APPENDIX K: RESERVES AND RELIABILITY – BACKGROUND INFORMATION

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OVERVIEW

This appendix provides a more detailed look at the general methodology used by the Council for analysis of reserve and reliability requirements and cost-effective methods of providing reserves designed to ensure adequate electric power at the lowest possible cost.[1] Additional discussion about modeling tools used to complete this analysis[2] will also be provided. While an exhaustive description or narrative of all modeling techniques and methodology is not provided in this appendix[3], this appendix does point to more detailed descriptions of the Council's models, more comprehensive source documentation, and the narrative from Chapter 16 when discussing the methodology to test balancing reserve sufficiency within the region.

GENERAL METHODOLOGY AND ASSUMPTIONS

The four steps used to assess balancing and flexibility sufficiency within the region involved the application of a suite of the Council's models. These steps are as follows[4]:

1. Assign Balancing Authority (BA) reserve requirements to hydro and non-hydro generation plants within the BA.
2. Use the TRAP hydropower and GENESYS hourly system simulation models in sequence, after reducing the operating range of hydropower generation units, to estimate available regional hydropower generation while holding balancing reserves.
3. After reducing the operating range of thermal generation units and inputting the available regional hydropower generation, use AURORA to perform an economic dispatch of the entire WECC-wide[5] portfolio.
4. Analyze the hourly results to determine if there are intra-hour or inter-hour insufficiencies in the test year of October 2020 to September 2021.

These steps are described in detail and in sequence in the sections below.

Assigning Reserve Requirements to Generators

As described in Chapter 16[6], reserve requirements from the Pacific Northwest National Lab study[7] were assigned to hydropower and thermal generators in the following large balancing authorities in the region: Bonneville Power Administration, Avista, Idaho Power, Mid-Columbia,[8] Northwestern Energy, PacifiCorp, Portland General Electric, Puget Sound Energy, Seattle City Light, and Tacoma

[1] Northwest Power Act, §4(e)(3)(E), 94 Stat. 2706
[2] For a preliminary discussion of the tools, see the 'Estimating Reserves Provided by Resources' section in Chapter 16.
[3] See the "Draft_Detailed_BalFlex_Methodology.docx" on the plan's technical page http://www.nwcouncil.org/energy/powerplan/7/technical.
[4] A flow chart diagram of this process is provided in Chapter 16 in Figure 16 -1.
[5] WECC-wide refers to the Western Electricity Coordinating Council footprint including states outside of the region.
[6] See the section in Chapter 16 on 'Provision of Cost-Effective Reserves'.
[7] Analysis of Benefits of an Energy Imbalance Market in the NWPP
[8] Note that the Mid-Columbia is not technically a single balancing authority, but since a significant amount of region's reserves are held on the Mid-Columbia hydropower plants it is treated as such for the methodology of the study.

Power. Note that there are many other smaller balancing authorities in the region, but it was assumed that subscribe to Bonneville Power Administration to carry a significant portion of their reserve burden. Therefore, it was determined that treating each of the small BAs separately was unnecessary given the fidelity of this study.

The available operating range on generating units in each BA capable of providing reserves was estimated based on discussion with the Systems Analysis Advisory Committee and regional stakeholders.[9] Table K - 1 shows the assumed operating range percentages estimated for each generator type modeled assuming the unit was not fuel constrained.[10] The operating ranges shown in Table K - 1 are not meant to substitute for actual operational assessments of how much range is available on a specific power plant, they are meant to be representative for a class of generation resource types, For example, the operating range on Combined Cycle Combustion Turbine natural gas plants tends to be significantly less than the range of a natural gas fueled reciprocating engine or aeroderivative, but across all gas generation it was assumed that 50 percent of plant capability was available to meet reserves.

The estimate shown in Table K - 1 were used as a starting point to determine the amount of reserves that could be held on the reserve capable hydropower portfolio of a BA's resources and how many reserves would need to be held on the reserve capable thermal portfolio of BA's resources. Note that in this analysis not all plants in a particular BA's portfolio were considered to be reserve capable. In general, the plants identified in utility resource plans as being capable of reserve provision were denoted as "reserve capable." Only these generating units were then considered to be available to provide operating range to serve reserve need for that BA.

Table K - 1: Percentage of Plant Capability Available for Reserve Provision

Fuel Type	Percent of Plant Capability Available to meet Reserves
Hydro	80%
Natural Gas	50%
Coal	50%

Using the assumed operating range percentages provided in Table K-1, total hydro power operating range was determined by multiplying 80 percent by the total potential amount of reserve capable hydropower capacity in a particular BA. Similarly, the thermal operating range was determined by

[9] See the presentation from the August 4th, 2015 SAAC meeting, "BalancingFlexibilityMethodologySAAC20150804.pptx". In addition, the reserve quantities represented in Table 16-1 in Chapter 16 were sent out to stakeholders for comment. Feedback received to date has been integrated into the estimates.

[10] Clearly, there are many times hydropower units cannot move 80% of the range of their generating capability within an hour because they must pass all the water through the turbines due to high runoff, for example during the spring in the Northwest.

multiplying 50 percent by the total potential amount of reserve capable thermal capacity in a particular BA. Then, the percentages of reserves carried on the reserve capable hydro and thermal generators in each BA were calculated as in Equation K-1 and Equation K-2, respectively.

Equation K - 1: Percentage of Hydro Generator Operating Range in a BA

$$Hydro\,\% = \frac{Hydro\ Operating\ Range}{Hydro\ Operating\ Range + Thermal\ Operating\ Range}$$

Equation K-2: Percentage of Thermal Generator Operating Range in a BA

$$Thermal\,\% = \frac{Thermal\ Operating\ Range}{Hydro\ Operating\ Range + Thermal\ Operating\ Range}$$

Using the assumption of even distribution of reserves throughout the capable range of the BA[11], the reserve requirements were assigned to the plants identified reserve capable. This was determined by multiplying the percent calculated above by the reserve requirements and limiting the operating capability of individual plants by raising the minimum generation level and lowering the maximum generation level of the units. In practice, this process required a bit of iteration, and then subsequent modification of the reserves assigned to each unit in the TRAP and AURORA models to ensure that reserve requirements were all met. See the sections below on reserve assignment for hydro and thermal resources for more information.

Modeling Reserves within the Regional Portfolio

Since none of the models available to the Council at this time fully captures the nuances of co-optimizing the regional power system for cost, reliability and balancing requirements, a hybrid modeling approach was developed. This involved using three of the Council's current models in sequence to best test cost-effective balancing and flexibility reserve sufficiency in the region. In general, since the TRAP and GENESYS models better represent the complicated problem of dispatching the region's hydropower system, their capabilities were used to represent flexibility of hydropower to shoulder a significant portion of the balancing and flexibility reserve burden. On the other hand, AURORAxmp has better representation of thermal generation plant dispatch and fundamental WECC-wide[5] power market economics. This is because the AURORAxmp model uses unit commitment logic in its programming and harnesses a WECC-wide plant dispatch in addition to dispatching plants within the region. The methodology of utilizing the strengths of each model, and then using one model's outputs as another's inputs hinges upon careful alignment of the inputs and outputs of the models and consistent assumptions whenever possible. The process followed to accomplish this task is described below.

[11] This assumption was discussed at the August 4th, 2015 SAAC meeting.

Models and Methods Used For Analysis

TRAP

The trapezoidal approximation (TRAP model)[12] is use to estimate the Pacific Northwest hydro system's sustained peaking capability. By approximating the Pacific Northwest twin peak load shape by a similar trapezoidal shape, linear programming can be used to maximize the sustained peaking capability of the regional hydro system[13]. The trapezoidal shaping splits each day into flat on-peak periods and flat off peak periods with two equal duration ramp periods. This modeling has been found consistent in the past with Bonneville hourly models in showing the influence of daily load shape on hydro shaping.

Inputs into the TRAP model in the past have included the following: Bonneville monthly regulated flows, system topology (modeled projects and zones), project type (i.e. reservoirs, pond limitations), minimum flow by period, forced outage rates, maintenance effects, plant efficiency curves ("h over k" curves), and the desired sustained peak length. TRAP was modified during the Seventh Power Plan preparation period to be able to model INC and DEC reserve requirements by groups of hydro projects[14].

The outputs of the TRAP model are monthly maximum and minimum allowed hydro generation limits assuming a particular sustained peaking operation of the hydro system.

GENESYS

The Council's GENESYS model is an hourly economic dispatch model that uses Monte Carlo simulations to test regional portfolio capability to meet load under the stochastic uncertainty of different hydro conditions, temperature-based load changes, wind generation levels and forced outages. GENESYS has traditionally been used by the Council to assess resource adequacy. A detailed general description of GENESYS' capabilities and uses is in Chapter 11 of the Seventh Power Plan.[15]

The GENESYS model uses the maximum and minimum generation limits from TRAP to determine the overall economic dispatch of the hydro system considering the stochastic risk variables summarized above. Since, GENESYS also has a rudimentary dispatch of other resources in the resource stack; it can refine the dispatch of the hydro system from the limits established as a result of the TRAP shaping algorithm. While cognizant of the economics of the region's resource stack,

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[12] For more information on the TRAP model, see "Trapezoidal Appendix.doc" on the plan technical page, http://www.nwcouncil.org/energy/powerplan/7/technical.
[13] Can maximize peaking capability for an input sustained peaking period, and thus multiple different peaking durations can be tested.
[14] See "TrapUpdate.pptx" on the Seventh Power Plan Technical Data site, http://www.nwcouncil.org/energy/powerplan/7/technical.
[15] See the section about "The GENESYS Model" in Chapter 11.

GENESYS adheres to the constraints of the hydro system and balancing reserves assigned within TRAP, and thus produces an hourly constrained economic dispatch of the hydro system.

AURORAxmp

AURORAxmp[16] performs an hourly economic dispatch of all resources in the WECC**Error! Bookmark not defined.**, based on market fundamentals. The unit-commitment logic inherent in the AURORA hourly dispatch better represents operations of thermal plants than the simple resource stacking method used by GENESYS. The hydro dispatch logic in the AURORAxmp model has a less sophisticated representation of the constraints of the regional hydropower system than the GENESYS model. AURORAxmp model has traditionally been used by the Council to generate electricity price forecasts.

Reserve Assignment and Hydro Generation Dispatch

The INC and DEC reserves were assigned to hydro units based on the methodology for assigning reserves to balancing authority resources as described above. The TRAP model was used to performed optimizations for 2, 4 and 10 hour sustained peaking operations in all 80 water year conditions, and the results were used to restrict monthly maximum and minimum generation in the GENESYS model.[17]

Then, the regional system was dispatched in the GENESYS model for 80 water year conditions each with a unique corresponding temperature, load and wind data profile. This resulted in a hydro dispatch that was modified by economic dispatch of all other existing resources in the region. The output of the GENESYS model includes an hourly hydro generation level for the regional hydro resources, hourly load, and hourly wind generation for each of the 80 years of water conditions.

The GENESYS model's hourly hydro generation data was not directly transferred to the AURORAxmp model because this would not allow the hydro dispatch to be affected by the assignment of the portion of the reserve requirements to the non-hydro reserve serving units (all thermal for this study). Instead, the maximum and minimum hydro generation levels for each on and off-peak period in a day were selected from the hourly hydro dispatch in the AURORAxmp model. This allowed the hourly information input to the AURORAxmp model to reflect the constrained, economic dispatch from the GENESYS model. This input was represented by two hourly maximum and minimum vectors. These are the daily on and off peak maximum generation values and the daily on and off-peak minimum generation values. This modification of the AURORAxmp model hydro input data allows the model the flexibility to use the hydro system within a tightly defined range that still reflects the constraints and more sophisticated economic dispatch of the hydro system provided by the GENESYS model.

[16] See http://epis.com/ for more information about AURORAxmp.
[17] Functionally, this data transfer incorporates for each sustained peaking operation, energy, maximum and minimum values for a month and single hour peak generation for each month. This data is utilized in GENESYS to impose the intra-monthly hydro constraints of the system whereas GENESYS natively has information that imposes the inter-monthly constraints of the hydro system.

Note that during the process of assigning reserves to hydro units, flow constraints in some of the more extreme hydro years[18] limited the ability of some generators to provide the reserves as assigned. If the resource belonged to a particular BA, the reserve requirements assigned to the hydro units in that BA were reduced in order to allow the constrained hydro dispatch to solve. The amount of the reserve reduction was then shifted to be served by the operating range of available reserve capable thermal units in that BA.[19]

Thermal Resource Reserve Assignment and Non-Hydro Generation Dispatch

In the AURORAxmp model, each thermal resource in the region that has been assigned INC and DEC reserves. As a result, these resources have their maximum capability reduced and minimum generation increased. This reduces the discretionary operating range of these plants. This is similar to the treatment of hydro resources in the TRAP model. Since the balancing reserves are hard-wired by fixing the operating range of the thermal plants, to ensure that those reserves are maintained throughout the study period, reserve-bearing plants are selected to be “must run.”[20] In actual operations, most reserve providing plants would be able to turn off when economics dictated. However, since the Council’s methodology is effectively a balancing reserve sufficiency test, this methodology seemed reasonable to ensure the dispatch was accounting for the appropriate reserve range.

Some of the assumptions made about reserve capable thermal operating range when making the original reserve assignment, did not align with operating range of the plants in the AURORAxmp model. To ensure that all reserve requirements were served, the reserve requirements were reduced for each plant that had more reserves assigned to it than its operating range in the AURORAxmp model would allow. These reserve requirements were then shifted to reserve capable thermal plants that had operating range still available. In practice, this shifted a considerable burden of reserves to coal-fired units.[21]

Per the discussion in the section above, the hydro generation maximum and minimum for the region as well as the demand and wind for the region are input into a reference table in the AURORAxmp model.[22] The model is then run for all hours in the study year (October 2020 through September 2021). Each of the 80 hydro conditions, with corresponding load and wind, from the GENESYS model requires a separate AURORAxmp model run. The results from the 80 runs are then analyzed to determine if there were any hours when the AURORAxmp model indicated that available resources could not meet the needs of the system with the resources required.

[18] Since for TRAP to solve, the reserve constraints must work for all 80 hydro conditions.
[19] Note that most of these issues ended up with needing reserves shifted to coal plants which would likely only happen in extreme hydro conditions.
[20] Designating a plant as “must run” in AURORA means that the plant cannot turn off completely and that it most operate at some level through all hours of the study period.
[21] Note that only Jim Bridger, Colstrip Units 3 and 4 coal plants were allowed to provide reserves to not overestimate the region’s capability after the scheduled coal retirements.
[22] This reference table is accessed via pointers and computational dataset capabilities in AURORA.