USER'S GUIDE

for the

Catawba-Wateree River Basin

CHEOPS™ Model

December 2014

Developed by:
HDR Engineering, Inc.

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CHEOPS USER'S GUIDE

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Section 1

Purpose and Definition

1.1 Purpose

HDR, Inc. (HDR) created the Computer Hydro-Electric Operations and Planning Software (CHEOPS) as an easy-to-use hydropower system simulation model for evaluating a wide range of physical changes (e.g., turbine upgrades) and operational constraints (e.g., minimum flows) on single- and multiple-development reservoir systems. One of the many strengths of the CHEOPS model is the degree of customization each individual model can contain. The model is tailored to meet the demands and requirements of the particular system being modeled. The unique CHEOPS program architecture provides a platform for investigating each project-specific feature under scrutiny.

CHEOPS is designed for long-term analysis of the effects of operational and physical changes within the modeled system. For production use, the CHEOPS model output should be reviewed on a monthly and annual basis where trends, based on changes to a system's physical and operational constraints, can be monitored. The detailed modeled output should be used primarily as a "check" that the model is scheduling the system in a reasonably representative manner.

A clear understanding of the model's design focus can help to avoid any misuse of the CHEOPS model. The model was not created as a real-time scheduling model. As stated earlier, CHEOPS should be used for long-term analyses. It is not designed to answer questions like "How should we schedule the system over the next 24-48 hours?" Rather, a more appropriate question might be "How much will it cost annually, on average, if we operate with an additional 200 cfs bypass flow at one of the plants in the system?"

1.2 System Requirements

Computer requirements, and the subsequent run times, vary according to the complexity of the model, principally involving the number of plants in the system. The CHEOPS model considers water control structures in the system (dam, diversion, gate structure, etc.) as a "plant." As with any mathematically and computationally intensive software, performance is directly related to

the processor speed and the amount of available memory (RAM) of the computer performing the calculations. In addition to the speed of the processor and quantity of RAM memory, the speed of the hard drive is important because the CHEOPS model outputs data in the form of text files and databases. Output to text files can be a time-consuming task.

The CHEOPS model is developed on computers running 2.2 GHz dual core processors with 16 Gigabytes (GB) of RAM memory and a 64-bit Windows operating system. These computers can run one year of a one-plant model in less than 2 seconds, depending on the complexity of the scenario and the hydrologic year that is chosen. As the system becomes increasingly constrained by both operational and hydrologic constraints, the model run-times can increase, as the model must check and perform more calculations.

The user needs a hard drive with approximately 20 GB of available capacity. The CHEOPS model uses a fairly small amount of space, less than 50 MB, but the detailed (15-minute) output can be quite large. One detailed output file requires approximately 3 to 4 MB of space for each plant for each year.

In addition to hardware, the user needs to have a copy of Microsoft Excel for Microsoft Office 2007 or later to view the summarized CHEOPS output data. Microsoft Office Access 2003 or later is required to edit the withdrawal and return node features.

1.2.1 Basic Hardware Requirements

- IBM Pentium PC or compatible computer
- 1 GB of RAM
- CD-ROM Drive (Depending upon installation type)
- VGA color monitor with 800 x 600 resolution (1024 x 768 is highly recommended)
- Microsoft Windows-compatible printer
- Microsoft-compatible mouse
- Hard disk space requirements vary depending on amount of detailed results stored. Approximately 3 to 4 MB are used per plant for each year of detailed output.

1.2.2 Basic Software Requirements

- Microsoft Windows XP or later
- Microsoft Excel for Microsoft Excel 2007 or later
- Microsoft .Net Framework 3.5 or later

1.3 Terms and Definitions

- **Accretion Flows** – The incremental flow between two plants, also known as local inflow.
- **Acre-ft** – A measure of volume – 1 acre-ft = 1 acre of water 1 foot deep (43,560 cubic feet).
- **Alternate Spillway Curve** – A curve that defines the elevation versus flow capacity relationship of a secondary spillway.
- **Basin** – The geographic area that conveys water to the reservoir. Basins do not include areas that convey water first to an upstream reservoir.
- **Bypass Flows** – Bypass flows are the flows that are required 24 hours a day and are not released through a powerhouse.
- **Bypass Flow Destination** – The ultimate destination for bypass flows, either returning at a downstream plant, or leaving the system altogether.
- **cfs** – A measure of flow – cubic feet per second.
- **CHEOPS™** – Computer Hydro-Electric Operations and Planning Software.
- **Component** – A named data-set that is a building block for a condition.
- **Condition** – The main building block of a scenario containing the data used by the model to simulate the system.
- **Constraint** – A requirement that must be met by the model.
- **Delinked** – Plants do not use coordinated operations of receiving support from other plants and providing support to other reservoirs to minimize spill or minimum elevation violations
  - **"Delinked – Owner"** – A plant will not be linked to other plants identified as being owned by the same licensee. If a plant is "Delinked – Owner" is it automatically delinked from all other plants in the system.
  - **"Delinked – System"** – A plant will not be linked to any other plant in the system owned by another licensee. The plant is still linked (provides and gets support) from plants operated by the same owner.

- **Dispatch** – A portion of CHEOPS that determines, given performance data for a specific plant, the most efficient way to divide flow among a plant's units.
- **Elevation Carry-Over** – Determines whether end-of-year elevations are to be used as the reservoir elevation starting point for the next year in a multi-year run.
- **Forecast Set-Up** – Controls the estimation of the future inflows into the projects.
  - **Accuracy** – Represents artificial error in the model's ability to look forward in time.
  - **Days** – Represents how many days the model looks forward to anticipate inflows.
- **Gate Leakage** – The amount of water that leaks through the wicket gates for each unit when the gates are closed.
- **Generator** – The device that converts rotating mechanical energy into electric potential.
- **Generator Efficiency Curves** – Curves that define the generator output versus efficiency relationship.
- **Gross Head** – The difference between the headwater elevation and the tailwater elevation.
- **Head** – A vertical height of water that represents potential energy.
- **Headloss** – The amount of energy (expressed in terms of feet of head) that is lost (to friction, etc.) between the headwater (reservoir/forebay/intake) and the tailwater.
- **High Inflow Protocol** – A system constraint which defines plant specific operation during high inflow periods as described by the requirements of the protocol file. This requires an additional excel file to operate.
- **Hydrology Set** – Identifies the hydrology file containing hydrology data.
- **Inflow** – The flow entering a plant's reservoir.
- **Level** – Reservoir surface elevation.
- **Level Fluctuation** – The change in reservoir surface elevation.
- **Loadshape** – The daily schedule of relative power pricing and the hour durations of each price in the peak, secondary-peak (or shoulder-peak), and off-peak periods.
- **Local Inflow** – The incremental inflow between two plants (also known as Accretion Flows).
- **Low Inflow Protocol** – A system constraint which defines plant specific operation during low inflow periods as described by the requirements of the protocol file. This requires an additional excel file to operate.
- **Low-Level Outlet Curve** – A curve that defines the elevation versus flow capacity relationship of an outlet, sluiceway, or other conveyance for passing flows downstream.

- **Maintenance Schedule** – The scheduled removal of a unit from service for repair or upgrade.
- **Maximum Flows** – A constraint indicating the maximum flow of water that must be released from the plant at all times of the day. This constraint is described by flow values that can vary based on time of day and day of year.
- **Maximum Flow from Elevation** – A constraint indicating the maximum flow of water that must be released from the plant at all times of the day. This constraint is described by flow values that can vary based on reservoir elevation.
- **Metering Loss** – A percent reduction to the gross generation calculated by the model accounting for losses, outages, and station service.
- **Minimum Daily Average Flow** – A constraint indicating the total volume of water that must be released from a plant in a day, expressed as a flow.
- **Minimum Elevations** – The lowest allowable reservoir elevation. At elevations below the Minimum, the model will generally set the daily release to 0 cfs.
- **Minimum Flow Unit** – A small unit that is installed specifically to generate power from the minimum instantaneous flow or bypass flows. Typically this unit is separate from the powerhouse and, therefore, requires handling outside of the core scheduling routines.
- **Minimum Instantaneous Flow** – A constraint indicating the minimum flow of water that must be released from a plant at all times of the day. This flow is available for generation.
- **Minimum Powerhouse Flow** – A constraint indicating the lowest flow that the powerhouse will use for generation.
- **Monthly Evaporation** – Defines the average daily evaporation coefficient in ft/acre on a monthly basis.
- **Natural Inflow** – The total unregulated flow at a particular point in the system. This is the flow the location would have received if there were no upstream plants, which is equal to the sum of all the upstream accretion inflows.
- **Net Head** – A measure of potential energy. The net head represents the effective head under which the unit operates. The net head is the difference between the gross head and the headloss.
- **Node** – Geographically located point of withdrawal or return flow.
- **Plant Operation Type** – A reference to the manner in which water is scheduled through a plant. At this time, there are nine operating types:

- **Non-Generating** – A storage plant, without a powerhouse, that releases flows to follow the target elevations.
- **Strictly Peaking** – A plant that schedules turbine discharges to maximize peak generation by scheduling water in highest value periods of day. Can instantaneously (in a 15-minute time increment) change load.
- **Peaking with Ramp Rates** – A peaking plant where the water release still closely follows the load shape (plant will peak); however, the plant is constrained by ramping rates.
- **Re-Regulating** – A plant designed to regulate peaked releases from upstream plants into smooth releases. This plant releases constant outflows for the whole day. Re-regulating plants may or may not be constrained by ramping rates. If constrained, they are then required to ramp between days.
- **Fill and Spill** – A plant that peaks with the loadshape, but gives priority to the upstream plant and will spill in order for the upstream plant to follow the loadshape as closely as possible.
- **Run-of-River (Daily Avg)** – A plant where inflows are generally equal to outflows on a daily average basis. The plant can use storage to maintain minimum instantaneous flows, and will increase reservoir elevation up to the spill elevation to minimize spill and use the volume for generation on subsequent days.
- **Run-of-River (Inst)** – A plant where inflows are equal to outflows on an instantaneous basis. Inflows below usable turbine flows are spilled to maintain elevation.

■ **Powerhouse Setup Condition** – A condition specifying the plant configuration with which the model will calculate generated power.

■ **Powerhouse Weekend Ops** – A condition identifying months where powerhouse operations are generally not desirable.

■ **Recreation Flows** – A constraint indicating the minimum flow of water that must be released from the reservoir either through the powerhouse or non-generating conveyance at specified times of the day and day of the week.

■ **Release** – Water released by a plant.

■ **Reservoir** – The water retained by a dam. Also referred to as headwater, storage, forebay, pool, or headpond.

- **Reservoir Area Curve** – A curve that defines a reservoir surface area in acres at various surface elevations. This is required if evaporation is to be modeled.
- **Reservoir Level Fluctuation Limits** – A constraint specifying the number of feet allowed between the maximum elevation and minimum elevation achieved each day.
- **Reservoir Level Fluctuation Rates** – A constraint specifying the maximum allowable rate of elevation change for the reservoir.
- **Reservoir Storage Curve** – A curve that defines a reservoir's volume in acre-ft at various surface elevations.
- **Scenario** – A collection of settings that constitutes a CHEOPS model run. Output data for a run are referenced by the scenario name.
- **Setting** – A collection of conditions that form the building blocks of a scenario. A setting is made up of conditions.
- **Spill** – Water passed over a spillway without going through the units.
- **Spillway Curve** – A curve that defines the maximum spill capacity in cfs for the spillway at various reservoir elevations.
- **Spill Elevations** – The reservoir elevation at which the plant's reservoir spills. The model will spill (given sufficient spillway capacity) to avoid going above this elevation.
- **Stage** – The river surface elevation in feet based on a local datum.
- **Tailwater Curve** – A curve that defines the tailwater elevation over the range of powerhouse/total project flows.
- **Tailwater Elevation** – The elevation where all energy from the water passing the turbine has been extracted. (Can be the turbine centerline or the river surface elevation at the point of powerhouse release.)
- **Target Elevations** – End-of-day elevations that the model tries to achieve.
- **Turbine** – A rotating machine that recovers mechanical energy from falling water.
- **Turbine Efficiency Curves** – Curves that define the flow versus efficiency relationship. The Turbine Efficiency Curves component calls for a Turbine Efficiency Curve at five net heads spanning the operating range of the powerhouse.
- **Unit** – A term referring to the combined turbine-generator machine.
- **Water Returns** – Water that is returned to a reservoir after being withdrawn.

- **Water Withdrawals** – Water that is withdrawn from the reservoir, not available for energy generation, that is lost from the system. Withdrawals can be either positive or negative. If positive, it is generally entered as a return.
- **Weekly Drawdown** – A decrease in reservoir elevation over a specified number of days.

Section 2
Model Architecture

CHEOPS is a Microsoft Windows-based software that utilizes a Microsoft Access database and a front-end Visual Studio application. All output data is contained in text files and can be viewed using Microsoft Excel workbooks created for processing and displaying the output data.

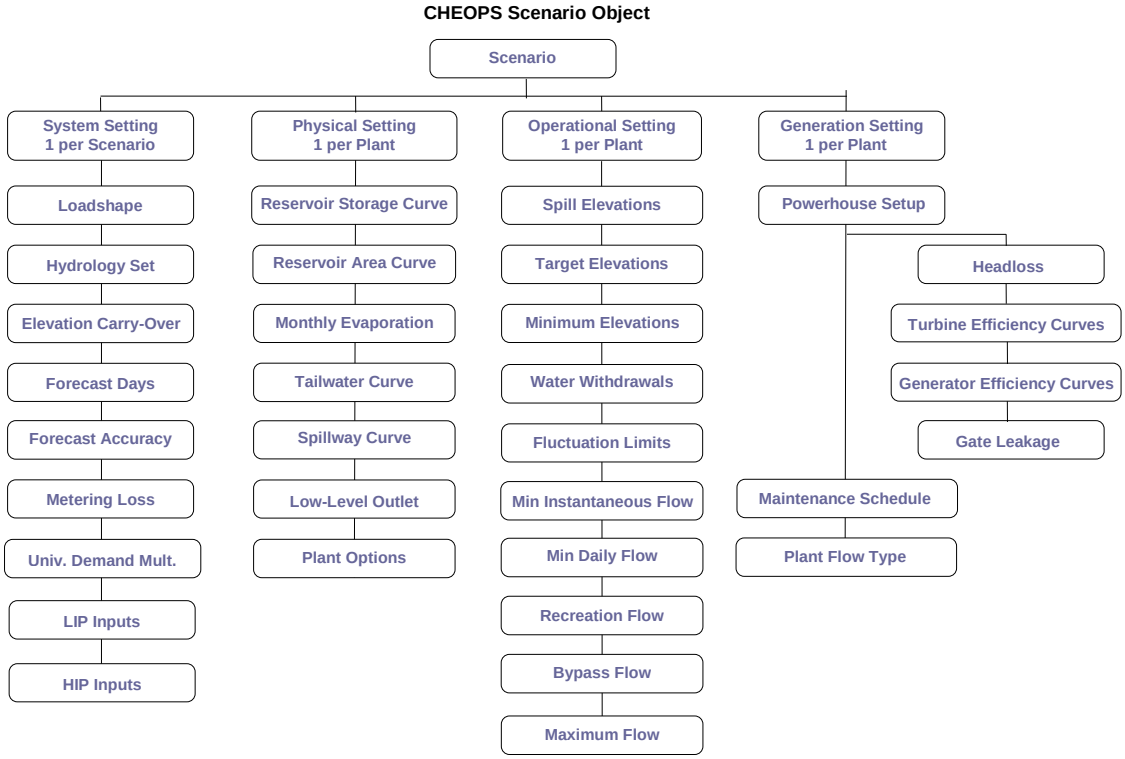
For each CHEOPS model, HDR assembles the model from a library of standard modules based on the unique physical and operational characteristics of the river system or powerplant under consideration. Additional coding is performed to account for project-specific constraints, design parameters, and operational characteristics.

2.1 Concept Overview

2.1.1 Scenarios

Because of the large amount of data involved in defining a hydro system, the method of data storage and retrieval in the CHEOPS model is somewhat involved. A CHEOPS model run is called a Scenario. In other words, a Scenario is made up of a particular set of data that defines a combination of physical attributes and operational requirements that make up one specific system configuration. For example, the "Baseline" Scenario typically includes all the data that defines the current system. A Scenario is a collection of Settings. Each Scenario has a System Setting and three additional settings (Physical, Operational, and Generation) for each plant in the system. Each Setting is a collection of Conditions. The Conditions hold the actual input data that the model uses to simulate the system. A schematic of the CHEOPS Scenario Object is shown below in Figure 2-1. The remainder of Section 2.1 explains each of the settings and conditions.

FIGURE 2-1
GRAPHICAL REPRESENTATION OF THE CHEOPS SCENARIO OBJECT



2.1.2 System Setting

The System Setting consists of the Conditions that refer to data applicable to either each plant in the system, or unique data solely applicable to one plant in the system. For example, the System Setting includes the Loadshape Condition, which contains the data for daily pricing and period hourly duration data. The Loadshape Condition applies to the entire system. Each of the System Setting Conditions is discussed below.

2.1.2.1 Loadshape Condition

The Loadshape Condition includes the data for the daily period durations and the daily period pricing by each month. Each month the model allows the user to enter a weekday loadshape curve and a weekend loadshape curve.

The weekday curve has seven periods made up of three different types of periods. These three types are Peak, Secondary-Peak (or Shoulder-Peak), and Off-Peak. The user enters dollar values for Peak, Secondary-Peak, and Off-Peak generation in dollars per MWh.

The weekend is limited to only two types of periods: Peak and Off-Peak. The user enters values for weekend Peak generation and weekend Off-Peak generation in dollars per MWh.

The model uses the loadshape data to schedule the release of water throughout the day, prioritizing generation during peak periods.

2.1.2.2 Hydrology Set

The Hydrology Set Condition identifies which hydrology file is to be used with the scenario run. The hydrology file is a Microsoft Excel workbook in the model's \HydrologyFiles folder. It is formatted in a specific fashion, which must be retained if hydrology data is to be modified. Typically the hydrology file does not need to be modified. Specify the hydrology file to be used in the dropdown box and save the condition.

2.1.2.3 Elevation Carry-Over Condition

The Elevation Carry-Over Condition controls how to treat the end- and beginning-of-year elevations. The model begins the run on January 1 of the start year with each reservoir at its target elevation. If the run is a multi-year run, then the model can either start subsequent years with the reservoirs at the target elevations or at the end of previous year elevations.

When Elevation Carry-Over is selected (the check box is checked), the model will carry-over the end-of-year elevations to the next year, and thus will start the next year at an elevation that may be different from the target elevations. If Elevation Carry-Over is not selected (check box is not checked), the model will start each year with the reservoirs at their January 1 target elevations.

Carrying-over elevations can have a significant effect on the model results. If the user runs "dry" hydrology and the reservoirs are drawn down, the next year will have less generation as

the model refills the reservoirs. The reverse is true if the user is running "wet" hydrology. It is important to understand the potential impact of this Condition when making multi-year runs with the CHEOPS model.

2.1.2.4 Forecast Set-Up Condition

CHEOPS can simulate the owner's ability to forecast inflows to the system. The Forecast Set-Up Condition requires two inputs: a number of forecast days and an accuracy of the forecast. This Condition has limited use for analysis depending upon usable storage in the reservoirs; however, it can provide a very rough estimate of the sensitivity of the system configuration to inflow forecast ability.

The number of days is how many days the model looks ahead in the inflow file to calculate how much water the system is going to receive. Since the model has "perfect" forecasting as it looks at the actual inflow file, the accuracy setting allows the user to adjust the model's ability to accurately forecast. The model looks ahead the given number of days, adds up the inflows, multiplies those inflows by the entered accuracy value, then schedules releases based on this forecasted inflow volume. If the accuracy setting is not 100 percent (1.0), then the forecasted volume is not accurate. By running the model with 90 percent accuracy, and then running again at 110 percent accuracy, the user can simulate operations where the owner has an ability to forecast inflows plus or minus 10 percent.

2.1.2.5 Metering Loss

Metering loss is a percent reduction to the gross generation calculated by the model. This value accounts for line loss and transformer loss between the generator leads and the revenue meter. Additionally, station service and a general reduction for unscheduled outage factor can be included for the model to output a generation value net of losses, outages, and station service.

2.1.2.6 High Inflow Protocol

The High Inflow Protocol Input identifies which High Inflow Protocol (HIP) input file is to be used with the scenario run. The HIP input file is a Microsoft Excel workbook in the model's \HydrologyFiles folder. It is formatted in a specific fashion, which must be retained if HIP data is to be modified. Specify the HIP input file to be used in the dropdown box and save the condition.

If the Low Inflow Protocol has not been invoked and a High Inflow Protocol (HIP) file is selected as part of the scenario System Settings, then the model will implement the following flow protocol:

For the period defined in the HIP excel input file, if the November to January median flow for the accretions to Plant 7 are at or above 105 percent of the long-term November to January median, then the model will increase the minimum flow at Plant 7 to the flow defined in the HIP excel input file. If the February median accretion flow is below the February long-term median accretion flow, then the minimum flow requirement at Plant 7 would drop back to the flow defined in the HIP excel input file on the date defined in the excel input file.

2.1.2.7 Low Inflow Protocol

The Low Inflow Protocol Input identifies which Low Inflow Protocol (LIP) input file is to be used with the scenario run. The LIP input file is a Microsoft Excel workbook in the model's \HydrologyFiles folder. It is formatted in a specific fashion, described in Appendix A, which must be retained if LIP data is to be modified. Specify the LIP input file to be used in the dropdown box and save the condition.

If a Low Inflow Protocol (LIP) file is selected as part of the scenario System Settings the model will implement the protocol as defined in the specified LIP Excel Input sheet. The LIP Input spreadsheet titled 'Data' allows the user to enter data in yellow cells for critical elevations and critical flows, then LIP Stage definitions (the triggers which signal when to enter into a specific stage), then Actions for the Licensee and Owners (owners of water supply intakes). The

reductions of consumptive use can be specified by node categories since different categories will have varying reduction requirements per the Comprehensive Relicensing Agreement.

2.1.3 Physical Settings

Each Scenario contains a unique Physical Setting for each plant. The Physical Setting contains the Conditions that can be categorized as physical attributes of the system. The Conditions included in a Physical Setting are described below. It is important that all elevation data for all plants be based on the same datum (mean sea level, for example) as the model compares tailwater stage and downstream plant headpond elevations in the detailed gross head computations.

2.1.3.1 Reservoir Storage Curve Condition

The Reservoir Storage Curve is the reservoir elevation versus volume curve. The elevations are in units of "ft" and the volumes are in "acre-ft." The model uses this curve to calculate elevations throughout the day based on inflows and model-determined releases.

Note: The user must ensure that the Reservoir Storage Curve exceeds the Spill Elevation so that the model has the information to accurately calculate reservoir elevations during times of spill.

2.1.3.2 Reservoir Area Curve Condition

The Reservoir Area Curve is similar to the Reservoir Storage Curve except instead of elevation versus volume, this curve is elevation versus surface area. The units for elevation are "ft" while the units for surface area are "acres." The model uses this data for evaporation-loss calculations each day and is not required unless evaporation data is entered and set as a condition.

2.1.3.3 Monthly Evaporation Condition

The Monthly Evaporation Condition contains daily evaporation coefficients for the plant by month (one coefficient per month). The coefficient's units are "ft/acre." To calculate evaporation, the model multiplies each day's surface area by the month's coefficient to get an evaporation volume for the day in "acre-ft." The evaporation volume is converted into a flow for the day and is removed from the reservoir evenly throughout the day. Use of this condition requires the Reservoir Area Curve to be included in the Physical Settings for the plant.

2.1.3.4 Tailwater Curve Condition

The Tailwater Curve relates the tailwater elevation to the river flow. The elevation is in units of "ft" while the river flow is in "cfs." The model uses this data to calculate a tailwater elevation from the instantaneous river flow. This tailwater elevation is subtracted from the reservoir elevation to compute the gross head driving the unit. If the downstream plant's reservoir elevation is higher than the calculated tailwater elevation, the model uses that downstream reservoir elevation as the tailwater elevation in the gross head calculations.

2.1.3.5 Spillway Curve Condition

The Spillway Curve contains the data relating reservoir elevation and spillway capacity. The elevation is in units of "ft" and the spillway capacity is in units of "cfs." This data allows the model to determine the maximum amount of water that can be spilled at the current reservoir elevation. If the dam has an inflatable crest, this curve should be the maximum capacity of the spillway with crest lowered. For a dam with gated spillways, enter the data set with all gates fully open. The model uses the spill elevation to determine when to spill, and this curve specifies the capacity of the spillway at that elevation.

2.1.3.6 Low-Level Outlet Curve Condition

The Low-Level Outlet Curve condition provides the opportunity to enter an outlet, sluiceway, or other conveyance to pass flows downstream. The elevation is in units of "ft" and the capacity is

in units of "cfs." This curve has two purposes depending upon the plant operation type. For non-generating plants, the Low-Level Outlet Curve condition will be used to compute the maximum outflow capacity for the day from the reservoir based on the starting elevation. If no Low-Level Outlet is specified for a non-generating plant, then the outlet capacity is set to be unlimited (1,000,000 cfs). For other plant operating types, the Low-Level Outlet Curve is used in conjunction with the Spillway Curve to compute total spill capacity over the dam.

2.1.3.7 Plant Options Condition

The Plant Options Condition contains four pieces of information about the individual plant. These values are: Minimum Powerhouse Flow; Plant Operation Type; two Delinked options: Delinked – Owner and Delinked – System; and Full Pond Elevation.

The Minimum Powerhouse Flow is the lowest flow that the powerhouse will use for generation. This data allows the user to control the model releases that result in rough unit operation (only at the low end). Without this data the model will use the full performance range of the units as entered in the turbine efficiency curves.

The Plant Operation Type is how the CHEOPS model classifies and operates the plant. There are nine plant operation types: Non-Generating, Strictly Peaking, Peaking with Ramp Rates, Re-Regulating, Fill and Spill, Run-of-River (Daily Average), and Run-of-River (Instantaneous)

- A *Non-Generating Plant* is a plant that does not have a powerhouse but has the ability to control releases.
- A *Strictly Peaking Plant* is a plant that can instantaneously peak from no release to a maximum release. The model schedules powerhouse releases to generate as much as possible during the peak period, followed by secondary-peak and then the off-peak periods. This plant type can be scheduled to have two peak periods in the day depending upon loadshape input.
- A *Peaking with Ramp Rates Plant* prioritizes its release in the peak periods but it is constrained by ramping rates. This plant will not double peak but will ramp up to the high daily release, remain at constant release, and then ramp back down to the off-peak release. This type of plant can handle ramping rates based on stage (feet/time) or flow (flow/time).

Note: This Plant Operation Type must be selected if the user is investigating ramping rates at a particular plant. It is not enough to simply enter in some ramping rates. Both constraints (Plant Operating Type set to Peaking with Ramp Rates, and a Ramping Rate constraint imposed) must be entered for the ramping rates to be used.

- A *Re-Regulating Plant* is scheduled for a constant release for the entire day, ramps to the next day's release, and releases constant flows again. This type of plant is usually found downstream from a peaking plant and is frequently the last plant in the system, with the goal of smoothing out peaked powerhouse flows. This Plant Operating Type can use ramping rates to determine how quickly the plant is allowed to change from one flow to another. If no ramping rate is specified, the plant will step from one day's daily average/continuous flow to the next day's flow.
- A *Fill and Spill Plant* is scheduled like a strictly peaking plant except that it is expected to spill. This type of plant is usually found downstream from a much larger plant with little intervening storage. The fill and spill plant turbine discharge capacity is usually undersized. Use of this plant type triggers the model to prioritize aggressive operation of the upstream plant rather than reschedule the high capacity plant to avoid spill at the downstream fill and spill plant.
- A *Pure Run-of-River (Daily Average) Plant* is a plant where inflows are generally equal to outflows on a daily average basis. The plant can use storage to maintain minimum instantaneous flows, and will increase reservoir elevation up to the spill elevation to minimize spill and use the volume for generation on subsequent days.
- A *Pure Run-of-River (Instantaneous) Plant* releases its inflow on a 15-minute basis. This plant releases the maximum of its capacity or inflow and spills the excess.

Two "Delinked" options are provided in the model. This condition is for testing or measuring the impact of coordinated operations between the various plants and licensees in the hydro system. Delinking is the process of removing the plant from coordinated operations within the hydro system. Upstream plants provide downstream support to ensure that downstream plant required outflows are being met through accretions, usable storage, and the current plant's discharge. During the detailed scheduling process, if downstream plants have spill or a minimum elevation violation, the upstream plant's detailed schedule may be modified to rectify

the violation. By delinking a plant, it neither receives support nor provides support to other plants.

- "Delinked – Owner" specifies that a plant will not be linked to other plants identified as being owned by the same licensee. If a plant is "Delinked – Owner" is it automatically delinked from all other plants in the system.
- "Delinked – System" specifies that a plant will not be linked to any other plant in the system owned by another licensee. The plant is still linked (provides and gets support) from plants operated by the same owner.

The Full Pond Elevation specifies the maximum reservoir elevation used in storage calculations. This value, in the same datum as the reservoir's storage-elevation curve, is used determine the critical elevation and the LIP step-down minimum elevation, if applicable.

2.1.4 Operation Settings

Similar to the Physical Settings, the Operation Settings are plant specific. Each scenario contains one Operation Setting for each plant. The Operation Setting contains conditions that control how the plant is operated: reservoir elevation constraints and required flow releases. A complete breakdown of the Operation Settings is described below. All elevations are in units of "ft" and should be based on the same datum as the Physical Settings.

2.1.4.1 Spill Elevation Condition

The Spill Elevation is the elevation at which the plant begins to spill to avoid going above. The elevation can relate to a variety of physical situations (spillway crest, partial gate coverage, top of normal operating pool, etc.), but it represents the elevation at which the model will begin to spill. Under a strictly peaking plant, when the model calculates an elevation above this elevation, the model will calculate spill as well. Under a strictly peaking plant, the model's logic attempts to reduce or eliminate occurrences when the reservoir elevation exceeds the spill elevation. For plants with gates that control the spillway release, the Spill Elevation should be the elevation at which operators start spilling to prevent overtopping. For plants with uncontrolled spillway crests, the Spill Elevation is the spillway crest elevation. Spill Elevations can vary through the year.

Note: The user must ensure that the Reservoir Storage Curve (Section 2.1.3.1) exceeds the Spill Elevation so that the model has the information to accurately calculate reservoir elevations during times of spill.

2.1.4.2 Target Elevations Condition

The Target Elevations are the end-of-day elevations which the model tries to return the reservoir to at the end of the day. These elevations can change each day. This condition allows the user to control seasonal storage. By changing the reservoir Target Elevations the model will either store or release water at a rate slower or faster than inflow. The Target Elevations should be less than the Spill Elevations and greater than the Minimum Elevations.

2.1.4.3 Minimum Elevations Condition

The Minimum Elevation is the reservoir elevation where discretionary discharges cease to occur. The elevation can be determined from regulations or by a physical limit (lowest available outlet invert). The model will operate to eliminate occurrences when the reservoir elevation dips below this elevation. This Minimum Elevation should be lower than the Spill Elevations and the Target Elevations. Once the reservoir reaches this elevation, discretionary discharges are ceased, but bypass flows, evaporation, withdrawals, leakage, and negative accretions can cause the reservoir to go below this elevation.

2.1.4.4 Water Withdrawals Condition

The Water Withdrawals Condition allows the user to model water removal and return that represents consumptive uses and returns such as irrigation and municipal water supply. The input condition is the filename of a specifically-formatted Excel workbook which contains a table with the nodes of the plant/basin currently being edited. Nodes are shown in columns across the top of the table, and the date values are on rows on the left of the table. At the intersection is a flow value for that period in cfs. The node setup information in the database is used by the model to determine if the flow is a Withdrawal or a Return. The second digit of the node name indicates this same information, where “W” indicates a withdrawal node, and “R” indicates a flow return node.

2.1.4.5 Fluctuation Limits Condition

Fluctuation Limits are the maximum allowable change in reservoir surface elevation, from maximum elevation to minimum elevation, within a single day. In other words, it defines the maximum difference allowed between the maximum elevation achieved on a particular day and the minimum elevation achieved that day.

In addition to setting the maximum fluctuation for the day, the user can specify if the limits are "Hard" limits. Hard Fluctuation Limits reset the Spill Elevations and Minimum Elevations based on the Target Elevation and the Fluctuation Limits set around this target elevation. If the user desires Hard limits then the user enters a percentage of the Fluctuation Limit that is above the Target Elevation and the model calculates the percentage that is below the Target Elevation. An example is below:

> If the Target, Spill, and Minimum Elevations are 1,500 ft, 1,520 ft, and 1,400 ft, respectively; and Hard Fluctuation Limit of 5 feet is set with 60 percent above the Target Elevation; then for that day, the Target Elevation is still 1,500 ft, but the Spill Elevation is recalculated to be 1,503 ft, and the Minimum Elevation is 1,498 ft.

This type of control allows the user to force the model to follow Target Elevations closer. The difference between *Hard* Level Fluctuation Limits and *regular* Level Fluctuation Limits ("Hard" is not checked) is that the Hard Fluctuation Limits will force the model to spill if the upper limit is exceeded. The cause of this spill may be that another constraint or unusual hydrologic situation is forcing the reservoir to go above the defined Hard limit.

2.1.4.6 Minimum Instantaneous Flow Condition

Minimum Instantaneous Flows are flows that must be released either through the low-level outlet or through the powerhouse, 24 hours a day. The model will meet this requirement before scheduling any excess water. The user can set this constraint with an Or Inflow option. The Or Inflow option sets the Minimum Instantaneous Flow equal to the lesser of the user-defined flow or the total inflow into the plant. The total inflow is the sum of the discharges from the upstream plant(s) plus the incremental accretion above this plant.

2.1.4.7 Minimum Daily Average Flow Condition

The Minimum Daily Flow Condition represents the minimum volume, defined as a daily average flow (cfs), that the plant must release for the day. The user can set this constraint to an Or Inflow option. The Or Inflow option sets the Minimum Daily Flow equal to the lesser of the user-defined flow or the sum of upstream plant discharges plus incremental accretions to the plant. The minimum daily volume may not be discharged as a continuous flow throughout the day. Depending upon the plant type, the scheduling logic may discharge most or all of the water during peak demand periods at higher flow rates, but the daily average flow from the powerhouse will equal the specified flow requirement.

2.1.4.8 Recreation Flows Condition

The Recreation Flows Condition is used to input plant output requirements that change within a day, and vary from the standard requirement from the plant. For each calendar day of the year, a different requirement can be set by day of the week that requires a specific flow between a start hour and an ending hour. Additionally, the required flow can be specified as being routed through the powerhouse or not. This condition's components are:

- Calendar Day
- Day of Week (in numeric form, where 0=all days of week, 1=Sunday, 2=Monday…)
- Flow (cfs)
- Start Hour (0 to 24)
- End Hour (0 to 24)
- Use Plant Discharge (check box)

For each change in Calendar Day, each day of the week may be given a specific flow requirement. If there is no specific flow requirement for a block of days or from a specific day through the end of the year, enter 0 as the flow requirement to cease the Recreation Flows. Entering a Start Hour that is greater than the End Hour will cause the requirement to be scheduled throughout the night, with the first day being the first day on or after the specified Calendar Day and on the day of week specified.

Checking the Use Plant Discharge check box will schedule the flow through the powerhouse at the optimal combination of units for that flow rate. If the flow requirement is below the usable turbine flow, then the water is 'leaked' through the units without any generation. The model will not increase the flows to be usable for generation. Unchecking the Use Plant Discharge check box will result in the water being scheduled and accounted for as spill. It is presumed that low-level outlet, fish attraction, or spillway conveyance exists to pass this water over or through the dam.

2.1.4.9 Bypass Flows Condition

The Bypass Flows Condition represents flows that are released through the dam, bypassing the powerhouse, and not available for generation. These requirements may include items such as bypass reach flows, upstream/downstream fish passage/attraction water, sluice gate discharges, and dam leakage. Bypass Flows are not available for generation. These flows have units of "cfs" and the flow is released as a constant flow for the entire day. In addition to setting the Bypass Flows, the user sets a destination for where the flows will re-enter the system.

The user can define this constraint as Or Inflow. The Or Inflow option sets the bypass flow equal to the lesser of the user-defined flow or the inflow into the plant. The inflow is the sum of the upstream plant's release, bypass return flow, and the incremental accretion flows between the upstream plant and the current plant. Bypass flows can draw the reservoir below the minimum elevation.

2.1.4.10 Maximum Flows Condition

The Maximum Flows Condition allows the user to specify maximum discretionary instantaneous powerhouse discharges with a starting hour and ending hour. The requirement can change on a daily basis if desired. If the Start Hour is greater than the End Hour, then the requirement applies through the night. This condition's components are:

- Calendar Day
- Flow (cfs)
- Start Hour (0 to 24)
- End Hour (0 to 24)

During high flow periods, or other times when the reservoir has no available storage and inflows are high, there may be times when spill would occur when attempting to limit reservoir outflows. When spilling, the model will pass the spill through the powerhouse if there is available turbine capacity, potentially exceeding its maximum flow limitation. This condition limits powerhouse/discretionary diversion flows only, and does not account for other potential downstream river flow contributions from bypass flows or spill.

2.1.5 Generation Settings

Generation Settings are plant specific and contain the data necessary to simulate power generation. The data includes turbine performance, generator performance, headloss data, gate leakage, unit outages, low-level outlet generating units, and powerhouse operations rules. This data, combined with the physical and operational data, allows the model to calculate generation on a 15-minute schedule.

2.1.5.1 Powerhouse Setup Condition

The Powerhouse Setup Condition contains data describing each turbine-generator unit in the plant. The four components of this condition are Headloss, Turbine Efficiency Curves, Generator Efficiency Curves, and Gate Leakage.

- **Headloss Component** – The CHEOPS model allows two common headloss coefficients for the plant and an individual coefficient for each unit. When creating a new Powerhouse Setup, the Headloss component must be created first to specify the number of units in this configuration. The user inputs a unit-specific headloss coefficient and associates each unit with a common coefficient, which defaults to Common Headloss Coefficient 1 unless the user checks the Use Common HL2 check box. Headloss for each unit is calculated by multiplying the unit's common coefficient by the total flow for that common coefficient squared, added to the individual coefficient multiplied by the individual unit flow squared. The formula is included below:

$$H_i = \left(\sum_{j=1}^{n} F_j \right)^2 h_c + F_i^2 h_i$$

Where:

H_i is the unit headloss in feet

h_c is the common coefficient for the ith unit

h_i is the individual coefficient for the ith unit

F_i is the flow for the ith unit

j runs from 1 to n

n is the number of units that have the same common coefficient as the unit i

- **Turbine Efficiency Curves Component** – Turbine performance is entered by plant. During plant setup the performance data is assigned to a particular unit. Each turbine performance data set can be assigned to multiple units, so if the plant has three identical units, the performance data set is only entered once.

  The performance data is entered as flow versus efficiency at five separate net heads. These net heads must span the entire performance range with which the units will be subjected. The performance data must have a minimum of three data points (rows), indicating minimum operating flow, peak operating flow, and maximum operating flow. The same number of rows of flow/efficiency observation points must be entered for all of the Net Head data sets. Turbine performance data should be entered as the full range of turbine operation. It is not necessary to truncated data due to generator or auxiliary equipment limitations.

  If the turbine performance data is available as combined turbine-generator data, enter the data into the Turbine Efficiency Curves component and create a generator performance data condition with generator efficiencies of 100 percent (see Generator Efficiency Curves Component).

- **Generator Efficiency Curves Component** – The generator data, like the turbine data, is entered by plant and then associated with a unit. Similar to the Turbine Efficiency Curves Component, if the plant has three identical generators, the performance data need only be entered once. The generator performance data is generator output in megawatts (MW) versus generator efficiency.

The generator condition includes a maximum generator output. This value is the maximum generator output the model will allow, assuming that there is turbine capacity to meet this limit. This input allows the user to limit turbine-generator outputs if other auxiliary equipment cannot handle full generator output. The model will limit turbine-generator output based on the generator Max Generator Capacity value.

- **Gate Leakage Component** – Gate leakage is the amount of water that leaks through the wicket gates when the turbine is offline. The model leaks this amount of water when that unit is offline. For instance, if the powerhouse has three units, each with gate leakage of 15 cfs, and Units 1 and 2 are operating while Unit 3 is off-line, then only Unit 3 is leaking 15 cfs. When a unit is out for maintenance its gate leakage is set to be zero.

2.1.5.2 Maintenance Schedule Condition

The Maintenance Schedule provides the functionality to take a unit out of service for all or part of each year for a scenario run. With this Condition, the user can analyze the impacts of major unit rehabilitation. The entire powerhouse can be taken offline by entering “999” in the Units Out for Service location. To return all units or the powerhouse to full service, an in-service date with unit out value of “0” must be entered. The Maintenance Schedule allows the user to remove one unit from service at a time, multiple units simultaneously, or the entire powerhouse.

2.1.5.3 Plant Flow Type Condition

The Plant Flow Type condition allows the modeler to specify that a powerhouse should operate the turbines at the maximum gate setting as opposed to the best gate setting. Typical operations are to discharge flows at the most efficient operating point of the turbine, unless high flows or unusual circumstances exist which require operating above or below that point. For Run-of-River plant types, this setting is not utilized. For other plant operation types, specify TRUE (checked box) if the plant should generally be scheduled to operate at the best efficiency point. Leaving the box unchecked will result in more detailed scheduled operations occurring at the maximum gate setting for the turbine units. This tends to result in slightly more peak period generation.

2.2 Unit Dispatch

The model uses the Unit Dispatch to compute generation based on the user-provided Powerhouse Setup data. The purpose of the Unit Dispatch is to produce a plant generation matrix or lookup table where plant generation (MW) is plotted against gross head and total plant flow. The model will use this lookup table to calculate plant generation in MW every 15 minutes. The Output Lookup Table is only created once for each Powerhouse Setup Condition.

The first step of the process is to generate a Unit Dispatch Table so the model knows the best way to distribute flows between the units. This step is also referred to as producing the optimal unit dispatch solution. The Unit Dispatch logic begins with very small plant flows. The routines calculate the optimal unit dispatch for each small flow. The rough estimate of the individual unit distribution is fine-tuned using partial differential equations to arrive at an optimal distribution for the given flow. The fine tuning process incrementally adds and subtracts flow from the units to hone in on the maximum possible generation for the given total plant release. As the plant dispatch routine increases the total plant flow, the model uses the previous Unit Dispatch distributions as well as new distributions to find the largest possible generation (most efficient use of the water) given the plant release. The final result is a collection of flow distributions by unit for the entire range of plant operating flows.

To calculate total plant generation, the Unit Dispatch Table is used in combination with a span of gross operating heads to calculate plant generation. The model has everything required: total plant flow, flow distribution between the units, headloss for each unit, and the plant gross head. The final result is the plant generation matrix of plant output (MW) based on plant gross head and plant total flow.

2.3 Daily Time-Step Logic Sequence

The CHEOPS output includes a small time-step detailed schedule of plant releases and generation. An intermediate step in producing the 15-minute schedule is calculating the daily inflows, releases, and elevation targets for each plant in the system. This section will detail the method used to calculate the daily average plant releases.

2.3.1 Retrieval of Constraint Data

The first step in the scheduling routines is to retrieve the constraints for that plant for that day. The model calculates the target elevation, minimum flows, bypass flows, water withdrawals, etc. Anything for that plant for that day that is day-specific is calculated and loaded into the model logic.

2.3.2 Sum of Inflows

With all the daily constraint data loaded into the model, the model then retrieves the upstream plant's releases for the day, local accretions, and any other bypass flows and/or spill flows that will arrive at that plant. The model sums these inflows and calculates a detailed, small time-step, inflow profile for the plant.

Inflows at each node are calculated as part of the sum of inflows. CHEOPS model input includes local accretions for each basin rather than at each node. This flow is distributed over the nodes in the basin. Accretion at a given node is a percentage of basin accretion equal to the incremental drainage area at the node divided by the drainage area of the basin. Inflow at a node inflow is the sum of node accretions and return flows for the node and each upstream node.

2.3.3 Daily Release Calculation

After the model determines the inflow volume for the plant, it calculates a daily average release. The daily average release is a function of the total daily inflow, forecasted project inflows, total node withdrawal flows, target elevations, plant capacity, and minimum and maximum release requirements. As part of this calculation, daily average flows at each node are calculated based on the inflow volume at each node and the withdrawal flows at withdrawal nodes. Node shortages may occur at withdrawal nodes if the scheduled withdrawal flow volume is greater than the available inflow volume at that specific node. If there is a shortage, the node withdrawal is reduced to the available inflow. This reduction impacts the total node withdrawal flows used to calculate net plant withdrawal. If a withdrawal node is located within a reservoir, withdrawal flow is not limited to upstream nodes' return flows and proportional accretions. The withdrawal is met even if it brings the reservoir below the critical elevation.

With the daily release calculated, the model checks the release against daily constraints such as minimum daily average flows, minimum instantaneous flows, reservoir constraints, and minimum and spill elevations. Adjustments are made to the daily average release as necessary to meet the plant constraints. The daily average release may be adjusted upward to provide support to downstream plants with high flow requirements and may be adjusted downward if downstream plants have less capacity and little storage. These adjustments are applied after the node flows are fixed.

2.4 15-Minute Time-Step

Once the daily average flows have been set, the model schedules the plant's 15-minute releases. The first priority is to meet the Minimum Instantaneous Flow for the plant. This Minimum Instantaneous Flow volume is removed from the volume available for peaking purposes. All daily constraint flows were accounted for in the derivation of the daily release volume. The primary guide for the 15-minute schedule is the Loadshape.

2.4.1 Release Priorities Based on Loadshape

The Loadshape contains the period durations for each month for both weekdays and weekends. The model uses this data to create the 15-Minute Schedule along with the plant's peak unit capacities. The model allocates the peaking volume of water into the peak periods first, the period between peaks, the secondary peak periods, and finally the off-peak periods. The model attempts to operate the units at peak efficiency in order to maximize the generation for the period.

If the plant has ramp rates, the model will schedule the plant to not violate the ramp rate requirements. If the plant is a Re-Regulating Plant, the model will schedule a flat-release characteristic of a Re-Regulating facility. If the plant is a Run-of-River Plant, the model will schedule releases to match the inflows.

2.4.2 Constraint Checking

After the peaking volume has been scheduled, the model calculates 15-minute reservoir elevations based on the 15-minute inflows and releases. With the elevations, the model will check for reservoir constraint violations. If violations are found, the model will incrementally

shift water either at the current plant or the upstream plant to remove reservoir violations. When the violations are eliminated to the best of the model's ability, the model proceeds to the next downstream plant.

2.5 Model Logic Flow Chart

Figures 2-2 and 2-3 give an overview of the model logic in sequence.

FIGURE 2-2
CHEOPS MODEL EXECUTION FLOW CHART

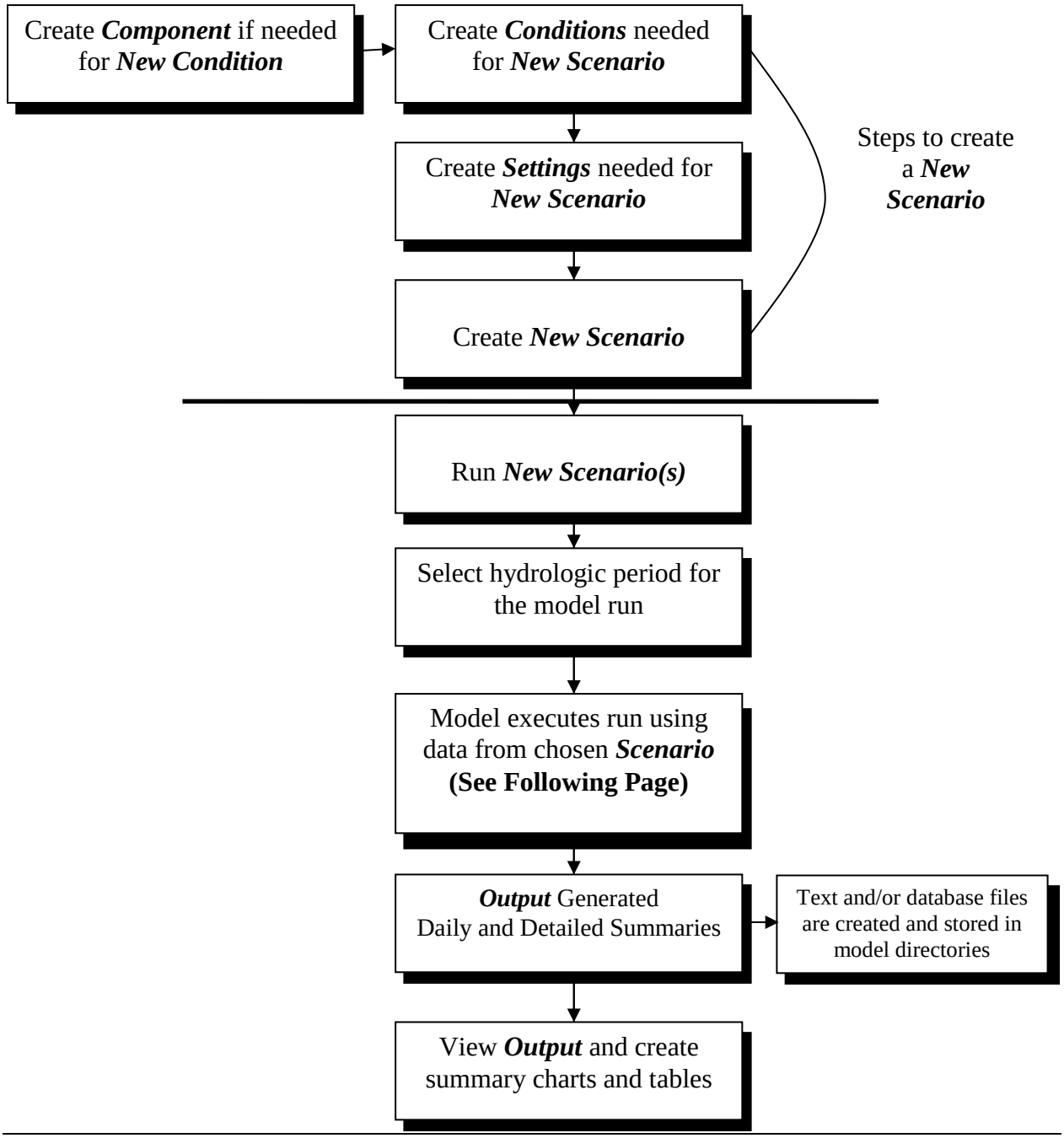
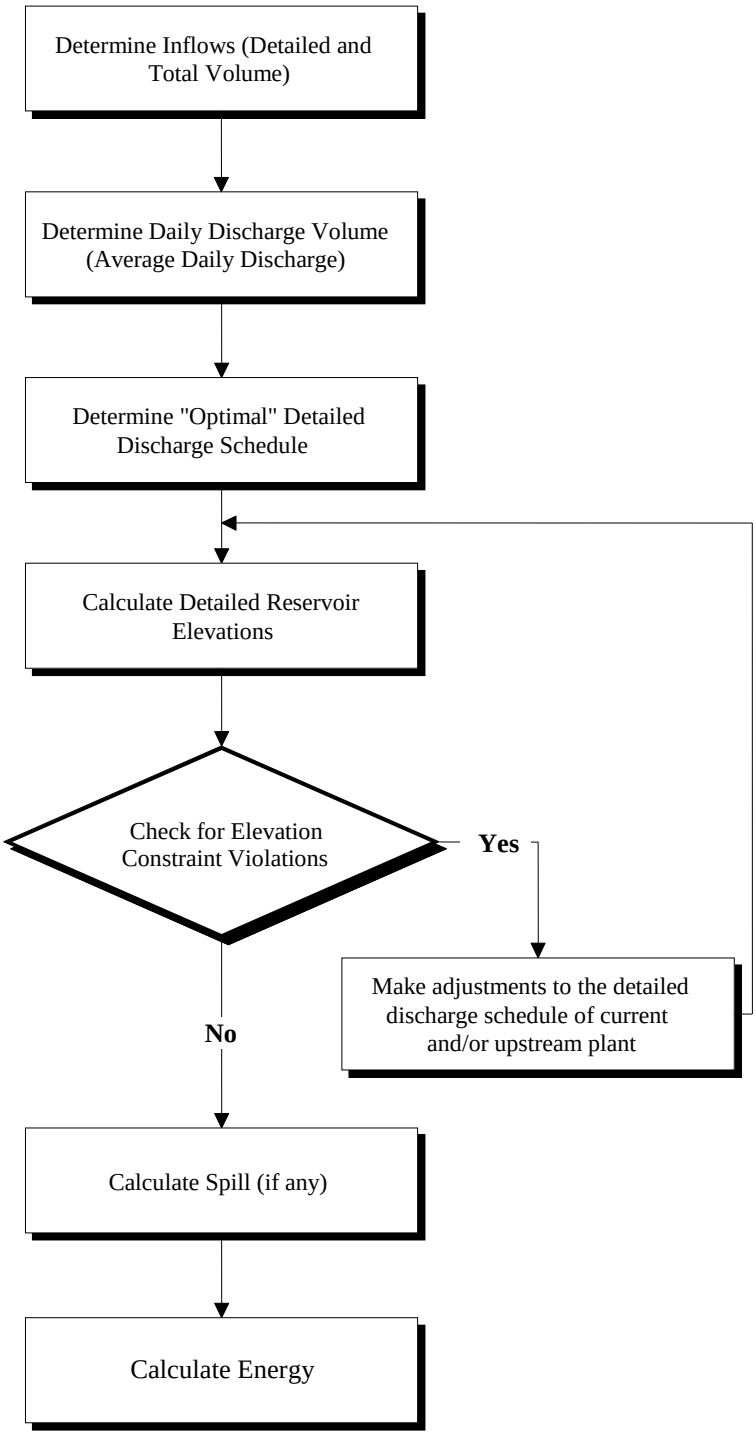


FIGURE 2-3
CHEOPS SCHEDULING FLOW CHART



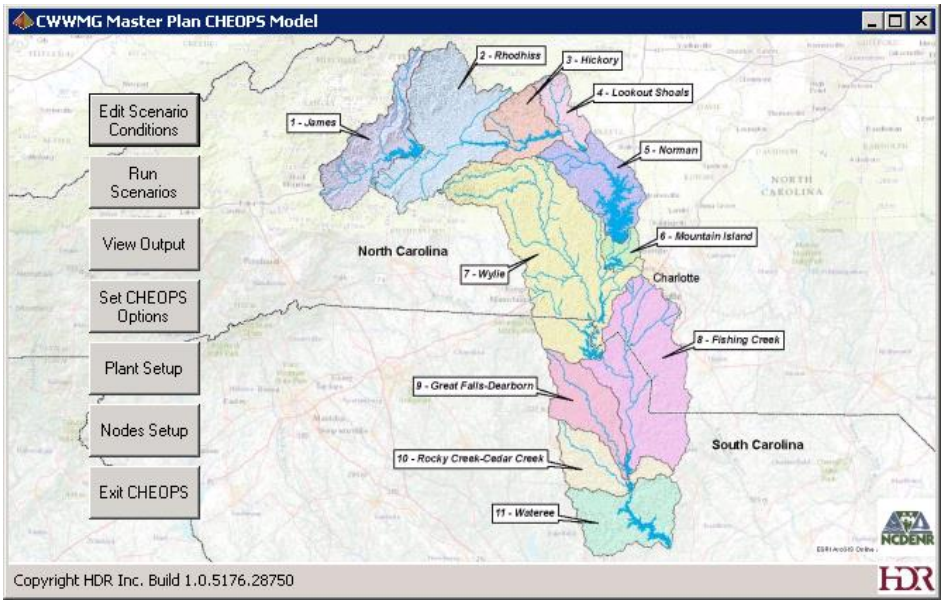
Section 3
User's Manual

This section contains Graphic User Interface (GUI) screen shots and descriptive text to illustrate how to enter and modify system data, run the model, and view the CHEOPS-generated output specific to the model. Also included are brief descriptions on where and how the model uses each piece of data. Refer to Section 2 for analysis about how the model logic works.

3.1 Main HDR CHEOPS Model Interface

The main HDR CHEOPS Model interface, as shown below in Figure 3-1, is the starting point for the model navigation. From this point the user can view individual plant data, system data, create a model scenario, run the model, and examine CHEOPS output.

FIGURE 3-1
HDR CHEOPS MODEL MAIN INTERFACE



3.1.1 Retrieving/Saving Data

The CHEOPS model is built from input data. All the data must be saved to the database for the model to incorporate the data. Retrieving and saving this data is done using almost identical

interface screens. These screens are described and shown below. Because manually editing the database, tables, or data may make the database non-functional, it is locked to prevent inadvertent corruption of data stored in the file.

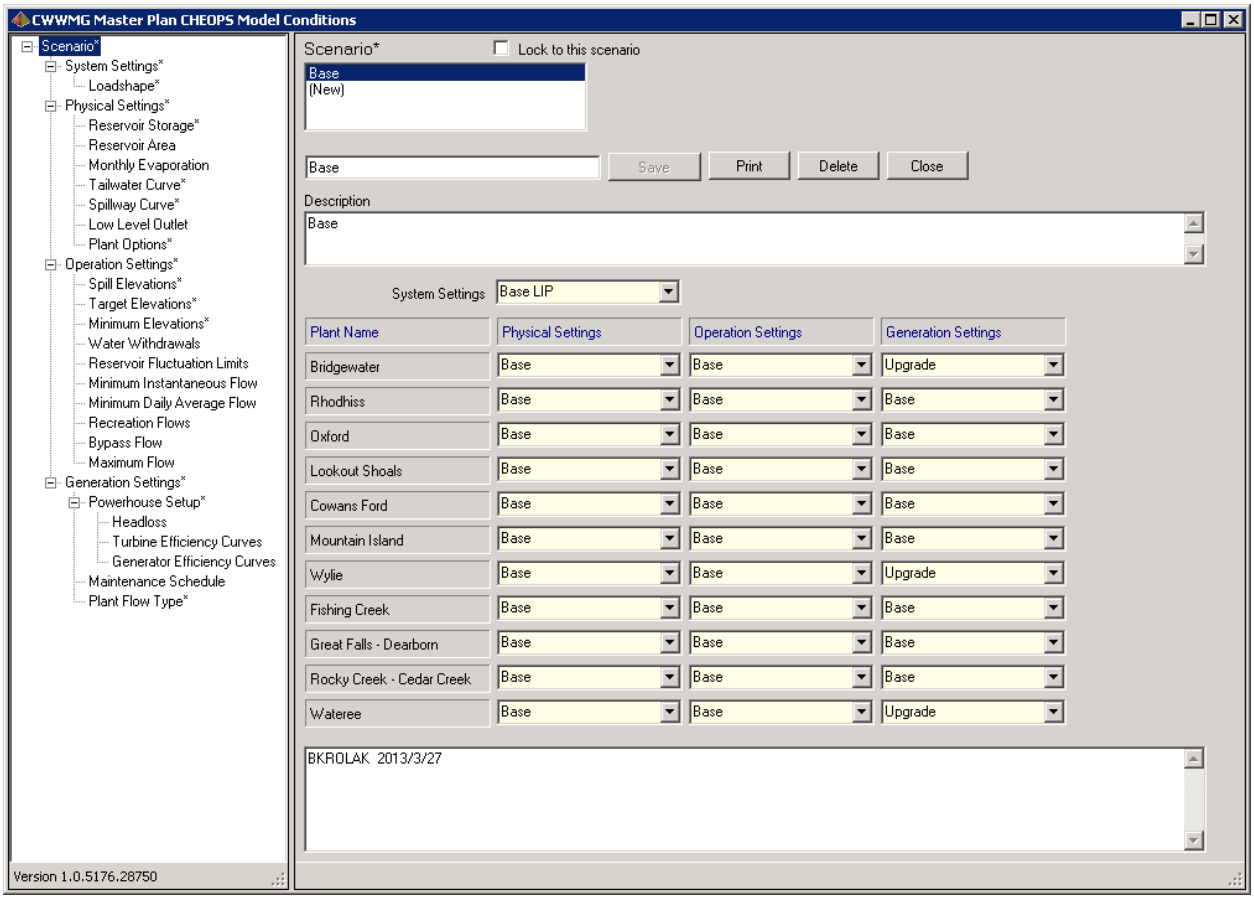
When modifications are performed to a Setting or Condition, the Save button becomes activated (available for use) and the Delete button becomes deactivated (unavailable for use). The user can then click the Save button. If the Condition name already exists and is the active selection, the user is prompted to overwrite the condition. If the user starts to modify a condition and then clicks away from the current condition, the user is prompted to abandon the changes. Answering No will permit the user to save the condition prior to clicking away.

Deleting a condition or setting is not reversible. Once deleted, the condition or setting is permanently deleted from the database. After clicking the Delete button, users are prompted to confirm the deletion prior to the condition actually being removed. A dialog indicating which upper-level settings or conditions rely on the condition about to be deleted is provided to allow a more informed decision.

3.1.2 Edit Conditions Interface

From the Main form, clicking on the Edit Scenario Conditions button will activate the Edit Conditions (Conditions) form, shown in Figure 3-2. The Conditions interface is the starting point for entering plant-specific data. From this form, the editing/creating of components into conditions, and conditions into settings, and settings into scenarios is accomplished. Multiple model users can access the same database simultaneously, thus preventing each user from having to recreate the same scenarios and conditions. If two users are editing the same condition on the same plant, there is a possibility that one user may delete a condition being modified by the other user. Coordination of model use between users is encouraged.

FIGURE 3-2
EDIT CONDITIONS INTERFACE



On the left side of the Conditions interface is a tree view layout of the Scenario, Settings, and Conditions available in the model. Required settings and conditions have an asterisk after the name. Clicking on a different condition name will change the displayed contents on the remainder of the form. The right portion or right panel of the form changes depending upon the condition chosen. The basic components of the screen that do not change are the listing of Setting/Condition names, a Description text box, a Notes text box, and several buttons. The various controls are described below.

- Scenario Name/Condition Name List Box – Alphabetically sorted list of scenario names or condition names which have been created and stored in the database.
- Plant Name List Box – List of plants entered into the model, sorted by plant number as stored in the database, typically from upstream to downstream. This is only displayed when a condition or setting varies by plant.
- Condition Name Input box – Text box which user types in a scenario, setting, or condition name when creating a new condition, setting, or scenario.

- Description Text Box – Located near the top of the form, this is where the user types information describing the condition being created. This can include source files for computations, sources of data, and purpose of the condition.
- Notes Text Box – Located at the bottom of the form, this is where the user types additional tracking information such as condition creation date, modification date, QC trace information, and other data as deemed appropriate.
- Save Button – Allows the user to save a condition to the database.
- Print Button – Sends the current form to the default Windows printer. If the current tree view item is Scenario, the user is prompted to output all scenario contents to a CSV (comma separated text) file. If the user answers No, the form is sent to the default printer. If the user answers Yes, then the user is prompted to input a folder and file name for the output file.
- Delete Button – Deletes the current scenario, setting, or condition after the user confirms the deletion action.
- Close Button – Closes the Edit Condition form and returns to the Main form.

Not all conditions are required for each plant. Conditions which are required at a minimum to run a scenario have an asterisk after the name in the tree view, and are shaded light yellow in the right panel of the form. Note that these required items may show as a different color depending upon the user's Windows settings.

3.1.2.1 Physical Conditions

Physical Conditions typically represent the data that simulates the concrete and rock structures. The techniques to input this type of data are included below.

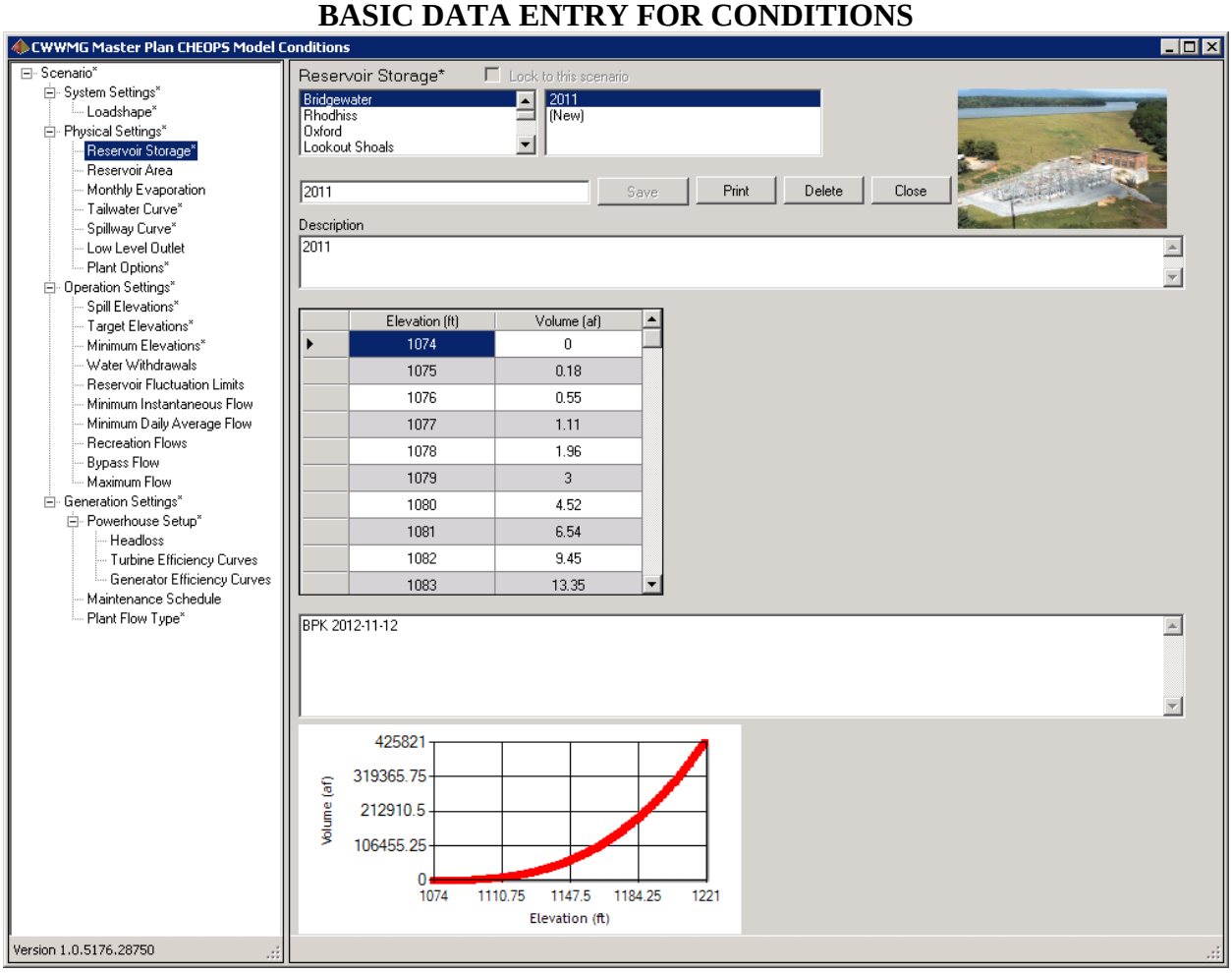
Entering Data Sets

A sample of the basic data-entry interface is included below in Figure 3-3. Specifically, Figure 3-3 represents the Reservoir Storage Curve input interface. Each condition has components that may be of numeric, text, or Boolean input types. The form will create tables when necessary to present options to the user and attempt to ensure only proper data types are entered.

To enter Condition data, first select the condition name in the tree view. Then select the appropriate plant name in the Plant list box. If modifying an existing condition, the user can select that condition name to have the condition's component values displayed. The user can then modify the appropriate values and click the Save button. A change to the condition Name, Description, Notes, or values will activate the Save button. If the user clicks away from the chosen condition, plant, or condition name while the Save button is active, the user is prompted whether the changes should be abandoned.

To create a new condition from a blank form, click the "(New)" keyword in the condition name box and type in description, name, notes, and values as appropriate. The model will not save the condition if no condition name has been entered. The user can click the Save button numerous times as data is filled out. Users are prompted to confirm overwriting a condition if the condition name already exists in the database.

FIGURE 3-3
BASIC DATA ENTRY FOR CONDITIONS

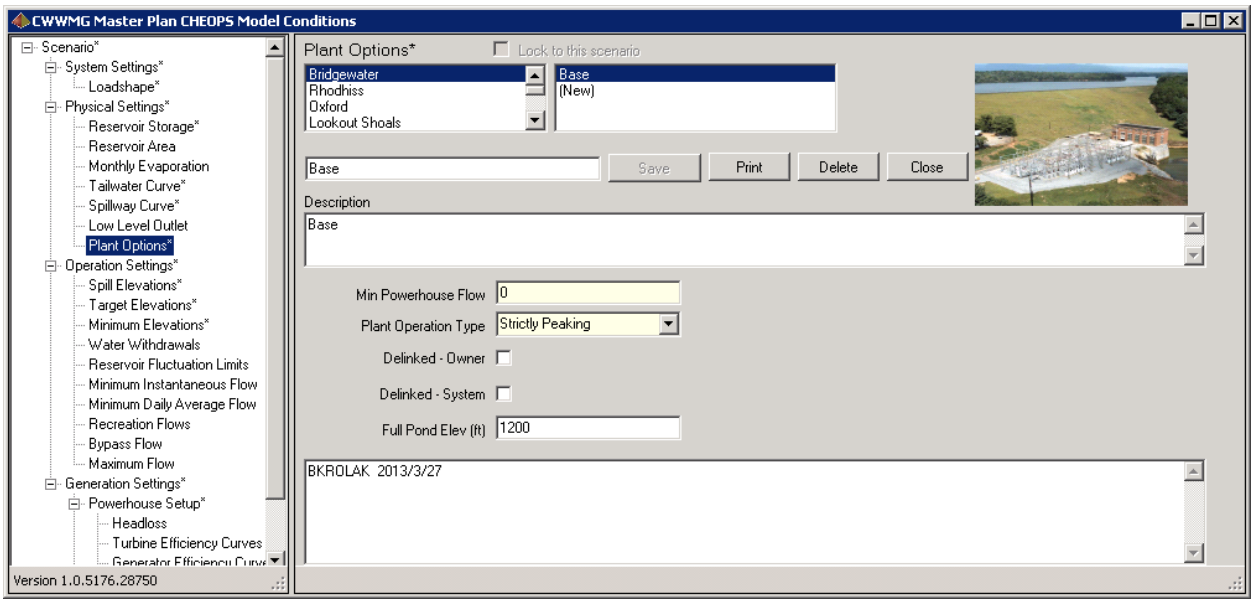


Except for the Plant Options interface, the interface for entering the other Physical Conditions is almost identical to the Reservoir Storage Curve interface with the exception of the units used and some of the wording. The difference for the Monthly Evaporation input interface is that the coefficients entered are constant for the month entered, and if the user does not enter data for a month, the model will fill in a zero for that month's coefficient.

Plant Options

The Plant Options interface is different than the other Physical Condition interfaces. This interface allows the user to enter four pieces of plant data that form the Plant Options Condition: Minimum Powerhouse Flow, Plant Operation Type, two Delinked options, and the Full Pond Elevation. A description of this data is included in Section 2.1.3.9. The interface is shown below in Figure 3-4.

FIGURE 3-4
PLANT OPTIONS INTERFACE



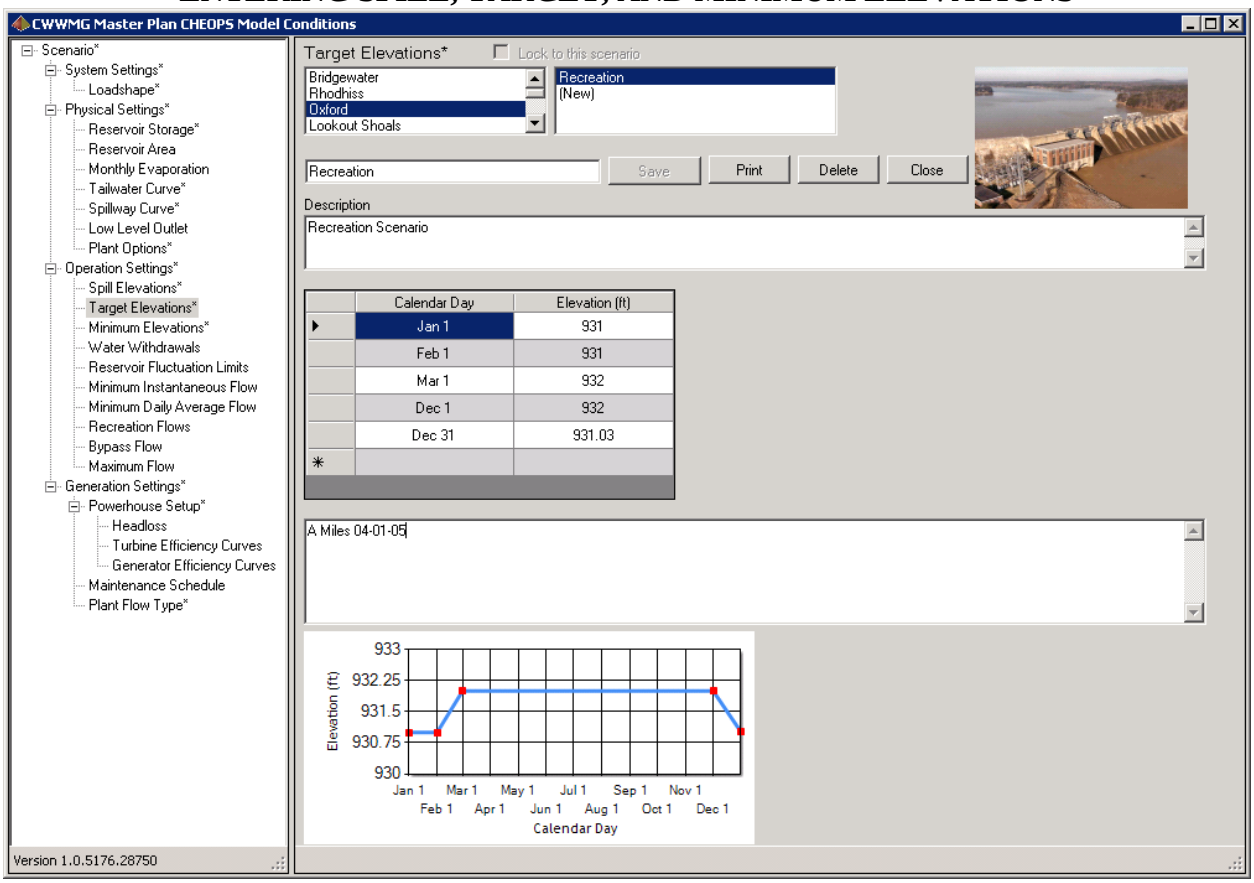
3.1.2.2 Operation Conditions

The Operation Conditions represent data that can vary by day throughout the year and data that is usually driven by regulatory constraints. Descriptions of how the model uses this data can be found in Section 2.1.4.

Spill, Target, and Minimum Elevations

The Spill, Target, and Minimum Elevations are all entered the same way. The user enters a day of the year and the corresponding elevation. The user can enter as many dates as necessary and as few as one day. The user can delete an elevation by double clicking the row header and answering the prompt. The Target Elevations Conditions interface is shown below in Figure 3-5.

FIGURE 3-5
ENTERING SPILL, TARGET, AND MINIMUM ELEVATIONS



The model will calculate the elevations for days, between those entered in the table, by linear interpolation.

Weekly Drawdown

The Weekly Drawdown interface identifies the reduction to be applied to the target elevation and the number of days in the drawdown cycle. The interface requires that the user enter the date,

number of days of the drawdown cycle, and the number of feet to be drafted. Ending the drawdown condition is performed by entering 0 feet for the drawdown value. For a weekly fill cycle, enter a negative value for the Feet value of elevation change. Note that if the daily target elevation goes above the Spill Elevation or below the Minimum Elevation, the model will reduce flows to stay within those limits. When this happens, the full cycle of drawdown does not occur.

The model converts the feet of drawdown to a storage change volume and applies this volume change evenly over the days of the drawdown cycle, reconverting the target volume to a reservoir elevation. Drawdown requirements are not interpolated between dates entered in the condition.

Water Withdrawals/Returns

The Water Withdrawals interface allows the user to specify an Excel workbook from which to read the flow values, whether withdrawal or return, for the nodes in the specific basin being edited. The Excel workbook used has a specific structure for inputting the values, so modifying the format can cause the model to not function as expected. The Excel workbook must be in the model's \HydrologyFiles folder. The names of the files provided with the model start with "W-R" to indicate the file is a withdrawal input file, thus assisting with file identification. One file can contain all nodes within the model's watershed, or each basin can have a separate file with all of the nodes and flow values for the basin being edited.

Fluctuation Limits and Fluctuation Rates

The Reservoir Level Fluctuation Limits interface controls how much the model can manipulate the reservoir surface elevation within the day. The interface for these conditions is similar to the interface for the elevations as show in Figure 3-5. However, the interface for the Fluctuation Limits has two additional fields for Hard Limits and Percent Above Target.

Hard Limits control how stringently to hold the reservoir to the target elevation. If Hard Limits is selected, the model will not operate the reservoir above the hard limit or below the hard limit (given sufficient spillway capacity or sufficient inflows). For example: if the model's target elevation is 1,200 ft, the fluctuation limit is a hard 4-ft limit, with 75 percent of the limit above

the target, then the model will keep the reservoir between 1,203 ft (75 percent of 4 ft above the target; 0.75 ≅ 4 ft + 1,200 ft = 1,203 ft) and 1,199 ft (25 percent of 4 ft below the target; 1,200 ft – (0.25 ≅ 4 ft) = 1,199 ft). This feature allows the user to control the daily fluctuations in an envelope around the target elevation.

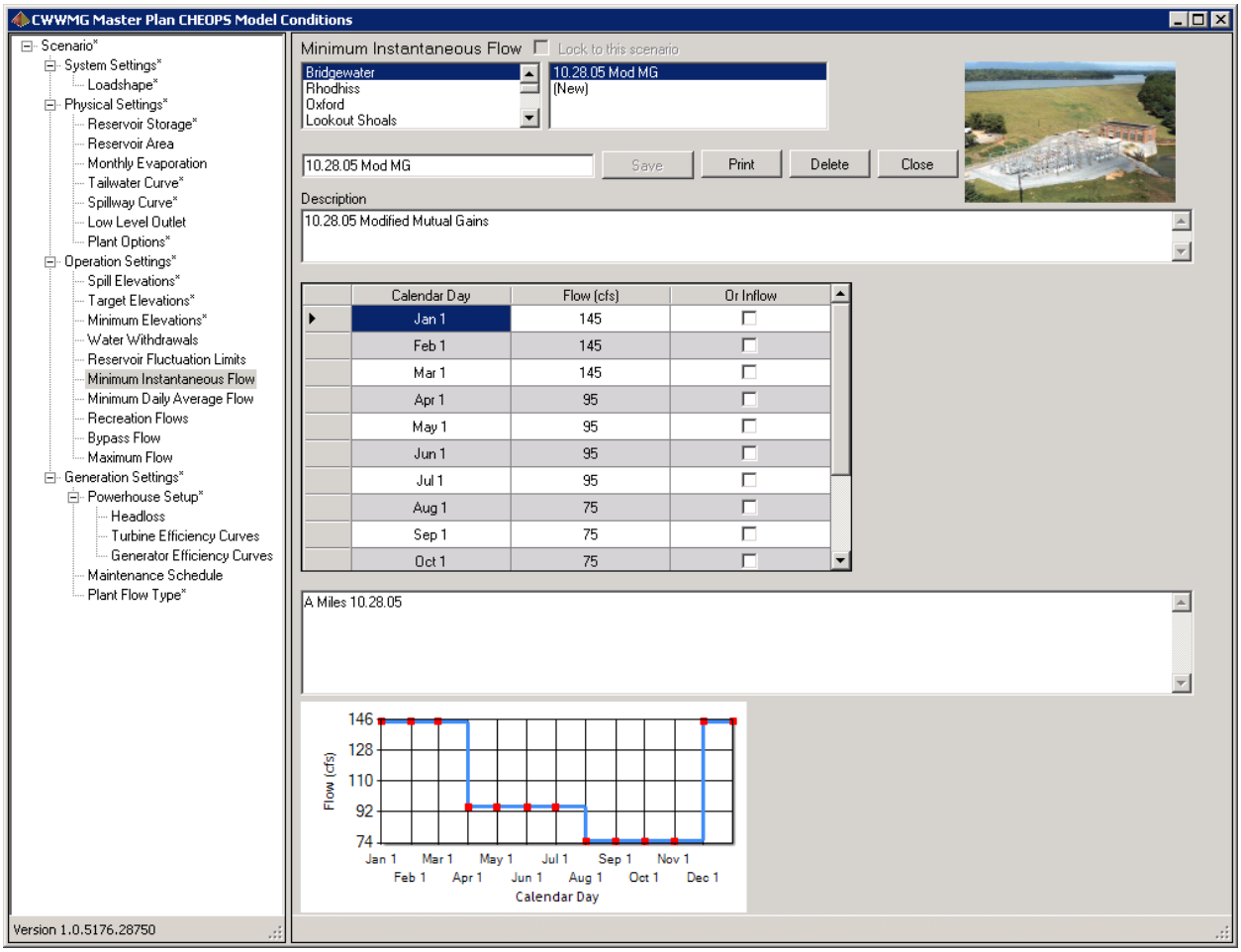
The fluctuation limit and rates do not get interpolated like the elevations for in-between days. If the user enters a fluctuation limit of 3 ft on January 1 and 2 ft on January 15, then the fluctuation limit on January 14 is 3 ft.

Minimum Instantaneous Flow and Minimum Daily Average Flow

The Minimum Instantaneous Flow interface is shown below in Figure 3-6. A date and a flow requirement are entered, and optionally the Or Inflow option can be checked. Flow requirements are not interpolated between days, staying in effect until changed. Minimum Instantaneous and Minimum Daily Average flow requirements are discussed in Section 2.1.4.

The Minimum Instantaneous Flows Conditions have an Or Inflow option. The Or Inflow option allows the model to limit the required minimum flow based on the plant's inflows. If a plant has a minimum daily average flow of 35 cfs but the plant's total inflow for the day is 32 cfs, the model reduces that day's minimum daily average flow requirement to 32 cfs. The model will not allow negative minimum flows. Minimum Instantaneous and Minimum Daily Average flow requirements are considered discretionary and may be reduced to 0 cfs or wicket gate leakage if powerhouse releases would cause the minimum elevation to be violated.

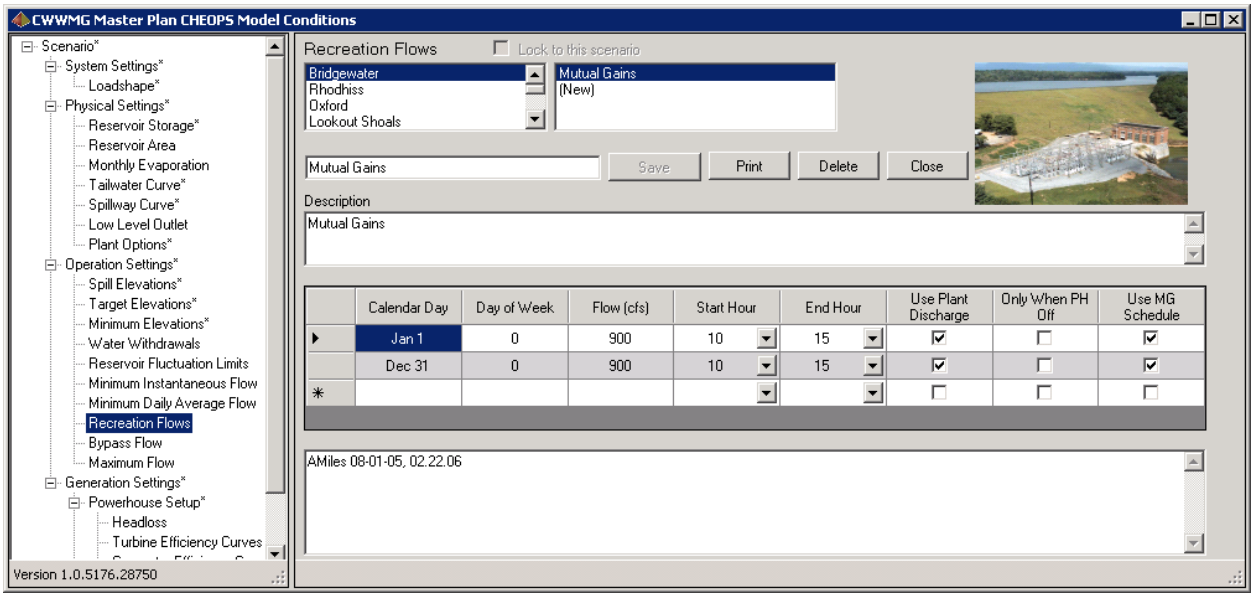
FIGURE 3-6
MINIMUM INSTANTANEOUS FLOWS



Recreation Flows

The Recreation Flows interface allows the user to specify plant outflow requirements that vary by day of the year and day of the week. A flow requirement with starting and ending hours, plus the option to route the flow through the powerhouse is entered. Further information on this condition is in Section 2.1.4. Like other flow conditions, the flow values are not interpolated for days between the days entered. The Recreation Flows interface is shown below in Figure 3-7.

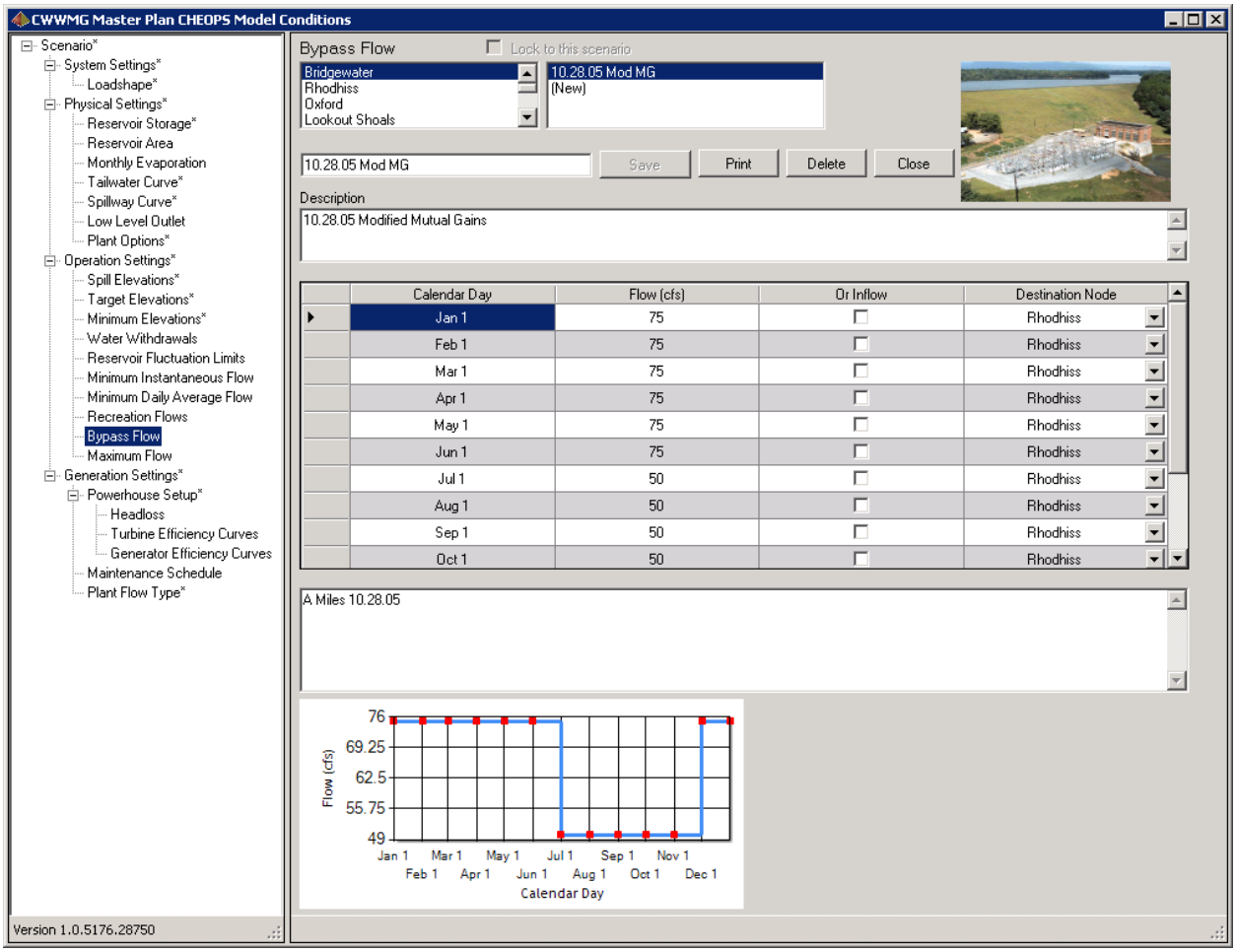
FIGURE 3-7
RECREATION FLOWS



Bypass Flows

The Bypass Flows interface is similar to the Spill Elevations interface. However, like the Fluctuation Conditions and the Minimum Flow Conditions, the flow values are not interpolated for days between the condition's days. The Bypass Flows interface is shown in Figure 3-8.

FIGURE 3-8
BYPASS FLOWS

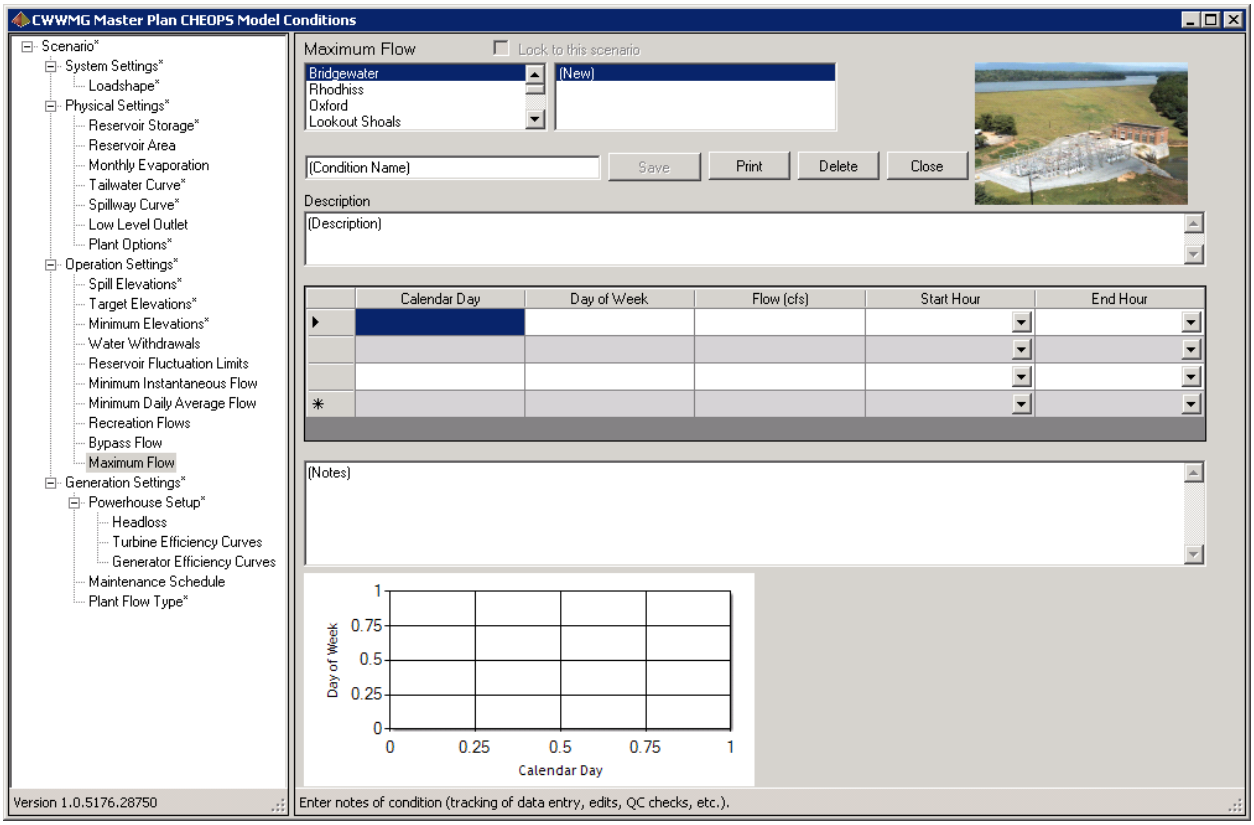


The Bypass Flows screen, like the Minimum Flows screen, has an Or Inflow option. Bypass flows do not go through the powerhouse and they can return to the system at any downstream plant. The user can also specify that bypass flows never return to the system. See Section 2.1.4.12 for further documentation.

Maximum Flows

The Maximum Flows interface is similar to the Recreation Flows interface, but does not have the option of specifying which day of the week the flow requirement applies. This flow requirement allows the user to change by day of the year the maximum discretionary flow between a starting and ending hour. Like other flow conditions, the flow values are not interpolated for days between the condition's days. The Maximum Flows interface is shown in Figure 3-9. See Section 2.1.4.13.

FIGURE 3-9
MAXIMUM FLOWS



3.1.2.3 Generation Conditions

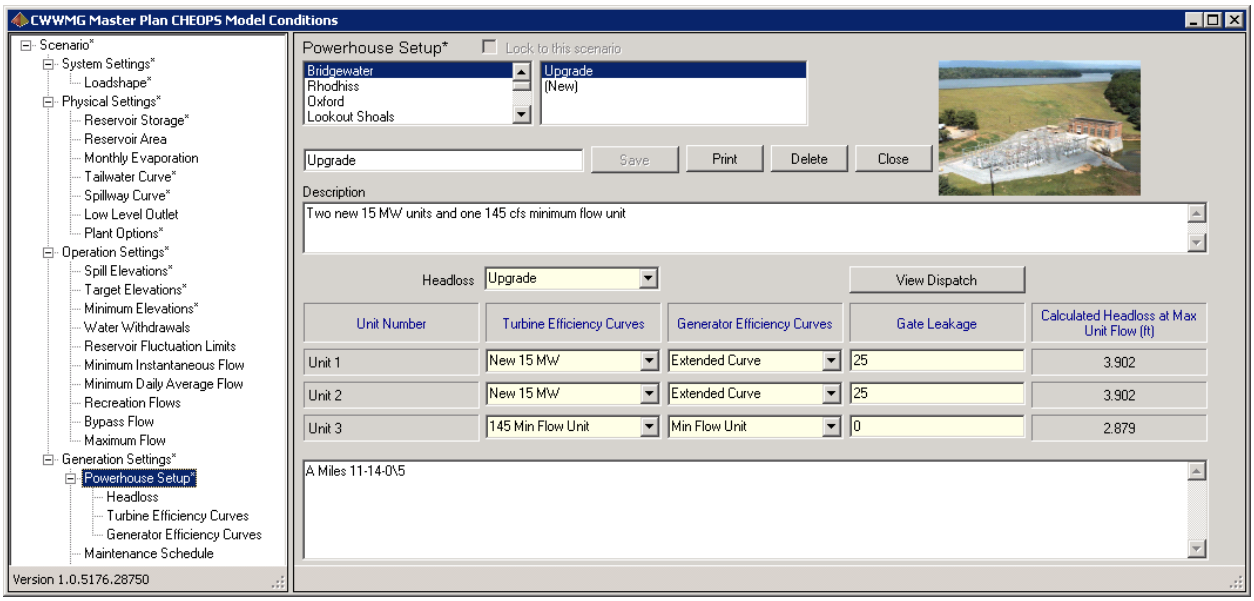
The generation conditions are conditions directly related to power generation and powerhouse operations. These conditions and components are described in more detail in Section 2.1.5.

Powerhouse Set-Up

The Powerhouse Setup Condition interface is where the user can create the plant configuration with which the model will calculate generated power. The Powerhouse Setup Condition interface is shown in Figure 3-10. The user selects a Headloss component which sets the number of units and the headloss for the plant as well as for each unit in the plant. Then select the Turbine Efficiency Curves, Generator Efficiency Curves, and enter Gate Leakage settings for each unit. The headloss, turbine efficiency curves, and generator efficiency curves component set-ups are included in subsequent sections.

The interface also displays the calculated headloss given the chosen headloss coefficient and maximum flow for the chosen turbine. This is to inform the user when evaluating various turbine upgrades with significant flow changes that the headloss coefficient may need to be recalculated.

FIGURE 3-10
POWERHOUSE SET-UP



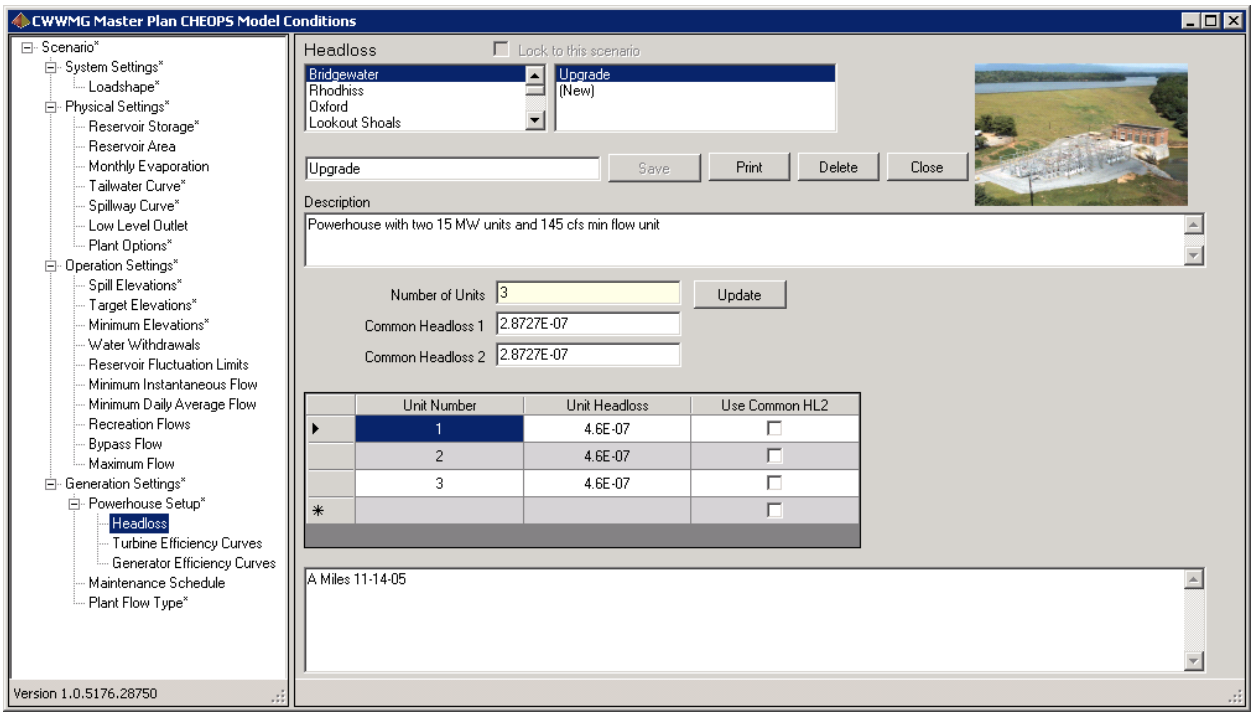
Once the powerhouse has been set up, the user can immediately dispatch the new configuration by clicking "View Dispatch," or allow the dispatch to occur during run-time. When the model runs a Scenario, it will automatically dispatch any plant setups that have not been previously dispatched.

■ Headloss

The Headloss interface is where the user can control the number of units in a plant. As shown in Figure 3-11, in the input table, enter the unit number, the unit headloss coefficient, and optionally click the Use Common HL2 check box. After all units are entered, optionally enter a Common Headloss 1 and Common Headloss 2 value, or 0 if there is no common penstock component. Manually enter the number of units or click the Update button.

The concept of multiple common coefficients is explained in more detail in Section 2.1.5.1. If headloss values are not available or if turbine performance curves are provided using gross head instead of the expected net head, enter 0 for the unit headloss coefficient.

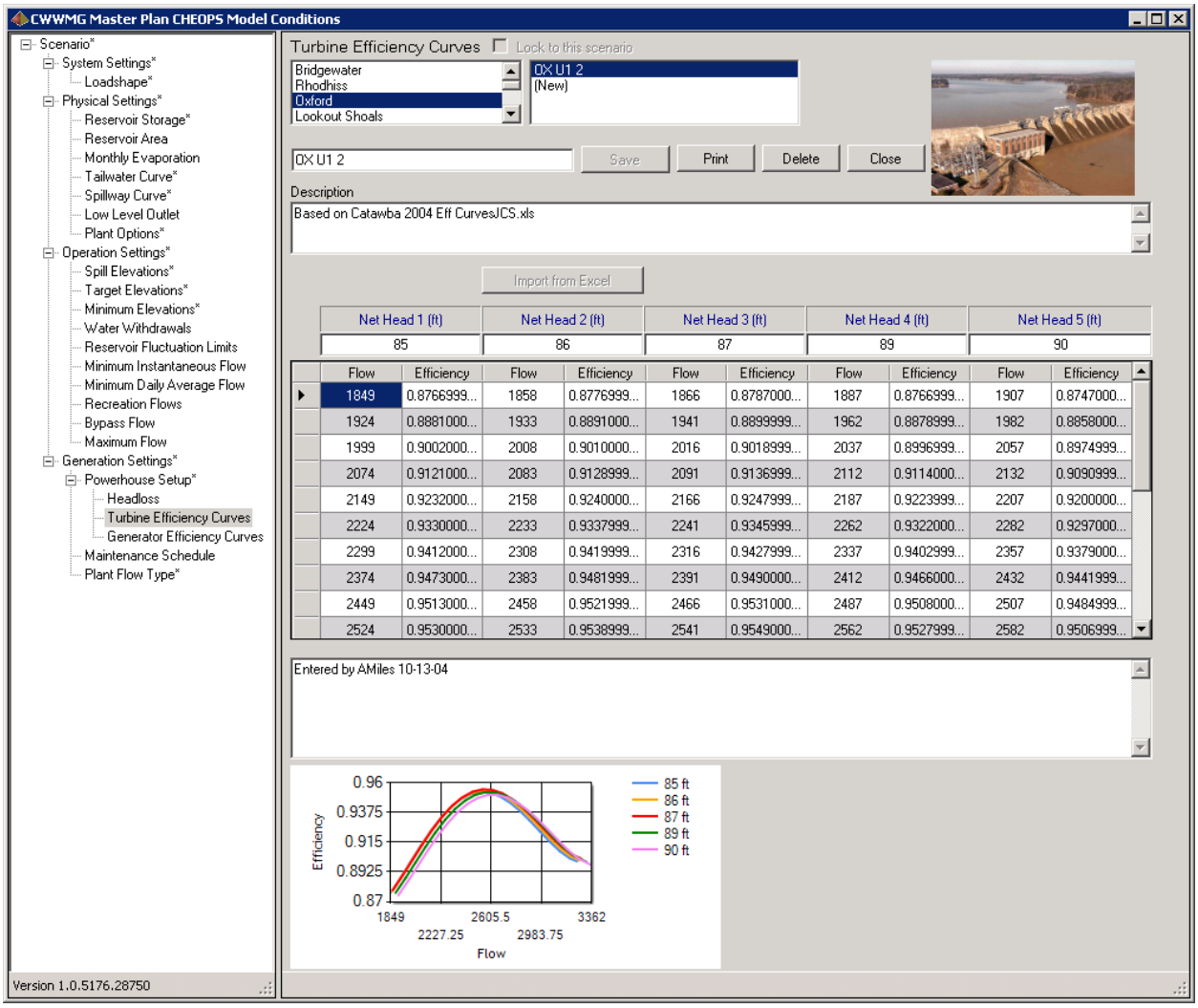
FIGURE 3-11
HEADLOSS



■ Turbine Efficiency Curves

CHEOPS turbine data is presented as flow versus efficiency at five net heads as shown in the Turbine Efficiency Curve interface in Figure 3-12. The net heads should span the operating range of the powerhouse. The model converts the net head to a gross head generation output table and uses this table for detailed output lookup. If the highest head entered is exceeded in modeled operation, then calculated generation for that period is likely to be too low. Conversely, if the lowest entered head is not low enough, then too much generation is computed for that period.

FIGURE 3-12
TURBINE EFFICIENCY CURVE



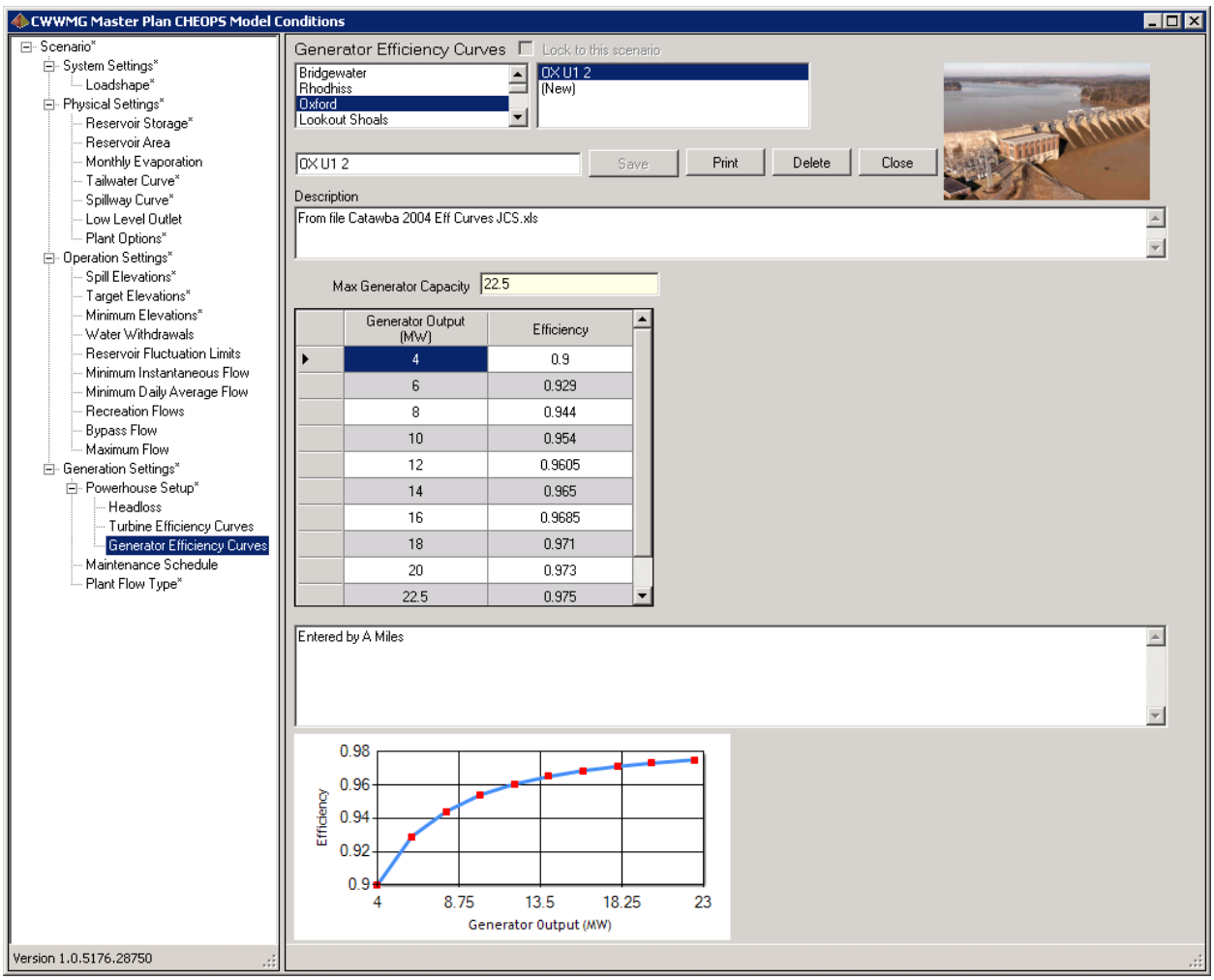
To enter flows and efficiencies, click on a cell and type in the data. All efficiency entries must be between 0 and 1, representing 0.0 percent to 100 percent.

To import turbine performance from the Excel template, the user needs to open the file named "Turbine.xls" in the "ExcelFiles" folder of the CHEOPS model directory (the default installation folder is C:\Program Files\CHEOPS II). Enter the performance data into the template. Save the template as a new file. Then, within the model, click the "(New)" entry in the condition listing box. This activates the "Import from Excel" button. Click on the "Import from Excel" button. The model will open a standard Windows Open dialog. Browse to and select the saved turbine data file and click the "Open" button. The model will then copy the performance data from the Excel file to the data table.

■ Generator Efficiency Curves

The generator data is similar to the turbine data except that there is no range of heads to enter. The Generator Performance interface, as shown in Figure 3-13, also includes a Maximum Generator Capacity value that the user must enter. This capacity is designed to represent the largest power output that the model will allow the generator terminals to produce. This feature allows the user to impose constraints on the system if other auxiliary equipment has capacities that limit plant generation.

FIGURE 3-13
GENERATOR PERFORMANCE

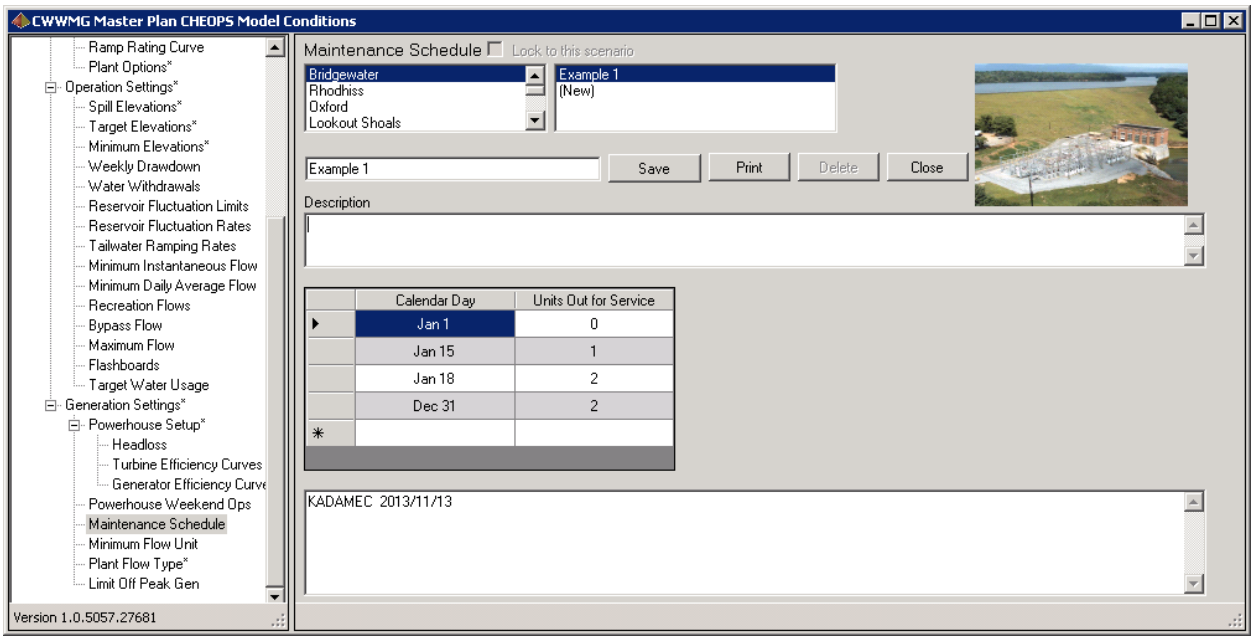


Maintenance Schedule

For the Maintenance Schedule the user enters a day and the unit number that is scheduled to be out for that day. If a unit is scheduled out, the model will not bring that unit back on line until

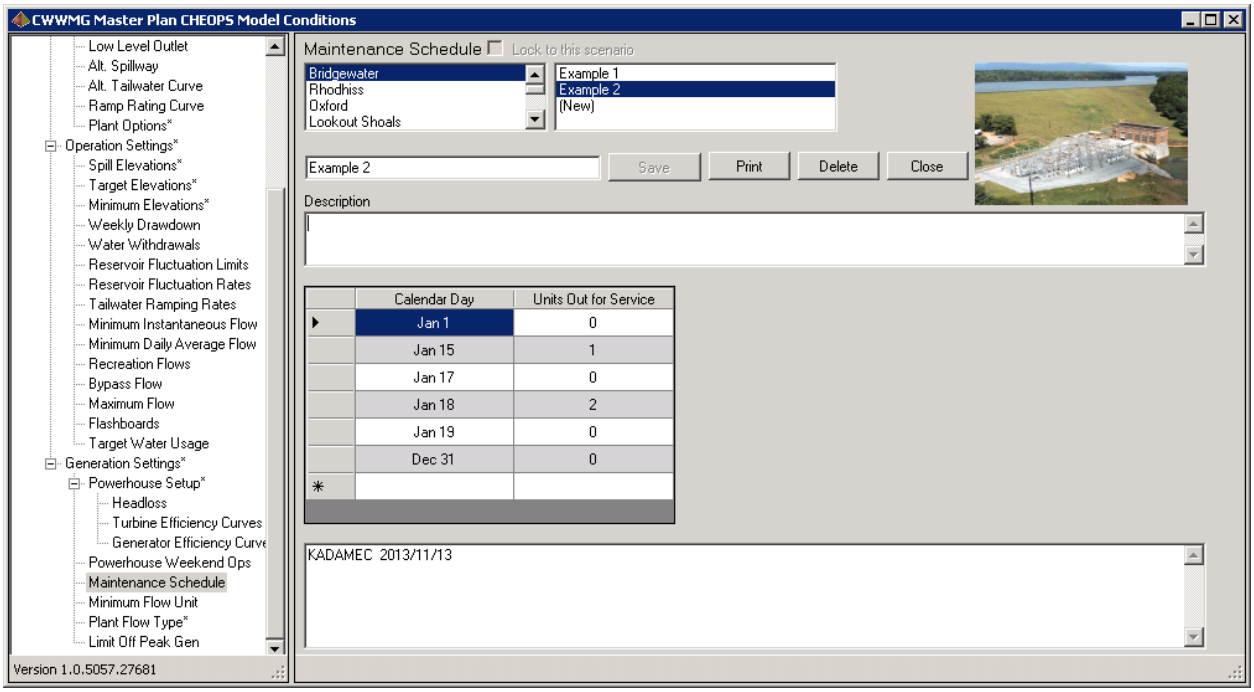
the model is told that *zero* units are out. For example, in Figure 3-14, if the user enters that Unit 1 is out on January 15, and Unit 2 is out on January 18, the model will operate with Unit 1 unavailable for generation on January 15, 16, and 17, then back online on January 18. Unit 2 will be unavailable for generation from January 18 until the end of the year.

FIGURE 3-14
FIRST EXAMPLE OF MAINTENANCE SCHEDULE



If Example 1 was modified by entering Unit 0 was out (all units available) on January 17, and Unit 0 was out (all units available) on January 19, as in Figure 3-15, then Unit 1 would be unavailable for generation on January 15 and 16, and Unit 2 would be unavailable for generation on January 18. On January 17, all units would be on line. On January 19 through the end of the year, all units would be online.

FIGURE 3-15
SECOND EXAMPLE OF MAINTENANCE SCHEDULE



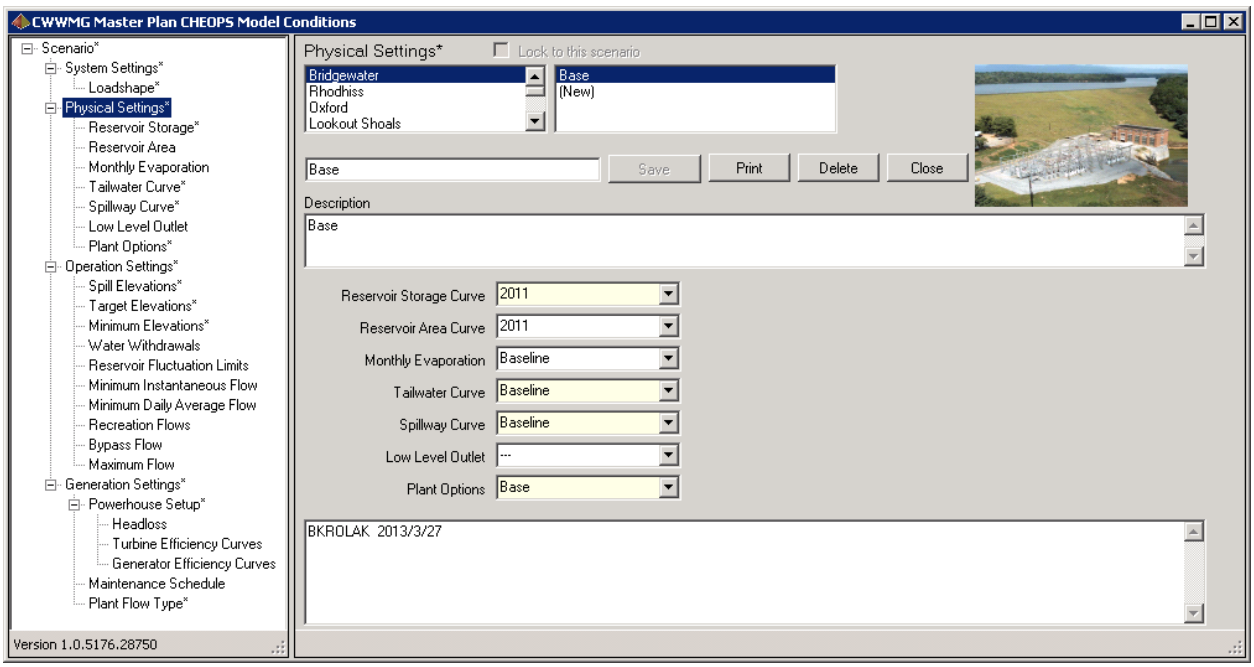
3.1.2.4 Settings

Thus far we have described entering and editing data to form Conditions; Conditions combine into Settings, and finally Settings combine into Scenarios. This section will discuss the creation of Settings.

Physical Settings

The Physical Settings interface is activated by clicking the Physical Settings label in the tree view on the left side of the form. This is displayed in Figure 3-16. Creating settings is a process of selecting a plant, choosing conditions from each dropdown box, then saving the Setting. If the dropdown box contains an option of "---" (none), and is not shaded yellow, then the Condition is optional. Saving a setting makes the setting available for creating a Scenario.

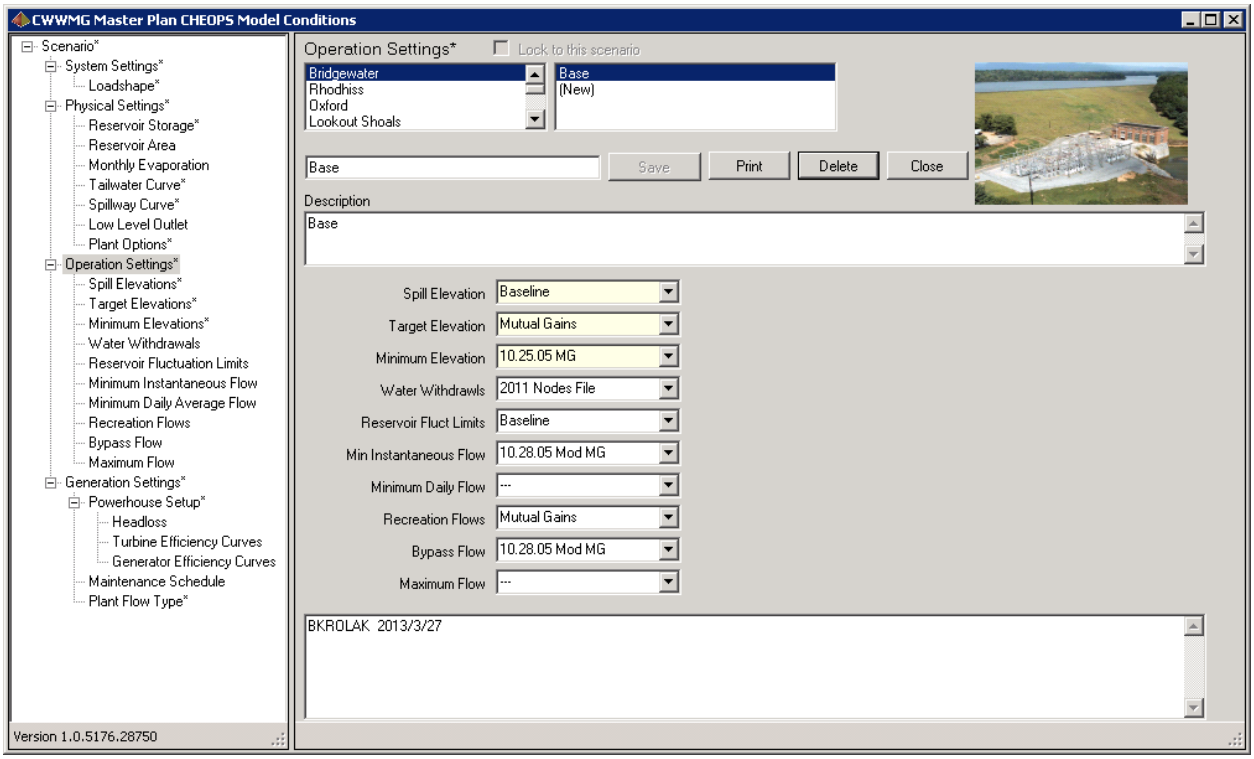
FIGURE 3-16
PHYSICAL SETTINGS INTERFACE



Operation Settings

Creating Operation Settings is the same as creating Physical Settings. The Conditions required for a Scenario run are Spill Elevations, Target Elevations, and Minimum Elevations. The remaining Conditions are optional. The process to save an Operation Setting is to choose a plant, select a Condition from each dropdown box, then save the Setting. The Setting will then be available when creating a Scenario. The Operational Settings interface is shown in Figure 3-17.

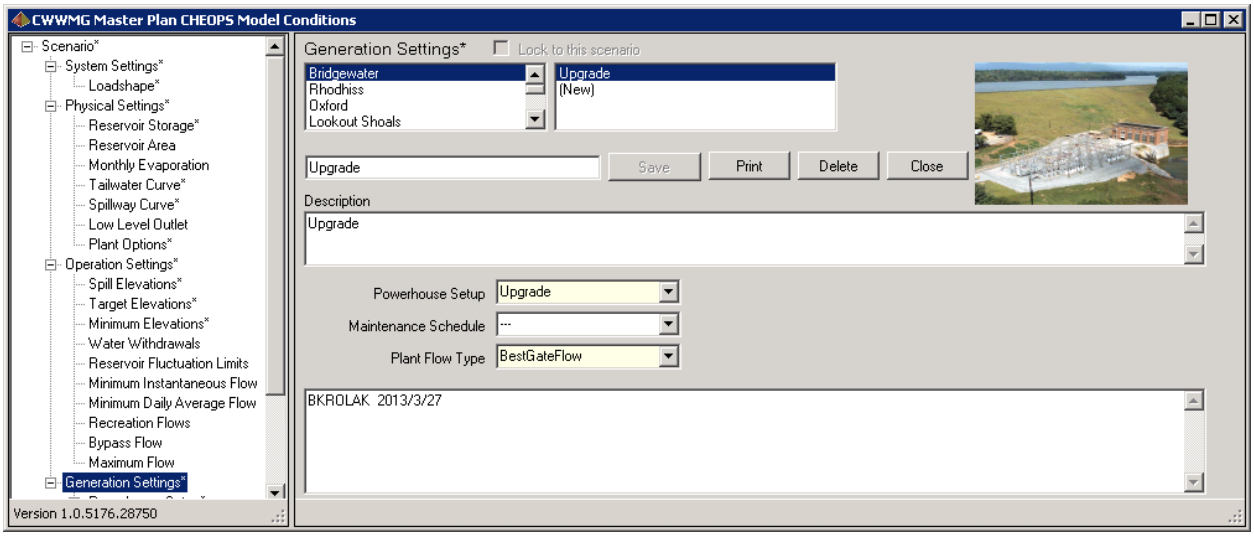
FIGURE 3-17
OPERATIONAL SETTINGS INTERFACE



Generation Settings

Generation Settings, as shown in Figure 3-18, are created in the same fashion as the other settings. By selecting a plant name, choosing options from the condition dropdown boxes, and saving the Setting, the Generation Setting is made available for inclusion in a Scenario.

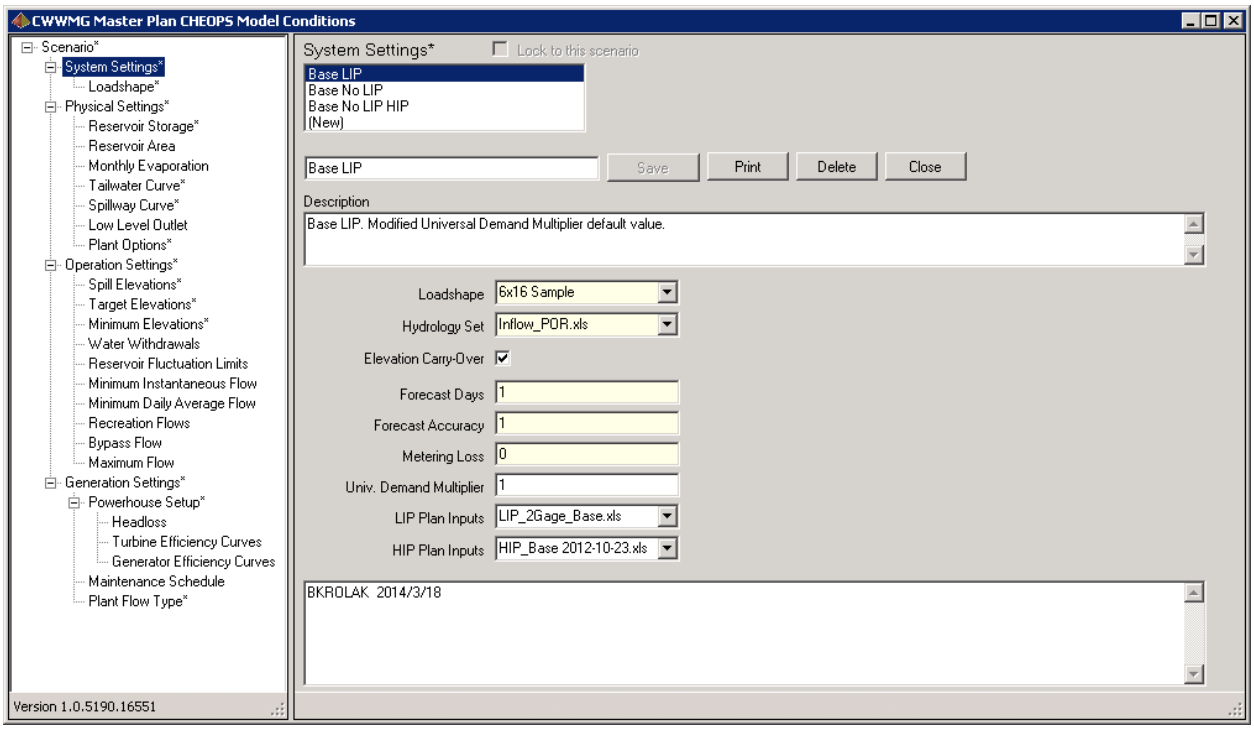
FIGURE 3-18
GENERATION SETTINGS INTERFACE



3.1.2.5 System Settings Interface

The System Settings interface contains dropdown boxes, text boxes, and check boxes used to create a System Setting. These are Conditions that apply to all the reservoirs and/or plants in the project. Buttons to activate Condition input dialogs are also included. A typical System Setting is shown in Figure 3-19.

FIGURE 3-19
SYSTEM SETTINGS



The Hydrology Set entry is a combo box which lists the available Excel files in the model's \HydrologyFiles folder. Choose the hydrology file of interest for the system setting.

The Elevation Carry Over check box specifies whether end-of-year reservoir elevations are to be used as the starting point of reservoir elevations for the next year in a multi-year run. This option has no affect if a scenario is run for only a single year. If checked, the model will carry over the elevations for multiple-year runs. If unchecked, the model will start each year with the reservoirs at their January 1 target elevation.

The Forecast Set-Up controls how the model estimates future inflows into the projects. Forecast Days represents how many days the model looks ahead to anticipate inflows. The Forecast

Accuracy box contains a number that represents the accuracy of the model's ability to look forward. Since the model has perfect knowledge of expected inflows from the inflow file, an artificial error in accuracy is introduced with the Forecast Accuracy setting. The model first adds up all the expected inflows for the number of days specified in Forecast Days, and then it multiplies the sum by the value in the Forecast Accuracy box. If the user would like to see how well the model operates assuming a plus or minus 20 percent accuracy, run the model once with the accuracy at 1.2, and then again with the accuracy set at 0.8.

The Metering Loss input allows the modeler to input a reduction for transformer and line losses between the generator and the point where generation is measured. This input can also be used to reduce generation for unscheduled outages. Typical metering and transformer loss value would be approximately 1.5 percent, entered in this field as 0.015.

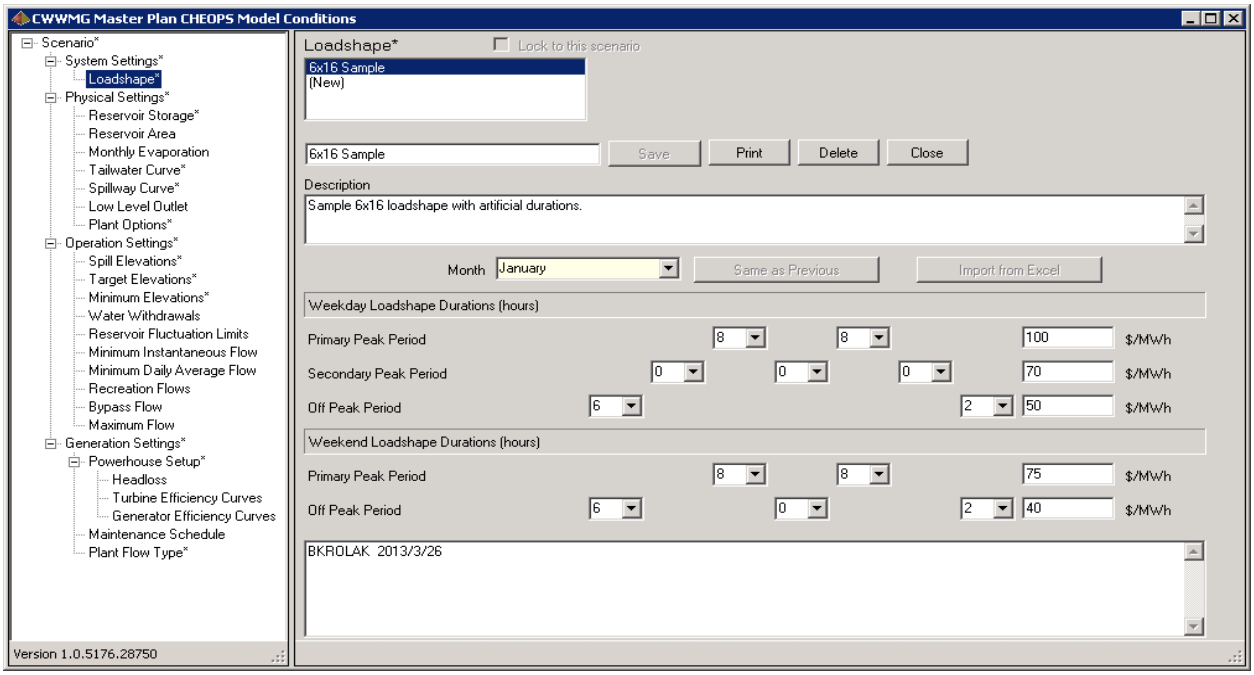
The Universal Demand Multiplier input allows the modeler to perform sensitivity analysis by increasing or decreasing withdrawal values by a multiplication factor. The default value is 1. The model will multiply all withdrawal and return values by the multiplier value provided. For example, entering 1.1 will cause all withdrawal and return flow values to be multiplied by 1.1, thus increasing flows by 10 percent.

The LIP Plan Input and HIP Plan Input controls allow the modeler to specify the Excel workbooks which contain the input conditions for these system requirements. For LIP inputs are described in Section 2.1.2.7 and Appendix A. HIP inputs are described in Section 2.1.2.6.

3.1.2.6 Loadshape

The Loadshape Condition provides the data necessary for the model to prioritize different generation periods during the day. The Loadshape interface is shown in Figure 3-20. Enter the duration in hours for each of the periods, plus a dollar value per MWh for electricity generated in that period for both weekday and weekend days. The user navigates through the months using the Month dropdown box. The Same as Previous button allows the user to copy the previous month's Loadshape and dollar values into the currently selected month.

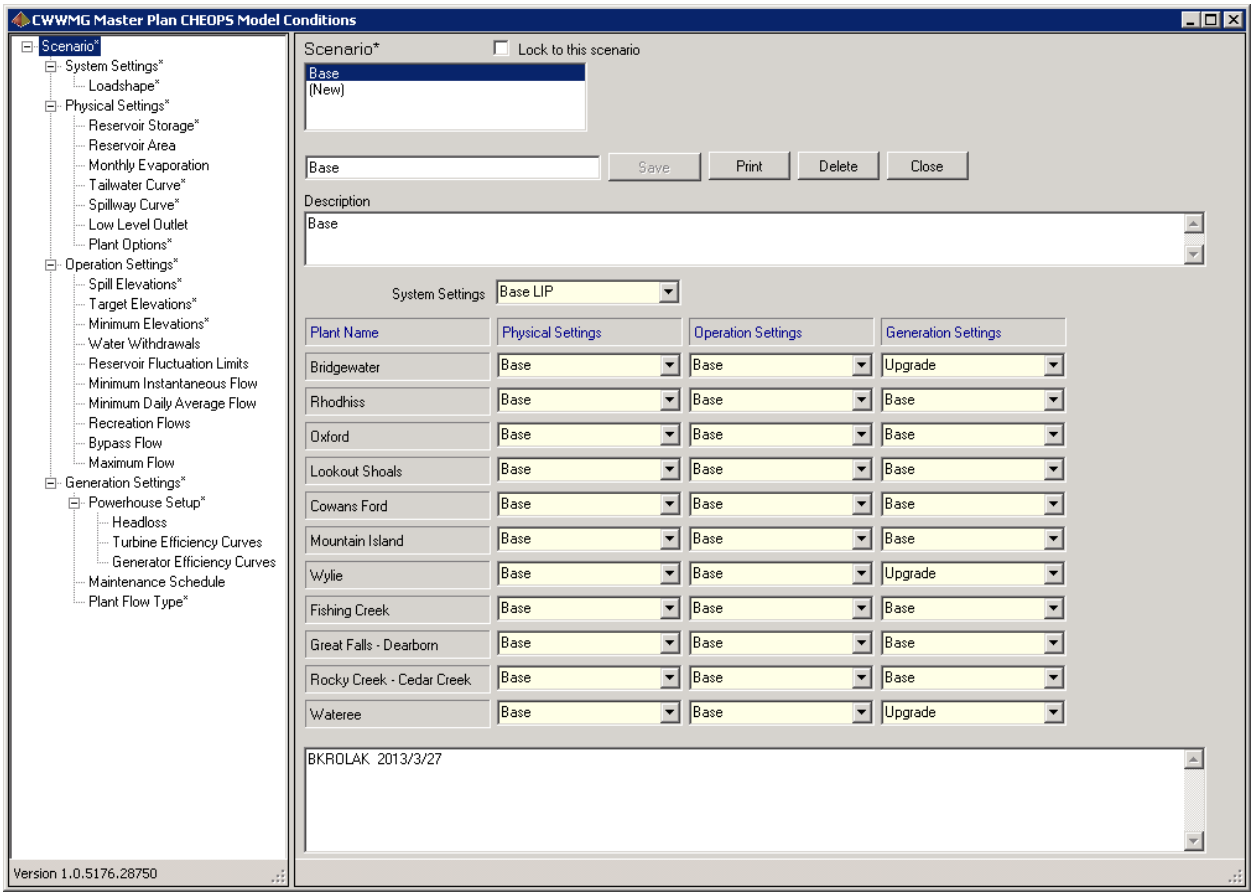
FIGURE 3-20
LOADSHAPE



3.1.2.7 Scenario Interface

After the user has entered all the requirements and settings into conditions and created all the Settings, the next step is to combine them into a Scenario. This is similar to creating the Settings and System Settings. Scenarios are set up by clicking Scenario in the tree view navigation panel, shown in Figure 3-21. This form contains a list of all the plants and dropdown boxes that contain all of the previously-built Settings for each plant in the appropriate Settings category. To create a Scenario, select the desired System Setting, plus Physical, Operational, and Generating Settings for each plant, then save the Scenario.

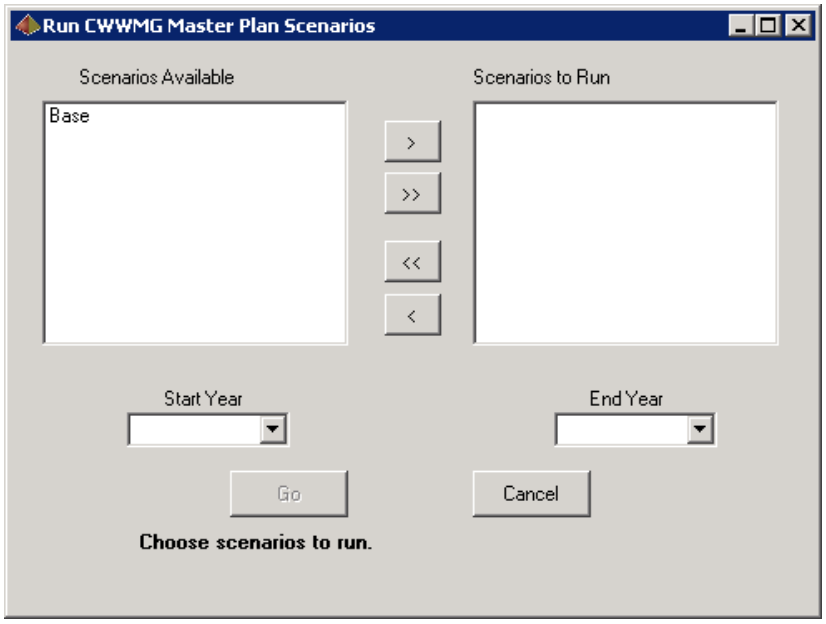
FIGURE 3-21
SCENARIO INTERFACE



3.1.3 Run Scenario Interface

To run a scenario, from the main HDR CHEOPS Model interface in Figure 3-1, click the "Run Scenarios" button. This will activate the Run Scenarios interface shown in Figure 3-22. This interface permits selecting one or more Scenarios to be run. Select a Scenario from the Scenarios Available listbox, and then click the right arrow (or double click the scenario name) to add that Scenario to the Scenarios to Run listbox. The user can also remove Scenarios from the list by selecting the undesired Scenario and clicking the left arrow (or double clicking the scenario name). Choose the beginning and ending hydrologic years in the Start Year and End Year dropdown boxes. Click the Go button to start the model run(s). It is important to not perform any Excel operations when the model runs, as the model will open and read input files. If the modeler is performing other activities in Excel simultaneously, then there is a chance the model may read from an inappropriate cell or workbook.

FIGURE 3-22
RUN SCENARIOS INTERFACE



The Model performs the scheduling for each chosen scenario, advancing through the Scenarios in the sequence shown in the listbox. The daily inflows, releases, elevations, and generation are computed and written to output files.

The CHEOPS model produces a detailed data output file for each plant for each year. Each detailed daily output file is approximately 3 to 4 MB in size. Hard drive space can be used up quickly if the model writes the detailed output files for many scenario runs over numerous multi-year periods.

The model displays a status bar during model operation. A label on the form informs the user as to which scenario is being run and which date is being calculated. Not all days will take the same amount of time, and not all scenarios take the same amount of time. Some days or scenarios require more calculations due to conditions being applied and upstream/downstream support modifications to detailed schedules.

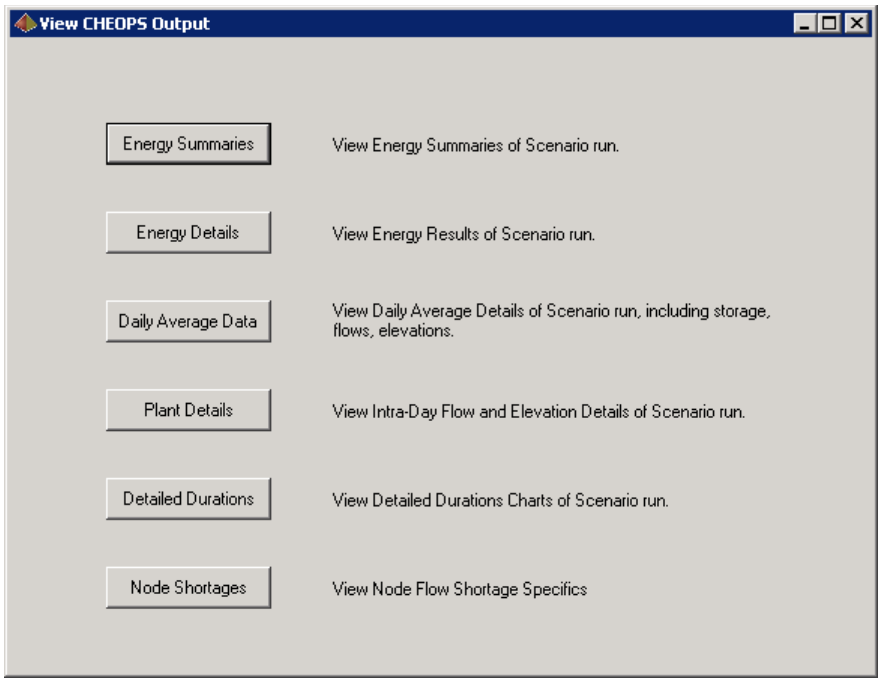
When the model has finished the scenario runs, a dialog is displayed indicating run completion and the amount of time elapsed for the runs. The user can then return to the main HDR CHEOPS Model interface and select "View Output," to view the output.

If the Cancel button is clicked during the model run, the user is prompted to confirm aborting the model run. If the user confirms the desire to cancel the run, then the current and any pending scenarios are not run. The current scenario will have incomplete output data and should be rerun before any analysis of output data is performed.

3.1.4 View Output Interface

From the main HDR CHEOPS Model interface, clicking the "View Output" button will activate a form listing output viewer options. This form is shown in Figure 3-23. Clicking on any of the options will result in an Excel workbook being opened, certain data cells being populated, and the workbook made available to import and view data. See Appendix B for instructions on how to operate the Excel-based output viewers.

FIGURE 3-23
VIEW OUTPUT INTERFACE



Output data is written to CSV files and grouped in a folder with the scenario name in several output files as described below. Example file names use the scenario name "Base." These output files can be opened in Notepad, Wordpad, Excel, and other applications for viewing or for other uses.

- Daily Average Data (Base_DailyAvg_Plant1.csv) – One file per plant per scenario run. Includes daily average, day ending, or user-input condition requirements for the scenario . This data is also in the "Base.dss" file.

- Detailed Data (Base_Details_Plant_1_1929.csv) – One file per plant per year of the scenario run. Includes detailed data including inflows, outflows, elevations, gross head, and generation.

- Discrepancy Log Data (DiscrepancyLog_Base.csv) – One file per scenario run. Shows the plant number, date, and violation information if a user-entered constraint was not met.

- Debug Data (Debug_Base.csv) – One file per scenario run. Shows information useful for tracking when a certain conditions were triggered.

- Generation Summaries (Base_GenSummaries.csv) – One file per scenario run. Shows monthly generation in MWh for each year at each plant.

- Node Flows (Base_NodeFlows_Basin_1.csv) – One file per plant per year of the scenario run. Includes daily average withdrawal minus return flow, accretion, and streamflow as well as downstream node and incremental drainage area for each node in the basin. The flows data from this file is also in the "Base_Nodes.dss" file.

- Basin Data (BasinData.csv) – One file per scenario run. Lists each basin ID, name, and drainage area.

- HIP Log (HIPLog_Base.csv) – One file per scenario run. Lists dates when HIP is in effect.

- LIP Log (LIPLog_Base.csv) – One file per scenario run. Shows LIP calculation values for each month.

- Node Data (NodeData.csv) – One file per scenario run. Lists each node ID with corresponding sub-basin number, state, withdrawal type, downstream node, drainage area, incremental drainage, drainage area percent, and indication of upstream nodes.

- Node Flow Shortage Log (NodeFlowsShortageLog_Base.csv) – One file per scenario run. Shows node information, date, and flow shortage if a node did not meet the flow requirement.

- Recreation Flows Grid (RecFlowsGrid.csv) – One file per scenario run. Shows a matrix of plant ID and dates that indicates True for dates where a recreation flow is in effect at a given plant.

- Recreation Flows Log (RecFlowsLog_Base.csv) – One file per scenario run. Lists recreation flow volumes and reductions by date.

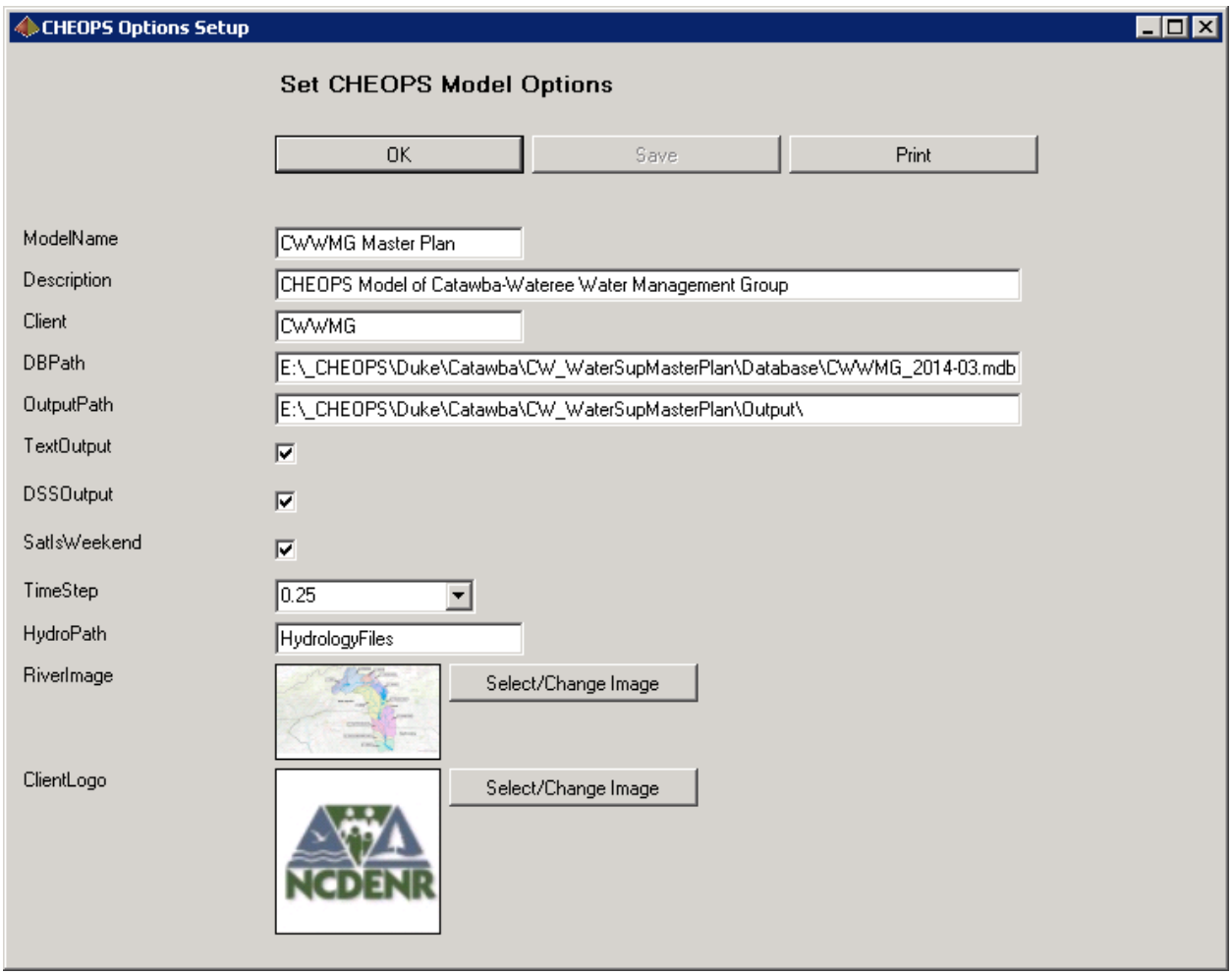
- Scenario Conditions (Scenario_Conditions_Base.csv) – One file per scenario run. Compiles model input data used for the scenario run.

The Excel output viewers contain macros and functionality to import, tabulate, query, and display data in a user friendly fashion. The files are provided as a tool to quickly review output data. The files can be modified if additional functionality is desired. These files save automatically when the file is closed or Excel is closed. If the file becomes corrupt, or changes inadvertently made, replace the appropriate Excel file in the model Output folder with an original copy from the installation media.

3.1.5 CHEOPS Options Setup

From the main HDR CHEOPS Model interface, clicking the "Set CHEOPS Options" button opens the CHEOPS Options Setup interface, shown in Figure 3-24. ModelName, Description, and Client fields allow the user to set general information about the model. DBPath and OutputPath specify the file path for the CHEOPS database file and the folder for model output storage, respectively. The user can enter a file path or double click the field and select the appropriate file or folder. The database file and output folder are further described in Appendix C.

FIGURE 3-24
CHEOPS OPTIONS SETUP



The TextOutput and DSSOutput options allow the user to specify desired output format. The model will generate text output if TextOutput is checked and DSS output if DSSOutput is checked. The fastest way to complete a run and output data to DSS is to write output data to text files and then move data from text files into the DSS structure in large sets, so the text output files are always created. If the TextOutput check box is not selected, the output CSV files will be deleted. If SatIsWeekend is checked, the model defines weekends as Saturday and Sunday. All weekday settings within the model refer to Monday through Friday. If SatIsWeekend is left unchecked, weekday settings refer to Monday through Saturday and weekend settings allow the user to specify alternate Sunday operations. TimeStep specifies the time increment of the model, in units of hours. The Savannah River CHEOPS model uses a 15-minute time increment, so the TimeStep field is set to 0.25, and only this value should be used. HydroPath specifies the folder name containing the hydrology file, as discussed in Appendix C. RiverImage and ClientLogo personalize the model interface images. When the modeler clicks on the Select/Change Image

button, a File Open dialog is opened to allow the modeler to select a JPG image of approximately proportional size and appropriate orientation for import into the database. The file is imported to the database and subsequently used within the model. The original image source file can be moved or deleted as desired.

When the model is installed, the program will be configured appropriately for the river system model installation being distributed. If the modeler chooses to modify some of the input options, then depending on the item being modified, certain other fields are disabled. For example, the DBPath and OutputPath values are stored in a text configuration file that is read when the program first starts. Once the database has been identified and opened, the remaining fields and scenario information is made available. So if the user modifies the DBPath field, all other fields other than OutputPath are disabled (unavailable for editing) since the first field being modified is a path field. Conversely, if the ModelName field is changed, the paths are disabled, since one cannot change a path to the database and a field within that database simultaneously.

3.1.6 Plant Setup

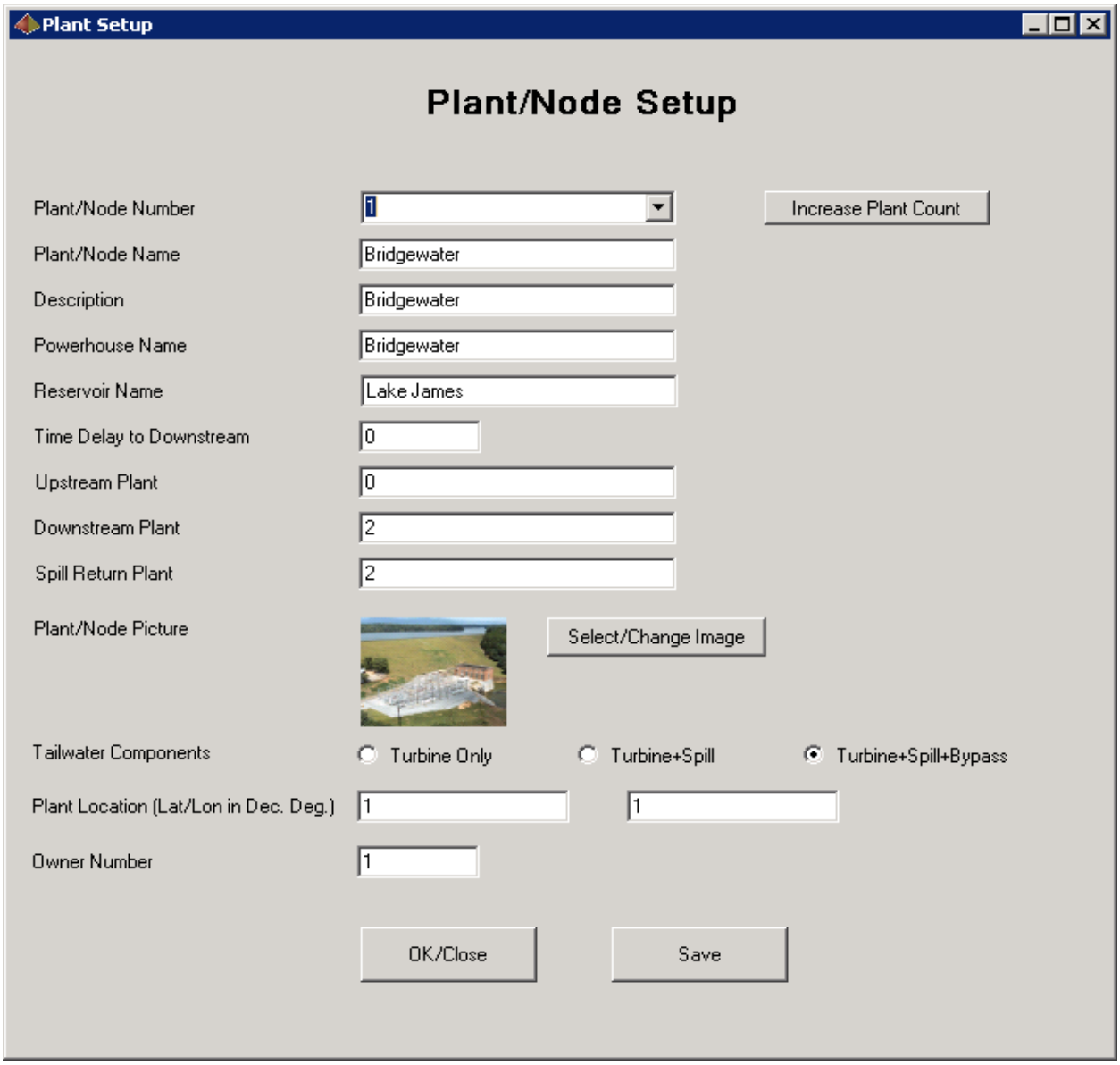
From the main HDR CHEOPS Model interface, clicking the "Plant Setup" button opens the Plant Setup interface, shown in Figure 3-25. Plant Setup specifies the system connectivity and is not typically modified in normal model use.

Each plant or node in the system is given a number. The Plant/Node Name, Description, Powerhouse Name, Reservoir Name, and Plant Location fields describe the plant or node and permit site-specific customization. Time Delay to Downstream specifies the time delay in units of hours. Tailwater Component identifies what flow components contribute to tailwater. If the plant or node does not contain a powerhouse, then Tailwater Component selection is irrelevant. Owner Number is a consistent number for each owner in the system. Owner Number is used for delinked owner/delinked system operations described in Section 2.1.3.9.

Upstream Plant, Downstream Plant, and Spill Return Plant describe the system connectivity. These fields accept valid plant numbers or 0. Upstream plant refers to a single upstream plant that can provide support to the plant in question through powerhouse or discretionary discharges. Downstream Plant specifies the number of the downstream plant which receives the powerhouse discharge from the currently selected plant. The same downstream plant can be specified by

more than one upstream plant. Spill Return Plant specifies the plant that receives spill, which may be different than the downstream plant depending on system configuration. In Figure 3-25, Bad Creek is the most upstream dam in the system, so Upstream Plant is 0, and Downstream Plant and Spill Return Plant refer to the same plant.

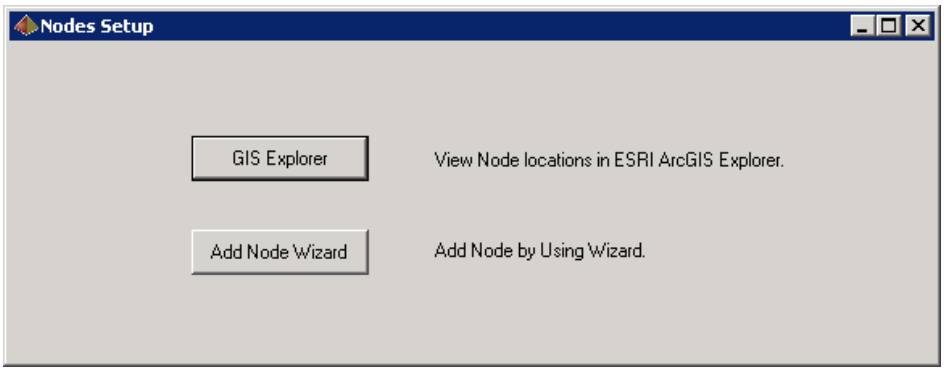
FIGURE 3-25
PLANT SETUP



3.2 Nodes Setup Interface

From the main HDR CHEOPS Model interface the user can access the Nodes Setup interface, shown in Figure 3-26. The Nodes Setup interface allows the user to view node locations and connectivity and add nodes to the model.

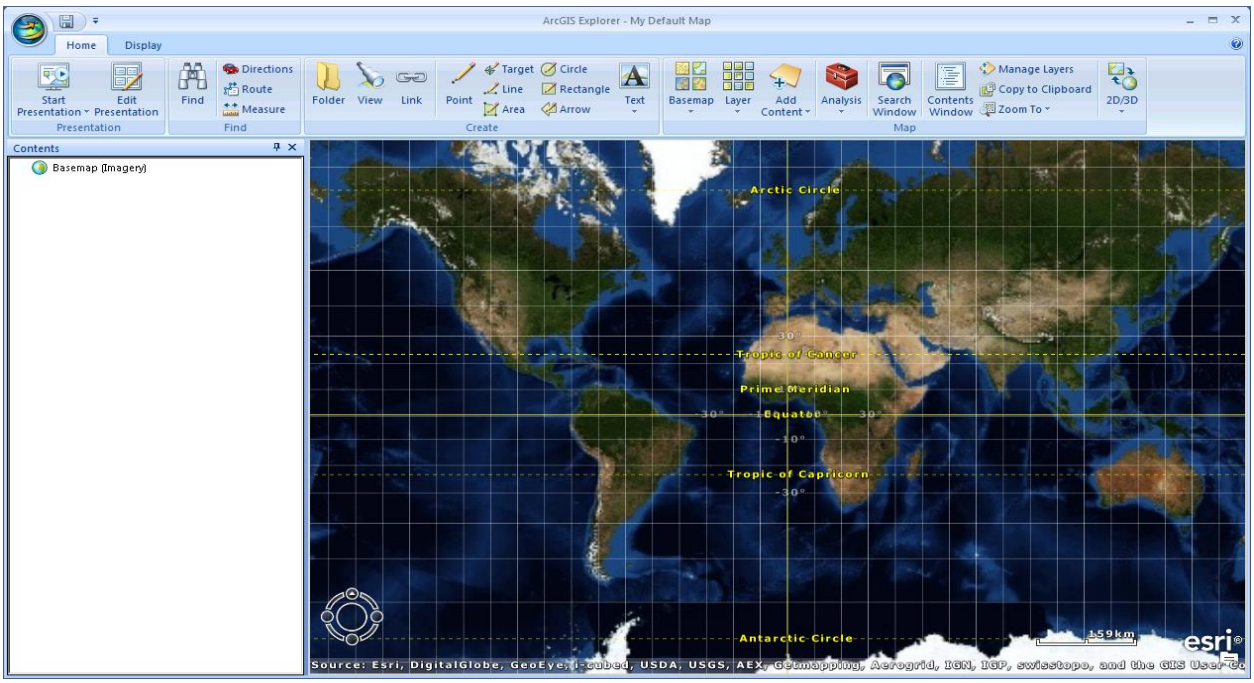
FIGURE 3-26
NODES SETUP INTERFACE



3.2.1 GIS Explorer

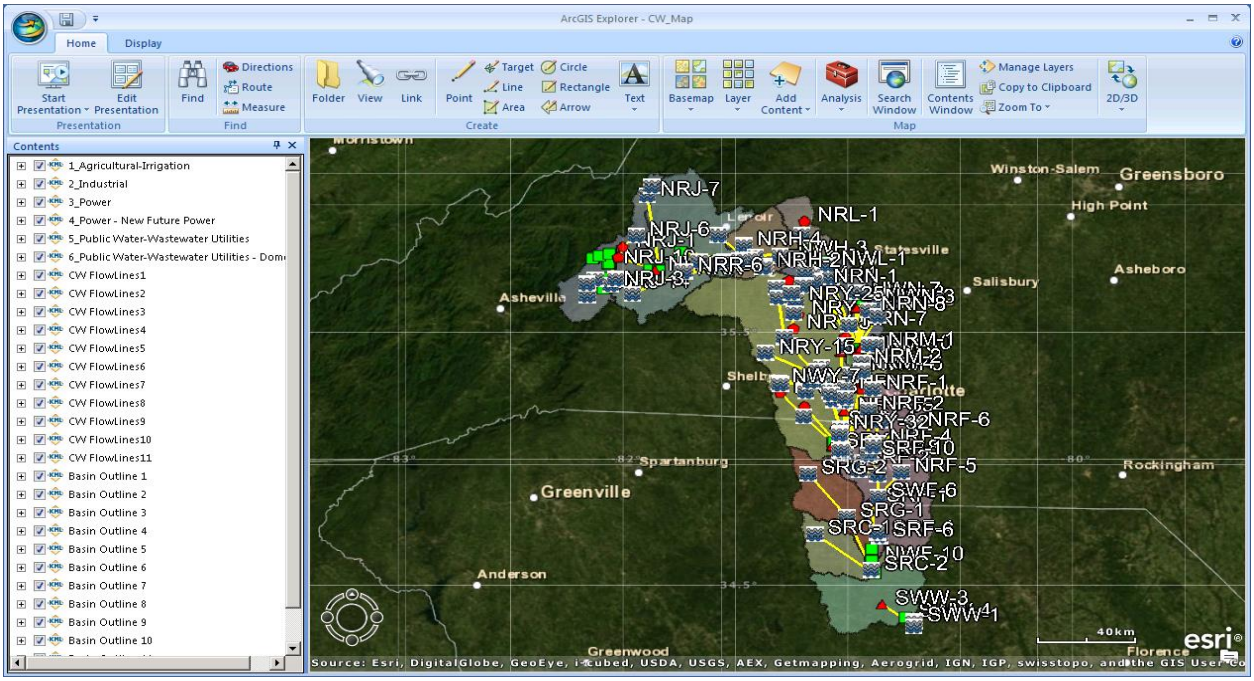
The GIS Explorer button opens ESRI ArcGIS Explorer, shown in Figure 3-27. ESRI ArcGIS Explorer software is bundled with this version of CHEOPS so a separate installation is not necessary. CHEOPS generates GIS files that allow the user to view basins, nodes, and node connectivity established by the model. These files are updated when the user adds nodes using the Add Nodes Wizard.

FIGURE 3-27
ESRI ARCGIS EXPLORER



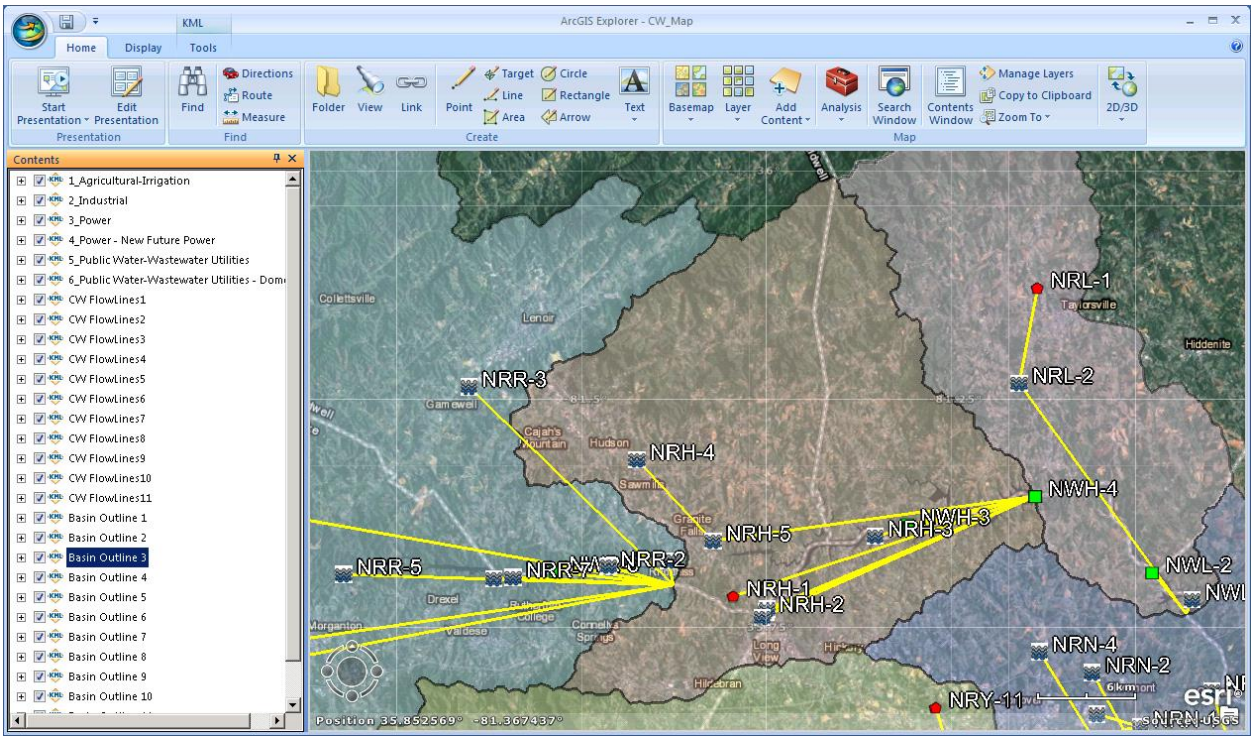
Click the upper left hand corner globe image and select Open. Navigate to the CHEOPS directory, open the KMLs folder, and open CW_Map.nmf (\KMLs\CW_Map.nmf). ArcGIS Explorer will load the map file and show Figure 3-28.

FIGURE 3-28
CATAWBA-WATEREE GIS MAP



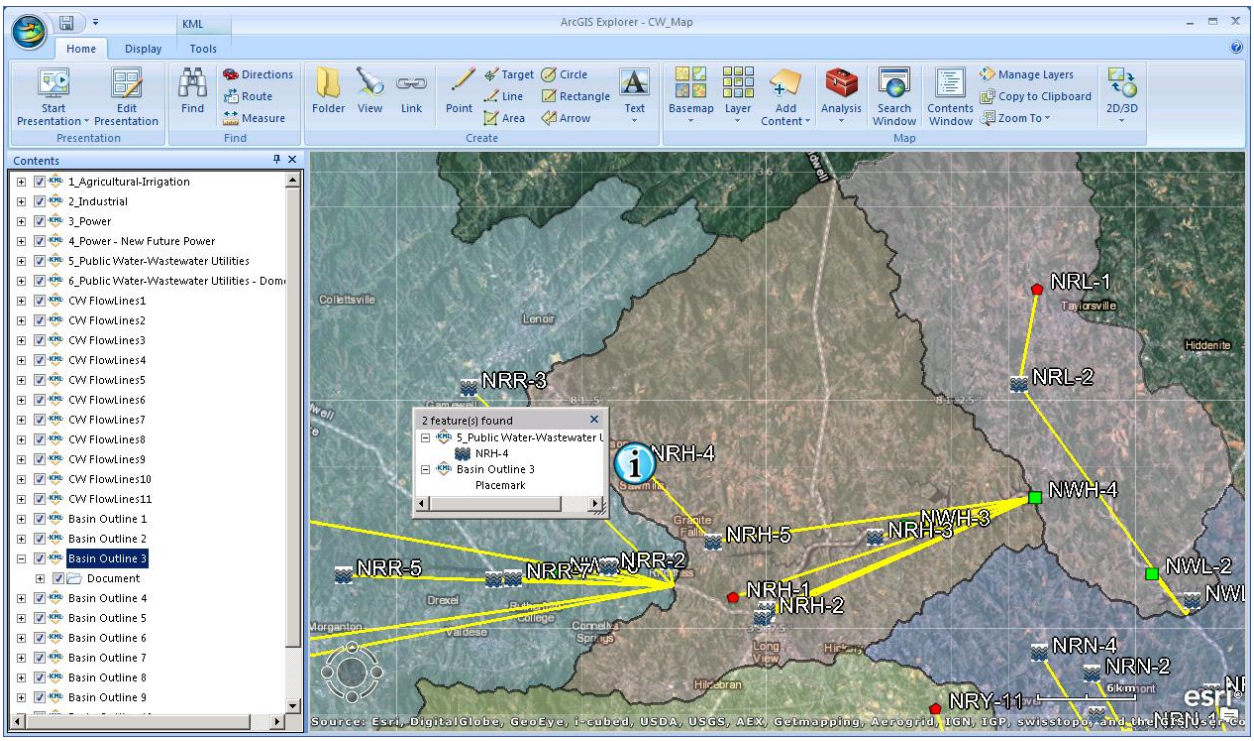
The GIS interface presents labels and icons for each node as well as flowlines indicating connectivity within each basin. Node icons vary based on node category. Figure 3-29 highlights a single basin. NWH-3 and NWH-4 are Agricultural/Irrigation nodes, NRH-1 is an Industrial node, and other visible nodes are Public Water/Wastewater nodes. Yellow flowlines show how NRH-4 flows to NRH-5 and other nodes flow to the basin.

FIGURE 3-29
BASIN IN ARCGIS



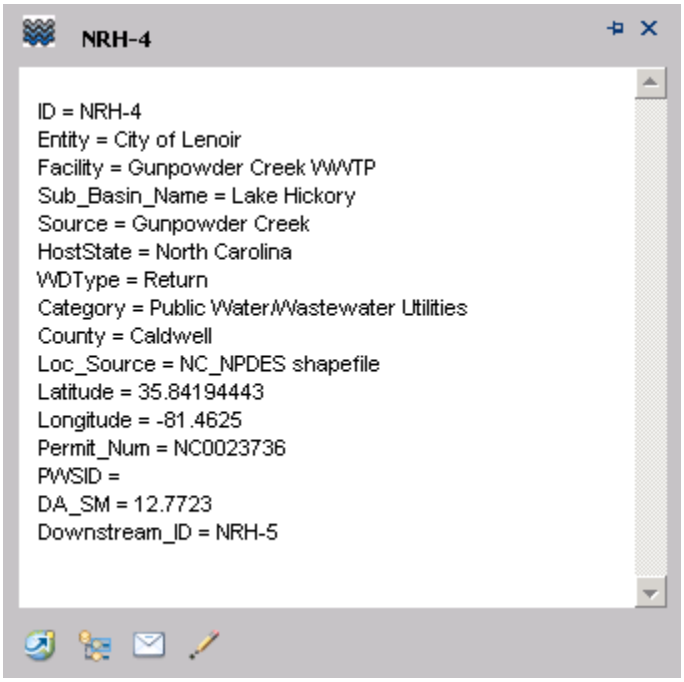
Clicking on a node shows information about the node, as in Figure 3-30. When multiple nodes have the same latitude and longitude, only one node ID will be visible on the map, but clicking on the node will show all of the nodes at that location.

FIGURE 3-30
ACCESSING NODE INFORMATION IN ARCGIS



Selecting the node feature from Figure 3-30 pulls up detailed node information, shown in Figure 3-31.

FIGURE 3-31
DETAILED NODE INFORMATION IN ARCGIS



3.2.2 Add Node Wizard

The recommended way to add new nodes to the model is through the Add Node Wizard. The Add Nodes Wizard guides the user step by step through the node addition process and ensures that all information necessary for a successful model run is included. The user can also add nodes by modifying the Nodes.mdb file directly, but this method is not recommended as node naming conventions and serial numbers may be incorrectly set without extreme diligence.

When the user selects the Add Node Wizard from the Nodes Setup interface, the user is prompted to confirm their desire to add a node to the Nodes.mdb database, as in Figure 3-32. Select "Yes" to continue with the wizard, then select "OK" in Step 2, Figure 3-33 to confirm your understanding of the wizard process.

FIGURE 3-32
ADD NODE WIZARD STEP 1: WIZARD CONFIRMATION

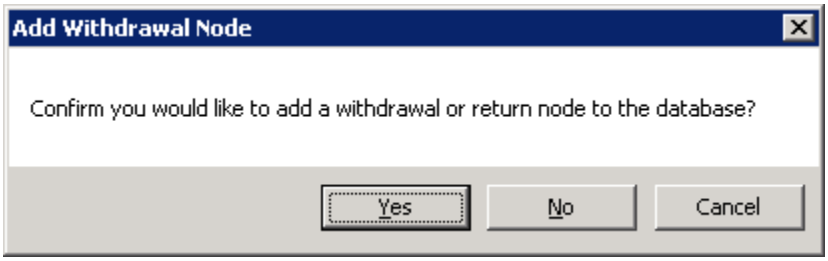
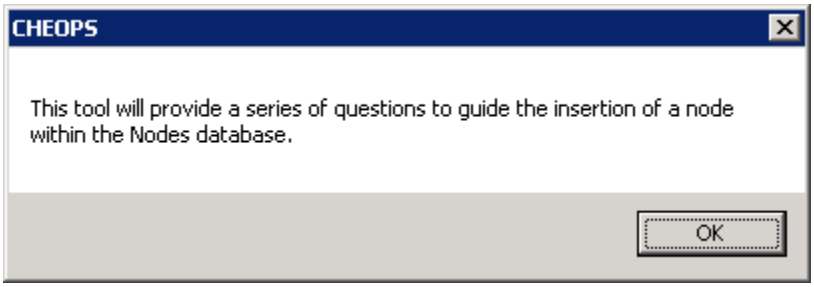
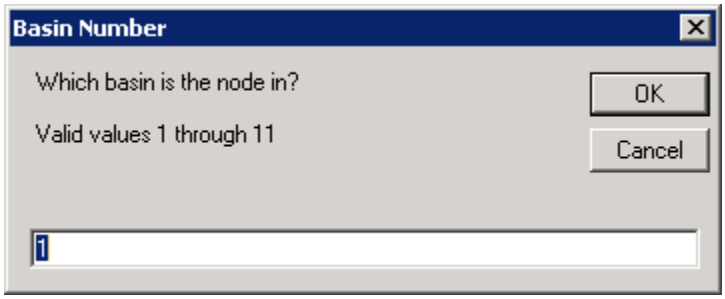


FIGURE 3-33
ADD NODE WIZARD STEP 2: WIZARD DESCRIPTION



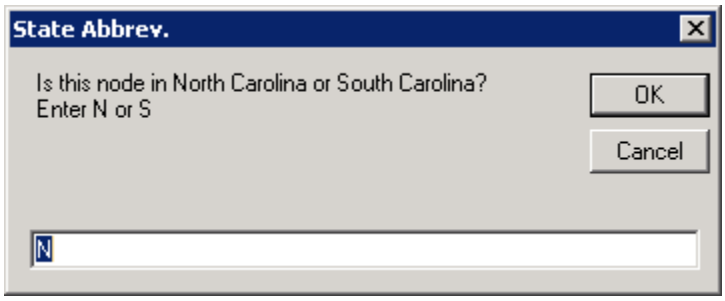
In Step 3, Figure 3-34, select which basin the node is located in. If the basin is located in only one state, the state is added to the node metadata automatically.

FIGURE 3-34
ADD NODE WIZARD STEP 3: BASIN



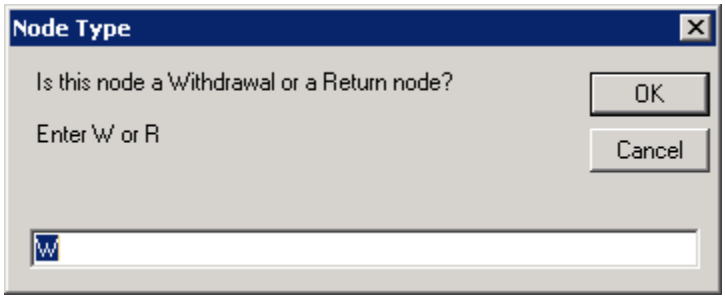
If the basin is located in basin 7 or 8, the node could be in either North Carolina or South Carolina. In Step 4, Figure 3-35, the user is prompted to indicate which state the node is located in. The state name is one piece of information associated with the node (i.e. node metadata). It is not currently used for model calculation.

FIGURE 3-35
ADD NODE WIZARD STEP 4: STATE



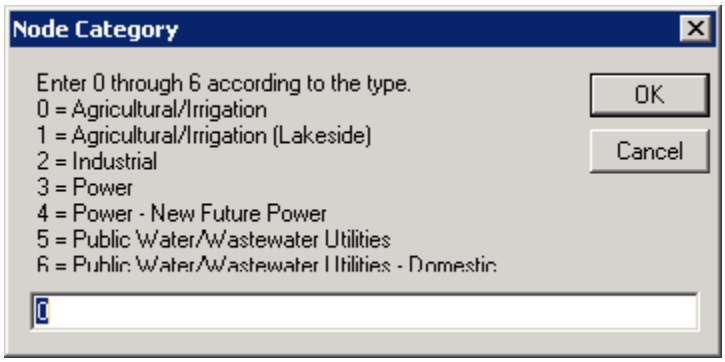
In Step 5, Figure 3-36, enter "W" if the node is a withdrawal node and "R" if the node is a return node.

FIGURE 3-36
ADD NODE WIZARD STEP 5: WITHDRAWAL OR RETURN



In Step 6, Figure 3-37, enter the number corresponding to the node category. The node category list is generated from existing categories in the Nodes.mdb database. New categories cannot be created in the Add Node Wizard.

FIGURE 3-37
ADD NODE WIZARD STEP 6: NODE CATEGORY



Steps 7 to 11, Figures 3-38 to 3-46 prompt for relevant node metadata. Entity name and facility name are required. When the prompt indicates "Blank OK.", the user can delete the default value from the text box and select "OK" instead of providing the requested information.

FIGURE 3-38
ADD NODE WIZARD STEP 7: ENTITY NAME

FIGURE 3-39
ADD NODE WIZARD STEP 8: FACILITY NAME

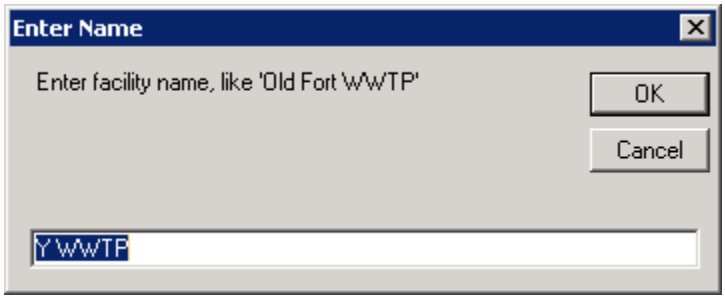


FIGURE 3-40
ADD NODE WIZARD STEP 9: SOURCE WATER BODY

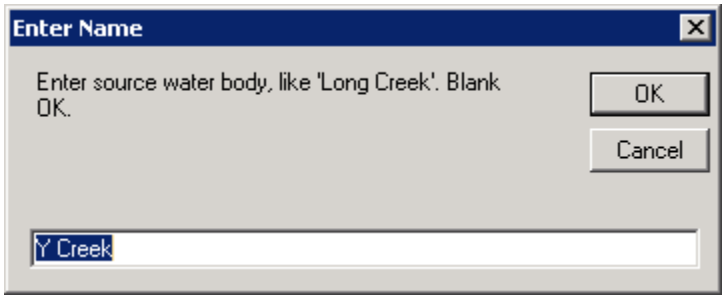


FIGURE 3-41
ADD NODE WIZARD STEP 10: COUNTY NAME

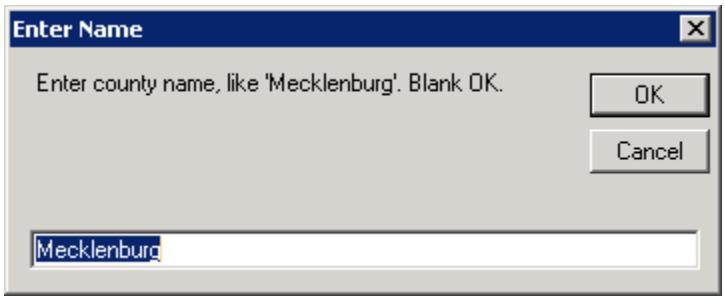
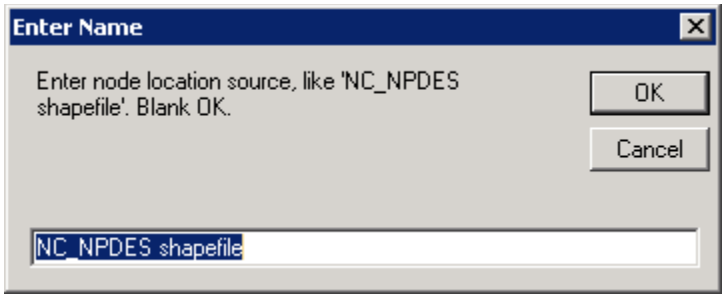


FIGURE 3-42
ADD NODE WIZARD STEP 11: NODE LOCATION SOURCE



If latitude or longitude values are blank, the Add Nodes Wizard will assign estimated values so the node can be viewed in ArcGIS Explorer.

FIGURE 3-43
ADD NODE WIZARD STEP 12: LATITUDE

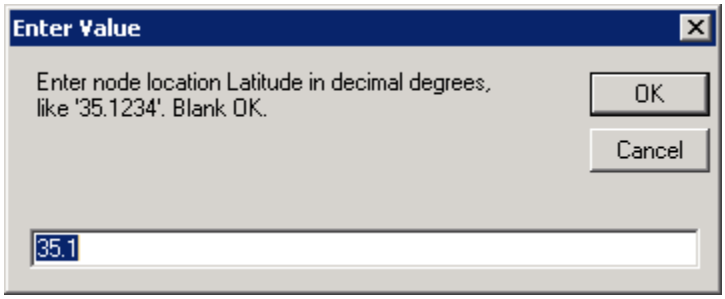


FIGURE 3-44
ADD NODE WIZARD STEP 13: LONGITUDE

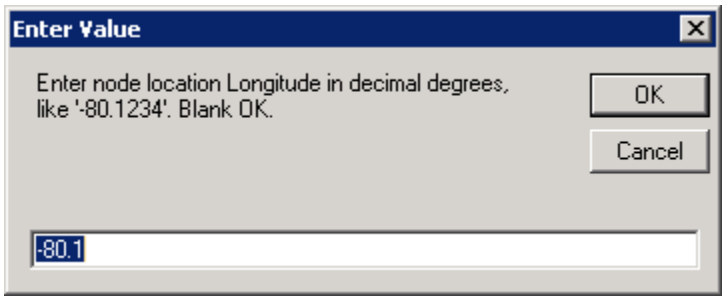


FIGURE 3-45
ADD NODE WIZARD STEP 14: PERMIT NUMBER

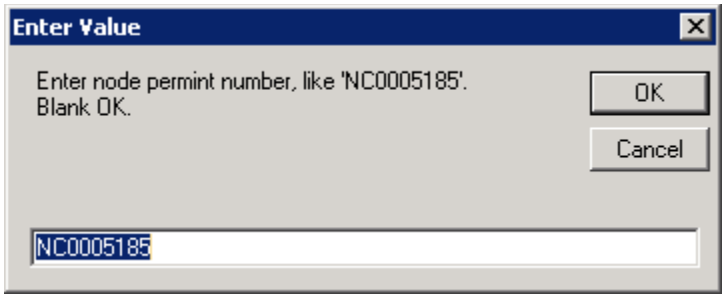
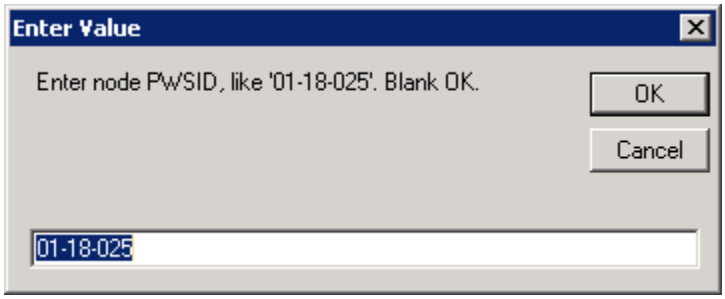
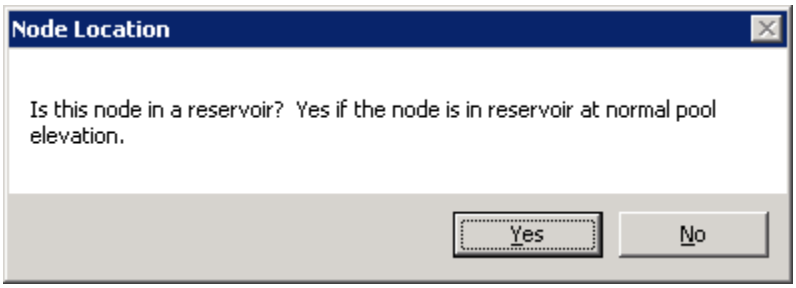


FIGURE 3-46
ADD NODE WIZARD STEP 15: PWSID



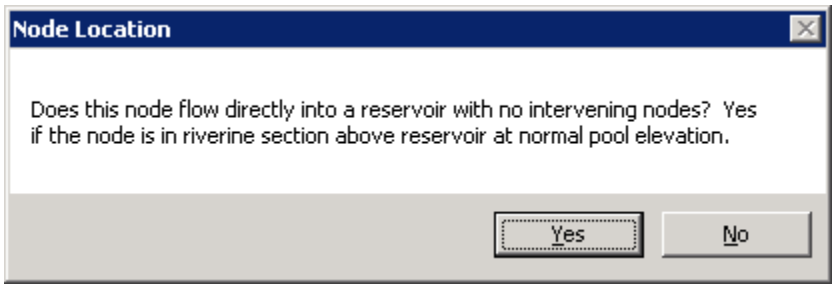
If the node is in a reservoir, the downstream node is the reservoir and all withdrawals and returns for the node are considered to come from the reservoir. Selecting yes to the prompt in Step 16, Figure 3-47 skips to the upstream node prompt.

FIGURE 3-47
ADD NODE WIZARD STEP 16: IN RESERVOR PROMPT



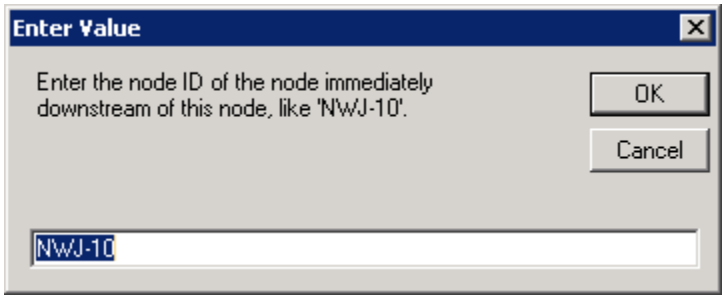
If the node is not in a reservoir, but does flow directly into a reservoir, the reservoir is set as the downstream location. Selecting yes to the prompt in Step 17, Figure 3-48 skips to the upstream node prompt.

FIGURE 3-48
ADD NODE WIZARD STEP 17: TO RESERVOR PROMPT



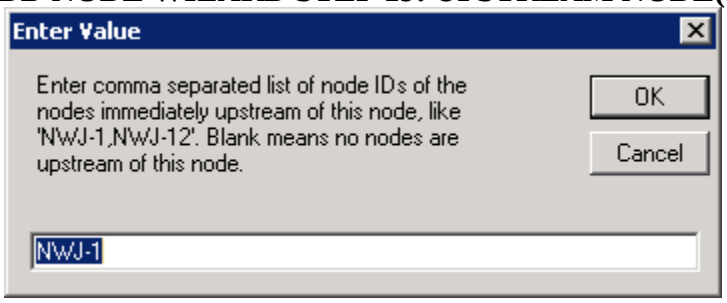
If the node is not in a reservoir and does not flow directly into a reservoir, the user is prompted for the downstream node ID in Step 18, Figure 3-49.

FIGURE 3-49
ADD NODE WIZARD STEP 18: DOWNSTREAM NODE



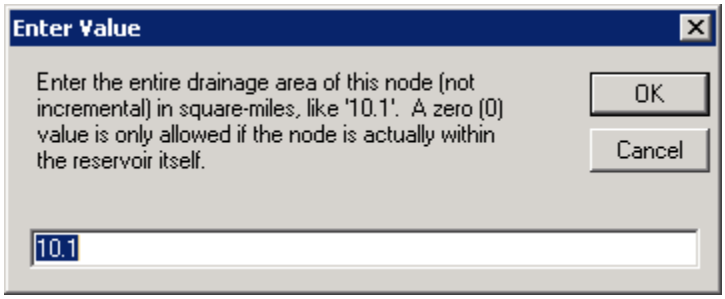
Though each node has only one downstream node, it can have multiple upstream nodes. Upstream nodes are entered in Step 19, Figure 3-50, separated by commas. In the Nodes.mdb database, node connectivity is established via the downstream node data associated with each node. The Add Node Wizard sets the new node as the downstream node for each node entered in Step 19.

FIGURE 3-50
ADD NODE WIZARD STEP 19: UPSTREAM NODE(S)



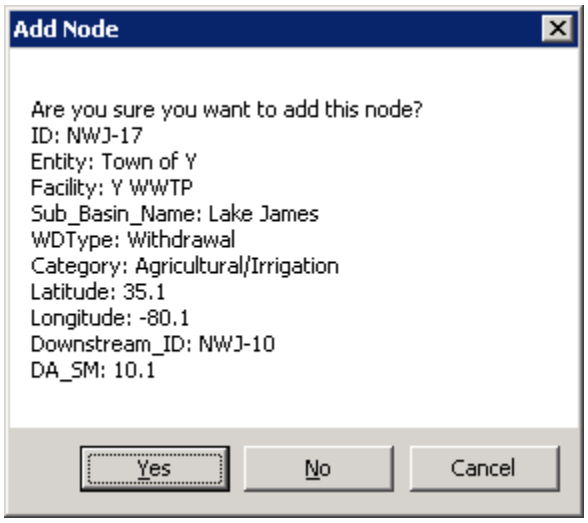
Enter drainage area in Step 20, Figure 3-51. As discussed in Section 2.3.2, drainage area is used to calculate the portion of basin inflow available at the node. Drainage area should be entered as the cumulative upstream drainage area rather than the incremental drainage area between the added node and the upstream node(s). For example, if NWJ-17 is added beneath NWJ-1 and NWJ-1 had a drainage area of 7 square miles and there are 3.1 square miles of drainage area between NWJ-1 and NWJ-17, the user would enter a drainage area of 10.1 square miles for NWJ-17.

FIGURE 3-51
ADD NODE WIZARD STEP 20: DRAINAGE AREA



After the wizard collects all information necessary to create the node, the user is asked to confirm the node addition in Step 21, Figure 3-52.

FIGURE 3-52
ADD NODE WIZARD STEP 21: ADD NODE CONFIRMATION

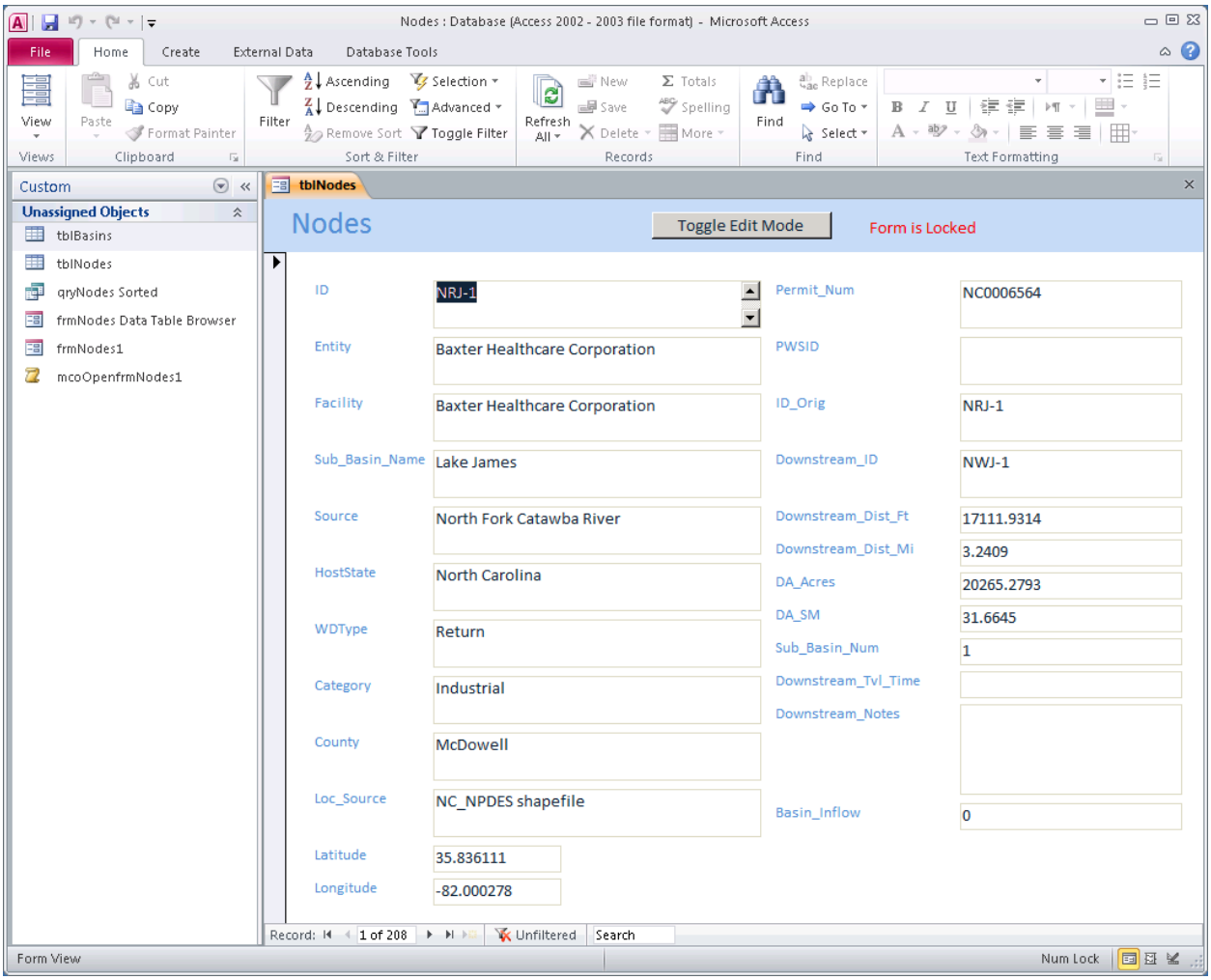


If the user wishes to add a node that receives flow directly from the upstream basin, the user must perform an additional modification. This situation should be relatively infrequent, as basin flows are only of concern when the new node is riverine, on the Catawba River, and added above any existing upstream-most riverine node. After following the steps for the Add Node Wizard, the user should manually add the upstream basin number to the "Basin_Inflow" column in tblNodes of the Nodes.mdb database for the new node. If the upstream basin number is applied to any other column in the "Basin_Inflow" column, the user must decide which node should receive the basin inflow. The upstream basin number must not be assigned to more than one node.

3.2.3 Viewing and Editing Node Data

Node data is stored in the Access database Nodes.mdb, located in the model's \Database folder (\Database\Nodes.mdb). The user must use Windows Explorer to browse to the appropriate folder and double click on the file. Alternatively, start Microsoft Access and open the Nodes.mdb file. Double-clicking on the entry mcoOpenfrmNodes1 runs a macro which opens the view shown in Figure 3-53. The user can navigate through all of the node records using the record navigation at the bottom of the window or can find specific information by right clicking in a box and using text or number filters.

FIGURE 3-53
VIEW/EDIT NODE DATA ACCESS INTERFACE

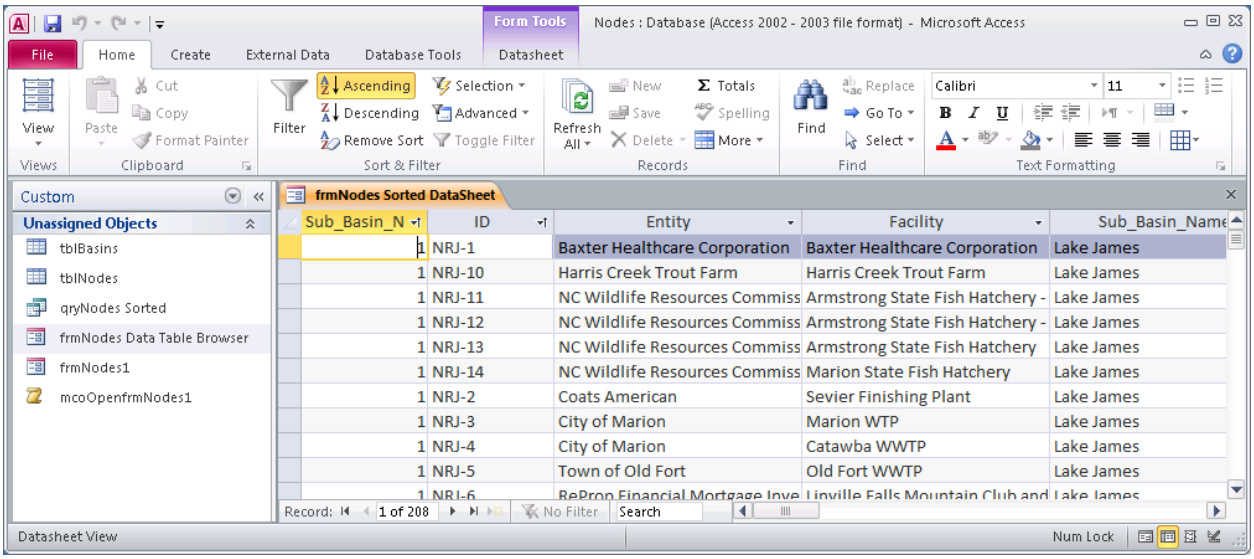


The interface in Figure 3-53 opens as a locked form. The user can view node data, but cannot make changes. Selecting the Toggle Edit Mode button allows the user to make changes to the node information. The Toggle Edit Mode button changes the form from locked to editable, as shown in Figure 3-54. Edits made to this form are stored to the database when the user navigates to a new node record. Selecting the button a second time locks the form once more.

FIGURE 3-54
TOGGLE EDIT MODE BUTTON

On the left hand menu, "frmNodes Data Table Browser" allows for Read-Only access to the tblNodes data. All other (sorting, filtering, searching) functionality within a typical table view are enabled. Figure 3-55 shows "frmNodes Data Table Browser."

FIGURE 3-55
DATA TABLE BROWSER ACCESS INTERFACE



Model information is stored in the data tables titled "tblNodes" and "tblBasins."

APPENDIX A
CATAWBA RIVER CHEOPS
LOW INFLOW PROTOCOL INPUT EXCEL FILE

Appendix A

Catawba River CHEOPS Low Inflow Protocol Input Excel File

The Catawba River CHEOPS model has additional logic to implement operations as required by the December 22, 2006 Comprehensive Relicensing Agreement between Duke Energy Carolinas, LLC (Duke) and stakeholders. To allow for a more flexible and easily transportable condition input mechanism, an Excel file has been formatted to allow the modeler to set conditions and input values to affect this unique logic.

1. Overview

    a. The Excel file is strictly formatted to contain specific values or value types. If the modeler enters non-numeric values in a cell where the model is expecting a numeric value, the model with either skip the condition, assume a standard value, or cease operating. The Excel file is opened and read at the start of the scenario run sequence. If read failures or file access errors occur, the modeler is notified at the beginning of the scenario run sequence.

    b. Cells which have a yellow fill pattern are locations where the user can modify or enter data. In a few instances, the model will expect one of a limited set of options, and in that case a data validation combo box is used to guide the user for proper input.

    c. In general, cells to the right or below yellow cells and table can be modified by the modeler for notes or calculations. Do not insert rows or columns which will cause the existing tables or data cells to be moved. The model will not hunt for values if the expected input is not found in the expected cell.

    d. Cell comments are entered in certain cells to inform the modeler as to the purpose of the cell values or options.

    e. Three worksheets (tabs) are used for reading data. Do not rename or resequence these sheets, as the model is expecting the basic structure to be retained.

2. "Data" Sheet - This sheet contains input parameters from the Low Inflow Protocol (LIP). Although CHEOPS has logic to support typical inter-reservoir support depending upon "Delinked – Owner" and "Delinked – System" settings, the wording of the 1968 MOA requires additional logic and inputs. Below is a description of the input cells and their purpose. Figure 1 shows a screen capture of the Drought Plan Input file for reference.

    a. Cells B3:B5 – Modeler annotation/record keeping cells

    b. Cell L4 – Identifies the day of the month for computing the LIP stage.

c. Cells B9 to L9 – Critical elevations for each reservoir in relative (Duke) datum.

d. Cells B13 to L24 – This is a table for iputting critical flow values. Each reservoir/basin is shown in the columns. The rows correspond to the twelve months of the year. At the intersection is the critical flow value which must be released from the reservoir. This critical value is used in computing the LIP-reduced values of the bypass and recreation flows. In any case, the critical flow must be met regardless of consequences to the reservoir elevation.

e. Cells B28 to E32 – This table is where the various conditions which describe the LIP stages is entered. Data is entered in yellow cells. Column B contains the "Ratio Less than or Equal to" component of LIP rules, and column C contains the "Ratio greater than" component. Column D contains the 6-month USGS gage hydrology sum conition. Column E contains the drought monitor (DM) condition which corresponds to an LIP stage.

f. Cells B36:P40 – This table contains the action requirements which correspond to the LIP stages. The five LIP stages (0 through 5) are shown in rows, and under the columns are various data items:

    i. Column B – Licensee Delay in days of implementing the actions required. The value "1" indicates a 1 day delay.

    ii. Column C – NLPF Reduction (%). This percent reduction is the reduction which is applied to the difference between the Non-Licensed Production Flow (NLPF) and the Critical Flow value. Thus, a value in the Stage 1 row of 60% indicates that the daily average flow is modified for a plant as follows:

        1. New Daily Average (NLPF) Flow = Critical Flow + (1-0.6)*(Original Daily Average Flow - Critical Flow)

    iii. Column D – Bypass Reduction (%) to difference between Bypass flows and Critical Flow. Percent value which corresponds to the reduction to the Bypass Flows for each LIP stage.

    iv. Column E – Recreation Flows Reduction (%) to difference between Recreation Flow and Critical Flow. Percent value which corresponds to the reduction to the Rec Flows for each LIP stage.

    v. Columns F through P – For each reservoir, each row corresponds to the number of feet the normal minimum pool elevation is lowered. Thus, for reservoir 5 (Lake Norman), at LIP stage 2 the normal minimum pool is reduced by 4 feet from the normal minimum pool elevation. Entry of the value "critical" indicates that the critical elevation entered in row 9 is used as the minimum elevation.

g. Ceells B44:I48 – This table contains the reductions in withdrawals for each row corresponding to an LIP stage. In column B is the Owner Delay in implementing the

reductions as LIP stages get worse, with a typical value of 14. For recovery from high LIP stages to less severe stages, there is no delay. In columns C through I are the percent reductions for each withdrawal or return node category. For certain node categories (e.g. agricultural/Irrigation) there is no expected or required reduction in withdrawal rate. Since return nodes typically receive their source water from one or more withdrawal nodes, the return flow values are reduced by the percentage as well as the withdrawal flow values.

3. "Streamflows" Sheet - This sheet contains two tables which are the results of computations from gages of interest. One table, in columns A and B, contains the date (column A) and the sum of the 6-month average flows of the gages of interest. For periods when not all gages were available, active gage data is used. The support file referenced on this sheet is available for extending the data sets when and if desired. The second table, in columns E and F, are the 366 entry table of the daily average flows for each day for the period of record. For each calendar day of a leap year, the daily average flow for that day is shown.

4. "DM" Sheet contains a time series of daily Drought Monitor (DM)values. The DM values are the 3 month rolling average of the drought monitor indexes. These are monitored, computed and reported by Duke on the site referenced in the sheet. If a model is run with the LIP during a period when DM is not available (pre-2006), the model will use only the Streamflows portion of the LIP requirement to compute the LIP stage.

FIGURE 1
SHEET "DATA"

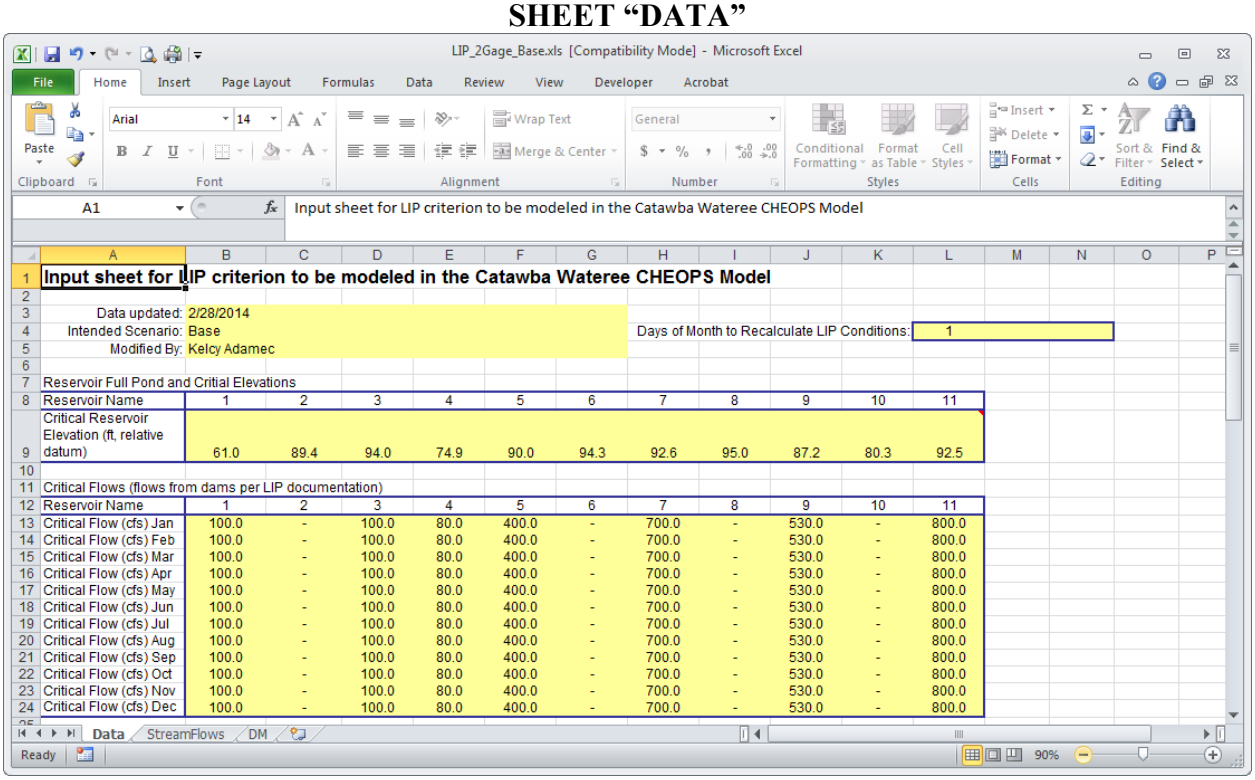
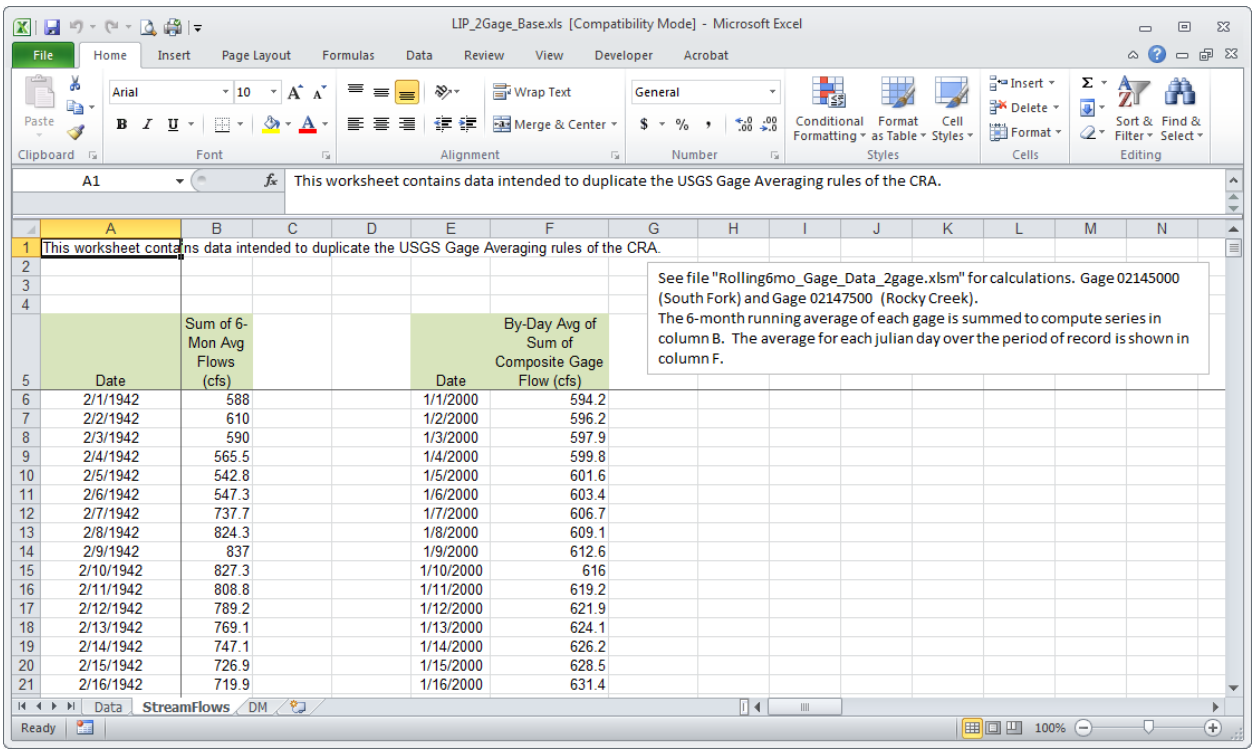


FIGURE 2
SHEET "STREAMFLOWS"

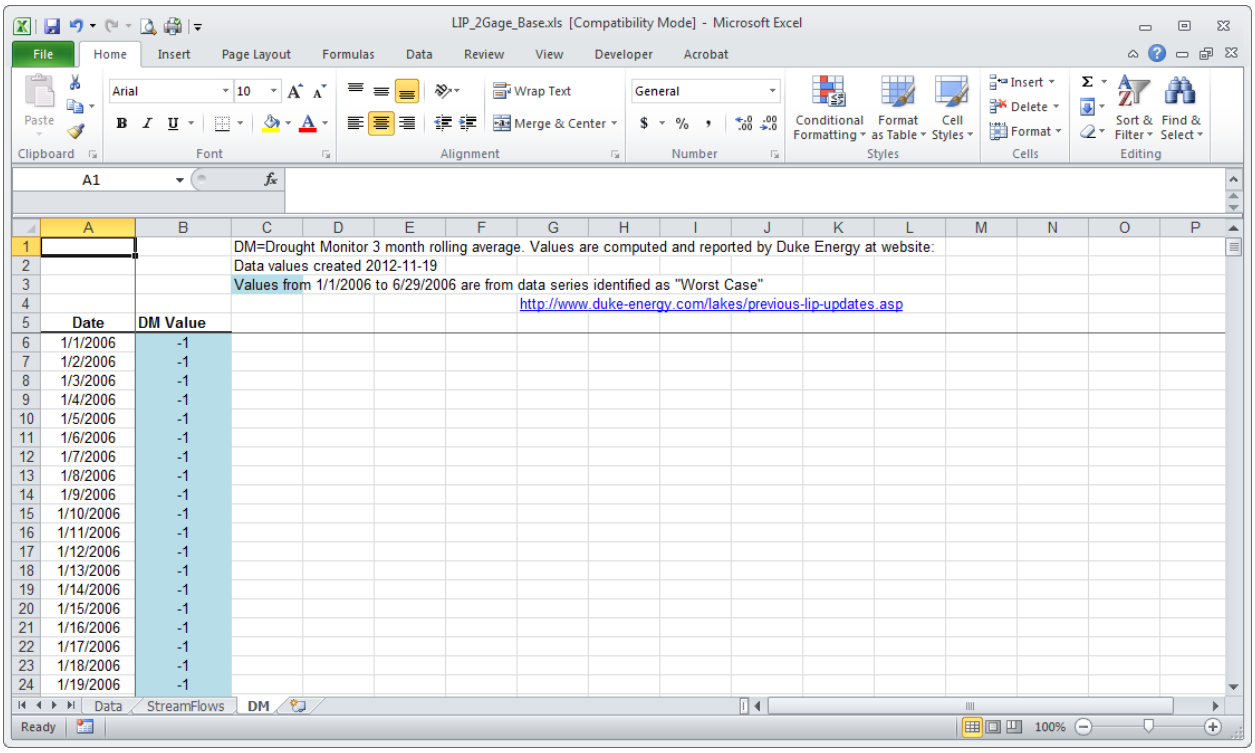


This worksheet contains data intended to duplicate the USGS Gage Averaging rules of the CRA.

See file "Rolling6mo_Gage_Data_2gage.xlsm" for calculations. Gage 02145000 (South Fork) and Gage 02147500 (Rocky Creek).
The 6-month running average of each gage is summed to compute series in column B. The average for each julian day over the period of record is shown in column F.

Date	Sum of 6-Mon Avg Flows (cfs)	Date	By-Day Avg of Sum of Composite Gage Flow (cfs)
2/1/1942	588	1/1/2000	594.2
2/2/1942	610	1/2/2000	596.2
2/3/1942	590	1/3/2000	597.9
2/4/1942	565.5	1/4/2000	599.8
2/5/1942	542.8	1/5/2000	601.6
2/6/1942	547.3	1/6/2000	603.4
2/7/1942	737.7	1/7/2000	606.7
2/8/1942	824.3	1/8/2000	609.1
2/9/1942	837	1/9/2000	612.6
2/10/1942	827.3	1/10/2000	616
2/11/1942	808.8	1/11/2000	619.2
2/12/1942	789.2	1/12/2000	621.9
2/13/1942	769.1	1/13/2000	624.1
2/14/1942	747.1	1/14/2000	626.2
2/15/1942	726.9	1/15/2000	628.5
2/16/1942	719.9	1/16/2000	631.4

FIGURE 3
SHEET "DM"



DM=Drought Monitor 3 month rolling average. Values are computed and reported by Duke Energy at website:
Data values created 2012-11-19
Values from 1/1/2006 to 6/29/2006 are from data series identified as "Worst Case"
http://www.duke-energy.com/lakes/previous-lip-updates.asp

Date	DM Value
1/1/2006	-1
1/2/2006	-1
1/3/2006	-1
1/4/2006	-1
1/5/2006	-1
1/6/2006	-1
1/7/2006	-1
1/8/2006	-1
1/9/2006	-1
1/10/2006	-1
1/11/2006	-1
1/12/2006	-1
1/13/2006	-1
1/14/2006	-1
1/15/2006	-1
1/16/2006	-1
1/17/2006	-1
1/18/2006	-1
1/19/2006	-1

APPENDIX B
CHEOPS EXCEL OUTPUT VIEWERS

Appendix B

CHEOPS Excel Output Viewers

Five output viewers are supplied with the model installation routine.

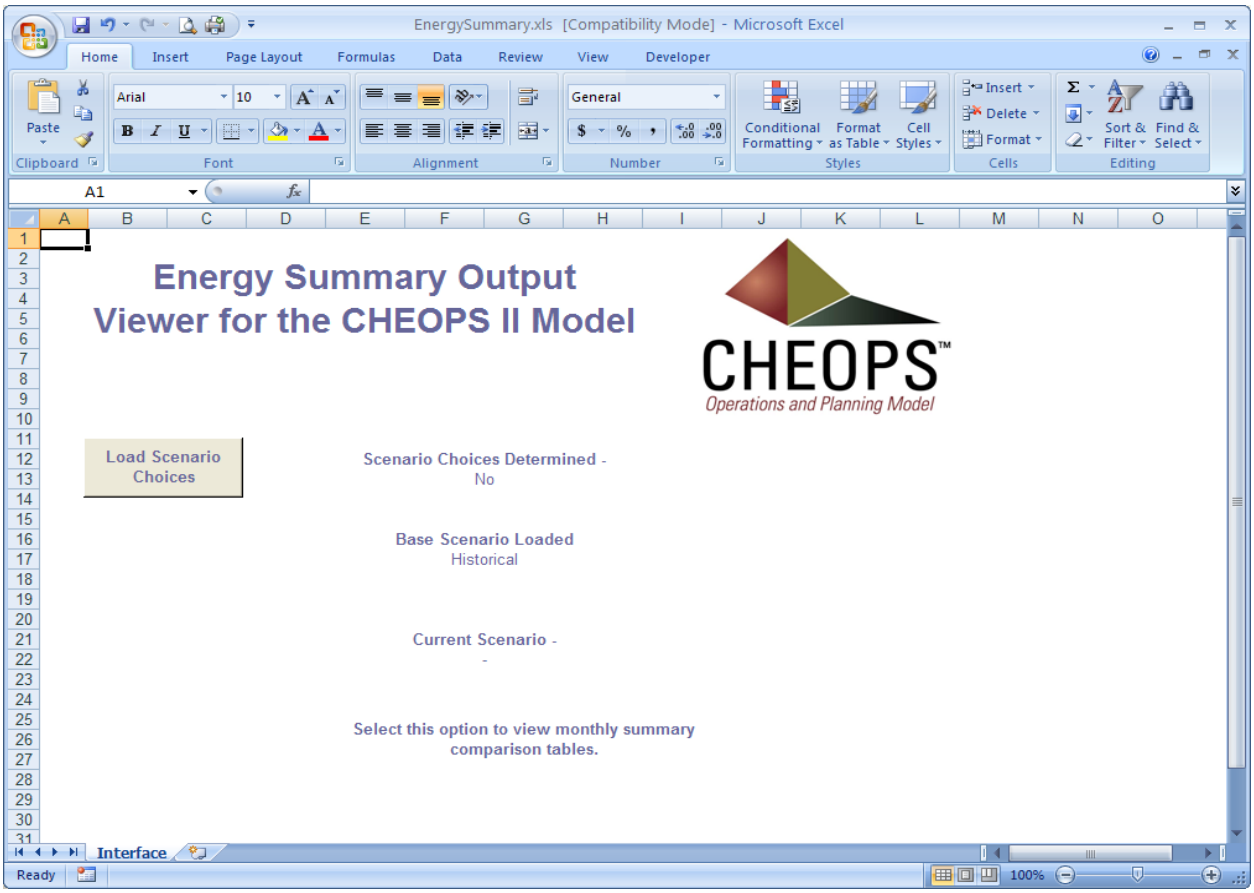
- Energy Summary
    - Imports and displays monthly generation details for each plant for one scenario
    - Imports and displays monthly generation details for each plant for a second scenario and compares results with the first imported scenario
- Energy Output
    - Imports and displays one scenario's generation by loadshape period, and revenues by plant by month, for each year of the scenario run
    - Imports and displays one scenario's generation and revenues by loadshape period, by plant for each year of a scenario run
- Daily Average Data
    - Imports and displays daily average and daily ending information for each plant, displaying results graphically, in Haze Chart, and in tabular form
- Plant Details
    - Imports and displays detailed intra-day model output results graphically. User selects the day(s) to be graphed.
- Detailed Durations
    - Displays duration charts (Exceedance Plots) of detailed model output data. User-selectable period covered, including entire period, as well as monthly for the period that the scenario was run. Can import and display duration charts for up to three different scenarios.

1.0 Energy Summary Viewer Interface

The Energy Summary Viewer opens and displays an output CSV file that contains each plant's generation values in MWh by month and year. The user can open the file from the Excel workbook instead of opening the file through Windows Explorer. Functionality exists to open a second Energy Summary file and have tables created which compute the differences in generation by MWh and by percent change from the original scenario.

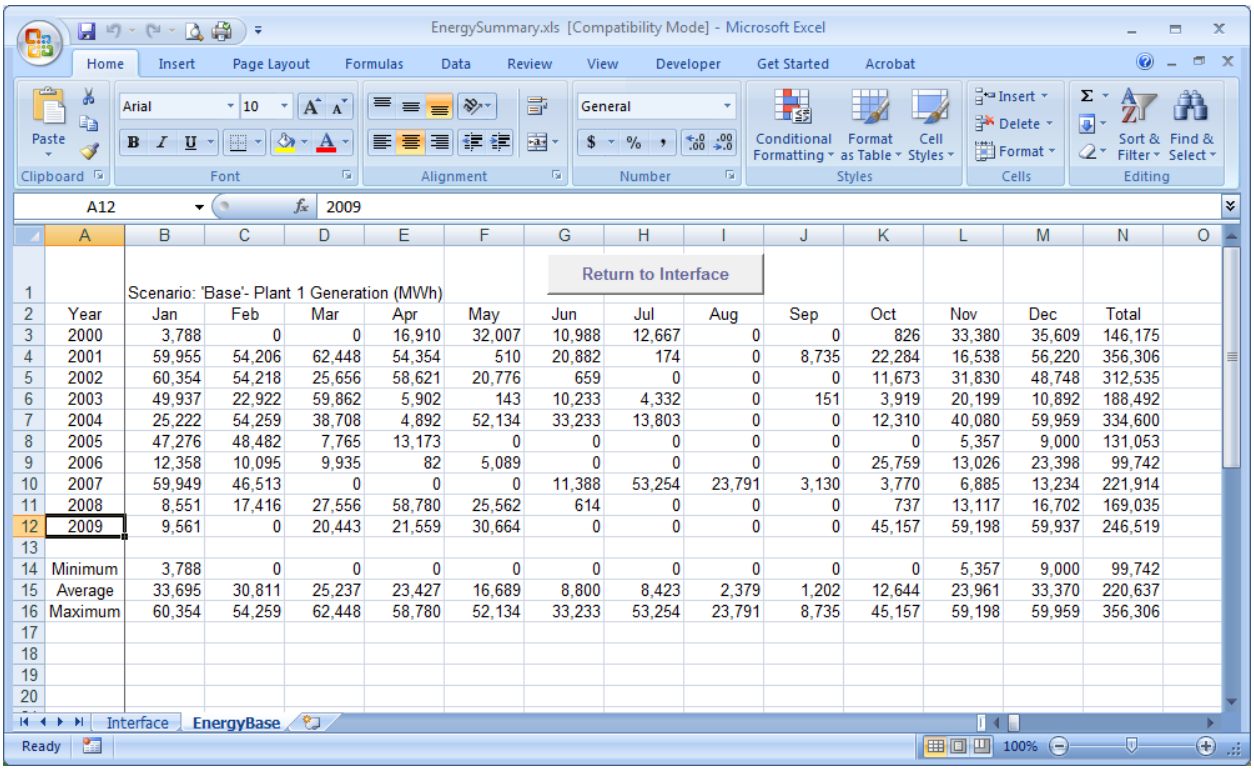
To open this viewer file, from the model, click the View Output button. From the View Output screen click the Energy Summaries button. Excel starts and opens the workbook. The below figure is the initial view.

DAILY AVERAGE DATA OUTPUT VIEWER



Click the Load Scenario Choices to have the output files read for beginning and ending years. The Load Base Generation button is clicked to load and display the first scenario or Baseline scenario. The Load Scenario button is clicked to open and display the comparison or variant scenario. The below figure shows the data tables displayed for these two buttons.

GENERATION SUMMARY OUTPUT VIEWER



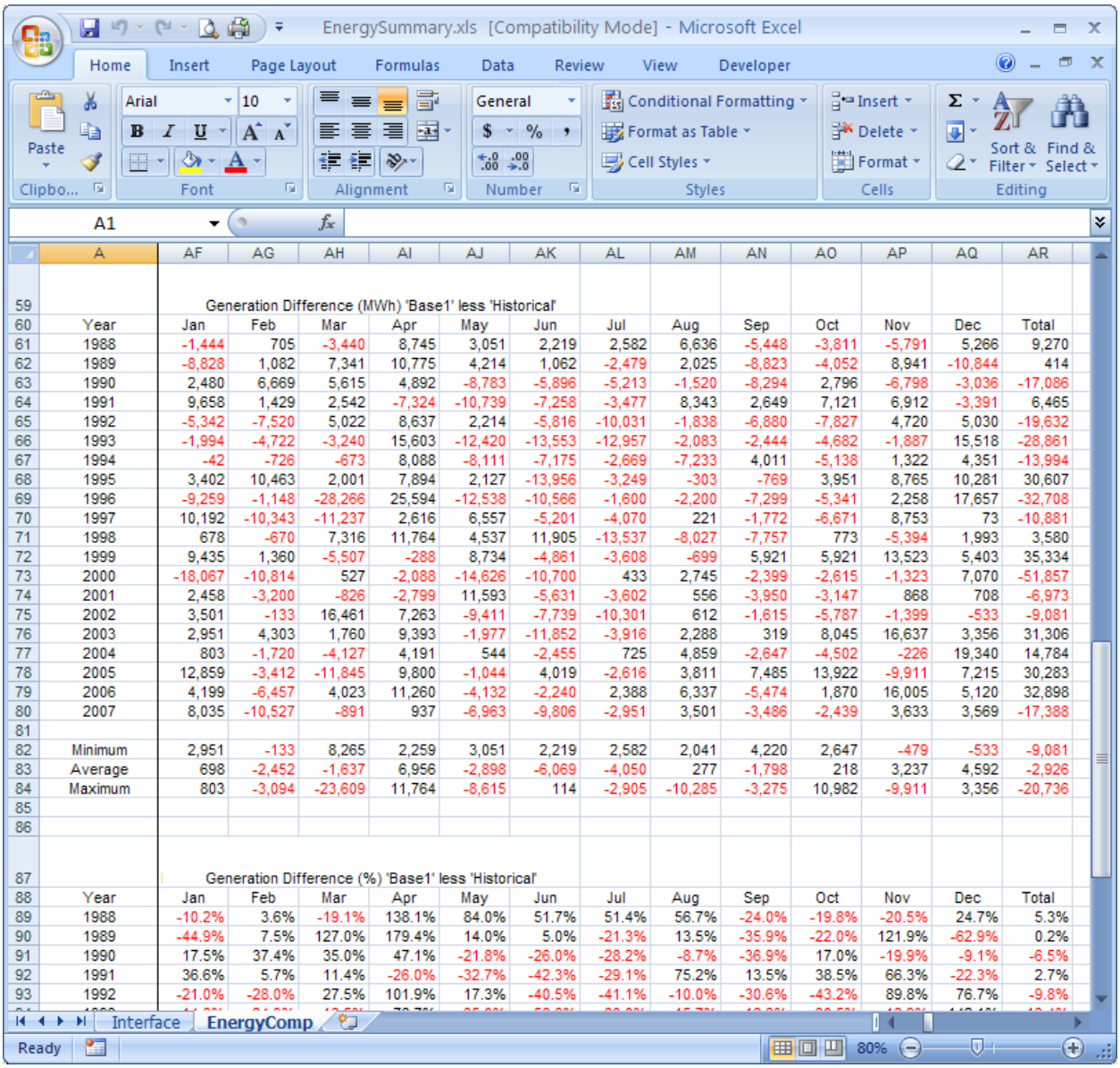
Return to Interface

Scenario: 'Base'- Plant 1 Generation (MWh)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2000	3,788	0	0	16,910	32,007	10,988	12,667	0	0	826	33,380	35,609	146,175
2001	59,955	54,206	62,448	54,354	510	20,882	174	0	8,735	22,284	16,538	56,220	356,306
2002	60,354	54,218	25,656	58,621	20,776	659	0	0	0	11,673	31,830	48,748	312,535
2003	49,937	22,922	59,862	5,902	143	10,233	4,332	0	151	3,919	20,199	10,892	188,492
2004	25,222	54,259	38,708	4,892	52,134	33,233	13,803	0	0	12,310	40,080	59,959	334,600
2005	47,276	48,482	7,765	13,173	0	0	0	0	0	0	5,357	9,000	131,053
2006	12,358	10,095	9,935	82	5,089	0	0	0	0	25,759	13,026	23,398	99,742
2007	59,949	46,513	0	0	0	11,388	53,254	23,791	3,130	3,770	6,885	13,234	221,914
2008	8,551	17,416	27,556	58,780	25,562	614	0	0	0	737	13,117	16,702	169,035
2009	9,561	0	20,443	21,559	30,664	0	0	0	0	45,157	59,198	59,937	246,519
Minimum	3,788	0	0	0	0	0	0	0	0	0	5,357	9,000	99,742
Average	33,695	30,811	25,237	23,427	16,689	8,800	8,423	2,379	1,202	12,644	23,961	33,370	220,637
Maximum	60,354	54,259	62,448	58,780	52,134	33,233	53,254	23,791	8,735	45,157	59,198	59,959	356,306

After the variant scenario has been loaded, click the Return to Interface button, and the main screen now has a View Comparison Tables button. Clicking this button creates four sets of tables for each plant: Baseline scenario generation; Variant scenario generation; Generation Difference (MWh); and Generation Difference (%), with minimum, maximum and average rows created. If there is significant difference in the years between the two scenarios, the min/max/average rows for the comparison tables are not computed. The below figure displays the third and part of the fourth table created in the worksheet.

GENERATION SUMMARY DIFFERENCE OUTPUT VIEWER



EnergySummary.xls [Compatibility Mode] - Microsoft Excel

Generation Difference (MWh) 'Base1' less 'Historical'

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1988	-1,444	705	-3,440	8,745	3,051	2,219	2,582	6,636	-5,448	-3,811	-5,791	5,266	9,270
1989	-8,828	1,082	7,341	10,775	4,214	1,062	-2,479	2,025	-8,823	-4,052	8,941	-10,844	414
1990	2,480	6,669	5,615	4,892	-8,783	-5,896	-5,213	-1,520	-8,294	2,796	-6,798	-3,036	-17,086
1991	9,658	1,429	2,542	-7,324	-10,739	-7,258	-3,477	8,343	2,649	7,121	6,912	-3,391	6,465
1992	-5,342	-7,520	5,022	8,637	2,214	-5,816	-10,031	-1,838	-6,880	-7,827	4,720	5,030	-19,632
1993	-1,994	-4,722	-3,240	15,603	-12,420	-13,553	-12,957	-2,083	-2,444	-4,682	-1,887	15,518	-28,861
1994	-42	-726	-673	8,088	-8,111	-7,175	-2,669	-7,233	4,011	-5,138	1,322	4,351	-13,994
1995	3,402	10,463	2,001	7,894	2,127	-13,956	-3,249	-303	-769	3,951	8,765	10,281	30,607
1996	-9,259	-1,148	-28,266	25,594	-12,538	-10,566	-1,600	-2,200	-7,299	-5,341	2,258	17,657	-32,708
1997	10,192	-10,343	-11,237	2,616	6,557	-5,201	-4,070	221	-1,772	-6,671	8,753	73	-10,881
1998	678	-670	7,316	11,764	4,537	11,905	-13,537	-8,027	-7,757	773	-5,394	1,993	3,580
1999	9,435	1,360	-5,507	-288	8,734	-4,861	-3,608	-699	5,921	5,921	13,523	5,403	35,334
2000	-18,067	-10,814	527	-2,088	-14,626	-10,700	433	2,745	-2,399	-2,615	-1,323	7,070	-51,857
2001	2,458	-3,200	-826	-2,799	11,593	-5,631	-3,602	556	-3,950	-3,147	868	708	-6,973
2002	3,501	-133	16,461	7,263	-9,411	-7,739	-10,301	612	-1,615	-5,787	-1,399	-533	-9,081
2003	2,951	4,303	1,760	9,393	-1,977	-11,852	-3,916	2,288	319	8,045	16,637	3,356	31,306
2004	803	-1,720	-4,127	4,191	544	-2,455	725	4,859	-2,647	-4,502	-226	19,340	14,784
2005	12,859	-3,412	-11,845	9,800	-1,044	4,019	-2,616	3,811	7,485	13,922	-9,911	7,215	30,283
2006	4,199	-6,457	4,023	11,260	-4,132	-2,240	2,388	6,337	-5,474	1,870	16,005	5,120	32,898
2007	8,035	-10,527	-891	937	-6,963	-9,806	-2,951	3,501	-3,486	-2,439	3,633	3,569	-17,388
Minimum	2,951	-133	8,265	2,259	3,051	2,219	2,582	2,041	4,220	2,647	-479	-533	-9,081
Average	698	-2,452	-1,637	6,956	-2,898	-6,069	-4,050	277	-1,798	218	3,237	4,592	-2,926
Maximum	803	-3,094	-23,609	11,764	-8,615	114	-2,905	-10,285	-3,275	10,982	-9,911	3,356	-20,736

Generation Difference (%) 'Base1' less 'Historical'

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1988	-10.2%	3.6%	-19.1%	138.1%	84.0%	51.7%	51.4%	56.7%	-24.0%	-19.8%	-20.5%	24.7%	5.3%
1989	-44.9%	7.5%	127.0%	179.4%	14.0%	5.0%	-21.3%	13.5%	-35.9%	-22.0%	121.9%	-62.9%	0.2%
1990	17.5%	37.4%	35.0%	47.1%	-21.8%	-26.0%	-28.2%	-8.7%	-36.9%	17.0%	-19.9%	-9.1%	-6.5%
1991	36.6%	5.7%	11.4%	-26.0%	-32.7%	-42.3%	-29.1%	75.2%	13.5%	38.5%	66.3%	-22.3%	2.7%
1992	-21.0%	-28.0%	27.5%	101.9%	17.3%	-40.5%	-41.1%	-10.0%	-30.6%	-43.2%	89.8%	76.7%	-9.8%

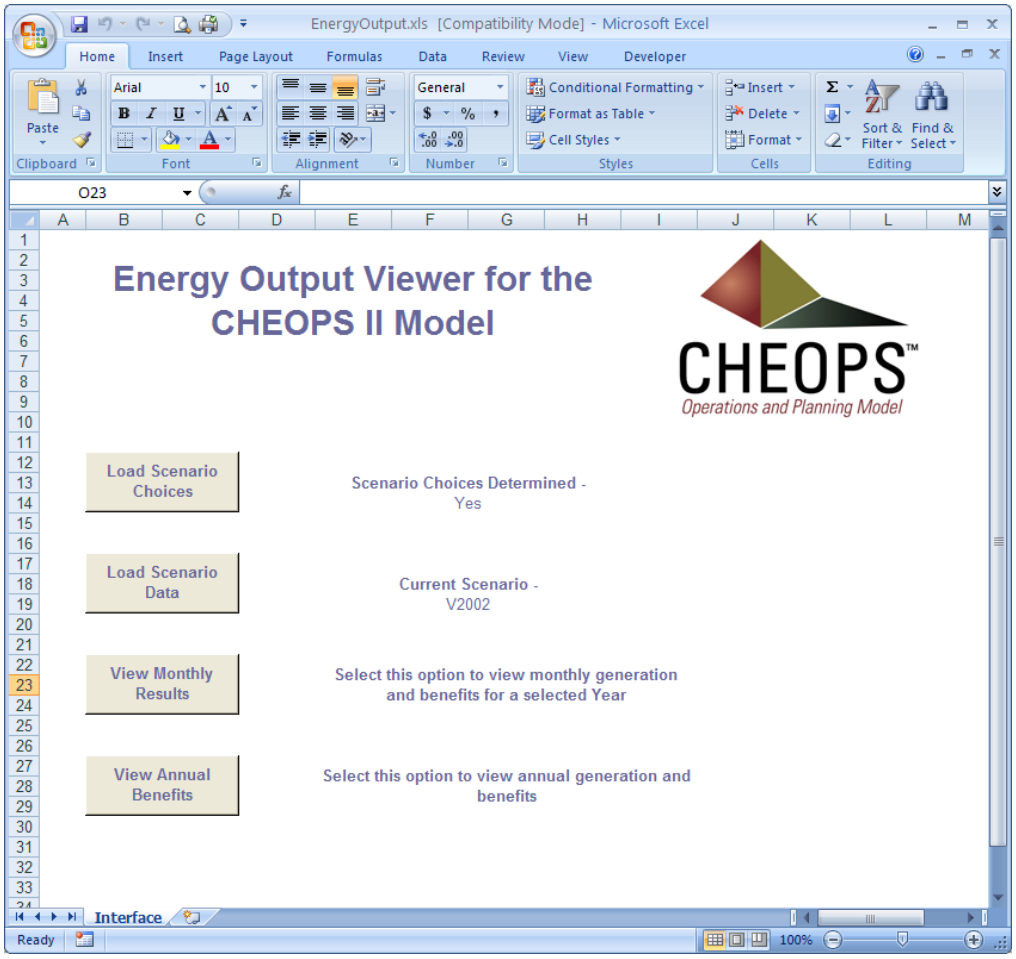
If additional scenarios are created and run while the workbook is open, the user must reopen the workbook from the model to re-read the scenario list. If a scenario is simply re-run, the user can click the Load Scenario Choices and Load Scenario Data from the Interface sheet without having to reopen the workbook.

2.0 Energy Output Viewer Interface

The Energy Output Viewer is opened from the model's View Output dialog by clicking the Energy Details button. The workbook is opened and the user must click the Load Scenario

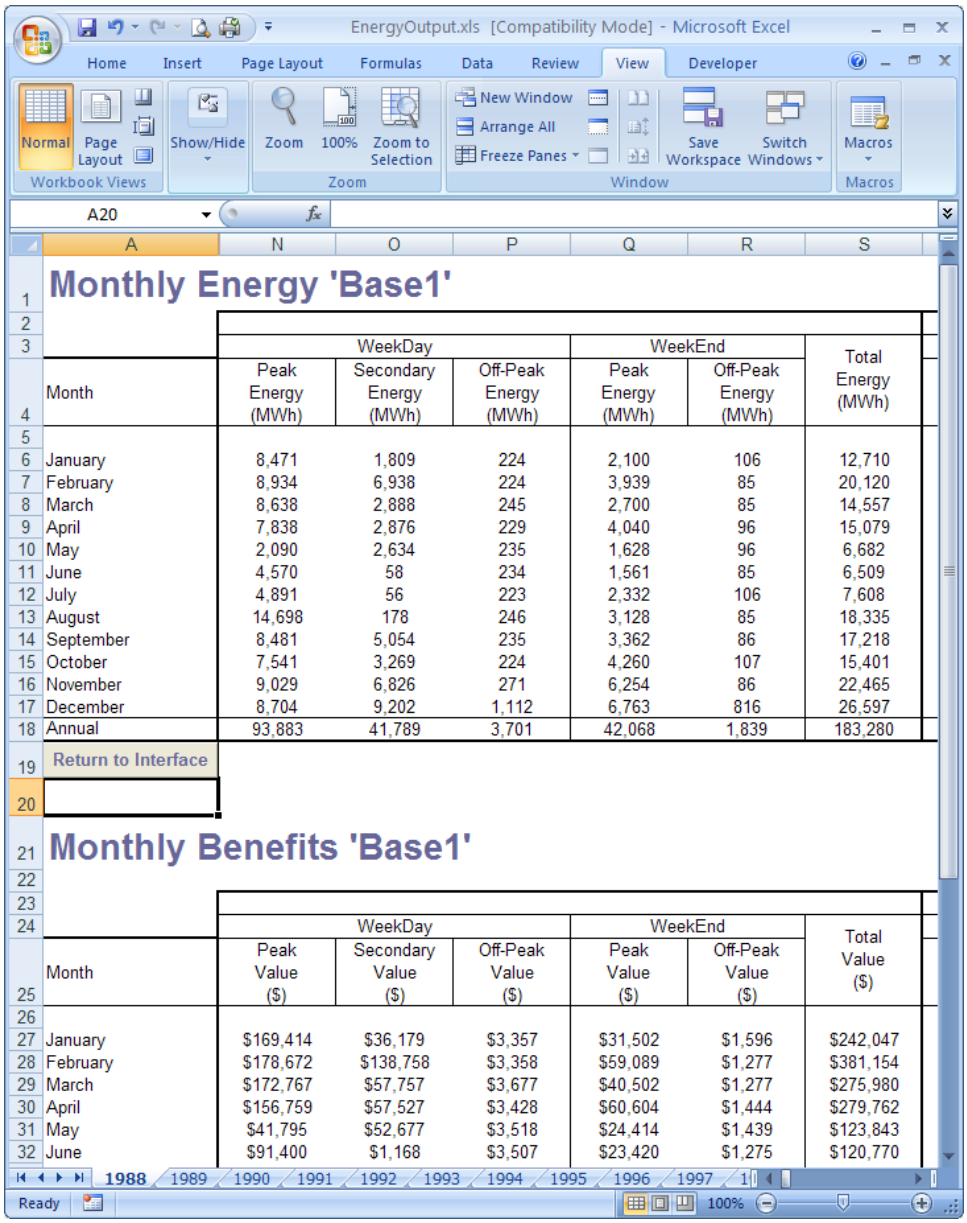
Choices button to have each scenario's output folder read for first and last years of the scenario run.

ENERGY OUTPUT VIEWER



After clicking the Load Scenario Choices button, the Load Scenario Data button becomes visible and should be clicked. The user then specifies which scenario to load. This process computes benefits of generation by loadshape period based on user entered data in the model. When the data load is complete, two buttons become visible. View Monthly Results displays generation and revenues by loadshape period by plant. A separate worksheet is created for each year of the scenario run. The first figure below is an example of the Monthly Generation results sheet. The second button is the View Annual Benefits button, which displays by plant, the loadshape annual sum of generation. A second sheet displays the revenues from the generation by loadshape period. The second figure below shows the annual generation by plant by loadshape period.

VIEW MONTHLY RESULTS VIEWER



Monthly Energy 'Base1'

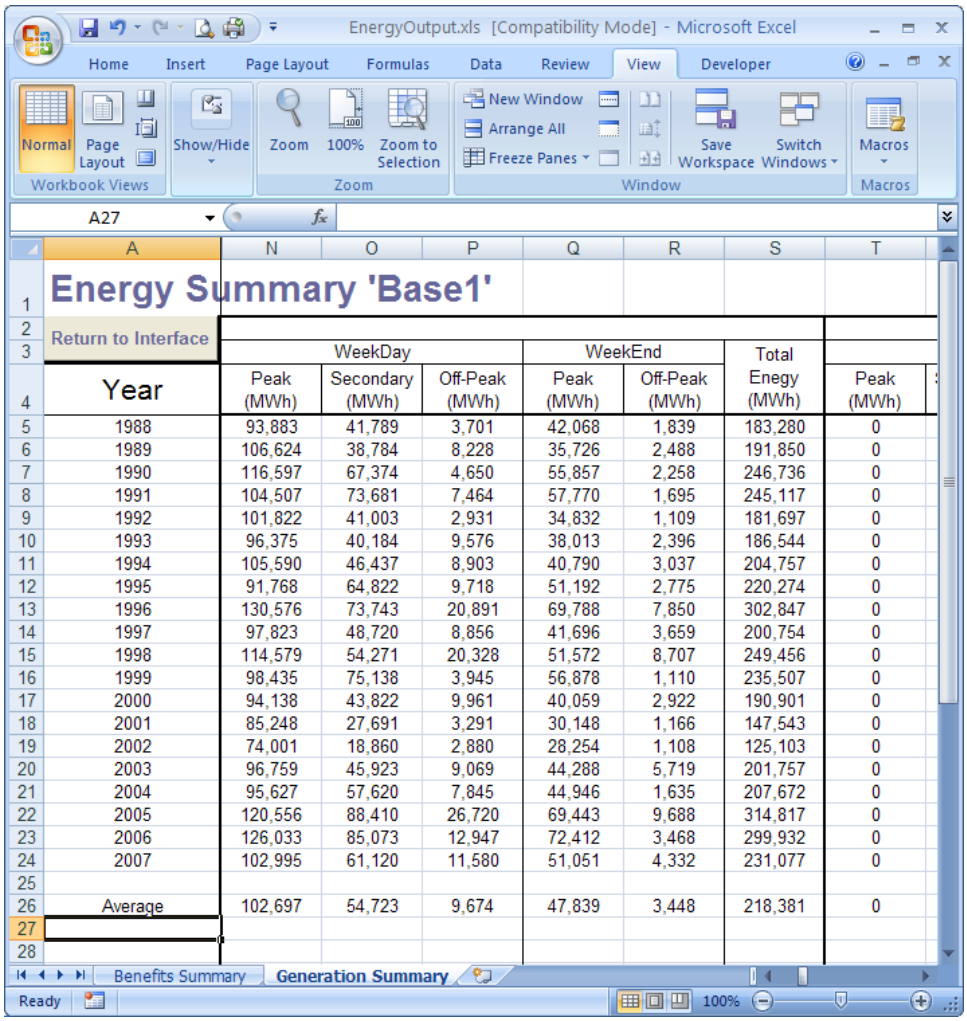
Month	WeekDay Peak Energy (MWh)	WeekDay Secondary Energy (MWh)	WeekDay Off-Peak Energy (MWh)	WeekEnd Peak Energy (MWh)	WeekEnd Off-Peak Energy (MWh)	Total Energy (MWh)
January	8,471	1,809	224	2,100	106	12,710
February	8,934	6,938	224	3,939	85	20,120
March	8,638	2,888	245	2,700	85	14,557
April	7,838	2,876	229	4,040	96	15,079
May	2,090	2,634	235	1,628	96	6,682
June	4,570	58	234	1,561	85	6,509
July	4,891	56	223	2,332	106	7,608
August	14,698	178	246	3,128	85	18,335
September	8,481	5,054	235	3,362	86	17,218
October	7,541	3,269	224	4,260	107	15,401
November	9,029	6,826	271	6,254	86	22,465
December	8,704	9,202	1,112	6,763	816	26,597
Annual	93,883	41,789	3,701	42,068	1,839	183,280

Return to Interface

Monthly Benefits 'Base1'

Month	WeekDay Peak Value ($)	WeekDay Secondary Value ($)	WeekDay Off-Peak Value ($)	WeekEnd Peak Value ($)	WeekEnd Off-Peak Value ($)	Total Value ($)
January	$169,414	$36,179	$3,357	$31,502	$1,596	$242,047
February	$178,672	$138,758	$3,358	$59,089	$1,277	$381,154
March	$172,767	$57,757	$3,677	$40,502	$1,277	$275,980
April	$156,759	$57,527	$3,428	$60,604	$1,444	$279,762
May	$41,795	$52,677	$3,518	$24,414	$1,439	$123,843
June	$91,400	$1,168	$3,507	$23,420	$1,275	$120,770

VIEW ANNUAL BENEFITS VIEWER



Energy Summary 'Base1'

Return to Interface

Year	WeekDay Peak (MWh)	WeekDay Secondary (MWh)	WeekDay Off-Peak (MWh)	WeekEnd Peak (MWh)	WeekEnd Off-Peak (MWh)	Total Enegy (MWh)	Peak (MWh)
1988	93,883	41,789	3,701	42,068	1,839	183,280	0
1989	106,624	38,784	8,228	35,726	2,488	191,850	0
1990	116,597	67,374	4,650	55,857	2,258	246,736	0
1991	104,507	73,681	7,464	57,770	1,695	245,117	0
1992	101,822	41,003	2,931	34,832	1,109	181,697	0
1993	96,375	40,184	9,576	38,013	2,396	186,544	0
1994	105,590	46,437	8,903	40,790	3,037	204,757	0
1995	91,768	64,822	9,718	51,192	2,775	220,274	0
1996	130,576	73,743	20,891	69,788	7,850	302,847	0
1997	97,823	48,720	8,856	41,696	3,659	200,754	0
1998	114,579	54,271	20,328	51,572	8,707	249,456	0
1999	98,435	75,138	3,945	56,878	1,110	235,507	0
2000	94,138	43,822	9,961	40,059	2,922	190,901	0
2001	85,248	27,691	3,291	30,148	1,166	147,543	0
2002	74,001	18,860	2,880	28,254	1,108	125,103	0
2003	96,759	45,923	9,069	44,288	5,719	201,757	0
2004	95,627	57,620	7,845	44,946	1,635	207,672	0
2005	120,556	88,410	26,720	69,443	9,688	314,817	0
2006	126,033	85,073	12,947	72,412	3,468	299,932	0
2007	102,995	61,120	11,580	51,051	4,332	231,077	0
Average	102,697	54,723	9,674	47,839	3,448	218,381	0

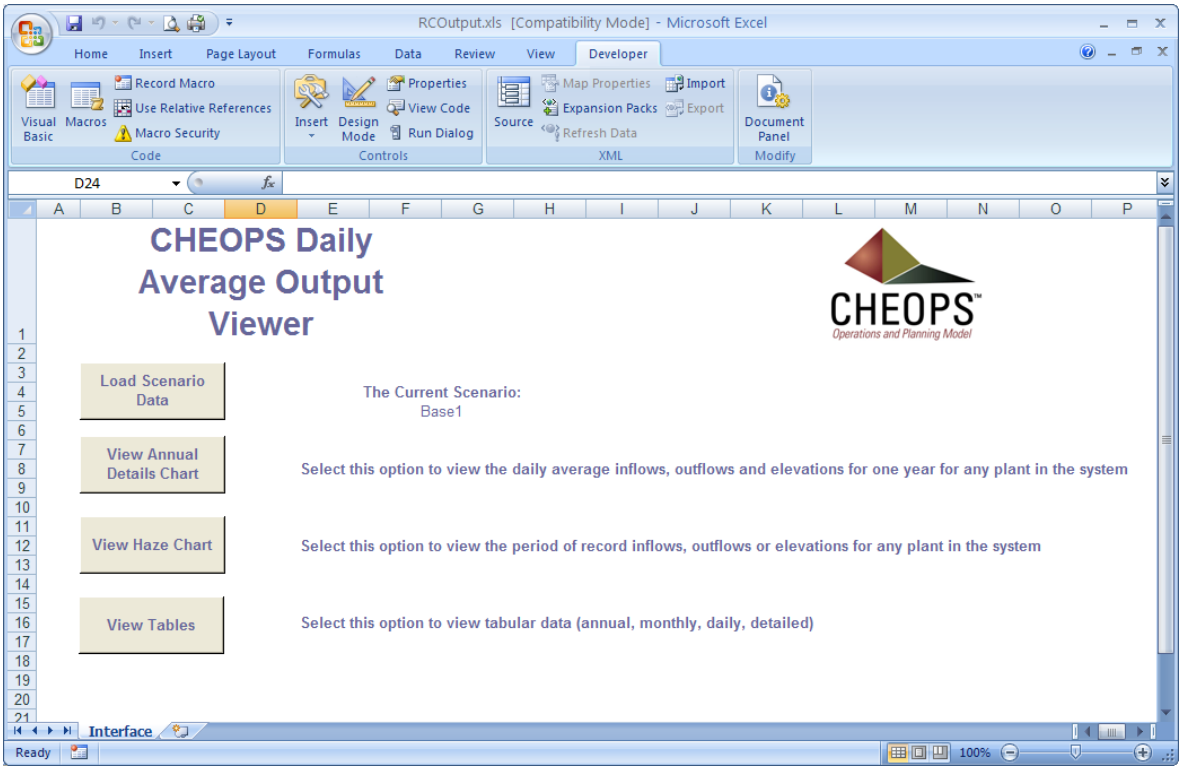
If additional scenarios are created and run while the workbook is open, the user must reopen the workbook from the model to re-read the scenario list. If a scenario is simply re-run, the user can click the Load Scenario Choices and Load Scenario Data from the Interface sheet without having to reopen the workbook.

3.0 Daily Average Data Output Viewer Interface

The Daily Average Data Output Viewer is an Excel file named "RCOutput.xls." This file is located in the "Output" folder of the CHEOPS model directory. The "RCOutput.xls" file contains internal macros and worksheets designed to sum and tabulate the daily average output data. The data can then be plotted and viewed in various formats. The main Daily Average

Output Viewer interface, as shown below, will open automatically when the "Daily Average Data" button is clicked in the CHEOPS View Output interface.

DAILY AVERAGE DATA OUTPUT VIEWER



The first step towards viewing the CHEOPS output is to load the Scenario data. Click on the "Load Scenario Data" button and select the scenario to load.

Note: The user must first re-open the Daily Average Output Viewer from the model in order to get the most up-to-date listing of scenarios that have been run. Otherwise, if the viewer is left open and the user adds and runs another scenario, the viewer will not include the new scenario results.

3.1 Annual Details Chart Description

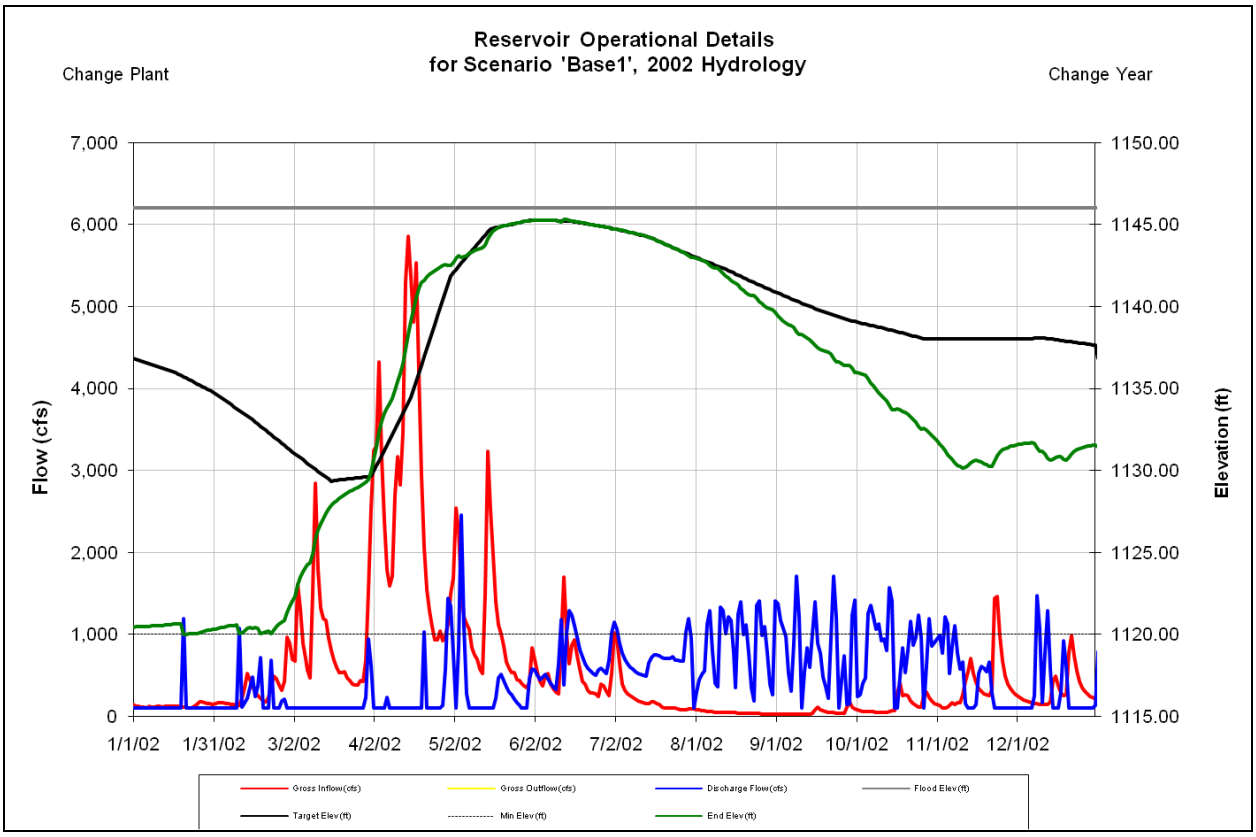
This chart displays one plant's daily average gross inflows, gross outflows, and turbine discharge on a daily average basis. End of day reservoir elevation is

graphed, along with the Target, Flood and Minimum elevations specified in the scenario conditions.

To change the plant displayed, click the Change Plant dropdown and choose another plant. To change the year displayed, click the Change Year dropdown box or use the spinner control to cycle through the years.

For comparison to historical data, there are two checkboxes on the lower left of the displayed chart, Show Historic Flows, and Show Historic Elevations. Historic data exists for some plants for the post-2002 period. Users are reminded that the historic data should only be compared to Verification scenarios, as model conditions for Baseline or other scenarios varies greatly from historic conditions. The below figure is the details chart.

ANNUAL DETAILS CHART

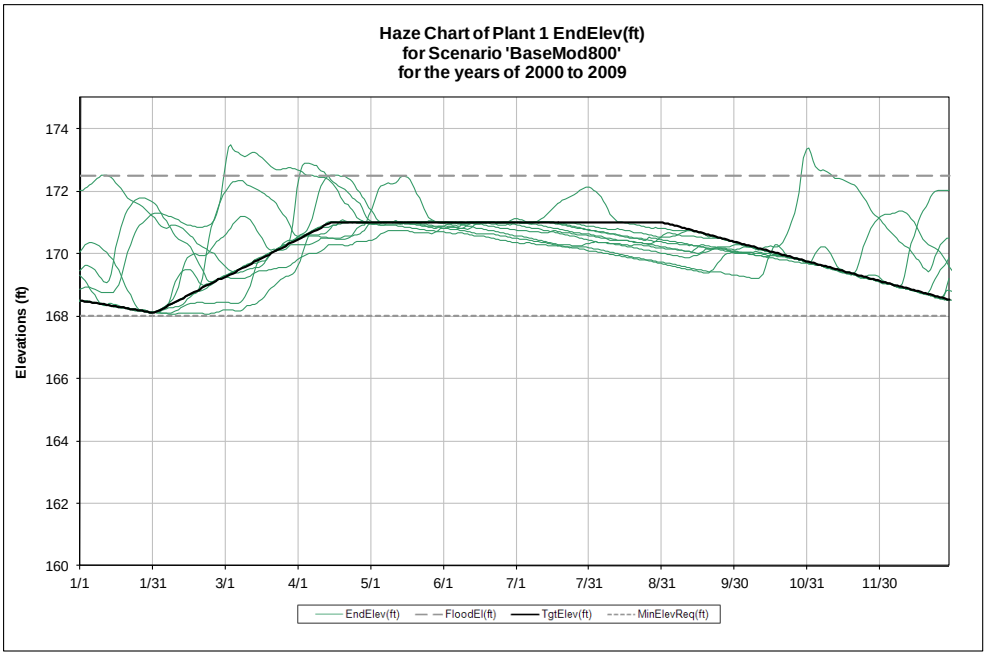


3.2 Haze Chart Description

Following the loading of the Scenario data, the user can view a Haze Chart. The Haze Chart allows you to view elevations, inflows, or outflows for a particular plant for the scenario. The plot is designed to give you an understanding of how the plant is operating on an annual scale. The Haze Chart answers questions like: How far does the reservoir get drawn down each year? How much volume is being carried over from year to year? And, How different are the inflows and releases between various years? When the Ending Elevation data set is chosen for display, the first year's Flood, Target and Minimum elevations are also displayed for comparison.

To display the Haze Chart, click on the "View Haze Chart" button. The model will open up a dialog that allows you to select which plant and what type of data you would like to see. The model will then calculate the Haze Chart and show the chart shown in the below figure. You can then either print the chart, or return to the main Interface screen. To view charts from another Scenario, you must load a different Scenario by clicking on the "Load Scenario Data" button.

HAZE CHART



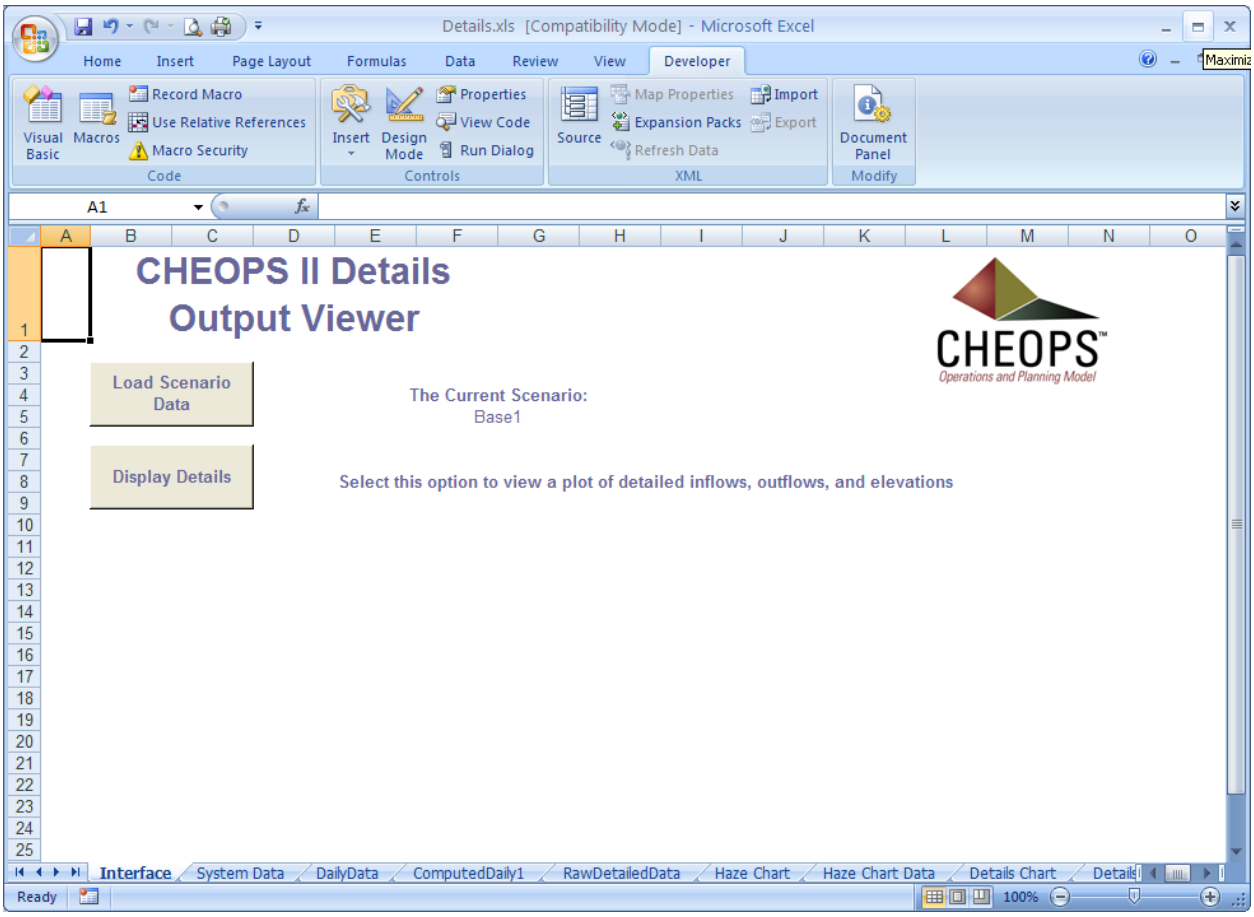
3.3 View Tables

Clicking on the "View Tables" button in the Daily Average Output Viewer will activate a dialog prompting the user to identify the plant and data set to display. The user can then print or copy the table, and then return to the Interface screen.

4.0 Detailed Output Viewer Interface

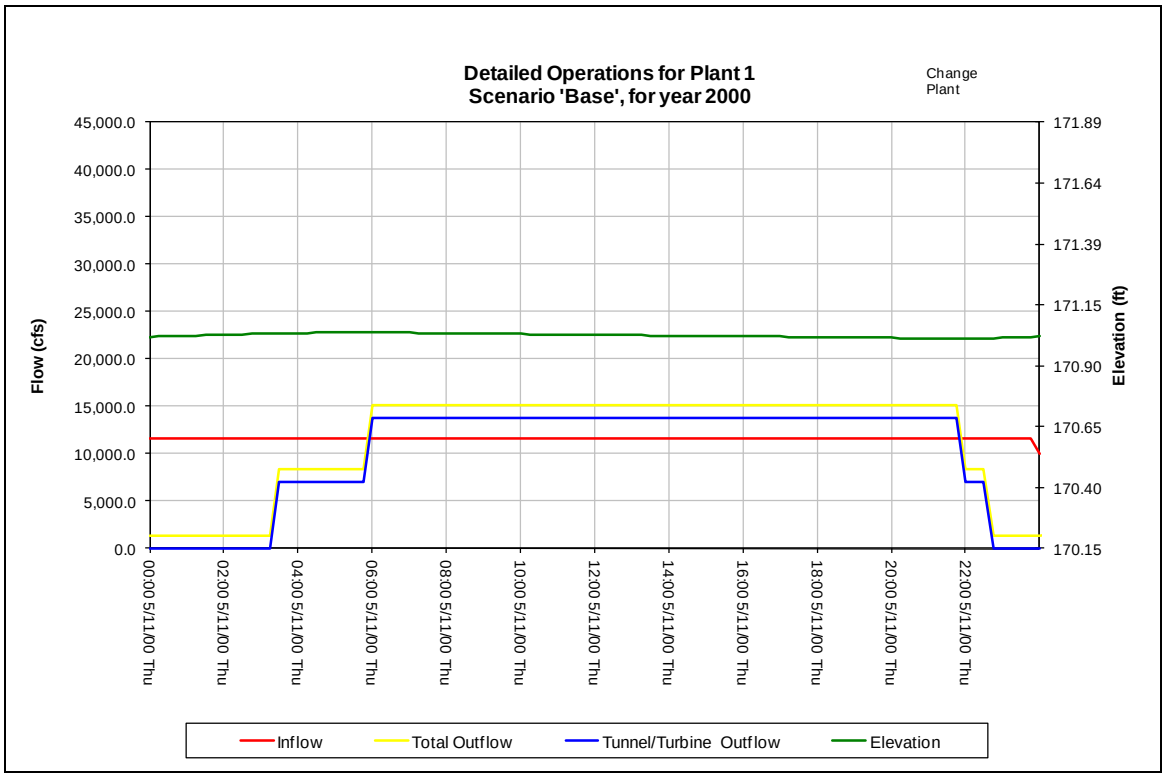
The Detailed Output Viewer is activated from the model's View Output interface by clicking the Plant Details button. The data presented is detailed series graphs of inflows, outflows, turbine/discretionary discharge, and reservoir elevation. The user can view multiple days or a single day, and can change between plants.

DETAILED OUTPUT VIEWER



The first step for the user is to click on the Load Choices button, where the output folders are read for contents. Next the user clicks the Display Details button, where the user will be prompted for the Scenario, Plant, and date information. The below figure represents the displayed graph.

DETAILS GRAPH



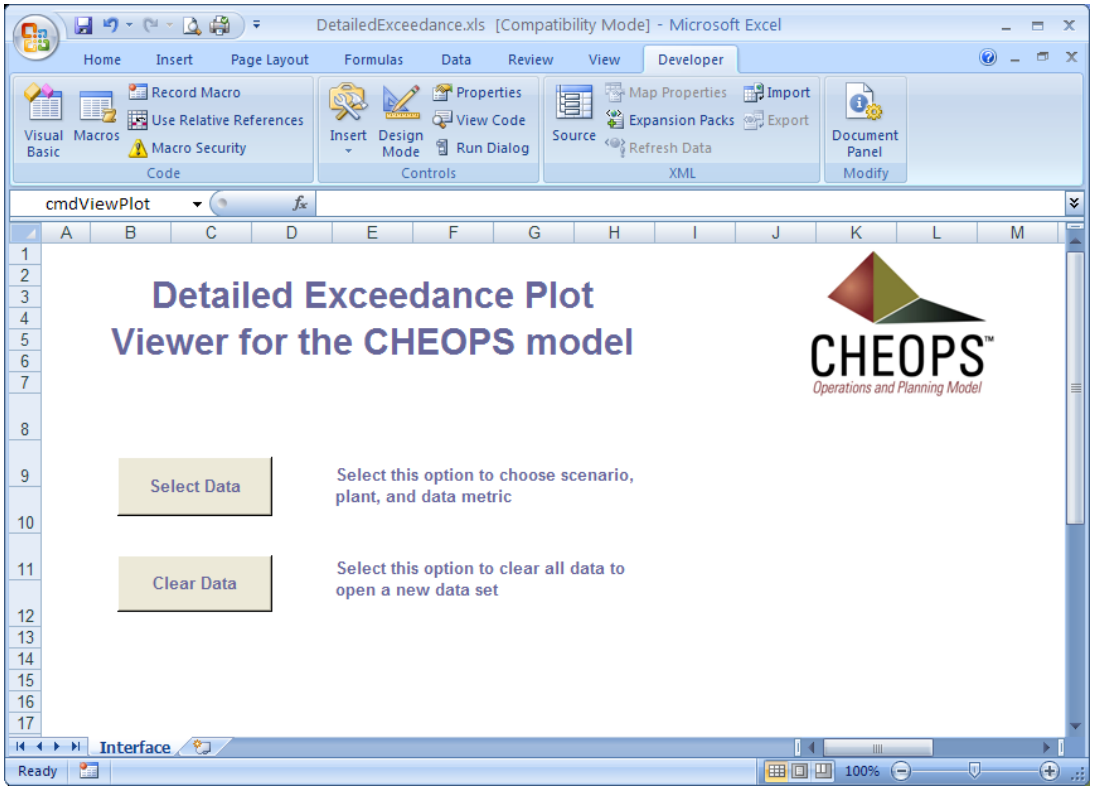
You can scroll through the days of each year by using the "Previous Day" and "Next Day" buttons at the top of the plot. Another plant's data can be displayed by clicking the Change Plant combo box. In order to view another scenario, you must return to the main Detailed Output Viewer screen. The detailed data is quite extensive and the output viewer can only load a single year of one plant's output data at one time.

5.0 Detailed Durations

The Detailed Durations Output Viewer is activated from the model's View Output interface by clicking the Detailed Durations button. The data available for calculation and presentation is each of the output data sets in the Detailed Output (e.g. 15-minute) file. From the main Interface

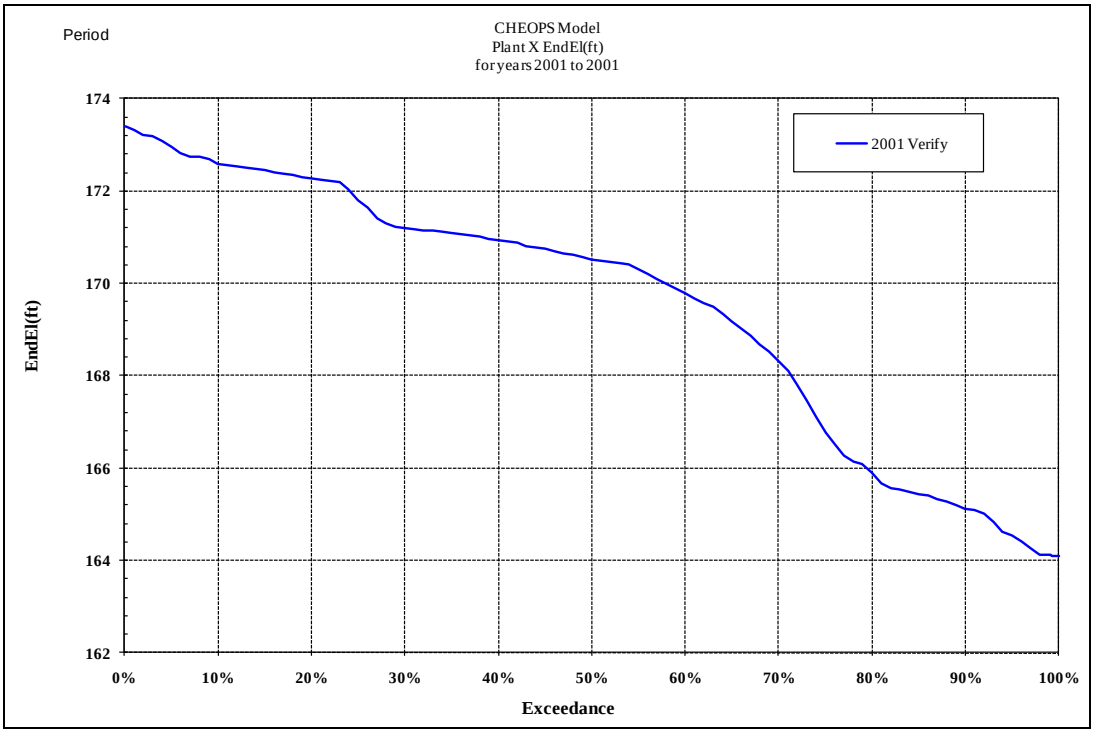
screen, click the Select Data button. A dialog is displayed allowing the user to select a Scenario, Plant, and Data Set for presentation.

DETAILED DURATIONS INTERFACE



After the data set is imported and presented in the graph as shown below, the user can add data to the graph from up to two additional scenarios by clicking on the Add Series button. The same plant and output data set (e.g. "EndEl(ft)") will be displayed automatically. The user can choose to view graphs covering different periods, from Annual (entire period of record) to each of the months individually.

DETAILED DURATIONS GRAPH



APPENDIX C
CHEOPS FILE STRUCTURE

Appendix C

CHEOPS File Structure

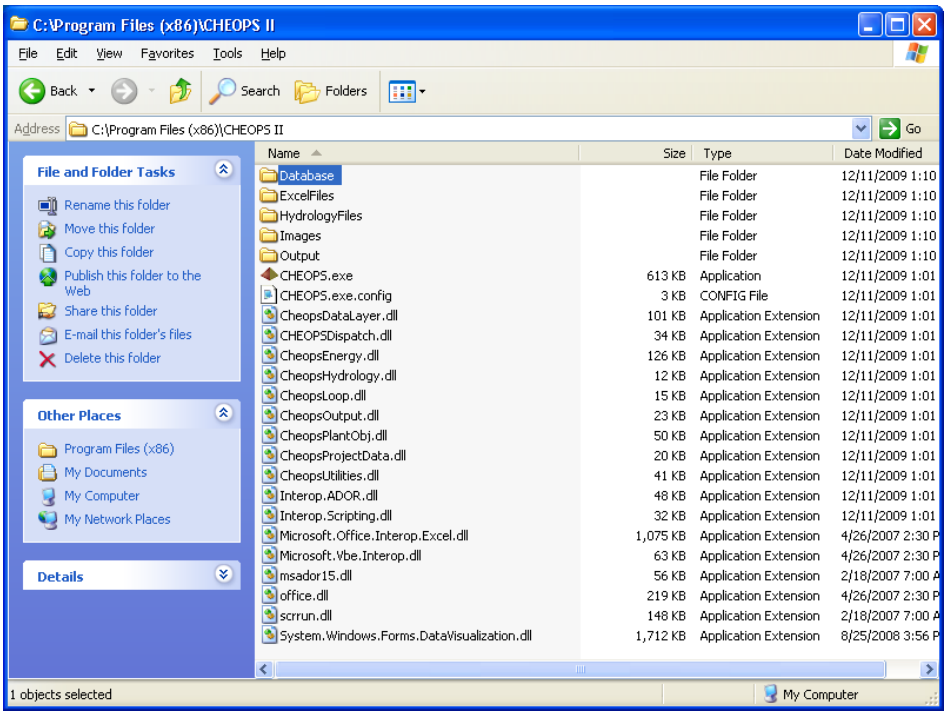
The default installation path for Windows 32 bit systems is “C:\Program Files\CHEOPS II”, and for 64 bit Windows the default path is “C:\Program Files (x86)\CHEOPS II”. This is referred to as the Model Installation Folder. The user may choose to modify the installation folder when the model is installed. All folders discussed herein are relative to this installation folder.

1. The model installation folder contains five folders and approximately 19 files as shown in the below figure. The files are model code libraries and are not editable.

    a. The file CHEOPS.exe is the executable file which starts the CHEOPS model.

    b. The file CHEOPS.exe.config is a text file which is editable in certain cases, but should be left in its original form unless otherwise instructed.

    c. If certain model code files are updated, the user may be requested to replace a DLL in the model installation folder.



2. The Database folder contains a Microsoft Access Database file with the scenario information, conditions and settings. It should not be edited manually.

3. The ExcelFiles folder contains several Excel files which are provided as import templates for Turbine Efficiency and Loadshape conditions. Other files can be added to this folder at the user's discretion. Use of these files is optional. The format and location of the cells in these files must be maintained for the import process to be successful. The use of formula, annotations, calculations, etc., outside of the import ranges is permitted.

4. The HydrologyFiles folder contains the inflow hydrology data set as an Excel 2003 (XLS) file. The format of the hydrology file must be strictly followed. Data is in columns for each plant in the system, and dates must be contiguous and complete from first year to last year of the data set. The model will read in negative accretions, so intentional use of negative values must be ensured. When imported into Excel, cell A1 contains the first year of the data set, cell B1 contains the last year of the data set, and cell C1 contains the number of plants. Columns cannot be added or removed without causing data read issues.

5. The Output folder contains the Output Viewer Excel files. If scenarios have been run, then subfolders of the scenario name will be created, and model run output CSV files will be stored in the subfolders. When a scenario is re-run, all of the original output files are cleared. If a user has one of these output files open in Excel or Notepad, the model notifies the user that the scenario could not be run due to an output file being open. The Output Viewer excel files can be replaced with updated versions, but some of the original format and functionality must remain unless the CheopsOutput.DLL library is also updated.