

# GENESYS Documentation

## (10/11/2016)

### CONTENTS

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- 1 Introduction ..... 2
  - 1.1 Purpose ..... 2
  - 1.2 History ..... 3
- 2 Overview ..... 3
  - 2.1 File Types..... 3
  - 2.2 Structure ..... 4
  - 2.3 Model Flow ..... 4
- 3 Stochastic Inputs ..... 4
  - 3.1 Load, Wind and Solar ..... 4
  - 3.2 Streamflows ..... 5
  - 3.3 Forced Outages ..... 5
- 4 Deterministic Inputs..... 5
  - 4.1 Topology..... 5
    - 4.1.1 Transmission ..... 5
    - 4.1.2 Resource..... 6
  - 4.2 Hydro Generation Parameters..... 7
    - 4.2.1 Constraints ..... 7
  - 4.3 Thermal Generation Parameters ..... 7
    - 4.3.1 Constraints ..... 7
  - 4.4 Other Generating Resource Parameters..... 8
    - 4.4.1 Constraints ..... 8
  - 4.5 Contracts/Market..... 8
    - 4.5.1 Constraints ..... 8
  - 4.6 Reserves ..... 8
- 5 Dispatch Logic ..... 9
  - 5.1 Summary ..... 9
  - 5.2 Period Dispatch ..... 11

5.3	Window Dispatch.....	12
5.4	Daily Dispatch.....	12
5.5	Hourly Dispatch.....	13
5.6	Slice Logic.....	13
5.7	Borrowed Hydro.....	13
5.8	Emergency Resource Dispatch.....	14
6	Appendix .....	14
6.1	Input Files.....	14
6.1.1	GenSimMain files .....	14
6.1.2	HYDSIM files.....	18
6.2	Output.....	22
6.2.1	GenSimMain Text files (.out files).....	22
6.2.2	GenSimMain Text files (.vbi files).....	25
6.3	Modules .....	27
6.3.1	TSR Modules.....	30
6.4	Subroutines .....	32
6.4.1	TSR Subroutines .....	39
6.5	GENESYS Configuration.....	40

# 1 INTRODUCTION

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GENESYS, **GEN**eration **EVALUATION SYStem**, is a constrained economic dispatch model that uses Monte Carlo sampling to simulate uncertainty in streamflows, short-term load, wind, solar and thermal generation forced outages. The model performs a chronological, multi-area, transmission constrained dispatch, which includes a detailed regulation of hydro power projects in the watershed of the Columbia River and a simple dispatch of Pacific Northwest regional thermal plants to meet regional load.<sup>1</sup>

## 1.1 PURPOSE

GENESYS is used by the Northwest Power and Conservation Council and Bonneville Power Administration (BPA) to perform studies requiring detailed hydro dispatch for planning purposes. More specifically the Council uses GENESYS for annual adequacy assessments, periodic regulated hydro flow studies and periodic analysis of lost revenue due to hydro dispatch change. The adequacy of the regional power supply is assessed probabilistically in GENESYS by evaluating any regional shortfall against the

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<sup>1</sup> This document will rely heavily on the work of previous documentation efforts by John Fazio and Gwen Shearer. Much of the language and information is compiled from “documentation.docx”, “GENESYS geneology.doc” and other documents in the Source Documentation folder in the GENESYS redevelopment folder.

Council's adequacy standard<sup>2</sup>. This standard has been designed to assess whether the region has sufficient resources to meet growing demand for electricity in future years. Regulated hydro flow studies have been performed for the Fish and Wildlife department for fish passage survival and life-cycle studies. Additionally, GENESYS is utilized for studies of changes in hydro generation due to Fish and Wildlife Program recommendations and climate change scenarios.

GENESYS is typically run for only one operating year (October through September) for which it runs thousands of simulations, modeling stochastic loads, forced outages, wind, solar and water conditions. It also has the capability of starting in any month with current starting conditions and running thru September.

## 1.2 HISTORY

In 1999, deterministic load-resource balance in the region was nearly 4,000 MW deficit. GENESYS was developed as a dispatch model to evaluate adequacy in a single year. A distinguishing characteristic of GENESYS from predecessor production cost models<sup>3</sup> was the ability to utilize stochastic and deterministic input variables and perform a hydro and thermal generation dispatch. Unlike predecessor models GENESYS was not designed to test long-term load uncertainty and utilize system expansion logic. In the Council's modeling portfolio, GENESYS is used to provide adequacy information to the Regional Portfolio Model (RPM) which considers long-term load uncertainty<sup>4</sup> and performs regional power system expansion studies.

## 2 OVERVIEW

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GENESYS is made up of multiple modules of which some can be run independently<sup>5</sup>.

### 2.1 FILE TYPES

The input, output and miscellaneous other files in GENESYS are stored as different types of files with the following suffixes:

.bin - Binary files used to store either input or output data.

.dat - Text files used to store input data.

.inp - Text files used to store input data.

.out - Text files used to store output data.

.vbi - Text files used to store output data for visual basic interface.

.f90 – FORTRAN 90 modules or sub routines.

.for - FORTRAN modules or sub routines.

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<sup>2</sup> See Chapter 11 in the 7<sup>th</sup> Power Plan for a more detailed description of the adequacy standard.

<sup>3</sup> System Analysis Model (SAM) and ISAAC

<sup>4</sup> The RPM assesses more long-term uncertainties other than load including fuel and power price uncertainty.

<sup>5</sup> Not currently used, but can run HYDSIM as a standalone module.

.log - Log files used for error trapping and reporting.

These files are discussed and categorized in more detail in the Appendix below.

## **2.2 STRUCTURE**

GENESYS is made up of modules, subroutines, as well as the input and output files that are needed to run GENESYS in multiple different modes. GENESYS has HYDSIM (BPA's hydro regulator) within it. GENESYS' structure has supported adding on functionality as needed (different hydro dispatch modes) and overwriting or switching off functionality that is legacy (long-term expansion logic).

## **2.3 MODEL FLOW**

The model is initiated by running the executable (*GENESYS VXX.exe*) that has file structure access to folders with the compiled FORTRAN 90 modules and subroutines, and the appropriate input files as described above. The input and output files are often stored in the same folder as the executable, but the compiled modules and sub-routines are stored in subfolders under the current GENESYS version.

# **3 STOCHASTIC INPUTS**

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The load, water conditions, wind generation, solar generation and thermal forced outages can all be modeled as random variables within GENESYS. A set of hourly loads and a set of hourly wind capacity factors for each temperature year are input, as well as a set of historical 14 period (April and August are divided into two periods) streamflows by water year (currently 80).

## **3.1 LOAD, WIND AND SOLAR**

Hourly loads and wind generation are associated with 77 temperature years from 1929 to 2005. Load and wind can be aligned by temperature-year or drawn randomly. Solar generation is handled similarly as to wind, but currently the data is somewhat limited. The uncertainty in wind and solar is captured through a multi-year generation record, with each year having a user defined number of possible scenarios.

Hourly loads are input into the model by temperature year for a particular operating year. The user has the option of inputting the hourly loads by node or in total, in which case percentages are used to apportion regional loads between nodes. The hourly load for a game is determined by the draw of a temperature year.

Wind is input as a nameplate capacity at a site (three sites are possible, each defined at a node) with hourly capacity factors by wind year for that site. The drawn wind year capacity factor multiplied by the nameplate capacity defines the wind generation for a particular game. There is an option for randomly picking from up to 20 different wind capacity factors for a particular wind year. Wind is modeled as a load reduction resource. The hourly wind at a node in a simulation is subtracted off the hourly loads and the residual load is what is used in the dispatch logic. Again, solar is modeled similar to wind, but only 20 years of data is currently available.

## **3.2 STREAMFLOWS**

An 80-year historical record of streamflows from 1929 to 2008 is sampled. The user can specify whether the water years are drawn from the historical record randomly, for a fixed set of years, or sequentially. The user can also alter the weighting of the water years when drawn randomly. Currently the model is typically run with the Canadian operation as fixed, based on a sequential water year selection and with one water year wrapping into another (thus each simulation starts at a different system hydro content). This mode of running GENESYS causes an end-of-year/beginning-of-year discontinuity when water years are chosen randomly, which is why the model is currently run sequentially. The model also has the ability to run a Treaty Storage Regulation that defines the operation of the Canadian system before doing the operation of the U.S. projects, and, in this mode, running with random water conditions does not cause a discontinuity and random water draws are appropriate. GENESYS can also be run in refill mode, that is, the October initial elevation is reset for each game. For Council studies the model is not commonly run in refill mode.

## **3.3 FORCED OUTAGES**

To reflect the uncertainty surrounding unexpected lack of availability (often unit failure) of thermal generation units, GENESYS reflects a forced outage rate and the mean amount of time it takes to repair each thermal unit. Each thermal generating resource has a user-defined forced outage rate and a mean repair time. The setting can be for zero outages, non-stochastic outages (reduction applied to every hour) or stochastic outages. When the setting is on “stochastic outages”, the forced outage rate and mean repair time are used to calculate the hours until the unit is forced out. Each resource has an initial “state” (operating or experiencing an outage) based on a random draw. The number of hours until subsequent states depends on additional random draws. The availability of thermal resources is updated every hour.

The model picks how long an outage state or an on-line state will last. For example, the state might last 257.543 hours. For 257 hours then the plant’s availability would be all the way up or down, depending on which state it’s in. The last hour the capacity available to be dispatch will transition by .543. So the thermal transitions up and down always take place over one hour, not several.

# **4 DETERMINISTIC INPUTS**

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All generation resources and contracts in the Pacific Northwest region are modeled in GENESYS. Each has a set of defined deterministic parameters that are used to determine the resource dispatch/availability under stochastic fuel uncertainty and/or forced outages.

## **4.1 TOPOLOGY**

### **4.1.1 Transmission**

The topology of GENESYS is set up into paths and nodes. The nodes are sub-regional accumulations of plants and the paths represent transmission available in a particular direction from those nodes. Represented in the “stick and bubble” format, where the paths are “sticks” and the nodes are

“bubbles,” Figure 1-1 is a diagram showing the nodes and paths in GENESYS as currently run by Council staff. BPA has a different node and path configuration with which it runs GENESYS that includes a node for BPA and a node for all other PNW utilities.

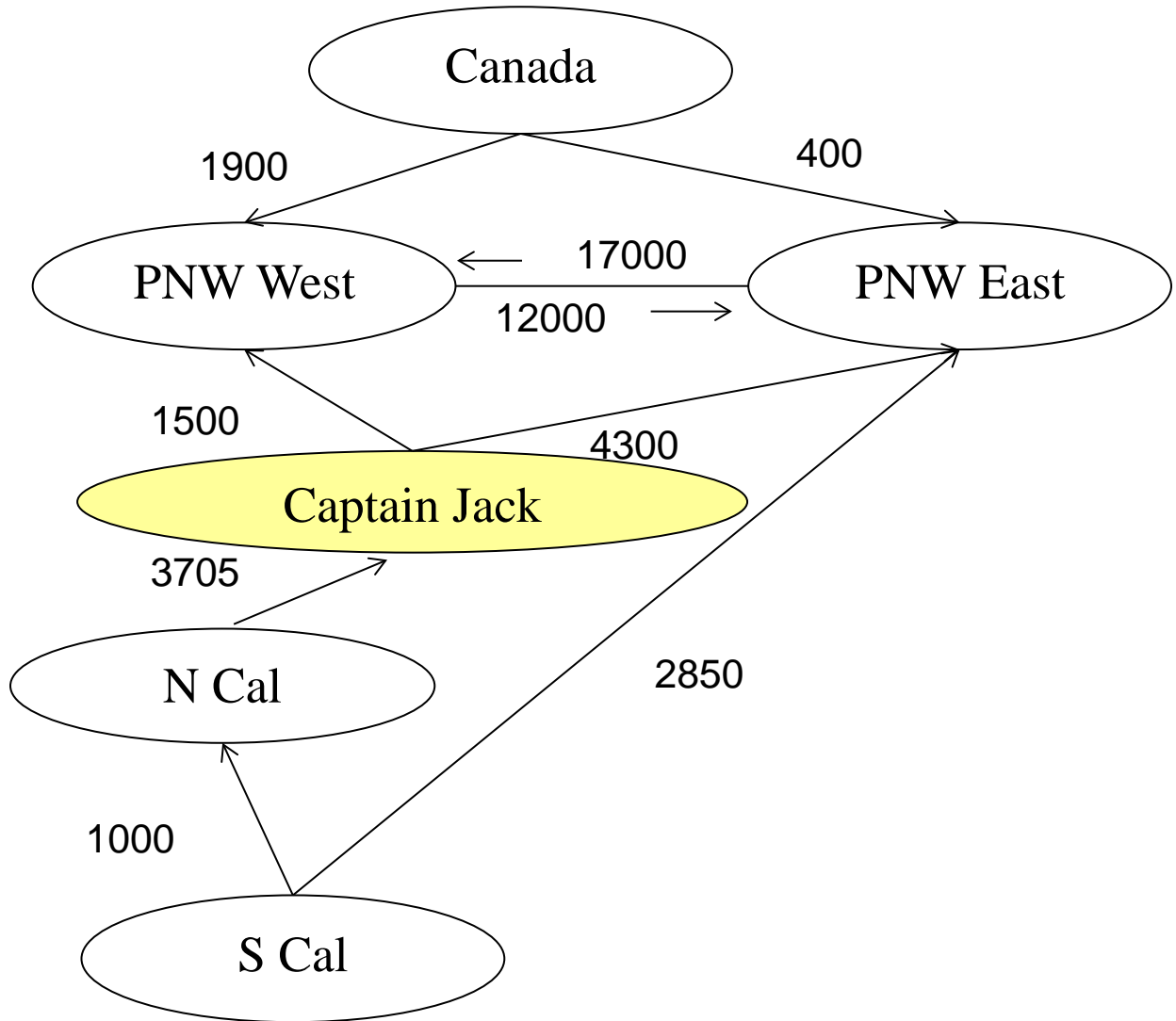


Figure 1-1: GENESYS Topology<sup>6</sup>

Currently GENESYS has two ways of modeling transmission losses that are being used. One way assumes losses are included in the load inputs. The other way models losses as a percentage of generation.

#### 4.1.2 Resource

Each resource in GENESYS is associated with a node, which defines any transmission limits on the resource. Each hydro resource is at a particular point in the Columbia River watershed which determines

<sup>6</sup> From a presentation made to the RAAC Modeling Subgroup on 10/22/2013, GENESYS Topography.pptx.

its water availability. Functionally, in GENESYS, the location of any other type resource does not determine its fuel usage capability<sup>7</sup>.

## **4.2 HYDRO GENERATION PARAMETERS**

The hydropower generation plants in GENESYS are split into regulated and independent hydropower plants. Each regulated plant and the independent hydro generation is associated with one of two nodes (PNW East and PNW West). For each hydro condition the independent hydro generation is fixed and there is assumed to be no flexibility in the operation<sup>8</sup>. Dispatching the regulated hydro generation plants is one of the primary focuses of the GENESYS model and the use of a multi-project hydro regulator provides the ability to evaluate tradeoffs between operation the system for reliability and strict adherence to fish and wildlife constraints.

### **4.2.1 Constraints**

The regulated hydro generation parameters include the configuration of the hydro projects, the generating capability of the hydropower plants, the water availability, and operating constraints (e.g. flow constraints, elevation targets). The hydro generation parameters are discussed in more detail in the Input Files section in the Appendix.

## **4.3 THERMAL GENERATION PARAMETERS**

Thermal generation plants in GENESYS like hydropower plants are associated with a node. Plant parameters include plant capacity, average heat rate, forced outage rate and mean time to repair (not applied deterministically), must run switch, online and offline dates, fuel type selection, maintenance schedule and fixed and variable costs. Most of the inputs are contained in the *GenRes.dat* and *GenRes cost.dat* and can be explored in more detail in the Input Files section of the Appendix. Thermal plants types include coal, nuclear, biofuel, and gas.

### **4.3.1 Constraints**

There are no explicit fueling constraints in GENESYS for thermal plants. A thermal plant generation is constrained by plant capability, maintenance outages, forced outages, must run determination, and transmission capability. There are two ways thermal commitment is currently modeled. One is specifically for coal plants. In this method, if a coal plant is dispatched in the day dispatch (explained later), it is treated as must run for the day. The other method is thermal commitment logic similar to the Aurora model. In that logic there are six types of thermal plants for which minimum down times, minimum up times and ramp rates constrain the plant's generation.

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<sup>7</sup> Operationally, thermal resources could also experience fuel limitations due to location, but that is not currently modeled in GENESYS. Thermal resources are not topologically limited. Wind resources are similarly dependent on fuel limitations by location, but the variability and constraints of that is very complex and modeled externally.

<sup>8</sup> However, from the TRAP, independents do provide some capacity and it is incorporated into the sustained peak file.

## **4.4 OTHER GENERATING RESOURCE PARAMETERS**

Wind and solar plants are currently modeled as must-take generation accumulated by node and their hourly generation is subtracted from the load.

### **4.4.1 Constraints**

There are no explicit deterministic fueling constraints in GENESYS for wind and solar resources. The stochastic nature of the fuel availability for wind and solar generation is defined in the Load, Wind and Solar section of the Stochastic Inputs.

## **4.5 CONTRACTS/MARKET**

Long-term contract obligations (between defined nodes) are modeled in GENESYS as well as short-term market purchases that are used to balance load in each Northwest node. Long-term contracts are defined by a particular seasonal, weekly and/or daily shape, source node and delivery nodes. Intraregional long-term contracts are executed by looping through source and delivery nodes and meeting total contract demand between nodes with the least expensive resources at the source node. Extra-regional market purchases are currently simulated as individual generic resources in the northern and southern California nodes. Spot market purchases are modeled with sufficiently high heat rate to ensure that they will be the last resource dispatched prior to using borrowed (emergency) hydro generation. Purchase ahead resources (purchased for a month, window, or day) are purchased if there is a forecast of a deficit and there is also an option to purchase ahead to displace high cost thermal in the PNW. There is currently not an extra regional demand for short-term market sales.

### **4.5.1 Constraints**

There are no explicit constraints in GENESYS for contracts. However, the model does accounting on each transmission node to which a contract is associated and calculates the net contract amount between each node for each hour. The net transmission transfer capability is adjusted, in both directions, based on long-term contracts. Extra-regional market purchases can have the same constraints as any thermal plant.

## **4.6 RESERVES**

GENESYS records reserve violations by hour when the reserve requirement is greater than the reserves available. The contingency reserve requirement is based either on the generation reserve requirement or the transmission reserve requirement, whichever is greater. The generation requirement is currently set to the sum of 7% of thermal generation and 5% of hydro generation in an hour<sup>9</sup>. The transmission requirement is the amount of megawatts flowing on the maximum loaded line. The check for reserves for either thermal or hydro generation is the sum over what is available for dispatch (in the case of hydro this is the total hydro capacity) minus what is being generated. Operating reserve requirements are explicitly considered in the trapezoid approximation (explained further under Day Dispatch) for hydropower resources but operating reserve requirements are not currently explicitly assigned to thermal resources.

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<sup>9</sup> This will be updated to reflect the 3% generation and 3% load WECC contingency reserve requirements.



## 5 DISPATCH LOGIC

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### 5.1 SUMMARY

GENESYS dispatches in a chronological order over four dispatch time frames<sup>10</sup>. It dispatches for the month, a user defined “window” of days, daily shape, and hourly. The thermal and hydro resources are dispatched to meet loads in each dispatch time frame according to the variable costs of the thermal and hydro “shadow prices”. The hydro “shadow prices” are represented relative to the variable costs of particular thermal plants, as defined by the user<sup>11</sup>. Figure 2 gives a schematic of the dispatch logic.

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<sup>10</sup> Source documentation from *documentation.docx*

<sup>11</sup> Note that this is a proxy for the opportunity cost of different hydro blocks.

### Periodic Dispatch:

- 14 Period streamflow forecast for hydro
- Incorporate HYDSIM rule curves to determine available hydro energy in each block. Each block is given a price.
- Build hydro-thermal resource stack based on price.
- Resource stack aligns average load net undispatchable variable energy resources and contracts.
- Outputs period hydro energy, and if necessary determines amount of period off-peak market purchases.



### Window Dispatch:

- Takes proportional amount of hydro and thermal energy from the period over the duration of the window.
- Resource stack aligns average load net undispatchable variable energy resources and contracts.
- Using the period hydro energy from Period Dispatch, determine marginal hydro price in the window and off-peak market purchase amount ahead over the window period.



### Daily Dispatch:

- Using average hydro and thermal from Window Dispatch and the TRAP results, determine hourly hydro shape.
- Resource stack aligns with load net undispatchable variable energy resources and contracts.
- Outputs available hourly hydro for next 24 hours and off-peak market purchase amount ahead over the day.



### Hourly Dispatch:

- Uses hourly hydro availability from daily dispatch and marginal hydro price from window dispatch to constrain dispatch of hydro in hourly dispatch step.
- Reserve requirements implicit in hydro peaking shape.
- Thermal resource are dispatched after forced outages.
- Resource stack aligns with load net undispatchable variable energy resources and contracts.
- If load net obligations are not met, additional spot market purchases up to limits and then borrowed hydro are used to meet gap.



### Emergency Resource Dispatch (Post Processor)

- Demand response and storage resources are dispatched within their constraints to meet any additional load that is unserved.
- After Emergency Resource dispatch, load still unserved is categorized as a curtailment.

Figure 2: Multi-period dispatch diagram

## 5.2 PERIOD DISPATCH

A hydro year is split up into 14 periods which are, for the most part, monthly, with April and August split into the first and last halves of the month<sup>12</sup>. The 14 period hydro regulator model used to determine available hydro in GENESYS is HYDSIM, developed and maintained by BPA. Reservoir and flow characteristics are modeled such as beginning and ending contents, minimum and maximum flows, minimum and maximum storage, and spills at each hydro project for each of the 14 periods. Each period, the amount of hydro energy is available to each node for the month is calculated, given the starting contents of the reservoirs of that month. The total available hydro energy is separated into what will be referred to as “blocks” of hydro energy. The hydro blocks are the amount of energy available if the system was drafted down to a given point. To determine the boundaries of the hydro blocks, the hydro regulator is run four times at the beginning of the month: to URC (Upper Rule Curve<sup>13</sup>), to VECC (Variable Energy Content Curve<sup>14</sup>), to draft point 6 (Proportional Draft Point), and to draft point 8 (Empty<sup>15</sup>).

*Hydro block 1* is the amount of energy that must be generated to get to URC plus the energy generated by the hydro independents.

- Basically must run (or spill) hydro, it is typically priced just more than Columbia Generating Station.

*Hydro block 2* is the amount of energy between URC and VECC.

- It is typically priced just less than Beaver 1-7.

*Hydro block 3* is the amount of energy between VECC and draft point 6.

- It is typically priced just more than Fredonia 1.

*Hydro block 4* is the amount of energy between draft point 6 and CRC, Critical Rule Curve<sup>16</sup>. XTRA1 on BPAREGU.OUT is the critical rule curve.

*Hydro block 5* is the amount of energy between hydro block 5 and draft point 8, limited by the user input for “borrowed hydro” of a 1000 MW-periods. Draft point 8 in BPAREGU.OUT is the total energy (XTRA2) when drafting from starting content to as close to empty as constraints allow.

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<sup>12</sup> This is due to distinctive runoff and operation characteristics between the first and second halves of April and August.

<sup>13</sup> *Upper Rule Curve* is also known as the flood control rule curve. Calculated by the Army Corp of Engineers, it “defines the drawdown required to assure adequate space is available in a reservoir to regulate predicted runoff for the year without causing flooding downstream.”, per “Modeling the System” pamphlet.

<sup>14</sup> *Variable Energy Content Curve* guides non-firm generation energy generation, and is usually the lowest of the four rule curves in winter and early spring and is based on the predicted runoff during the year. Functionally this is a reservoir energy content curve. Drafting a reservoir no further than this point ensures a high probability of refilling by the end of spring runoff season. VECC is made up of Made up of the Assured Refill (ARC), Variable Refill (VRC), and Limiting Rule (LRC) Curves from BPA

<sup>15</sup> Because of constraints other than the rule curves, GENESYS never gets to empty.

<sup>16</sup> *Critical Rule Curve* “defines the reservoir elevations that meet firm energy hydro requirements under the most adverse streamflows on record”, per “Modeling the System” pamphlet.

Note that the minimum amount of hydro in each of the hydro blocks is set to one megawatt. The hydro blocks are divided between the nodes in the PNW region according to the total amount of hydro energy output from the hydro projects specified at each node.

After using the 14 period hydro regulator to estimate how much hydro energy is available in a “month”, GENESYS estimates how much hydro energy will be needed from the hydro system to meet load in the current month by doing an economic dispatch of hydro and thermal average energy by node. This total amount of monthly (or period) hydro energy defines the trapezoid approximation function (described later) used to determine the sustained peaking limits in each hydro window. The marginal monthly hydro value is calculated as the shadow price of the last hydro block dispatched.

### **5.3 WINDOW DISPATCH**

The hydro “window” is a number of days, defined by the user either as a set number of days (currently using two days) or by the days of the week in which case a window is either a) Monday thru Sunday or b) the number of days at the beginning and end of the month left over from dividing the month into weeks.

An economic dispatch is done for a window using the average loads for the window<sup>17</sup>, the expected thermal for the window (using information on whether the thermal was forced out in the last window), and the hydro available per the period dispatch step. A key piece of information coming out of the window dispatch is the marginal hydro price for that window. It is used as the shadow hydro price for hydro in all the hourly dispatches for that window. In the hourly dispatch the marginal hydro price is the price of all the hydro above hydro minimums, but below “borrowed” hydro. The estimated hydro energy from the window dispatch is used to estimate the sustained peaking capacity based on inputs from the trapezoidal approximation (explained in more detail in Daily Dispatch). The hydro block availabilities and estimated current draft levels are updated, and the borrowed hydro accounting is performed for every window.

### **5.4 DAILY DISPATCH**

The dispatch for the first day of the window immediately follows the window dispatch in the GENESYS logic. The most important piece of information from the day dispatch is the amount of hydro energy needed from the system for that day. The amount of hydro energy dispatched for the day is then shaped hourly based on the load shape, sustained peaking limits, and hydro minimums. The amount specified in each hour from this shaping sets the hydro available to the hourly dispatch, except for hourly borrowed hydro. The code tries to preserve the load shape in shaping the hydro as much as possible. The thermal is assumed to be dispatched flat through the day, except for off peak thermal purchases or resources, as defined by the user.

The trapezoidal approximation is a preprocessor to GENESYS that estimates the hydro system's peaking capability based on a linear approximation model. It approximates the typical twin peak load shape to be that of a trapezoid, which is run against a set of detailed hydro regulator model outputs for a given fish flow regime across the 80-year water record. The results are synthesized into GENESYS inputs representing the sustained peaking capability and hydro minimum of the system as a function of

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<sup>17</sup> From a specific temperature-year.

monthly energy generated. The sustained peaking capability is defined for a 1, 2, 4, and 10 hour duration. As explained above, in GENESYS, after the hydro energy for the day has been shaped into the day's hours, the hourly amounts are checked against the sustained peaking constraints and the hydro minimums, and then adjusted if necessary before the hourly operation.

## **5.5 HOURLY DISPATCH**

After the day dispatch, each hour of the day is modeled. The loads and resources and their shadow prices have been defined via the window dispatch, day dispatch, and hourly hydro shaping before the hourly dispatch. The key thing that can change in the hourly dispatch is thermal generation based on forced outages. The dispatch logic that the model goes through is similar to the month, window, and day dispatches.

After all hours of the day are modeled, the next day in the window is dispatched, first as a day average and then on an hourly basis, until all days in the window have been dispatched at which time the next window in the month is dispatched.

After the hourly dispatch is done for each hour of the month, the amount of hydro dispatched in the month in total is added up and the hydro regulator is run again to determine the ending contents of the reservoirs for that month, which become the starting contents for the next month.

## **5.6 SLICE LOGIC**

The slice logic is only used for BPA runs. All hydro, thermal, wind, and contracts are assumed to be sliced resources unless otherwise specified by the user. Each sliced resource is reduced by the slice percent before being placed in the dispatch resource stack. After the dispatch, each resource's generation is increased by the slice percent. The generation above what was dispatched to loads is the amount that is deemed to go to the slice customers.

## **5.7 BORROWED HYDRO**

Hydro can be "borrowed" in periods of system stress to serve load in the window, day, or hourly dispatches. The amount of hydro energy available in the window and day dispatches can be determined by the user defined borrowed hydro limit, or the maximum of the user defined borrowed hydro limit and the amount of hydro block 7 available from the period hydro regulator. The price that defines where the borrowed hydro is dispatched amongst the thermal is user defined. Borrowed hydro dispatched in the day dispatch is added to the other hydro, shaped to load, and included in the check on sustained peaking limits. In the hydro shaping routine, no differentiation is made between borrowed hydro and other hydro, and, therefore, in the hourly dispatch the borrowed hydro is not broken out separately from the other hydro.

The difference between the maximum amount of borrowed hydro available to the day dispatch and what was dispatched in the day dispatch is converted to megawatt-hours and that amount is made available at the borrowed hydro price to the hourly dispatches within that day. In addition, if there is any hydro in an hour that was shaped into that hour, but not dispatched in that hour's dispatch, it is also added to this megawatt-hour amount and dispatched at the borrowed hydro price. As the hourly borrowed hydro is dispatched through the day, the amount of megawatt-hours available in each hour is

decremented. After each hourly dispatch, the sustained peaking limits are checked. If the sustained peaking limits are reached, the borrowed hydro is made unavailable for the rest of the day.

Before the window dispatch, the amount the system has “flexed” in borrowing hydro in the last window is calculated and is equal to the average hydro dispatched over the window hours minus what the firm rights to hydro for the period was from the hydro regulator. From this, the maximum megawatt-hour flex amount for the period and the end-of- period flex megawatt amount is calculated. The end-of- period amount megawatt target is indicative of how much the hydro regulator will have to make up at the start of the next period.

Borrowed hydro is priced so that it will be dispatched last. If later in the period, not all the hydro available is used in a window, the system begins to “pay back” the borrowed hydro. If at the end of the period, the borrowed hydro has not all been recouped, the beginning contents of the next period reflects that deficit therefore, and, therefore, the amount of hydro energy available in the next period is less.

## **5.8 EMERGENCY RESOURCE DISPATCH**

The emergency resource dispatch is a post processing step used to include the capability of high cost resources used for system reliability such as demand response, pumped hydro, and dispatchable standby generation. All these resources have constraints on total hours of generation and total available capacity per period. The emergency resources are the last resources dispatched before system curtailment is examined for resource adequacy purposes.

# **6 APPENDIX**

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This appendix contains a list of input and output files in addition to modules and subroutines needed to run current and latent functionality in GENESYS. The files are broken into three types: those that are associated with the running of the HYDSIM portion of GENESYS, those that are associated with running the rest of GENESYS (denoted by GenSimMain), and those associated with the Post Processor.

## **6.1 INPUT FILES<sup>18</sup>**

Some of these input files are currently required to run GENESYS. Some support what is as of now legacy capability.

### **6.1.1 GenSimMain files**

#### **6.1.1.1 *GenSimMain binary input files***

"Hourly Loads","OYHRLD","Hourly Loads 2019.bin"

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<sup>18</sup> Details about input files was derived heavily from conversations with John Fazio and *documentation.doc* by Gwendolyn Shearer.

- Input file- User specified hourly loads for the run. 80 years of hourly loads represented in an 8760 by 80 matrix, no leap year.

wind\_XX.bin

- Input files – hourly capacity values in an 8760 by 77 matrix.
- One file for each of the 20 different temperature correlations to the capacity factor.
- Only Columbia Gorge wind

solar\_XX.bin

- Input files – hourly capacity values in an 8760 by 12 matrix.
- Currently only for Southern Idaho from NREL WWSIS<sup>19</sup>

### 6.1.1.2 *GenSimMain text input files*

"Allocation data", "ALLO", "Alloc.dat"

- Input file – allocates demand (PNW Demand section) into the nodes via specified percentage amounts if the switch “Hourly Load File by Node” is set to false in Studydef.

"Main Stem Hydro Allocation", "ALLOCHYD", "AllocMainHydro.dat"

- Input file – assigns hydro generation resource to a particular node

"Cashflow", "CASH", "Cashflow.dat"

- Input file –percentage split of costs between years project is being built. Carryover from production costing algorithms.

"Conservation Program Data", "CONS", "Conserv.dat"

- Input file – conservation parameters for when we want to explicitly add effect of conservation, instead of just netting it out in the *HourlyLoads.bin* file.
- Not currently used to input conservation.

"Contracts", "CONTR", "Contracts.dat"

- Input file – Firm contract price, shape (by period and by hour), volume by source and delivery nodes.

"Demand Daily Shapes", "DSHP", "DayShape.dat"

- Input data – 24 hour shape that is applied to resources defined as off peak, new large single loads, conservation, or contracts to create hourly availability or amounts

"Northern Cal Daily Temp", "NCTMP", "Daytemp NCal.dat"

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<sup>19</sup> WWSIS, Western Wind and Solar Integration Study

- Input file – Northern CA daily average temperatures used to modify import capability based on temperatures.
- Data read into model, but model does not do anything with it.

"Daily Temperature", "DTMP", "DAYTEMP.DAT"

- Input file – Regional daily average temperatures weighted by loads in Portland, Seattle, Spokane and Boise.
- These temperatures are used in the Council's short-term load forecasting model to generate the 8760 (hour) by 80 (temp year) load file used in GENESYS.
- Data read into model, but model does not do anything with it.

"Demand", "DMND", "Demand.dat"

- Input file – Defines nodes.

"Escalation Data", "ESCL", "Escl.dat"

- Input file – Cost escalation rates.
- Not currently used.

"Financial Data Sets", "FNCE", "Finance.dat"

- Input file – Financial life and discount rate.
- Not currently used.

"Fixed Flow Years", "FIXYR", "FixFlowYears.dat"

- Input file – This file is for when switch activated in StudyDef.dat to feed the order of the water years for every game that is run

"Fixed Load Years", "FIXLOAD", "FixLoadYearsCycle.dat"

- Input file – This file is for when switch activated in StudyDef.dat to feed the order of the load years for every game that is run.

"Flow Augmentation", "FLOWAUG", "FlowAug.dat"

- Input file – Flow augmentation adjustments to be used with TSR GENESYS runs.

"Forced Outage Override", "FORO", "FOR.dat "

- Input file -

"Fuels Data", "FUEL", "Fuels.dat"

- Input file – Fuel prices and pointers toward escalation and shaping by fuel type.

"Gen Vs Temp Functions", "GTEMP", "Gen Vs Temp.dat"

- Input file – Factors to derate thermal output according to temperature.
- Not currently used.



"New Gen Resource Data", "GRES", "GenRes.dat"

- Input file – Generation resources available for dispatch (does not include regulated hydro, but includes IPP, out-of-region spot market and purchase-ahead resources).

"Resource Cost Data", "GCOST", "GenRes Cost.dat"

- Input data – Generation resource fixed and variable cost, and pointers to multi-year shape information.

"Monthly Distribution Data", "SEAS", "Month Distr.dat"

- Input file – Periodic shape file used for contracts and gen resource (or anything that has a monthly shape) capacity factors
- This file is how Genesys reflects thermal maintenance schedules

"Reserve Amount", "RESAMT", "ResAmt.dat"

- Input file – Additional reserve requirements beyond the percent reserves input in Studydef.

"Slice Resources", "SLCRES", "SliceResources.dat"

- Input file – Slice percentage used and other information

"OY Solar Capacity", "OYSOLCP", "SolarCapacity.dat"

- Input file – Solar Nameplate capacities for different sites

"Multiple Solar Sets", "SolarSampling.dat"

- Input file – Definition of filenames for solar data

StudyDef.dat

- Input file – User inputs, study parameters (like study start and stop, number of games), , switches used and specifies input files used in the run.
- Like a run setup sheet. File must be named Studydef.dat.

"Hydro Sustained Peak Data", "SUSPK", "Peaking\_2node.dat"

- Input file – Sustained peak versus energy curves for 2, 4 and 10 hours by node.
- Input from TRAP (trapezoidal approximation program).
- Can include the effects of INC and DEC.

ThermCommittmentData.dat

- Input file – This is data for unit commitment logic that is similar to Aurora.
- File must be named ThermCommittmentData.dat

"Day Thermal Maintenance", "DAYTHERM", "ThermMaint.dat"

- Input file – Thermal maintenance times specified from start day to stop day

- Alternative way to input thermal maintenance schedules as opposed to using MonthDist file that derates plant for whole month.

"Transmission Links","TRANS","Trans.dat"

- Input file – Transmission parameters between nodes, including the SW inertia.

TSRdef.dat

- Input file – Treaty Storage Regulation definitions
- Must be named TSRdef.dat

TSRfilenames.dat

- Input file – Files needed to run Treaty Storage Regulation
- Must be named TSRfilenames.dat

"TSR Loads","TSRLD","TSRloads.dat"

- Input file – loads for Treaty Storage Regulation of HYDSIM
- Firm and secondary loads (aMW) by period
- Only used when running TSR (Treaty Storage Regulation) mode. This input file allows GENESYS to dynamically calculate the AOP elevations for random water year runs.
- When not running TSR studies, Canadian operation is fixed based on an AOP study from outside the model which prevents doing random draws on water years.

"Water Year Set Override","UFLOW","WaterYearOverride80.dat"

- Input file – In random hydro mode, this is used to weight the water year draws

"OY Wind Capacity","OYWDCP","WindCapacity.dat"

- Input file – Defines the nameplate capacity for a maximum of three wind sites and the nodes where they reside

"Multiple Wind Sets","WindSampling.dat"

- Input file – Definition of filenames for the 20 temperature correlated wind profiles.

## 6.1.2 HYDSIM files

### 6.1.2.1 Hydsim binary input files

"Actual Energy Regulation (AER) data","AER","AER.BIN"

- Input file - Actual Energy Regulation, initial guesses at the end of period target elevation for all the reservoirs

constraints00.bin

- Output and input file – constraints violated in general, Hydsim can read this file if the constraints haven't changed from the previous study

constraintswy.bin

- Output and input file – constraints violated for specific water years, Hydsim can read this file if the constraints haven't changed from the previous study

"Hydro period data","HPER","PERIOD.bin"

- Input file – contains all the temporal data, changes period-by-period for each water year.
- Examples: modified natural flows adjusted for irrigation and evaporation, rule curves.

"Hydro plant data","HPLT","PLANT.bin"

- Input file- Non-Temporal data for reservoirs and run-of-river projects
- Examples: H/K versus head, tailwater versus outflow, storage versus elevation, head versus tailwater

### **6.1.2.2 Hydsim text input files**

"Spill bypass dates file","BYPAS","BYP.DAT"

- Input file – Bypass spill parameters.
- Currently overwritten by information from operexcep.dat or the SPILL.dat file

"Assured refill file","ARFL","ECC\_ARC.dat"

- Input file – Assured Refill Curves for September to December by reservoir plant

"Encroachment data","ENCRCH","ENCROACH.dat"

- Input file – Used by HYDSIM to determine encroachment by upstream plant. Shows relationship between upstream tailwater and downstream forebay elevation.
- Currently used by HYDSIM.

"Flow limits table","HFLOW","FLOW\_LIM.DAT"

- Input file – Flow constraints by dam.
- Examples: QL (Min flow), QH (Max flow), WB (Water budget) BiOp flow constraints, DR (draft from upstream dam), QP (flow requirement at downstream dam), CM (comments).

"Hydro Independent data","HIND","HI.dat"

- Input file – Hydro independents generation (aMW) for each of the 80 hydro conditions
- Nodes must be in the same order as Demand.dat

"Power factor (H/K) file","HKAV","HKcpav.dat"

- Input file – Initial guess at the power factor (H over K) for each of the regulated hydro projects

"Hydro availability data", "HAVAIL", "HYAVAIL.DAT"

- Input file – Hydro generation resource availability
- Percent available by resource by period

"Multidam Regulator User Inputs", "HDEF2", "HYDDEF.DAT"

- Input file – Study definition file for running HYDSIM, file must be named HYDDEF.dat
- User switches, some data (e.g. drawdown limit for Coulee).

MDFilenames.dat

- Input file – Defines data files necessary to run GENESYS in oper regulation or non-TSR mode.
- Shows the name and the path to run HYDSIM portion of GENESYS
- File must be named MDFilenames.dat

"Mica data", "MICA", "MICA.DAT"

- Input file – Flow and reservoir information on Mica and Arrow.
- Canadian operations are fixed with the exception of this water balancing data for Mica and Arrow.
- Tells GENESYS what ending elevations need to be for Mica and Arrow depending on flow.

"Runoff forecast file", "FCST", "NWSFCST.DAT"

- Input file – Volume forecast of modified natural flows going into The Dalles, by hydro condition year and period.
- Decisions are based on this forecast, but the model is then run on the modified streamflows per the *PERIOD.dat* file.

"Exception file for final operation", "HEXCP", "OPER\_EXCEP.DAT"

- Input file – the operating constraints for all hydro projects, for which the binding constraint is the last listed.
- Examples: Min and Max elevation, min and max flow, and bypass spill.
- These override *FLOW\_LIM.dat*, *STOR\_LIM.dat* and *SPILL.dat*.

"Residual hydro loads", "HLOAD", "RHL\_12RC19F.dat"

- Not used with Genesys

"Runoff volume file", "RNOFF", "RUNOFF.dat"

- Residual runoff in Maf through July for 80 water conditions

SCLFishData.dat

- Input file – Flow constraints for fish passage by fish type
- File must be named SCLFishData.dat

"List of plants to run at AER", "SETAER", "settoaer.dat"

- Input file – Sets certain projects to run at the Actual Energy Regulation curve
- This can override the target elevations set in the AER.bin file

"Multidam Regulator Main User Input", "HDEF1", "simhydro.dat"

- Not used with Genesys

"Initial content file", "HINIT", "SI\_OPER.dat"

- Input file – Initial contents or elevation by project.
- Implementation period for these starting contents or elevations is determined in the *STUDY.def* file.

"Sliding spill file", "SLDSPL", "SLIDE\_SPL.DAT"

- Input file – Used in the past for sliding scale bypass spill as a function of flow.
- Not currently populated.

"Spill table", "HSPIL", "SPILL.DAT"

- Input file – Defines bypass spill, spill cap limits and other spill parameters by hydro project

"Spill priority file", "SPLPRI", "SPILPRI.DAT"

- Input file – If there is more generation than load, this tells you which projects you can spill the extra generation.
- Defines priority of spill in overgeneration instances.

"Storage limits table", "HSTOR", "STOR\_LIM.DAT"

- Input file – Defines storage parameters by hydro project.
- Examples: max and min elevations (soft and physical)

"Water Year Set Override", "UFLOW", "WaterYearOverride80.dat"

- Input file – In random hydro mode, this is used to weight the water year draws
- Note that this is an input to GenSimMain and Hydsim

"Water year selection file", "WSEL", "watysel.inp"

- Not used with Genesys

### 6.1.3 Post Processor Input Files

Standby.dat

- Input file – Provides energy and peak capacity limits for emergency resources.
- Includes demand response, pumped storage, etc.
- Post-processing, not dynamic within GENESYS.

## 6.2 OUTPUT

Listed below is a catalog of a common output file types that can be selected for GENESYS

### 6.2.1 GenSimMain Text files (.out files)

#### Borhydsum.out

- Monthly summary of hydro, other resources, unserved load, forced outages, and load by day
- Includes information on hydro (including borrowed hydro) dispatched in window and day dispatches

#### Contractdbg.out

- Summary of contract inputs by contract by hour for Weekday, Saturday, and Sunday
- Used for debug

#### DispatchResources.out

- MW dispatched by hour for all games for a resource specified in Studydef

#### EndCont.out

- Ending contents of each reservoir at the end of each game
- Used to reproduce the results of an individual game

#### FILEREC.out

- Report of file paths of the files used to run GENESYS.
- Does not include files to run HYDSIM, which are shown in MDFILEREC.out

#### Flex.out

- Maximum borrowed hydro in MWh used during a month and the amount still in the system at the end of the month

#### FOR.out

- Total forced outages in MW and the percent forced out for every hour of every game

#### Gameseed.out

- Random seeds used for every game, IF switch is activated in *StudyDef.dat*.
- Could be random seed same for all games, different for any game, or random seed taken from clock.

#### HourlyLoadDebug.out

- Loads, wind, and solar by hour, used for debug purposes

#### HydCapac.out

- Window hydro availability

- Sustained peak limits used each day
- Hourly hydro shaping information
- Used for debug purposes

#### Message.out

- GENESYS error and warning log.

#### MonthlyHyd.out

- Size of hydro blocks in MW and total hydro generation for each month for the first ten games

#### NodePath.out

- All possible permutations of transaction paths between nodes. Note that a transaction can move between several nodes before getting to final destination.
- Includes wheeling cost (in \$ per MWh), losses, shadow price, node names.
- Includes resources by home node and destination nodes.

#### OPRFileRec.out

- Report of the files used to run HYDSIM in an OPR run when running with the TSR

#### Overgen.out

- Amount of overgeneration spill in MW
- Must run thermal not used in MW
- Load reduction resources not used in MW

#### PurMW.out

- Purchase ahead resources purchased
- Purchases by day, window, and month each shown by hour

#### RelibRec.out

- Hourly output by game that returns megawatts curtailed, reserve violation flag, load, reserve requirement, additional reserves, thermal generation, contract purchases, hydro generation, wind generation, megawatts forced out, percentage of thermal resources forced out, wind capacity factor, and slice account (which is zero unless running a BPA version).

#### ResOut.out

- Hourly dispatch for specified resources, for the game specified in Studydef.
- Resources included in file are specified in GenRes

#### SegOp.out

- Hourly generation by resource for the game specified in Studydef
- Includes reserve violations, unserved load, overgeneration, and transmission flows

#### Slicesystem.out

- Similar information as System.out, but also includes slice generation
- Output for BPA version

#### SliceSegOp.out

- Similar information as SegOp, but also includes slice generation
- Output for BPA version

#### SOS1.out

- State of the System output
- Average dispatch over all games and all hours, by period of resource types.
- Raw LOLP (prior to emergency resource dispatch), probability of using borrowed hydro, maximum borrowed hydro used in a game (GWh).

#### SOS2.out

- State of the System output
- Dispatch level percentiles over all games by resource type, unserved load and market.

#### SOS3.out

- State of the System output
- Hourly duration curves by period by selected resource type and for unserved load.

#### SustPkLimHits.out

- Gives the game, year, month, and day a sustained peaking limit was hit, what the limit is, and the hourly shape of the hydro before and after adjusting for the limit.

#### System.out

- Specified single game summary (default is game 1).
- Supply demand summary, supply availability and dispatch, node-to-node, contracts, transmission loading across all nodes by period.

#### Therm.out

- Total gas, coal, nuclear, other thermal, and IPP running by hour for the game specified in Studydef

#### Transact.out

- Dispatch information for month, window, day and hour dispatches for the game and months specified in Studydef
- Supply stack, initial pass dispatch, opportunity transactions available, final dispatch, and period summary

#### Tranflow.out

- Mean, minimum, and maximum transmission flow between nodes by period for a game
- Note: there seems to be a bug in this output with respect to the game number



TSRFileTec.out

- Report of the files used to run HYDSIM in a TSR run

UnservdReason.out

- Summary of generation dispatched in those hours that have load curtailment.
- Note: there seems to be a bug in this output with respect to the games ouiput

WeatherYr.out

- Selection for the water, temperature and the wind year plus the wind set (out of the 20 different correlated wind capacity factors for that temperature year)

### **6.2.2 GenSimMain Text files (.vbi files)**

These text files often summarize the above text output files in a format created for the graphics package in an old user interface.

DayUSDDurat.vbi

- Duration curve data for daily unserved demand by node.

Exceed.vbi

- Unserved demand by percentile

GamePV.vbi

- Present values for each game.

MeanDemand.vbi

- Mean period nodal demand

MeanMonthlySourceAvail.vbi

- Mean period resource availability across all games

MeanMonthlySourceCapacity.vbi

- Mean period resource capacity across all games

MeanMonthlySourceFixOp.vbi

- Mean period fixed operating costs by resource across all games (in millions \$)

MeanMonthlySourceFuelUse.vbi

- Mean period source fuel use by resource across all games (in trillions of Btu)

MeanMonthlySourceOutput.vbi

- Mean period output by resource for all games (in aMW)

#### MeanMonthlySourceVarOp.vbi

- Mean period variable operating costs by resource (in millions of dollars)

#### Multidam.vbi

- Subset of the BPAREGU.OUT results.
- 6160 by 14 periods of minimum flows, forced spill, bypass spill, generation, ending content, ending elevation, flood control and PDP.

#### NetDemandDurat.vbi

- Duration curve for period demand

#### PNW Balance.vbi

- Average load resource balance by period by game

#### Pods.vbi

- Probability of designated shortage values

#### SegTrak.vbi

- For a specified game, gives hourly load, curtailment, long-term purchases, hydro generation, wind generation, contract imports/exports, reserve requirements, hydro reserves, thermal reserves, reserve violation.

#### SegTrans.vbi

- Hourly transmission flows by node for a specified game.

#### SegUnservedDurat.vbi

- Hourly unserved demand data (MW) by year for a specified game.

#### SourceAvailDurat.vbi

- Sorting hourly availability for resources specified in GenRes by period

#### SourceOutput.vbi

- Sorted hourly generation for resources specified in GenRes by period

#### Srccecost.vbi

- Mean variable and fixed operating costs, and capital costs by resource.

#### TranFlow.vbi

- Mean transmission flow by period for each transmission source/destination pair.

#### TransDuratMo.vbi

- Sorted hourly transmission observations by period for four transmission segments

### 6.2.3 Hydsim Text Files (.out and .log files)

#### BPAREGU.out

- End of period results by plant.
- Outflow, bypass spill, force spill (spill because flow above turbine limits), overgeneration, other spill (sluiceway, leakage, locks), incremental H over K (H over K for that plant and everything downstream), average MW, draft (in ksf), end storage (in ksf), ending elevation (in feet above sea level), rule curves (flood control, ECC, AER in ksf), constraint violations in order of violation (farthest right violation is first constraint violated, farthest left is the last constraint encountered, which controlled plant operation).
- Asterisk by plant name means generation not counted in the total to meet load.
- Period energy that one can get to draft to each hydro block.
- System generation summary including hydro independents, pumping (currently always zero, built into loads), One Dam model stats like content of the entire system in energy (MW-periods).

#### DEBUG.out

- Error trapping for HYDSIM.

#### MDFileREC.out

- Report of file paths of the files used to run HYDSIM.
- WaterYearOverride80.dat file path is overwritten by FILEREC.OUT

#### OvergenSpill.log

- Logs when certain constraints were relaxed in order to allocate the overgeneration spill in HYDSIM.

### 6.2.4 Post Processor Text Files (.out files)

#### Plant by Plant Generation.out

- Output of a post-processing program, READBPAREGU program.
- Builds summary matrices of output or input by plant.

## 6.3 MODULES

- All modules<sup>20</sup> called by GENESYS have the suffix .f90, except for some that are contained within HYDSIM, which is maintained by BPA.

AllocateLoads – Declares the variables used in various options for shaping hydro according to loads.

arroflow – Declares flow constraints for fish spawning at Arrow.

CFlow – Declares variables used in cash flow analysis (a legacy feature).

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<sup>20</sup> Modules in Fortran 90 contain variable declarations and subprograms.

Conserv1 – Contains the conservation data

ContractData – Contains the long-term contract data

Costdata1 – Contains cost data

Cststat1 – Cost statistics variables and arrays

Demand1 – Declares demand and nodal settings.

Demand2 – Declares more demand settings.

DiscFac – Declares discount factors for present value calculation.

DISTRIB1 – Declares distribution array settings.

DuraStor – Declares variables for creating duration curves.

Equate – Declares variables for fixed load year mode and first and last year of historical data.

Errflag1 – Declares and establishes initial settings for error flagging capability.

Escl1 – Declares and establishes initial parameters for escalation and deflation.

Esp – Declares variables for setting up mid-year start runs and one game runs that rerun one game out of a larger study

FILELUN1 – Defines variables and settings to delineate output reports.

FINANCE1 – Declares variables used for holding financial data.

FlexInfo - Declares variables for keeping track of borrowed hydro.

Flowaug – Declares variables for flow augmentation.

Fueldata1 – Declares fuel data structure and type.

GenTempVar – Declares variables for transmission capacity limit as a function of demand.

HydBlockInfo – Declares the variables used for defining hydro blocks.

HYDIND – Declares the variables used for storing hydro independent data.

Ifilename1 – Declares variables used to store file input names.

INITS – Declares variables for use in HYDSIM runs.

LoopFlow1 – Declares and defines variables for use in transmission loop flow for transactions.

MargInfo1 – Declares variables for use in demand segments.

Misc1 – Declares miscellaneous variables.

Misc2 - Declares miscellaneous variable.

Mparam - Declares and defines hardwired run parameters used in all modes.

Mwmon – Declares variables for input from TRAP and sets parameters for some hydro inputs.

NLDVars1 – Defines variables used for demand and node information.

NodeGroupInfo – Declares variables for grouping nodes.

Nrgsplit – Declares nodal split for hydro energy.

Oper1 – Declares variables for system operation and transactions.

OverrideInfo – Declares variables for override data.

OWNER1 – Declares variables containing ownership information.

OYHrlyLd – Declares parameters, variables and switches associated with hourly load data.

OYWinddata - Declares parameters, variables and switches associated with hourly wind data.

PathData – Declares variables associated with the paths connecting nodes.

PERINFO – Declares sub-period data variables.

RELIB1 – Declares variables associated with reliability.

ReserveAmt – Declares variables associated with calculating reserve requirements

Runoff – Declares variables associated with hydro runoff.

SEASDAT1 – Declares variables associated with seasonal distribution data.

SegDef – Declares and initializes variables associated with demand segments.

SegOpVar – Declares segment operational variables.

SegVars – Declares variables used to delineate segment size and demand

Simhydro – Declares variables used to store HYDSIM output for use in GENESYS.

Slice\_customers – Declares variables used to delineate slice resources when slice logic on.

Solardata – Declares variables for solar modeling

SOSReport – Set up variables for SOS reporting.

Source1 – Declares supply source variables.

Source2 - Declares supply source variables.

Source3 - Declares supply source variables (used by HYDSIM and GENESYS)

STACK – Declares variables used in stacking hydro blocks.

Stparms – Declares variables used to store general study parameters.

SurrogateFlows – Declares variables used to store information about surrogate flows.

TDFunctionVar – Defines and initializes variables for transmission capacity limit as a function of demand.

ThermCommitment – Defines variables containing thermal commitment parameters.

thermMaintdata – Defines variables containing thermal maintenance data.

Transm1 – Declares variables used for transmission topology

Transmission\_losses – Declares transmission losses variables.

Weather1 – Declares variables associated with weather and temperature.

Workdata – Declares variables used to transfer operating year to calendar year data.

WRITESW1 – Declares switches used to determine output files written.

Wrkstrng – Declares variables used for internal to the program.

### 6.3.1 TSR Modules

- The following modules are used specifically for the treaty storage regulation portion of the model. They are either a part of the HYDSIM library or are a modified HYDSIM file. They must be included as a part of GENESYS in order for it to compile. These modules must be kept consistent with HYDSIM modules.

Aerpdp	HYavlc	Opr_bpasdat
Albeni_mod	Hydfish	Opr_bpaspl
Alder_mod	Hydhk	Opr_bypdates
BPAmica	Hydsize	Opr_constraint_mod
Bpaperdat	Hytime	Opr_Errors
Bparegdef	Lfalls	Opr_Expect1
Bpascom	Mcnary_tw	Opr_flovol
Bpasdat	Merwin_mod	Opr_hyavlc
Bpaspl	PeriodPeriodMod	Opr_hydfish
Bypdates	Opr_AERPDP	Opr_hydhk
Calendar	Opr_Albeni_Mod	Opr_hydind
Constraint_mod	Opr_Alder_mod	Opr_hydsize
Environment	Opr_bpaarc	Opr_hytime
Errors	Opr_bpamica	Opr_Inits
Expect1	Opr_bpaperdat	Opr_lfalls
Flovol	Opr_bparegdef	Opr_mcnary_tw
Gorgemin_mod	Opr_bpascom	Opr_merwin_mod

Opr_periodperiodmod	Tsr_Alder_mod	Tsr_Recdrft_mod
Opr_pltlkup	Tsr_BPAmica	Tsr_Reglun
Opr_projname	Tsr_Bpaperdat	Tsr_Settoaer
Opr_recdrft_mod	Tsr_Bparegdef	Tsr_Slide_spill
Opr_settoaer	Tsr_Bpascom	Tsr_Spill
Opr_simhydro	Tsr_Bpasdat	Tsr_Splcutoff
Opr_slide_spill	Tsr_Bpaspl	Tsr_parms
Opr_Source3	Tsr_Bypdates	Tsr_pltlkup
Opr_spill	Tsr_Calendar	Tsr_projname
Opr_splcutoff	Tsr_Constraint_mod	Tsr_recdrft_mod
Opr_stparms	Tsr_Environment	Tsr_settoaer
Opr_Waterb	Tsr_Errors	Tsr_simhydro
Opr_wbslide	Tsr_Expect1	Tsr_slide_spill
Opr_xfmr_losses	Tsr_Flovol	Tsr_Source3
Param	Tsr_Gorgemin_mod	Tsr_spill
Pltlkup	Tsr_HYavlc	Tsr_splcutoff
Projname	Tsr_Hydfish	Tsr_stparms
Recdrft_mod	Tsr_Hydhk	Tsr_Waterb
Reglun	Tsr_Hydsiz	Tsr_wbslide
Secondary	Tsr_Hytime	Tsr_xfmr_losses
Settoaer	Tsr_Lfalls	
Slide_spill	Tsr_Mcnary_tw	
Spill	Tsr_Merwin_mod	
Splcutoff	Tsr_PeriodPeriodMod	
Stparms	Tsr_Param	
Tsr_aerPDP	Tsr_Pltlkup	
Tsr_Albeni_mod	Tsr_Projname	

## 6.4 SUBROUTINES<sup>21</sup>

- All subroutines<sup>22</sup> currently run by GENESYS have the suffix .f90, except for a few within HYDSIM, which is maintained by BPA.
- Subroutines that look at financial accounting for plants and explicit conservation build-out are mostly legacy, as the GENESYS resource expansion logic is no longer used.
- Only GenSimMain and MDInterface are described in detail as they are major routines in the hierarchy of GENESYS.

AddStack – Adds supply block to the dispatch stack.

Annrept – Writes out annual reports from GENESYS output.

BorHydWrite – Writes out borrowed hydro report.

Btrim – Trims leading and trailing blanks from character variables.

CalcProbDurCurve – Calculates probability distributions for different variables.

CapCost - Determines cash flow and capital revenue requirements for new source and transmission projects, and conservation programs.

CapItem - Determines cash flow and capital revenue requirements for a specific capitalized item.

CFlowIn – Reads cash flow data.

CheckSustpkAgain - Checks the sustained peaking limits after any additions of borrowed hydro in the hourly dispatch.

ChooseWindow – Defines window size and can develop allocation procedure for hydro energy within the window.

Config - Determines transmission system configuration for current year.

Consched - Calculates annual schedule for conservation program units.

Consin2 - Reads conservation data.

Consper - Calculates hourly conservation by node and by site for current period. Used in SliceSegOp.out

ContractIn – Reads contract data file.

CostIn – Reads financial and cost data.

CostStat – Keeps track of cost statistics like mean present value, mean operating costs, etc.

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<sup>21</sup> A list of the GENESYS subroutines with more detailed explanations is catalogued in *GENESYS\_Subroutines\_20011212.doc*

<sup>22</sup> Subroutines in Fortran 90 are similar to functions in Fortran 90 but they can have any number of inputs and outputs.



Dataidx - Does data indexing and error checking on input pointers.

DayShapeIn - Reads day shape and demand segment definition data.

Defin - Reads Study Definition File (Studydef.dat)

Deflset - Sets up deflation information.

Demandin - Reads demand data file.

Discset - Sets up discount rate factors.

Echo - Prints study parameters back to screen.

Esclin - Reads escalation data.

Exchsort - Exchange sort. Original array is reordered. Value of "direction" determines sort order.

Exchsort2 - Exchange sort for integers. Original array is reordered in ascending order. Secondary array is in same order as original.

ExSortdx - Exchange sort returning pointers. Expects real array.

Fileclose - Closes any open files.

FileOpen - Opens files which are held open for entire study. E.g, binary flow and weather data files, VB interface, output files, daily results binary files.

Finanin – Reads in financial data.

Finish - Sorts for recorded game results, etc. Writes a number of vbi files. Called once at completion of game loop.

FlowAugIn – Read in flow augmentation data.

Fuelln – Reads in fuel cost data.

### **GenSimMain**

- Main subroutine for GENESYS completes the following tasks:
  - 1) Creates Study ID
  - 2) Initializes values not read in input files
  - 3) Calls definition input and echo subroutines.
  - 4) Calls the following input routines:
    - a) Fuelln
    - b) CostIn
    - c) TransIn
    - d) SourceIn
    - e) DemandIn
    - f) SustPklIn
    - g) EsclIn
    - h) SeasIn

- i) FinanIn
  - j) CflowIn
  - k) Dayshapeln
  - l) OwnerIn
  - m) ConsIn
  - n) ContractIn
  - o) GTFunctionIn
  - p) ReserveAmtIn
  - q) ReadHourlyLoads
  - r) WxIn
  - s) Dataidx
- 5) If switches selected, calls the following subroutines:
    - a) RunoffIn
    - b) ReadThermCommit
    - c) CallSurrogateDailyFlows
    - d) Readwinddata
    - e) ReadSolarData
  - 6) If TSR run enabled, calls the following subroutines:
    - a) GetTSRFileNames
    - b) TSRHydata
    - c) ReadTSRLoads
    - d) GetOPRFileNames, oprHYDATA, and FlowAugIn
  - 7) If TSR run not enabled, then the following sub routines are called:
    - a) GetMDFileNames and HYDATA
  - 8) Opens files which persist throughout study and preprocesses study by calling
    - a) FileOpen
    - b) Preproc
  - 9) Set up the conservation savings schedule, if calculated explicitly within study by calling the below subroutine. Currently conservation is entered by modifying the load.
    - a) ConSched
  - 10) Calculate capital costs for resource and transmission projects, by calling the subroutine below. GENESYS not currently used for resource expansion.
    - a) Capcost
  - 11) Start simulation loop. Does year loop, period/period loop, and day loop  
Subroutines always used are as follows:
    - a) Resetgam
    - b) HydroInd
    - c) GetHDay
    - d) HydWinDisp2
    - e) HydroDayCheck2
    - f) PerDemand
    - g) HydroDayShape2
    - h) HydroPost
    - i) PeriodPost

- j) Sysstat
- k) Annrept
- l) PresVal
- m) CostStat

Subroutines used depending on configuration are as follows:

- n) WeatherSet
- o) PickHourlyHydroShape
- p) Config
- q) MoCons
- r) ResetAnn
- s) Windcap
- t) Solarcap
- u) OPRSetUp
- v) SourceCapac
- w) SourcePrice
- x) OYHourDemand
- y) MoTrans
- z) PathOrder
- aa) HydroPre
- bb) ChooseWindow
- cc) Slice\_PerDemand

12) Develops output, writes state of the system reports and closes routine by calling the following subroutines.

- a) writeSOSReport
- b) writeEndContent
- c) Finish
- d) VbiStdy
- e) Fileclose

GenTempAdj - Estimates thermal availability for the next "period\_days" days, for appropriate resources whose availability is function of temperature.

GetHDay - Determines day and how many days are left in the current hydro window.

GetOverride – Reads thermal and transmission override data.

GetUFlow – Reads user defined flow year data.

GTFunctionIn – Reads generation versus temperature function data.

HrloadSubs - Calculates observed hourly demands for single large loads. Calculates observed hourly conservation program savings for the current period. Calculates observed hourly contract flows between nodes.

HydEDisp – Sets up and performs window and day dispatchs.

HydroCapState - Determines observed state levels for hydro capacity functions. Builds the hydro capacity vs energy functions used for the current time period.

HydroDayCheck2 – Sets up and performs day dispatch

HydroDayShape2 - Determines PNW east/west hydro shaping for the current day.

HydroInd – Reads in hydro independent data.

HydroPost – Performs end-of-period hydro regulation.

HydroPre – Performs beginning-of-period hydro regulation.

HydroVal – Calculates value associated with the different hydro blocks.

HydWinDisp2 – Sets up and performs window dispatch and sets capacity limits.

Indxchar – Creates array positions linking pointer values to data IDs (Indexing program).

Indxchar2 - Creates array positions linking pointer values to data IDs (Another indexing program).

Initialize – Initializes variables where input is not read in.

Inumval - Finds position of last non-zero entry in an integer vector.

Linterp – Performs linear interpolation on input data.

Locate – A find and replace routine that returns the found data and replaces with a pointer.

LocateW - A secondary find and replace routine that returns the found data and replaces with a pointer.

MallocNLD - Allocates memory for new large demand variables.

MargCalc – Calculates a node’s marginal value.

## **MDINTERFACE**

- Interface to the multi-dam model.
- Calls HYDSIM modules from GENESYS multiple times to draft to rule curves to get the hydro block sizes.
- Then, after GENESYS “dispatch” calls one more time to draft to the amount of hydro generation specified by the GENESYS “dispatch.”

Mocons – Calculates nodal monthly savings for conservation programs.

PeriodPost – Period post processing

MoTrans - Adjusts transmission capacities for seasonality in current month.

Numval - Finds position of last non-zero entry in a real vector

OneDamCap - Estimates hydro capacity using pre-determined trapezoidal functions..

OpenPC – Opens and reads in file.

Operate2 – Performs dispatch for month, window, day or hour.

Overparm - Writes error message to logfile on for exceeding parameters.

Override - Overrides thermal availability states, with user defined occurrences

Ownerin – Reads in ownership and allocation data, and trues up shares to 100%.

OYHourDemand - Called by period. Uses one operating year of hourly loads input by user in HourlyLoad\_file. Results for month stored in annual array Hrload in current period dimension. Also calls single large demand and hourly conservation shaping routines.

Page - Does form feed (unless page=1), writes passed page number and study ID to the passed logical unit.

PARPurchase – Governs purchase ahead resource (market purchases) acquisition.

PathDef – Finds transmission paths.

PathOrder – Determines node to node path order for current period.

Peraggr - Accumulate current sub period values into larger time periods.

PerDemand - Calculates observed nodal segment demands for current dispatch day. Could be either individual day or period average.

PHB\_SubS – Contains sorting routines.

PickHourlyHydroShape – Picks hourly hydro shape from surrogate hydro data.

Preproc2 - Perform any general preprocessing that can be done outside of game loop.

Presval - Calculates present values.

Ran2 – Random number generator.

ReadHourlyLoads - Reads binary hourly load file.

READPeriodCheck – Reads hydro period data.

ReadSolarData – Reads hourly solar data.

ReadSurgDailyFlows – Reads surrogate daily flows.

ReadThermCommit – Reads thermal commitment data.

ReadThermMaint – Reads thermal maintenance data

Readwinddata - Reads hourly wind binary files for up to three sites that contain hourly capacity factors at the site. Also reads the wind capacity file that gives the capacity at each site.

ReserveAmtIn – Read in fixed reserve amounts for each period.

ReserveCalc - Calculate reserve levels for demand segment just dispatched. Calculate reserves and reserve requirements for NW thermal and hydro. Find the biggest import for single largest contingency calc.

Resetann - Reset annual variables.

Resetgam - Resets specific variables used in game loop.

RunoffIn – Reads in runoff and finds quintiles of runoff.

Seasin - Reads seasonal distribution data and sets up period shaping factors.

SegWrite - Write Segment operations report and *SegOp.vbi*.

Slice\_PerDemand - Calculates single large load and sliced contract amounts for current dispatch day.

SliceIn – Reads in slice resources from *slice\_res* file.

SliceSegWrite - Write Segment operations report *SliceSegOp.out*.

Slicesubs - Availability of dispatchable resource is reduced by *slice\_percent*.

Slint - Simple linear interpolation routine.

SolarByMonth - Calculates hourly solar generation by node and by site for current month.

Solarcap – Calculates hourly solar generation for the year by site.

SourceCapac - Sets source capacity for current period.

Sourcein2 – Reads supply source data.

SourcePrice - Source current month variable costs

Supply – Performs hourly dispatch.

SustPkIn - Reads sustained peak data.

Sysstat – Calculates source use, reliability, transmission use and other statistics.

ThermalSetFD - Use frequency/duration method for determination of thermal states.

Transin - Reads transmission data.

Ucase – Makes lower case input data into upper case.

VBbool – Returns true or false depending on VB Boolean operator read in.

VbiStudy - Writes several end of study VB Interface Files.

WeatherSet - Determine historical year to use for flows, weather (loads), wind, and solar.

Weekday - Calculates day of week corresponding to a specific date.

Windbymonth - Calculates hourly wind generation by node and by site for current month.

WinCap - Calculates hourly wind generation for the year by site.

writeEndContent – Writes end contents (for one game debugging)

writeSOSreport – Writes the state of system output.

Wxin – Reads weather data.

#### 6.4.1 TSR Subroutines

The following subroutines are used specifically for the treaty storage regulation portion of the model. They are either a part of the HYDSIM library or are a modified HYDSIM file. They must be included as a part of GENESYS in order for it to compile. These modules must be kept consistent with HYDSIM.

GetOPRFileNames	oprREADPr	tsrHYSPRD
GetTSRDef	oprREGDEF_HYDSIM	tsrINITHKAV
GetTSRFileNames	oprSCANSEQ	TSRINTERFACE
OprBLDCONSTR	oprSET_PERIOD_TIMING	tsrINTERP
OprCHKPLT	oprSETUP	tsrMICARD
OprCHKROR2	oprSLIDE_SPL	tsrMonthPeriodInit
OprFINDMO	oprSTODATE	tsrPROCESSDR
OprGETBYD	oprUPDATECONSTR	tsrQMINIT
OprGETHKS	oprWBPREP	tsrRDSINIT
OprHYAVAIL	oprWRITECONSTR	tsrREADCONSTR
OprHYDATA	ReadTSRLoads	tsrReadFishGorge
OprHYPLA	RunTSR	tsrREADPR
OprHYSPRD	TBLSET_old	TSRREGDEF_HYDSIM
OprINITHKAV	tsrBLDCONSTR	tsrSCANSEQ
OprINTERP	tsrCHKPLT	tsrSET_PERIOD_TIMING
OprMICARD	tsrCHKROR2	tsrSLIDE_SPL
oprMonthperiodInit	tsrFINDMO	tsrSTODATE
oprPROCESSDR	tsrGETBYD	tsrUPDATECONSTR
oprQMINIT	tsrGETHKS	tsrWBPREP
oprRDSINIT	tsrHYAVAIL	tsrWRITECONSTR
oprREADCONSTR	TSRHydata	
oprREADFISHGORGE	TSRHypla	

## 6.5 GENESYS CONFIGURATION

### GenSim

-Date and Time	
-Initialize	-srand
-Defin	-locatew
	-ReadBool
	-ReadHydPrice
	-inumval
	-numval
	-chkfile
-Echo	
-Fuelin	-locatew
-Costin	-locatew
-Transin	
-SourceIn	-locatew
	-overparm
	-ReadBool
-DemandIn	-locatew
	-overparm
	-ReadBool
	-MallocNLD
	-linterp
-SustPkIn	-OpenRead
	-locate
-EsclIn	-locatew
	-overparm
	-linterp
-SeasIn	-locatew
-FinanIN	-locatew
	-overparm
-CflowIN	-locatew
	-overparm
	-numval
-DayshapeIn	-locatew
	-indxchar
-OwnerIn	-locatew
	-overparm



	-linterp	
-ConsIn	-locatw	
	-overparm	
	-ReadBool	
	-linterp	
-ContractIn	-locatw	
	-linterp	
-GTFunctionIn	-locatw	
-ReserveAmtIn	-locatw	
-ReadThermCommit		
-ReadThermMaint	-locatw	
-ReadSurrogateDailyFlows		
-ReadHourlyLoads		
-Readwinddata	-locatw	
-Readsolardata	-locatw	
-WxIn	-locatw	
-GetOverride	-locatw	
-GetULoad	-locatw	
-GetUFlow	-locatw	
-DataIdx	-btrim	
	-indxchar	
	-PathDef	-ConnectNode
	-overparm	
-Deflset	-page	
-Discset	-page	
-SliceIn	-locatw	
-GetTSRFileNames	-locatw	
	-ChkFile	
-GetTSRDef	-ReadBool	
-TSRHydata	-TSRregdef_hydsim	
	-TSRhypla	-hashinit
		-dateinit
		-tsrScanSeq
		-tsrMonthPeriodInit
		-Tblset_Old
		-tsrChkROR2
		-tsrQminit
		-tsrMicard
		-tsrHysprd
		-tsrHyavail

		-tsrUpdateConstr	
		-tsrSlide_Spl	
		-tsrGetByd	
		-tsrReadFishGorge	
		-tsrInitHKAv	
		-tsrRDSInit	
		-tsrWBPrep	
		-tsrChkPlt	
		-tsrInterp	
		-tsrFindMo	
		-tsrReadPr	
	-readPeriodCheck		
-ReadTSRLoads	-locatew		
-GetMDDef	-locatew		
	-ReadBool		
-GetOprFileNames	-locatew		
	-ChkFile		
-OprHydata	-OPRregdef_hydsim		
	-OPRhypla	-hashinit	
		-dateinit	
		-oprScanSeq	-oprReadPR
			-Datetos
			-oprStoDate
		-oprMonthPeriodInit	
		-Tblset_Old	
		-oprChkROR2	
		-oprQminit	
		-oprMicard	-Mica_Conv
		-oprHysprd	
		-oprHyavail	
		-oprUpdateConstr	-oprBldConstr
		-oprSlide_Spl	
		-oprGetByd	
		-oprReadFishGorge	-Hashmo
		-oprInitHKAv	-oprGetHKS
		-oprRDSInit	-interp
		-oprWBPrep	-oprChkPlt
		-oprChkPlt	
		-oprInterp	
		-oprFindMo	-Datetos

-oprReadPr -oprSet\_Period\_Timing

-FlowAugIn -readPeriodCheck  
-GetMDFileNames -locatew  
-Hydata -regdef\_hydsim  
-hypla -dialogmsg  
-hashinit  
-dateinit  
-scanseq  
-Monthperiodinit  
-tblset  
-chkror2  
-qminit  
-micard  
-hysprd  
-hyavail  
-updateconstr  
-slide\_spl  
-getbyd  
-readfishgorge  
-getarc  
-inithkav  
-rdsinit  
-wbprep  
-chkplt  
-interp  
-findmo  
-readpr

-FileOpen  
-Preproc  
-ConSched  
-CapCost -page  
-CapItem  
-StoreCap  
-Salvage  
-CapOut  
-RefYrDemand -wrfunc  
-wrshap

-----game loop begins-----

```

-Resetgam
-----year loop begins-----
-WeatherSet      -system_clock
                  -ReadWindData
-PickHourlyHydroShape
-Config          -ExSortDx
-MoCons
-ResetAnn
-Windcap
-Solarcap
-RunTSR          -TSRInterface    >>>Hydsim
-OprSetUp
-HydroInd
-----month loop begins-----
-SourceCapac
-SourcePrice
-OYHourDemand -SingleLarge
                  -ConsShape
                  -SetContract
                  -Windbymonth
                  -Solarbymonth
-MoTrans
-PathOrder      -ExSortDx
-HydroPre       -MDInterface    >>> Hydsim
                  -HydroVal
                  -HydEDisp
                  -GenTempAdj    -Slint
                  -ADDSTACK
                  -ExSortdx
                  -Operate    -Sliceit
                                      -Slint
                                      -GetTransAvl
                                      -GetTransAvl3
                                      -NewTransact
                                      -RecordTrans3
                                      -ExSortdx
                                      -GetTransAvl2
                                      -Unslice
                                      -WriteSourceUse
                                      -WriteTransUse
                                      -WriteDispRes

```

```

-HydroCapState
-ChooseWindow
-----day loop begins-----
-GetHDay
-HydWinDisp2 -HydEDisp (see above call to HydEDisp)
-HydroDayCheck2 -HydEDisp (see above call to HydEDisp)
-OneDamCap
-PerDemand
-Slice_PerDemand -Consper
-HydroDayShape2 -CheckSustLim
-Supply -ThermalSetFD -InitOutageState
-UpdateOutageState
-GenTempAdj -Slint
-Override
-Addstack
-ExSortdx
-Operate (see above call to Operate)
-CheckSustPkAgain -CheckSustLim
-ReserveCalc
-PerAggr
-SliceSegWrite
-SegWrite
-BorHydWrite
-SegWriteVbi
-ThermWrite
-RelDtIWrite
-Daytrak -Scanwin2
-----day loop ends-----
-HydroPost -MDInterface >>>Hydsim
-MonthPost
-----month loop ends-----
-Sysstat
-Annrept -page
-CalcAnnAvg
-----year loop ends-----
-PresVal
-CostStat
-MargCalc
-system_clock
-Slint
-Slint

```

-----game loop ends-----

-writeSOSReport

-calcprobdurcurve

-DivConQuick\_Sort

-findfancybins

-writeEndContent

-Finish

-exchsort

-WriteVBImp

-WriteVBImp2

-SortDurInt

-SortDurReal

-SortQQ

-VbiStdY

-FileClose