PSE PUGET SOUND ENERGY

QUANTA TECHNOLOGY

Eastside Transmission Solutions Report

King County Area

REDACTED VERSION

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Puget Sound Energy

Report prepared by:
Thomas J. Gentile, P.E. – Quanta Technology
Donald J. Morrow, P.E. – Quanta Technology
Zach A. Gill Sanford – Puget Sound Energy
Carol O. Jaeger, P.E. – Puget Sound Energy
Jens V. Nedrud, P.E. – Puget Sound Energy

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1.0 Executive Summary

The planning analysis discussed in this report has identified five alternative solutions to address the transmission capacity deficiency identified in the “Eastside Needs Assessment Report – Transmission System King County” dated October 2013 (“Needs Assessment Report”). Each of these five solutions fully satisfies the needs identified in the Needs Assessment Report and they satisfy the solution longevity and constructability requirements established by PSE as discussed in the body of this report.

These five solutions include two 230 kV transmission sources and three transformer sites, which are summarized in Table 1-1. Routing analysis performed by Tetra Tech, Inc. shows the two line alternatives can be broken down into 16 different segments. These segments can be combined to form multiple routes options to use to develop the line. These segments are shown in Figure 1-1.

The next step will be to engage the public in a series of events and outreach efforts to collect their input for PSE to establish the specific route for the 230 kV source and determine the substation location for the transformers. Once PSE selects the final route, the project will move into design, environmental review and the permit application process.

Table 1-1: Eastside Transmission and Transformer Solutions

	230 kV Line Alternative	Substation Alternative
2b	Rebuild one Talbot Hill-Lakeside-Sammamish 115 kV line to 230 kV and loop through new substation	Westminster
2e	Rebuild one Talbot Hill-Lakeside-Sammamish 115 kV line to 230 kV and loop through new substation	Lakeside
4b	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Westminster
4c	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Vernell
4e	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Lakeside

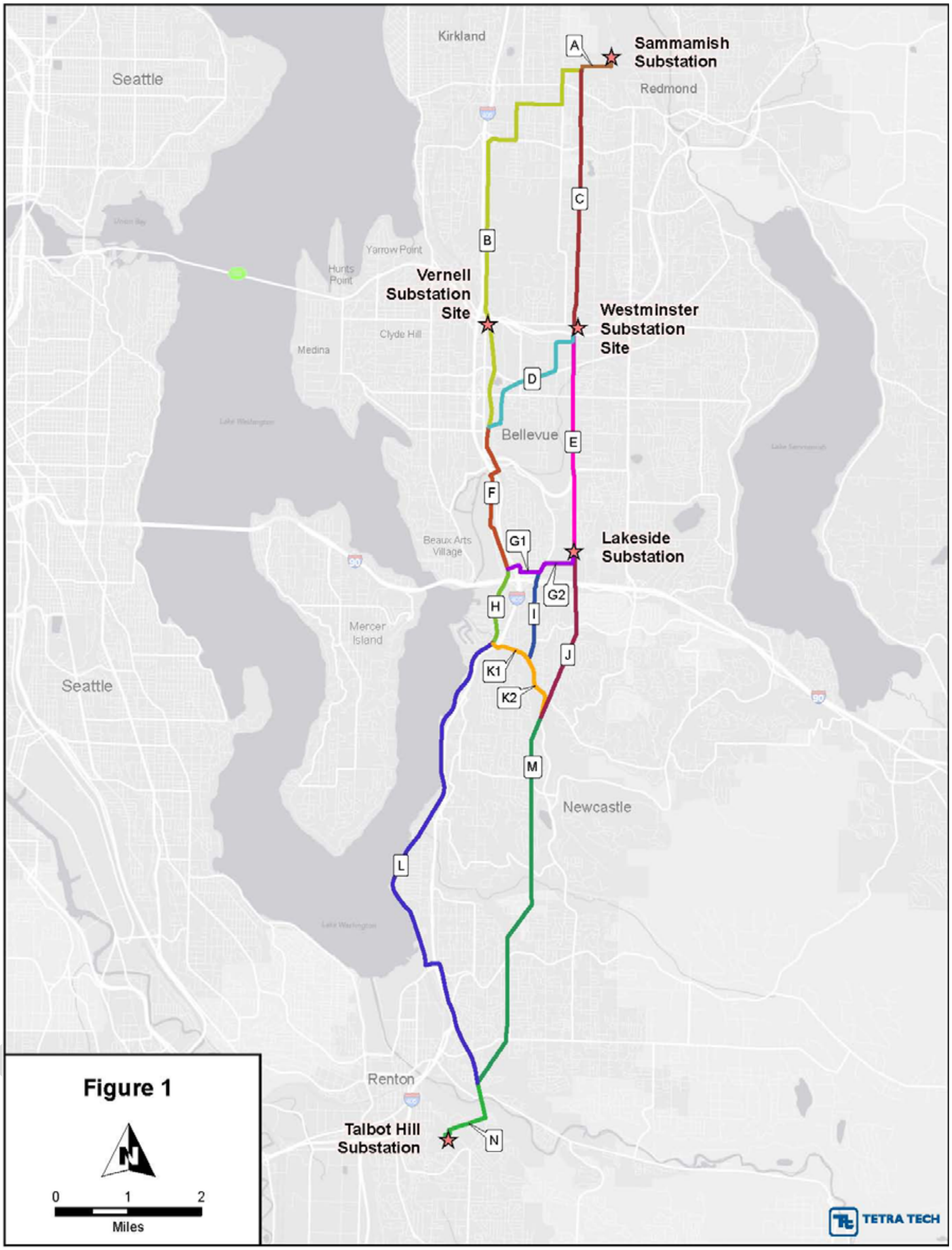

Figure 1-1: Segment Ladder Diagram

1.1 Solution Study Objective

The objective of the solution study was to address the transmission capacity deficiency in the Eastside area of Lake Washington which will develop by the winter of 2017-18. As identified in the Needs Assessment Report, this transmission capacity deficiency is expected to continue to increase beyond that date. Cities in the deficiency area include Redmond, Kirkland, Bellevue, Clyde Hill, Medina, Mercer Island, Newcastle, and Renton along with towns located at Yarrow Point, Hunts Point, and Beaux Arts. In that assessment, there were four main areas of concern identified:

- Overload of PSE Facilities in the Eastside Area
- Small Margin of Error to Manage Risks from Inherent Load Forecast Uncertainties
- Increasing Use and Expansion of Corrective Action Plans
- Emerging Regional Impacts Identified by ColumbiaGrid

1.2 Method and Criteria

The Solutions Study used the following process:

Step One: Brainstorm potential solution types to solve this problem including: Demand Side Management, Generation, Transformers, Transmission Lines, and combinations of all.

Step Two: Identify possible alternatives for each solution type and perform power flow analysis on the alternatives using cases from the Needs Assessment and an extensive list of contingencies.

Step Three: Assess the most promising alternatives from the perspective of system performance, operational flexibility, and longevity.

Step Four: Refine the list of viable electrical solutions using non-electrical factors, to determine the most promising electrical solutions.

Step Five: Review the impact of land use and environmental factors on each of the remaining viable electric solutions using the linear routing tool (LRT) to develop real world physical routes.

Step Six (Future): Take the resulting route options to the public. Through a series of open houses and a Community Advisory Group process, the community will help to guide PSE's final selection of a route.

To be a viable solution, the proposed project must solve the power flow issues identified in the Needs Assessment Report, satisfy longevity criteria, be constructible, and be acceptable environmentally.

1.3 Study Assumptions

For the Solutions Study analysis, the following key assumptions were adopted from the Needs Assessment Report:

- The study horizon selected was the ten year period from 2012 to 2022.
- System load levels used the PSE corporate forecast published in June 2012.
- Area forecasts were adjusted by substation to account for expected community developments as identified by PSE customer relations and distribution planning staff.
- Generation dispatch patterns reflected reasonably stressed conditions to account for generation outages as well as expected power transfers between PSE and its interconnected neighbors.

- ➢ Winter peak Northern Intertie transfers were 1,500 MW imported from or exported to Canada.
- ➢ Summer peak Northern Intertie transfers were 2,850 MW imported from or 2,000 MW exported to Canada.

These generation dispatches and Northern Intertie flows are used in PSE's modeling methodology for conducting annual mandatory NERC transmission reliability studies.

1.4 Solution Screening Process

During the brainstorming session, the team evaluated four main solution types: 1) Conservation, 2) Generation, 3) Transformer Addition with Minimal System Reinforcements, and 4) Transmission Lines plus Transformers.

Conservation includes Energy Efficiency (EE), Demand Response (DR), and Distributed Generation (DG). Energy and Environmental Economics, Inc. (E3) was hired to determine whether there was enough achievable incremental conservation to avoid or defer the need of the transmission upgrade options. Significant conservation was already included in the analysis since the effects of conservation were reflected in the load forecast used as the basis for the study. E3's assessment showed that there was not enough incremental achievable conservation available to avoid or defer the proposed transmission solution[1]. As a result, additional conservation was eliminated as a potential alternative.

The planning team also evaluated generation and determined that a 300 MW gas turbine could be located within the Eastside and may, therefore, be a feasible solution. Three locations were evaluated: Lakeside Switching Station, Lake Tradition Substation and Cedar Hills. Lakeside and Lake Tradition were found to be extremely challenging to permit due to environmental constraints related to noise and atmospheric emissions. The Cedar Hills site was retained for further analysis.

The planning team evaluated three sites for a new 230-115 kV transformer: Sammamish Substation, Talbot Hill Substation and Lake Tradition. All three sites currently have nearby 230 kV sources. These sites were modeled and studies showed numerous transformer and transmission lines overloads, which could not be solved by building additional new 115 kV transmission lines. As a result, the transformer only solution was not deemed a viable alternative.

Finally, the planning team also identified seven potential new 230 kV transmission lines and seven potential transformer sites. By inspection, it was clear that not all transformer sites aligned well with the new transmission options. Aligning the transformer sites with the lines reduced this set to 26 different alternatives. These 26 transformer alternatives along with the Cedar Hills generating station (27 total) are summarized in Table 4-2 below.

1.5 Detailed Power Flow Analysis

Detailed power flow studies were performed on these 27 alternatives to determine the best performers. The analysis helped to evaluate the ability of each alternative to address the need and how well its performance compared with the others. The team reduced the 27 alternatives down to the 12 that had sufficient performance. The results of this analysis are summarized in Table 4-1 on page 33.

[1] Jack Moore, Lakshmi Alagappan, & Katie Pickrell, Eastside System Non-Wires Alternatives Screening Study, February 2014

Based upon this review, the Cedar Hills generation site was eliminated from further study since it was not sufficient to resolve the transmission capacity deficiency even though the solution study included connecting two 115 kV lines to the site. (Note: these two line interconnections required building 17 miles of new transmission and rebuilding an additional 24 miles of existing lines to connect to the Lake Tradition and Berrydale substations.)

The remaining 12 alternatives were then assessed for their impacts on other adjacent portions of the PSE system, longevity, and operational flexibility to reduce or eliminate reliance on Corrective Action Plans (CAPs). The results of this analysis are summarized in Table 5-1 on page 57.

Based upon this analysis, the team determined that all 12 alternatives were sufficient to resolve the transmission capacity deficiency and recommended that they move forward into the non-electrical based evaluation as solutions.

1.6 Non-Electrical Based Factors

PSE did a non-electrical based review of these 12 solutions and, as a result, further reduced the set of solutions down to five. This reduction occurred for the following reasons:

- The Maple Valley to SnoKing 230 kV double circuit line was removed as an alternative since Seattle City Light determined they will need the lines to satisfy their own future needs.
- The Woodridge site alternative was removed from consideration since Woodridge is a new site that requires additional siting analysis, has site acquisition costs and there are three other viable sites that already satisfy the performance requirements.
- The Vernell transformer site was eliminated from use with PSE's Talbot Hill – Lakeside - Sammamish corridor since Lakeside and Westminster sites are much closer to that corridor.

The five remaining solutions are summarized in Table 1-1 on page 1.

1.7 Right of Way Assessment

For the two remaining 230 kV source solutions, PSE performed a right of way (ROW) assessment to identify a specific routing plan for these lines using the Linear Routing Tool (LRT)[2]. Based upon a scoring methodology that weighted multiple available GIS data layers and combined them to recognize the areas of greatest opportunity and greatest constraint, 16 different, viable routing segments were identified that could be combined to create multiple paths for the final circuit to be built. These segments are laid out in a ladder arrangement with two north to south routes that have multiple crossover segments as shown in Figure 1-1 on page 2.

1.8 Next Steps

Following completion of this study, PSE will engage the public in a months-long process that will provide critical input into PSE's final route selection, using the ladder of segments identified by the LRT. PSE will collect public input through an engagement process that includes a series of events, outreach efforts and engagement of a Community Advisory Group (CAG) that reflects Eastside stakeholders. PSE will also continue to evaluate requirements and

[2] Software tool developed and used by Tetra Tech, Inc.

constraints. Once PSE selects the final route, the project will move into design, environmental review and the permit application process.

2.0 Needs Assessment Summary of Results

PSE performed a needs assessment[3] of the Eastside of Lake Washington, which focused on the cities of Redmond, Kirkland, Bellevue, Clyde Hill, Medina, Mercer Island, Newcastle, and Renton along with the towns of Yarrow Point, Hunts Point, and Beaux Arts.

The 2013 Eastside Needs Assessment Report revealed that transformers or transmission lines will overload, or are close to overloading.

In the winter, when the PSE system load reaches approximately 5,200 MW, which is in the 2017-18 time frame; the overloads will occur when regional power flows are south to north, in the Talbot Hill Substation area.

In the summer, when the PSE system load reaches approximately 3,500 MW, which is in the 2018 time frame; the overloads will occur when the regional power flows are north to south, in the Sammamish Substation area.

In both cases, the transmission system is stressed by the need to provide power to PSE Eastside communities.

The capacity deficiency was first identified during PSE's 2009 comprehensive reliability assessment, an analysis performed annually as part of the mandatory North American Electric Reliability Corporation (NERC) Compliance Enforcement Program. The results of the 2009 analysis showed there was a potential thermal violation with the loss of one of the two autotransformers at the Talbot Hill substation. Since 2009, other issues have also been identified which impact this portion of the PSE system. For the 2013 Eastside Needs Assessment, PSE performed an updated analysis to evaluate if this potential thermal violation would still exist with the updated load forecasts.

The results of the Needs Assessment analysis demonstrated that parts of PSE's transmission system will not meet mandatory reliability requirements set by NERC, and that transmission lines will overload or will be close to overloading starting in 2017.

PSE utilizes operating procedures as interim corrective action plans (CAPs) to prevent these overloads. These CAPs are used in the winter on the Talbot Hill transformer banks and in the summer on the Sammamish transformer banks.

[3] Eastside Needs Assessment Report - Transmission System, King County, October 2013

The function of these CAPs are to reconfigure the transmission system by manually opening 115 kV breakers at Talbot Hill or Sammamish substations, which reconfigures the supply to the load (single line supply) that in turn, reduces the loading on the transformers. Taking this action reduces the inherent reliability of the network; because when the 115 kV breakers are opened there is no back-up, therefore the next outage on any of those radial lines will result in a loss of service to customers. As the load on the system grows, the overloads of the transformers may not be sufficiently reduced by the existing CAPs. This would result in having additional breakers opened, putting an even greater number of customers at risk.

The potential overloads of Talbot Hill and Sammamish transformers, in addition to a number of 115 kV lines, point to the need for additional transmission capacity to support the growing Eastside area. In King County, local generation cover less than 10% of the peak load, making the county dependent on external generating resources and transmission, rather than a local generation source to meet demand.

3.0 Methodology and Key Assumptions

Section 3.1 describes the overall methodology performed to develop and determine preferred solutions that meet the mandatory performance and operating requirements, system longevity, and constructability. To be a viable solution, the proposed project must solve the power flow issues identified in the 2013 Eastside Needs Assessment Report, must be constructible, and must be acceptable environmentally. The key assumptions and study criteria used in determining the preferred solutions are discussed below.

3.1 Methodology

To develop viable solutions, the following methodology was used:

Step One: Brainstorm to identify potential types of technology that could solve this problem. The following types were on the table for discussion: Conservation, Generation, Transformers, Transmission Lines, and combinations of all. Additional details are found in Section 4.0.

Step Two: Identify possible alternatives for each type of technology and perform power flow analysis on the alternatives using cases from the Needs Assessment and an extensive list of contingencies (Table 3-6). The power flow analysis was used to determine the reliability of each alternative. Additional details are found in Section 4.0.

Step Three: Assess the most promising alternatives from the perspective of system performance, operational flexibility, and longevity. This resulted in identifying twelve viable electrical solutions. Additional details are found in Section 5.0.

Step Four: Refine the list of viable electrical solutions using non-electrical factors. This resulted in the most promising electrical solutions. Additional details are found in Section 6.0.

Step Five: Review the impact of land use and environmental factors on each of the viable electric solutions using the linear routing tool (LRT) to develop real world physical routes. These factors included ROW, land use, wildlife and vegetation, endangered species, topography, historic resources, and others. The ladder map of transmission line based solutions emerged from this analysis. Additional details are found in Sections 7.0 and 8.0.

Step Six (Future): Take the resulting route options to the public and collect input through a series of open houses and a Community Advisory Group process. Continue to collect data and perform environmental analysis necessary to address requirements and constraints. Review collected data, study results, and consider public input to identify a preferred route. Additional details are found in Section 9.0.

3.2 Steady State Model Assumptions

3.2.1 Study Assumptions

The steady state analysis performed in the Solutions Study using power flow software[4]. Results were compiled using an Excel-based program termed “Post Processor”, which was developed by the Bonneville Power Administration

[4] PowerWorld Simulator software by PowerWorld Corporation.

(BPA) system planning department and shared with PSE. The cases and assumptions used in the analysis were the same cases used in the 2013 Eastside Needs Assessment Report.

The steady state models used in the Solutions Study represented the long-term projection of the winter peak system demand. This load projection was then used to assess reliability performance under heavy load conditions. The model assumptions included Puget Sound area generation units (see Sections 3.2.5 & 3.2.9 below), as well as variations in surrounding area transfer level conditions (see Section 3.2.8).

The primary focus of the steady state models was on the winter peaks for years 2017-18 and 2021-22 utilizing the 2012 corporate load forecast. Load forecasts were allocated by substation as determined by the PSE Economic Development Group and Distribution Planners. A summer peak case was also used for year 2018. For this study, the Eastside load was defined as the sum of the MW flows out of the buses at the Talbot Hill, Sammamish, Shuffleton, and Lake Tradition Substations which consist of the following 115 kV lines (as shown in blue in Figure 3-1):

- Talbot Hill - Lakeside #1 & #2
- Shuffleton - Lakeside
- Lake Tradition - Goodes Corner - Lakeside
- Sammamish - Lakeside #1 & #2
- Sammamish - North Bellevue - Lakeside
- Sammamish - Lochleven - Lakeside
- Sammamish - Ardmore – Lakeside

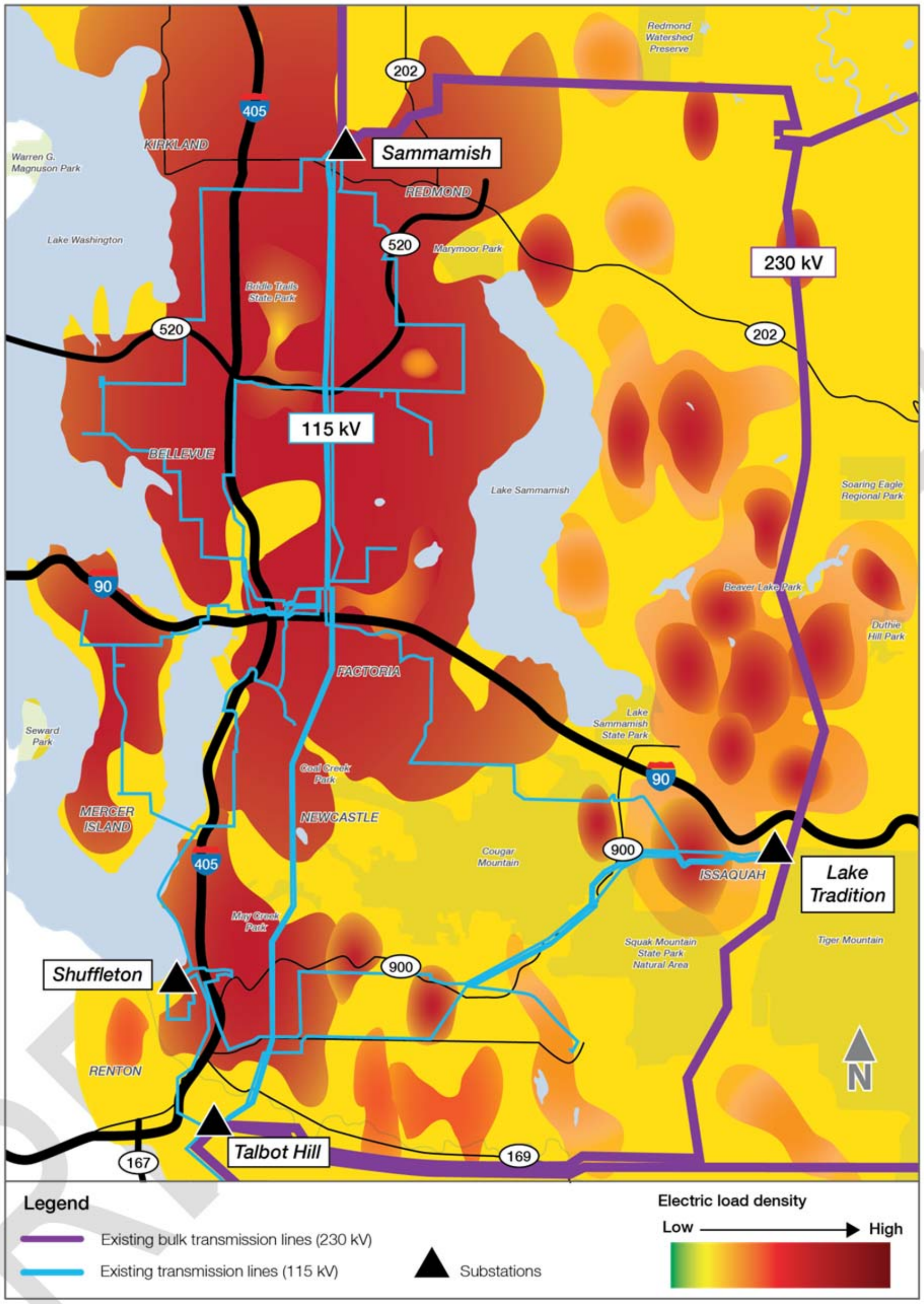

Figure 3-1: Eastside Area Load Density and Electrical Transmission System

3.2.2 Source of Power Flow Models

Power flow models used in this study were based on Western Electric Coordinating Council (WECC) base cases created in 2012 for the winters 2016-17 and 2021-22, and for summer 2017. To ensure that regional conditions are appropriately reflected, WECC members update the system Base Cases annually. These regional adjustments include revised load forecasts, newly identified transmission projects, generation changes, and anticipated dispatch changes.

3.2.3 PSE Model Adjustments

PSE modified the 2016-2017 winter base case to reflect the expected 2017-18 winter loads. PSE also modified the 2017 summer base case to reflect the 2018 summer load. To make these changes, a block load adjustment was made where expected load is known for substations in King County. Additionally, the PSE system load for each of the study years was scaled to the level forecasted by PSE's Load Forecast Group in 2012.

The winter cases were adjusted for regional power flows and generation dispatch levels. Northern Intertie levels determine regional power flows on transmission lines that carry power from PSE and BPA transmission systems across the Canadian border into the British Columbia Transmission Company system. By varying modeled regional flows and Puget Sound generation levels, four scenarios were developed:

i. High south to north power flows with high Puget Sound area generation
ii. High south to north power flows with no Puget Sound area generation
iii. High north to south power flows with no Puget Sound area generation
iv. High north to south power flows with high Puget Sound area generation

The 2018 summer case was run through the same four generation and Northern Intertie scenarios, as described above, for PSE's 2012 NERC Transmission Planning report.

Finally, the cases were modified to reflect recent and anticipated system improvements on the PSE transmission system. For the region, inductors planned for installation on Seattle City Light's (SCL) system and a 500-230 kV transformer planned by BPA at Raver Substation were modeled. The 230-115 kV transformer modeled at Lakeside in the 2021-22 case was removed from the base case model.

The key case assumptions are summarized in Table 3-1 below.

Table 3-1: Eastside Transmission Solutions Study Assumptions

Case Name	Season & Year	Amount of Conserv	System Load	Eastside Load	Northern Intertie	PSE/SCL Westside Gen	Model Adjustments
100% Conserv 2017-18 Winter South-North Flow, No Gen	Winter 2017-18	100%	5208 MW	706 MW	1500 MW Export	0 MW	Block load allocated per King Co Dist Plnrs; Planned improvements include Saint Clair 230-115 kV transformer; Talbot Hill - Berrydale #1 line uprate; Starwood autotransformer removal with Tacoma Power voltage increase; Alderton 230-115 kV transformer; Beverly Park 230-115 kV transformer; Raver 500-230 kV transformer; SCL series inductors
75% Conserv 2017-18 Winter South-North Flow, No Gen	Winter 2017-18	75%	5325 MW	722 MW	1500 MW Export	0 MW	
75% Conserv 2021-22 Winter South-North Flow, No Gen	Winter 2021-22	75%	5415 MW	789 MW	1500 MW Export	0 MW	Block load allocated per King Co Dist Plnrs; Planned improvements include 2017-18 adjustments

Case Name	Season & Year	Amount of Conserv	System Load	Eastside Load	Northern Intertie	PSE/SCL Westside Gen	Model Adjustments
75% Conserv 2021-22 Winter South-North Flow, Hi Gen	Winter 2021-22	75%	5415 MW	789 MW	1500 MW Export	2859 MW	
75% Conserv 2021-22 Winter North-South Flow, No Gen	Winter 2021-22	75%	5415 MW	789 MW	1500 MW Import	0 MW	
75% Conserv 2021-22 Winter North-South Flow, Hi Gen	Winter 2021-22	75%	5415 MW	789 MW	1500 MW Import	2859 MW	
100% Conserv 2021-22 Extreme Winter South-North Flow, No Gen	Extreme Winter 2021-22	100%	5772 MW	845 MW	1500 MW Export	0 MW	
100% Conserv 2018 Heavy Summer South-North Flow, No Gen	Summer 2018	100%	3554 MW	552 MW	2000 MW Export	0 MW	Planned improvements include Saint Clair 230-115 kV transformer; Talbot Hill - Berrydale #1 line uprate; Starwood autotransformer removal with Tacoma Power voltage increase; Alderton 230-115 kV transformer; Beverly Park 230-115 kV transformer; Raver 500-230 kV transformer; SCL series inductors; White River - Electron Heights 115 kV line re-route into Alderton; White River 2nd bus section breaker; Lake Hills - Phantom Lake 115 kV line; Sammamish-Juanita 115 kV line
100% Conserv 2018 Heavy Summer South-North Flow, Hi Gen	Summer 2018	100%	3554 MW	552 MW	2000 MW Export	2276 MW	
100% Conserv 2018 Heavy Summer North-South Flow, No Gen	Summer 2018	100%	3554 MW	552 MW	2850 MW Import	0 MW	
100% Conserv 2018 Heavy Summer North-South Flow, Hi Gen	Summer 2018	100%	3554 MW	552 MW	2850 MW Import	2276 MW	

3.2.4 Transmission Topology Changes

Projects added to the Eastside Solutions Study base case are listed in Appendix B.

3.2.5 Generation Additions and Retirements

In addition to any generation additions included in the WECC base cases by other utilities, PSE added generation capacity at the Snoqualmie and Lower Baker hydro units in 2013. This additional capacity was modeled in the summer and winter scenarios that used high Puget Sound area generation.

3.2.6 Forecasted Load Levels Studied

For the power flow studies associated with the Eastside Transmission Solutions Study, the winter 2017-18 and 2021-22 cases were used. Substation loading for the Solution Study cases were developed using the substation loading at the time of the January 18, 2012 system peak as a proxy for the sharing of the load. There were a few substations without SCADA load readings. Those substations were assigned values based on substation load readings during the same load cycle. Both megawatt (MW) and megavar (MVAr) values were determined in this manner.

The winter peak load for the PSE area is made up of projected load forecast plus 270 MW of non PSE load served by the PSE transmission system. For completeness, the non PSE load was included in the Eastside Transmission Solutions Study and is shown in Table 3-2 below.

The 2012 PSE Corporate system load forecast was used as a basis for the load levels modeled in the study. PSE Annual Corporate Customer and Sales Forecasts include summer and winter peak load forecasts for a 20 year period. Forecasts for non PSE Network Loads and other T & D service categories are obtained from customers annually for a 10-year period. The Solution Study used the most recent normal peak loads as a starting point and checked sensitivities to forecasted load as set forth in the NERC Transmission Planning (TPL) requirements[5].

The 2013 Eastside Needs Assessment shows a need for system reinforcement at a load level of approximately 5,200 MW winter peak. To illustrate the reliability risks, the team forecasted PSE load levels under a variety of conditions at 100% of forecasted conservation. To assess the risk due to higher than expected economic growth, conservation levels of 75% were studied as a proxy for higher load growth than forecasted. If only 75% of forecasted conservation materializes, the 5,200 MW load level would be reached as early as 2015 under normal weather conditions.

Reliability risk still exists even if 100% conservation is achieved. By the winter of 2017-18 the load is projected to reach the 5,200 MW load level. Under extreme weather conditions PSE could exceed the 5,200 MW level as soon as the winter of 2013-14. These variations in load and future years are illustrated in Figure 3-2 for multiple conservation outcomes.

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[5] TPL-001-2 R2.1.4: http://www.nerc.com/docs/standards/sar/atfnsdt_recirc_ballot_tpl_001_2_clean_20110711.pdf

Figure 3-2 shows the projected corporate winter load growth with varying levels of conservation.

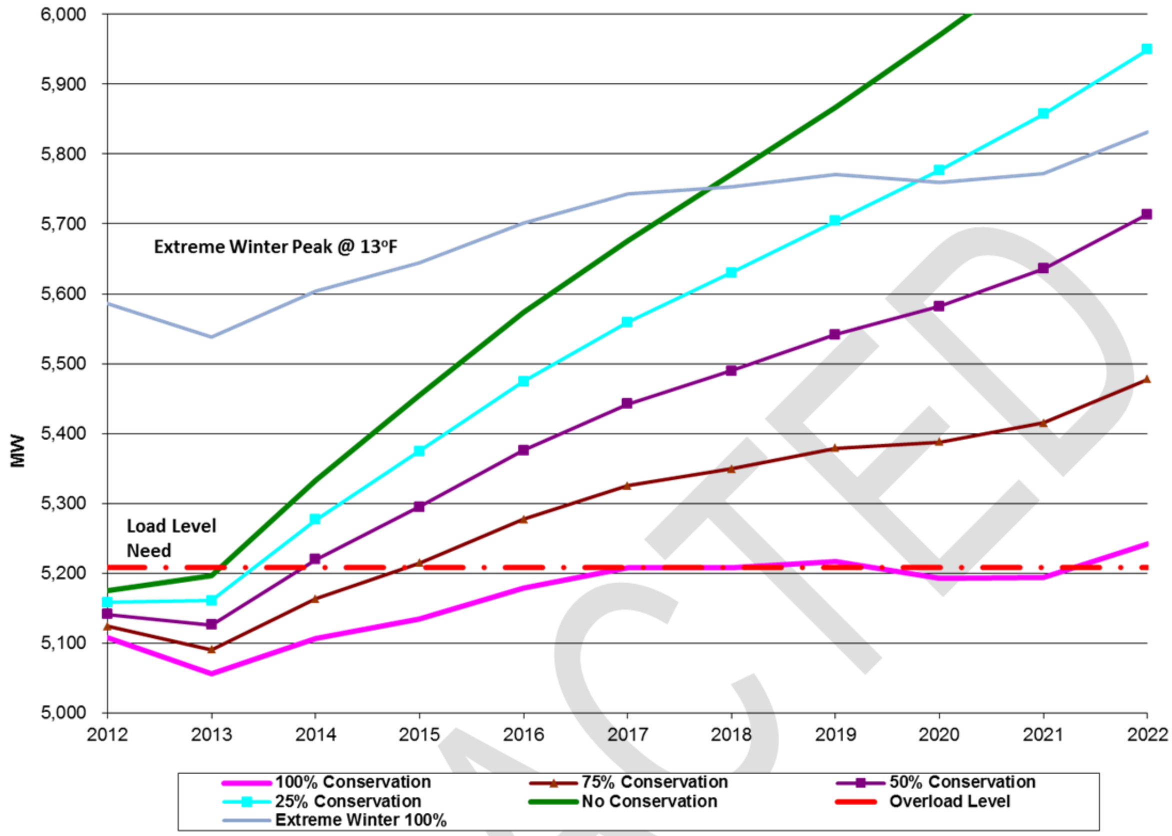

Figure 3-2: Corporate System Load Forecast for Winter 2012 to 2022

Table 3-2 provides a summary of the winter load levels used in the Solutions Study.

Table 3-2: Winter Peak Load Levels Studied in the Eastside Transmission Solutions Study

Year Studied	Season	Normal Peak 100% Conserv	Normal Peak 75% Conserv	Normal Peak 50% Conserv	Normal Peak 25% Conserv	Normal Peak 0% Conserv	Extreme Peak 100% Conserv	Extreme Peak 75% Conserv	Extreme Peak 50% Conserv	Extreme Peak 25% Conserv	Extreme Peak 0% Conserv
2013-14	Winter	5055	5090	5126	5161	5196	5537	5572	5608	5643	5678
2017-18	Winter	5208	5325	5442	5559	5676	5742	5859	5976	6093	6210
2021-22	Winter	5193	5415	5636	5857	6078	5772	5993	6214	6435	6656

Note: PSE Load Forecast is provided for PSE system load, not including the 270 MW of Transmission Customer industrial load. Transmission Customer load is included in the area load for the TPL and Eastside 230 kV studies

The 2013 Eastside Needs Assessment shows a summer load level of need at approximately 3,340 MW. Summer peak load is calculated for an 86^0 F peak day. This load level could occur as early as 2014 and becomes more likely with time. While PSE has traditionally been a winter peaking utility, the increase in commercial load has driven summer load growth disproportionately higher than the winter growth in recent years. The corporate load forecast does not include a forecast for an “extreme summer” peak. This condition would be expected to be higher than shown on in Figure 3-3.

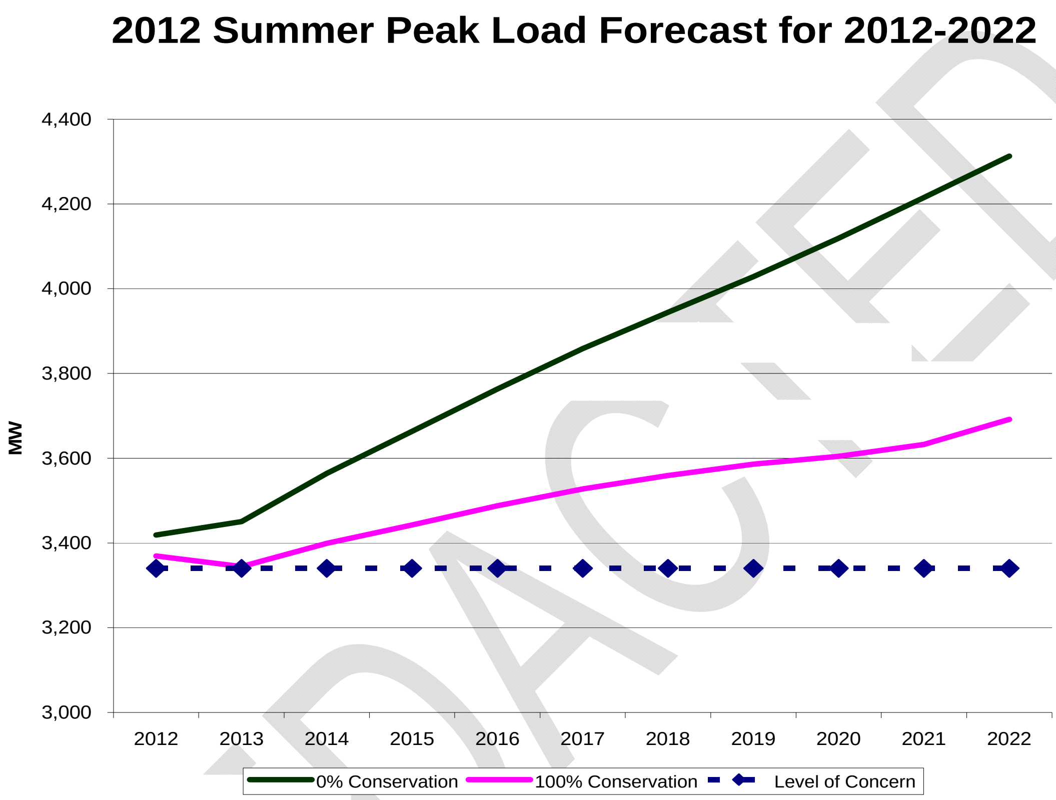

Figure 3-3: Corporate Load Forecast for Summer Peak from 2012 to 2022

Table 3-3 provides a summary of the summer load levels used in the Solutions Study.

Table 3-3: Summer Peak Load Levels Studied in the Eastside Transmission Solutions Study

Year Studied	Season	Normal Peak 100% Conservation	Normal Peak 75% Conservation	Normal Peak 50% Conservation	Normal Peak 25% Conservation	Normal Peak 0% Conservation
2014	Summer	3399	3440	3482	3523	3564
2018	Summer	3559	3655	3752	3848	3944
2022	Summer	3692	3847	4002	4158	4313

3.2.7 Load Power Factor Assumptions

The power factor at each substation was based on the MW and MVAR loadings at the time of the January 18, 2012 system peak. As the load levels changed based on the load forecast, these power factors were held constant.

3.2.8 Transfer Levels

The Northern Intertie ("NI") flows were assumed based on seasonal historic flows and set to the following values:

- Winter Peak NI: 1,500 MW South to North
- Winter Peak NI: 1,500 MW North to South
- Summer Peak NI: 2,850 MW North to South
- Summer Peak NI: 2,000 MW South to North

3.2.9 Generation Dispatch Scenarios

To adjust winter and summer cases for generation scenarios, PSE and SCL generation west of the Cascades was adjusted to either fully on or off. Tacoma Power generation remained in service. These generation configurations were utilized to represent winter and summer stressed conditions are also used in PSE's TPL reports to WECC[6]. The generators adjusted in the Solutions Study are the same as in the Eastside Needs Assessment as listed in Table 3-4.

[6] WECC TPL Planning Standards

Table 3-4: List of Puget Sound Study Generators Adjusted in the 2013 Transmission Solutions Study

Generation Plant	Winter MW Rating	Summer MW Rating	Type	Owner	Transmission Delivery Area
Enserch	184.8	173	Natural Gas, Combined Cycle	PSE	Whatcom County
Sumas	139.8	133.7	Natural Gas, Combined Cycle	PSE	Whatcom County
Ferndale	282.1	266.5	Natural Gas, Combined Cycle	PSE	Whatcom County
Whitehorn	162.2	144.4	Natural Gas, Simple Cycle	PSE	Whatcom County
Fredonia	341	304.2	Natural Gas, Simple Cycle	PSE	Skagit County
Sawmill	31	31	Biomass	Private Owner	Skagit County
Upper Baker	106	101.3	Hydro Dam	PSE	Skagit County
Lower Baker	78	109.7	Hydro Dam	PSE	Skagit County
Komo Kulshan	14	14	Hydro Run-of-River	Private Owner	Skagit County
March Point	151.6	139.9	Natural Gas, Combined Cycle	Shell	Skagit County
Ross	450	116.7	Hydro Dam	SCL	Snohomish County
Gorge	190.7	123.2	Hydro Dam	SCL	Snohomish County
Diablo	166	105.7	Hydro Dam	SCL	Snohomish County
South Tolt River	16.8	16.8	Hydro Run-of-River	SCL	Northeast King County
Snoqualmie	37.8	37.8	Hydro Run-of-River	PSE	East King County
Twin Falls	24.6	24.6	Hydro Run-of-River	Private Owner	East King County
Cedar Falls	30	30	Hydro Run-of-River	SCL	East King County
Freddy 1	270	245.4	Natural Gas, Combined Cycle	Atlantic Power/PSE	Pierce County
Electron	20	13.6	Hydro Run-of-River	PSE	Pierce County
Frederickson	162.2	144.4	Natural Gas, Simple Cycle	PSE	Pierce County

3.2.10 Reactive Resource and Dispatch Assumptions

All existing and planned area reactive resources were assumed available and dispatched if conditions called for their dispatch.

3.2.11 Conservation Assumptions

PSE employs conservation as a strategic measure to manage energy requirements and provide customer benefits. Conservation programs have been funded for over 20 years and are projected to continue to receive strong funding over the next 20 years. PSE's Energy Efficiency Group has demonstrated the efficacy of its funded programs on a continuing basis. As a result, an aggressive conservation program is included in PSE's Integrated Resource Plan (IRP)[7] as a cost-effective source of new energy. The contributions from conservation are captured in the resulting load forecast.

3.3 PSE Study Criteria

3.3.1 Planning Standards, Criteria, and Guidelines

The following is a list of planning standards, criteria, and guides that apply to this document:

- NERC TPL-001- System Performance Under Normal (No Contingency) Conditions (Category A)
- TPL-001-WECC-CRT-2 – System Performance Criterion Under Normal Conditions, Following Loss of a Single BES Element, and Following Extreme BES Events
- NERC TPL-002 - System Performance Following Loss of a Single Bulk Electric System Element (Category B)
- NERC TPL-003 - System Performance Following Loss of Two or More Bulk Electric System Elements (Category C)
- PSE's Transmission Planning Guidelines

3.3.2 Steady State Criteria

This study examined thermal overloads for Category A (N-0), Category B (N-1) and Category C (N-2 and N-1-1) outages as required by NERC reliability standards, WECC criteria and PSE Transmission Planning Guidelines. The following points are taken from NERC, WECC and PSE. References to tables are references to tables contained in the NERC standards.

[7] Puget Sound Energy Integrated Resource Plan 2011

- **NERC TPL-001- System Performance Under Normal (No Contingency) Conditions (Category A):** PSE shall demonstrate through a valid assessment that its portion of the interconnected transmission system is planned such that, with all transmission facilities in service and with normal (pre-contingency) operating procedures in effect, the Network can be operated to supply projected customer demands and projected Firm (non- recallable reserved) Transmission Services at all Demand levels over the range of forecast system demands, under the conditions defined in Category A of Table I.

- **NERC TPL-002 – System Performance Following Loss of a Single Bulk Electric System Element (Category B):** PSE shall demonstrate through a valid assessment that its portion of the interconnected transmission system is planned such that the Network can be operated to supply projected customer demands and projected Firm (non-recallable reserved) Transmission Services, at all demand levels over the range of forecast system demands, under the contingency conditions as defined in Category B of Table I.

  Category B outages can occur at any time when a single element trips off line. The NERC TPL Standards Table 1 Category B[8] states that there should be no loss of load or curtailed firm transfers with the exception outlined in footnote b of Table 1[9] Utilities may only shed directly-connected ("consequential") load to stay compliant. Therefore, any overloads showing up for a Category B event are very serious.

- **NERC TPL-003 – System Performance Following Loss of Two or More Bulk Electric System Elements (Category C):** PSE shall demonstrate, through a valid assessment, that its portion of the interconnected transmission systems is planned such that the network can be operated to supply projected customer demands and projected Firm (non-recallable reserved) Transmission Services, at all demand levels over the range of forecast system demands, under the contingency conditions as defined in Category C of Table I.

  Category C outages have subcategories of N-2 and N-1-1. An N-2 outage is when a single event trips multiple facilities, such as a transmission bus fault tripping all breakers on the bus or a double-circuit transmission line outage. Breaker failure is also included as a Category C outage. For these outages, there is no time allowed for operator response, but the utility is allowed to have automatic processes to shed non-consequential load to stay compliant.

  An N-1-1 Category C outage is a Category B outage followed by a period of time to manually adjust the system to a secure state, followed by a second Category B outage. PSE utilizes 30 minutes to make manual system adjustments after the first outage occurs, to prevent overloads upon the second outage event.

- **TPL-001-WECC-CRT-2: System Performance Criterion Under Normal Conditions, Following Loss of a Single BES Element, and Following Extreme BES Events.** System simulations and associated

[8] Table 1 TPL-002 - System Performance Following Loss of a Single Bulk Electric System Element (Category B)

[9] Footnote b Table 1 - Planned or controlled interruption of electric supply to radial customers or some local Network customers, connected to or supplied by the Faulted element or by the affected area, may occur in certain areas without impacting the overall reliability of the interconnected transmission systems. To prepare for the next contingency, system adjustments are permitted, including curtailments of contracted Firm (non-recallable reserved) electric power Transfers.

assessments are needed periodically to ensure that reliable systems are developed that meet specified performance requirements with sufficient lead time, and that systems continue to be modified or upgraded as necessary to meet present and future system needs.

- PSE Transmission Planning Guidelines, November 2012: The Transmission Planning Guidelines explain the criteria and standards used to assess the ability of Puget Sound Energy's (PSE) existing and future electric transmission system, and how they are applied to provide safe and reliable service at reasonable cost. The guidelines address both specific and general issues the transmission planner needs to consider. There may be issues specific to site, project, region, or customer that will require plans to be developed on a case-by case basis. However, the Transmission Planning Guidelines are structured in a way that will help achieve consistency across the PSE transmission system.

3.3.3 Steady State Thermal and Voltage Limits

System steady state voltages and post contingency voltage deviation shall be within acceptable limits. For PSE system the acceptable limits are: the steady state voltage levels are not above 105% or below 90% for any bus, the voltage deviation for Category B events does not exceed 5%, and the voltage deviation for multiple contingency Category C events does not exceed 10%.

PSE has two thermal operating limits; normal and emergency. The normal operating limit is a specific level of electrical loading that a system, facility, or element can support or withstand through the daily demand cycles without loss of equipment life. The emergency limit is a specific level of electrical loading that a system, facility, or element can support or withstand for a finite period. The emergency rating assumes acceptable loss of equipment life or other physical or safety limitations for the equipment involved. If there is a violation of the emergency limit, a transmission line may not meet applicable clearance, tension and sag criteria. PSE's operating practice is to shift or shed load or dispatch generation to avoid reaching an emergency limit.

3.3.4 Steady State Solution Parameters

Devices with automatic settings were allowed to adjust automatically for base case runs, reflecting manual operation by Transmission Operators: LTC's, phase-shifters, and shunt reactive devices. During contingency runs, LTC and phase-shifter cannot respond in the time frame of the contingency, therefore automatic adjustments were disabled. Shunt reactive devices with known fast-acting schemes were allowed to switch. Inter-area AGC was enabled for the analysis since generation or load loss simulations for the Eastside Needs Assessment were all modeled within the Northwest area and AGC response would be expected for those conditions (Table 3-5).

Table 3-5: Study Solution Parameters

Case	Area Interchange	Transformer LTCs	Phase Angle Regulators	SVDs & Switched Shunts
Base	Tie Lines Regulating	Stepping	Regulating or Statically Set	Regulating
Contingency	Tie Lines Regulating	Disabled	Disabled	Regulating

3.3.5 Steady State Contingencies/Faults Tested

The winter and summer power flow cases were tested utilizing Categories A, B, and C contingencies described in the NERC TPL, WECC Standards and PSE's Transmission Planning Guidelines. Descriptions of the type of contingencies tested are listed in Table 3-6 below.

Table 3-6: Summary of NERC and/or WECC Category Contingencies Tested

NERC WECC Categories	Description of Outaged Element(s)	Contingency Types Modeled[10]
A	All lines in service	N/A
B A-2; 6.1 a. PP4; 3.1 a.	Loss of a generator, transmission circuit, transformer or single pole DC line	Category B contingencies included all PSE and interconnected transmission lines, transmission transformers, and generators.
C A-2; 6.1 a. PP4; 3.1 a.	Normally loss of a bus or circuit breaker; or Loss of any category B element followed by another category B element with system adjustments between events; or Loss of any two circuits of a multi circuit tower line or loss of a bipolar DC line; or A stuck breaker with delayed clearing of a generator, transmission circuit, transformer or bus section.	a. Category C: N-2 contingencies included all common-structure double circuit lines, all transmission buses and bus sections with 3 or more transmission elements, and all stuck transmission breakers. b. Category C: N-1-1 included a pairwise combination of all Category B elements followed by all other Category B elements.
D A-2; 6.1 a. PP4; 3.1 a.	Loss of a generator, transmission circuit, transformer or bus section; or Other transmission planning entity selected critical outage or Loss of a category B element followed by loss of any two circuits of a multi circuit tower or a stuck breaker	Category D was not performed in this study.

[10] All contingencies that could have an impact in the study area were included.

3.3.6 Longevity Criteria

For the solution study, a solution needed to achieve no more than 90% transformer emergency loading and no more than 95% transmission line emergency loading within the study area for any studied contingency in the 2021-22 normal winter south to north case with 75% conservation. These limits were selected at a lower level than the full emergency limit and load forecast adjusted so that the solution will remain viable for a few years following solution implementation before additional system upgrades are required.

To further test for longevity, the 2021-22 extreme winter case with 100% conservation was studied with regional power flows in the south to north direction with no Puget Sound area generation turned on. This provided an indication of how soon other solutions would be required.

4.0 Solution Types Considered and Technical Evaluation

The needs analysis established that by the winter of 2017-18, PSE has a transmission supply need on the Eastside of Lake Washington, which impacts PSE customers in the cities of Redmond, Kirkland, Bellevue, Clyde Hill, Medina, Mercer Island, Newcastle, and Renton along with towns located at Yarrow Point, Hunts Point, and Beaux Arts.

In Step One, the study team reviewed the various types of potential solutions. Because the need is driven by demand within the Eastside area, the project team investigated four main solution types: 1) conservation within the Eastside area; 2) adding new generation supply within the Eastside; 3) transformer additions within the Eastside area; and 4) both transmission reinforcement and transformer additions/upgrades within the Eastside area.

Regardless of solution type, the team also required that any proposed solution had to satisfy the following conditions:

- The solution fully solves the reliability issues identified in the 2013 Eastside Needs Assessment Report for 5-10 years following construction of the selected solution.
- The solution satisfies the longevity criteria as stated in Section 3.3.6.
- The solution is environmentally acceptable to PSE and the communities it serves.
- The solution is constructible and can be in-service by the winter of 2017-18.

A brief description of each Solution Type and power flow results are provided below.

4.1 Conservation within the Eastside Area

PSE currently employs conservation as a strategic measure to manage energy requirements and provide customer benefits. Conservation programs have been funded for over 20 years and are projected to continue to receive strong funding in PSE's budgets through the next 20 years. PSE's Energy Efficiency Group has demonstrated that these funded programs are effective and have had a positive impact on the PSE's load (both energy and peak usage). From 2012 to 2022 PSE expects the Conservation programs to reduce peak load by approximately 900 MW (2012 Forecast - Appendix A) system wide. These reductions in peak are substantial and of such magnitude that the overall PSE peak load forecast was not expected to increase much between 2017 and 2021, even with the assumption of a return to a normal economic climate.

Despite these high levels of conservation embedded into the load forecast, the PSE team considered whether additional demand side options Energy Efficiency (EE), Demand Response (DR), and Distributed Generation (DG) within the King County area would reduce the load adequately to eliminate or delay any needed transmission reinforcements. Based on power flow analysis, the amount of incremental conservation needed in the King County area to delay, not avoid, the transmission upgrades ranges from a low of 70 MW to a high of 140 MW. The 70 MW is in addition to being able to achieve 100% (444 MW) of the projected conservation for King County, and the 140 MW is in addition to achieving 75% (333 MW) of the projected conservation for King County. The 100% conservation level for the PSE system, based on the 2012 forecast, is 885 MW and 75% conservation is 664 MW.

A range of conservation is utilized because of the uncertainties in load growth, long-term prediction of conservation programs in the IRP vs. implementation programs, with customers willing to participate, customer operating characteristics, incentives of the offerings, expected savings measurements, and timing of the conservation. Also, conservation program potentials do not account for program interactions. The methods used to evaluate the technical potential and achievable technical potential of the conservation programs draw upon the best practices in the utility industry and are consistent with the methodology used by the Northwest Power and Conservation Council[11] in its assessment of regional conservation potentials in the Northwest and the Washington Energy Independence Act.

Uncertainties in load growth can occur from faster load growth than predicted, changes in weather, for example colder weather than planned for (23^{o}F), and shortfall in conservation relative to IRP plan. The IRP predicts conservation levels over the long-term and is utilized as a long-term guideline. The conservation values in the IRP are rigorously estimated based on the best information available at the time but are generally different at the program stage. At the program stage there is more focus based on given market factors and PSE's granular knowledge. PSE in cooperation with the Commission sets the savings targets and the Commission sets the rules to evaluate the savings targets.

Predicting expected conservation savings for specific programs has uncertainties. For example, there are a number of uncertainties in achieving energy savings from HVAC maintenance measures[12]. HVAC maintenance measures in residential and small commercial buildings have been demonstrated in the laboratory to have the potential to save a significant amount of energy. However, evaluation, measurement and verification (EM&V) studies of these programs have shown mixed results. The uncertainties are more than just inaccuracies in measurements. They include programmatic, process, instrumentation, system, and human factors uncertainties.

Energy and Environmental Economics, Inc. (E3) was hired to determine how much incremental economic and achievable conservation was possible and whether there was enough achievable incremental conservation to avoid or defer the need of the transmission upgrade options. This conservation is in addition to the proposed conservation included in the 2012 load forecast. E3's analysis indicates that the cost-effective non-wires potential in the area, including energy efficiency (EE), demand response (DR) and distributed generation (DG) measures, does not represent a permanent alternative to avoid the need for the transmission upgrade options. This assessment also indicates that the non-wires potential is not sufficient to cost-effectively defer the need date of transmission upgrades while maintaining equivalent reliability levels.[13]

4.2 Generation Supply Additions within the Eastside Area

Adding generation on the Eastside was also considered as a means to supply load within the Eastside area. This option was considered since generation added within the area would be located close to the load. This would reduce the amount of electricity that would need to be imported into the area; therefore, might resolve the transmission capacity deficiency.

In general, generation can be added either as conventional generation or as distributed generation (DG). Conventional generation is a large generation source that uses the efficiencies of scale to cost effectively generate

[11] PSE 2011 IRP, Appendix I – Comprehensive Assessment of Demand Side Resources; Northwest Power and Conservation Council, Regional Technical Forum, Complete Operative Guidelines, April 16, 2013

[12] Kristin Heinemeier, Marc Hoeschele, Elizabeth Weitzel, Brett Close, Marshall Hunt, Uncertainties in Achieving Energy Savings from HVAC Maintenance Measures in the Field, ASHRAE Conference Paper, San Antonio TX, June 2012

[13] Jack Moore, Lakshmi Alagappan, & Katie Pickrell, Eastside System Non-Wires Alternatives Screening Study, February 2014

large amounts of electrical energy. Conventional generation includes combustion turbines, combined cycle facilities, coal plants, and nuclear units.

DG includes small scale, behind the meter generation that is installed by PSE customers. In order for DG to meaningfully impact the needs identified within the Eastside area, a large amount of DG must be installed. DG includes solar panels, combined heat-power units, micro-turbines, thermal generators, and small wind turbines.

PSE's existing supply-side resources are diversified geographically and by fuel type as shown in Figure 4-1. Most of the company's gas-fueled resources are in western Washington. The major hydroelectric contracted resources are in central Washington, outside PSE's service area. Wind facilities are located in central and eastern Washington. Coal-fired generation is located in eastern Montana. Currently, there are no utility-owned generation resources in the Eastside study area.

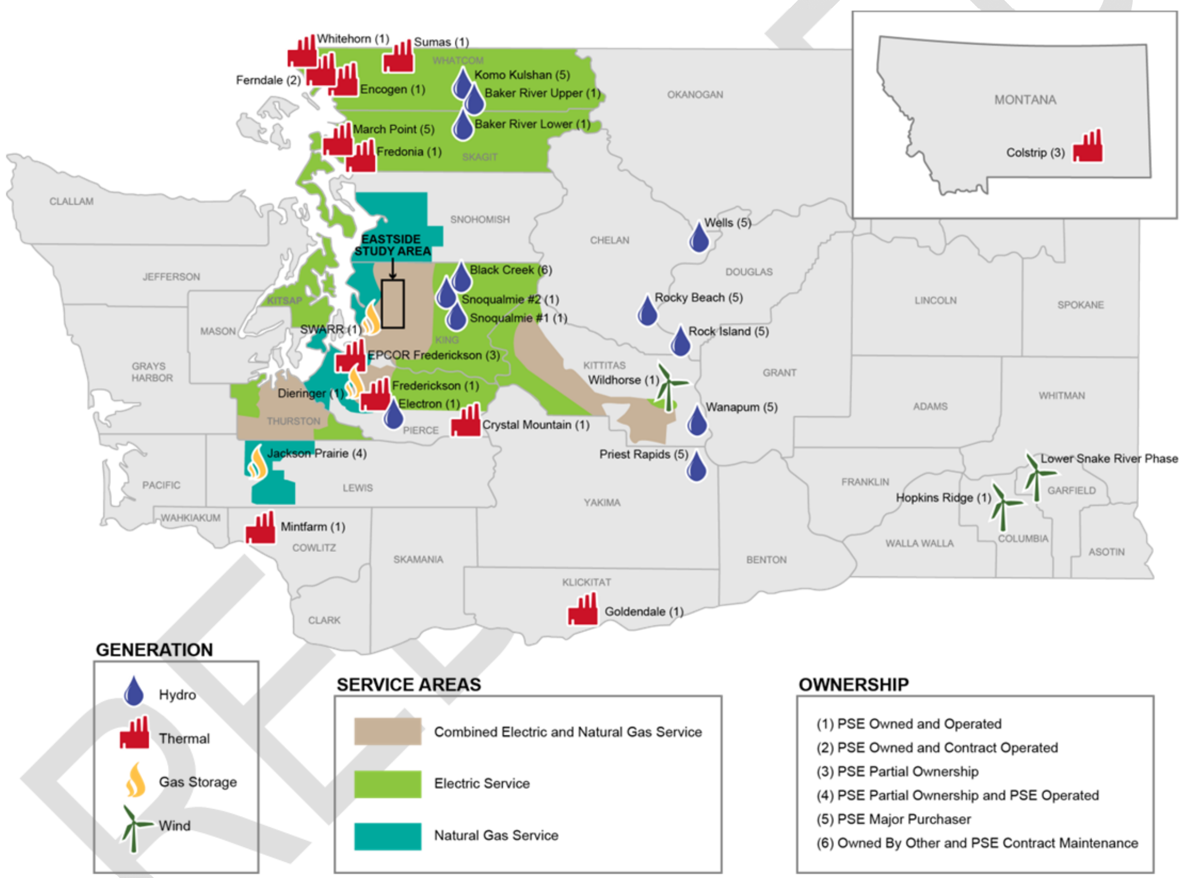

Figure 4-1: PSE Generation Sources

To be effective, the team determined that the total amount of generation would need to be at least 300 MW. Locating conventional generation of this size on the Eastside has major siting and environmental concerns. Locating 300 MW of renewable generation within the area also has its challenges.

Nuclear and coal fired plants were eliminated from consideration due to difficulty in siting and permitting. The team identified natural gas fired generation as a potential alternative. It was noted that there are high pressure natural gas lines accessible in some locations that may be sufficient to support a 300 MW gas fired combined cycle generating plant. This size would be comparable to the 325 MVA nameplate capacity of PSE's 230-115 kV transformers. Besides proximity to high pressure gas lines, the generating plant would ideally be located near several 115 kV lines in order to integrate the new resource at the 115 kV level. New generation would have to be sited so that it could relieve the 230-115 kV substation transformers and 115 kV transmission lines that were identified as being at risk of overload in the 2013 Eastside Needs Assessment Report.

Using the guidelines of proximity to high pressure gas lines and 115 kV transmission lines, PSE considered three sites for a natural gas fired 300 MW generating plant:

4.2.1 Lakeside Switching Station

- Lakeside Switching Station in Bellevue, on property held by PSE south of the existing 115 kV substation. This location is immediately north of I-90 and approximately 1 mile east of I-405.
- The site already has a well-developed 115 kV switching station and a PSE high pressure gas line ¼ mile away.
- This is an urban area where the atmospheric emissions and noise associated with a combined cycle gas-fired generating plant would be extremely challenging, if not impossible to permit.

4.2.2 Lake Tradition Switching Station

- Lake Tradition Switching Station east of Issaquah, on property to be acquired next to PSE's substation. This location is approximately ½ mile south of I-90 and one mile east of downtown Issaquah.
- The site already has a well-developed 115 kV switching station and a Williams transmission gas line ½ mile away.
- This is suburban area within the Mountains to Sound Greenway where the atmospheric emissions and noise associated with a combined cycle gas-fired generating plant would be extremely challenging, if not impossible to permit.

4.2.3 Cedar Hills

- Cedar Hills vicinity, on property to be acquired at a location east of Renton and south of Issaquah near Lake McDonald Substation, Mirrormont Substation, and the BPA Covington-Maple Valley corridor.
- The 115 kV transmission system does not extend to this site and will require constructing new and rebuilding of existing transmission lines.
- The site is near a Williams transmission gas line, which is approximately ½ mile away.
- Permitting a combined cycle gas-fired generation plant at this site may be possible. Local development in the area is rural in nature.

The Lakeside and Lake Tradition sites were reviewed by PSE's Land Planning Group and found to be extremely challenging to permit due to environmental constraints related to noise and atmospheric emissions in an inhabited area as well as restrictive land use requirements. The Cedar Hills area was considered more feasible to permit, and so it was considered as a potential solution.

At this time, biomass, batteries, pumped storage hydro, solar, fuel cells, geothermal, tidal, and wind were not modeled. PSE has observed some recent activity in biomass generation development plans, both for cogeneration and standalone facilities. The typical plant size is approximately 25 MW, but plants up to 50 MW are being proposed. The majority of the plants that have been proposed in this region would interconnect with BPA. Pumped storage hydro, tidal, geothermal, and wind are locational and would require additional transmission to get the supply to the load center of the Eastside area. Fuel cells and batteries have been growing in both number and scale, but are not yet operating at a gross generation scale. Fuel cells operate or are being developed at scales from several hundred watts, such as those to power portable electric equipment, up through several MW to power equipment, buildings, or provide backup power.

Therefore, based upon this review, a 300 MW gas turbine at Cedar Hills generation was considered as a potential alternative.

4.3 Transformer Additions with Minimal Upgrades to Support the Eastside Area

Electricity is typically converted to high voltages in order to move power over long distances without significant losses. PSE's highest voltage system operates at 230 kV. Transformers are devices that move electricity from one voltage to another and are used to convert electricity up to 230 kV for transfer and down to 115 kV or below for use in a given area. The needs for the Eastside were first identified by studies which showed that existing 230-115 kV transformers would overload under certain conditions. A solution type that was considered to mitigate transformer overloads, as identified in the 2013 Needs Assessment, was to add more 230-115 kV transformers in the Eastside area using the existing 230 kV transmission infrastructure at the Talbot Hill, Sammamish or Lake Tradition substations.

As part of Step One, preliminary screening analysis was performed on the transformer additions. The substations considered for the transformer addition needed to have access to 230 kV supply and a well-developed 115 kV bus. Since Sammamish and Talbot Hill were the closest transmission substations to the Eastside that had 230 kV capability, a third 325 MVA 230-115 kV transformer was modeled at each of these substations. A 230-115 kV transformer was also modeled at Lake Tradition, since it has close proximity to a 230 kV line and several 115 kV transmission lines connected to its bus, which serves as an outlet to distribute the electricity. Each of the transformer site options also include upgrading the existing 230 kV SCL Maple Valley-SnoKing lines as part of each alternative to meet the regional need.

The results of the simulation are shown in Appendix F.

4.3.1 Sammamish

Adding a third 325 MVA 230-115 kV transformer was modeled at Sammamish Substation, connecting to the middle section of both 230 and 115 kV buses. There are three existing 230 kV lines feeding the substation and nine 115 kV lines distributing power out to neighboring distribution and transmission substations.

To avoid problems associated with loss of two adjacent bus sections, it would be necessary to also add circuit breakers in the 230 kV and 115 kV buses next to existing breakers. This would prevent a breaker failure from simultaneously tripping two transformers. Adding the two new 230 kV bus section breakers and the two new 115 kV bus section breakers would be challenging due to the existing substation layout and space constraints.

With the third transformer modeled at Sammamish, analysis of the winter cases showed that the south to north power flows created overloads in the Talbot Hill area in 2017-18 with 100% conservation (5,208 MW) and in 2021-22 with 75% conservation (5,400 MW). For these conditions, some of the 115 kV lines in the Talbot Hill area showed loading above 95% for N-1, N-2, and N-1-1 contingencies. Also the Talbot Hill transformer banks #1 and #2 both showed loading above 95% in 2017-18 (5,208 MW) and 2021-22 (5,400 MW) for N-1-1 loss of [redacted]

The summer north to south power flows indicated problems with overloads in the 115 kV and 230 kV systems north of Sammamish. Most telling were the overloads of the Monroe-Novelty Hill 230 kV line for N-1 loss of the [redacted] or the N-2 loss of the [redacted] [redacted] in 2018. The Maple Valley-Sammamish 230 kV line also showed overload for N-1-1 loss of the [redacted]. These summer overloads indicate a weakness in the 230 kV system.

Four additional 115 kV lines were then modeled from Sammamish to Lakeside for both winter 2017-18 with 100% conservation (5,208 MW) and 2018 summer (3,554 MW) to distribute power more effectively from the new transformer. As additional 115 kV lines were added, overloads on Talbot Hill - Lakeside 1 & 2 and Talbot Hill - Paccar were incrementally reduced. Loading on the Maple Valley - SnoKing lines and the Maple Valley - Sammamish line were also reduced as more 115 kV lines were added. Overloads on the Talbot Hill transformer increased slightly as more lines were added. Loading on Shuffleton - Mercer Island was reduced below the 90% threshold, but only with all four 115 kV lines added. While the additional 115 kV lines did solve the winter 115 kV line overloads, they did not solve the winter overloads of the Talbot Hill transformers during N-1-1 outages of [redacted]. Also, the Talbot Hill 230 kV bus would require significant improvements (see Section 6.2.2 for description) to avoid overloads during several line or bus contingencies. In the summer, most overloads were solved except for the Monroe-Novelty Hill 230 kV line overloads for N-1-1 outages of the [redacted] plus any of several 230 kV or 115 kV lines. The third Sammamish transformer together with four new 115 kV lines did not solve the summer and winter transformer overload problems.

Since the addition of four 115 kV lines was not successful in resolving the system problems, the Sammamish transformer option was eliminated.

4.3.2 Talbot Hill

Adding a third 325 MVA 230-115 kV transformer was modeled at Talbot Hill Substation, connecting to the north 230 kV bus and the middle section of the 115 kV bus. There are five existing 230 kV lines feeding the substation and nine 115 kV lines distributing power out to neighboring distribution and transmission substations.

The Talbot Hill 230 kV bus would need significant improvements before a new transformer could be reliably added (see Section 6.2.2 for description). The existing 230 kV bus does not have any bus section breakers. To avoid problems associated with loss of two adjacent bus sections, it would be necessary to add new breakers on the Talbot Hill end of two 230 kV lines and reconfiguring the 230 kV bus to double bus-double breaker layout. It would also be necessary to add circuit breakers in the 115 kV bus next to existing breakers. This would prevent a breaker failure from simultaneously tripping two transformers.

Expanding the substation to extend the 230 and 115 kV buses and install the third transformer would be challenging due to space constraints at the substation.

The power flow analysis of the third transformer at Talbot Hill indicated that with a third transformer in place at Talbot Hill, there would be several 115 kV lines near Talbot Hill that would overload for many contingencies. In addition summer overloads would remain on both transformers at Sammamish Substation for N-1-1 loss of [redacted]. Talbot Hill transformer #1 and Berrydale transformer both show winter overloads for N-2 bus outages. There are overloads in summer of one 115 kV line near Sammamish for north to south flows.

Four additional 115 kV lines were then modeled from Talbot Hill for both winter 2017-18 with 100% conservation (5,208 MW) and 2018 summer (3,554 MW) to distribute power more effectively from the new transformer. As additional 115 kV lines were added, winter overloads on Talbot Hill - Lakeside 1 & 2 and Talbot Hill - Paccar were incrementally reduced. With the addition of the 115 kV lines, loading on the Talbot Hill transformers increased, typically with the loss of one of the [redacted] or loss of [redacted]. Loading on the Novelty - Stillwater, Stillwater - Duvall and Avondale - Cottage Brook lines increased for each additional 115 kV line. Loading on the Maple Valley - Sammamish 230 kV line was reduced below 90% with the addition of two or more 115 kV lines. Loading on the Maple Valley and O'Brien transformers increased above 90% but did not overload as more 115 kV lines were added. Loading on Shuffleton - Mercer Island was reduced below the 90% threshold with the addition of one line.

There were fewer impacts on the summer cases, but in general, issues were identified on the Horse Ranch tap of the Monroe - Snohomish line for outages of 500 kV lines. Results demonstrate that some contingencies show that the issues were exacerbated by the addition of 115 kV lines, while other contingencies show that the overloads were relieved by the addition of 115 kV lines. Loading on the 115 kV lines at the northern end of King County and southern end of Snohomish County were generally reduced as more lines were added. The overload of the Sammamish transformer #2 was not solved by additional 115 kV lines at Talbot Hill. The Monroe-Novelty Hill 230 kV line showed overloads for many contingencies, including N-1 and N-2 contingencies. Overloads on the Monroe - Novelty line were increased when the transformer was placed at Sammamish, but decreased if the transformer was placed at Talbot Hill.

When the Talbot Hill third transformer was modeled with four new 115 kV lines from Talbot Hill to Lakeside and Lake Tradition to better distribute the power from the new transformer, there were still overloads in winter and summer. While 115 kV line overloads near Talbot Hill in winter were solved by the third new 115 kV line, transformer overloads of O'Brien and Talbot Hill transformer #3 were made worse. In summer, Sammamish transformer overloads were not solved by the third Talbot Hill transformer with four new lines.

Based upon this review, the team concluded that the Talbot Hill third transformer did not solve the power system problems identified in the needs assessment.

4.3.3 Lake Tradition

Building out Lake Tradition Substation with 230 kV bus and circuit breakers and installing a 325 MVA 230-115 kV transformer was also modeled. The 230 kV source was modeled using the existing Maple Valley-Sammamish 230 kV line which is located ½ mile east of the substation. BPA owns the line between Maple Valley and Novelty Hill Substations, with PSE using the line under a lease that will expire in 2018. Presently Lake Tradition is a 115 kV switching station with eight 115 kV lines distributing power out to neighboring distribution and transmission substations. The 115 kV bus does not have bus section breakers or an auxiliary bus, so would require some additional work to improve reliability when adding 230-115 kV transformation to the substation. The site was laid out originally for future 230-115 kV transformation, so space will not be an issue at this location.

Before connecting a 325 MVA transformer to BPA's line, BPA would need to study the impacts to their transmission system. It is expected that some system upgrades would be required before PSE would be allowed to connect the BPA line to the Lake Tradition Substation.

When the proposed Lake Tradition transformer was analyzed using power flow studies, there were still winter overloads of several lines in the Talbot Hill area, as well as transformer overloads at O'Brien, Talbot Hill, and Berrydale substations. For summer contingencies, there was greater stress in the north end, where overloads occur on both the Maple Valley-Sammamish and Monroe-Novelty Hill 230 kV lines, as well as the Beverly Park-Cottage Brook 115 kV line. The Sammamish transformer #2 still showed N-1-1 overloads in summer.

Four additional 115 kV lines were then modeled from Lake Tradition for both winter 2017-18 with 100% conservation (5,208 MW) and 2018 summer (3,554 MW) to distribute power more effectively from the new transformer. As additional 115 kV lines were added, overloads on Talbot Hill - Lakeside 1 & 2, Shuffleton - Mercer Island and Talbot Hill - Paccar were incrementally reduced; Loading on the Novelty - Stillwater, Stillwater - Duvall and Cottage Brook - Duvall lines decreased for two additional 115 kV lines, but increased for three and four additional 115 kV lines back to the base case values and overloads on Avondale - Cottage Brook. Power flow on the Norkirk - Sammamish increased slightly as more 115 kV lines were added. Loading on the Berrydale transformer increased above the 90% threshold and in some cases overloaded with the addition of the fourth 115 kV line. Overloads on the Maple Valley - Sammamish 230 kV line were reduced, but not solved by adding additional 115 kV lines. Loading on the Maple Valley - Snoking lines was reduced as more 115 kV lines were added. Loading on the Talbot Hill transformers oscillated in both directions by 1-2%.

When the proposed Lake Tradition transformer was modeled with four new 115 kV transmission lines connecting to Lakeside and Berrydale, there were still problems in winter and summer. In winter, even with four new lines, there were still overloads of the Talbot Hill transformers for N-1-1 outages of [redacted]. At the same time, the fourth 115 kV line caused overloads of the Berrydale transformer for several N-1-1 outage contingencies. A significant improvement of the Talbot Hill 230 kV bus would also be required (see Section 6.2.2 for description) to prevent overloads due to several contingencies. In summer, the Sammamish transformer #2 overloaded for N-1-1 outages of the [redacted] and the [redacted]. Also, the Beverly-Cottage Brook 115 kV line overloaded for the N-1-1 loss of [redacted], even with the four new 115 kV lines. Adding four new 115 kV lines to the new Lake Tradition transformer was not sufficient and even detrimental to solving the system overloads.

Based upon this review, the team concluded that the Lake Tradition transformer did not solve the power system issues identified in the Needs Assessment.

Adding transformers where 230 kV was already established or readily available and the 115 kV lines well developed did not provide relief to the line and transformer overloads identified in the Needs Assessment, even when additional 115 kV lines were modeled. Therefore, the Lake Tradition, Sammamish, and Talbot Hill transformer alternatives were removed from further consideration.

4.4 Transmission Reinforcements and Transformer Additions/Upgrades to support the Eastside area

The final solution type considered was a combination of adding transformers and new 230 kV transmission lines to provide a new transmission source for the Eastside area. This was considered after adding transformers to existing substations failed to provide a sufficient solution.

From the brainstorm meeting, the team identified seven potential new 230 kV transmission lines and seven potential transformer sites that could be combined into as many as 49 different alternatives. These are shown below in Figure 4-2.

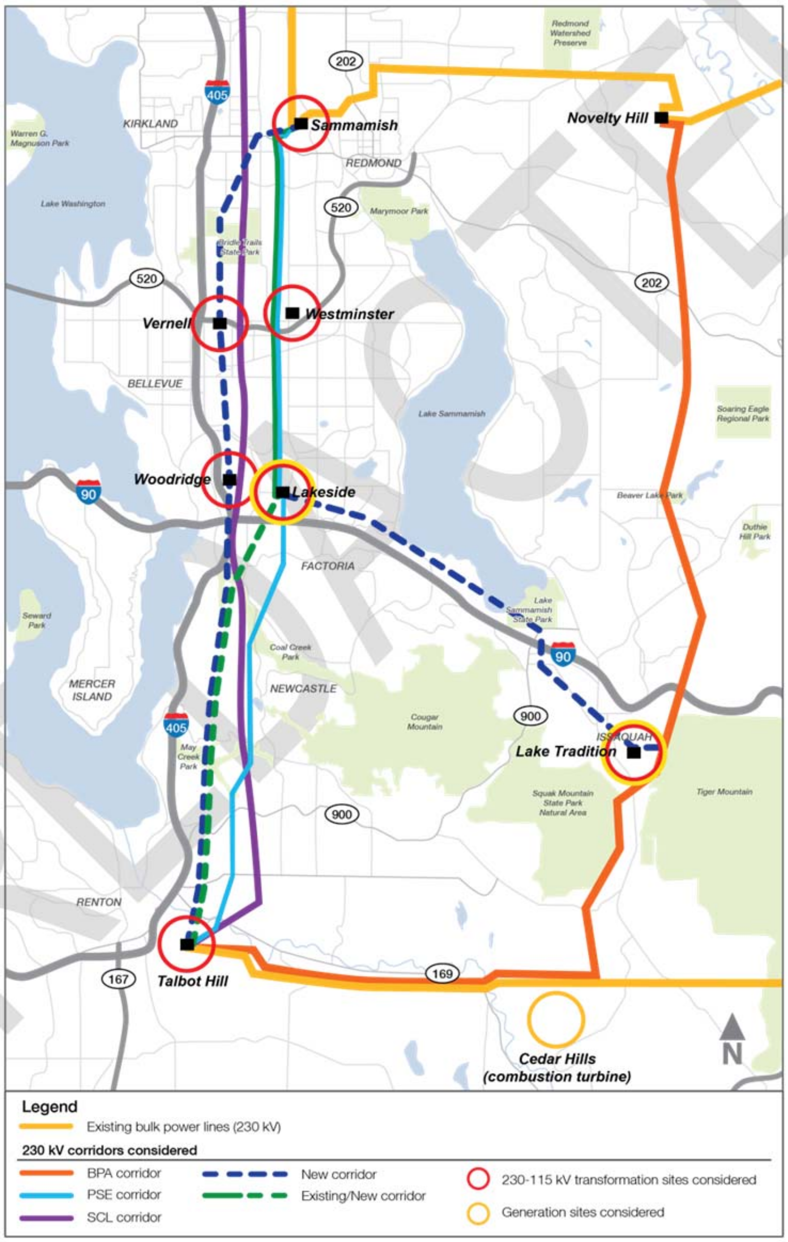

Figure 4-2: Locations of Transformer and Generation Alternatives Studied

4.5 Results of Step One Brainstorming Process

From the brainstorming in **Step One**, the team identified 52 potential solutions -- seven potential 230 kV sources, seven potential transformation sites, and three generation sites. Table 4-1 below shows the 52 potential alternatives and, if it was eliminated in **Step One**, the reason for its elimination, thereby reducing the number of alternatives to twenty-seven.

Table 4-1: Eastside 230 kV Project Alternative Solutions Initial Screening Observations

	230 kV Line Alternative	Generation or Substation Alternative	East-West Distance between 230 kV line and substation	Reason to eliminate alternative
1a	Loop through one SCL Maple Valley-SnoKing Line	Sammamish	3 miles	Other 230 kV line sources are closer proximity to this substation
1b	Loop through one SCL Maple Valley-SnoKing Line	Westminster	1 mile	
1c	Loop through one SCL Maple Valley-SnoKing Line	Vernell	1/2 mile	
1d	Loop through one SCL Maple Valley-SnoKing Line	Woodridge	Adjacent	
1e	Loop through one SCL Maple Valley-SnoKing Line	Lakeside	1 mile	
1f	Loop through one SCL Maple Valley-SnoKing Line	Lake Tradition	9 miles	Other substations are closer proximity to this 230 kV source
1g	Loop through one SCL Maple Valley-SnoKing Line	Talbot Hill	1/2 mile	Not a realistic system configuration
2a	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Sammamish	Adjacent	
2b	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Westminster	Adjacent	
2c	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Vernell	1 mile	
2d	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Woodridge	1 mile	
2e	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Lakeside	Adjacent	

	230 kV Line Alternative	Generation or Substation Alternative	East-West Distance between 230 kV line and substation	Reason to eliminate alternative
2f	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Lake Tradition	8 miles	Other substations are closer proximity to this 230 kV source
2g	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Talbot Hill	Adjacent	
3a	Tap Maple Valley-Sammamish line and SCL lines, loop new substation between tapped lines	Sammamish	3 miles	Not a realistic system configuration
3b	Tap Maple Valley-Sammamish line and SCL lines, loop new substation between tapped lines	Westminster	9+ miles	Other substations are closer proximity to this 230 kV source
3c	Tap Maple Valley-Sammamish line and SCL lines, loop new substation between tapped lines	Vernell	9+ miles	Other substations are closer proximity to this 230 kV source
3d	Tap Maple Valley-Sammamish line and SCL lines, loop new substation between tapped lines	Woodridge	9+ miles	Other substations are closer proximity to this 230 kV source
3e	Tap Maple Valley-Sammamish line and SCL lines, loop new substation between tapped lines	Lakeside	9+ miles	
3f	Tap Maple Valley-Sammamish line and SCL lines, loop new substation between tapped lines	Lake Tradition	9+ miles	Other substations are closer proximity to this 230 kV source
3g	Tap Maple Valley-Sammamish line and SCL lines, loop new substation between tapped lines	Talbot Hill	Adjacent	Not a realistic system configuration
4a	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Sammamish	Adjacent	
4b	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Westminster	Up to 2 miles	
4c	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Vernell	Up to 2 miles	
4d	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop	Woodridge	Up to 2 miles	

	230 kV Line Alternative	Generation or Substation Alternative	East-West Distance between 230 kV line and substation	Reason to eliminate alternative
	through new substation			
4e	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Lakeside	Up to 2 miles	
4f	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Lake Tradition	6-10 miles	Other substations are closer proximity to this 230 kV source
4g	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Talbot Hill	Adjacent	
5a	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Sammamish	Adjacent	
5b	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Westminster	Adjacent	
5c	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Vernell	1 mile	
5d	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Woodridge	1 mile	
5e	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Lakeside	Adjacent	
5f	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Lake Tradition	8 miles	Other substations are closer proximity to this 230 kV source
5g	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Talbot Hill	Adjacent	
6a	Loop BPA Maple Valley-Sammamish line through new sub; upgrade SCL lines	Sammamish	Adjacent	Not a realistic system configuration
6b	Loop BPA Maple Valley-Sammamish line through new sub; upgrade SCL lines	Westminster	16+ miles	Other substations are closer proximity to this 230 kV source

	230 kV Line Alternative	Generation or Substation Alternative	East-West Distance between 230 kV line and substation	Reason to eliminate alternative
6c	Loop BPA Maple Valley-Sammamish line through new sub; upgrade SCL lines	Vernell	18+ miles	Other substations are closer proximity to this 230 kV source
6d	Loop BPA Maple Valley-Sammamish line through new sub; upgrade SCL lines	Woodridge	18+ miles	Other substations are closer proximity to this 230 kV source
6e	Loop BPA Maple Valley-Sammamish line through new sub; upgrade SCL lines	Lakeside	16+ miles	Other substations are closer proximity to this 230 kV source
6f	Loop BPA Maple Valley-Sammamish line through new sub; upgrade SCL lines	Lake Tradition	1/2 mile	
6g	Loop BPA Maple Valley-Sammamish line through new sub; upgrade SCL lines	Talbot Hill	1/2 mile	Not a realistic system configuration
7a	Reconductor SCL Maple Valley-SnoKing lines	Sammamish	Not applicable	
7b	Reconductor SCL Maple Valley-SnoKing lines	Westminster	Not applicable	Fails to provide a 230 kV source to new substation
7c	Reconductor SCL Maple Valley-SnoKing lines	Vernell	Not applicable	Fails to provide a 230 kV source to new substation
7d	Reconductor SCL Maple Valley-SnoKing lines	Woodridge	Not applicable	Fails to provide a 230 kV source to new substation
7e	Reconductor SCL Maple Valley-SnoKing lines	Lakeside	Not applicable	Fails to provide a 230 kV source to new substation
7f	Reconductor SCL Maple Valley-SnoKing lines	Lake Tradition	Not applicable	Fails to provide a 230 kV source to new substation
7g	Reconductor SCL Maple Valley-SnoKing lines	Talbot Hill	Not applicable	
7h	Reconductor SCL Maple Valley-SnoKing lines	Cedar Hills Generation	Not applicable	
7i	Reconductor SCL Maple Valley-SnoKing lines	Lakeside Generation	Not applicable	Environmental permitting restrictions
7j	Reconductor SCL Maple Valley-SnoKing lines	Lake Tradition Generation	Not applicable	Environmental permitting restrictions

Combinations that were clearly not realistic or were similar to other potential solutions that had substations closer to the 230 kV source were eliminated from further consideration. This reduced the initial 52 potential alternatives down to 27 realistic combinations, which are listed in Table 4-2 and shown on Figure 4-3.

Table 4-2: Identified Potential Combinations of Line Sources with Transformer and Generation Sites

Source ID No.	230 kV Transmission Sources	Site ID	Transformer and Generation Sites	Combinations of Sources & Sites
1	Loop thru one SCL Maple Valley - SnoKing line	a	Sammamish	1b, 1c, 1d, 1e
2	Loop thru one Talbot Hill - Lakeside - Sammamish line PSE Corridor	b	Westminster	2a, 2b, 2c, 2d, 2e, 2g
3	Tap Maple Valley - Sammamish line, new lines to Lakeside, SCL lines	c	Vernell	3e
4	Talbot Hill - Sammamish 230 kV line on new ROW	d	Woodridge	4a, 4b, 4c, 4d, 4e, 4g
5	Talbot Hill - Lakeside 230 kV line on new ROW, rebuild Lakeside - Sammamish lines (PSE Corridor)	e	Lakeside	5a, 5b, 5c, 5d, 5e, 5g
6	add loop thru BMA-SAM, SCL lines	f	Lake Tradition	6f
7	only reconductor SCL lines	g	Talbot Hill	7a, 7g, 7h
		h	Cedar Hills Generation	

4.6 Results of Step Two Screening Process

Step Two was the screening process to understand the reliability impacts and help eliminate from the potential alternatives those which were electrically infeasible. Power flow simulations were performed on the 27 potential alternatives, utilizing cases from the Needs Assessment and a set of select contingencies, to determine the reliability impacts of each alternative (Figure 4-3). Because the Needs Assessment indicated supply concerns in the winter at approximately 5,200 MW and the summer at approximately 3,500 MW, power flow simulations were performed using Heavy Winter 2017-18 at 100% conservation (5,208 MW) and 75% conservation (5,325 MW), 2021-22 Heavy Winter at 75% conservation (5,415 MW), and 2018 Heavy Summer at 100% conservation (3,554 MW). The results presented in the tables below generally are from the Heavy Winter 2017-18 at 100% conservation case, which is a load level of 5,208 MW. The results of 2021-22 Heavy Winter at 100% conservation case are not shown, because the forecasted load level of 5,193 MW is less than the 2017-18 at 100% conservation case.

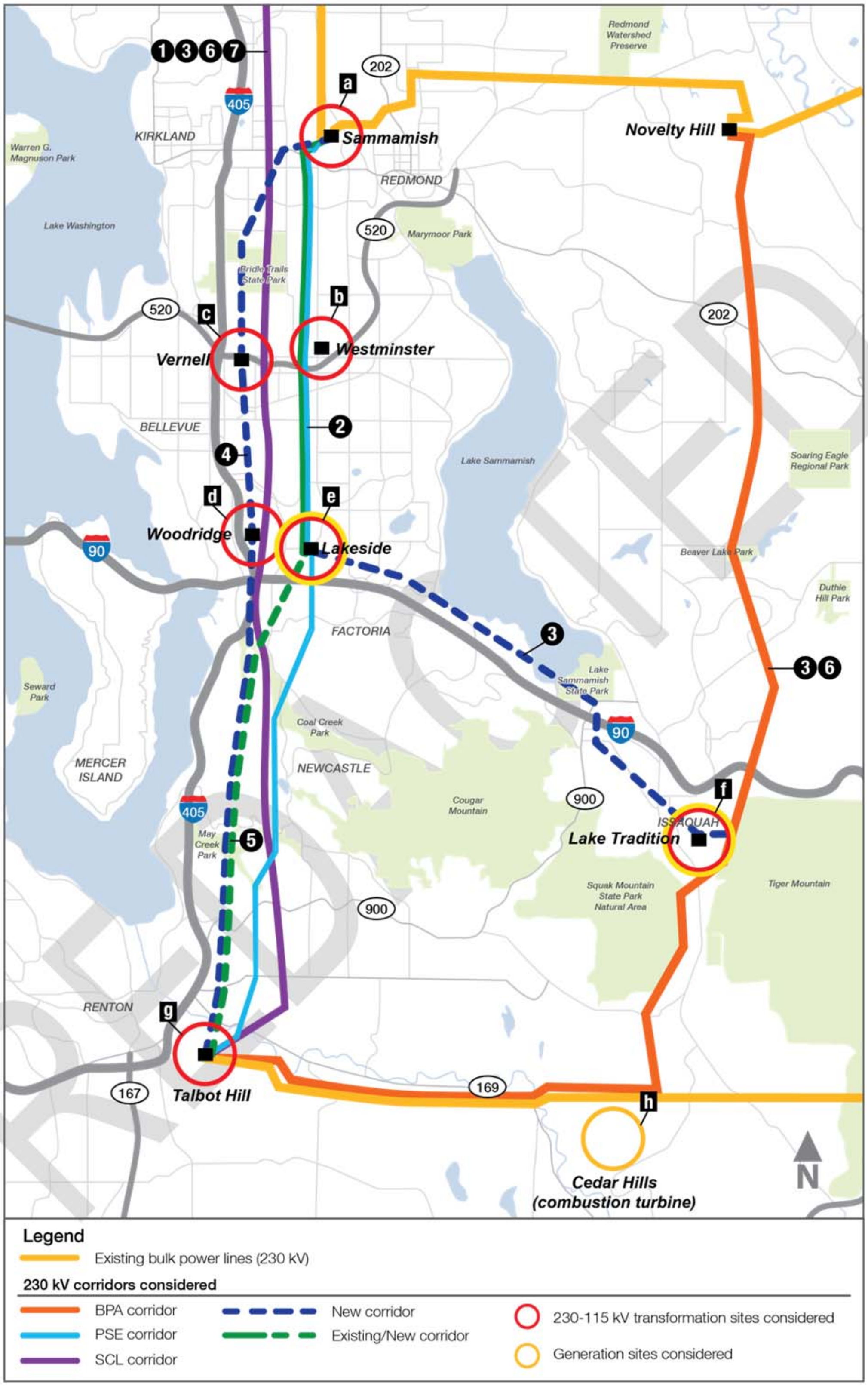

Figure 4-3: Identified Potential Alternatives

The results of the analyses are presented in tables showing the percent loading based on the emergency rating (limit). The emergency limit is a specific level of electrical loading that a system, facility, or element can support or withstand for a finite period. The emergency rating assumes acceptable loss of equipment life or other physical or safety limitations for the equipment involved. If there is a violation of the emergency limit, a transmission line may not meet applicable clearance, tension, and sag criteria. Percentages below 100% down to 90% of the emergency limits are also shown in the tables. Transformers percentages are shown down to 90% and transmission lines are shown down to 95%. The 90% and 95% values represent warning limits used by the system operators.

A "—" in the tables mean that the percent of the emergency rating was below 90% for transformers (XFR) and 95% for transmission lines. A "**" in the tables mean the case did not solve.

BPA has a CAP procedure in place that protects the Maple Valley – SnoKing 230 kV lines from overloading. So the potential overloads of those lines are not included in the tables below.

4.6.1 Source 1: Loop Thru one SCL Maple Valley - SnoKing Line, Sites: *b*-Westminster, *c*-Vernell, *d*-Woodridge, and *e*-Lakeside Substations

The first set of simulations analyzed the impacts using Source 1 and substation sites *b*, *c*, *d*, and *e*, which comprised the reconductoring with high temperature conductor of both Seattle City Light's SnoKing-Maple Valley 230 kV transmission lines and looping one of them to a new transmission substation; *b*-Westminster, *c*-Vernell, *d*-Woodridge, or *e*-Lakeside (Figure 4-3). The results of the Heavy Winter 2017-18, 100% conservation, showed that reconductoring of the two Maple Valley – SnoKing 230 kV lines was not sufficient to mitigate the overloads identified in the Needs Assessment (Table 4-3). There were several 115 kV lines overloading or close to overloading; therefore the simple reconductoring did not have enough capacity to prevent the overloads. In order to make Source 1 viable, rebuilding the SCL 230 kV lines with high temperature 1590 Falcon conductor would be necessary. Appendix E summarizes results of power flow simulations for the 2018 Heavy Summer and 2021-22 Heavy Winter cases. Using Source 1-rebuilding the SCL 230 kV lines from Maple Valley to Sammamish substations and sites *b*-Westminster, *c*-Vernell, *d*-Woodridge, or *e*-Lakeside shows no overloads.

Table 4-3: Results of 2017-18 Heavy Winter 100% Conservation for Source 1 and Loop through Various Substations *Redacted*

4.6.2 Source 2: Loop Thru One Talbot Hill - Lakeside - Sammamish Line (PSE Corridor), Sites: *a*-Sammamish, *b*-Westminster, *c*-Vernell, *d*-Woodridge, *e*-Lakeside, and *g*-Talbot Hill Substations

The second set of simulations analyzed the impacts using Source 2 and sites *a, b, c, d, e,* and *g*, which comprised a rebuild of two existing 115 kV transmission lines to 230 kV to connect the Talbot Hill and Sammamish substations while looping one of the rebuilt lines through a new 230 kV – 115 kV substation at *a*-Sammamish, *b*-Westminster, *c*-Vernell, *d*-Woodridge, *e*-Lakeside, or *g*-Talbot Hill (Figure 4-3).

Table 4-4 shows the summary of results of power flow simulations for the 2017-18 Heavy Winter at 100% Conservation, using Source 2 and various transformation sites. For simulations using Sammamish and Talbot Hill substations as transformation sites, the simulations show that for many N-1-1, N-2, and breaker failure contingencies, there were overloads or near overloads on the following: Shuffleton-Lakeside 115 kV ckt 1; Talbot Hill – Boeing Renton – Shuffleton 115 ckt 1; Shuffleton-O'Brien 115 kV ckt 1; Sammamish 230-115 XFR ckt 1; and Sammamish 230-115 XFR ckt 2. There was also an overload of the Talbot Hill – Boeing Renton – Shuffleton 115 ckt 1 when using Vernell Substation as a transformation site. This overload could be mitigated with the rebuild of a three mile line section of the Talbot Hill – Boeing Renton #2 line.

For simulations using Source 2 and Westminster, Woodridge, or Lakeside transformation sites, no overloads occurred.

Table 4-4: Results of 2017-18 Heavy Winter 100% Conservation for Source 2 and Looping through Various Substations *Redacted*

4.6.3 Source 3: Tap Maple Valley - Sammamish 230 kV line, New Lines to Lakeside, SCL Lines, Site: *e*-Lakeside

The third set of simulations analyzed the impacts using Source 3 and Site *e*, which is a 230 kV loop of the Maple Valley to Sammamish 230 kV line that goes to a new 230-115 kV Lakeside Substation (Figure 4-3). In addition, the SCL SnoKing - Maple Valley 230 kV lines were reconductored with high-temperature conductors.

Table 4-5 shows the summary of results of power flow simulations for Source 3 for the 2017-18 Heavy Winter, 100% and 75% conservation. For many of the contingencies, overloads or near overloads will occur on a number of 115 kV, and 230 kV lines and transformers.

Table 4-5: Results of 2017-18 Heavy Winter at 100% & 75% Conservation for Source 3 and Loop through Lakeside (e) Substation *Redacted*

4.6.4 Source 4: Talbot Hill - Sammamish 230 kV Line on New ROW, Sites: *a*-Sammamish, *b*-Westminster, *c*-Vernell, *d*-Woodridge, *e*-Lakeside, and *g*-Talbot Hill Substations

The fourth set of simulations analyzed the impacts using Source 4 and sites *a, b, c, d, e,* and *g*, which comprised a single 230 kV transmission line on a new transmission corridor that connects the Talbot Hill and Sammamish substations, while looping the line through a new substation; *a*-Sammamish, *b*-Westminster, *c*-Vernell, *d*-Woodridge, *e*-Lakeside, or *g*-Talbot Hill substation (Figure 4-3).

Table 4-6 shows the summary of results of power flow simulations for Source 4 for the 2017-18 Heavy Winter at 100% conservation. For simulations using Sammamish and Talbot Hill substations as transformation sites it was shown that for many N-1-1 and breaker failure contingencies, overloads or near overloads for: Talbot Hill – Lakeside 115 kV ckt 1 and 2; Talbot Hill - Boeing Renton – Shuffleton 115 kV ckt 1; and Talbot Hill 230 kV-115 kV XFR ckt 1.

Source 4 using Westminster, Woodridge, and Lakeside as transformation sites did not have any overloads.

Table 4-6: Results of 2017-18 Heavy Winter at 100% Conservation for Source 4 and Looping through Various Substations *Redacted*

4.6.5 Source 5: Talbot Hill - Lakeside 230 kV line on New ROW, Rebuild Lakeside - Sammamish lines (PSE Corridor), Sites: *a*-Sammamish, *b*-Westminster, *c*-Vernell, *d*-Woodridge, *e*-Lakeside, and *g*-Talbot Hill Substations

The fifth set of simulations analyzed the impacts using Source 5 and sites *a, b, c, d, e*, and *g*, which is comprised of a new 230 kV source on new ROW between Talbot Hill and Lakeside substations. This would also require the rebuild of the existing 115 kV line from Lakeside to Sammamish substations while looping through one of the following transformation sites; *a*-Sammamish, *b*-Westminster, *c*-Vernell, *d*-Woodridge, *e*-Lakeside, or *g*-Talbot Hill substations (Figure 4-3).

Table 4-7 shows the summary of results of power flow simulations for Source 5 for the 2017-18 Heavy Winter at 100% conservation. Although no overloads were shown, near overload occurred for Talbot Hill 230 kV-115 kV XFR ckt 2 for simulations using Sammamish Substation as the transformation site.

Table 4-7: Results of 2017-18 Heavy Winter 100% Conservation for Source 5 and Looping through Various Substations *Redacted*

4.6.6 Source 6: Add Loop Thru Maple Valley - Sammamish, SCL Lines, Site: *f*-Lake Tradition Substation

The sixth set of simulations analyzed the impacts using Source 6 and Site *f*, which is to loop the Maple Valley to Sammamish 230 kV line through the Lake Tradition Substation, as well as reconductor the SCL SnoKing-Maple Valley 230 kV lines with high-temperature conductors (Figure 4-3).

Table 4-8 shows the summary of results of power flow simulations for the 2017-18 heavy winter, 100% conservation, using Source 6. The summary of results show, for many contingencies, overloads or near overloads for a number of 115 kV, and 230 kV lines and transformers.

Table 4-8: Results of 2017-18 Heavy Winter 100% & 75% Conservation for Source 6 and Loop through Lake Tradition (*f*) Substation ***Redacted***

4.6.7 Source 7: Only Reconductor SCL Lines, Sites*:* *a*-Sammamish, and *g*-Talbot Hill Substations, and *h*-Cedar Hills Generation

The seventh set of simulations analyzed the impacts using Source 7 and sites *a* and *g*, and with *h*-Cedar Hills generation. Source 7 comprised the reconductoring (high temperature conductor) of both Seattle City Light's SnoKing-Maple Valley 230 kV transmission lines, looping one of the SCL lines to a new transmission substation at either *a*-Sammamish or *g*-Talbot Hill substations, plus *h*-Cedar Hill generation (Figure 4-3).

Table 4-9 shows the summary of results of power flow simulations for Source 7 for the 2017-18 Heavy Winter at 100% conservation. When using Sammamish and Talbot Hill substations as transformation sites, many overloads or near overloads occur for a number of 115 kV lines and Talbot Hill 230 kV-115 kV XFR ckts 1 & 2. The results using Cedar Hill generation (Table 4-10), show a partial set of overloads on many 115 kV, and 230 kV lines and transformers, such as Talbot Hill – Lakeside 115 ckt 1 and Talbot Hill – Lakeside 115 ckt 2 for various contingencies. A full set of results are shown in Appendix E.

Table 4-9: Results of 2017-18 Heavy Winter at 100% & 75% Conservation for Source 7 and Loop through Lake Sammamish (a) or Talbot Hill (g) Substations *Redacted*

Table 4-10: Partial Results for Source 7 and with Cedar Hill Generation (*h*) ***Redacted***

4.6.8 Summary of the Analysis - Twenty Seven Potential Solutions

The transformation sites closest to the load centers resulted in the best performance. The review of the results also verified that the simple reconductoring of the SCL lines with high-temperature conductors on the existing structures was not sufficient to solve the problem. Instead of reconductoring the SCL 230 kV lines, a rebuild of SCL’s 230 kV lines from Maple Valley to Sammamish and reconductor from Sammamish to SnoKing would be required to make it a viable solution.

In order to integrate Cedar Hills generation into the 115 kV system, it was necessary to connect the two 115 kV transmission lines that go to both Lake Tradition and Berrydale transmission substations. The 115 kV line interconnections would require building 17 miles of new 115 kV transmission lines and rebuilding 21 miles of existing 115 kV transmission lines. According to the power flow studies, generation alone did not provide enough relief to solve the capacity problems (Appendix E).

Table 4-11 below shows the 27 potential alternatives and, if it was eliminated in Step Two, the reason for its elimination. This resulted in 12 alternatives to move forward to Step Three.

Table 4-11: Twenty Seven Potential Solutions and Elimination of Alternatives in Step Two

	230 kV Line Alternative	Generation or Substation Alternative	East-West Distance Between 230 kV Line and Substation	Reason to Eliminate Alternative
1b	Loop through one SCL Maple Valley-SnoKing Line (Rebuild Maple Valley to Sammamish and Reconductor Sammamish to SnoKing)	Westminster	1 mile	
1c	Loop through one SCL Maple Valley-SnoKing Line (Rebuild Maple Valley to Sammamish and Reconductor Sammamish to SnoKing)	Vernell	1/2 mile	
1d	Loop through one SCL Maple Valley-SnoKing Line (Rebuild Maple Valley to Sammamish and Reconductor Sammamish to SnoKing)	Woodridge	Adjacent	
1e	Loop through one SCL Maple Valley-SnoKing Line (Rebuild Maple Valley to Sammamish and Reconductor Sammamish to SnoKing)	Lakeside	1 mile	
2a	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Sammamish	Adjacent	Did not perform as well as other transformer sites for this same source
2b	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Westminster	Adjacent	

	230 kV Line Alternative	Generation or Substation Alternative	East-West Distance Between 230 kV Line and Substation	Reason to Eliminate Alternative
2c	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Vernell	1 mile	
2d	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Woodridge	1 mile	
2e	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Lakeside	Adjacent	
2g	Rebuild one Talbot Hill-Lakeside-Sammamish Line to 230 kV and loop through new substation	Talbot Hill	Adjacent	Did not perform as well as other transformer sites for this same source
3e	Tap Maple Valley-Sammamish line and SCL lines, loop new substation between tapped lines	Lakeside	9^{+} miles	Electrically did not perform well…too many overloads
4a	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Sammamish	Adjacent	Did not perform as well as other transformer sites for this same source
4b	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Westminster	Up to 2 miles	
4c	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Vernell	Up to 2 miles	
4d	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Woodridge	Up to 2 miles	
4e	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Lakeside	Up to 2 miles	
4g	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Talbot Hill	Adjacent	Did not perform as well as other transformer sites for this same source

	230 kV Line Alternative	Generation or Substation Alternative	East-West Distance Between 230 kV Line and Substation	Reason to Eliminate Alternative
5a	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines New ROW South	Sammamish	Adjacent	Same result as 4a
5b	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Westminster	Adjacent	Similar electrical result as 4b; final route to be determined
5c	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Vernell	1 mile	Similar electrical result as 4c; final route to be determined
5d	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Woodridge	1 mile	Similar electrical result as 4d; final route to be determined
5e	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Lakeside	Adjacent	Similar electrical result as 4e; final route to be determined
5g	Build new Talbot Hill-Lakeside 230 kV line on new right of way, rebuild Lakeside-Sammamish lines	Talbot Hill	Adjacent	Same result as 4g
6f	Loop BPA Maple Valley-Sammamish line through new sub; upgrade SCL lines	Lake Tradition	1/2 mile	Electrically did not perform well; too many overloads
7a	Reconductor SCL Maple Valley-SnoKing lines	Sammamish	Not applicable	Electrically did not perform well; too many overloads
7g	Reconductor SCL Maple Valley-SnoKing lines	Talbot Hill	Not applicable	Electrically did not perform well; too many overloads
7h	Reconductor SCL Maple Valley-SnoKing lines	Cedar Hills Generation	Not applicable	Electrically did not perform well; too many overloads

5.0 Performance, Operational Flexibility and Longevity Analysis

A detailed analysis of the most promising twelve alternatives from the perspective of performance, operational flexibility and longevity was performed as Step Three. To test for performance, operational flexibility, and longevity, full contingency analysis was performed utilizing Heavy Winter 2021-22 at 100% conservation (5,193 MW) and Heavy Summer 2018 at 100% conservation (3,554 MW) cases. PSE and SCL generation west of the Cascades was adjusted to either fully on or off. Tacoma Power generation remained in service. These generation configurations were utilized to represent winter and summer stressed conditions and were also used in PSE's mandatory TPL reports to WECC[14].

To test for future longevity, full contingency analysis was performed utilizing 2021-22 Heavy Winter 75% conservation (5,415 MW) and 2021-22 Extreme Winter 100% conservation (5,742 MW).

5.1 Steady State Performance Results

For each of the 12 proposed solution alternatives, the same power flow simulations were performed as the ones performed in the Needs Assessment. The results showed that the potential violations identified in the Needs Assessment Report were mitigated. Power flow results are located in Appendix D.

5.1.1 N-0 Thermal and Voltage Performance Summary

For each of the twelve proposed alternatives, no potential thermal or voltage violations relevant to the defined Eastside area were identified for N-0 for base years 2018 Summer and 2021-22 Winter with 100% conservation.

5.1.2 N-1 Thermal and Voltage Performance Summary

For each of the twelve proposed alternatives, no potential thermal or voltage violations relevant to the defined Eastside area were identified when performing N-1 contingencies for base years 2018 Summer and 2021-22 Winter with 100% conservation.

5.1.3 N-1-1 & N-2 Thermal and Voltage Performance Summary

For each of the twelve proposed alternatives, no potential thermal or voltage violations relevant to the defined Eastside area were identified when performing N-1-1 or N-2 contingencies for base years 2018 Summer and 2021-22 Winter with 100% conservation.

5.2 Operational Flexibility

The focus of the operational flexibility assessment is to determine if a proposed alternative will allow for the elimination or reduce the need for Corrective Action Plans (CAPs). CAPs are used to prevent thermal overloads of transmission lines and transformers. For example, there is an existing CAP in place to prevent overloads in the winter on either of the Talbot Hill transformer banks. This CAP requires the manual opening of 115 kV breakers at [redacted]

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[redacted], which removes the two 115 kV lines between the Talbot Hill and Lakeside substations. Taking this step switches the load to radial (non-network) connections, which reduces the inherent reliability of the network since the transmission system cannot handle as many contingencies without overloads, voltage issues, or loss of customers' power.

As stated in the Needs Assessment Report, as the PSE system load grows, the overload of either Talbot Hill 230 kV transformer at winter peak may not be sufficiently mitigated by this CAP. If loading on the overloading transformer is not reduced by use of the existing CAP, then the [redacted] and the [redacted] will also need to be opened. In addition to the reduction in reliability discussed above, opening these four 115 kV lines results in splitting northern King County from southern King County; thereby putting approximately 32,400 customers at risk of outage as they would be served by just one transmission line without a backup line available (i.e., "radial supply"). This action also puts an additional 33,000 customers in Bellevue and Kirkland at risk of outage should there be an outage of either Sammamish 230 kV transformer while the north and south systems are operating separately.

There are two contingencies in the north end of King County that would trigger a CAP under summer conditions. These contingencies are (1) the loss of [redacted] and the [redacted]; and (2) the loss of [redacted] and the loss of [redacted] This CAP would require opening 115 kV lines from [redacted] Taking this action places 33,000 customers at risk of outage should an additional transmission line outage occur. The 33,000 customers are served from two separate lines, so a single line outage would take out approximately half of the 33,000.

The performance testing utilized in Section 5.1 above is the same testing used to determine the need for CAPs. Based on the power flow results shown in Appendix D, the CAPs above will not be needed in the study period after one of the twelve alternatives has been placed into service.

5.3 Longevity Results for Proposed Alternatives

Longevity tests were performed for each of the twelve proposed alternatives. To represent approximately 10 to 20 years after 2022, PSE reviewed the following cases: Heavy Winter 2021-22 at 75% conservation (5,415 MW); 2021-22 Extreme Winter at 100% conservation (5,742 MW); and Heavy Summer at 100% conservation (3,554 MW). In reviewing the results, the PSE electrical study team identified potential limitations in reliability associated with the proposed alternatives. Proxy projects to solve the identified issues were included in the analysis and are more fully described in Section 0. The proxy projects included:

- Rebuild of the Talbot Hill-Boeing Renton-Shuffleton 115 kV line between Talbot Hill and Paccar for greater capacity.
- Build a new four mile 115 kV transmission line between Talbot Hill and the Mercer Island Tap and rebuild seven miles of the existing 115 kV lines across Mercer Island, including the two submarine cable crossings to Mercer Island.
- Install a new 230-115 kV transformer in South King County.
- Install a second 325 MVA-115 kV transformer at the new Eastside site. Construct at least one or more 230 kV line and 115 kV lines adequate to distribute power from the substation

These proxy projects will need to be addressed on a case by case basis. The timing for each project may vary depending on which solution is selected from this report. The future projects and their likely year of need are shown in Table 5-1.

For those alternatives where the existing PSE Talbot Hill-Sammamish 115 kV corridor is rebuilt to 230 kV, the Talbot Hill – Paccar 115 kV line rebuild is the only addition needed within the study period (Appendix D); however, this would not be needed until 2032 and 2035 for the New ROW and SCL Lines Rebuild solutions, respectively.

All other additional projects (Talbot Hill – Mercer Island 115 kV line, South King Area Projects, and a second Eastside 230 kV Line & Transformer) are not needed until 2026-2030 or later.

Table 5-1: Longevity Testing Results

230 kV Line Source	Site	Approx. Miles of 230 kV corridor (Total / New)	Miles of new 115 kV lines	Miles of rebuilt 115 kV lines	Need for Additional Projects *: Talbot Hill - Paccar 115 kV line rebuild		Talbot Hill - Mercer Island 115 kV line; Mercer Island system rebuild		South King Area Projects		2nd Eastside Line & Transformer	
					Year	System Load	Year	System Load	Year	System Load	Year	System Load
New Right of Way New single-circuit 230 kV line on new ROW from Talbot Hill to E230 site to Sammamish	Westminster	18 / 18	1	0	2032	5790 MW	2030	5700 MW	2033	5700 MW	2038	6120 MW
	Vernell	18 / 18	2	1	2033	5830 MW	2031	5730 MW	2032	5760 MW	2038	6110 MW
	Lakeside	18 / 18	0	0	2032	5810 MW	2031	5710 MW	2038	5880 MW	2034	5870 MW
	Woodridge	18 / 18	0.5	0	2032	5810 MW	2031	5730 MW	2039	5920 MW	2034	5910 MW
PSE Corridor Rebuild PSE corridor to two 230 kV lines from Talbot Hill to E230 site to Sammamish	Westminster	16 / 0	1	193	2018	concurrent with E230 project	2029	5610 MW	2036	6010 MW	2032	5780 MW
	Vernell	18 / 2	2	204	2018	concurrent with E230 project	2028	5570 MW	2035	5980 MW	2033	5820 MW
	Lakeside	16 / 0	0	193	2018	concurrent with E230 project	2029	5640 MW	2040	6290 MW	2030	5640 MW
	Woodridge	18 / 2	0.5	193	2018	concurrent with E230 project	2029	5630 MW	2039	6230 MW	2032	5780 MW
SCL Lines Rebuild SCL	Westminster	29 / 4	1	0	2035	5990 MW	2037	6090 MW	2030	5880 MW	2031	5730 MW

corridor to double-circuit 230 kV line from Maple Valley to SnoKing with one line looping thru E230 site and the other line looping thru Sammamish	Vernell	28 / 3	2	1	2035	5950 MW	2037	6090 MW	2031	5810 MW	2032	5760 MW
	Lakeside	29 / 4	0	0	2036	6020 MW	2037	6090 MW	2033	6150 MW	2026	5440 MW
	Woodridge	27 / 2	0.5	0	2036	6050 MW	2037	6110 MW	2034	6190 MW	2027	5480 MW

* "Need for Additional Projects" year and system load estimates based on linear extrapolation between 2021-22 Heavy Winter with 75% conservation (assumed to be year 2026 with 100% conservation based on linear extrapolation of Eastside area forecast) and 2021-22 Extreme Winter (assumed to be year 2032 with 100% conservation based on linear extrapolation of Eastside area forecast)

5.4 Summary Results of Step Three System Performance, Operational Flexibility, and Longevity

Electrically, all potential sites and sources meet the mandatory performance requirements and are projected to continue meeting those requirements for 10-15 years following energization of the project. There are three potential 230 kV sources and four potential substation sites which meet the performance requirements, combining to make twelve electrically viable solutions. The twelve final solutions are listed in Table 5-2.

Table 5-2: Results of Step Three Detailed Analysis - 12 Combinations of Sources and Substation Sites

Source ID No.	230 kV Sources	Site ID.	Substation Sites
2	TAL-LAK-SAM	*b*	Westminster
4	New ROW	*c*	Vernell
6	Rebuild SCL 230 kV lines	*d*	Woodridge
		e	Lakeside

6.0 Impact of Non-Electrical Factors

Step Four was to review the impact of non-electrical factors on each of the twelve potential solutions. Since the exact routes will not be finalized until input is received from the community, the non-electrical factors focused on the availability of the SCL corridor and the added value of a new substation versus the use of an existing site for the new 230 – 115 kV transformer.

Discussions were held between PSE and SCL, wherein SCL indicated they have future plans for the Maple Valley to SnoKing 230 kV corridor. Therefore, the solutions that included the rebuild of the SCL 230 kV lines were removed because SCL has determined that they will need the capability of those lines for future growth.

Based on Table 5-2, there are four transformation sites identified. Three sites, Westminster, Vernell, and Lakeside, are on land owned by PSE. The Woodridge site alternative was removed from consideration since it would require additional cost to purchase the property, additional siting analysis, and there are three other viable sites that already satisfy the performance requirements. The team also removed the combination of PSE corridor plus Vernell because there are two existing sites, Westminster and Lakeside, which are closer to the PSE corridor.

Base on the above analysis of the non-electrical factors, the number of solutions was reduced from twelve to five, which are listed in Table 6-1.

Table 6-1: Reduction of Sites & Sources Resulting from Non-Electrical Based Factors of Step Four

	230 kV Line Alternative	Substation Alternative	East-West Distance Between 230 kV Line and Substation
2b	Rebuild one Talbot Hill-Lakeside-Sammamish 115 kV line to 230 kV and loop through new substation	Westminster	Adjacent
2e	Rebuild one Talbot Hill-Lakeside-Sammamish 115 kV line to 230 kV and loop through new substation	Lakeside	Adjacent
4b	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Westminster	Up to 2 miles
4c	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Vernell	Up to 2 miles
4e	Build new Talbot Hill-Sammamish 230 kV line on new right of way, loop through new substation	Lakeside	Up to 2 miles

6.1 Detailed Descriptions of the Five Solutions

Section 6.1 provides detailed electrical descriptions of the five solutions presented in Table 6-1 to provide a clearer electrical understanding and the associated requirements of each solution. The descriptions include points of interconnection, whether additional property is required, distribution impacts, substation requirements, and ultimate build outs. The descriptions are separated by source and then by site.

6.1.1 PSE Corridor

The alternatives which rebuild one of the Talbot Hill-Lakeside-Sammamish lines on the PSE Corridor to 230 kV were also studied to determine whether it was necessary to rebuild the remaining 115 kV line on the same corridor. It was found that the 115 kV line south of the new substation needed to be rebuilt to avoid overloads, while the 115 kV line north of the new substation did not require rebuilding to avoid overloads. However, looking to the future for the second 230-115 kV transformer installation, a new 230 kV line will be required to provide adequate reliability for the second transformer. Rather than return at that time to rebuild the same corridor between the new substation and Sammamish Substation, it's more efficient to rebuild both lines with this project and operate the second line at 115 kV until needed for future 230 kV operation.

6.1.1.1 Solution 2b - 230 kV Source on PSE Corridor – Westminster

This solution includes a rebuild of two 115 kV transmission lines to 230 kV between Talbot Hill and Sammamish substations (PSE Corridor), as well as connecting to a new transmission substation called Westminster as shown on the one-line diagram (Figure 6-1).

The 230 kV source to the new Westminster substation would come from the PSE Corridor, where both 115 kV transmission lines would be rebuilt (16 miles) to 230 kV, with Falcon conductor rated at 200°C. One line will loop into the 230 kV bus at the new substation, while the other line will be operated at 115 kV until a second 230 kV line is needed. The 115 kV line will loop into the 115 kV bus at the new substation.

The new transmission substation would be built on undeveloped property owned by PSE located at NE 24th Street and approximately 136th Avenue NE in Bellevue. The property is adjacent to PSE's transmission corridor on which the two parallel Sammamish-Lakeside 115 kV lines are built. In addition, the Sammamish-North Bellevue 115 kV line passes by the site on NE 24th Street.

The substation will be built for future second transformer layout. The second transformer will require a second 230 kV looped line and an additional four 115 kV lines to distribute the load. The 230 kV lines will be available by cutting over the rebuilt 115 kV line on the PSE corridor from 115 kV to 230 kV operation and doing some rebuild work at Rose Hill Substation.

The following requirements are noted for this project:

230 kV lines

- Remove Talbot Hill – Lakeside #1 & #2 and Sammamish – Lakeside #1 & #2 115 kV lines
- Two new lines built on PSE Corridor, 1590 Falcon conductor @ 200°C, one energized at 230 kV connecting Talbot Hill to Westminster to Sammamish, the other energized at 115 kV connecting Talbot Hill to Lakeside to Westminster to Rose Hill to Sammamish

115 kV lines

- Loop in two 115 kV lines adjacent to site
  - Sammamish – Lakeside #2 (rebuilt)
  - Sammamish – North Bellevue
- Extend and loop in Lakeside – Ardmore #1 line, ½ mile double circuit, 1272 Bittern conductor @ 100° C
- Rebuild the 3 mile line section between Talbot Hill and Paccar on the Talbot Hill – Boeing Renton #2 line to 1272 Bittern conductor @ 100° C

230 kV substation

- Three bays, double-bus double-breaker
  - Two overhead lines
  - One 230-115 kV transformer

115 kV substation

- Eight bays, breaker-and-a-half
  - Six overhead lines
  - One 230-115 kV transformer
  - One capacitor installation, 2-21 MVAr banks each with a circuit switcher

Ultimate build-out

- 230 kV double bus double breaker with six bays
  - Two 230 kV lines initially
  - Future two additional 230 kV lines
  - 325 MVA 230-115 kV transformer initially
  - Future 325 MVA 230-115 kV transformer
- 115 kV bus breaker and a half with 12 bays
  - Eight 115 kV lines
  - Two transformers
  - Two 42 MVAr, 115 kV capacitor banks
- No distribution transformers

Rose Hill Substation

Loop thru rebuilt Sammamish – Lakeside #2 115 kV line, rebuild any portions of loop thru limiting the 517 MVA line rating

REDACTED

Figure 6-1: PSE Corridor - Westminster One Line Diagram *Redacted*

6.1.1.2 Solution 2e - 230 kV Source on PSE Corridor – Lakeside

This solution includes a rebuild of two 115 kV transmission lines to 230 kV, thereby connecting Talbot Hill to Lakeside transmission substation and the Sammamish Substation. See the one-line diagram in Figure 6-2.

The 230 kV source to the new Lakeside substation would come from the PSE corridor, where both 115 kV transmission lines would be rebuilt (16 miles) with 230 kV Falcon conductor rated at 200°C. One line will loop into the 230 kV bus in the new portion of the Lakeside substation, while the other line will be operated at 115 kV until a second 230 kV line is needed. The 115 kV line will loop into the 115 kV bus at the existing Lakeside 115 kV switching station. The new 230 kV portion of the Lakeside substation would connect to the existing switching station with a bundled 115 kV Bittern line at 100° C.

The new transmission substation would be built on undeveloped PSE owned property located south of the existing Lakeside Switching Station at SE 30th Street and approximately 136th Avenue NE in Bellevue. The property is on PSE's transmission corridor where the two parallel Talbot Hill-Lakeside 115 kV lines are built.

If the existing 115 kV switching station had not previously been configured for breaker and a half, then a double bus section breaker would be installed to replace the existing oil-filled bus section breaker. The Lakeside-Phantom Lake and Lakeside-Lochleven lines would be swapped on the north bus to improve reliability.

The substation will be built for future second transformer layout. The second transformer will require a second 230 kV looped line and eight or more 115 kV lines to distribute the load. The 230 kV lines will be available by cutting over the rebuilt 115 kV line on the PSE corridor from 115 kV to 230 kV operation and doing some rebuild work at Rose Hill Substation. The required 115 kV lines are already located at the Lakeside 115 kV switching station.

The following requirements are noted for this project:

230 kV lines

- Remove Talbot Hill – Lakeside #1 & #2 and Sammamish – Lakeside #1 & #2 115 kV lines
- Two new lines built on PSE Corridor, 1590 Falcon conductor @ 200°C, one energized at 230 kV connecting Talbot Hill to Lakeside to Sammamish, the other energized at 115 kV connecting Talbot Hill to Lakeside to Rose Hill to Sammamish

115 kV lines

- Rebuild the three mile line section between Talbot Hill and Paccar on the Talbot Hill – Boeing Renton #2 line to 1272 Bittern conductor @ 100° C

230 kV substation

- Three bays, double-bus double-breaker
  - o Two overhead lines
  - o One 230-115 kV transformer

115 kV substation

- Re-use two bays vacated by Talbot Hill – Lakeside #1 and Sammamish – Lakeside #1
  - o One 230-115 kV transformer
  - o One capacitor installation, 2-21 MVAr banks each with a circuit switcher

Additional work required if 115 kV substation has not already been rebuilt to breaker and a half:

- A double bus section breaker would be installed to replace the existing oil filled bus section breaker
- The oil-filled breakers used for the transformer and capacitor connections would be replaced with SF6 breakers appropriately sized
- The Lakeside – Phantom Lake and Lakeside – Lochleven lines would be swapped on the north bus to improve reliability, including constructing new transmission poles outside the substation

Ultimate build-out

- 230 kV double bus double breaker with six bays
  - Two 230 kV lines initially
  - Future 2 additional 230 kV lines
  - One 325 MVA 230-115 kV transformer initially
  - Future 325 MVA 230-115 kV transformer
- No distribution transformers

Rose Hill Substation

Loop thru rebuilt Sammamish – Lakeside #2 115 kV line, rebuild any portions of loop thru limiting the 517 MVA line rating

REDACTED

Figure 6-2: PSE Corridor - Lakeside One Line Diagram *Redacted*

6.1.2 New Right-of-Way

6.1.2.1 Solution 4b - 230 kV Source on New Right of Way – Westminster

This solution includes construction of a single 230 kV transmission line on a new transmission corridor connecting Talbot Hill to a new transmission substation called Westminster and the Sammamish Substation. See the one-line diagram in Figure 6-3.

The 230 kV source to the new substation would be a single 230 kV Falcon conductor line rated at 200°C, that follows a new right of way from Talbot Hill to Westminster and then to the Sammamish Substation. This alternative does not include the PSE transmission corridor south of Westminster, although it could include the PSE transmission corridor north of Westminster.

The new transmission substation would be built on undeveloped property owned by PSE at NE 24th Street and approximately 136th Avenue NE in Bellevue. The property is adjacent to PSE's transmission corridor on which the two parallel Sammamish-Lakeside 115 kV lines are built. The Sammamish-North Bellevue 115 kV line passes by the site on NE 24th Street.

The substation will be built for future second transformer layout. The second transformer will require an additional 230 kV looped line and an additional four 115 kV lines to distribute the load.

The following requirements are noted for this project:

230 kV lines

- New single-circuit line built on new right-of-way, 1590 Falcon conductor @ 200°C, connecting Talbot Hill to Westminster to Sammamish

115 kV lines

- Loop in three 115 kV lines adjacent to site
  - Sammamish – Lakeside #1
  - Sammamish – Lakeside #2
  - Sammamish – North Bellevue
- Extend and loop in Lakeside – Ardmore #1 line, ½ mile double circuit, 1272 Bittern conductor @ 100° C

230 kV substation

- Three bays, double-bus double-breaker
  - Two overhead lines
  - One 230-115 kV transformer

115 kV substation

- Ten bays, breaker-and-a-half
- Eight overhead lines
- One 230-115 kV transformer
- One capacitor installation, two-21 MVAr banks each with a circuit switcher

Ultimate build-out

- 230 kV double bus double breaker with six bays
  - Two 230 kV lines initially
  - Future two additional 230 kV lines
  - One 325 MVA 230-115 kV transformer initially
  - Future 325 MVA 230-115 kV transformer
- 115 kV bus breaker and a half with 12 bays
  - Eight 115 kV lines
  - Two transformers
  - Two 42 MVAr, 115 kV capacitor banks
- No distribution transformers

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Figure 6-3: New Right of Way - Westminster One Line Diagram *Redacted*

6.1.2.2 Solution 4c - 230 kV Source on New Right of Way – Vernell

This solution includes construction of a single 230 kV transmission line on a new transmission corridor connecting Talbot Hill to a new transmission substation called Vernell and the Sammamish Substation. See the one-line diagrams in Figure 6-4.

The 230 kV source to the new substation would be a single 230 kV Falcon conductor line rated at 200°C, from Talbot to Vernell to Sammamish Substation. The new 230 kV line would follow a new right-of-way that does not include the PSE transmission corridor south of Vernell, although it could include the PSE transmission corridor north of Vernell.

The new Vernell Substation would be built on property owned by PSE at 116th Avenue NE and approximately NE 22nd Street in Bellevue. The Sammamish-North Bellevue 115 kV line passes by the site on 116th Avenue NE.

As part of this solution the Overlake Loop, which ends 1/8 mile from the Vernell substation site, will be rebuilt to higher capacity and extended to the new substation. It will be necessary to rebuild the Clyde Hill Substation to terminate the far end of the Overlake Loop on a 115 kV bus with breakers. Alternatively, the line could be rebuilt an additional 1.2 miles and extended an additional ¼ mile to terminate at Lochleven Substation; thereby eliminating the need to rebuild the Clyde Hill Substation.

The substation will be built for future second transformer layout. The second transformer will require an additional 230 kV looped line and an additional four 115 kV lines to distribute the load.

The following requirements are noted for this project:

230 kV lines

- New single-circuit line built on new right-of-way, 1590 Falcon conductor @ 200°C, connecting Talbot Hill to Vernell to Sammamish

115 kV lines

- Loop in two 115 kV lines adjacent to site
  - Sammamish – North Bellevue
  - East end of Overlake Loop, rebuild one mile of Overlake Loop to 1272 Bittern conductor @ 100° C and loop thru Clyde Hill
- Build new two mile overhead line from Vernell to Ardmore, 1272 Bittern conductor @ 100 ° C

230 kV substation

- Three bays, double-bus double-breaker
  - Two overhead lines
  - One 230-115 kV transformer

115 kV substation

- Six bays, breaker-and-a-half
  - Four overhead lines
  - One 230-115 kV transformer
  - One capacitor installation, 2-21 MVAr banks each with a circuit switcher

Ultimate build-out

- 230 kV double bus double breaker with 6 bays
  - Two 230 kV lines initially
  - Future two additional 230 kV lines
  - One 325 MVA 230-115 kV transformer initially
  - Future 325 MVA 230-115 kV transformer
- 115 kV breaker and a half bus with twelve bays
  - Four lines initially
  - Future four additional 115 kV lines
  - Two 325 MVA 230-115 kV transformers (one initially)
  - Two 42 MVAr, 115 kV capacitor banks (one initially)
- Two distribution transformers and associated 12.5 kV feeders

Clyde Hill Substation

- Rebuild substation to four bay, ring bus
  - Three overhead lines
  - One 115-12.5 kV transformer

Ardmore Substation

- Add one ring bus bay for new line

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Figure 6-4: New Right of Way - Vernell One Line Diagram *Redacted*

6.1.2.3 Solution 4e - 230 kV Source on New Right of Way – Lakeside

This solution includes construction of a single 230 kV transmission line on a new transmission corridor to connect the Talbot Hill, new Lakeside and Sammamish substations. See the one-line diagrams in Figure 6-5.

The 230 kV source to the new Lakeside substation would be a single 230 kV Falcon conductor line rated at 200°C between Talbot Hill, Lakeside, and the Sammamish Substation. This alternative follows a new right-of-way that does not include the PSE transmission corridor south of Lakeside, although it could include the PSE transmission corridor north of Lakeside.

The new transmission substation would be built on undeveloped property owned by PSE south of the existing Lakeside 115 kV Switching Station at SE 30th Street and approximately 136th Avenue NE in Bellevue. The property is on PSE's transmission corridor where the two parallel Talbot Hill – Lakeside 115 kV lines are built.

The 230 kV portion of the substation would connect to the existing 115 kV switching station with a bundled 115 kV Bittern line at 100º C.

The substation will be built for future second transformer layout. The second transformer will require an additional 230 kV looped line and eight 115 kV lines to distribute the load. The 115 kV lines are already constructed and connected to the existing Lakeside Switching Station 115 kV bus.

The following requirements are noted for this project:

230 kV lines

- New single-circuit line built on new right-of-way, 1590 Falcon conductor @ 200°C, connecting Talbot Hill to Lakeside to Sammamish

115 kV lines

- None

230 kV substation

- Three bays, double-bus double-breaker
    - Two overhead lines
    - One 230-115 kV transformer

115 kV substation

- Two bays, breaker-and-a-half
    - One 230-115 kV transformer
    - One capacitor installation, 2-21 MVAr banks each with a circuit switcher

Additional work required if 115 kV substation has not already been rebuilt to breaker and a half:

- A double bus section breaker would be installed to replace the existing oil filled bus section breaker
- The oil-filled breakers used for the transformer and capacitor connections would be replaced with SF6 breakers appropriately sized
- The Lakeside-Phantom Lake and Lakeside-Lochleven lines would be swapped on the north bus to improve reliability, including constructing new transmission poles outside the substation

Ultimate build-out

- 230 kV double bus double breaker with 6 bays
    - Two 230 kV lines initially
    - Future two additional 230 kV lines
    - One 325 MVA 230-115 kV transformer initially
    - Future 325 MVA 230-115 kV transformer
- No distribution transformers

REDACTED

Figure 6-5: New Right of Way - Lakeside One Line Diagram *Redacted*

6.2 Substation Work Required to Connect New 230 kV Lines at Sammamish and Talbot Hill Substations

If a new 230 kV line is built and terminates at Sammamish and/or Talbot Hill substations, work will be required within the established substation to accommodate the new line(s).

6.2.1 Breaker Work at Sammamish Substation

In order to connect the new 230 kV line(s) to the Sammamish 230 kV bus, the following improvements are required at Sammamish Substation.

- Add a 3,000 A gas breaker in a new bay located on the east or west bus. The determination of which bus is used will depend on transmission line design and which alternative solution is selected. Empty bays are available on both east and west buses to accommodate the additional breaker and line.
- Replace Breaker 7067 with a 3,000 A breaker for higher capacity.

6.2.2 Bus and Breaker Work at Talbot Hill Substation

In order to connect the new 230 kV line to the Talbot Hill 230 kV bus, the following improvements are required at Talbot Hill Substation, as shown on the one line diagram (Figure 6-6). This work is required for all alternative solutions that terminate at Talbot Hill Substation, whether using the PSE corridor or a new right-of-way.

- Add a 3,000 A gas breaker in Bay G to terminate the new 230 kV line.
- Add a 3000 A gas breaker on PSE end of BPA Maple Valley – Talbot Hill #2 line. Revise the differential protection scheme on the North Bus
- Replace Oil Breaker 1086 with new 3,000 A Gas Breaker
- Relocate the Maple Valley – Talbot #1 line to Bay H and add a 3,000 A gas breaker. Revise the differential protection scheme on the South Bus.

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Figure 6-6: Talbot Hill 230 kV Bus Improvements One Line Diagram ***Redacted***

6.3 Descriptions of Future Projects

During the course of this study, other issues not directly related to the Eastside 230 kV study surfaced. The following describes four future projects that conceptually resolve those issues. The expected future need dates were indicated in Table 5-1. These descriptions are preliminary and will probably change when these projects are initiated.

6.3.1 Talbot Hill – Paccar 115 kV line rebuild

- Rebuild the three mile line section between Talbot Hill and Paccar on the Talbot Hill – Boeing Renton #2 115 kV line to 1272 Bittern conductor @ 100° C. The line voltage will remain 115 kV. See Figure 6-7.

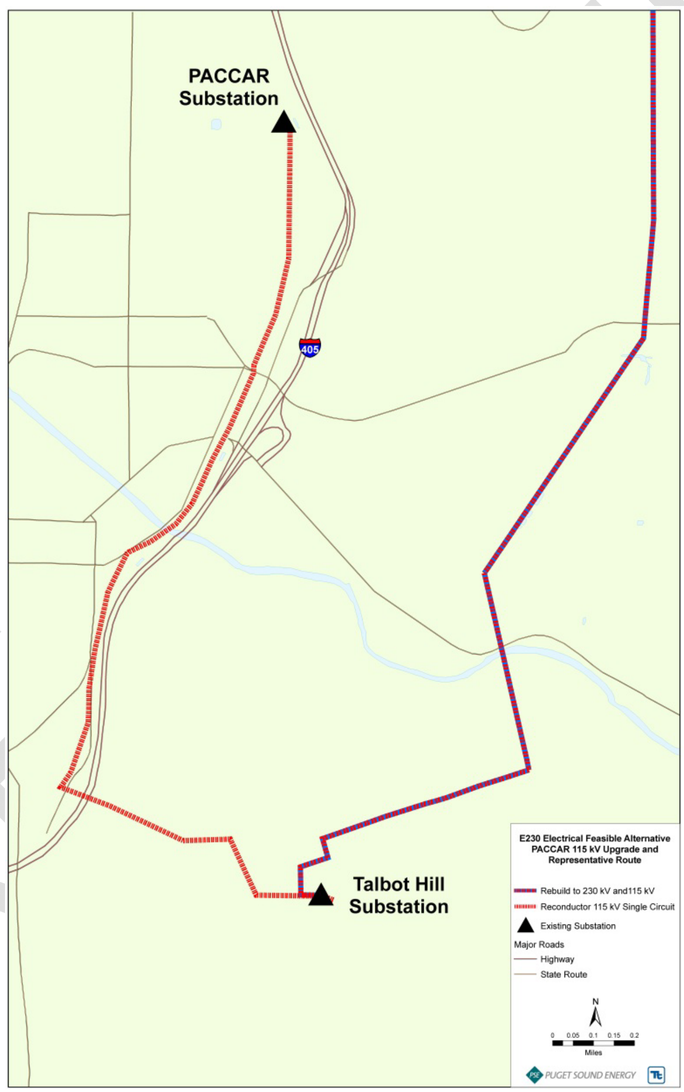


Figure 6-7: Talbot Hill - Paccar 115 kV Line Rebuild

6.3.2 Talbot Hill – Mercer Island Tap 115 kV New Line; Mercer Island 115 kV System Rebuild

- Build new Talbot Hill – Mercer Island 115 kV line
- Replace 115 kV submarine cables serving Mercer Island
- Rebuild 6 miles 115 kV lines across Mercer Island to Factoria Substation

6.3.3 South King Area Projects

The projects listed below are required to build a new 325 MVA 230-115 kV transformer in South King County to address problems in the local area in future years, 2030 or later. For this proxy project, Berrydale is used in this report. Following are the minimum requirements for the new transformer and system improvements.

- New 230-115 kV Transformer at Berrydale
- Rebuild Berrydale 230 kV bus to breaker-and-a-half
- Build four bay 230 kV system at Christopher
- Rebuild 230 kV Talbot Hill – O'Brien line
- Rebuild O'Brien – Christopher line
- New 230 kV line bay at BPA Covington
- New 8 mile 115 kV line connecting O'Brien and Berrydale

6.3.4 Second 230 kV-115 kV Transformer at New Eastside Substation

In the future, an additional 230-115 kV transformer will be required at the substation site selected under this project. Consideration should be given at the time of site selection to requirements which will be necessary to build out the future second transformer. Following are the minimum requirements for the second transformer, independent of which site is selected.

- New 325 MVA, 230 kV-115 kV transformer
- Extend new 230 kV line to the substation
- Extend new 115 kV lines to substation. The amount of lines is unknown at this time and depends on the chosen site.

7.0 Route Development (LRT)

The screening analysis resulted in two viable 230 kV sources and three viable transformation sites. The two viable 230 kV sources are 1) Rebuild the existing 115 kV transmission lines in the PSE Corridor to 230 kV, and 2) New 230 kV source on new ROW. The three viable transformation sites are 1) Westminster, 2) Vernell, and 3) Lakeside.

PSE performed the transmission line route selection process using the Linear Routing Tool (LRT)[15]. Route development using the LRT is a collaborative process between multiple disciplines within PSE that combines powerful analytical software with project experience and local knowledge. The LRT helps identify the most suitable route alternatives based on environmental and cost scenarios.

The process, **Step Five**, began by identifying a LRT study area with sufficient size and configuration to meet the objectives for PSE's proposed transmission line. Any new line route must utilize a combination of the two viable 230 kV sources and route through one of the three viable transformation sites. The resulting LRT study area is approximately 255 square miles in size and encompasses the PSE Sammamish Substation site in the north, and PSE's Talbot Hill Substation site in the south, bounded on the west by the eastern shore of Lake Washington, and extending just east of Lake Sammamish to include the BPA corridor.

A variety of data was collected for the LRT assessment including:

- existing available data and geographic information system (GIS) files for land ownership;
- existing and future land use;
- public and private rights-of-way (ROW);
- wildlife;
- vegetation;
- threatened and endangered (T&E) species;
- wetlands;
- topography;
- historical resources; and
- other factors that would influence the location of the proposed transmission line.

The data collection process was designed to provide geospatial information on factors that could represent either opportunities or constraints for the location of an above-ground transmission line.

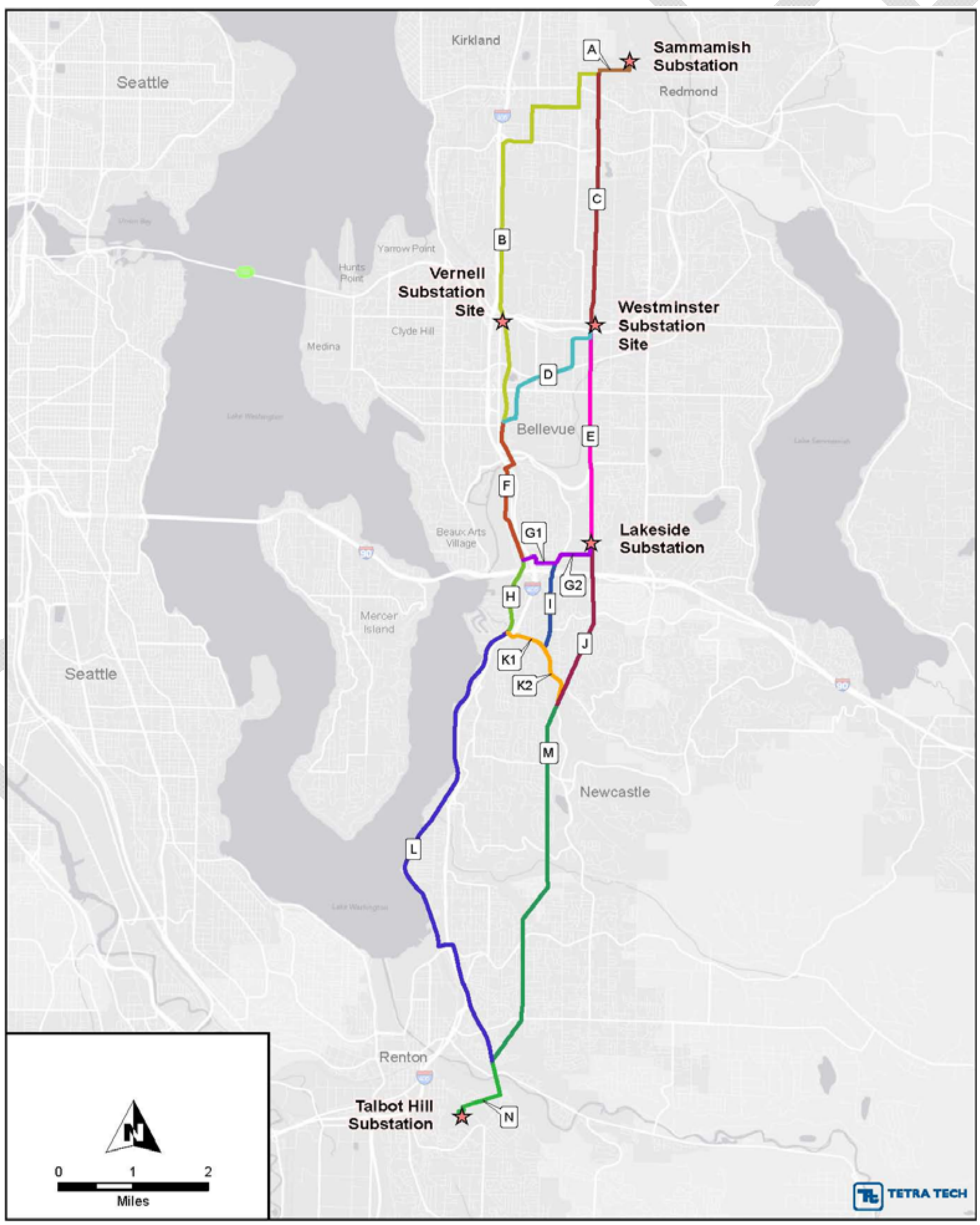
The various data layers were individually weighted and then combined to identify the areas of greatest opportunity and greatest constraint. Multiple corridors, with varying degrees of opportunities and constraints were generated and used to develop alternative routes. The details of the development of the segments and their constraint scores are found in a separate report.

[15] Software tool developed and used by Tetra Tech, Inc.

7.1 LRT Results

The top five percent of the positively scored routes were mapped and divided into individual segment combinations. The mapping exercise revealed that there were four general subareas, which when combined, formed a "ladder" of route alternatives. The "leg" components of the ladder comprised the north-south running routes connecting the Sammamish, Talbot Hill, and one of the new transformation sites. Moving east to west between the "legs" could be accomplished by using one of the three cross-over segments or "rungs." The only exception to this being an additional north-south segment situated in the central part of the study area, south of I-90. Each of the fourteen legs and rungs were given a unique identifier A through N (Figure 7-1).

All of the mapped segment combinations can be used to develop a route that meets the goal of connecting the Sammamish Substation with the Talbot Hill Substation using a combination of the two sources, while connecting to any one of the three intermediary substations sites.



8.0 Construction Scope

The LRT analysis resulted in 16 segments that can be combined to create a variety of different route alternatives. The following sections describe the scope required for each segment and site so that a valid combination meets the electrical requirements for one of the solutions described in Section 6.1.

8.1 Segment Scope

The scope and length for each segment is listed in Table 8-1. The scope describes the infrastructure improvements required for each segment. While the scope for most segments is independent of the route, some segments have different scope options that are dependent upon adjacent connecting segments or the substation site. These are listed in the option column. To illustrate, if segment A is combined with segment B the scope would be a single-circuit 230kV line, but if it is combined with segment C then segment A would need to have both lines rebuilt.

8.2 Site Scope

8.2.1 Vernell

The scope for the Vernell substation site includes constructing a new 230-115 kV transmission substation. The initial build out will include connecting the new 230 kV lines into a three bay double-bus double-breaker 230 kV bus. One 325 MVA 230-115 kV transformer will tie to the eight bay breaker-and-a-half 115 kV bus. In addition, a capacitor bank installation of two 21 MVAr banks will be needed. The related 115 kV line work and work at other affected substations include the following:

115 kV lines

- Loop in two 115 kV lines adjacent to site
  - Sammamish – North Bellevue
  - East end of Overlake Loop, rebuild one mile of Overlake Loop to 1272 Bittern conductor @ 100° C and loop thru Clyde Hill
  - Rebuild Sammamish – Lakeside #2
- Build new two mile overhead line from Vernell to Ardmore, 1272 Bittern conductor @ 100 ° C

Clyde Hill Substation

- Rebuild substation to four bay, ring bus
  - Three overhead lines
  - One 115-12.5 kV transformer

Ardmore Substation

- Add one ring bus bay for new line

See the one-line diagram in Section 6.1.2.2.

Table 8-1: Infrastructure Scope per Segment

Segment	Length (Miles)	Option	Scope			
			New single-circuit 230 kV line, 1590 Falcon conductor @ 200°C	Two new lines built on PSE corridor, 1590 Falcon conductor @ 200°C , one energized at 230 kV, the other energized at 115 kV	Rebuild existing three mile 115kV Talbot Hill – Boeing Renton #2 line between Talbot Hill and Paccar, 1272 Bittern conductor @ 100° C	Phase Tie Existing 115kV lines on PSE Corridor
A	0.6	With Seg. B	X			
		With Seg. C		X*		
B	8.4		X			
C	3.7			X*		
D	5.8		X			
E	3.0			X*		
F	2.1		X			
G1	0.5		X			
G2	0.7		X			
H	1.1		X			
I	1.2		X			
J	2.4			X	X	
K1	0.6		X			
K2	0.9		X		X	Seg J
L	6.9		X			
M	9.9			X	X	
N	1.3	With Seg. L	X			
		With Seg. M		X		

* Rebuilding the second line prepares for future growth and adds longevity to the solution.

8.2.2 Westminster

The scope for Westminster substation site includes constructing a new 230-115 kV transmission substation. The initial build out will include connecting the new 230 kV lines into a three bay double-bus double-breaker 230 kV bus. One 325 MVA 230-115 kV transformer will tie to the eight to ten bay breaker-and-a-half 115 kV bus. In addition, a capacitor bank installation of two 21 MVAr banks will be needed. The related 115 kV line work includes the following:

115 kV lines

- Loop in three 115 kV lines adjacent to site
  - Sammamish – Lakeside #1
  - Sammamish – Lakeside #2
  - Sammamish – North Bellevue
- Extend and loop in Lakeside – Ardmore #1 line, 0.5 miles double circuit, 1272 Bittern conductor @ 100° C

See the one line diagrams in Sections 6.1.1.1 or 6.1.2.1.

8.2.3 Lakeside

The scope for the Lakeside substation site includes constructing a new 230 kV transmission substation and expanding the existing 115 kV substation. The initial build out will include connecting the new 230 kV lines into a three bay double-bus double-breaker 230 kV bus. One 325 MVA transformer will tie to the existing 115 kV substation bus. The related 115 kV substation expansion and line work includes the following:

115 kV substation

- Two bays, breaker-and-a-half
  - One 230-115 kV transformer
  - One capacitor installation, 2-21 MVAr banks each with a circuit switcher

Additional work required if 115 kV substation has not already been rebuilt to breaker and a half:

- A double bus section breaker would be installed to replace the existing oil filled bus section breaker
- The oil-filled breakers used for the transformer and capacitor connections would be replaced with SF6 breakers appropriately sized
- The Lakeside – Phantom Lake and Lakeside – Lochleven lines would be swapped on the north bus to improve reliability, including constructing new transmission poles outside the substation

See the one line diagrams in Sections 6.1.1.2 or 6.1.2.3.

8.2.4 Sammamish

The scope of work at the Sammamish site is described in Section 6.2.1.

8.2.5 Talbot

The scope of work at the Talbot substation site is described in Section 6.2.2.

8.3 Segment Combinations

Using the ladder map in Figure 7-1 as a guide multiple different route combinations can be developed using a combination of segments A-N. The different route possibilities represent a mix between the five electrical solutions described in Section 6.0. Some routes exclusively use the existing PSE ROW, others use entirely new ROW, and the remaining is a mix of the two. Each route is a viable real-world alternative that corresponds to an electrical solution as long as the scope for all of the included segments and sites are as described in Sections 8.1 and 8.2.

It is important to note a couple of basic guidelines for developing route options. First the routes should generally be developed from a north-south direction and second, back-tracking over additional segments should be avoided wherever possible. The goal is to connect Sammamish to Talbot Hill using one of the three intermediary sites. Using these key guidelines over nineteen unique route combinations can be developed.

8.4 Estimated Costs of Alternative Solutions

The nineteen unique route combinations represent a range of alternative solutions that can be proposed. Grouped together, all of the solutions are viable electrically; however, vary in terms of key performance factors. The cost estimate range provided below is based on a conceptual engineering design and an assessment for each of the segment and site combinations. The costs do not include contingency and are conceptual grade estimates (+100%/-50%). The estimates were based on 2013 dollars escalated to an in-service year of 2018 using a 3% escalation factor per year. The cost ranges from a low of $155 million to a high of $288 million.

9.0 Next Steps to a Preferred Route

Following completion of this study, PSE will engage the public in a months-long process that will provide critical input into PSE's preferred route selection, using the ladder of segments identified by the LRT. PSE will collect public input through an engagement process that includes a series of events, outreach efforts and engagement of a Community Advisory Group (CAG) that reflects Eastside stakeholders. PSE will also continue to evaluate requirements and constraints. Once PSE selects the preferred route, the project will move into design, environmental review and the permit application process.

9.1 Community Advisory Group (CAG) Approach

The CAG will learn about PSE's proposed route segments, PSE's route analysis work to date, and the complexity of identifying the route segments. Over the course of several months, CAG members will collaborate with PSE to decide on a community values-based evaluation process and work with PSE to combine segments to develop a recommended route. The CAG will also provide a forum for the community to give meaningful input on route segments and help PSE better understand community values as PSE selects the final route that balances the needs of their customers, the local community, and PSE.

PSE anticipates hosting six CAG meetings to finalize the CAG recommended route. CAG meetings will include time during each meeting for:

- Stakeholder input regarding community conversations and concerns
- Presentations on topics such as undergrounding, load, power delivery systems and the problems currently facing the existing Eastside system
- Stakeholder feedback for PSE on topic discussion
- Public comment period for CAG members to hear from the public

To help CAG members make informed decisions, the first meetings will include background on how the national, regional, and local power systems work, as well as the Eastside project history and need. In subsequent meetings, members will learn about how PSE arrived at the solution identified in Section 5.0 and how they identified the segments illustrated in Section 8.0. Members will then engage in an interest-based conversation on combining route segments into potential routes and trade-offs between them. They will decide on an evaluation process to allow the CAG to make a recommendation on the route.

PSE will also convene sub-area working groups. These will help focus conversation on challenges that are specific to individual neighborhoods and communities.

Once PSE selects the final route, it will move into design, environmental review and the permit application process.

Appendix A Load Forecast

Table A-1: 2012 Annual Peak Load Forecast Distribution

Year	100% Conservation		Net of 100% Conservation			Gross of Conservation (0% Conservation)		
	Normal 23º	Extreme 13º	Normal Peak (23º)	Extreme Peak (13º)	ERM Peak (PSO)	Normal Peak (23º)	Extreme Peak (13º)	ERM Peak (PSO)
2012	68	68	4,837	5,316	5,316	4,905	5,384	5,384
2013	140	140	4,785	5,267	5,267	4,926	5,408	5,408
2014	226	226	4,836	5,333	5,333	5,063	5,560	5,560
2015	319	319	4,865	5,375	5,375	5,184	5,694	5,694
2016	394	394	4,909	5,432	5,432	5,303	5,826	5,826
2017	468	468	4,938	5,472	5,472	5,406	5,940	5,940
2018	562	562	4,938	5,483	5,483	5,500	6,045	6,045
2019	651	651	4,946	5,501	5,501	5,597	6,152	6,152
2020	778	778	4,923	5,490	5,490	5,701	6,268	6,268
2021	885	885	4,923	5,502	5,502	5,808	6,386	6,386
2022	944	944	4,972	5,562	5,562	5,916	6,506	6,506
2023	986	986	5,039	5,641	5,641	6,025	6,627	6,627
2024	1,023	1,023	5,117	5,732	5,732	6,140	6,754	6,754
2025	1,061	1,061	5,193	5,820	5,820	6,254	6,881	6,881
2026	1,100	1,100	5,266	5,905	5,905	6,365	7,004	7,004
2027	1,138	1,138	5,341	5,993	5,993	6,479	7,131	7,131
2028	1,172	1,172	5,426	6,090	6,090	6,598	7,262	7,262
2029	1,203	1,203	5,515	6,192	6,192	6,718	7,396	7,396
2030	1,236	1,236	5,605	6,296	6,296	6,840	7,531	7,531
2031	1,270	1,270	5,694	6,399	6,399	6,964	7,668	7,668
2032	1,305	1,305	5,785	6,504	6,504	7,090	7,808	7,808
2033	1,341	1,341	5,878	6,610	6,610	7,219	7,951	7,951

Table A-2: 2012 Annual Peak Load Forecast for Eastside Area

Year	Normal Peaks (23 ^{0}F) Net of Conservation			Extreme Peaks (13 ^{0}F) Net of Conservation			Normal Peaks (23 ^{0}F) Gross of Conservation		Extreme Peaks (13^{0}F) Gross of Conservation	
	Eastside % of King Co	Eastside	King	Eastside % of King Co	Eastside	King	Eastside	King	Eastside	King
2012	27.5	646	2,348	27.4	709	2,586	655	2,381	718	2,619
2013	27.5	652	2,371	27.5	718	2,615	671	2,440	737	2,685
2014	27.5	660	2,399	27.5	729	2,652	691	2,512	760	2,764
2015	28.0	676	2,413	28.0	748	2,672	720	2,572	793	2,831
2016	28.5	694	2,434	28.5	769	2,699	750	2,630	825	2,896
2017	28.8	706	2,448	28.8	782	2,719	773	2,681	849	2,952
2018	29.0	710	2,449	29.0	790	2,725	792	2,729	872	3,006
2019	29.5	724	2,454	29.5	807	2,735	820	2,779	903	3,061
2020	30.0	733	2,445	30.0	820	2,732	850	2,834	937	3,122
2021	30.9	756	2,449	30.8	845	2,742	893	2,892	982	3,187
2022	30.9	765	2,476	31.0	861	2,776	912	2,950	1,008	3,251
2023	30.9	777	2,514	31.0	874	2,821	930	3,010	1,028	3,317
2024	30.9	790	2,558	31.0	890	2,871	949	3,073	1,050	3,387
2025	30.9	804	2,602	31.0	906	2,922	969	3,137	1,072	3,458
2026	30.9	818	2,646	31.0	922	2,973	989	3,201	1,094	3,530

NOTES:

1. Normal and Extreme County Peaks taken from PSE F2012: Electric County Peaks worksheet.
2. Eastside Normal and Extreme Peaks for years 2013, 2017 and 2021 are taken from the E230 Project worksheet: Eastside Load. The King County load was adjusted for expected block loads known to PSE Planning within the 10-year study period.
3. The Eastside load is calculated for years 2013, 2017 and 2021 based on the expected block loads with interpolation being used to calculate the in between years.

Appendix B Upgrades Included in Study Case

Table B-1: Projects Added to the Eastside Area Study Winter Base Case

2013-14	2017-18	2021-22
Beverly Park - Cottage Brook breaker replacement	Beverly Park - Cottage Brook breaker replacement	Beverly Park - Cottage Brook breaker replacement
Cottage Brook - Moorlands line reconductor	Cottage Brook – Moorlands line reconductor	Cottage Brook - Moorlands line reconductor
Saint Clair 230-115 kV transformer	Saint Clair 230-115 kV transformer	Saint Clair 230-115 kV transformer
Talbot Hill - Berrydale #1 line uprate	Talbot Hill - Berrydale #1 line uprate	Talbot Hill - Berrydale #1 line uprate
Starwood autotransformer removal / Tacoma Power voltage increase	Starwood autotransformer removal / Tacoma Power voltage increase	Starwood autotransformer removal / Tacoma Power voltage increase
	Alderton 230-115 kV transformer	Alderton 230-115 kV transformer
	Lake Holm Substation (block load)	Lake Holm Substation (block load)
	Beverly Park 230-115 kV transformer	Beverly Park 230-115 kV transformer
	Sensitivity Study 2: Raver 500-230 kV transformer	Sensitivity Study 2: Raver 500-230 kV transformer
	Sensitivity Study 2: SCL series inductors	Sensitivity Study 2: SCL series inductors

Table B-2: Projects Added to the Summer NERC TPL Base Case for the Eastside Area

2014	2018
Beverly Park - Cottage Brook breaker replacement	Beverly Park - Cottage Brook breaker replacement
Cottage Brook - Moorlands line reconductor	Cottage Brook - Moorlands line reconductor
Saint Clair 230-115 kV transformer	Saint Clair 230-115 kV transformer
Talbot Hill - Berrydale #1 line uprate	Talbot Hill - Berrydale #1 line uprate
Starwood autotransformer removal / Tacoma Power voltage increase	Starwood autotransformer removal / Tacoma Power voltage increase
	Alderton 230-115 kV transformer
	White River - Electron Heights 115 kV line re-route into Alderton
	White River 2nd bus section breaker
	Lake Hills - Phantom Lake 115 kV line
	Lake Holm Substation (block load)
	Cumberland Substation 115 conversion (block load)
	Beverly Park 230-115 kV transformer

Appendix C Detailed Descriptions of Eliminated Electrical Solutions

C.1 PSE Corridor

C.1.1 Alternative 2c - 230 kV Source on PSE Corridor – Vernell

This alternative includes a rebuild of two 115 kV transmission lines to 230 kV connecting Talbot Hill to a new transmission substation called Vernell to Sammamish Substation. See the one-line diagram below.

The 230 kV source to the new substation would come from the PSE corridor, where both 115 kV transmission lines would be rebuilt (16 miles) with 230 kV Falcon conductor rated at 200°C. Both lines will need to be extended approximately 1.5 miles to the substation. One line will loop into the 230 kV bus at the substation, while the other line will be operated at 115 kV until a second 230 kV line is needed. The 115 kV line will loop into the 115 kV bus at the substation.

The new transmission substation would be built on property owned by PSE at 116th Avenue NE and approximately NE 22nd Street in Bellevue. The Sammamish-North Bellevue 115 kV line passes by the site on 116th Avenue NE.

A three mile line section of the Talbot Hill – Boeing Renton #2 line would be rebuilt.

It will be necessary to rebuild the Clyde Hill Substation to terminate the far end of the Overlake Loop on a 115 kV bus with breakers. Alternatively, the line could be rebuilt an additional 1.2 miles and extended an additional ¼ mile to terminate at Lochleven Substation.

It is planned to have two distribution transformers and associated 12.5 kV feeders at this substation at ultimate build out.

The following requirements are noted for this project:

- 230 kV lines
  - Remove Talbot Hill – Lakeside #1 & #2 and Sammamish – Lakeside #1 & #2 115 kV lines
  - Two new lines built on PSE Corridor, 1590 Falcon conductor @ 200°C, one energized at 230 kV connecting Talbot Hill to Vernell to Sammamish, the other energized at 115 kV connecting Talbot Hill to Vernell to Rose Hill to Sammamish
  - Please Note: Two miles of double-circuit line on a new right of way is necessary to extend the line from the PSE corridor to Vernell, this includes both the 230 kV line and the 115 kV line, for a total of four circuits, one mile each, between the PSE corridor and Vernell
- 115 kV lines
  - Loop in three 115 kV lines adjacent to site
  - Sammamish – North Bellevue
  - Rebuilt Sammamish – Lakeside #2
  - East end of Overlake Loop, rebuild one mile of Overlake Loop to 1272 Bittern conductor @ 100° C and loop thru Clyde Hill
  - Build new two mile overhead line from Vernell to Ardmore, 1272 Bittern conductor @ 100° C

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- Rebuild the three mile line section between Talbot Hill and Paccar on the Talbot Hill – Boeing Renton #2 line to 1272 Bittern conductor @ 100° C

o 230 kV substation
  - Three bays, double-bus double-breaker
    - Two overhead lines
    - One 230-115 kV transformer

o 115 kV substation
  - Eight bays, breaker-and-a-half
    - Six overhead lines
    - One 230-115 kV transformer
    - One capacitor installation, two-21 MVAr banks each with a circuit switcher

o Ultimate build-out
  - 230 kV double bus double breaker with six bays
    - 2 230 kV lines initially
    - Future two additional 230 kV lines
    - 325 MVA 230-115 kV transformer initially
    - Future 325 MVA 230-115 kV transformer
  - 115 kV breaker and a half bus with 12 bays
    - Four lines initially
    - Future four additional 115 kV lines
    - 2 325 MVA 230-115 kV transformers (one initially)
    - 2 42 MVAr, 115 kV capacitor banks (one initially)
  - Two distribution transformers and associated 12.5 kV feeders

o Clyde Hill Substation
  - Rebuild substation to four bay, ring bus
    - Three overhead lines
    - One 115-12.5 kV transformer

o Ardmore Substation
  - Add one ring bus bay for overhead line (if infeasible, then underground line and install underground termination on the line)

o Rose Hill Substation
  - Loop thru rebuilt Sammamish – Lakeside #2 115 kV line, rebuild any portions of loop thru limiting the 517 MVA line rating

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Figure Redacted

C.1.2 Alternative 2d - 230 kV Source on PSE Corridor – Woodridge

This alternative includes rebuild of two 115 kV transmission lines to 230 kV connecting Talbot Hill to a new transmission substation called Woodridge to Sammamish Substation. See the one-line diagram below.

The 230 kV source to the new substation would come from the PSE corridor, where both 115 kV transmission lines would be rebuilt (16 miles) with 230 kV Falcon conductor rated at 200°C. Both lines will need to be extended approximately 1 mile to the substation. One line will loop into the 230 kV bus at the substation, while the other line will be operated at 115 kV until a second 230 kV line is needed. The rebuilt 115 kV line will loop into the 115 kV bus at the substation.

The new transmission substation would be built on property not presently owned by PSE at 125th Avenue SE and SE 32nd Street in Bellevue. The Lakeside-North Bellevue and Lakeside-Mercer Island 115 kV lines pass by the site on SE 32nd St. The Seattle City Light SnoKing-Maple Valle #1 and #2 230 kV lines run north-south in a corridor on the west side of this property.

A three mile line section of the Talbot Hill – Boeing Renton #2 line would be rebuilt.

It is not planned to have distribution transformers at this substation.

The following requirements are noted for this project:

- 230 kV lines
  - Remove Talbot Hill – Lakeside #1 & #2 and Sammamish – Lakeside #1 & #2 115 kV lines
  - Two new lines built on PSE Corridor, 1590 Falcon conductor @ 200°C, one energized at 230 kV connecting Talbot Hill to Woodridge to Sammamish, the other energized at 115 kV connecting Talbot Hill to Woodridge to Rose Hill to Sammamish
  - Please Note: Two miles of double-circuit line on a new right of way is necessary to extend the line from the PSE corridor to Woodridge, this includes both the 230 kV line and the 115 kV line, for a total of four circuits, one mile each, between the PSE corridor and Woodridge
- 115 kV lines
  - Loop in four 115 kV lines adjacent to site
    - Lakeside – North Bellevue
    - Lakeside – Mercer Island
    - Rebuilt Sammamish – Lakeside #2
  - Extend and loop in Lakeside – Lochleven line, ¼ mile double circuit, 1272 Bittern conductor @ 100° C
  - Rebuild the three mile line section between Talbot Hill and Paccar on the Talbot Hill – Boeing Renton #2 line to 1272 Bittern conductor @ 100° C
- 230 kV substation
  - Three bays, double-bus double-breaker
    - Two overhead lines
    - One 230-115 kV transformer
- 115 kV substation
  - Ten bays, breaker-and-a-half

        - Eight overhead lines
        - One 230-115 kV transformer
        - One capacitor installation, two-21 MVAr banks each with a circuit switcher
- o Ultimate build-out
    - 230 kV double bus double breaker with six bays
        - Two 230 kV lines initially
        - Future two additional 230 kV lines
        - 325 MVA 230-115 kV transformer initially
        - Future 325 MVA 230-115 kV transformer
    - 115 kV breaker and a half bus with 12 bays
        - Initially six lines, one transformer and one capacitor bank
        - Future two 115 kV lines, one additional transformer and one additional capacitor bank
    - No distribution transformers
- o Rose Hill Substation
    - Loop thru rebuilt Sammamish – Lakeside #2 115 kV line, rebuild any portions of loop thru limiting the 517 MVA line rating

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Figure Redacted

C.2 New Right of Way

C.2.1 Alternative 4d - 230 kV Source on New Right of Way – Woodridge

This alternative includes a single 230 kV transmission line on a new transmission corridor connecting Talbot Hill to a new transmission substation called Woodridge to Sammamish Substation. See the one-line diagrams below.

The 230 kV source to the new substation would be a single 230 kV Falcon line rated at 200° C, from Talbot to Woodridge to Sammamish. The new 230 kV line would follow a new right of way which does not include the PSE transmission corridor south of Woodridge, although it could include the PSE transmission corridor north of Woodridge.

The new transmission substation would be built on property not presently owned by PSE at 125th Avenue SE and SE 32nd Street in Bellevue. The Lakeside-North Bellevue and Lakeside-Mercer Island 115 kV lines pass by the site on SE 32nd Street. The Seattle City Light SnoKing-Maple Valley #1 and #2 230 kV lines run north-south in a corridor on the west side of this property.

It is not planned to have distribution transformers at this substation.

The following requirements are noted for this project:

- 230 kV lines
  - New single-circuit line built on new right-of-way, 1590 Falcon conductor @ 200°C, connecting Talbot Hill to Woodridge to Sammamish
- 115 kV lines
  - Loop in three 115 kV lines adjacent to site
    - Lakeside – North Bellevue
    - Lakeside – Mercer Island
  - Extend and loop in Lakeside – Lochleven line, ¼ mile double circuit, 1272 Bittern conductor @ 100° C
- 230 kV substation
  - Three bays, double-bus double-breaker
    - Two overhead lines
    - One 230-115 kV transformer
- 115 kV substation
  - Eight bays, breaker-and-a-half
    - Six overhead lines
    - One 230-115 kV transformer
    - One capacitor installation, two-21 MVAr banks each with a circuit switcher
- Ultimate build-out
  - 230 kV double bus double breaker with six bays
    - Two 230 kV lines initially
    - Future two additional 230 kV lines
    - 325 MVA 230-115 kV transformer initially
    - Future 325 MVA 230-115 kV transformer

- 115 kV breaker and a half bus with 12 bays
    - Initially six lines, one transformer and one capacitor bank
    - Future two 115 kV lines, one additional transformer and one additional capacitor bank
- No distribution transformers

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Figure Redacted

C.3 SCL Lines

C.3.1 Alternative 6b - 230 kV Source Using SCL 230 kV Lines – Westminster

This alternative includes rebuilding both of the Seattle City Light SnoKing-Maple Valley 230 kV transmission lines, looping one of them to a new transmission substation called Westminster and looping the other to Sammamish Substation. See the one-line diagram below.

The 230 kV source to the new substation would be from the Seattle City Light SnoKing-Maple Valley #1 and #2 lines. Both lines will be rebuilt for approximately 15 miles to 230 kV Falcon line rated at 200°C from Maple Valley Substation to the loop to Sammamish Substation. Both lines will be reconductored for approximately 10 miles to composite core 795 kcmil conductor rated at 200°C using the existing structures from the loop to Sammamish Substation to SnoKing Substation. One line will be extended and on separate poles 1 mile to loop through the Westminster Substation. The other line will be extended on separate poles approximately 1 mile to loop through the Sammamish Substation.

The new transmission substation would be built on undeveloped property owned by PSE at NE 24th Street and approximately 136th Avenue NE in Bellevue. The property is adjacent to PSE's transmission corridor on which the two parallel Sammamish-Lakeside 115 kV lines are built. The Sammamish-North Bellevue 115 kV line passes by the site on NE 24th Street.

It is not planned to have distribution transformers at this substation.

The following requirements are noted for this project:

- o 230 kV lines
    - Remove SCL Maple Valley – SnoKing #1 & #2 230 kV structures from Maple Valley to the loop to Sammamish
    - New double-circuit line built on SCL corridor from Maple Valley as far as the loop to Sammamish, 1590 Falcon conductor @ 200° C, one connecting Maple Valley to Westminster to SnoKing, the other connecting Maple Valley to Sammamish to SnoKing
    - Reconductor SCL Maple Valley – SnoKing #1 & #2 230 kV lines from the loop to Sammamish to SnoKing using existing structures, 795 kcmil composite core conductor @ 200° C
- o 115 kV lines
    - Loop in three 115 kV lines adjacent to site
        - Sammamish – Lakeside #1
        - Sammamish – Lakeside #2
        - Sammamish – North Bellevue
    - Extend and loop in Lakeside – Ardmore #1 line, ½ mile double circuit, 1272 Bittern conductor @ 100° C
- o 230 kV substation
    - Three bays, double-bus double-breaker
        - Two overhead lines
        - One 230-115 kV transformer
- o 115 kV substation
    - Ten bays, breaker-and-a-half

        - Eight overhead lines
        - One 230-115 kV transformer
        - One capacitor installation, two-21 MVAr banks each with a circuit switcher
- Ultimate build-out
    - 230 kV double bus double breaker with six bays
        - 2 230 kV lines initially
        - Future two additional 230 kV lines
        - 325 MVA 230-115 kV transformer initially
        - Future 325 MVA 230-115 kV transformer
    - 115 kV bus breaker and a half with 12 bays
        - Eight 115 kV lines
        - Two transformers
        - Two 42 MVAr, 115 kV capacitor banks
    - No distribution transformers
- Maple Valley Substation
    - Drop in rebuilt Maple Valley – SnoKing #1 & #2 lines, rebuild any portions of line bays limiting the 1034 MVA line rating
- SnoKing Substation
    - Drop in reconductored Maple Valley – SnoKing #1 & #2 lines, rebuild any portions of line bays limiting the 736 MVA line rating
- Sammamish Substation
    - Loop in one Maple Valley – SnoKing 230 kV line
        - Two new line bays, one on the east bus, the other on the west bus

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C.3.2 Alternative 6c - 230 kV Source Using SCL 230 kV Lines – Vernell

This alternative includes rebuilding both of the Seattle City Light SnoKing-Maple Valley 230 kV transmission lines, looping one of them to a new transmission substation called Vernell and looping the other to Sammamish Substation. See the one-line diagram below.

The 230 kV source to the new substation would be from the Seattle City Light SnoKing-Maple Valley #1 and #2 lines. Both lines will be rebuilt for approximately 15 miles to 230 kV Falcon line rated at 200° C from Maple Valley Substation to the loop to Sammamish Substation. Both lines will be reconductored for approximately 10 miles to composite core 795 kcmil conductor rated at 200° C using the existing structures from the loop to Sammamish Substation to SnoKing Substation. One line will be extended on separate poles approximately 1 mile to loop through the Vernell Substation. The other line will be extended on separate poles approximately 1 mile to loop through the Sammamish Substation.

The new transmission substation would be built on property owned by PSE at 116th Avenue NE and approximately NE 22nd Street in Bellevue. The Sammamish-North Bellevue 115 kV line passes by the site on 116th Avenue NE.

It will be necessary to rebuild the Clyde Hill Substation to terminate the west end of the Overlake Loop on a 115 kV bus with breakers. Alternatively, the Overlake Loop line could be rebuilt an additional 1.2 miles to the south and extended with new transmission line an additional ¼ mile to terminate at Lochleven Substation.

It is planned to have two distribution transformers and associated 12.5 kV feeders at this substation at ultimate build out.

The following requirements are noted for this project:

- 230 kV lines
  - Remove SCL Maple Valley – SnoKing #1 & #2 230 kV structures from Maple Valley to the loop to Sammamish
  - New double-circuit line built on SCL corridor from Maple Valley to loop to Sammamish, 1590 Falcon conductor @ 200° C, one connecting Maple Valley to Vernell to SnoKing, the other connecting Maple Valley to Sammamish to SnoKing
  - Reconductor SCL Maple Valley – SnoKing #1 & #2 230 kV lines from the loop to Sammamish to SnoKing using existing structures, 795 kcmil composite core conductor @ 200°C
- 115 kV lines
  - Loop in two 115 kV lines adjacent to site
    - Sammamish – North Bellevue
    - East end of Overlake Loop, rebuild one mile of Overlake Loop to 1272 Bittern conductor @ 100° C and loop thru Clyde Hill
  - Build new two mile overhead line from Vernell to Ardmore, 1272 Bittern conductor @ 100° C
- 230 kV substation
  - Three bays, double-bus double-breaker
    - Two overhead lines
    - One 230-115 kV transformer

- 115 kV substation
  - Six bays, breaker-and-a-half
    - Four overhead lines
    - One 230-115 kV transformer
    - One capacitor installation, 2-21 MVAr banks each with a circuit switcher
- Ultimate build-out
  - 230 kV double bus double breaker with six bays
    - Two 230 kV lines initially
    - Future two additional 230 kV lines
    - 325 MVA 230-115 kV transformer initially
    - Future 325 MVA 230-115 kV transformer
  - 115 kV breaker and a half bus with 12 bays
    - Four lines initially
    - Future four additional 115 kV lines
    - Two 325 MVA 230-115 kV transformers (one initially)
    - Two 42 MVAr, 115 kV capacitor banks (one initially)
  - Two distribution transformers and associated 12.5 kV feeders
- Clyde Hill Substation
  - Rebuild substation to four bay, ring bus
    - Three overhead lines
    - One 115-12.5 kV transformer
- Ardmore Substation
  - Add one ring bus bay for overhead line (if infeasible, then underground line and install underground termination on the line)
- Maple Valley Substation
  - Drop in rebuilt Maple Valley – SnoKing #1 & #2 lines, rebuild any portions of line bays limiting the 1,034 MVA line rating
- SnoKing Substation
  - Drop in reconductored Maple Valley – SnoKing #1 & #2 lines, rebuild any portions of line bays limiting the 736 MVA line rating
- Sammamish Substation
  - Loop in one Maple Valley – SnoKing 230 kV line
    - Two new line bays, one on the east bus, the other on the west bus

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C.3.3 Alternative 6d - 230 kV Source Using SCL 230 kV Lines – Woodridge

This alternative includes rebuilding both of the Seattle City Light SnoKing-Maple Valley 230 kV transmission lines, looping one of them to a new transmission substation called Woodridge and looping the other to Sammamish Substation. See the one-line diagram below.

The 230 kV source to the new substation would be from the Seattle City Light SnoKing-Maple Valley #1 and #2 lines. Both lines will be rebuilt for approximately 15 miles to 230 kV Falcon line rated at 200° C from Maple Valley Substation to the loop to Sammamish Substation. Both lines will be reconductored for approximately 10 miles to composite core 795 kcmil conductor rated at 200° C using the existing structures from the loop to Sammamish Substation to SnoKing Substation. One line will be extended on separate poles approximately 1 mile to loop through the Vernell Substation. The other line will be extended on separate poles approximately 1 mile to loop through the Sammamish Substation.

The new transmission substation would be built on property not presently owned by PSE at 125th Avenue SE and SE 32nd Street in Bellevue. The Lakeside-North Bellevue and Lakeside-Mercer Island 115 kV lines pass by the site on SE 32nd Street. The Seattle City Light SnoKing-Maple Valle #1 and #2 230 kV lines run north-south in a corridor on the west side of this property.

It is not planned to have distribution transformers at this substation.

- 230 kV lines
    - Remove SCL Maple Valley – SnoKing #1 & #2 230 kV structures from Maple Valley to the loop to Sammamish
    - New double-circuit line built on SCL corridor from Maple Valley to loop to Sammamish, 1590 Falcon conductor @ 200° C, one connecting Maple Valley to Woodridge to SnoKing, the other connecting Maple Valley to Sammamish to SnoKing
    - Reconductor SCL Maple Valley – SnoKing #1 & #2 230 kV lines from the loop to Sammamish to SnoKing using existing structures, 795 kcmil composite core conductor @ 200° C
- 115 kV lines
    - Loop in three 115 kV lines adjacent to site
        - Lakeside – North Bellevue
        - Lakeside – Mercer Island
    - Extend and loop in Lakeside – Lochleven line, ¼ mile double circuit, 1272 Bittern conductor @ 100° C
- 230 kV substation
    - Three bays, double-bus double-breaker
        - Two overhead lines
        - One 230-115 kV transformer
- 115 kV substation
    - Eight bays, breaker-and-a-half
        - Six overhead lines
        - One 230-115 kV transformer
        - One capacitor installation, two-21 MVAr banks each with a circuit switcher
- Ultimate build-out

        - 230 kV double bus double breaker with six bays
            - Two 230 kV lines initially
            - Future two additional 230 kV lines
            - 325 MVA 230-115 kV transformer initially
            - Future 325 MVA 230-115 kV transformer
        - 115 kV breaker and a half bus with 12 bays
            - Initially six lines, one transformer and one capacitor bank
            - Future two 115 kV lines, one additional transformer and one additional capacitor bank
        - No distribution transformers
    - Maple Valley Substation
        - Drop in rebuilt Maple Valley – SnoKing #1 & #2 lines, rebuild any portions of line bays limiting the 1,034 MVA line rating
    - SnoKing Substation
        - Drop in reconductored Maple Valley – SnoKing #1 & #2 lines, rebuild any portions of line bays limiting the 736 MVA line rating
    - Sammamish Substation
        - Loop in one Maple Valley – SnoKing 230 kV line
            - Two new line bays, one on the east bus, the other on the west bus

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C.3.4 Alternative 6e - 230 kV Source Using SCL 230 kV Lines – Lakeside

This alternative includes rebuilding both of the Seattle City Light SnoKing-Maple Valley 230 kV transmission lines, looping one of them to a new transmission substation called Lakeside and looping the other to Sammamish Substation. See the one-line diagram below.

The 230 kV source to the new substation would be from the Seattle City Light SnoKing-Maple Valley #1 and #2 lines. Both lines will be rebuilt for approximately 15 miles to 230 kV Falcon line rated at 200° C from Maple Valley Substation to the loop to Sammamish Substation. Both lines will be reconductored for approximately 10 miles to composite core 795 kcmil conductor rated at 200° C using the existing structures from the loop to Sammamish Substation to SnoKing Substation. One line will be extended on separate poles approximately 1 mile to loop through the Lakeside Substation. The other line will be extended on separate poles approximately 1 mile to loop through the Sammamish Substation. The substation would connect to the existing switching station.

The new transmission substation would be built on undeveloped property owned by PSE south of the existing Lakeside Switching Station at SE 30th Street and approximately 136th Avenue NE in Bellevue. The property is on PSE's transmission corridor on which the two parallel Talbot Hill-Lakeside 115 kV lines are built.

If the switching station had not previously been configured for breaker and a half, then a double bus section breaker would be installed to replace the existing oil filled bus section breaker. The Lakeside-Phantom Lake and Lakeside-Lochleven lines would be swapped on the north bus to improve reliability.

It is not planned to have distribution transformers at this substation.

The following requirements are noted for this project:

- 230 kV lines
  - Remove SCL Maple Valley – SnoKing #1 & #2 230 kV structures from Maple Valley to the loop to Sammamish
  - New double-circuit line built on SCL corridor from Maple Valley to loop to Sammamish, 1590 Falcon conductor @ 200° C, one connecting Maple Valley to Lakeside to SnoKing, the other connecting Maple Valley to Sammamish to SnoKing
  - Reconductor SCL Maple Valley – SnoKing #1 & #2 230 kV lines from the loop to Sammamish to SnoKing using existing structures, 795 kcmil composite core conductor @ 200° C
- 230 kV substation
  - Three bays, double-bus double-breaker
    - Two overhead lines
    - One 230-115 kV transformer
- 115 kV substation
  - Two bays, breaker-and-a-half
    - One 230-115 kV transformer
    - One capacitor installation, two-21 MVAr banks each with a circuit switcher
  - Additional work required if substation has not already been rebuilt to breaker and a half:

        - A double bus section breaker would be installed to replace the existing oil filled bus section breaker
        - The oil-filled breakers used for the transformer and capacitor connections would be replaced with SF6 breakers appropriately sized
        - The Lakeside-Phantom Lake and Lakeside-Lochleven lines would be swapped on the north bus to improve reliability, including constructing new transmission poles outside the substation
- Ultimate build-out
    - 230 kV double bus double breaker with six bays
        - Two 230 kV lines initially
        - Future two additional 230 kV lines
        - One 325 MVA 230-115 kV transformer initially
        - Future 325 MVA 230-115 kV transformer
    - No distribution transformers
- Maple Valley Substation
    - Drop in rebuilt Maple Valley – SnoKing #1 & #2 lines, rebuild any portions of line bays limiting the 1,034 MVA line rating
- SnoKing Substation
    - Drop in reconductored Maple Valley – SnoKing #1 & #2 lines, rebuild any portions of line bays limiting the 736 MVA line rating
- Sammamish Substation

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Appendix D Power Flow Results for the Twelve Electrical Solutions *Redacted Pages 109-166*

D.1 Power Flows which Indicate Longevity *Redacted Pages 116-166*

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Appendix E Power Flow Results for Rejected Transformer and Generator Solutions *Redacted Pages 167-183*

Sammamish Transformer with Simple Reconductor of Seattle City Light SnoKing-Maple Valley #1 & 2 230 kV Lines *Redacted Pages 167-172*

Sammamish Transformer with New Sammamish-Talbot Hill 230 kV Line on PSE Corridor *Redacted Pages 173-176*

Talbot Hill Third Transformer with Simple Reconductor of Seattle City Light SnoKing-Maple Valley #1 & 2 230 kV Lines *Redacted Pages 177-178*

Talbot Hill Transformer with New Sammamish-Talbot Hill 230 kV Line on PSE Corridor *Redacted Pages 179-180*

Lake Tradition Transformer *Redacted Pages 181-182*

Cedar Hills Generator and Reconductoring of SCL Lines *Redacted Page 183*

Appendix F **Summary Results of Transformer Additions with Minimal Upgrades to Support the Eastside Area** *Redacted Pages 184-214*

Sammamish Transformer with up to Four New 115kV Lines – Winter *Redacted Pages 183-192*

Sammamish Transformer with up to Four New 115kV Lines – Summer *Redacted Pages 193-194*

Lake Tradition Transformer with up to Four New 115kV Lines – Winter *Redacted Pages 194-199*

Lake Tradition Transformer with up to Four New 115kV Lines – Summer *Redacted Pages 200-201*

Talbot Hill Transformer with up to Four New 115kV Lines – Winter *Redacted Pages 202-212*

Talbot Hill Transformer with up to Four New 115kV Lines – Summer *Redacted Pages 213-214*

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Appendix G Quanta Technology and Puget Sound Energy Author Biographies

Quanta Technology assisted Puget Sound Energy in conducting this study, including research, analysis and documentation. Quanta Technology is an expertise-based, independent consulting company providing business and technical expertise to the energy and utility industries. They assist with deploying strategic and practical solutions to improve a company's business performance. Their mission is to provide value to clients in every engagement with the industry-best technical and business expertise, holistic and practical advice, and industry thought leadership.

Thomas J. Gentile, PE, *Quanta Technology Vice President Transmission Strategy,* is based in Massachusetts and has over 36 years of experience and proven leadership with transmission and distribution system planning, analysis, engineering, program/project management and interfacing with RTOs/ISOs and regulatory agencies. Mr. Gentile has participated in various planning, operating and market committees at NERC, NPCC, NYISO and ISO-NE. Tom received MSEE and BSEE degrees from Iowa State University and Northeastern University. He is a registered professional engineer in the State of Massachusetts.

Donald J. Morrow, PE, *Quanta Technology Partner, Senior Vice President of Corporate Strategy and Quanta Technology Expert*, has more than 30 years of utility and consulting experience. During the course of his career, Don has held a wide range of technical and management responsibilities including system planning, control area operations, transmission operations, energy trading, maintenance scheduling, operator training, protection, distribution operations, energy management systems and natural gas dispatch. Don received his BSEE and MBA from the University of Wisconsin, Madison. Don developed the transmission practice at Quanta Technology and he has led several transmission planning projects since 2006, including the SPP EHV Overlay study, the Smartransmission Project (www.smartstudy.biz), and Companhia de Electricidade de Macau in Macua, China. He is a registered professional engineer in the states of Wisconsin and Arkansas.

Carol O. Jaeger, PE, *Puget Sound Energy Consulting Engineer*, *Transmission Planning*, has over 30 years experience in transmission and distribution planning, distribution design, and substation design and operations. She received her BSEE from the University of Washington and is a registered professional engineer in the state of Washington.

Zach Gill Sanford, *Puget Sound Energy Engineer, Transmission Planning*, has over 4 years experience in transmission planning and NERC compliance. He received his BSEE from the University of Washington.

Jens V. Nedrud, PE, *Puget Sound Energy Project Manager, Project Delivery,* has over 8 years experience in distribution planning, substation design, and utility project management. He received his MSEE and BSEE degrees from the University of Washington and is a registered professional engineer in the state of Washington.