreamflow.
    - Insert the station results into the temporary HUC Components table.
    - Append results from the temporary HUC Components table to the HUC Components table.
    - Free the temporary HUC Components table.
- If the forecasted runoff component is being used for the current month and the HUC has at least one assigned station:
    - Create a temporary copy of the HUC Components table.
    - Append rows for the HUC-station assignments.
    - Set the component type to ForecastedRunoff.
    - Insert the station results into the temporary HUC Components table.
    - Append results from the temporary HUC Components table to the HUC Components table.
    - Free the temporary HUC Components table.
- Free the HUC-station tables from memory to be used in the next HUC.
- End of the HUC loop.
- The HUC Components table is sorted on Basin, HUC ID, Component Type, and Component ID.
- The HUC Components table is written to Excel.
- The dated summary workbook is closed, prompting TSTool to write the results from memory to file.
- The Basin Summary, HUC Summary, and HUC Components tables are freed from memory to prepare for the next month.
- End of the month loop.

60c –CompareFcstSWSI-NRCS.TSTool

Purpose:

- To compare the forecast SWSI values computed using the Colorado SWSI Automation Tool to those calculated by the NRCS for the recent period.

Workflow Details:

- Properties are read from Excel for the start of the recent period and the current date.
- Read the Combined Inputs table and make a list of unique HUCs.
- Perform an automated check on the number of HUCs.
- Read the NRCS forecast SWSI values for the recent period.
- Read the Colorado forecast SWSI values for the recent period.
- Loop on the HUCs.
- Expand a template to make a time series product for the HUC comparing the Colorado and NRCS SWSI values.

- Create and output a graphic based on the time series product.

Appendix D – Historical Period Data Issues

DWR provided to OWF the initial version of the CO-SWSI-Control.xlsx file. During the development of the Colorado SWSI Automation Tool, the historical data were reviewed by OWF and the issues are documented herein along with the implemented solutions. Unresolved issues are noted using red text.

Observed Natural Flows

- A station identifier without the leading zero was fixed in the master control file.
- Multiple stations had no historical SRVO data from the NRCS and were replaced with alternate station selections.
    - 06695000 S Platte abv Eleven Mile: This was a data entry error and was replaced with 06695500 Eleven Mile Canyon Reservoir Inflow.
    - 07097000 Arkansas R abv Portland: Gage was replaced with 07099400 Arkansas R abv Pueblo.
    - 07124200 Purgatoire R at Madrid: Gage was replaced with 07124500 Purgatoire River at Trinidad.
    - 09110000 Taylor R at Almont: Gage was replaced with 09109209 Taylor River below Taylor Park Reservoir.
    - 09166950 Lost Canyon Creek near Dolores: This gage and 09166500 Dolores at Dolores were removed. Replacement gage is 09169000 Dolores River below McPhee Reservoir.
    - 09354500 Los Pinos River at La Boca: Gage was replaced with 09353500 Los Pinos River nr Bayfield.
    - 09362750 Florida R abv Lemon Res: Gage was replaced with 09363100 Florida R Inflow to Lemon Reservoir.
- Multiple gages start after the historical period start of Oct 1970 or have periods of missing SRVO data during the historical period that were filled for a complete dataset.
    - 06710385 Bear Creek above Evergreen: Data start 1984.
    - 07111000 Huerfano River near Redwing: Missing data 1991-94.
    - 07114000 Cucharas River at Boyd Ranch nr La Veta: Missing data 1987-1994.
    - 08241500 Sangre de Cristo: Multiple missing periods, mostly before 1980.
    - 09169000 Dolores River below McPhee Reservoir: Some missing data 1980-1984.
    - 09242500 Elkhead River near Milner: Data start 1990 and winter values missing 2009-2012.
    - 09246200 Elkhead Creek above Long Gulch: Data start 1995.
    - 09370500 Mancos River near Mancos: Data start 1975 and missing data 1984-1990.
    - After applying automated filling in the historical and recent periods, one data value continues to be missing for 06719505 Clear Creek at Golden for 2014-08.
- Multiple gages have negative values in the SRVO time series obtained from the NRCS. Natural flow volumes can be computed to be negative if there are errors in the input terms, in particular during low flow months. If negative values occur in the months of June-August, when data are needed for the previous month's streamflow component, then manual overrides were specified to eliminate the negative values while preserving runoff volumes with adjacent months.
    - 06729500 SOUTH BOULDER CK NR ELDORADO SPRINGS, CO:
        - Affects HUCs 10190003, 10190005, 10190012.
        - 3 negative values during months when the data are used for SWSI analysis APR-SEP)
        - Prev Mo Flow Component negative 1989-09

        - Forecasted Runoff component ok
    - 08250000 CULEBRA CREEK AT SAN LUIS
        - Affects HUC 13010002
        - 13 negative values during months when the data are used for SWSI analysis APR-SEP)
        - Prev Mo Flow Component negative: 9 values
        - Forecasted Runoff component ok
    - 09070500 COLORADO RIVER NEAR DOTSERO
        - Affects HUC 14010001
        - No negative values during months when data are used for SWSI analysis
    - 09132500 NORTH FORK GUNNISON R NR SOMERSET
        - Affects HUC 14020004
        - No negative values during months when data are used for SWSI analysis
    - 09251000 YAMPA R NEAR MAYBELL
        - Affects HUC 14050002
        - 1 negative value during months used for SWSI
        - Prev Mo Flow Component negative: 1 value
        - Forecasted Runoff component ok
    - 09370500 MANCOS RIVER NEAR MANCOS
        - Affects HUC 14080107
        - 5 negative values during months when the data are used for SWSI analysis APR-SEP)
        - Prev Mo Flow Component negative: 5 values
        - Forecasted Runoff component ok
    - Manual overrides were specified to correct negative values that occurred in the months when data were needed for the previous month's streamflow component. Adjacent months were altered to preserve overall runoff volumes, with consideration of whether the values occurred on the rising or falling limb of the hydrograph. However, the specified values are subjective and no investigation was done into whether the specified values significantly affect the results.
- There were at least two cases where the station identifier and name used by the NRCS are not the same as used by the USGS. While the NRCS could not explain the history of this issue, they confirmed the stations being used are correct. The NRCS information for these stations follows:
    - 09169000 Dolores River below McPhee Reservoir
    - 09363100 FLORIDA RIVER INFLOW TO LEMON RESERVOIR
- There was at least one case where the specified stations are redundant (i.e., both upstream tributary gages and downstream outlet gages are included) and would cause flow volumes to be double-counted.
    - HUC 14010001 Colorado Headwaters Colorado. OWF removed the upstream tributary gages from the analysis per DWR direction.

Forecasted Natural Flows

- Multiple HUCs use different station sets for observed natural flows and forecasted natural flows. OWF discussed this issue with DWR and this approach is being retained to ensure natural flow values are available in real-time.
    - HUC 14010001 Colorado Headwaters Colorado: Three additional upstream gages were specified for the observed natural flows. OWF removed the upstream tributary gages

from the analysis per DWR direction so the gage sets are now the same in the observed and forecast period.
    - HUC 14020002 Upper Gunnison Colorado: The Gunnison River gage changes between the observed and forecast period.
    - HUC 14050001 Upper Yampa: Gage 09246400 was replaced with gage 09246200 so the gage sets are now the same in the observed and forecast period.
- The NRCS AWDB service returns forecast values with mixed unit codes – some are ac-ft and some are kac-ft – although the forecast values do not change order-of-magnitude with the unit changes. After e-mails with the NRCS, OWF is assuming all forecast values are kac-ft regardless of the unit code returned. The NRCS intends to fix the unit codes being returned by the web service.
- Multiple stations did not return forecast data.
    - 09246400: Gage was replaced with 09246200 ELKHEAD CREEK ABOVE LONG GULCH.
    - 06710500: Gage was replaced with 06710385 BEAR CREEK ABV EVERGREEN.

Reservoir Storage

- Two reservoirs are not included in the NRCS AWDB service. Data need to be obtained from the State of Colorado data sources. The ColoradoWaterSMS data service fails for a start date before 2000.
    - LONRESCO LONG HOLLOW RESERVOIR: Reservoir began filling in 2014. Elevation data begin in 2014 but storage data are not available until February 2015.
    - BKIRESCO BUCKEYE RESERVOIR: Although the reservoir was built many years ago, HydroBase data begin in 1992 and SMS data begin in 2007. DWR is investigating StateMod as a potential source for pre-1992 data. The Colorado SWSI Automation Tool does not currently read StateMod data. DWR can add manual overrides to specify the data or a future tool enhancement could include adding StateMod as a data source. For now, the reservoir was removed from the analysis.
- Multiple reservoirs came on-line after 1970 based on the available storage data. The period between the start of the historical period and the start of the storage data are filled with zero values.
    - 16016025 SPINNEY MOUNTAIN RESERVOIR: Data start 1981-10
    - 07007090 PUEBLO RESERVOIR: Data start 1973-12
    - 07007100 TRINIDAD LAKE: Data start 1977-08
    - 09041395 WOLFORD MOUNTAIN RESERVOIR: Data start 1995-06
    - 09125800 SILVER JACK RESERVOIR: Data start 1973-07
    - 09116500 VOUGA RESERVOIR NEAR DOYLEVILLE: Data start 1997-10
    - 09147022 RIDGEWAY RESERVOIR: Data start 1986-10
    - MPHC2000 MCPHEE RESERVOIR: Data start 1984-03
    - 09237495 STAGECOACH RESERVOIR NR OAK CREEK: Data start 1988-10
    - YAMRESCO YAMCOLO RESERVOIR: Data start 1980-10
    - LONRESCO LONG HOLLOW RESERVOIR: Data start 2015-02
- Based on a visual assessment of the storage data, multiple reservoirs have undergone changes in operations during the historical period and/or were filling during the beginning of the historical period. No action was taken – these issues are noted for the record.
    - 06016160 JACKSON LAKE RESERVOIR: Apparent operations change in 1990.
    - 07007110 TURQUOISE LAKE: Reservoir was filling in the 70s?
    - 07007120 TWIN LAKES RESERVOIR: Operations change in 1983?

  - 07007070 MEREDITH RESERVOIR: Operations change in 1982
  - 07007010 ADOBE CREEK RESERVOIR: Operations change in 1981?
  - 09009100 PAONIA RESERVOIR: Change in operations ~1980?
  - MPHC2000 MCPHEE RESERVOIR: Reservoir was filling until 1986?
  - 09237495 STAGECOACH RESERVOIR NR OAK CREEK: Reservoir was filling until 1989?
  - YAMRESCO YAMCOLO RESERVOIR: Reservoir was filling until 1981?
- Multiple reservoirs have missing data after the point at which they began storing water. These data values can be filled using linear interpolation or historical average monthly data values for a complete dataset.
  - 06016280 STANDLEY RESERVOIR: Missing WY2002
  - 06016260 BUTTONROCK (RALPH PRICE) RESERVOIR: Missing 1975-10 to 1982-09 and 1991-10 to 2005-10 plus other sporadic points
  - 06016040 BOYD LAKE: Missing a few data points
  - 06016180 LAKE LOVELAND RESERVOIR: Missing a few data points
  - 06016190 LONE TREE RESERVOIR: Missing a few data points
  - 06016200 MARIANO RESERVOIR: Missing a few data points
  - 08008150 SANTA MARIA RESERVOIR: Missing WY 1976
  - MTNRESCO MOUNTAIN HOME: Multiple missing periods (mostly short)
  - 09009330 FRUITLAND RESERVOIR: Missing data 1991-1993
  - 09009340 CRAWFORD RESERVOIR: Missing data 1991-1993
  - 09125800 SILVER JACK RESERVOIR: Sporadic missing data until 1987
  - 09009170 GROUNDHOG RESERVOIR: Sporadic missing
- For HUC 10190012, Jackson Lake Reservoir was used with station ID 06016160. The name was ambiguous but station selection was confirmed using NRCS station metadata.
- After automated filling, only one missing value remained for Standley Reservoir for 2015-02.

Appendix E – Current Water Year Data Issues

During the development of the Colorado SWSI Automation Tool, the current water year data were reviewed by OWF and the issues are documented herein along with the implemented solutions. Unresolved issues are noted using red text.

- The Cucharas Reservoir has been decommissioned and is no longer storing water. In Step 25 FillDataAuto, the storage data for Cucharas Reservoir are filled with zeroes through the current month.
- Mountain Home Reservoir storage data were missing from the NRCS AWDB web service beginning in February 2015, which prevented results from being computed for HUC 13010002 Alamosa-Trinchera and for the Rio Grande basin. The data source was switched to ColoradoWaterSMS and ColoradWaterHBGuest.
- The remaining missing values are documented in **Table 14**. DWR should consider specifying manual overrides to fill these values.

Table 14. Missing Data Values that Require Overrides

Time Series Alias	Station ID	Station Name	Date
07124500-ForecastedNaturalFlow-Month	07124500	PURGATOIRE RIVER AT TRINIDAD	2015-03
06016280-ReservoirStorage-Month	06016280	STANDLEY RESERVOIR	2015-02
07124500-ForecastedNaturalFlow-Month	07124500	PURGATOIRE RIVER AT TRINIDAD	2015-02
07124500-ForecastedNaturalFlow-Month	07124500	PURGATOIRE RIVER AT TRINIDAD	2015-01
06719505-NaturalFlow-Month	06719505	CLEAR CREEK AT GOLDEN	2014-08

Appendix F – Recent Period Data Issues

During the development of the Colorado SWSI Automation Tool, the recent period data were reviewed by OWF and the issues are documented herein along with the implemented solutions. Unresolved issues are noted using red text.

- To avoid a burden being placed on DWR to fill a large number of missing values in the recent period, OWF implemented automated filling for the natural flows and the reservoir storage data through the end of the recent period. If desired, DWR can supply manual overrides to fill data in the recent period (see Table 14).