LAKE CHELAN HYDROELECTRIC PROJECT NO. 637

ENERGY GENERATION SIMULATION MODEL DESCRIPTION (CHEOPS)

April 30, 2003

In the Lake Chelan relicensing process, the CHEOPS model was used to evaluate various scenarios of lake level and flow, including the selected alternative, PME14. It will also serve as a means of documenting the proposed alternative and a basis for evaluating the cost or benefit of future changes in lake level cycle or flow that may be required during the license period. The following paragraphs provide a brief description of the model and brief explanations of how it documents and can be used to evaluate combinations of required lake level and flow.

MODEL DESCRIPTION

CHEOPS is a computer model developed by Duke Engineering & Services, Inc. that simulates operation of the Lake Chelan Project. It has two parts: a reservoir model and an energy model. Both make use of Microsoft Excel spreadsheets and Visual Basic programs.

Reservoir Model

The reservoir model simulates the response of the reservoir to different scenarios of inflow and outflow. Information put into the model includes an elevation/capacity curve, inflow data, flood elevation, absolute minimum elevation, required minimum flows, and target elevations. The model uses historical information from 1952 to 1995 to simulate how the project would respond if operated under different criteria.

The model works through each year, day by day, and calculates the reservoir's response. It spills water as necessary to avoid flooding as the lake approaches flood level, makes required minimum releases unless the absolute minimum elevation (1,079 ft.) is reached, tries to reach target elevations, and keeps track of water available for generation or spill. The model regulates releases of water, other than those for required flows, as necessary to reach target elevations.

Target elevations might best be defined as intended lower limits. They are not always reached and are often exceeded. One target elevation is set for each month. The day of the month can be picked, also. The model looks ahead to the next target elevation and regulates outflow from the lake in an effort to meet or exceed that elevation on the appropriate date. Generation is stopped as necessary to reach target elevations, but minimum flows are not. If target elevations are exceeded, that is generally considered OK. If the target can't be reached despite shutting off generation, the model misses the target.

Output from the reservoir model includes a variety of graphs and tables. The most useful are graphs of lake level, inflow, and outflow for individual years or for the average of the years from 1952 to 1995 and tables summarizing the same data by month. These graphs and tables compare the results of various operating requirements.

Energy Model

The second half of CHEOPS is the energy model which simulates power production from the project given the results of the reservoir model. Other input information includes turbine efficiency and rating curves, and values for peak and off-peak power generation.

To calculate the amount of power generated, the energy model works through the results of the reservoir model, day by day, and uses available water for generation. This yields MWh. The program then allocates power produced each day to peak and off-peak hours and multiplies by the appropriate power value for the hour and month.

Output from the energy model includes tables of generation in MWh for each month, sorted into peak and off-peak generation. Similar tables are also developed which present benefits in dollars. These tables are available for individual years, the period of record (1952 to 1995) or for the wet, dry and median inflow years.

Glossary:

- Elevation/capacity curve – a curve or series of numbers that describes the relationship between lake elevation and volume of water stored.
- Inflow data – the model uses the average inflow, in cubic feet per second (cfs), for each day. This is the rate at which water entered the lake on that day.
- Flood elevation – For Lake Chelan the flood elevation is 1,100 ft. The model will take whatever steps are necessary to avoid a lake level higher than this.
- Absolute minimum elevation – For Lake Chelan the minimum elevation allowed is 1,079 ft. The model will not allow the lake level to drop below this point.
- Required minimum flows are flows that must be maintained, either through the powerhouse or the spillway, regardless of whether target elevations are reached. They are used to model such requirements as those for continuous flows through the river (called Bypass Flow), through the powerhouse (called Minimum Flow), or from the lake without regard to the means of release (called Base Flow).
- Target elevations are monthly elevations goals which the model will attempt to meet or exceed. Required minimum flows take precedence over target elevations.

ATTACHMENT A
CHEOPS OPERATIONAL INSTRUCTIONS

April 30, 2003

LAKE OPERATIONS - PME14

The proposed lake level cycle and required minimum river flows were modeled as scenario PME14, using a version of the CHEOPS model issued June 11, 2001. This version has been run on Microsoft Excel '97 SR2, and on Excel 2002 SP-2. The files that comprise the model and results are contained on the accompanying CD-ROM. To run the model, the files will have to copied onto a disk that is not write-protected.

The following paragraphs include a summary of information that will be helpful to anyone attempting to modify key parts of the input to evaluate the effects of contemplated changes. Additional details may be found in CHEOPS Lake Chelan Project Model Documentation, Duke Engineering & Services, September 1998.

Input Data

Use the following steps to view and alter input data:

- Once the model files are installed on a hard disk, open the cheops.xls file.
- Verify that the displayed path for data and files is correct.
- Select the "exit model" tab on the toolbar and click "return to excel menus".
- Select "CHEOPS model" on the toolbar and click "view cheops worksheets".
- Select sheet "Input 1".

This should reveal a page of the spreadsheet that includes all the input to the CHEOPS model that is likely to change. Key data locations are as follows:

- Bypass flows are found in cells E284:E313 and the start dates for those flows are in cells F284:F313.
- Minimum flows are found in cells D302:D313 and the start dates for those flows are in cells A302:B313.
- Base flows are found in cells I302:I313 and the start dates for those flows are in cells G302:H313.
- Target elevations are found in cells D428:D439 and the dates for those elevations are in cells A428:B439.

Once input data have been reviewed and changes as desired, select "CHEOPS model" and click "Return to cheops menus" to return to the model interface.

Model Operation

Most of the model operations are adequately documented in the manual prepared by DE&S, referred to above. Three items have been added or changed subsequent to preparation of the manual to the extent that additional explanation is useful.

The first addition is that when the reservoir model is run, separately or together with the energy model, a small window opens that offers three options:

- Carry over end elevations
- Use output as "Base Case" Generation Requirement
- Use "Base Case" flow file to match generation

The "Carry over end elevations" option should always be checked to take full advantage of the 45 year baseline of historical data in the model. If this option is not checked, the model will reset the lake elevation to its target elevation at the start of each year.

Generally, the second "Use output as 'Base Case'…" option should be checked and the third "Use 'Base Case' flow file…" option should be un-checked. This feature was added to allow the effect of required flows on lake levels to be evaluated if generation remained as nearly constant as possible. If the second option is un-checked and the third is checked, the model uses the current required flows and also attempts to match the powerhouse flows from the immediately preceding model run. This is not expected to be of general interest during the license period.

The second addition to the model is the "Output2.xls" file found on the CD-ROM. This file is not generated by the model, but was developed by Chelan PUD staff to provide a useful summary of data. It consists of the "Output.xls" file, which generated by the model, with an added "Summary" page which collects the energy data from each year and creates a summary table of average peak, off-peak and total generation for each month over the years in the database, and an average generation per year. To the extent one is able to accurately predict peak and off-peak prices by month, it will also use those predictions to calculate the value of energy produced.

After each run of the energy model, this page must be added to the new "Output.xls" file and saved as "Output2.xls". It is worth noting that if the modified file is inadvertently saved as a replacement for "Output.xls" that file is corrupted and will no longer function properly.

The third addition to the model files is the "Rcsummary.xls" file. This file is not actually a part of the model, but was developed as a useful tool for summarizing flow and lake elevation data from the model. Its function is to produce tables and graphs of average outflow and lake elevation for each day of the year, averaged over the 45 year baseline. It includes instructions.