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Table of Contents

1 INTRODUCTION 8
2 EXECUTIVE SUMMARY 8
3 DETAILED SUMMARY 12
3.1 Kenai- Anchorage Transmission 12
3.2 Southcentral Alaska Reliability 15
3.3 Anchorage-Fairbanks Intertie Reliability/Economics 15
3.4 Proposed System Transmission Maps 17
4 POWER FLOW & TRANSIENT STABILITY ANALYSIS 20
4.1 Introduction 20
4.2 Methodology 20
4.3 System Analysis and Base Cases 21
4.4 Unit Commitment, Dispatch, and Spinning Reserves 22
4.5 Intertie Export Limits 22
4.6 Assumptions 23
4.7 BESS Spinning Reserves 23
4.8 HVDC Tie Modeling 23
4.9 Nikiski Overfrequency Relaying 23
4.9.1 Fairbanks Area Generation 23
4.10 PSS/E Modeling Changes 24
4.10.1 Dynamics 24
4.10.2 Power Flow 24
4.11 Performance Standards & Criteria 24
4.11.1 Stability Criteria 25
4.11.2 Voltage Criteria 25
4.12 Contingencies 25
4.13 Existing Kenai Intertie 29
4.13.1 Generation Scenarios 29
4.13.2 Results 32
4.13.3 Explanation of Limits 33
4.13.4 Winter Peak 33
4.13.5 Summer Peak & Summer Valley 34
4.13.6 Spinning Reserve Sensitivities 34
4.13.7 Bradley Lake Limits 36
4.14 Anchorage-Fairbanks Alaska Intertie 36
4.14.1 Generation Scenarios 36
4.15 Results 40
4.15.1 Winter Peak 41
4.15.2 Summer Peak 41
4.15.3 Summer Valley 42
4.15.4 Sensitivity to Fairbanks Area Generation 42
4.15.5 UFLS 43
4.16 Kenai Area System Improvements 43

4.17 System Improvement Projects 43
4.18 Generation Scenarios 44
4.19 Results 46
4.19.1 BESS Sizing 47
4.19.2 UFLS 47
4.20 Southcentral and Northern Area System Improvements 47
4.20.1 Southcentral System Improvement Projects 47
4.20.2 Northern System Improvement Projects 49
4.20.3 Generation Scenarios 50
4.21 Results 53
4.21.1 Sensitivity to Fairbanks Area Generation 54
4.21.2 UFLS 55
4.22 Conclusions 55
5 PRODUCTION COST SIMULATIONS 55
5.1 The Structure of the Model 55
5.2 Assembling the Data 55
5.3 Data Sources 56
5.4 Base Case and Sensitivities 57
5.5 Loads 57
5.6 Escalation 58
5.7 Fuel Prices – Base Case 58
5.8 Fuel Prices – Sensitivities 59
5.9 The Consistency of the Modeling 59
5.10 Resource Sensitivities 61
5.11 Results of this Analysis 62
6 PROJECT PRIORITIZATION 64
7 PRIORITIZATION: PROCESS 67
8 PRIORITIZATION: CONCLUSIONS 70
A APPENDIX: A COST/BENEFITS 71
B APPENDIX B: PRIORITIZATION 77
C APPENDIX C: DETAILED COST ESTIMATES 78
D APPENDIX D: ECONOMIC ANALYSIS SENSITIVITY 129
E APPENDIX E: PRODUCTION MODELING PRESENTATION 134
F APPENDIX F: PRE-WATANA SIMULATION RESULTS 178

List of Tables

Table 2-1: Economic/Reliability Projects 10
Table 2-2: Reliability Projects 11
Table 2-3: Sensitivity Cases 12
Table 2-4: Sensitivity Case Summaries 12
Table 3-1: Kenai Project Costs 15
Table 3-2: Southcentral Project Costs 15
Table 3-3: Northcentral Project Costs 16
Table 3-4: Northcentral Project Costs –230 kV Line Upgrades 16
Table 4-1: Seasonal and Utility Loads 21
Table 4-2: Railbelt UFLS Scheme Load Distribution 21
Table 4-3: Kenai Area Line/Transformer Contingencies 26
Table 4-4: Southcentral Area Line/Transformer Contingencies 27
Table 4-5: Northern Area Line/Transformer Contingencies 28
Table 4-6: All Area Generation Contingencies 29
Table 4-7: Existing Winter Peak Base Case Dispatches 30
Table 4-8: Existing Summer Peak Base Case Dispatches 31
Table 4-9: Existing Sumer Valley Base Case Dispatches 32
Table 4-10: Seasonal Results – Final Export Limits 33
Table 4-11: Seasonal Results – Spin Comparison 35
Table 4-12: Bradley Lake Plant Limits with No RAS 36
Table 4-13: Healy Area Generation Scenarios 37
Table 4-14: Existing Winter Peak Base Case Dispatches 38
Table 4-15: Existing Summer Peak Base Case Dispatches 39
Table 4-16: Existing Summer Valley Base Case Dispatches 40
Table4-17: Winter Peak Export Stability Limits 41
Table 4-18: Summer Peak Export Stability Limits 42
Table4-19: Summer Valley Export Stability Limits 42
Table4-20: Winter Peak Generation Scenarios 45
Table 4-21: Summer Peak Generation Scenarios 46
Table 4-22: Existing/Future Kenai Area Export Limits 47
Table4-23: BESS Sizing Requirements 47
Table 4-24: Winter Peak Generation Scenarios 51
Table 4-25: Summer Peak Generation Scenarios 52
Table 4-26: Summer Valley Generation Scenarios 53
Table 4-27: Winter Peak Existing/Future Southcentral Export Limits 54
Table 4-28: Summer Peak Existing/Future Southcentral Export Limits 54
Table 4-29: Summer Valley Existing/Future Southcentral Export Limits 54
Table 5-1: Load Alternatives 57
Table 5-2: Load Sensitivities 57
Table 5-3: Escalation Rates 58
Table 5-4: Base Case Projections 58
Table 5-5: 2030 Fuel Prices – c/mmBTU 59
Table 5-6: Study Cases 60
Table 5-7: Comparison of Base Case Runs 61
Table 5-8: Production Costs for Each Modeled Case 63
Table 5-9: Casewise Atmospheric Emissions 63
Table 5-10: Transmission Losses for Different Cases 64
Table 6-1: Project Summary Cost and Benefits 64

Table 6-2: Recommended Project Sequence ... 66
Table 6-3: Project Sections and Subcomponents used for Analysis ... 68
Table A-1: Year 2023 Railbelt Seasonal Loads by Substation ... 72
Table A-2: Conductor Ratings ... 73
Table A-3: Historically Displaced Energy ... 73
Table A-4: Bradley Stranded Capacity ... 73
Table A-5: Kenai Loss Analysis ... 74
Table A-6: 2nd Bradley Lake – Soldotna Line, Substation Costs ... 75
Table A-7: 2nd Bradley Lake – Soldotna Line, Line Construction Costs ... 75
Table A-8: Dave's Creek – University 230 kV Station Conversion Costs ... 75
Table A-9: Dave's Creek – University 230 kV Line Conversion Costs ... 75
Table A-10: Dave's Creek – Quartz Creek Line Upgrade ... 75
Table A-11: HVDC and BES System Costs ... 76
Table A-12: Eklutna Express Substation Addition Costs ... 76
Table A-13: Lorraine & Douglas Substation Addition Costs ... 76
Table A-14: Lorraine – Douglas 230 kV Line Addition Costs ... 76
Table A-15: Northern Intertie Station Upgrade Costs ... 77
Table A-16: 2nd Northern Intertie Line ... 77
Table C-1: Bernice Lake-Beluga HVDC ... 78
Table C-2: 35 MW/20 MWh BESS ... 79
Table C-3: Bradley-Soldotna 115 kV – Line Sections ... 79
Table C-4: Bradley Substation ... 80
Table C-5: Soldotna Substation ... 82
Table C-6: Dave's Creek - Hope 230kV Line ... 84
Table C-7: Hope – Portage 230kV Line ... 85
Table C-8: Portage - Girdwood 230kV Line ... 86
Table C-9: Girdwood - Indian 230kV Line ... 87
Table C-10: Indian - University 230kV Line ... 88
Table C-11: Dave's Creek Substation ... 89
Table C-12: Summit & Hope Substations ... 91
Table C-13: Portage Substation ... 93
Table C-14: Girdwood Substation ... 95
Table C-15: Indian Substation ... 97
Table C-16: University Substation ... 99
Table C-17: Quartz Creek Substation ... 100
Table C-18: Dave's Creek - Quartz Creek Upgrade ... 102
Table C-19: Fossil Creek Substation ... 103
Table C-20: Eklutna Hydro Substation ... 105
Table C-21: Lorraine Substation ... 107
TableC-22: Douglas Substation ... 109
Table C-23: Healy Substation ... 113
Table C-24: Gold Creek Substation ... 117
Table C-25: Lorraine-Douglas 230 kV Line ... 119
Table C-26: Douglas – Healy 230 kV line ... 120
Table C-27: Healy – Gold Hill 230 kV Line ... 121
Table C-28: Clear and Eva Creek Substations ... 122
Table C-29: Nenana Substation ... 123
Table C-30: Ester Substation ... 125
Table C-31: Gold Hill and Wilson Substations ... 127

Table of Figures

Figure 3-1: Northern Proposed Transmission System 18
Figure 3-2: Kenai and Southcentral Proposed Transmission System 20
Figure 6-1: Estimated Yearly and Cumulative Expenditures (USD) 66

1 Introduction

This report includes the findings of the transmission system analysis and economic studies completed to determine the future composition of the Railbelt transmission system.

Since the last draft report was issued in March, 2014, new reliability and operating standards have been adopted by the Railbelt utilities, and new generation plants for all utilities have been commissioned. Additionally, the Railbelt utilities have spent considerable effort reviewing and updating the economic models used to simulate the Railbelt's cost of power production. As a result of the new standards, new power plants, and the utilities' work on the economic model; the transmission studies have been updated to reflect 2016 conditions, and the economic studies to use the latest economic models available from the utilities.

The purpose of this plan is to outline a transmission system that meets the requirements of the Railbelt Transmission System Planning Standard, AKTPL-001-4. Per the standard, once identified, each project must undergo an evaluation which includes economic and reliability factors to justify its construction. This plan outlines the transmission system improvements required to meet the standard, but does not attempt to complete each projects' analysis required in the standard to determine when it should be constructed.

The transmission system improvements needed to support the Watana project, or any major generation project not currently under construction or completed are not included in the report.

2 Executive Summary

Electric Power Systems (EPS) has completed an analysis to determine the recommended future transmission system in the Railbelt. The need for the transmission plan was driven by the changes in the Railbelt generation and transmission system since the completion of the 2010 Regional Integrated Resource Plan (RIRP) administered by the Alaska Energy Authority (AEA).

The recommended transmission system improves reliability and has the potential to mitigate future cost increases to Railbelt rate payers and allow significant energy transfers between different areas of the Railbelt system. Bradley Lake hydroelectric project energy is unconstrained and coordination between hydro and thermal resources throughout the Railbelt can be optimized. While the proposed improvements are far from what would be required for a transmission system in the Lower 48, they do significantly improve the reliability of the Railbelt and allow the utilities to pursue additional load and resource pooling options not possible in the existing transmission system. The proposed improvements allow increased use of variable renewables, such as wind and PV in the Railbelt system, which is currently near its limit of renewable penetration. The improvements can also reduce CO_2 emissions by 372,000,000 lbs. annually in the Railbelt area.

Most transmission improvements are typically justified by the cost of unserved energy, or the value of system reliability, and are rarely justified purely on hard economic benefits. However, the value of unserved energy was not factored into the benefit analysis of the proposed transmission improvements in this study. There is currently no uniform estimate of unserved energy throughout the Railbelt, nor are there adequate records or criteria to allow it to be equitably evaluated. Typically, in the Lower 48, these type of reliability improvements are required as part of the power systems' mandate to meet NERC's and/or the transmission areas' reliability criteria. Projects are not evaluated solely in terms of the pure economic benefit of the project for fuel savings or reduced losses. That these projects can be evaluated in terms of pure economic benefit, as opposed to the primary purpose of their justification, speaks to the meager state of the Railbelt transmission system.

The fuel savings possible from the new transmission system were segregated into "pooling" savings; savings that could be currently achieved by pooling the generation assets of the utilities "transmission" savings; savings that could only be achieved following the construction of the proposed transmission system. The benefits of generation pooling vary widely depending on what transactions are assumed possible absent the pool. Since the issuance of the 2014 draft report, the utilities have made a significant effort in updating the economic model of the Railbelt to more accurately portray the system's operation, and some of the utilities are in active discussions on power pooling and its associated benefits. The maximum savings through pooling using the existing system could result in a decrease in reliability of the Railbelt as a whole, since more power deliveries are scheduled over single transmission lines. This study assumes the utilities will implement a defined level of generation pooling prior to 2030. In addition to generation pooling, the study also assumed the utilities would maximize the benefit of hydro-thermal coordination prior to 2030, including the energy from the new Battle Creek project at Bradley Lake, neither of which are in the latest model used by the utilities. This improvement in the cost of Railbelt generation was estimated in 2030 in order to determine the incremental benefit made possible only by the improved transmission system. The assumptions for determining the pool savings were not critical for determining the benefits of the transmission system, but were a method to remove pooling benefits from the calculated benefits following the transmission additions. The benefits of the transmission system are independent of the power pooling benefits and are not influenced by the assumptions used to evaluate the pool.

It is important to emphasize that the transmission benefits outlined in this report can only be realized following the construction of projects and their associated costs. Therefore, the true measure of the projects is their net benefit to the Railbelt utilities and consumers. It is also important to understand that the impact these large construction projects, which can be designed and constructed using Alaskan labor and the transmission system's ability to serve additional loads or make use of renewable energy would have on the State's economy are also not estimated or included in the evaluations.

This report is not a mandate to construct, but rather it should be considered the first step in the transmission planning process outlined in the recently completed transmission planning standard, specifically AKTPL-001-4. Each of the projects must undergo further cost and benefit analysis prior to making the decision to construct the project. Some projects may be deemed feasible and constructed following the assessment and others may be put on hold until economic or other conditions warrant their construction.

All of the projects identified in the study are projects required for reliability improvements, with most having the added benefit of positive economic value. As the projects are evaluated going forward, the value of unserved energy, value of renewable energy, value of future load-serving capability and the value of significant reduction in greenhouse gasses should be computed and utilized in each projects' analysis. However, some of the projects are strictly reliability driven projects with little or very small economic benefits and can only be justified by more traditional transmission evaluation methods. These projects should be evaluated separately from the projects with large economic benefits.

The benefits derived by fully utilizing the existing transmission system are different than the benefits derived from the proposed transmission system. In the existing system, trying to maximize the benefits of pooling will increase transfers across the single transmission lines between the Kenai, Anchorage and Fairbanks areas. Any outage to these lines will result in outages to various areas of the Railbelt. While the cost of unserved energy was not used in the justification for the construction of new transmission lines, the larger outages caused by increased pooling over the existing system were also not deducted from the pooling benefits of the existing system.

The maximum pooling benefits also assumed the Anchorage-Kenai transmission line was available 100% of the time for the annual production cost simulation. However, in the last 10 years, the line has been out of service almost one month out of every year. If considered in the evaluations, the outage would reduce the maximum pooling benefits of the existing system and increase the benefits of the proposed transmission system.

The fuel usage with the proposed transmission system resulted in annual savings ranging from $64,592,000 per year for the low load cases to $135,277 per year for the high load cases, with the base case being $96,478,000 per year. Fuel prices do not have a marked influence on the overall fuel savings, provided the difference between Fairbanks and Southcentral energy remains relatively stable. The wide range in system fuel savings is more a product of the uncertainty in utility load forecasts as opposed to ranges in the cost of fuel.

In addition to the above fuel savings, historically, the Bradley participants have received an average of 49,466 MWH/year of Bradley energy when the project is operated at 90 MW and above that will be lost if the transmission constraints are enacted without mitigation. Further, the utilities have received 173,884 MWh/year of energy when Bradley is operated above 65 MW. This energy take is at risk utilizing the existing transmission system. While the energy could be utilized, it may not be utilized at a time that provides the same economic benefit as its historical use.

The economic benefit of improved reliability as measured by unserved energy, capacity deferral of individual utilities and reservoir optimization of the Bradley and Cooper Lake hydro plants made possible with the improved transmission system were not evaluated in this report.

A summary of the projects that have both economic and reliability benefits are included in Table 2.1.

Table 2-1: Economic/Reliability Projects

Priority	Project	Description	Cost (Millions)
1	Bernice Lake-Beluga HVDC	100 MW HVDC Intertie	$ 185.3
2	35 MW/20 MWh BESS	Anchorage area battery	$ 41.1
3	Bradley-Soldotna 115 kV Line	New line & Bradley/Soldotna sub	$ 53.3
4	University-Dave's Creek 230kV	Reconstruct existing line	$ 57.5
5	University-Dave's Substations	Convert line for 230 kV operation	$ 36.3
6	Dave's Creek - Quartz Creek	Upgrade line to Rail conductor, Quartz sub	$ 16.2
1	Lorraine-Douglas	Lorraine - Douglas 230 kV line/stations	$ 128.5
2	Douglas – Healy line	New 230 kV line operated at 138 kV	$ 245.7
1	Healy-Fairbanks 230 kV	Convert 138 kV to 230 kV	$ 107.9
Total Reliability & Economic Projects			**$ 871.7**

With a total construction cost of $871,700,000 this results in a simplified benefit/cost ratio of 1.64 utilizing only the production cost savings, an extremely high ratio for electrical transmission projects. While all costs are included in the analysis, only fuel savings are considered as a benefit. The cost/benefit evaluation of individual projects was beyond the scope of this report.

Projects that do not include definitive economic benefits are shown in Table 2.2.

Table 2-2: Reliability Projects

Priority	Project	Description	Cost (Millions)
1	Fossil Creek	New 115 kV substation	$ 11.9
3	Eklutna Hydro	New 115 kV substation	$ 10.1
1	115 kV line	Plt 1-Raptor-Fssl Ck	$ 17.3
1	Communications Upgrade	Communications between Anch-Fairbanks	$ 15.0
Total Reliability Only Projects			**$ 54.3**

Including projects that produce little measurable economic benefit, the benefit/cost ratio decreases to 1.55.

Additional production cost simulations were completed to determine the sensitivity of the project benefits to several different conditions. These sensitivities included; differing fuel prices in the Railbelt, LNG availability in the Fairbanks area, new units in the Fairbanks area, loss of existing load and addition of new loads in the system. The sensitivity cases indicate that the availability of LNG at GVEA's North Pole and the construction of a new combined cycle unit and six 9 MW reciprocating engines at North Pole results in the lowest savings for the transmission system at $37.3M/year. However, this low level of savings can only be experienced after the large capital expenditure for LNG and a new power plant with additional generator was installed at the North Pole facility. Absent this large capital expenditure, the next lowest sensitivity is the loss of 44 MW of load in the Fairbanks area and little or no load growth over the next 50 years, with a savings of $64,592,000/year. Sensitivities in gas pricing do not have an appreciable impact on the base case savings. The retirement of Healy1 and the Aurora plant in Fairbanks do not have an appreciable impact on the transmission benefits since the existing system can support additional sales. However, this increase in sales comes with a decrease in reliability as the GVEA system will suffer larger outages as a result of the loss of the transmission line between Fairbanks and Anchorage.

The introduction of LNG into GVEA's North Pole plant, without an additional unit does not have an appreciable impact on the transmission benefits.

The only scenario where the benefit/cost ratio is less than 1.0 is the case where LNG is used in the new units and powerplant at North Pole. All other investigations resulted in B/C ratios ranging from 1.1 to 2.3.

A summary of the sensitivity cases is presented in the Table 2-3.

Table 2-3: Sensitivity Cases

Scenario	Total Pool Load	Annual Production Costs - K$			Annual Savings - K$	
		Existing Transmission	Existing Transmission	Upgraded Transmission		From New
	Annual GWh	No Pooling	Full Pooling	Full Pooling	From Pooling	Transmission
Base Case	$ 5,175	$ 576,770	$ 553,182	$ 456,705	$ 23,588	$ 96,478
High Load	5174.5 + 573.0	$ 747,343	$ 712,602	$ 577,324	$ 34,741	$ 135,277
Low Load	5174.5 - 306.6	$ 499,607	$ 473,882	$ 409,290	$ 25,725	$ 64,592
Aurora & Healy 1 Retired	$ 5,175	$ 617,925	$ 575,809	$ 480,389	$ 42,116	$ 95,420
LNG @ NPCC only	$ 5,175	$ 564,789	$ 539,790	$ 453,288	$ 24,998	$ 86,502
High Fuel Cost	$ 5,175	$ 757,051	$ 727,573	$ 639,067	$ 29,478	$ 88,507
Low Fuel Cost	$ 5,175	$ 444,794	$ 425,634	$ 346,470	$ 19,159	$ 79,164
Re-Build of North Pole (New units & LNG)	$ 5,175	$ 531,502	$ 509,710	$ 472,398	$ 21,792	$ 37,312

The range of benefit/cost ratio of the projects are seen in Table 2-4.

Table 2-4: Sensitivity Case Summaries

Scenario	Transmission Costs	Annual Benefits From New Transmission	Benefit/Cost Ratio	Transmission Costs - w/o reliability projects	Annual Benefits From New Transmission	Benefit/Cost Ratio
Base Case	$ 926.0	$ 96,478	1.55	$ 871.7	$ 96,478	1.64
High Load	$ 926.0	$ 135,277	2.17	$ 871.7	$ 135,277	2.3
Low Load	$ 926.0	$ 64,592	1.03	$ 871.7	$ 64,592	1.1
Aurora & Healy 1 Retired	$ 926.0	$ 95,420	1.53	$ 871.7	$ 95,420	1.62
LNG @ NPCC only	$ 926.0	$ 86,502	1.39	$ 871.7	$ 86,502	1.47
High Fuel Cost	$ 926.0	$ 88,507	1.42	$ 871.7	$ 88,507	1.51
Low Fuel Cost	$ 926.0	$ 79,164	1.27	$ 871.7	$ 79,164	1.35
Re-Build of North Pole	$ 926.0	$ 37,312	0.6	$ 871.7	$ 37,312	0.63

There may be other combinations of transmission alternatives that provide equal or higher benefit/cost ratios but that do not meet the reliability criteria of AKTPL-001-4. These alternatives may serve as a building block to the preferred transmission system but were not in the scope of this study.

3 Detailed Summary

A detailed description of the projects and benefits for each of the Railbelt areas is presented below.

3.1 Kenai-Anchorage Transmission

Transmission between the Kenai Peninsula and the Railbelt transmission system has depended on a single 115kV transmission line to deliver power to or receive power from Southcentral Alaska. This line was originally built to transfer a relatively small amount of Cooper Lake Hydro power (16 MW) into the Anchorage area. The Bradley Lake Hydroelectric Project, commissioned in 1991, has been constrained in its operation since its completion due to the inadequate transmission system between the Kenai and the northern and southcentral Railbelt systems. In the past, the Bradley Lake project participants successfully mitigated the constraints to the greatest extent possible by cooperative agreements and actions among the utilities. The changing atmosphere of the Cook Inlet gas situation and the evolving landscape of generation in the Railbelt has foreclosed many of the mechanisms historically available to the Railbelt utilities to mitigate the constraints on the Bradley project. As a result of the loss of the mitigation measures and the changing aspects of the generation and gas systems, without improvements to the transmission system between Anchorage and Kenai, the utilities will experience substantial increases in both electrical line losses, lost generation capacity and operating costs due to the transmission constraints placed on transfers from the Kenai.

In addition to the near-term constraints identified above, the Anchorage-Kenai constraints severely inhibit the integration of additional variable resources such as wind energy. These constraints prevent Kenai hydro energy being used as part of an overall hydro management or coordination strategy. The lack of transmission capacity also limits the amount of other Kenai resources that can be used to mitigate the impacts of variable generation such as wind energy and will significantly increase the cost of integrating renewables into the Railbelt system. The Eklutna hydro facility is the only hydro resource not constrained by the Railbelt transmission system.

The basic constraint of the Bradley project is the lack of an adequate transmission system used to deliver the project's energy from Kachemak Bay to Anchorage and Fairbanks. Besides only a single transmission line between the Cooper Lake area and Anchorage, a single 115 kV transmission line from Soldotna to the Cooper Lake area makes up the connection between the majority of the Railbelt and Bradley Lake. These two single lines have a combined length of 146 miles. Although the lines have been well maintained and improved by the utility Owners, they were not originally designed to carry large amounts of power over long distances. For comparison, the line between Anchorage and Fairbanks carries slightly less power than the University to Dave's Creek Line, but is constructed to a much higher voltage and uses two large conductors per phase instead of the one small conductor per phase, as used on the Kenai line.

The solution to eliminating the Bradley constraints is an improved transmission system between Anchorage and Kenai. This can be accomplished by either an additional transmission path between the two regions, upgrading the existing transmission line to a larger capacity line, or a combination of both building a new line and improving the existing line.

The study evaluated all three options. Adding a new transmission line between the regions greatly increases the reliability and relieves some constraints on Bradley Lake, but a new line by itself does not remove constraints on Bradley Lakes' energy, since Bradley Lake must be operated in compliance with the lowest operating condition of the new line or the existing line. Upgrading the existing transmission line from Soldotna to Anchorage was also studied, however it was not recommended due to higher costs, construction timing, and constraints associated with continued operation of a transmission system with a single transmission line between Kenai and Anchorage.

The recommended transmission system is composed of improvements to portions of the existing Anchorage – Kenai transmission system combined with a new transmission line connecting the Southcentral area's 230 kV transmission system at Beluga to the 115 kV transmission system at Bernice Lake or Soldotna. The combination of these two projects results in the lowest overall cost as well as the most benefits and fewest constraints on the Bradley project.

The routing of the submarine cable and overhead transmission line were based on a paper study using our past experience with the Southern Intertie. Other routing options that could reduce the cost of the line may be possible with further evaluation of the project.

In the draft report, an attempt was made to quantify the benefits of individual or groups of projects. The final report did not include identification of individual project or group benefits due to funding constraints.

A summary of the costs of the proposed projects to unconstrain the Bradley Lake hydroelectric project are presented in Table 3-1. The costs are estimated to be budgetary figures +/- 20%.

Table 3-1: Kenai Project Costs

Priority	Project	Description	Cost (Millions)
1	Bernice Lake-Beluga HVDC	100 MW HVDC Intertie	$ 185.3
2	35 MW/20 MWh BESS	Anchorage area battery	$ 41.1
3	Bradley-Soldotna 115 kV Line	New line & Bradley/Soldotna sub	$ 53.3
4	University-Dave's Creek 230kV	Reconstruct existing line	$ 57.5
5	University-Dave's Substations	Convert line for 230 kV operation	$ 36.3
6	Dave's Creek - Quartz Creek	Upgrade line to Rail conductor	$ 16.2
	Electrical Projects Total		$ 389.6

3.2 Southcentral Alaska Reliability

A single 115kV transmission line between the Anchorage and the Palmer areas connects ML&P's Plant 2 to the Eklutna Hydro Plant. A recent upgrade of this line has added a second circuit, which is not connected to the system due to limitations in available substation space for new breaker positions. Improvements to the reliability of the Southcentral Railbelt system serving Anchorage and the Mat-Su area consist of two substation projects allowing this additional circuit to be placed into service. The projects are driven by reliability requirements. The benefits of un-served energy are used through-out the electrical industry to evaluate potential projects, however the value of un-served energy has not been established by study in the Railbelt. The Fossil Creek Substation allows the interconnection of the second transmission line into the Railbelt system and also a second interconnection between the ML&P system and Fossil Creek through Raptor station. This second path into the ML&P system eliminates generation constraints for the new Eklutna Generation Station and increases the critical clearing time for 115 kV faults to manageable levels.

A second tie into the AML&P system via Raptor Substation increases reliability to the AML&P/JBER area and completes the path between the AML&P 115 kV and the 230 kV systems. This segment is comprised of Plant 1 – Raptor (7.0 Mi) and Raptor – Fossil Creel (4.1 Mi).

A summary of the costs of the proposed projects for the Southcentral Railbelt are presented in Table 3-2.

Table 3-2: Southcentral Project Costs

Priority	Station	Description	Costs (Millions)
1	Fossil Creek	New 115 kV substation	$ 11.9
1	Eklutna Hydro	New 115 kV substation	$ 10.1
1	115 kV line	Plt 1-Raptor-Fssl Ck	$ 17.3
	Total		$ 39.3

3.3 Anchorage-Fairbanks Intertie Reliability/Economics

Transfers between the Fairbanks area to or from the Anchorage/Kenai systems are currently limited to a single line between each of the two areas. Due to the single lines, all power transfers are "economic" transfers that occur only when energy is available in the south through unloaded generation and the line is in service. GVEA currently maximizes the use of the existing intertie, but must maintain sufficient generation and fuel resources in its area in case the single interties between the areas is out of service. The absence of a second transmission line between the areas precludes the contracting for firm power between the Northern and Southern systems and precludes GVEA from contracting for known quantities of fuel or energy from the southern utilities including the sharing of capacity reserves across the Railbelt system.

The addition of a second line between Anchorage and Fairbanks increases the amount of energy capable of being transferred between the areas from 69 MW of non-firm in the existing system to over 189 MW of firm power sales with Healy 2 on-line (all of Fairbanks area load). It's important to note the difference in service between the existing system and the proposed system when comparing the improvements in transfer. Under the existing system, any transfer from Anchorage above 30-40 MW will result in loadshedding in the Fairbanks area following the loss of the single line. Maximizing the "pooling" benefits using the existing system requires more energy to flow across the single tie. The increased energy flow will result in larger outages for any interruption to the single tie between the load centers. It also assumes that the single tie will not be out of service for any length of time for maintenance or repairs. This is considerably different than the 189 MW limit of the proposed system which would not suffer any customer outages for the loss of a single line.

The second transmission line spanning the 171 miles between Healy and Anchorage will prevent outages to Fairbanks and allow GVEA to access electrical and gas markets in the Southcentral system.

A summary of the costs of the proposed projects to provide reliability and economic energy transfers between the northern and southern systems is presented in 3-3.

Table 3-3: Northcentral Project Costs

Group	Item	Description	Costs (Millions)
1	Lorraine-Douglas	Lorraine - Douglas 230 kV line/stations	$ 128.5
2	Douglas – Healy line	New 230 kV line operated at 138 kV	$ 245.7
	Communications Upgrade		$ 15.0
	Total		$ 389.1

The analysis determined that upgrading the 138 kV lines into the Fairbanks area to 230 kV essentially eliminated transfer constraints between southern generation and resources and the Fairbanks area. The costs of the 230 kV transmission line upgrades are presented in Table 3-4

Table 3-4: Northcentral Project Costs –230 kV Line Upgrades

Group	Item	Description	Cost (Millions)
1	Healy-Fairbanks 230 kV	Convert 138 kV to 230 kV	$ 107.9

3.4 Proposed System Transmission Maps

Transmission maps were created for the proposed transmission system and a shown below in Figure *3-1*: Northern Proposed Transmission System and Figure 3-2: Kenai and Southcentral Proposed Transmission System.

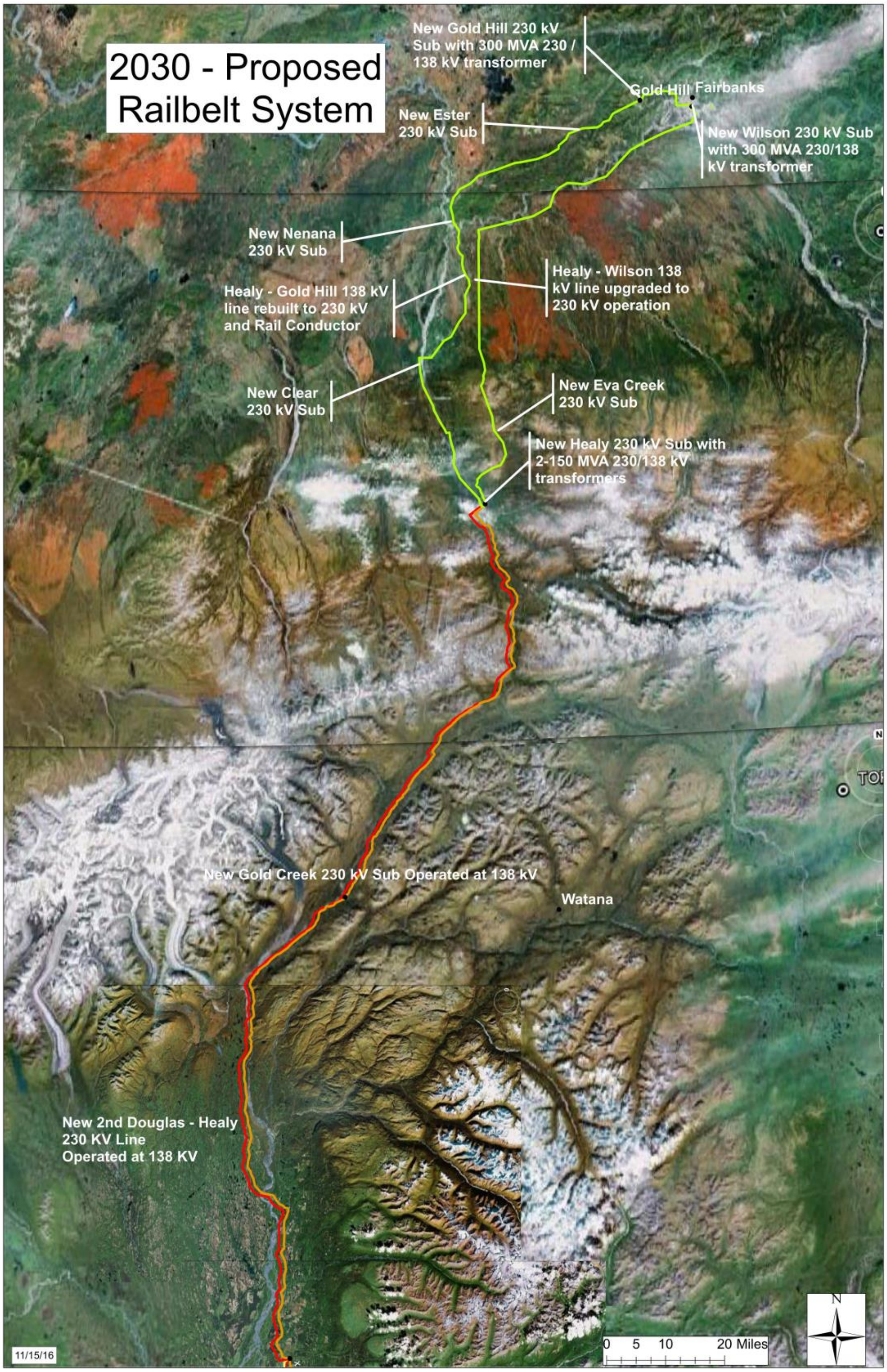


Figure 3-1: Northern Proposed Transmission System

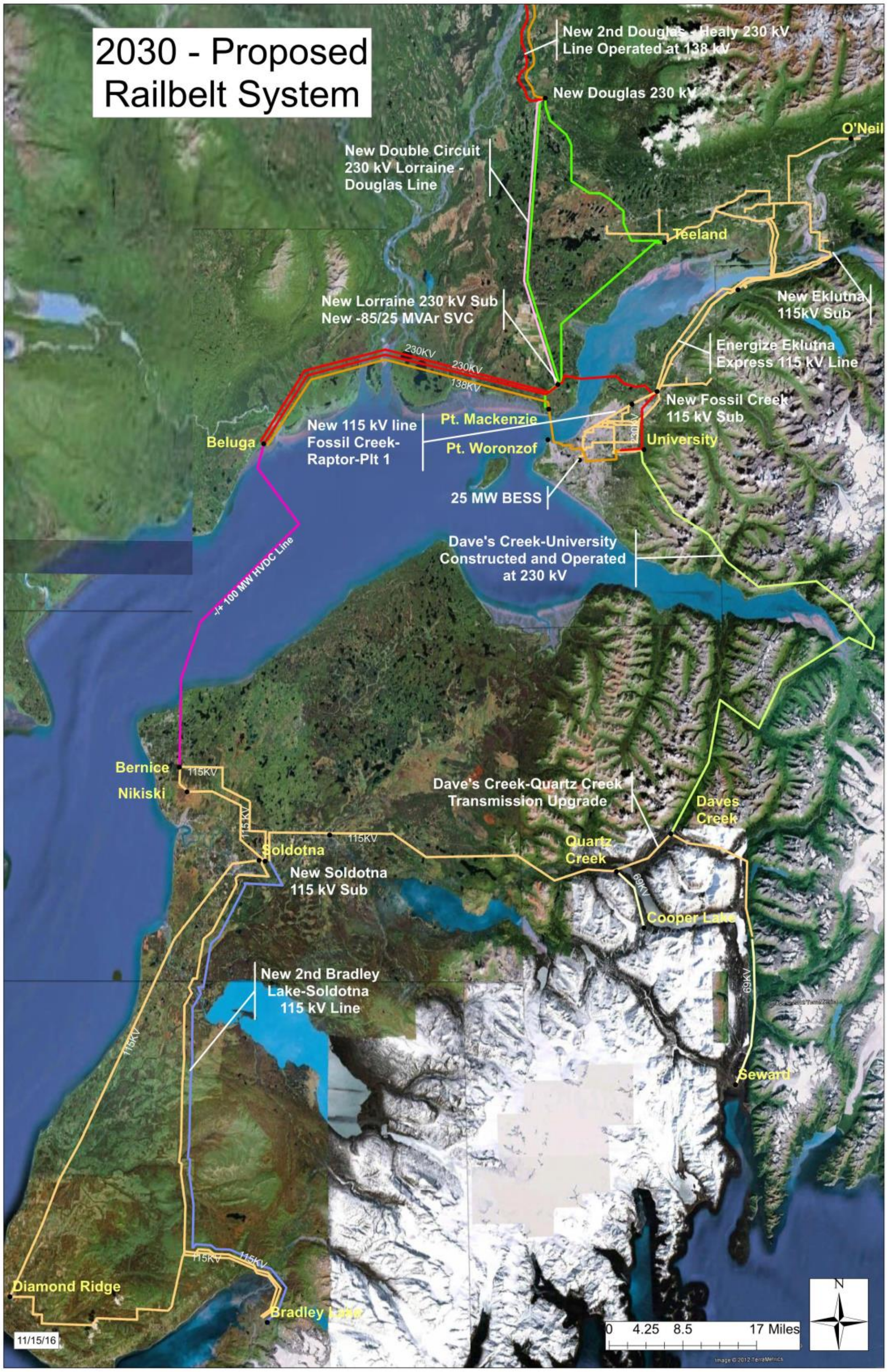

2030 - Proposed
Railbelt System
New 2nd Douglas - Healy 230 kV
Line Operated at 138 kV
New Douglas 230 kV
O'Neil
New Double Circuit
230 kV Lorraine -
Douglas Line
Teeland
New Eklutna
115kV Sub
New Lorraine 230 kV Sub
New -85/25 MVAr SVC
Energize Eklutna
Express 115 kV Line
230KV
230KV
138KV
New Fossil Creek
115 kV Sub
New 115 kV line
Fossil Creek-
Raptor-Plt 1
Pt. Mackenzie
Pt. Woronzof
University
Beluga
25 MW BESS
Dave's Creek-University
Constructed and Operated
at 230 kV
-/+ 100 MW HVDC Line
Bernice
Nikiski
115KV
Dave's Creek-Quartz Creek
Transmission Upgrade
Daves
Creek
Quartz
Creek
Soldotna
New Soldotna
115 kV Sub
Cooper Lake
69KV
New 2nd Bradley
Lake-Soldotna
115 kV Line
Seward
115KV
Diamond Ridge
Bradley Lake
11/15/16
0 4.25 8.5 17 Miles
N

Figure 3-2: Kenai and Southcentral Proposed Transmission System

4 Power Flow & Transient Stability Analysis

4.1 Introduction

The goal of the Railbelt Transmission Plan ("Plan") system study is to help determine the recommended future transmission system for the Railbelt. The study focuses on the technical requirements of the system. The study results coordinate with the system's economic analysis to determine the final recommended system improvements. The objectives of the Plan include improving reliability, mitigating future cost increases to Railbelt rate payers, allowing unconstrained energy transfers and use of peaking capacity from the Bradley Lake hydroelectric project, and increasing energy transfers between all areas of the Railbelt.

This system study was completed to support the final revision of the Plan, and built from the Draft Plan dated March 17, 2014 ("Pre/Post – Watana Transmission Study") and other supporting studies. Portions of the technical results and conclusions from the 2014 Draft Plan remain unchanged and are used to support the final recommended system improvements. Some of the conclusions from the previous 2014 Draft report, including various transmission configuration alternatives, steady state contingency analysis, and loss analyses, remain unchanged. This system study assumed that the economic justifications for the various system improvement projects recommended in the 2014 Draft Plan will change or will be revised, but the conclusions that justify the various improvements will not change.

A listing of the most important past system studies leading up to this Final Plan follows:

- Pre/Post – Watana Transmission Study, March 17, 2014 (Draft Plan)
- Kenai Transmission Study, March 7, 2014
- Regulation Resource Study, March 7, 2014
- Post Watana Transmission Study, January 27, 2014
- Northcentral Analysis, May 3, 2013

The updated system study for the Final Plan includes the use of the recently adopted set of Railbelt Utility Reliability Standards as well as the most current Railbelt system models. The current Railbelt models incorporate various changes to the system including refinements to the dynamic response of the system models based on benchmarking of the models.

4.2 Methodology

The methodology of the system study focused on two stages of analysis in order to meet the objectives of the Plan. The first stage consisted of existing system analysis identifying the limitations of the existing system. This primarily included the determination of the transfer limits between the Kenai and Anchorage areas (Kenai Intertie) and the Anchorage and Fairbanks areas (Alaska Intertie). The system was also assessed for any weak points where system improvements may be necessary or required based on the recently adopted transmission planning criteria. The results of the first stage of the analysis are used to provide a starting point for the economic analysis.

The second stage of analysis involves the determination of the required system improvements, based on the transmission planning criteria, or determination of other system improvements that will improve system reliability and / or system economics. All final recommended system improvements are justified economically in the Final Transmission Plan, based on the results of production simulations, with costs provided in the final report. The 2014 Draft Plan report included an extensive assessment of various system improvement options. The value and overall benefit of these improvements has not changed enough from the results in the Draft Plan to change the final recommendations. As a result, the focus of this updated system study was to re-evaluate the limitations of the existing system and the technical benefits of the recommended options found in the 2014 Draft Plan. No changes in the recommended system improvements, when compared to those in the 2014 Draft Plan, are proposed.

4.3 System Analysis and Base Cases

The system study was performed using the Power Systems Simulator Engineer ("PSS/E") software. Power flow and transient stability analysis was completed considering seasonal load and generation variations and several types of contingencies. The contingencies included generation trips, transformer faults, and line fault conditions.

The starting base cases used for the study consisted of the most current 2016 Railbelt System Studies Subcommittee (SSS) cases dated approximately 12/11/2015. The cases include changes to the models determined during the recent benchmarking analysis completed in the fall 2015. One base case from each of the three seasons was used as a starting point. Table 4-1 includes the loads found in the bases cases. Table 4-2 describes the under-frequency load shedding (UFLS) scheme found for each season. The Railbelt utilities indicated that insignificant load growth can be expected in the near future and that the loads in the SSS cases represent reasonable seasonal load for the purposes of the transmission planning study.

Table 4-1: Seasonal and Utility Loads

Season	Case	Utility						Total System	
	Description	HEA	AMLP	GVEA	CEA	SES	MEA	Load	Losses
Winter Peak	Base	91.7	182.0	226.5	229.0	9.0	138.0	876.2	33.6
Summer Peak	Base	90.6	167.8	190.8	161.0	8.0	86.0	704.2	28.7
Summer Valley	Base	48.3	89.0	118.8	94.0	6.0	50.0	406.0	24.9

Table 4-1: Railbelt UFLS Scheme Load Distribution

Frequency Set Point (Hz)	Pickup Timer (sec)	Breaker Timer (sec)	Load by Stage & Season (MW/% Load)					
			Summer Valley		Summer Peak		Winter Peak	
			Load MW	393 %	Load MW	670 %	Load MW	840 %
59.0	0.083-0.15	0.05-0.0833	39.0	9.9%	69.0	10.3%	85.1	10.1%
58.7	0.083-0.15	0.05-0.0833	43.3	11.0%	75.5	11.3%	92.8	11.1%
58.5	0.083-0.15	0.05-0.0833	41.5	10.6%	70.8	10.6%	91.4	10.9%

4.4 Unit Commitment, Dispatch, and Spinning Reserves

The setup for the various generation scenarios used for the study was initially based on the commitments and dispatches found in the SSS cases. The modifications made to generation for the study cases were necessary to determine the intertie limits and other generation sensitivities found during existing and future system conditions. The resulting commitments, dispatches, and spinning reserves reflect the generation scenarios needed in a planning study and do not necessarily reflect the scenarios used in an operations study. The cases represent a reasonable spectrum of conditions, especially at high transfer levels, that can be expected to normally occur. This includes cases with no extra spinning reserves and no regulating reserves, beyond the minimum requirements. This ensures that the results produce a long range plan that can work in a wide range of operating conditions, without putting the system at undue risk for severe outages or possible system collapse.

The amount of spinning reserves used in the cases varied depending on the particular area of analysis. For the existing Kenai Intertie study, the amount of spin found North of Dave's Creek Substation was kept to levels exceeding the amount of transfer on the Kenai Intertie. In most cases, this level was larger than the largest conventional generation contingency.

Both hydro based and combustion turbine / steam turbine (CT/ST) based spinning reserves were studied. This was done in order to determine the sensitivity of the system response to the type of units carrying the reserves, and to support the economic analysis. The hydro based cases maximized the spin available on the Bradley Lake, Cooper Lake, and Eklutna Hydro generation units (Bradley Lake spin was limited to a maximum of 27 MW per existing Railbelt operating practices). The CT/ST based spin cases had limited or no spin available from the hydro units. The GVEA Battery Energy Storage System (BESS) at Wilson substation was set to 26 MW of spin in the PSS/E models for all cases analyzed. The CT/ST spin was usually located at Plant 2a, although some cases required spin on the Nikiski CT/ST and the Soldotna CT.

Other generation sensitivities were also studied for the Kenai Intertie and Alaska Intertie export limits. Some of the Kenai Intertie generation alternatives included Cooper Lake on/offline and variations in output and commitment of the Nikiski and Soldotna units. The Healy area generation (Healy #1, #2, Eva Creek) commitment was also varied to determine the Alaska Intertie and Healy export limits during varying generation conditions in the Northern area.

4.5 Intertie Export Limits

The intertie flows were varied to determine the stability based flow limits. The change in flow was facilitated by changing the generation in one area, either Kenai or Fairbanks, and allowing the generation in the Anchorage area to provide the corresponding opposite change in generation and to adjust for changes in system losses. Typically Plant 2a was used for the generation adjustments in Anchorage.

The change in generation produced a range of flows along each intertie, with each case then checked to determine the stability of the system at that flow. The step size for the change in generation varied throughout the study based on generation conditions, but was roughly 3-5 MW. Throughout each range of flows, no changes in unit commitment were made. The total system spin was therefore relatively constant and only changed due to changes in system losses.

The export limits were determined by the detection of an out-of-step condition, a generator loss of synchronism condition, and/or a voltage collapse condition. The export limit results stated in this report represent the level of intertie flow one step lower than the case that resulted in the stability criteria violation. This step value is roughly 3-5 MW with no additional margin applied to the stated limit.

It should be noted that the overall limit results presented in the study are a combination of stability, voltage, thermal, generation, or load based limits. In some cases, the stated limit is not based on a criteria violation, but one based on practical operating considerations. For instance, some of the limits for the Kenai Intertie are based on conditions with the maximum amount of generation online, and higher flows cannot be achieved. Similarly, some of the limits on the Alaska Intertie are based on the amount of load in the Northern region, and higher flows again cannot be achieved.

4.6 Assumptions

Several assumptions relating to the modeling and methodology used to complete the analysis have been made. A brief description of the major assumptions follows.

4.7 BESS Spinning Reserves

The GVEA BESS has been configured to provide 26 MW of spin for almost all PSS/E simulations. The only exception to this occurs when the BESS needs to be auto-scheduled for a specific disturbance to a value greater than 26 MW. The BESS model within PSS/E does not provide parallel control functions for spinning reserves and auto-scheduling. However, the actual equipment in the field does provide for parallel control functions. To work around this issue for simulation purposes, the BESS was configured for either 26 MW of spin or was auto-scheduled from 26-40 MW depending on the disturbance and system conditions. This work around for the PSS/E model does not negatively impact the simulation results.

4.8 HVDC Tie Modeling

The proposed HVDC tie was modeled within PSS/E using constant power loads to simulate the HVDC interconnection between Bernice Lake Substation and Beluga Substation. The tie flows along the HVDC line are assumed to be scheduled at the 75 MW nominal rating of the tie under normal conditions. The continuous overload capacity of the tie is assumed to be 100 MW. Four percent losses are assumed for the tie. The PSS/E modeling consists of a positive valued load placed at Bernice and a negative value load placed at Beluga for flow from Bernice to Beluga.

4.9 Nikiski Overfrequency Relaying

The Nikiski CT modeling within PSS/E includes an overfrequency protective relay. The relay trips the unit when the unit frequency exceeds 60.6 Hz for 3 seconds. The relay is modeled properly within PSS/E, but has been disabled for this study, due to the negative impact of the unit trip on the Kenai frequency for Kenai islanding events. The Nikiski unit frequently trips offline when the Kenai is separated from the Anchorage area or the tie flow is reduced, and negatively impacts the Kenai system, frequently causing load shedding. EPS recommends that this overfrequency relay setting be re-evaluated in order to avoid tripping Nikiski when possible.

4.9.1 Fairbanks Area Generation

The minimum amount of Fairbanks area generation required for stability and voltage purposes impacts the results of the study. This is especially true as Douglas export limits are increased with system improvements and the stability limits to the north are greater than the load demand in Fairbanks. The generation or unit commitment found in the 2016 SSS power flow cases has been used as the starting point for our cases. Sensitivity cases were also run with some or all GVEA generation in Fairbanks taken offline.

4.10 PSS/E Modeling Changes

Various changes to the Railbelt PSS/E model have been made since the Draft Plan was produced. The many of the changes are subtle and are considered to be normal maintenance items necessary as the utility systems are upgraded and more PSS/E benchmarking is performed. The Railbelt SSS has been very active identifying and administering the required changes to the PSS/E models. The changes include modifications to the power flow and dynamic models. The following is a summary of the changes made to the models that may contribute to differences between the Draft and Final Plan system study results.

4.10.1 Dynamics

- Teeland/Healy/Gold Hill SVC's – New custom Alstom models (power flow/dynamics)
- EGS Units – Changes to generator, exciter, governor, and under-excitation limiter models, from benchmarking study (power flow/dynamics)
- SPP Units – Governor response, inertia, from benchmarking study
- Beluga 3 Unit – Governor response, droop, from benchmarking study
- North Pole CT Unit - Governor droop, from benchmarking study
- Chena 5 Unit – Turn off governor due to lack of response
- UFLS Settings – Various modifications to the UFLS scheme from the SSS
- UF/OF Settings – Various islanding and generation unit under and over frequency relay settings additions and modifications, from the SSS
- GVEA BESS – Auto-scheduling for specific system conditions

4.10.2 Power Flow

- 2016 Loads
- Healy #1, #2 – VAr control limits
- SPP Unit Transformers – Impedance and other changes
- University-Indian – Line impedance change due to reconductoring
- Plant 2a – Generator source impedance change

4.11 Performance Standards & Criteria

The performance standard used to perform the system analysis and assess the system was Standard AKTPL-001-4. The final revision, submitted for IMC approval, of this document is dated February 11, 2016. The development of this standard included eight revisions starting November 5, 2015. The standard development time period coincided with the Final Plan study time period.

4.11.1 Stability Criteria

The transient stability criteria include limits on the system frequency, voltage levels, system response, and unit response. The transient criteria listed below were used for N-1 contingency analysis.

- Sustained voltages on the transmission system buses must not be below 0.8 pu
- Frequency must stay between 57 Hz and 62 Hz
- System response must not exhibit large or increasing amplitude oscillations in frequency or voltage
- Units must not exhibit out of step or loss of synchronism response
- Single contingency events cannot cause uncontrolled load shedding

It is not accepTable to operate the system in a configuration that would result in unsTable system response for single contingencies. Therefore, infrastructure improvements or operational constraints must be completed to eliminate the possibility of an unsTable condition occurring.

4.11.2 Voltage Criteria

The criteria to be applied include limits on the maximum and minimum voltages allowed on the Railbelt system as well as operational limits of the generators and the SVC's. The criteria are listed below.

- Voltages at 230 kV, 138 kV undersea cables must be below 1.02 pu
- Voltages at 230 kV, 138 kV, and 115 kV substations serving load must be below 1.05 pu
- Voltages at 230 kV, 138 kV, and 115 kV substations NOT serving load must be below 1.10 pu
- Voltages at 230 kV, 138 kV, and 115 kV substations must be above 0.95 pu

As with the stability criteria, it is not accepTable to operate the system in a configuration that would result in the system violating the voltage criteria. Therefore, infrastructure improvements or operational constraints must be completed to eliminate the possibility of a voltage violation occurring.

4.12 Contingencies

As previously discussed, the contingencies performed for the study included generation, transformer, and transmission line outages. In accordance with Standard AKTPL-001-4, a list of the contingencies anticipated to have the most severe impact was created. The most limiting contingencies, those that ultimately determined the final recommended system improvements, varied from case to case based on system conditions and generation scenarios.

The following list describes the disturbances simulated for this analysis. Table 4-3 through Table 4-6 list the contingencies used for the analysis. The listings include all disturbances considered in the existing and future analysis. General comments about the contingencies follow.

- All disturbances that include a fault were simulated with a three-phase fault.

- Almost all clearing times associated with generator, line, and transformer disturbances used five cycle clearing times. The only exception to this is for the far end clearing times for a fault on the Douglas to Healy line (30 cycles).
- Generator contingencies included the trip of the generator. For some contingencies, the generator trip was preceded by a three-phase generator bus fault.
- EGS and North Pole CC generation contingencies were simulated by the loss of a GSU transformer where multiple units interconnect to the system via a single transformer.
- Faults on the Bradley Lake-Soldotna line were simulated with and without the transfer trip of one of the Bradley Lake units, for sensitivity analysis purposes.
- For the existing system simulations, the GVEA BESS was auto-scheduled according to the type of disturbance and system operating conditions. No auto-scheduling was required for the future system with the recommended improvements.
- For the future system including the recommended improvements, any fault and subsequent line clearing condition opening the 115 kV line from Soldotna to Dave's Creek results in an increase of 25 MW in scheduled flow on the HVDC tie from Bernice Lake to Beluga.

Table 4-3: Kenai Area Line/Transformer Contingencies

ID	Description	Comment
a00	Dry Run	No disturbance
a01	Bradley-Soldotna_115@Soldotna	No Bradley unit transfer trip
a02	Bradley-Soldotna_115@Brad_Lk	No Bradley unit transfer trip
a08	Quartz-Daves_115@Daves_Ck	
a11	Soldotna_SVC_115@Soldotna	
a13	Soldotna-Diamond_115@Soldotna	
a14	Soldotna-Diamond_115@Diamond	
a15	Bradley-Soldotna_115@Sold-xfer	Bradley unit transfer trip
a16	Bradley-Soldotna_115@Brad-xfer	Bradley unit transfer trip
a20	Quartz-Daves_115@Daves_Ck-DC	Increase DC tie flow
a22	Bernice-Beluga_DC@Bernice	
a23	Bernice-Beluga_DC@Beluga	
a24	Soldotna-Sterling@Soldotna	No increase DC tie flow
a25	Soldotna-Sterling@Sterling	No increase DC tie flow
a26	Soldotna-Sterling@Soldotna-DC	Increase DC tie flow
a27	Soldotna-Sterling@Sterling-DC	Increase DC tie flow

Table 4-4: Southcentral Area Line/Transformer Contingencies

ID	Description	Comment
b01	230_Cable_230@Plant_2	
b02	230_Cable_230@Pt_Mack	
b03	University-Plant_2_230@University	
b04	University-Plant_2_230@Plant_2	
b05	Pt.Mack-Teeland_230@Pt_Mack_RAS	Teeland-Douglas line transfer trip >50 MVA
b06	Pt.Mack-Teeland_230@Teeland_RAS	Teeland-Douglas line transfer trip >50 MVA
b09	Anchorage-University_115@University	
b10	Plant_2-Anchorage_115@Plant_2	
b11	Plant_2-Anchorage_115@Anchorage	
b12	Plant_2-EGS_115@Plant_2	
b13	Plant_2-EGS_115@EGS	
b14	Beluga-Pt.Mack@Beluga	
b15	Beluga-Pt.Mack@Pt.Mack	
b16	Teeland-Hospital_115@Teeland	
b17	Teeland-Hospital_115@Hospital	
b18	Teeland-Douglas_138@Teeland	
b19	Teeland-Douglas_138@Douglas	
b20	ITSS-University_138@ITSS	
b21	ITSS-University_138@University	
b22	EGS_XFMR-@XFMR	Four units maximum lost generation
b23	ITSS-Pt_Mack1_138@ITSS	
b30	Plant_2-Fossil_115@Plant_2	
b32	230_Cable_230@Plant_2	
b33	230_Cable_230@Lorraine	
b34	Lorraine-Teeland@Lorraine	
b35	Lorraine-Teeland@Teeland	
b36	Lorraine-Douglas@Lorraine	
b37	Lorraine-Douglas@Douglas	
b38	Lorraine-Pt_Mack@Lorraine	
b39	Lorraine-Pt_Mack@Pt_Mack	

Table 4-5: Northern Area Line/Transformer Contingencies

ID	Description	Comment
c01	Healy-Douglas@Healy	GVEA BESS autoscheduling
c02	Healy-Douglas@Douglas	GVEA BESS autoscheduling
c03	Healy-Gold_Hill@Healy	GVEA BESS autoscheduling
c04	Healy-Gold_Hill@Gold_Hill	GVEA BESS autoscheduling
c05	Healy-Eva_Creek@Healy	GVEA BESS autoscheduling
c06	Healy-Eva_Creek@Eva_Creek	GVEA BESS autoscheduling
c07	Eva_Creek-Wilson@Eva_Creek	GVEA BESS autoscheduling
c08	Eva_Creek-Wilson@Wilson	GVEA BESS autoscheduling
c09	North_Pole_Combined_XFMR-@XFMR	GVEA BESS autoscheduling
c09	North_Pole_Combined_XFMR-@XFMR	GVEA BESS autoscheduling, CT/ST lost generation
c10	Douglas-Gold_Creek@Douglas	
c11	Douglas-Gold_Creek@Gold_Creek	
c12	Healy-Gold_Creek@Healy	
c13	Healy-Gold_Creek@Gold_Creek	
c14	Healy-Eva_Creek_230@Healy	
c15	Healy-Eva_Creek_230@Eva_Creek	
c16	Healy-Clear_230@Healy	
c17	Healy-Clear_230@Clear	
c18	Wilson_XFMR_230@230_XFMR	
c19	Wilson_XFMR_230@138_XFMR	
c20	Gold_Hill_XFMR_230@230_XFMR	
c21	Gold_Hill_XFMR_230@138_XFMR	

Table 4-6: All Area Generation Contingencies

ID	Description	Comment
g00	Bradley 1	
g01	Bradley 1/Fault	
g02	Nikiski 1	
g03	Nikiski 1/Fault	
g04	Sold 1	
g05	Sold 1/Fault	
g06	Plant 2a 10	
g07	Plant 2a 10/Fault	
g08	SPP 12	
g09	SPP 12/Fault	
g10	Beluga 5	
g11	Beluga 5/Fault	
g12	Healy 2	GVEA BESS autoscheduling
g12	Healy 2	No GVEA BESS autoscheduling
g13	Healy 2/Fault	
g14	NPCC 3	GVEA BESS autoscheduling
g14	NPCC 3	No GVEA BESS autoscheduling
g15	Chena 5	
g16	NP 1	GVEA BESS autoscheduling
g16	NP 1	No GVEA BESS autoscheduling
g18	Healy 1	GVEA BESS autoscheduling
g18	Healy 1	No GVEA BESS autoscheduling
g20	Plant 2a 9	

4.13 Existing Kenai Intertie

The key objective for the existing Kenai Intertie portion of this study was to determine the maximum export limits. The export flow is measured at Dave's Creek Substation with positive flow to Hope Substation. The export limits are determined based on the minimum stability, voltage, or thermal limit discovered. Several generation scenarios were used to determine the export limit sensitivity to unit commitment and output.

4.13.1 Generation Scenarios

Table 4-7Table through Table 4-9 describe the base generation scenarios used to determine the export limits. The amount of generation for each main generation source is shown. The amount, type, and location of spin are also provided along with the amount of export for the Kenai Intertie and the Alaska Intertie. Each case represents the maximum export conditions while maintaining system stability.

Two base cases for each season are shown in the Tables. The two cases differ in the location of the spinning reserves. There is either an emphasis on Hydro or CT (CT/ST) spin. The additional generation sensitivities include changing the status of Cooper Lake, varying the Soldotna CT unit output, varying the commitment of Nikiski CC and Soldotna CT, and changing the status of the Nikiski ST unit.

Appendix A illustrates a more detailed description of all of the generation scenarios used in the existing Kenai export analysis. Appendix G details the naming convention used for the various cases and simulations used throughout the study.

To vary the intertie flow and determine the export limit, Bradley Lake, Nikiski, or Soldotna generation was adjusted in the Kenai area while Plant 2a was adjusted in the Anchorage area. The emphasis on the type of spin determined whether or not Bradley Lake, Nikiski, or Soldotna generation was varied.

Table 4-7: Existing Winter Peak Base Case Dispatches

Description Case Name	Base - Hydro Spin wp_g010_s085_n022		Base - CT/ST Spin wp_g110_s087_n020	
	Generation	Spin	Generation	Spin
Bradley Lake Hydro	115.7	4.3	119.8	0.2
Cooper Lake Hydro	14.0	5.6	19.6	-
Eklutna Hydro	2.0	38.0	40.0	-
Nikiski CC	60.8	0.2	53.9	7.1
Soldotna CT	-		-	
Tesoro	10.0	-	10.0	-
Beluga Plant	78.6	-	78.6	-
SPP	188.5	(0.0)	188.5	(0.0)
Plant 1	-		-	
Plant 2a	93.3	21.7	51.6	63.4
EGS	136.0	-	136.0	-
Healy 1	28.5	-	28.5	-
Healy 2	61.9	0.0	61.9	0.0
Eva Creek	10.0	-	10.0	-
GVEA BESS	-	26.0	-	26.0
North Pole CC	64.7	0.3	64.7	0.3
Chena 5	23.0	-	23.0	-
UAF	11.0	-	11.0	-
Fort Wainwright	15.0	-	17.0	-
Eielson AFB	8.0	-	8.0	-
Fort Knox	(11.0)	-	(11.0)	-
Generation/Spin Total	910.0	96.2	911.0	97.1
Dave's North Spin		86.1		89.8
Hydro Spin		47.9		0.2
CT/ST Spin		48.3		96.9
Dave's Creek - Hope Flow	84.9		87.5	
Douglas - Stevens Flow	22.2		20.1	

Table 4-8: Existing Summer Peak Base Case Dispatches

Description Case Name	Base - Hydro Spin sp_g010_s086_n020		Base - CT/ST Spin sp_g110_s086_n017	
	Generation	Spin	Generation	Spin
Bradley Lake Hydro	119.8	0.2	119.8	0.2
Cooper Lake Hydro	19.6	-	19.6	-
Eklutna Hydro	2.0	38.0	40.0	-
Nikiski CC	51.1	-	51.1	-
Soldotna CT	-		-	
Tesoro	8.0	-	8.0	-
Beluga Plant	59.0	-	59.0	-
SPP	141.0	(0.0)	141.0	(0.0)
Plant 1	-		-	
Plant 2a	71.2	21.6	31.5	61.3
EGS	85.0	-	85.0	-
Healy 1	26.4	-	26.4	-
Healy 2	61.9	-	61.9	-
Eva Creek	6.0	-	6.0	-
GVEA BESS	-	26.0	-	26.0
North Pole CC	40.0	-	40.0	-
Chena 5	23.0	-	23.0	-
UAF	5.0	-	7.0	-
Fort Wainwright	15.0	-	15.0	-
Eielson AFB	10.0	-	10.0	-
Fort Knox	(11.0)	-	(11.0)	-
Generation/Spin Total	733.1	85.8	733.4	87.5
Dave's North Spin		85.6		87.3
Hydro Spin		38.2		0.2
CT/ST Spin		47.6		87.3
Dave's Creek - Hope Flow	85.5		85.5	
Douglas - Stevens Flow	19.5		17.3	

Table 4-9: Existing Sumer Valley Base Case Dispatches

Description Case Name	Base - Hydro Spin sv_g010_s096_n017		Base - CT/ST Spin sv_g110_s095_n017	
	Generation	Spin	Generation	Spin
Bradley Lake Hydro	91.6	27.0	119.8	0.2
Cooper Lake Hydro	14.0	5.6	19.6	-
Eklutna Hydro	2.0	38.0	40.0	-
Nikiski CC	55.3	-	22.7	32.6
Soldotna CT	-		-	
Tesoro	2.9	-	2.9	-
Beluga Plant	-	-	-	-
SPP	109.1	(0.1)	72.9	36.1
Plant 1	-		-	
Plant 2a	17.9	37.5	17.2	38.2
EGS	34.0	-	34.0	-
Healy 1	-		-	
Healy 2	61.9	-	61.9	-
Eva Creek	7.9	-	7.9	-
GVEA BESS	-	26.0	-	26.0
North Pole CC	-	-	-	-
Chena 5	23.0	-	23.0	-
UAF	1.5	-	1.5	-
Fort Wainwright	5.0	-	5.0	-
Eielson AFB	5.0	-	5.0	-
Fort Knox	-	-	-	-
Generation/Spin Total	431.1	134.0	433.5	133.1
Dave's North Spin		101.4		100.3
Hydro Spin		70.6		0.2
CT/ST Spin		63.4		132.9
Dave's Creek - Hope Flow	96.2		95.1	
Douglas - Stevens Flow	17.0		17.0	

4.13.2 Results

The results of the analysis for the existing system show that the Winter Peak cases are limited by stability or voltage conditions, while the summer cases are primarily limited by the thermal ratings of the 115 kV line between Soldotna and Dave's Creek. Table -10 describes the limits along with the limiting condition and the basic generation configuration differences.

Table 4-10: Seasonal Results – Final Export Limits

Season	Bradley Lake	Nikiski CC	Soldotna	Cooper Lake	Limits (MW)		
					Voltage	Thermal	Stability
WP	both online	on	on	both online	53-73	126-146	87
	both online	on	on		43-63	126-146	72
	both online	on		both online	53-73	126-146	80
	both online	on			43-63	126-146	67
	both online		on	both online	53-73	126-146	68
SP	both online	on	on	both online	53-73	49-69	88
	both online	on	on		43-63	49-69	73
	both online	on		both online	55-75	49-69	86
	both online	on			54-74	49-69	61
	both online		on	both online	53-73	49-69	67
SV	both online	on		both online	61-81	49-69	90
	both online	on			50-70	49-69	76
	both online		on	both online	61-81	49-69	84

4.13.3 Explanation of Limits

The limits, as shown in Table 4-10, are derived as follows. The stability limit is determined by stability simulations where the initial flow equals the flow limit, a contingency occurs and the system responds, and the result is a sTable system response. The stability limits shown Table 4-10 include a margin of 5 MW.

In a parallel manner, the voltage limit is the initial steady state flow on the Dave's Creek – Hope line, such that when the contingency reserves on the Kenai are required and must flow north toward Anchorage and the remaining system, the resulting flow on the Kenai tie will result in a steady state voltage along the tie above 0.95 per unit. Power flow cases were run for the different generation scenarios to determine the flow limit along the tie where a low voltage of 0.95 per unit (pu) is reached. The voltage limit used in the results is derived by taking the flow value that yields a voltage of 0.95 pu, subtracting the Reserves on the Kenai, and then subtracting 5 MW of margin. The reserves range from 27 MW for Bradley Lake alone, to 47 MW representing 27 MW at Bradley Lake, 11 MW from HEA, and another 9 MW from Cooper Lake.

Likewise, the thermal based export limit is derived by taking the seasonal line ratings and subtracting 27 to 47 MW for reserves, with no extra margin added in. No margin was added because thermal limits include inherent time delays before damage occurs, yielding time for generation to be re-dispatched to alleviate the overload.

4.13.4 Winter Peak

For the Winter Peak cases, the thermal rating (173 MW) of the intertie is far greater than the voltage or stability constraints. Thus, there are no thermal rating concerns related to the Winter Peak cases.

The voltage limit is a steady state limit based on the minimum voltage found on the 115 kV intertie. The minimum voltage allowed is 0.95 pu and this typically occurs at actual export levels of 105 MW when Cooper Lake is online and 95 MW when offline. During these higher transfer conditions, the lowest voltage is typically found at Portage Substation. Reserves of 27 to 47 MW are included in the voltage based flow limits as previously discussed, plus a margin of 5 MW.

The Winter Peak cases are limited by voltage when Bradley Lake, Nikiski, and Soldotna units are all online and high reserve levels from the Kenai area are relied upon.

For the other Winter Peak cases with less generation online in the Kenai area, the export limits are limited by stability constraints. The limiting contingency in all cases is the fault and trip of the Soldotna SVC transformer resulting in an out-of-step condition on the Kenai Intertie.

4.13.5 Summer Peak & Summer Valley

Unlike the Winter Peak cases, the summer cases are dominated by thermal overload conditions limiting the export levels. The thermal rating (96 MW) of the intertie is nearly half of the winter rating. The section of the tie that is the heaviest loaded varies depending on the output of Cooper Lake. With Cooper Lake online, the heaviest loaded line section is Quartz Creek to Dave's Creek. With Cooper offline, all of the exported power flows on the Soldotna to Sterling line, thus making it the heaviest loaded line section under these generation conditions.

The sole summer case exhibiting a stability limit has a generation scenario with Nikiski generation offline and the Soldotna unit online. Similar to the Winter Peak case results, the stability limit is a fault and trip of the Soldotna SVC transformer. Note that the stability limit is only slightly lower than the thermal limit for this case (75 MW).

4.13.6 Spinning Reserve Sensitivities

Table Table 4-11 illustrates the differences in the export stability limits comparing cases with an emphasis in Hydro versus CT/ST spin, for the fault and trip of the Soldotna SVC. The comparison shows that the difference is negligible for all seasons and generation configurations studied. The largest difference found is 3 MW. This value is within the tolerance, or incremental steps in flows, used to determine the limiting export level. The difference in type of spin is more significant for the contingencies where generation is lost and the inertial and governor response of the generation units is more of a factor in the results. Note that these results do not include a stability limit margin of 5 MW.

Table 4-11: Seasonal Results – Spin Comparison

Season	Generation Configuration	Stability Export Limit (MW)		Spin (MW)			
				Hydro Emphasis		CT/ST Emphasis	
		Hydro	CT/ST	Hydro	CT/ST	Hydro	CT/ST
WP	Base	85	87	47.9	48.3	0.2	96.9
	Base - Cooper	72	72	41.7	36.9	0.2	79.3
	Base + Sold Max	92	93	70.6	61.1	0.2	149.9
	Base + Sold Min	95	94	66.6	84.2	0.2	149.9
SP	Base	86*	86*	38.2	47.6	0.2	87.3
	Base + Red. HEA Load	91**	91**	38.2	53.9	0.2	93.6
	Base - Cooper	66*	66*	38.2	31.0	0.2	70.8
	Base - Nikiski + Sold	73	72	41.8	37.0	0.2	80.1
	Base + Sold Max	96	93	68.5	62.7	0.2	129.6
	Base + Sold - Cooper	80	78	65.0	49.9	0.2	111.9
	Base + Sold Min	93	94	58.3	72.8	0.2	129.2
SV	Base	96	95	70.6	63.4	0.2	132.9
	Base - Cooper	84	81	64.5	53.2	0.2	115.3
	Base - Nikiski + Sold	90	89	65.0	58.3	14.0	107.7

Kenai area Base generation configuration includes 2-Bradley units, Nikiski CC, and 2-Cooper units online
Soldotna Min assumed to be 28 MW
* Limit may be larger, no spin remaining south of Dave's Creek
** Reduced load to increase export capacity

The two most significant outages that resulted in load shedding were the loss of the Kenai tie, and the trip of Beluga 5 (when online). Additionally, the loss of Healy 2 caused load shedding in some cases.

In all cases, there were spinning reserves online greater than the size of the outage. This also includes the Kenai tie outage case where the spin north of the tie outage was equal to or larger than the flow on the tie. However, the Kenai tie outage simulations were performed for flow levels at the stability limit which is greater than the voltage or thermal based limit in most cases.

The under-frequency response of the spinning reserves on the system consists of response from the Wilson BESS, the combustion turbines, and the hydro units. The response is a complex interaction of all these components.

A detailed analysis of the amount and quality of spin necessary to avoid load shedding per the performance criteria was not completed for the existing system study and is outside the scope of this study. Additionally, the issues of spin amounts and spin quality are impacted by all the generation changes that have recently occurred or are about to occur in the Railbelt. These changes include the addition of a number of lighter inertia units such as aero-derivative combustion turbines, combined with the retirement of the larger HRSG units.

The recommended system improvements include adding a BESS in the Anchorage area. The Anchorage BESS will assist in the prevention of load shedding and will also alleviate Kenai area transmission system overloads.

The UFLS results using the Hydro spin cases versus the CT/ST spin cases provide marginal insight into the difference in quality of spin. Some sensitivity cases were run that indicate that the UFLS results are dependent on how much spin is on hydro units versus combustion turbines, and on how many combustion turbines carry spin. However, a definitive evaluation of spin amounts and spin quality was outside the scope of the transmission planning study.

4.13.7 Bradley Lake Limits

The Bradley Lake Plant is limited in total plant output due to instabilities related to the loss of the Bradley Lake-Soldotna 115 kV line. At high plant output levels, when there is a fault and trip of the Bradley-Soldotna line, the Bradley Lake units lose synchronism with the remaining system. Historically, a remedial action scheme has been proposed for this event, but the RAS is not currently in service. Table 4-12 provides the approximate plant limits for each season, assuming that the RAS is not in service. Note that the loss of generation for a single line outage such as the Bradley Lake – Soldotna 115 kV line is not compliant with the transmission planning criteria. In addition to the stability, voltage, and thermal limits, the Bradley Lake plant limits must also be met to satisfy the performance criteria.

Table 4-12: Bradley Lake Plant Limits with No RAS

Season	Plant Limit with No RAS (MW)
WP	110
SP	111
SV	96

4.14 Anchorage-Fairbanks Alaska Intertie

The key objective for the existing Alaska Intertie portion of the study was to determine the maximum export limits along the Alaska Intertie. The export flow is measured at Douglas Substation with positive flow north toward Healy. Three key values are required to fully describe the flow from Anchorage to Fairbanks and to capture the limiting conditions. These values are (1) the flow north out of Douglas, (2) the generation at both Healy and Eva Creek, and (3) the total flow north leaving the Healy / Eva Creek area. Only two of these values can be varied independently. For each limiting condition, either the limit is reached along the Douglas line looking north, or along the two lines north out of the Healy / Eva Creek area toward Fairbanks. The limits described below include each of the three key quantities and identify where the limit is reached.

The export limits are determined based on the minimum stability limit. The Alaska Intertie is not constrained by the same thermal and voltage sensitivities as the Kenai Intertie does. Many generation scenarios were used to determine the export limit sensitivity to unit commitment and output in the Fairbanks, Healy, and Anchorage areas.

4.14.1 Generation Scenarios

The generation scenarios chosen to determine the stability limits for the Alaska Intertie are based on two initial assumptions. First, the Kenai area generation and export on the Kenai Intertie remains constant at the seasonal stability limit determined in this study. Second, eight generation scenarios for the Healy area generation were created to cover the potential generation configurations and variations in output. These scenarios ranged from all generation at its maximum output to no generation online in the Healy area. A description of the eight scenarios is presented in Table 4-13. The total range in generation is 0-114 MW.

Table 4-13: Healy Area Generation Scenarios

Dispatch	Healy Area Generation			Seasonal Generation (MW)		
	Healy #2	Healy #1	Eva Creek	WP	SP	SV
1	on	on	on	114	112	114
2	on	on	-	90	88	90
3	on	-	on	86	86	86
4	on	-	-	62	62	62
5	-	on	on	53	50	53
6	-	on	-	29	26	29
7	-	-	on	24	24	24
8	-	-	-	-	-	-

Tables 4-14 through 4-16 describe the generation scenarios used to determine the stability limits. Each season is shown with four different dispatches. Two of the dispatches represent the generation with a Hydro based emphasis on spin, while the other two represent the CT/ST spin emphasis cases. In these Tables, only two of the eight Healy area generation scenarios are provided. The two shown illustrate the two extreme cases with the Healy area generation at its maximum and minimum values. Appendix B illustrates a more detailed description of all of the generation scenarios used in the existing Alaska Intertie export analysis.

The Fairbanks area generation used in the Winter Peak and Summer Peak cases is similar to the SSS provided cases. The North Pole CC plant is online with Chena 5 and the other Department of Defense (DOD) generation. For some of the Summer Valley cases, the Fairbanks area generation was reduced to only Chena 5 online. This occurred when the amount of Healy area generation plus the Alaska Intertie flow provided all of the northern generation needs without reaching the stability limit.

In addition to the variations in the Alaska Intertie flow (export) directly caused by the changes in the Healy area generation, the export levels were adjusted by changing the North Pole CC Plant in the north, while Plant 2a was adjusted in the Anchorage area. In some Summer Valley cases, the Chena 5 unit was adjusted if the North Pole CC Plant was not online.

Table 4-14: Existing Winter Peak Base Case Dispatches

Description	Hydro Spin - 1, 2, Eva		Hydro Spin - None		CT/ST Spin - 1, 2, Eva		CT/ST Spin - None	
Case Name	wp_g220_s085_n054_h151		wp_g290_s085_n071_h053		wp_g320_s087_n055_h151		wp_g390_s087_n069_h050	
	Generation	Spin	Generation	Spin	Generation	Spin	Generation	Spin
Bradley Lake Hydro	115.7	4.3	115.7	4.3	119.8	0.2	119.8	0.2
Cooper Lake Hydro	14.0	5.6	14.0	5.6	19.6	-	19.6	-
Eklutna Hydro	2.0	38.0	2.0	38.0	40.0	-	40.0	-
Nikiski CC	60.8	0.2	60.8	0.2	53.9	7.1	53.9	7.1
Soldotna CT	-		-		-		-	
Tesoro	10.0	-	10.0	-	10.0	-	10.0	-
Beluga Plant	78.6	-	78.6	-	78.6	-	78.6	-
SPP	188.5	(0.0)	188.5	(0.0)	188.5	(0.0)	188.5	(0.0)
Plant 1	32.0	-	32.0	-	32.0	-	32.0	-
Plant 2a	111.4	3.7	95.6	19.4	72.2	42.8	53.9	61.2
EGS	119.0	-	153.0	-	119.0	-	153.0	-
Healy 1	28.5	-	-		28.5	-	-	
Healy 2	61.9	0.0	-		61.9	0.0	-	
Eva Creek	24.0	-	-	-	24.0	-	-	-
GVEA BESS	-	26.0	-	26.0	-	26.0	-	26.0
North Pole CC	46.4	18.6	51.2	13.8	43.9	21.1	51.2	13.8
Chena 5	-	-	23.0	-	-	-	23.0	-
UAF	11.0	-	11.0	-	11.0	-	11.0	-
Fort Wainwright	15.0	-	15.0	-	17.0	-	17.0	-
Eielson AFB	8.0	-	8.0	-	8.0	-	8.0	-
Fort Knox	(11.0)	-	(11.0)	-	(11.0)	-	(11.0)	-
Generation/Spin Total	915.8	96.4	847.5	107.2	916.9	97.3	848.5	108.2
Dave's North Spin		86.3		97.2		90.0		100.9
Hydro Spin		47.9		47.9		0.2		0.2
CT/ST Spin		48.6		59.4		97.1		108.0
Dave's Creek - Hope Flow	84.9		84.9		87.5		87.5	
Douglas - Stevens Flow	54.4		71.0		55.0		68.8	
Healy Export	151.0		53.0		151.0		50.0	

Table 4-15: Existing Summer Peak Base Case Dispatches

Description	Hydro Spin - 1, 2, Eva		Hydro Spin - None		CT/ST Spin - 1, 2, Eva		CT/ST Spin - None	
Case Name	sp_g220_s086_n047_h140		sp_g290_s086_n081_h060		sp_g320_s086_n047_h140		sp_g390_s086_n079_h058	
	Generation	Spin	Generation	Spin	Generation	Spin	Generation	Spin
Bradley Lake Hydro	119.8	0.2	119.8	0.2	119.8	0.2	119.8	0.2
Cooper Lake Hydro	19.6	-	19.6	-	19.6	-	19.6	-
Eklutna Hydro	2.0	38.0	2.0	38.0	40.0	-	40.0	-
Nikiski CC	51.1	-	51.1	-	51.1	-	51.1	-
Soldotna CT	-		-		-		-	
Tesoro	8.0	-	8.0	-	8.0	-	8.0	-
Beluga Plant	59.0	-	59.0	-	59.0	-	59.0	-
SPP	141.0	(0.0)	141.0	(0.0)	141.0	(0.0)	141.0	(0.0)
Plant 1	28.0	-	28.0	-	28.0	-	28.0	
Plant 2a	88.2	4.6	73.8	19.1	51.0	41.9	34.1	58.7
EGS	68.0	-	119.0	-	68.0	-	119.0	-
Healy 1	26.4	-	-		26.4	-	-	
Healy 2	61.9	0.0	-		61.9	0.0	-	
Eva Creek	24.0	-	-	-	24.0	-	-	-
GVEA BESS	-	26.0	-	26.0	-	26.0	-	26.0
North Pole CC	22.0	18.0	34.2	5.8	19.5	20.5	34.2	5.8
Chena 5	-	-	23.0	-	-	-	23.0	-
UAF	5.0	-	5.0	-	7.0	-	7.0	-
Fort Wainwright	15.0	-	15.0	-	15.0	-	15.0	-
Eielson AFB	10.0	-	10.0	-	10.0	-	10.0	-
Fort Knox	(11.0)	-	(11.0)	-	(11.0)	-	(11.0)	-
Generation/Spin Total	738.0	86.9	697.5	89.1	738.3	88.6	697.8	90.8
Dave's North Spin		86.7		88.9		88.4		90.6
Hydro Spin		38.2		38.2		0.2		0.2
CT/ST Spin		48.7		50.9		88.4		90.6
Dave's Creek - Hope Flow	85.5		85.5		85.5		85.5	
Douglas - Stevens Flow	47.0		81.0		47.3		78.6	
Healy Export	140.0		60.0		140.0		58.0	

Table 4-16: Existing Summer Valley Base Case Dispatches

Description Case Name	Hydro Spin - 1, 2, Eva sv_g220_s071_n0012_h086		Hydro Spin - None sv_g290_s071_n076_h058		CT/ST Spin - 1, 2, Eva sv_g320_s072_n0012_h086		CT/ST Spin - None sv_g390_s072_n079_h060	
	Generation	Spin	Generation	Spin	Generation	Spin	Generation	Spin
Bradley Lake Hydro	60.0	27.0	60.0	27.0	90.0	27.0	90.0	27.0
Cooper Lake Hydro	14.0	5.6	14.0	5.6	19.6	-	19.6	-
Eklutna Hydro	2.0	38.0	9.1	30.9	40.0	-	40.0	-
Nikiski CC	55.3	-	55.3	-	22.7	32.6	22.7	32.6
Soldotna CT	-		-		-		-	
Tesoro	2.9	-	2.9	-	2.9	-	2.9	-
Beluga Plant	-	-	-	-	-	-	-	-
SPP	109.1	(0.1)	109.1	(0.1)	72.9	36.1	95.5	13.5
Plant 1	-		-		-		-	
Plant 2a	26.9	28.5	110.7	0.1	24.3	31.1	95.4	15.4
EGS	17.0	-	17.0	-	17.0	-	17.0	-
Healy 1	28.5	-	-		28.5	-	-	
Healy 2	61.9	0.0	-		61.9	0.0	-	
Eva Creek	24.0	-	-	-	24.0	-	-	-
GVEA BESS	-	26.0	-	26.0	-	26.0	-	26.0
North Pole CC	-	-	26.8	26.2	-	-	24.4	28.6
Chena 5	20.0	-	20.0	-	20.0	-	20.0	-
UAF	-	-	-	-	-	-	-	-
Fort Wainwright	-	-	-	-	-	-	-	-
Eielson AFB	-	-	-	-	-	-	-	-
Fort Knox	-	-	-	-	-	-	-	-
Generation/Spin Total	421.6	125.0	424.9	115.7	423.8	152.9	427.5	143.2
Dave's North Spin		92.4		83.1		93.3		83.5
Hydro Spin		70.6		63.5		27.0		27.0
CT/ST Spin		54.4		52.2		125.9		116.2
Dave's Creek - Hope Flow	71.0		71.0		72.1		72.1	
Douglas - Stevens Flow	(12.0)		76.4		(12.0)		79.1	
Healy Export	86.0		58.0		86.0		60.0	

4.15 Results

TableTables 4-17 through 4-19, shown in the following subsections, present the stability based export limits determined for the Alaska Intertie. As previously mentioned, the Alaska Intertie is not limited by thermal or voltage based constraints as compared to the Kenai Intertie. Thus, the export limits are the also the stability limits unless limited by load. Note that the limits in 4-17 through 4-19 do not include any stability limit margin.

Values are shown in the Tables for each Healy area generation scenario, season, and spin configuration. Export flows are provided for the Douglas – Stevens line and the combined Healy area export. The combined Healy area export value is the sum of the Eva Creek generation and the two 138 kV line flows heading north out of Healy. Note that similar to the findings in the Kenai Intertie results, there is no significant difference between the Hydro and CT/ST spin cases in terms of the export limit. This is because the stability limits are derived from line outage contingencies and not from outages that create a generation / load imbalance condition.

The limiting contingencies for the stability limited cases vary depending on the amount of generation produced in the Healy area. Typically, for high generation levels in the Healy area (lower flows out of Douglas), the limiting contingency is located in the Healy area (such as for a fault near Healy on the Healy-Eva Creek Line). The results also show that the status of the Healy

1 unit impacts this limit. The majority of cases with Healy 1 online are limited by a Healy area fault. Recent Railbelt studies have also shown instabilities related to the status of Healy 1 and the initial reactive power output of the Healy 1&2 units. At higher reactive power outputs, the system is more sTable and can maintain slightly higher transfers.

For the lower generation levels in the Healy area (higher flows out of Douglas), the limiting contingencies are typically in the Anchorage area. These contingencies include faults near generation such as SPP and Plant 2a. 138 kV line faults near ITSS were the most limiting contingencies in many cases.

4.15.1 Winter Peak

The Winter Peak export limits range from 54-72 MW out of Douglas and 50-151 MW out of Healy. Note that the stated export levels are coincident and are limited by either a Healy area or Anchorage area fault and associated line outage. Thus, it is possible that the flows out of Douglas could be increased if the Healy exports are reduced for Dispatches 1 & 2.

Table4-17: Winter Peak Export Stability Limits

	Healy Area Generation				WP - Stability Export Limits (MW)			
					Hydro Emphasis		CT/ST Emphasis	
Dispatch	Healy #2	Healy #1	Eva Creek	Total (MW)	Douglas	Healy	Douglas	Healy
1	on	on	on	114	54	151	55	151
2	on	on	-	90	67	139	65	137
3	on	-	on	86	72	139	72	139
4	on	-	-	62	72	115	72	116
5	-	on	on	53	72	106	71	105
6	-	on	-	29	65	75	65	76
7	-	-	on	24	67	73	67	73
8	-	-	-	-	68	50	69	50

No shading indicates a Douglas flow or Anchorage based limiting contingency
Shading indicates a Healy export or Northern area limiting contingency

4.15.2 Summer Peak

The Summer Peak export limits range from 47-81 MW out of Douglas and 58-140 MW out of Healy. These results are similar to the Winter Peak results, although flows out of Douglas are increased by 12-13 MW for low levels of generation in the Healy area. During high levels of Healy area generation, the Douglas exports are lower than the Winter Peak cases.

Table 4-18: Summer Peak Export Stability Limits

	Healy Area Generation				SP - Stability Export Limits (MW)			
					Hydro Emphasis		CT/ST Emphasis	
Dispatch	Healy #2	Healy #1	Eva Creek	Total (MW)	Douglas	Healy	Douglas	Healy
1	on	on	on	112	47	140	47	140
2	on	on	-	88	61	130	62	130
3	on	-	on	86	69	135	69	135
4	on	-	-	62	79	120	80	120
5	-	on	on	50	71	101	72	102
6	-	on	-	26	77	83	78	83
7	-	-	on	24	80	83	80	83
8	-	-	-	-	81	60	79	58

No shading indicates a Douglas flow or Anchorage based limiting contingency
Shading indicates a Healy export or Northern area limiting contingency

4.15.3 Summer Valley

The Summer Valley results are very different compared to the peak cases due to the reduced load levels. For the majority of cases, the stability limit exceeds the export levels required to serve the Fairbanks area load. With the Healy area at its two lowest generation levels, the exports are stability limited with similar limits to the Summer Peak cases.

Table4-19: Summer Valley Export Stability Limits

	Healy Area Generation				SV - Stability Export Limits (MW)			
					Hydro Emphasis		CT/ST Emphasis	
Dispatch	Healy #2	Healy #1	Eva Creek	Total (MW)	Douglas	Healy	Douglas	Healy
1	on	on	on	114	(12)	86	(12)	86
2	on	on	-	90	12	86	12	86
3	on	-	on	86	16	86	16	86
4	on	-	-	62	41	86	41	86
5	-	on	on	53	49	84	49	84
6	-	on	-	29	64	75	64	75
7	-	-	on	24	79	84	79	84
8	-	-	-	-	76	58	79	60

No shading indicates a Douglas flow or Anchorage based limiting contingency
Shading indicates a Healy export or Northern area limiting contingency
Shading indicates Fairbanks at minimum generation, no stability limit

4.15.4 Sensitivity to Fairbanks Area Generation

For the Summer Valley cases where the stability limit was not reached (shaded in blue in the Tables), sensitivity cases were run associated with the GVEA generation in Fairbanks. For the summer valley cases, the minimum generation in Fairbanks was assumed to consist of the UAF and military generation, plus the Aurora unit (Chena 5). Sensitivity cases were run with the Aurora unit offline, such that only the UAF and DOD units were online in Fairbanks. In all these cases, the system remained sTable for the contingencies studied and the flows north out of Douglas and Healy were only limited by the minimum load in the Fairbanks area.

4.15.5 UFLS

The UFLS results related to the Alaska Intertie export limits can be placed into two categories. The first category is the loss of the Intertie. The loss of the tie can occur for any line outage between Teeland and Healy. The tie can also be lost for a fault on the 230 kV Pt. MacKenzie-Teeland line because this outage at higher flow levels will cause a trip of the 138 kV Teeland-Douglas line, islanding the system to the north.

The amount of load shedding that occurs when the northern system is islanded is dependent on the online generation north of Healy and the level of auto scheduling on the GVEA BESS. Although two stages of load shedding does occur in some cases for a Healy area fault on the tie, with the BESS scheduled at a high value, the use of auto scheduling shows a clear improvement over outages south of Douglas where the BESS is not auto-scheduled. However, these cases are compliant with the transmission planning criteria because the outages create an islanding condition, and the actual load shedding is less than the allowable amount of load shedding per the criteria.

The results for the Winter Peak and Summer Peak seasons are similar. The Summer Valley season is more sensitive to load shedding simply because of the lightly loaded system and minimum amount of generation online.

The other category where UFLS occurs is for the loss of a generation unit. These cases are essentially identical to the Kenai tie lines with respect to load shedding. As expected, the largest units cause the most load shedding. In the majority of Winter Peak cases, Beluga 5 at full output causes one stage of load shedding. No load shedding for unit trips occurred in the Summer Peak cases. This is primarily due to the reduced summer rating of Beluga 5. The Summer Valley cases produce some load shedding for the loss of the Healy 2 unit, and in one case for Healy 1. As many as two stages of load shedding occur for Healy 2 outages without auto-scheduling of the Wilson BESS. At least one stage of load shedding can be avoided for the loss of Healy 2 if auto-scheduling of the BESS occurs.

4.16 Kenai Area System Improvements

The system improvements associated with the Kenai area are recommended to provide increased and firm energy transfers to the southcentral and northern areas of the Railbelt system from the Kenai. The projects recommended are the same as those that were recommended in the 2014 Draft Plan. This study establishes updated system limits and capabilities with the recommended improvements in place.

4.17 System Improvement Projects

4.17.1.1 100 MW HVDC Intertie Beluga - Bernice Lake

Currently, the Kenai Intertie has one connection available for transfers, thus eliminating the ability to provide firm energy transfers to the Anchorage area. To facilitate firm energy transfers, a second line is needed connecting the Kenai and Anchorage areas. The second line also helps to eliminate load shedding from occurring with the loss of the tie, because the system will not island and cause an under-frequency condition in the area north of the tie.

The HVDC tie line is recommended with connections at Bernice Lake Substation and Beluga Switchyard. The HVDC line is nominally rated at 75 MW with a 100 MW continuous overload capacity. The overload capacity is required in order to increase the scheduled flow along the

HVDC tie if the existing AC Kenai tie opens. The overload capacity needs to be available for a period of time long enough to re-dispatch generation or add any necessary generation to the system in order to reduce the initial impact of a loss of the existing AC Kenai tie. Thus the HVDC tie allows for 100 MW firm transfer capacity with the loss of the existing AC tie.

4.17.1.2 2nd Bradley Lake – Soldotna Line

In addition to providing firm transfers by adding a second tie to the Kenai, unconstraining the Bradley Lake output is beneficial. A second line from Bradley Lake to Soldotna Substation is recommended and is necessary to unconstrain the output of Bradley Lake. Without a second line, high transfer levels out of Bradley Lake are not possible without violating the planning criteria. Adding the second line eliminates this restriction, reduces losses, and also eliminates the existing thermal constraints when a Bradley Lake line is out of service.

4.17.1.3 230 kV Conversion University – Dave's Creek

The existing 115 kV University to Dave's Creek line is recommended to be converted to 230 kV. The recommendation is primarily based on the economic benefit attained by the reduction in losses across the line. A secondary benefit is the stability export limits are increased with this line converted to 230 kV. In addition to 230 kV related conversion requirements, a 10 MVAr reactor is required at Dave's Creek Substation for voltage control.

4.17.1.4 Reconductor Dave's Creek – Quartz Creek

The 115 kV line from Quartz Creek to Dave's Creek is recommended to be reconductored to alleviate the overload conditions that can occur during summer conditions. Reconductoring to 954 ACSR conductor will unconstrain Cooper Lake generation in the summer for the loss of the HVDC tie at high transfer levels. Additionally, the reconductoring will slightly decrease the losses along the tie.

4.17.1.5 35 MW BESS – Anchorage Area

An Anchorage area BESS rated at 35 MW is recommended for steady state and dynamic improvements. In steady state, a 35 MW BESS is required to alleviate overloads on the AC Kenai Intertie when the HVDC tie is out of service. The operation of the BESS provides time for the Anchorage area generation to be re-dispatched. The overloads occur in the summer during heavy export conditions. The BESS is sized for these overload conditions.

The BESS also provides dynamic response for unit outages and can assist the system response for the loss of the either of the two recommended Kenai Intertie lines (AC or DC), especially during heavy export conditions. Load shedding for single contingencies will be eliminated with the use of the BESS.

4.18 Generation Scenarios

With the recommended Kenai Area improvements added to the existing system seasonal models, the system was evaluated to determine the improved export limits. The Winter Peak and Summer Peak seasons were the focus of the analysis. The Summer Valley case was not relevant in determining economic benefits of higher export limits.

Two basic generation scenarios were created for each season. The difference between the scenarios is the status of the Cooper Lake generation. No sensitivities for the type of spin were studied due to the minimal difference in stability results found during the existing system analysis. For all cases, a scheduled HVDC tie flow of 75 MW was assumed for the initial condition. Tables 4-20 and 4-21 describe the generation scenarios used for the analysis. A detailed listing of all of the generation and other system information can be found in Appendix C. Note that the recommended 35 MW Anchorage area BESS is not included in the spinning reserve totals in the Tables.

Table4-20: Winter Peak Generation Scenarios

Description	Base		Base - Cooper Offline	
Case Name	wp_g020_s148_n016_h099_u019		wp_g021_s128_n016_h099_u019	
	Generation	Spin	Generation	Spin
Bradley Lake Hydro	119.8	0.2	119.8	0.2
Cooper Lake Hydro	19.6	-	-	-
Eklutna Hydro	28.0	12.0	26.0	14.0
Nikiski CC	60.8	0.2	60.8	0.2
Soldotna CT	49.0	0.2	49.0	0.2
Tesoro	10.0	-	10.0	-
Beluga Plant	-	-	-	-
SPP	188.5	(0.0)	188.5	(0.0)
Plant 1	-		-	
Plant 2a	90.6	24.4	94.7	20.4
EGS	119.0	-	136.0	-
Healy 1	28.5	-	28.5	-
Healy 2	61.9	0.0	61.9	0.0
Eva Creek	10.0	-	10.0	-
GVEA BESS	-	26.0	-	26.0
North Pole CC	64.7	0.3	64.7	0.3
Chena 5	23.0	-	23.0	-
UAF	11.0	-	11.0	-
Fort Wainwright	19.0	-	19.0	-
Eielson AFB	10.0	-	10.0	-
Fort Knox	(11.0)	-	(11.0)	-
Generation/Spin Total	902.3	63.4	901.8	61.3
Dave's North Spin		62.8		60.7
Hydro Spin		12.2		14.2
CT/ST Spin		51.2		47.1
Dave's Creek - Hope Flow	72.5		53.3	
HVDC Tie Flow	75.0		75.0	
Total Kenai Export	147.5		128.3	
Douglas - Stevens Flow	15.7		15.7	

Table 4-21: Summer Peak Generation Scenarios

Description Case Name	Base sp_g020_s131_n013_h089_u019		Base - Cooper Offline sp_g021_s112_n013_h089_u019	
	Generation	Spin	Generation	Spin
Bradley Lake Hydro	119.8	0.2	119.8	0.2
Cooper Lake Hydro	19.6	-	-	-
Eklutna Hydro	12.0	28.0	10.0	30.0
Nikiski CC	51.1	-	51.1	-
Soldotna CT	40.0	0.1	40.0	0.1
Tesoro	8.0	-	8.0	-
Beluga Plant	-	-	-	-
SPP	141.0	(0.0)	141.0	(0.0)
Plant 1	-		-	
Plant 2a	81.8	11.1	85.9	7.0
EGS	68.0	-	85.0	-
Healy 1	26.4	-	26.4	-
Healy 2	61.9	-	61.9	-
Eva Creek	6.0	-	6.0	-
GVEA BESS	-	26.0	-	26.0
North Pole CC	40.0	-	40.0	-
Chena 5	23.0	-	23.0	-
UAF	11.0	-	11.0	-
Fort Wainwright	15.0	-	15.0	-
Eielson AFB	10.0	-	10.0	-
Fort Knox	(11.0)	-	(11.0)	-
Generation/Spin Total	723.6	65.3	723.1	63.2
Dave's North Spin		65.1		63.0
Hydro Spin		28.2		30.2
CT/ST Spin		37.1		33.0
Dave's Creek - Hope Flow	56.0		36.8	
HVDC Tie Flow	75.0		75.0	
Total Kenai Export	131.0		111.8	
Douglas - Stevens Flow	12.9		12.9	

4.19 Results

The results of the analysis show that the 2016 system with the recommended system improvements has greatly increased transfer limits as compared to the existing system. The transfer limits are not based on stability, voltage, or thermal limits as they are in the existing system study, but instead are limited by the amount of Kenai Area generation. No margin has been applied to these limits.

The generation limits in the Kenai area include the Bradley Lake, Nikiski, and Soldotna Plants at full output. These units have a total output of 230 MW in the winter and 211 MW in the summer. These generation and export levels allow for the entire amount of unconstrained Bradley Lake generation to be provided to each utility.

Table 4-22 describes the improved system export limits along with the existing system limits. For all seasons and generation scenarios, the transfers from the Kenai to Anchorage areas have been more than doubled with the improvements. More detailed results can be found in E.

Table 4-22: Existing/Future Kenai Area Export Limits

Season	Bradley Lake	Nikiski CC	Soldotna	Cooper Lake	Existing System		Future System	
					Limit (MW)	Limit Type	Limit (MW)	Limit Type
WP	both online	on	on	both online	61	Voltage	148	Generation
	both online	on	on		57	Voltage	128	Generation
SP	both online	on	on	both online	55	Thermal	131	Generation
	both online	on	on		48	Thermal	112	Generation

4.19.1 BESS Sizing

Table 4-23 shows the minimum required BESS size for all seasons and generation scenarios. The sizing estimate is based on adding generation in the Anchorage area to alleviate the overloaded 115 kV line sections on the AC Kenai Intertie following the loss of the HVDC tie. The recommended size of 35 MW is sufficient for relieving overloads for all seasons, and also provides the benefit of eliminating load shedding for many unit outage contingencies.

Table4-23: BESS Sizing Requirements

Season	Bradley Lake	Nikiski CC	Soldotna	Cooper Lake	BESS Size (MW)
WP	both online	on	on	both online	10
	both online	on	on		15
SP	both online	on	on	both online	33
	both online	on	on		33

4.19.2 UFLS

No UFLS occurs for the improved system. This is primarily due to the additional HVDC tie line and 35 MW BESS. Note that for the loss of the AC tie, an increase of 25 MW of flow is assumed for the scheduled flow on the HVDC tie.

4.20 Southcentral and Northern Area System Improvements

The system improvements associated with the southcentral and northern areas are required in order to provide increased and firm energy transfers between the southcentral and northern areas of the Railbelt system. The recommended projects are the same as those recommended in the 2014 Draft Plan for the southcentral and northern areas. This study establishes updated operating conditions and limitations with the recommended improvements in place.

4.20.1 Southcentral System Improvement Projects

4.20.1.1 Fossil Creek 115 kV Substation

This project includes the construction of a 115 kV substation near the existing Briggs Tap/Fossil Creek on the Eklutna – ML&P transmission line. The project includes the construction of a 115 kV substation to interconnect the Eklutna Express circuit, the Eklutna local circuit, the Briggs Tap circuit, and the ML&P express circuit with provisions for possible future 230/115 kV transformers and Raptor substation interconnections. This project provides a redundant path for the MEA substations between EGS and Briggs Tap and improves the system compliance with the transmission planning criteria.

4.20.1.2 Eklutna Hydro 115 kV Substation

This project includes the construction of a new 115 kV substation at the Eklutna Hydro Plant. The Eklutna substation is currently located on the roof of the Eklutna Power Plant and has no room for expansion. The new substation will be constructed adjacent to the power plant. The project includes the construction of a 115 kV substation to interconnect the Eklutna Express circuit, the Eklutna local circuit, and the 115 kV Palmer circuit as well as the generating units at the plant. This project also improves the MEA system compliance with the transmission planning criteria.

4.20.1.3 Lake Lorraine 230 kV Substation

This project includes the construction of a 230 kV substation, near the junction where the two 230 kV lines traveling north from Pt. MacKenzie separate and travel in different directions. The line to Teeland continues north while the line to West Terminal travels east. This location is in the vicinity of Lake Lorraine. The substation will intersect the Pt. Mackenzie – Teeland and Pt. Mackenzie – Plant 2 230 kV transmission lines. The substation will be built to include six line terminations, two 230 kV lines to Pt. Mackenzie, one 230 kV line to Teeland, one 230 kV line to Plant 2, and two 230 kV lines to Douglas. Terminals at the substation will also be included for reactive compensation and a possible future 230/115 kV transformer.

A -40/+25 MVAr SVC is also recommended at Lake Lorraine to control voltages on the 230 kV Railbelt system. The proposed substation location is near one end of the undersea 230 kV cable, maximizing the effect of the reactive compensation in terms of its ability to limit the undersea cable voltages to below 1.02 per unit, per the planning criteria for voltages along the undersea cables.

The addition of the Lake Lorraine 230 kV substation, along with the proposed lines to Douglas, eliminates 26 miles of single contingency 230 kV line from Pt. Mackenzie to Teeland and an additional 26 miles of single contingency exposure from Teeland to Douglas (all along the Alaska Intertie) and provides a connection point for transmission line additions recommended to Douglas substation.

4.20.1.4 Douglas Substation Expansion

This project includes the construction of a 230 kV/138 kV substation at the existing Douglas substation near Willow, Alaska. The substation will serve as the voltage conversion for the 138 kV Anchorage-Fairbanks Intertie and will include two 230 kV/138 kV substation transformers. The station will be constructed to include two 230 kV/138 kV power transformers, two 230 kV transmission line terminations (Lorraine to Douglas), two 138 kV transmission line terminations (Healy/Gold Creek) built to 230 kV but operated at 138 kV, one 138 kV/24.9 kV power transformer, and one 138 kV line (Teeland).

4.20.1.5 Lake Lorraine - Douglas 230 kV Transmission Lines

This project includes the construction of two 42-mile, 230 kV transmission lines from Lake Lorraine substation to Douglas Substation. The transmission line additions eliminate 50 miles of single contingency 230 kV/138 kV line to Fairbanks on the Alaska Intertie. Note that two lines on separate towers are required in order to be compliant with the transmission planning criteria.

4.20.2 Northern System Improvement Projects

4.20.2.1 Gold Creek 138 kV Substation

This project includes the construction of a 230 kV (operated at 138 kV) substation near Gold Creek on the Alaska Intertie. The station will provide compensation and sectionalizing support for the recommended Anchorage – Healy transmission lines and will include 4 line terminals and two reactors.

The addition of the Gold Creek substation will reduce the reactive support requirements for the proposed lines by more than 50% compared to locating support at Douglas and/or Healy. The station also improves the stability and sectionalizing capability by dividing the Douglas to Healy lines by approximately 50% of its existing length. The Gold Creek substation will utilize two 15 MVAr reactors to control voltage along the lines between Healy and Douglas. The reactors can remain in service even during heavy transfer conditions without the voltage decreasing below limits.

4.20.2.2 Healy 230 kV Substation

This project includes the construction of a 230 kV substation near Healy, Alaska on the Alaska Intertie. The substation will be operated at 138 kV for the lines to the south (operated at 138 kV to Gold Creek). The station will provide the termination for a new line from Gold Creek into Healy. The station will be constructed for possible future operation at 230 kV to Gold Creek. The station will include terminations for two 230 kV (operated at 138 kV) lines to Gold Creek, one 230 kV line to GVEA's Wilson Substation and one 230 kV line to GVEA's Gold Hill Substation, and a line to the existing Healy plant.

4.20.2.3 2nd Douglas - Healy 230 kV Transmission line (operated at 138 kV)

This project includes the construction of a 171-mile, 230 kV (operated at 138 kV) transmission line from Douglas Substation to Healy Substation, interconnecting with the proposed new Gold Creek Substation. The line will be constructed as a single-circuit transmission line utilizing construction similar to the existing Anchorage-Fairbanks Intertie at 230 kV. The line will utilize bundled, 954 conductor to minimize losses and match the characteristics of the existing Douglas – Healy line. The line will terminate at the Douglas, Gold Creek, and Healy Substations.

The addition of the second 138 kV line from Healy to Douglas greatly increases the reliability of energy transfers into Healy and significantly reduces losses. The second line eliminates GVEA islanding due to single contingencies and allows the import of energy into the GVEA system to become firm, allowing economic transfer of energy and more flexibility in capacity sharing and planning. The transfer levels also increase due to the addition of this line.

The addition of this line completes a corridor of transmission infrastructure between the Lake Lorraine Substation (including the proposed Lorraine – Douglas lines) in the Anchorage area and the Healy Substation near Fairbanks.

4.20.2.4 230 kV Conversion Healy – Fairbanks

The recommended 230 kV upgrade includes rebuilding the Healy to Gold Hill line utilizing 230 kV construction and 954 "Rail" conductor. The existing Healy – Wilson line is already built to 230 kV standards. The conversion will include 150 MVA, 230 kV/138 kV transformers at Healy, Gold Hill, and Wilson Substations. The distribution substations located between Healy-Gold Hill will also be upgraded to 230 kV operation.

4.20.2.5 Communication Infrastructure

This project includes the development and installation of communication infrastructure between the Teeland, Lorraine, Douglas, Gold Creek, and Healy Substations. The communications will be used for high-speed protective relaying communications between control areas and for control and monitoring of the substation equipment. This positively impacts the proposed system by decreasing the clearing times for line faults between Healy and Lorraine Substations.

4.20.3 Generation Scenarios

With the recommended Kenai, Southcentral, and Northern area improvements added to the existing system seasonal models, the system was re-evaluated to determine the improved export limits. All seasons were included in the analysis.

Similar to the existing system study for the Northern system, the eight generation scenarios for the Healy area generation were used. Table 4-24 through 4-26 describe the two of the generation scenarios used for each season. The two scenarios shown illustrate the two extreme cases with the Healy area generation at its maximum and minimum values. The Kenai area generation is the same configuration that was used to produce the maximum flow conditions in the recommended Kenai Intertie results.

No sensitivities for the type of spin were studied due to the minimal difference in stability results found during the existing system analysis, for line outages. Appendix D illustrates a more detailed description of all of the generation scenarios used in the improved Alaska Intertie export analysis. Note that the 35 MW BESS is not included in the spinning reserve totals in the Tables.

Table 4-24: Winter Peak Generation Scenarios

Description	Healy 1, 2, Eva		None	
Case Name	wp_g220_s148_n094_h189_u100		wp_g290_s148_n171_h149_u100	
	Generation	Spin	Generation	Spin
Bradley Lake Hydro	119.8	0.2	119.8	0.2
Cooper Lake Hydro	19.6	-	19.6	-
Eklutna Hydro	2.0	38.0	32.0	8.0
Nikiski CC	60.8	0.2	60.8	0.2
Soldotna CT	49.0	0.2	49.0	0.2
Tesoro	10.0	-	10.0	-
Beluga Plant	78.6	-	78.6	-
SPP	188.5	(0.0)	188.5	(0.0)
Plant 1	-		32.0	-
Plant 2a	100.7	14.3	101.1	13.9
EGS	136.0	-	153.0	-
Healy 1	28.5	-	-	
Healy 2	61.9	0.0	-	
Eva Creek	24.0	-	-	-
GVEA BESS	-	26.0	-	26.0
North Pole CC	-	-	39.0	26.0
Chena 5	5.0	-	5.0	-
UAF	11.0	-	11.0	-
Fort Wainwright	14.0	-	14.0	-
Eielson AFB	8.0	-	8.0	-
Fort Knox	(11.0)	-	(11.0)	-
Generation/Spin Total	906.4	79.0	910.5	74.5
Dave's North Spin		78.4		73.8
Hydro Spin		38.2		8.2
CT/ST Spin		40.8		66.3
Dave's Creek - Hope Flow	72.5		72.5	
HVDC Tie Flow	75.0		75.0	
Total Kenai Export	147.5		147.5	
Douglas - Stevens/GC Flow	94.0		171.0	
Healy Export	189.0		149.0	

Table 4-25: Summer Peak Generation Scenarios

Description Case Name	Healy 1, 2, Eva sp_g220_s131_n054_h147_u100		None sp_g290_s131_n172_h147_u100	
	Generation	Spin	Generation	Spin
Bradley Lake Hydro	119.8	0.2	119.8	0.2
Cooper Lake Hydro	19.6	-	19.6	-
Eklutna Hydro	4.0	36.0	4.0	36.0
Nikiski CC	51.1	-	51.1	-
Soldotna CT	40.0	0.1	40.0	0.1
Tesoro	8.0	-	8.0	-
Beluga Plant	-	-	59.0	-
SPP	141.0	(0.0)	141.0	(0.0)
Plant 1	-		28.0	-
Plant 2a	81.2	11.7	80.3	12.5
EGS	119.0	-	153.0	-
Healy 1	26.4	-	-	
Healy 2	61.9	0.0	-	
Eva Creek	24.0	-	-	-
GVEA BESS	-	26.0	-	26.0
North Pole CC	-	-	-	-
Chena 5	5.0	-	5.0	-
UAF	10.0	-	10.0	-
Fort Wainwright	15.0	-	15.0	-
Eielson AFB	10.0	-	10.0	-
Fort Knox	(11.0)	-	(11.0)	-
Generation/Spin Total	725.0	74.0	732.8	74.8
Dave's North Spin		73.7		74.5
Hydro Spin		36.2		36.2
CT/ST Spin		37.8		38.6
Dave's Creek - Hope Flow	56.1		56.1	
HVDC Tie Flow	75.0		75.0	
Total Kenai Export	131.1		131.1	
Douglas - Stevens/GC Flow	54.0		172.0	
Healy Export	147.0		147.0	

Table 4-26: Summer Valley Generation Scenarios

Description Case Name	Healy 1, 2, Eva sv_g220_s135_n0010_h088_u100		None sv_g290_s135_n106_h088_u100	
	Generation	Spin	Generation	Spin
Bradley Lake Hydro	119.8	0.2	119.8	0.2
Cooper Lake Hydro	19.6	-	19.6	-
Eklutna Hydro	2.0	38.0	2.0	38.0
Nikiski CC	55.3	-	55.3	-
Soldotna CT	-		-	
Tesoro	2.9	-	2.9	-
Beluga Plant	-	-	-	-
SPP	54.5	(0.0)	109.1	(0.1)
Plant 1	-		-	
Plant 2a	19.3	36.0	47.6	7.8
EGS	17.0	-	51.0	-
Healy 1	28.5	-	-	
Healy 2	61.9	0.0	-	
Eva Creek	24.0	-	-	-
GVEA BESS	-	26.0	-	26.0
North Pole CC	-	-	-	-
Chena 5	5.0	-	5.0	-
UAF	1.5	-	1.5	-
Fort Wainwright	5.0	-	5.0	-
Eielson AFB	5.0	-	5.0	-
Fort Knox	-	-	-	-
Generation/Spin Total	421.4	100.3	423.8	71.9
Dave's North Spin		143.4		71.7
Hydro Spin		38.2		38.2
CT/ST Spin		105.4		33.7
Dave's Creek - Hope Flow	59.7		59.7	
HVDC Tie Flow	75.0		75.0	
Total Kenai Export	134.7		134.7	
Douglas - Stevens/GC Flow	(10.0)		106.0	
Healy Export	88.0		88.0	

4.21 Results

The results of the analysis show that the system with the recommended system improvements has greatly increased transfer limits. Similar to the Kenai export limits, the improved Alaska Intertie limits are not based on stability limits as they are in the existing system, but are limited by the amount of load found north of Healy.

Tables 4-27 through 4-29 describe the improved system export limits along with the existing system limits for all seasons. Note that these limits do not include any added margin. For all seasons and generation scenarios, the transfers from Douglas and Healy have been increased with the improvements. With the exception of three of the Winter Peak cases with reduced levels of Healy area generation, the export limits are only limited by the amount of load found north of Healy and the estimated minimum generation requirements in the Fairbanks area. More detailed results can be found in Appendix F.

Table 4-27: Winter Peak Existing/Future Southcentral Export Limits

	Healy Area Generation				WP - Stability Export Limits (MW)			
					Existing		Future	
Dispatch	Healy #2	Healy #1	Eva Creek	Total (MW)	Douglas	Healy	Douglas	Healy
1	on	on	on	114	54	151	94	189
2	on	on	-	90	67	139	119	190
3	on	-	on	86	72	139	123	189
4	on	-	-	62	72	115	149	190
5	-	on	on	53	72	106	159	189
6	-	on	-	29	65	75	175	181
7	-	-	on	24	67	73	163	166
8	-	-	-	-	68	50	171	149

Shading indicates a Healy export or Northern area limiting contingency
Shading indicates Fairbanks at minimum generation, no stability limit

Table 4-28: Summer Peak Existing/Future Southcentral Export Limits

	Healy Area Generation				SP - Stability Export Limits (MW)			
					Existing		Future	
Dispatch	Healy #2	Healy #1	Eva Creek	Total (MW)	Douglas	Healy	Douglas	Healy
1	on	on	on	112	47	140	54	147
2	on	on	-	88	61	130	79	147
3	on	-	on	86	69	135	81	147
4	on	-	-	62	79	120	106	147
5	-	on	on	50	71	101	118	147
6	-	on	-	26	77	83	144	147
7	-	-	on	24	80	83	146	147
8	-	-	-	-	81	60	172	147

Shading indicates Fairbanks at minimum generation, no stability limit

Table 4-29: Summer Valley Existing/Future Southcentral Export Limits

	Healy Area Generation				SV - Stability Export Limits (MW)			
					Existing		Future	
Dispatch	Healy #2	Healy #1	Eva Creek	Total (MW)	Douglas	Healy	Douglas	Healy
1	on	on	on	114	(12)	86	(10)	88
2	on	on	-	90	12	86	14	88
3	on	-	on	86	16	86	18	88
4	on	-	-	62	41	86	43	88
5	-	on	on	53	49	84	52	88
6	-	on	-	29	64	75	77	88
7	-	-	on	24	79	84	81	88
8	-	-	-	-	76	58	106	88

Shading indicates Fairbanks at minimum generation, no stability limit

4.21.1 Sensitivity to Fairbanks Area Generation

For the future system cases where the stability limit was not reached (shaded in blue in the Tables), sensitivity cases were run associated with the GVEA generation in Fairbanks. The minimum generation in Fairbanks was initially assumed to consist of the UAF and military generation, plus the Aurora unit (Chena 5). Sensitivity cases were run with the Aurora unit offline, such that only the UAF and DOD units were online in Fairbanks. In almost all cases, the system remained stable for the contingencies studied and the flows north out of Douglas and Healy were only limited by the load in the Fairbanks area. For the future system, in the winter peak condition, the only scenarios where additional generation beyond the UAF and DOD generation were required were the cases with Healy 2 offline. All other cases were stable with no GVEA generation online in Fairbanks.

4.21.2 UFLS

No UFLS occurs for the improved system. This is primarily due to the 35 MW BESS and the other system improvements that create two transmission paths into each area of the system.

4.22 Conclusions

The updated system study results including the recommended improvements confirm that the recommendations to the transmission system provide increased transfer capacities and can un-constrain generation per the technical objectives of the study. Overall, the objectives of the Final Plan are met by improving reliability, mitigating future cost increases to Railbelt rate payers, allowing unconstrained energy transfers and use of peaking capacity from the Bradley Lake hydroelectric project, and increasing energy transfers between all areas of the Railbelt.

The updated study for the Final Plan includes the recently adopted set of Railbelt Utility Reliability Standards as well as the most current Railbelt system models. The current Railbelt models incorporate various changes to the system including refinements to the dynamic response of the system.

5 Production Cost Simulations

5.1 The Structure of the Model

The model employed for these analyses was the PROMOD IV® power system production modeling program, the core of which produces unit commitment and economic dispatch solutions. The particular configuration of PROMOD for this work included the Hourly Monte Carlo, (HMC), module to simulate generator forced outages and the Transmission Analysis Module, (“TAM”), to incorporate a branch-by-branch, bus-by-bus model of the transmission system being studied. The use of these two modules allows the generation dispatch to be represented by a set of deterministic hourly chronological values for each load, generation source and branch flow. This enables the program to produce an economic dispatch that respects line and interface flow limits, survives contingencies, as well as respecting the various system and generator constraints.

5.2 Assembling the Data

The data assembly for this configuration of PROMOD begins with importing, into the program, the “raw” file resulting from a PSS/E load flow run of the transmission system involved in the analysis. The power flow data is used by PROMOD to set up a bus-by-bus, branch-by-branch model of the system as part of its data.

System data is input to PROMOD to set up an organizational structure of areas, companies and pools and the relationships among them. In addition, there are included requirements for operating, spinning and regulation reserves for companies and/or pools.

The individual generation resources are "mapped" to their appropriate busbars in the transmission data, then the data describing the ownership, nature, operating characteristics and operating costs of each generating resource are loaded into the production modeling data Tables. Most operating data can vary on a monthly basis, but where necessary specific items can vary hourly or daily. This data includes fuels, emissions and non-fuel operation and maintenance costs.

Data defining a particular run is also input to the program and includes the nature of the run, the time period involved and the outputs required. All of the data input up to this point is stored in a data file written in the program's porTable file format, (".PFF").

Load data, including weekly peak load & energy and hourly load shape for each area is provided in a separate file, which is read into PROMOD at the time of execution. PROMOD converts this data into hour-by-hour Company loads that it "maps" to the load busses. Also read in at execution, is a file of information, (the EVENT file,) concerning the various line and interface flow limits and contingencies to be obeyed and considered in developing a least cost dispatch.

Because two different transmission systems were involved in this study, the existing transmission and the upgraded transmission, two different Transmission/Production datasets were created as described above, as well as two different Event files. Only one Load file was required.

5.3 Data Sources

EPS Inc. Provided the PSS/E raw files for the two transmission systems, as well as a description of the reserve requirements and transmission flow limitations for the two cases.

With the exception of the fuel price data, the production data was mainly the result of the modeling process recently carried out with the utilities as part of the activities of their Economic Dispatch Group, ("EDG").

Because the EDG data was developed for the 2020 year, and this study was being performed for the year 2030, various cost items such as Variable O&M costs and Natural Gas transportation costs had to be escalated. The year-to-year escalation rates used for this task were the GDP deflators implicit in the Tables of the projected fuel price information found in the Energy Information Administration's, ("EIA's"), 2016 Annual Energy Outlook, ("AEO"), Reference Case.

The load projection used in the Base Case of this study was based on the EDG load projections, but were not as pessimistic. The non-mining load was escalated from 2020 to 2030 at very low rates, which were different for each company, and the Fort Knox mine was assumed to remain in production. The low load scenario in this study assumed Ft. Knox would close and the high load scenario assumed that the Livengood Mine would be developed by 2030 and the Fort Knox load would remain on the GVEA system.

The Fuel prices in the Base Case were derived from the 2020 EDG fuel prices with adjustments intended to remove the effect of current contracting and adjustments to include the price movements in the EIA 2016 AEO Reference Case. High and Low price projections made use of two other AEO cases, as recorded in Section 5.4 below.

Details of the Base Case and sensitivity runs developed in this study are in the following Section 5.4.

5.4 Base Case and Sensitivities

Eight Cases were developed to explore the value of the transmission upgrades in alternative future conditions. The alternatives were made up of various cases for loads, fuel costs and generation resources, as shown in Tables 5-1 and 5-2.

Table 5-1: Load Alternatives

Sensitivity	Load	Fuel Costs	Resources
Base Case	Base Case	Base Case	Base Case
High Load	High Load	Base Case	Base Case
Low Load	Low Load	Base Case	Base Case
Retire Old Coal	Base Case	Base Case	Ret. Aurora-Healy 1
LNG for NPCC	Base Case	Base Case	LNG for NPCC
High Fuel	Base Case	High Fuel Cost	Base Case
Low Fuel	Base Case	Low Fuel Cost	Base Case
Rebuild North Pole	Base Case	Base Case	Rebuild North Pole

5.5 Loads

Table 5-2: Load Sensitivities

		GWh					
Year 2020		**Railbelt**	**GVEA**	**MEA**	**ML&P**	**CEA/SES**	**HEA**
Base Case		5078.6	1467.9	782.0	1079.8	1283.9	465.1
Lower Load							
Sensitivity		4771.2	1160.5	782.0	1079.8	1283.9	465.1
Higher Load							
Sensitivity		5653.2	2042.5	782.0	1079.8	1283.9	465.1
Year 2030							
Base Case		**5175.4**	**1491.3**	**813.8**	**1090.6**	**1309.8**	**469.8**
Lower Load							
Sensitivity		**4868.0**	**1183.9**	**813.8**	**1090.6**	**1309.8**	**469.8**
Higher Load							
Sensitivity		**5750.0**	**2065.9**	**813.8**	**1090.6**	**1309.8**	**469.8**

Notes

1. The Lower Load sensitivity represents the loss of the GVEA Fort Knox mine load.
2. The Base Case load represents the retention of Fort Knox load

3 The Higher Load sensitivity represents the addition of the Livengood mine load to GVEA's load.
4 The remainder of GVEA's load is grown at a rate of 0.2 %/year.
5 MEA, ML&P, CEA/SES and HEA loads are grown at 0.4, 0.1, 0.2 and 0.1 %/year respectively.

5.6 Escalation

As a general escalation rate, used for cost items such as non-fuel operation and maintenance expense and natural gas transportation costs, the GDP deflator, used by the EIA in the 2016 AEO Reference Case, was chosen (Table 5-3).

Table 5-3: Escalation Rates

Year	GDP Deflator
2016	2.04
2017	2.04
2018	2.04
2019	2.04
2020	2.04
2021	2.06
2022	2.06
2023	2.06
2024	2.06
2025	2.06
2026	2.00
2027	2.00
2028	2.00
2029	2.00
2030	2.00

5.7 Fuel Prices – Base Case

The Base Case fuel prices were first developed for the year 2020 from the fuel prices contributed by the utilities. As far as possible, the effects of contract timing and short term special deals were removed from the individual utility projections. Commodity price changes beyond 2020 were derived for the individual fuels from the "Reference case" projections of the EIA's 2016 AEO. Table 5-4 shows Base Case projections for 2020 and 2030. NG delivery was escalated at the GDP deflator.

Table 5-4: Base Case Projections

Fuel Item	Location	2020 Price c/mmBTU	2030 Price c/mmBTU
Coal		397	485.4
NG - Commodity		750	1075

NG - Transportation	Beluga, Bernice, Nikiski	48.875	59.754
	Uklutna GS	50.0	61.129
	MLP, MLP2A	32.5	39.734
	Soldotna	66.175	80.904
	SPP	20.0	24.452
Naptha		1413	2207.7
ULSD	Most locations	1815	2818.8
	Delta, Small Diesels	1900	2950.8

5.8 Fuel Prices – Sensitivities

The source material for the High and Low Fuel Price sensitivities came from comparison Tables for three case projections that were part of the EIA's 2016 Annual Energy Outlook. The three cases were the Reference Case which was the basis for the Base Case Fuel Prices, the "Low Oil and Gas Resource and Technology Case," which provided the basis for the High Fuel Price sensitivity, and the "High Oil and Gas Resource and Technology Case," which provided the basis for the Low Fuel Price sensitivity. The 2030 prices for the sensitivities are shown in Table 5-5.

Table 5-5: 2030 Fuel Prices – c/mmBTU

Fuel Item	Location	Low Price Sensitivity	High Price Sensitivity
Coal		466.5	511.9
NG - Commodity		729.2	1665.9
NG - Transportation	As in Base Case		
Naptha		1725.7	2489.1
ULSD	Most locations	2203.3	3177.9
	Delta, Small Diesels	2306.5	3326.8

5.9 The Consistency of the Modeling

Recently Slater had performed dispatch analyses of the Railbelt System for the Utilities' Economic Dispatch Group, (EDG,) aimed at exploring the benefits of pooled operation in the 2020 year. Accordingly, it was advisable to show that the modeling for this study was consistent with the modeling in the EDG work.

There were modeled cases in both studies that represented the same load/resource/transmission situations except for being ten years apart. In these Transmission studies, the Base Case has a load situation which is the same as in the Sensitivity 1 case in the EDG analyses, that is, the Fort Knox mine remains in operation. There is another match between the "Retire Aurora & Healy" sensitivity in these studies and the EDG Sensitivity 5 which keeps the Fort Knox load and retires Aurora and Healy 1.

To get as close a data match as possible between the Transmission Study cases and the EDG cases, a number of Transmission Study 2030 data items that were specific to the Transmission Study were replaced with the corresponding 2020 EDG data items. These items (illustrated in Table 5-6) included the following,

- Company Loads.
- EVENT File. (The Transmission Study file represented more complex and stringent interface flow limits.)
- Fuel Prices.
- All non-fuel O&M.
- Minor data items. Several minor data items changed between studies
- Battle Crk. removed. Bradley energy was returned to 2020 levels
- HEA line outages. The 2020 HEA 115kV line outages were added
- Planned outages. Certain planned maintenance outages are different in 2030 and 2020

There were just two 2030 data items which could not be matched to 2020 items. The major one was the underlying power flow data from the PSS/E raw file, which describes the physical transmission system to which is attached or "mapped" the majority of the remaining data. The 2030 power flow data was different than the 2020 data, and could not be changed without dismantling the 2030 data base. The other item is hydro plant outages that are aligned with particular days of the week.

For each of the two matched pairs of cases, two runs were made for each case, the first with no arrangements for pooled operation, and the second with fully pooled operation. The results are displayed below.

The closeness of the modeling results shows the consistency between the modeling in this study and the modeling in the EDG analyses. In the following Table, Production Costs are thousands of dollars, and Energy is in GWh. However, because there were noticeable differences between the two sets of Power Flow data on which the data bases were built, there are some differences in results.

Some key differences between the 2020 EDG Production cost simulation results are as follows:

Transmission Constraints – The EDG study utilized most of the transmission constraints produced in the 2013 Transmission Study. The 2016 Transmission Study implemented all of the transmission constraints identified in the 2016 study which resulted from a more exhaustive analysis of voltage collapse, thermal ratings and transient stability limitations than was reflected in the EDG study.

Bradley Energy – The EDG study did not include the energy from the Battle Creek project. The 2016 Transmission Study added the Battle Creek energy to the amount of energy utilized in the EDG study to obtain the total Bradley energy.

Table 5-6: Study Cases

2030 Scenario				**2020 EDG Scenario**		
	Existing Tr.	Existing Tr.		Existing Tr.	Existing Tr.	
	No Pooling	Full Pooling		No Pooling	Full Pooling	
Base Case	**371,057**	**336,787**	**Production Cost**	**373,780**	**335,407**	**Sensitivity 1**
	5,078.3	5,078.3	System Load	5079.1	5079.1	
	15.2	13.5	Dump Energy	14.3	14.8	

	90.1	96.5	Losses	101	107	
	5,184	5,188	Total MHh	5,194	5,201	
Retire Healy1/ Aurora						
	402,233	**355,967**	**Production Cost**	**404,587**	**353,036**	**Sensitivity 5**
	5,078.3	5,078.3	Load	5079.1	5079.1	
	16.3	13.6	Dump Energy	14.5	14.5	
	96.8	128.6	Losses	104.9	127.1	
	5,191	5,221	Total Generation	5,199	5,221	

The changes in the 2030 Transmission Study data to 2020 EDG values, which are necessary to achieve the close results depicted above, were quite significant. To illustrate just how significant these data differences are, the following comparison (Table 5-7) contrasts the actual 2030 Base Case runs and "Retire Old Coal" runs with the equivalent 2020 EDG runs.

Table 5-7: Comparison of Base Case Runs

	Existing Transmission No Pooling K$	Existing Transmission Full Pooling K$	Value of Pooling K$
2030 Base Case	576,770	553,182	23,588
EDG 2020 Sens. 1	373,780	335,407	38,373
2030 Retire Old Coal	617,925	575,809	42,116
EDG 2020 Sens. 5	404,587	353,036	51,551

Even though the pairs of runs above are modeling the same case, there are differences in all of the items discussed in paragraphs above. When none of these differences are removed, the differences in the end results are significant. Various trial runs during the replacement of data in the "benchmark" described above indicated that the data differences most responsible for the differences in results, shown in the table immediately above, were the transmission flow limits contained in the EVENT files.

5.10 Resource Sensitivities

In addition to the four sensitivities involving variation in system load and fuel costs, three sensitivities were examined which dealt with changes to generation resources. The first of these, "Retire Old Coal" made no changes to loads or fuel cost, but retired, prior to 2030, the two old coal fired resources, the Aurora Energy LLC units in the Fairbanks area and the GVEA Healy 1 unit. In this sensitivity, no generating capacity was added to replace the old coal capacity.

The second resource sensitivity involved changing the fuel for the North Pole combined cycle unit from Naptha to LNG shipped into Fairbanks. In this sensitivity, the price of the LNG was set at 1300 c/mmBTU in 2020, escalating to 1863.33 c/mmBTU in 2030.

The third resource sensitivity involved major changes to GVEA generation prior to 2030. The old coal units (Aurora and Healy 1) would be retired, along with the two old CT's at North Pole. A second combustion turbine would be added to the North Pole combined cycle unit, and six 9 MW Wartsila Diesel generators would also be installed at North Pole.

An LNG supply would be arranged to fuel all generation at the North Pole generating station.

5.11 Results of this Analysis

For each of the Base Case and seven sensitivities, three computer model runs were made. The first, "Existing Transmission – No Pooling" used the data bases created on the power flow data for the existing transmission with inter-utility transaction hurdles and company reserve requirements set to cause each utility system to commit sufficient resources to satisfy its own load, reserve and regulation needs, while not committing any resources to serve the needs of any other utility system, unless to fulfil a specific, pre-determined bi-lateral obligation as part of its own needs, and also to permit inter-utility economy transactions, using only those committed resources, that provided a profit sufficient to compensate for wheeling, etc.. The hurdles were set at $4,000/MWh for commitment and $50/MWh for dispatch. These hurdle values don't represent any actual economic relationships among the utilities, but were set at these values to achieve the "loose pool" behavior described above.

It should be noted that the "Existing Transmission – No Pooling" runs in these Transmission Studies included a bi-lateral sale by ML&P to MEA of 100 GWh/year, just as was included in each equivalent EDG run along with the $4,000/MWh and $50/MWh commitment and dispatch hurdles.

The second model run for each case, "Existing Transmission – Full Pooling," used the same data as the first model run, with no inter-utility transaction hurdles, with reserve requirements set at the pool level rather than company level and with hydro resources set to serve the pool load rather than individual company loads. The differences between the first and second runs were recorded as the benefits of pooling.

The third model run for each case, "Upgraded Transmission – Full Pooling," was set up the same way as the second model run, described above, except that the data bases, including EVENT files, were those created on the power flow data for the upgraded transmission. The differences between the second and third runs were recorded as the benefits of the upgraded transmission. The derived benefits of pooling do not influence the benefits of the new transmission system. Pooling benefits can be assumed higher or lower than the values in this study, but so long as the parameters are consistent between the pooling and new transmission system, the benefits of the transmission system will not be impacted by the pooling benefits.

Table 5-8 shows the production cost results for each modeled case, while Table 5-9 records the atmospheric emissions for each case, and Table 5-10 displays the transmission losses.

Table 5-8: Production Costs for Each Modeled Case

		Annual Production Costs - K$			Annual Savings - K$	
Scenario	Total Pool Load Annual GWh	Existing Transmission No Pooling	Existing Transmission Full Pooling	Upgraded Transmission Full Pooling	From Pooling	From New Transmission
Base Case	5174.5	$ 576,770	$ 553,182	$ 456,705	$ 23,588	$ 96,478
High Load	5174.5 + 573.0	$ 747,343	$ 712,602	$ 577,324	$ 34,741	$ 135,277
Low Load	5174.5 - 306.6	$ 499,607	$ 473,882	$ 409,290	$ 25,725	$ 64,592
Aurora & Healy 1 Retired	5174.5	$ 617,925	$ 575,809	$ 480,389	$ 42,116	$ 95,420
LNG @ NPCC only	5174.5	$ 564,789	$ 539,790	$ 453,288	$ 24,998	$ 86,502
High Fuel Cost	5174.5	$ 757,051	$ 727,573	$ 639,067	$ 29,478	$ 88,507
Low Fuel Cost	5174.5	$ 444,794	$ 425,634	$ 346,470	$ 19,159	$ 79,164
Re-Build of North Pole (New Units & LNG)	5174.5	$ 531,502	$ 509,710	$ 472,398	$ 21,792	$ 37,312

Table 5-9: Casewise Atmospheric Emissions

		Emissions - 1000 lbs			Annual Savings - 1000 lbs	
Scenario	Effluent	Existing Transmission No Pooling	Existing Transmission Full Pooling	Upgraded Transmission Full Pooling	From Pooling	From New Transmission
Base Case	CO_2	6,394,018	6,263,598	5,891,514	130,420	372,084
	NO_x	9,964	9,364	5,747	600	3,617
	SO_2	4,387	4,419	2,548	(32)	1,871
High Load	CO_2	7,289,496	7,109,276	6,710,206	180,221	399,070
	NO_x	13,855	13,010	8,439	845	4,571
	SO_2	7,595	7,522	3,509	73	4,013
Low Load	CO_2	5,908,656	5,801,487	5,509,900	107,169	291,588
	NO_x	7,990	7,292	5,167	699	2,124
	SO_2	3,116	3,053	2,420	63	633
Aurora & Healy 1 Retired	CO_2	5,698,416	5,402,579	5,122,001	295,837	280,578
	NO_x	10,271	8,896	5,313	1,375	3,584
	SO_2	3,720	3,300	744	420	2,555
LNG @ NPCC only	CO_2	6,233,981	6,098,681	5,858,677	135,300	240,004
	NO_x	7,705	7,073	5,391	633	1,682
	SO_2	4,396	4,377	2,467	19	1,911
High Fuel Cost	CO_2	6,452,340	6,265,850	5,886,331	186,490	379,519
	NO_x	10,176	9,395	5,781	780	3,614
	SO_2	4,511	4,455	2,534	56	1,922
Low Fuel Cost	CO_2	6,359,766	6,197,704	5,883,293	162,061	314,412
	NO_x	9,904	9,150	5,716	754	3,434
	SO_2	4,325	4,293	2,509	33	1,783
Re-Build of North Pole	CO_2	5,137,336	4,972,705	4,978,296	164,632	(5,591)
(New Units & LNG)	NO_x	4,837	3,961	4,127	876	(166)
	SO_2	623	579	585	45	(6)

Table 5-10: Transmission Losses for Different Cases

Scenario	Losses - GWh Existing Transmission No Pooling	Losses - GWh Existing Transmission Full Pooling	Losses - GWh Upgraded Transmission Full Pooling	Annual Savings - GWh From Pooling	Annual Savings - GWh From New Transmission
Base Case	77.6	80.9	94.6	-3.3	-13.7
High Load	88.4	94.4	114.4	-6.0	-20.0
Low Load	69.2	74.1	76.0	-4.9	-1.9
Aurora & Healy 1 Retired	88.4	91.5	116.8	-3.1	-25.3
LNG @ NPCC only	76.8	80.9	94.2	-4.1	-13.3
High Fuel Cost	74.0	80.9	93.2	-6.9	-12.3
Low Fuel Cost	77.7	81.2	94.7	-3.5	-13.5
Re-Build of North Pole (New Units & LNG)	79.2	91.4	107.0	-12.2	-15.6

6 Project Prioritization

Electric Power Systems (EPS) has completed an analysis to make recommendations for the future transmission system in the Railbelt. The need for a new transmission plan is driven by changes in the Railbelt generation and transmission system since the completion of the 2010 Regional Integrated Resource Plan (RIRP) administered by the Alaska Energy Authority (AEA). The project identification analysis is included in the prior section of this report. This analysis and report covers the recommended prioritization and ranking of projects for construction and funding.

Table 6-1 summarizes the projects and associated production cost benefits identified in the previous study. In addition to these production cost benefits, the study identified non-production cost benefits that will increase the total benefits of each project, and for the projects as a whole.

Table 6-1: Project Summary Cost and Benefits

Area	Total Costs (Millions)	Summary Benefit (Millions)	Benefit / Cost Ratio
Bradley Constraints	$ 388.2	$ 893.1	2.3
Flexible Gas Storage	$ 18.2		
Southcentral / Overall	$ 20.4	$ 482.3	23.7
Northern System	$ 494.7	$ 1,672.5	3.4
Total	$ 921.4	$ 3,047.9	3.3

This report outlines the recommended construction and implementation sequence of projects to the greatest extent possible. Portions of the final sequence may be based on non-deterministic factors such as funding availability, geographic location, etc. Although these factors are considered, they are not drivers for the recommended sequence.

The projects that comprise the Bradley Constraints Area (Table 6-1) encompass a group of projects that mitigate the constraints on Kenai area hydro projects such as Bradley Lake and Cooper Lake. These projects can be completed in a relatively short period of time, and appear to be some of the largest benefit drivers. These projects also have the opportunity to bring benefits forward in time, with relatively short on-line projects, such as the HVDC Intertie, and Anchorage Area BESS projects. Due to their relatively short design and construction period, and the ability to incrementally capture benefits as the projects are completed, these projects were evaluated as the highest overall priority.

The Northern area projects provide excellent benefits, but require longer planning and construction periods. In addition, there are no incremental benefits realized until all of the projects are completed and operational. Although the benefit/cost ratio could be very high for these projects, the longer-term completion period and the lack of incremental benefits as the project stages are completed result in these projects being considered slightly lower than the Bradley constraint projects.

The Southcentral area projects are critical to the implementation of both the Northern and Southern projects, and are critical to new Southcentral area generation, particularly at AML&P and MEA. These are short-duration projects ready for engineering design and construction. These projects are Reliability driven, with little economic justification.

In assigning the priorities for the projects, each was divided into several sub-components: permitting, design, and construction. Prioritization and sequencing were completed on the component level of the projects, instead of for the overall project. Prioritizing at the component level allows projects with high-priorities, but long completion times, to start critical permitting and design processes earlier in the process, while optimizing the costs and benefits for the overall plan. It was assumed that several projects would be undertaken concurrently, with different projects in permitting, design and construction phases during the same period.

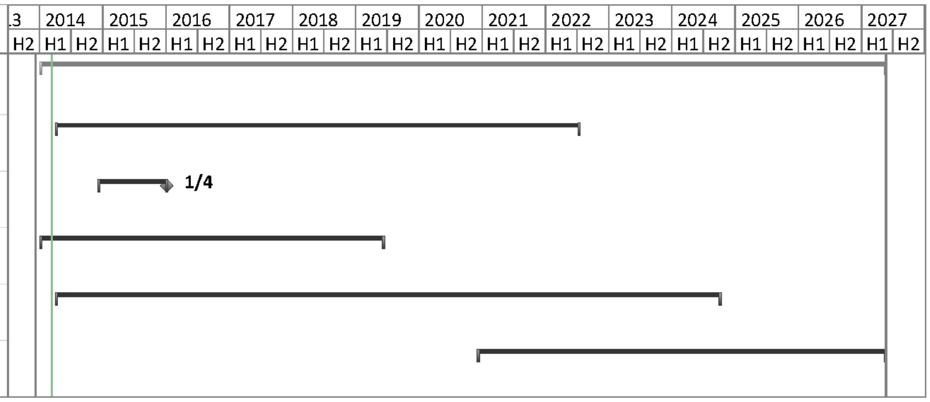
While there may be a single project description for a project, in most cases each project contains several smaller projects forming a larger project. For instance, the Bradley-Soldotna transmission line is made up of substation changes at Bradley Lake and Soldotna, as well as the transmission line between the two stations. Each of these smaller divisions is prioritized within the larger project to ensure the project's completion is coordinated, and that overall costs and benefits are optimized.

The prioritization assumed a fifteen-year construction period, during which all of the projects would be permitted, designed, and constructed. Within this period, it was assumed that year one would be used to initiate design and permitting, and years 2-15 would be used to complete construction of the remaining projects. The total dollars required in years 2-15 was attempted to be levelized to the greatest extent possible for all activities (permitting, design, construction). The desire to maintain fairly constant dollar expenditures in years 2-15 had significant impacts on the prioritization and recommended project sequence, however even with the restructuring of the projects to levelize expenditures, there are several high dollar outlay years due to large projects such as the HVDC Intertie, the BESS, and the Lorraine SVC. These cannot be spread over several years of construction.

A summary of the recommended project sequence is outlined in Table 6-2.

Table 6-2: Recommended Project Sequence

ID	Task Name	Cost
0	**Railbelt_Projects**	**$921,427.72**
1	**Unconstrain Bradley**	**$388,171.36**
39	**262 MWh Flexible Gas Storage**	**$18,200.00**
42	**Southcentral Projects**	**$61,580.81**
55	**Anchorage-Healy Projects**	**$346,697.05**
86	**Healy - Fairbanks Projects**	**$106,778.50**



The annual and cumulative cash flow for the recommended sequence is shown on Figure 6-1: Estimated Yearly and Cumulative Expenditures (USD) below.

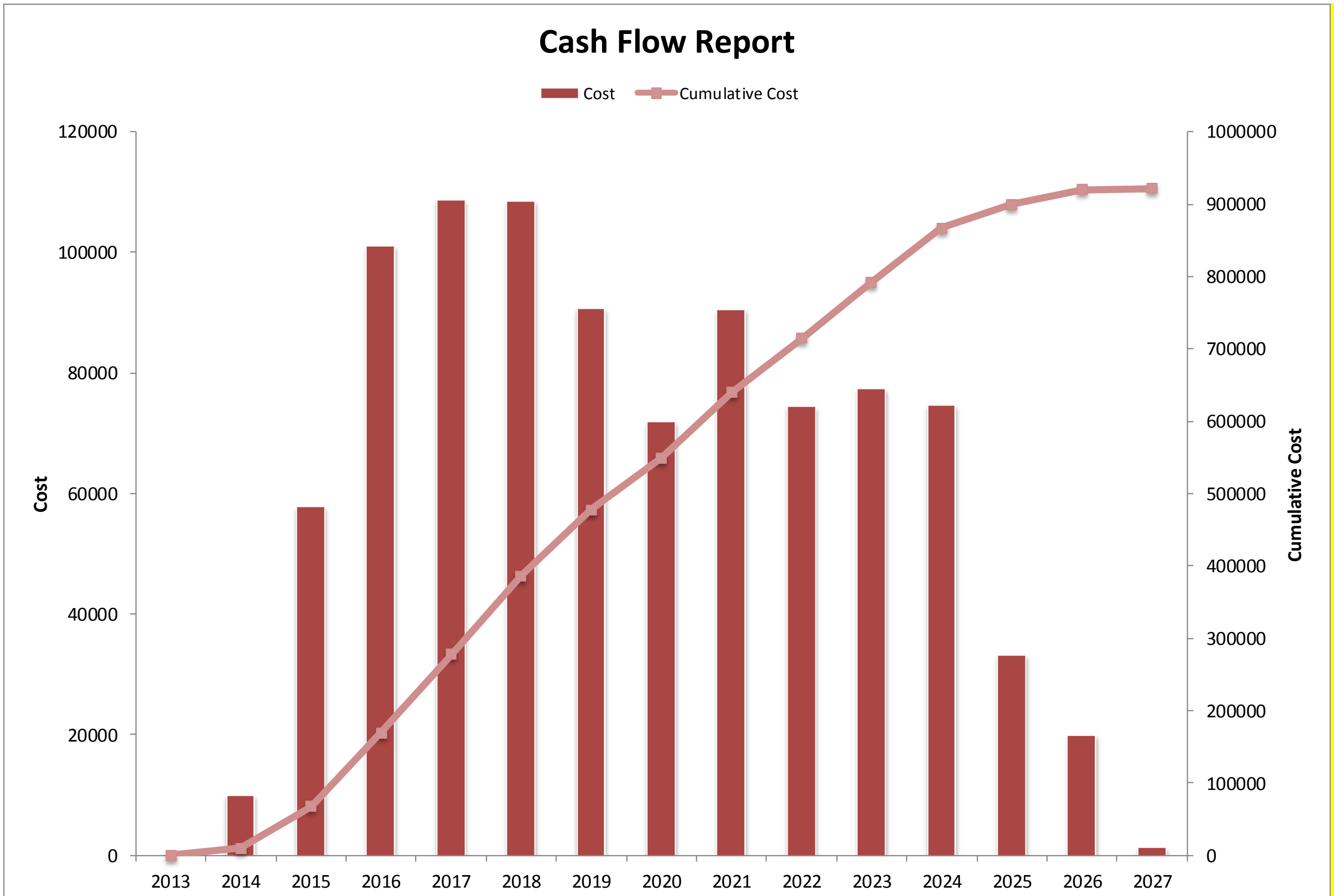


Figure 6-1: Estimated Yearly and Cumulative Expenditures (USD)

7 Prioritization: Process

Each major project was broken into appropriate smaller projects that collectively comprise the overall scope of the larger project. Each of the smaller projects was broken into required permitting, design, and construction tasks with estimated completion times and budgets before prioritization.

Prioritizing the components of each project allowed some projects to start long-duration activities, such as permitting as a priority project, while maintaining the construction of the project as a lower priority. In instances where the project would likely be a design/build type project, such as the Teeland SVC, the project was not subdivided into separate design and build sections. For projects that included the design and construction of long transmission lines, the projects were divided into roughly the same level of effort for each section of the project. Since the preliminary design has not been authorized for any projects, each section was assumed to require equal effort. The breakdown of each major section and its subcomponents are shown in Table 6-3.

Table 6-3: Project Sections and Subcomponents used for Analysis

Priority	Group	Project	Description	Phase	Duration (months)	Cost
1	Kenai	Bernice Lake-Beluga HVDC	100 MW HVDC Intertie	Permitting	24-36	$ 1,278,000
1	Kenai		100 MW HVDC Intertie	Engineering	7	$ 19,170,000
1	Kenai		100 MW HVDC Intertie	Construction	36	$ 164,862,000
1	Kenai	25 MW/14 MWh BESS	Anchorage area battery	Design	8	$ 3,020,000
1	Kenai		Anchorage area battery	Construction	30	$ 27,180,000
2	Kenai	University-Dave's 230 kV	Convert line for 230 kV operation - I	Design	3	$ 1,916,667
2	Kenai		Convert line for 230 kV operation - I	Construction	6	$ 17,250,000
3	Kenai		Convert line for 230 kV operation - II	Design	3	$ 1,916,667
3	Kenai		Convert line for 230 kV operation - II	Construction	6	$ 17,250,000
4	Kenai		Convert line for 230 kV operation - III	Design	3	$ 1,916,667
4	Kenai		Convert line for 230 kV operation - III	Construction	6	$ 17,250,000
3	Kenai		Convert substations for 230 kV operation - I	Design	6	$ 2,249,000
4	Kenai		Convert substations for 230 kV operation - I	Construction	12	$ 15,055,000
4	Kenai		Convert substations for 230 kV operation - I	Design	6	$ 2,249,000
4	Kenai		Convert substations for 230 kV operation - I	Construction	12	$ 15,055,000
6	Kenai		Quartz Creek modify 115kV station	Design	9	$ 135,380
6	Kenai		Quartz Creek modify 115kV station	Construction	15	$ 1,218,422
5	Kenai		Upgrade QC-DC line to Rail conductor	Design	4	$ 1,050,000
5	Kenai		Upgrade QC-DC line to Rail conductor	Construction - I	6	$ 12,600,000
5	Kenai	Bradley - Soldotna 115 kV Line	Soldotna 115kV station - Ring bus	Design	15	$ 768,441
5	Kenai		Soldotna 115kV station - Ring bus	Construction	24	$ 6,915,965
5	Kenai		Add new bay/115kV cable to Bradley GIS	Design	12	$ 286,514
5	Kenai		Add new bay/115kV cable to Bradley GIS	Construction	15	$ 2,578,627
5	Kenai		115 kV Line Bradley to Soldotna	Permitting	30	$ 550,000
5	Kenai		115 kV Line Bradley to Soldotna	Design	12	$ 5,500,000
5	Kenai		115 kV Line Bradley to Soldotna	Construction	18	$ 48,950,000
2	Kenai	262 MWh Flexible Gas Storage	Gas storage at local plant	design	6	$ 1,200,000
2	Kenai		Gas storage at local plant	construction	8	$ 17,000,000
1	SouthCentral	Fossil Creek Substation	115 kV Substation	Permitting	24	$ 571,179
1	SouthCentral		115 kV Substation	Design	5	$ 925,324
1	SouthCentral		115 kV Substation	construction	8	$ 9,182,065
3	SouthCentral	Eklutna Substation	115 kV Substation	Design	4	$ 881,122
3	SouthCentral		115 kV Substation	Construction	6	$ 8,811,218
4	SouthCentral	Loraine Substation	230 kV Substation	Design	6	$ 1,760,170
4	SouthCentral		230 kV substation	Construction	10	$ 20,225,730
5	SouthCentral		Lorraine SVC	Design/Construction	18	$ 19,224,000

Priority	Group	Project	Description	Phase	Duration (months)	Cost
7	Northern	Communications Upgrade	Communications Upgrade	Design	48-60	$ 3,000,000
7	Northern		Communications Upgrade	Construction	36-48	$ 12,000,000
6	Northern	Douglas-Lorraine 230 kV Double Circuit Line	230 kV Douglas Substation	Design	6	$ 2,914,189
6	Northern		230 kV Douglas Substation	Construction	14	$ 29,141,892
6	Northern		230 kV Double Circuit	Permitting	6	$ 150,000
6	Northern		230 kV Double Circuit	Design	8	$ 6,242,235
6	Northern		230 kV Double Circuit	Construction	18	$ 49,688,190
6	Northern		230 kV Gold Creek Substation	Design	6	$ 1,575,652
6	Northern		230 kV Gold Creek Substation	Construction	18	$ 16,356,520
1	Northern		230 kV T-Line - Doug - Healy	Permitting	48-72	$ 1,881,000
7	Northern		230 kV T-Line - Doug - Gold Ck	Design - I	15	$ 4,702,500
7	Northern		230 kV T-Line - Doug - Gold Ck	Design - II	15	$ 4,702,500
7	Northern		230 kV T-Line - Doug - Gold Ck	Construction	18	$ 41,852,250
7	Northern		230 kV T-Line - Doug - Gold Ck	Construction	18	$ 41,852,250
7	Northern		230 kV T-Line - Gold Vk - Healy	Design	15	$ 4,702,500
7	Northern		230 kV T-Line - Gold Vk - Healy	Design	15	$ 4,702,500
7	Northern		230 kV T-Line - Gold Vk - Healy	Construction	18	$ 41,852,250
7	Northern		230 kV T-Line - Gold Vk - Healy	Construction	18	$ 41,852,250
7	Northern		Healy 230kV/138 kV Station	Permitting	24	$ 1,454,050
7	Northern		Healy 230kV/138 kV Station	Design	8	$ 3,302,580
7	Northern		Healy 230kV/138 kV Station	Construction	18	$ 32,771,750
7	Northern	Healy-Gold Hill 230 kV T-Line	230 kV Conversion Gold Hill - Healy	Permitting	24	$ 103,153
7	Northern		230 kV Conversion Gold Hill - Healy	Design	24	$ 1,031,527
7	Northern		230 kV Conversion Gold Hill - Healy	Construction	18	$ 28,195,065
7	Northern		230 kV Conversion Gold Hill - Healy	Construction	18	$ 28,195,065
7	Northern		230 kV Conversion Gold Hill - Healy	Construction	18	$ 28,195,065
7	Northern		Healy-Gold Hill Subs (Clear, Nenana, Ester, Gold Hill)	Design	9	$ 1,369,414
7	Northern		Healy-Gold Hill Subs (Clear, Nenana, Ester, Gold Hill)	Construction	24	$ 12,324,726
7	Northern	Northern Intertie Conversion	Northern Intertie Subs (Eva Creek, Wilson)	Design	8	$ 771,600
7	Northern		Northern Intertie Subs (Eva Creek, Wilson)	Construction	18	$ 6,592,870

8 Prioritization: Conclusions

The recommended sequence for the design and construction of the projects is a mix of attempting to bring the largest portion of benefits forward in time, while maintaining a fairly level annual budget throughout the plan. The recommended plan results in Railbelt utilities realizing substantial benefits approximately three years after the plan's approval and funding, with a significant jump in benefits 1-2 years following that with the completion of the HVDC transmission line.

There are numerous strategies and possibilities for the plan, for instance construction of the major 230 kV and 115 kV transmission lines could be extended over a longer period. Although it is possible that the plan could be shortened, this should be analyzed for impacts to the Alaska labor market, and for associated cost impacts and project financing.

A detailed plan of our recommended project sequence is included in Appendix B.

A Appendix: A Cost/Benefits

A.1 Notes on Benefit/Cost Ratios

The costs completed for these projects were developed based on a 2012 cost basis using information supplied by various Railbelt utilities and conceptual designs for each project. The cost estimates are estimated to be +/- 20% of actual construction costs. The project costs were reviewed in 2015 and appear to be within the +/- 20% range of project construction costs.

The benefits for the projects as a whole are simplified simulations based on one year of the project's operation. The identified benefits are assumed to be constant for the life of the project. The actual benefit of any project will vary over time as energy resources, load, transmission lines and operating practices change in the Railbelt.

The development of benefits for individual projects was not completed for this final phase of the study. The intent of this study was to develop a transmission plan compliant with the initial steps of AKTLP 1-4. Within that standard, once a project has been identified, additional studies and cost/benefit analysis is required prior to construction of the project.

The Net Present Value utilized a discount of 5.00% and an assumed life of each project of 50 years. The Benefit/ Cost ratio was a simplified ratio developed by the ratio of the 2012 costs over the NPV of the project benefits. The actual construction of the projects will consume 10-15 years and as such the construction sequence will have an impact on the benefits available for each project. Certain projects for instance, depend on other projects being constructed in order to obtain the identified benefits. For the feasibility level analysis completed in this study, it was assumed all projects were available in year one.

A.2 Railbelt Seasonal Loads

Table A-1: Year 2023 Railbelt Seasonal Loads by Substation

Area	Bus Name	Summer Valley	Summer Peak	Winter Peak	Area	Bus Name	Summer Valley	Summer Peak	Winter Peak
HEA	Soldotna	4.3	9.7	9.6	MEA	Briggs	1.5	2.6	4.2
	Sterling	1.8	1.8	6.1		Johnson	3.6	6.2	10.0
	Thompson	4.4	9.1	10.1		Pippel	7.3	12.6	20.1
	Kasilof	2.5	0.0	6.8		Parks	2.2	3.7	6.0
	Anchor Pt.	2.2	3.9	5.7		Reed	2.5	4.2	6.8
	Diamond Ridge	0.8	0.8	2.7		Eklutna	0.0	0.1	0.1
	Hatfield	5.0	8.5	12.3		Dow	2.6	4.4	7.1
	Fritz Creek	0.7	1.1	1.7		Palmer	1.5	2.5	4.1
	Tesoro	12.1	15.1	18.1		Lucas	7.4	12.7	20.3
	Bernice	6.4	8.0	11.8		Hospital	4.3	7.4	11.9
	Beaver Creek	1.6	2.3	6.8		Oneil	1.9	3.3	5.3
	Marathon	3.9	7.1	6.9		Lazelle	3.6	6.2	9.9
MLP	Plant 1	28.2	57.6	62.4		Shaw	5.1	8.8	14.1
	Sub #6	13.8	25.9	26.5		Herning	8.2	14.2	22.7
	SUB#7	5.5	10.3	10.7		Cottle	2.3	3.9	6.3
	SUB#8	10.1	19.0	18.1		Theodore	2.7	4.6	7.4
	SUB#10	6.2	11.7	13.7		McRae	2.8	4.9	7.8
	SUB#12	0.0	2.9	5.2		Redington	1.1	1.9	3.1
	SUB#14	7.9	14.9	15.9		Anderson	3.2	5.5	8.8
	SUB#15	7.9	14.8	17.3		Douglas	3.7	6.4	10.3
	SUB#16	9.4	17.6	15.3	GVEA	Cantwell	1.2	1.4	1.2
	SUB#20	4.0	7.4	9.2		Healy	5.9	7.1	7.1
	SUB #22	9.3	17.4	14.8		Nenana	0.9	1.2	2.0
	Raptor	10.9	10.9	10.9		Ester	1.4	2.1	3.9
CEA	Airport	1.0	1.7	2.5		Gold Hill	0.3	0.5	1.1
	Arctic	6.7	11.2	16.3		Musk Ox	2.2	3.6	7.9
	Baxter	3.3	5.5	8.0		Chena Pump	2.6	4.5	7.9
	Boniface	3.9	6.5	9.5		University Ave	2.2	4.7	5.6
	Campbell	5.0	8.4	12.3		Aurora	3.3	7.0	9.0
	DeBarr	7.3	12.2	17.9		Zhender	5.0	9.4	9.6
	Dowling	6.9	11.5	16.8		Kasalak	3.7	6.1	10.9
	Hillside	3.0	5.0	7.4		Fox	1.2	1.7	2.6
	Huffman	3.6	6.0	8.7		International	4.5	7.9	11.4
	Jewel LA	3.9	6.6	9.6		Peger Rd	3.5	7.4	9.0
	Klatt	5.7	9.5	13.8		Chena	11.3	20.1	17.9
	LaTouche	5.1	8.5	12.4		South Side	8.7	5.9	12.3
	O'Malley	4.3	7.2	10.4		South Fairbanks	2.8	6.7	8.2
	Raspberry	4.3	7.1	10.4		Hamilton	5.5	12.5	16.1
	Sand Lake	5.3	8.9	12.9		BESS AUX	0.1	0.3	0.2
	Spenard	4.5	7.6	11.1		Badger Road	3.2	5.5	10.1
	Turnagain	2.7	4.5	6.5		Brockman	1.3	2.3	4.6
	Woodland	3.2	5.3	7.7		Hwy Park	3.3	5.8	9.0
	Beluga	1.5	2.5	3.7		N. Pole Sub	0.0	0.2	0.2
	Tyonek	0.5	0.9	1.3		N. Pole CC1	2.7	2.7	2.7
	Loss	5.9	9.8	14.4		Dawson	2.2	4.6	7.4
	Post Mark	3.0	5.0	7.3		Johnson	1.1	1.3	2.9
	Daves Crk	0.4	0.7	1.0		TECKPOGO	11.6	11.5	12.7
	Indian	0.3	0.3	0.3		Jarvis	4.2	3.8	13.3
	Girdwood	5.3	5.3	5.3		Pump 9	6.9	6.9	6.9
	Portage	1.4	1.4	1.4		Mds	1.7	1.7	1.7
	Hope	0.3	0.3	0.3		Wilson	0.2	0.2	0.2
Seward	Seward	7.7	10.3	11.9		Jarvis	0.1	0.1	0.1
						Mapco	7.0	19.4	19.4
						UAF	0.0	11.9	11.9
						Ft. Wainwright	0.0	16.0	16.0
						Eielson AFB	0.0	9.6	9.6
						FGA	2.0	2.0	2.0

A.3 Conductor Ratings

Table A-2: Conductor Ratings

Conductor			Name	Circuit Type	Conductor Rating (MVA)					
					115 kV		138 kV		230 kV	
					Winter	Summer	Winter	Summer	Winter	Summer
4/0	AWG	ACSR	Penguin	OH	88	51	106	61	176	102
336	MCM	ACSR	Linnet	OH	124	70	149	84	249	140
556	MCM	ACSR	Dove	OH	173	96	208	115	347	192
795	MCM	ACSR	Drake	OH	220	120	263	144	439	240
954	MCM	ACSR	Rail	OH	241	154	290	185	483	309
2-954	MCM	ACSR	Rail (x2)	OH	616	434	739	521	1232	868
1900	MCM	Cu	Cable	UG	155	140	186	169	310	281

A.4 Loss/Energy/Capacity

Table A-3: Historically Displaced Energy

Historically Displaced Energy (MWh)				
	Annual MWh	Historical losses	Projected Losses	Difference
HEA energy	47,289	946	1,419	473
Northern users	193,973	3,879	21,337	17,458
Battle Creek - HEA	4,680	0	140	140
Battle Creek - Northern Users	34,320	0	3,775	3,775
Historically wheeled energy to Northern users (MWh)				
Wheeled energy	152,738	4,582	16,801	12,219
Total energy losses				34,065

Table A-4: Bradley Stranded Capacity

Bradley Stranded Capacity (MW)					
Bradley output	HEA Share	SES Load	Losses	Cooper	Export
85.4	14.4	10	6	-20	75

Table A-5: Kenai Loss Analysis

Kenai Loss Analysis

Values			Line Losses / Bus Angles Bradley Output			
			90		120	
From Bus	To Bus	Ckt ID	base	upgraded	base	upgraded
University	Indian	1	1.0	0.3	1.8	0.5
Indian	Girdwood	1	0.6	0.2	1.2	0.3
Girdwood	Portage	1	0.5	0.2	1.0	0.4
Portage	Hope	1	1.4	0.4	2.6	0.7
Hope	Daves Creek	1	1.3	0.3	2.2	0.6
Daves Creek	Quartz Creek	1	0.7	0.2	1.1	0.3
Quartz Creek	XFMR	1	no line	0.0	no line	0.0
Quartz Creek	Soldotna	1	3.7	1.0	6.7	1.8
Quartz Creek	Soldotna	2	no line	1.0	no line	1.8
Subotal: University - Soldotna			9.2	3.4	16.7	6.2
Soldotna	Bradley Lake	1	2.2	0.8	4.2	1.5
Soldotna	Bradley Lake	2	no line	0.8	no line	1.5
Subtotal: Soldotna - Bradley Lake			2.2	1.5	4.2	3.0
Soldotna	Thompson	1	0.0	0.0	0.0	0.0
Thompson	Kasilof	1	0.0	0.0	0.2	0.0
Kasilof	Anchor Pt	1	0.4	0.1	1.0	0.3
Anchor Pt	Diamond Ridge	1	0.2	0.1	0.4	0.1
Diamond Ridge	Fritz Crk	1	0.2	0.1	0.3	0.1
Fritz Crk	Bradley Lk	1	0.7	0.4	1.1	0.6
Subtotal: Soldotna - Bradley Lake			1.6	0.7	3.0	1.1
Total: University - Bradley Lake (All Lines)			12.9	5.6	23.9	10.3
Reduction of losses			7.3		13.6	
Kenai tie flow			77.6	81.5	100.2	107.6
SPP 138 kV angle			-3.4	-2.7	-8.8	-7.3
University 138 kV angle			-3.9	-3.1	-9.2	-7.7
Bradley Lake 115 kV angle			39.5	20.2	51.5	24.0
Angle Difference Bradley Lake - SPP			42.9	22.9	60.3	31.3
Reduction of angle			20.0		28.9	

Notes:
- Cooper Lake unit 1 online, at 9.8 MW
- Cooper Lake unit 2 online, at 9.8 MW
- only changes are Bradley Lake output
- swing bus at Beluga 7
- tie flow measured on Dave's Creek - Hope line
- HEA taking 14.4 MW of Bradley Lake

A.5 Kenai Transmission Cost Analysis

Below are the detailed cost analyses for the different upgrades proposed for the Kenai transmission system.

A.5.1 2nd Bradley Lake – Soldotna Line

Table A-6: 2nd Bradley Lake – Soldotna Line, Substation Costs

Station	Description	Costs
Bradley Lake	Add new Bay/115 kV cable to Bradley GIS	$ 2,865,141
Soldotna	115 kV station - Ring Bus	$ 7,684,406
Total	Substation Additions	$ 10,549,547

Table A-7: 2nd Bradley Lake – Soldotna Line, Line Construction Costs

Line	Description	Costs
Bradley to Bradley Junction	New 19.2 mi. 115kV X-tower , Drake Conductor	$ 18,000,000
Bradley Junction to Soldotna	New 48.6 mi. 115kV H-frame, Drake Conductor	$ 37,000,000
Total	Line Construction	$ 55,000,000

A.5.2 Dave's Creek – University 230 kV Station Conversion

Table A-8: Dave's Creek – University 230 kV Station Conversion Costs

Station	Description	Costs
Dave's Creek	230 kV Transformer,breaker, reactor	$ 20,216,517
Summit	230 kV Circuit Switcher/transformer	$ 1,803,319
Hope	230 kV Circuit Switcher/transformer	$ 1,803,319
Portage	230 kV Circuit Switcher/transformer	$ 3,791,449
Girdwood	230 kV GIS, Circuit Switcher/transformers	$ 12,038,689
Indian	230 kV Circuit Switcher/transformer	$ 3,026,814
University	230 kV relaying/controls	$ 361,475
Totals	Substation Conversion	$ 43,041,582

A.5.3 Dave's Creek – University 230 kV Line Conversion

Table A-9: Dave's Creek – University 230 kV Line Conversion Costs

Line	Description	Costs
University to Daves Creek	Upgrade 77 mi. from 115 to 230kV, Drake Conductor	$ 57,500,000

A.5.4 Dave's Creek – Quartz Creek Line Upgrade

Table A-10: Dave's Creek – Quartz Creek Line Upgrade

Line	Description	Costs
Daves Creek to Quartz Creek	Upgrade 14.5 mi. Conductor to Rail	$ 13,650,000

A.5.5 HVDC Connection Bernice Lake to Beluga, BES System

Table A-11: HVDC and BES System Costs

Line/Station	Description	Costs
100 MW , 80kV Converter	2-36mi. Submarine DC cables, connect to Bernice 115kv & Beluga 138kV	$185,310,000
35 MW BES	BES in Anchorage	$ 41,072,000
Total	New HDVC Tie	$226,382,000

Costs for the HVDC terminals vary greatly with the value of the dollar and the expanding off-shore wind generation market. Costs for the terminals should be evaluated further and in more detail as part of the requirements of AKTPL 1-4.

The cost of the BESS is estimated based on the current pricing of several systems currently in production. However NREL, predicts that the cost of BESS systems could drop 25-30% over the next 3-5 years due to changes in technology and manufacturing costs.

A.6 Southcentral Transmission Cost Analysis

Below are the detailed cost analyses for the different upgrades proposed for the Southcentral transmission system.

A.6.1 Fossil Creek – Eklutna (Eklutna Express) Substation Additions

Table A-12: Eklutna Express Substation Addition Costs

Station	Description	Costs
Fossil Creek	New 115kV Ring Bus, 4 line terminals	$ 10,678,568
Eklutna Hydro	New 115kV Ring Bus, 3 line terminals, 2 Xformers	$ 9,692,340
Total	Substation Additions	$ 20,370,908

A.6.2 Lorraine – Douglas Station Additions / Upgrades

Table A-13: Lorraine & Douglas Substation Addition Costs

Station	Description	Costs
Lorraine	New 230kV station w. 5 line Terminals, SVC	$ 41,209,900
Douglas	New 230/138kV station w. 5 line terminals & 3 Xformers	$ 32,056,081
Total	Substation improvements	$ 73,265,981

A.6.3 Lorraine – Douglas 230 kV Line Addition

Table A-14: Lorraine – Douglas 230 kV Line Addition Costs

Line	Description	Costs
Lorraine to Douglas	New 42 mi double circuit 230kV line	$ 56,080,425
Total	Line Construction	$ 56,080,425

A.7 Northcentral Transmission Cost Analysis

Below are the detailed cost analyses for the different upgrades proposed for the Northcentral transmission system.

Table A-15: Northern Intertie Station Upgrade Costs

Station	Description	Costs
Healy	new 230kV station w. 5 line terminals (oper. 138kV)	$37,528,380
Gold Creek	new 230kV station w. 4 line terminals & 2 reactors	$37,528,380
Total	Substation improvements	$ 75,056,760

Table A-16: 2nd Northern Intertie Line

Line	Description	Costs
Douglas to Healy	New 171 mi 230kV single circuit line	$ 188,100,000
Total	Line Construction	$ 188,100,000

B Appendix B: Prioritization

C Appendix C: Detailed Cost Estimates

C.1 Bradley Constraints

Table C-1: Bernice Lake-Beluga HVDC

Kenai Transmission Upgrades

HVDC Bernice Lake to Beluga

2- 100 MW monopoles, 2 - 80kV submarine cables (36 mi ea.), solid insulation, double armor, no embedment- except shore ends

Item	Description	Qty.	Unit-$	Total $
A	100MW -80kV Monopole Converter	4		$60,000,000
B	80kV Submarine Cable	36x2	$1,800,000	$64,800,000
C	Beluga 138kV bay	1	$1,500,000	$1,500,000
D	Bernice 115kV Bay	1	$1,500,000	$1,500,000
	Total			$127,800,000
	Land Rights and Permits	1%*		$1,278,000
	Design	15%*		$19,170,000
	Construction Management	9%*		$11,502,000
	Overheads	20%*		$25,560,000
	* of Total Construction $			$57,510,000
	Project costs			$185,310,000

Table C-2: 35 MW/20 MWh BESS

Location	MW	MWh	BESS Costs	Sub/Connection Costs	Total Costs
Anchorage	35	20	$35,321,920	$ 5,800,000	$41,121,920

Table C-3: Bradley-Soldotna 115 kV – Line Sections

Line Section	Existing Structure Type	Existing Framing	Existing Line Miles	Proposed Structure Type	Proposed Framing	Proposed Location	Total Costs
Bradley - Bradley Jct	X-Twr	115kV	19.2	X-Twr	115kV	Parallel to Existing	$ 18,000,000
Bradley Jct - Soldotna	STH-1A	115kV	48.6	STH-1A	115kV	Parallel to Existing	$ 37,000,000
Total							$ 55,000,000

Table C-4: Bradley Substation

Kenai Transmission Upgrades

Bradley Lake 115kV Station

Scope: Add 1 breaker position to existing GIS switchgear
115kv Cable Exit

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	Line Terminal &Cable Terminal	1	$7,500	$33,000	$40,500	$7,500	$33,000	$40,500
					$0	$0	$0	$0
	Total A. Structures					$7,500	$33,000	$40,500
	C. Arresters							
C-1	115kv arrestors @ line/cable terminal	3			$0	$0	$0	$0
					$0	$0	$0	$0
	Total C. Arresters					$0	$0	$0
	E. Circuit Breakers							
E-1	Gis Bay	1	$30,000	$1,000,000	$1,030,000	$30,000	$1,000,000	$1,030,000
					$0	$0	$0	$0
	Total E. Circuit Breakers					$30,000	$1,000,000	$1,030,000
	G. Protection and Control							
G-1	Line Panel	1	$20,000	$80,000	$100,000	$20,000	$80,000	$100,000
					$0	$0	$0	$0
	Total G. Protection And Control					$20,000	$80,000	$100,000
	J. SCADA and Communications							
J-1	Add line communications	1	$10,000	$5,000	$15,000	$10,000	$5,000	$15,000
					$0	$0	$0	$0
	Total J. Scada and Communications					$10,000	$5,000	$15,000
	K. Conduit and Cables							
K-1	RGS and 600V Cable	1	$45,000	$20,000	$65,000	$45,000	$20,000	$65,000
K-2	115kV EPR Cable exit in 6" HDPE	1800	$100	$150	$250	$180,000	$270,000	$450,000
	Total K. Conduits and Cables					$225,000	$290,000	$515,000
	L. Foundations							
L-1	Terminal	4	$3,500		$3,500	$14,000	$0	$14,000
					$0	$0	$0	$0
	Total L. Foundations					$14,000	$0	$14,000
	O. Grounding							
O-1	Add to existing	1	$10,000	$2,000	$12,000	$10,000	$2,000	$12,000
					$0	$0	$0	$0
	Total O. Grounding					$10,000	$2,000	$12,000
	Location Adder for Labor	30%				$94,950		
	Total Construction					$411,450	$1,410,000	$1,821,450
	Land Rights and Permits	1%*						$18,215
	Design	13%*						$236,789
	Construction Management	9%*						$163,931
	Overheads	20%*						$364,290
	* of Total Construction $							

Kenai Transmission Upgrades

Bradley Lake 115kV Station

Scope: Add 1 breaker position to existing GIS switchgear
115kv Cable Exit

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	Total Project Costs (+10%)							$2,865,141

Assumption:
115kv cable/conduit can be routed along road

Table C-5: Soldotna Substation

South Central Alaska Transmission Plans

115kV Soldotna new

Scope: Install a new Substation
with 115kV ring bus & terminals for OH line to Bradley, SVC, existing station

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-2	A-Frame 115kV	2	$5,000	$30,000	$35,000	$10,000	$60,000	$70,000
A-4	115kV 3-ph bus support	8	$1,500	$3,500	$5,000	$12,000	$28,000	$40,000
A-5	115kV 3-ph disconnect support	8	$2,500	$2,800	$5,300	$20,000	$22,400	$42,400
A-7	115kV bus work	1	$60,000	$90,000	$150,000	$60,000	$90,000	$150,000
A-8	115kv PT stand	3	$1,000	$1,500	$2,500	$3,000	$4,500	$7,500
	Total A. Structures					$105,000	$204,900	$309,900
	B. Disconnects							
B-1	115kV 3-ph disconnect	7	$10,000	$10,000	$20,000	$70,000	$70,000	$140,000
B-3	115kV 3-ph V switch	2	$10,000	$10,000	$20,000	$20,000	$20,000	$40,000
	Total B. Disconnects					$90,000	$90,000	$180,000
	C. Arresters							
C-2	115kv arrestor	3	$1,200	$1,500	$2,700	$3,600	$4,500	$8,100
	Total C. Arresters					$3,600	$4,500	$8,100
	E. Circuit Breakers							
E-2	115kV GCB	3	$7,000	$55,000	$62,000	$21,000	$165,000	$186,000
	Total E. Circuit Breakers					$21,000	$165,000	$186,000
	G. Protection and Control							
G-2	115kV PT	6	$2,000	$7,000	$9,000	$12,000	$42,000	$54,000
	Total G. Protection And Control					$12,000	$42,000	$54,000
	H. Power Transformers							
H-2	Sta. Service Xformer 24.9/.24kV, 300N	1	$2,000	$15,000	$17,000	$2,000	$15,000	$17,000
	Total H. Power Transformers					$2,000	$15,000	$17,000
	J. SCADA and Communications							
J-1	115kV facilities	1	$100,000	$100,000	$200,000	$100,000	$100,000	$200,000
J-3	cables, connections etc.	1	$70,000	$40,000	$110,000	$70,000	$40,000	$110,000
	Total J. Scada and Communications					$170,000	$140,000	$310,000
	K. Conduit and Cables							
K-1	RGS & Cables	1	$400,000	$200,000	$600,000	$400,000	$200,000	$600,000
	Total K. Conduits and Cables					$400,000	$200,000	$600,000
	L. Foundations							
L-1	A-Frame	8	$2,500		$2,500	$20,000	$0	$20,000
L-2	Switch Support	7	$5,000		$5,000	$35,000	$0	$35,000
L-3	Bus Support	8	$5,000		$5,000	$40,000	$0	$40,000
L-5	PT Support	2	$2,500		$2,500	$5,000	$0	$5,000
L-6	Control Enclosure	1	$80,000		$80,000	$80,000	$0	$80,000
L-7	Conduit Vault	6	$3,000	$7,000	$10,000	$18,000	$42,000	$60,000
L-8	Sta. Service Xformer	1	$1,500	$3,000	$4,500	$1,500	$3,000	$4,500

South Central Alaska Transmission Plans

115kV Soldotna new

Scope: Install a new Substation
with 115kV ring bus & terminals for OH line to Bradley, SVC, existing station

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
L-9	Light Pole	10	$2,000	$2,000	$4,000	$20,000	$20,000	$40,000
L-10	Microwave tower	1	$25,000		$25,000	$25,000	$0	$25,000
L-11	115kV GCB	3	$2,500		$2,500	$7,500	$0	$7,500
	Total L. Foundations					$252,000	$65,000	$317,000
	M. Site Work							
M-1	Excavation	1	$750,000		$750,000	$750,000	$0	$750,000
M-2	Backfill	1	$600,000	$200,000	$800,000	$600,000	$200,000	$800,000
	Total M. Site Work					$1,350,000	$200,000	$1,550,000
	N. Fence							
N-1	Perimeter Fence	1	$100,000	$150,000	$250,000	$100,000	$150,000	$250,000
					$0	$0	$0	$0
	Total N. Fence					$100,000	$150,000	$250,000
	O. Grounding							
O-1	Groundgrid	1	$200,000	$200,000	$400,000	$200,000	$200,000	$400,000
					$0	$0	$0	$0
	Total O. Grounding					$200,000	$200,000	$400,000
	P. Building							
P-1	230kV/115 Control Enclosure & Contr	1	$150,000	$300,000	$450,000	$150,000	$300,000	$450,000
					$0	$0	$0	$0
	Total P. Building					$150,000	$300,000	$450,000
	V. Station Lighting							
V-1	Light Pole	10	$1,000	$5,000	$6,000	$10,000	$50,000	$60,000
V-2	Lights, receptacles, J-boxes	1	$5,000	$40,000	$45,000	$5,000	$40,000	$45,000
	Total V. Yard Lights					$15,000	$90,000	$105,000
	Location Adder for Labor	10%				$287,060		
	Total Construction					$3,157,660	$1,866,400	$5,024,060

Land Rights and Permits	1%**	$550,241
Design	13%*	$653,128
Construction Management	9%*	$452,165
Overheads	20%*	$1,004,812
* of Total Construction $		
** includes land purchase $500,000		
Total Project Costs		**$7,684,406**
$/terminal		$1,921,101

Assumption:
Land is available in the area - 10 to 15 acres @$50,000

Table C-6: Dave's Creek - Hope 230kV Line

115 & 230KV TRANSMISSION LINES - KENAI PENINSULA

Davis Creek - Hope (230KV) 18.9 MILES

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Tangent Structure	70	ea	$14,400	$5,800	$20,200	$1,411,059
Medium Angle	20	ea	$19,300	$30,800	$50,100	$999,916
DE/Large Angle	10	ea	$23,400	$42,000	$65,400	$652,640
30% Pipe Pile Fdn	69	ea	$960	$6,000	$6,960	$479,241
10% Special Foundations	23	ea	$3,000	$8,000	$11,000	$252,474
Drake Conductor	19	crkt mi	$22,176	$63,360	$85,536	$1,616,630
OPGW	19	mi	$10,000	$22,000	$32,000	$604,800
OHSW	19	mi	$2,000	$18,000	$20,000	$378,000
Dampers	299	ea	$50	$600	$650	$194,594
Aerial Balls/Bird Diverters	20	ea	$300	$2,000	$2,300	$45,904
Structure Signs	100	ea	$100	$500	$600	$59,875
20% Clearing	4	mi	$0	$25,000	$25,000	$94,500
Remove H-Structure	125	ea		$4,000	$4,000	$498,960
Remove Conductor	19	crkt mi		$31,680	$31,680	$598,752
Subtotal						$7,887,346
Mob/Demob						$236,620
Engineering, Management, Permitting @15%						$1,183,102
Subtotal						$9,307,068
Contingency @20%						$1,861,414
Winter Construction @15%						$2,792,120
Total Construction						$13,960,602

Table C-7: Hope – Portage 230kV Line

115 & 230KV TRANSMISSION LINES - KENAI PENINSULA

Hope - Portage (230KV) 19.7 MILES

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Tangent Structure	73	ea	$14,400	$5,800	$20,200	$1,470,786
Medium Angle	21	ea	$19,300	$30,800	$50,100	$1,042,240
DE/Large Angle	10	ea	$23,400	$42,000	$65,400	$680,265
30% Pipe Pile Fdn	72	ea	$960	$6,000	$6,960	$499,526
10% Special Foundations	24	ea	$3,000	$8,000	$11,000	$263,160
Drake Conductor	20	crkt mi	$22,176	$63,360	$85,536	$1,685,059
OPGW	20	mi	$10,000	$22,000	$32,000	$630,400
OHSW	20	mi	$2,000	$18,000	$20,000	$394,000
Dampers	312	ea	$50	$600	$650	$202,831
Aerial Balls/Bird Diverters	21	ea	$300	$2,000	$2,300	$47,847
Structure Signs	104	ea	$100	$500	$600	$62,410
30% Clearing	6	mi	$0	$25,000	$25,000	$147,750
Remove H-Structure	130	ea		$4,000	$4,000	$520,080
Remove Conductor	20	crkt mi		$31,680	$31,680	$624,096
Subtotal						$8,270,451
Mob/Demob						$248,114
Engineering, Management, Permitting @15%						$1,240,568
Subtotal						$9,759,133
Contingency @20%						$1,951,827
Winter Construction @15%						$2,927,740
Total Construction						$14,638,699

Table C-8: Portage - Girdwood 230kV Line

115 & 230KV TRANSMISSION LINES - KENAI PENINSULA

Portage - Girdwood (230KV) 11 MILES

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Tangent Structure	41	ea	$14,400	$5,800	$20,200	$821,251
Medium Angle	12	ea	$19,300	$30,800	$50,100	$581,962
DE/Large Angle	6	ea	$23,400	$42,000	$65,400	$379,843
20% Pipe Pile Fdn	27	ea	$960	$6,000	$6,960	$185,949
10% Special Foundations	13	ea	$3,000	$8,000	$11,000	$146,942
Drake Conductor	11	crkt mi	$22,176	$63,360	$85,536	$940,896
OPGW	11	mi	$10,000	$22,000	$32,000	$352,000
OHSW	11	mi	$2,000	$18,000	$20,000	$220,000
Dampers	174	ea	$50	$600	$650	$113,256
Aerial Balls/Bird Diverters	12	ea	$300	$2,000	$2,300	$26,717
Structure Signs	58	ea	$100	$500	$600	$34,848
20% Clearing	2	mi	$0	$25,000	$25,000	$55,000
Remove H-Structure	73	ea		$4,000	$4,000	$290,400
Remove Conductor	11	crkt mi		$31,680	$31,680	$348,480
Subtotal						$4,497,544
Mob/Demob						$89,951
Engineering, Management, Permitting @15%						$674,632
Subtotal						$5,262,127
Contingency @20%						$1,052,425
Access @25%						$1,315,532
Total Construction						$7,630,084

Table C-9: Girdwood - Indian 230kV Line

115 & 230KV TRANSMISSION LINES - KENAI PENINSULA

Girdwood - Indian (230KV) 10.7 MILES

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Tangent Structure	40	ea	$14,400	$5,800	$20,200	$798,853
Medium Angle	11	ea	$19,300	$30,800	$50,100	$566,090
DE/Large Angle	6	ea	$23,400	$42,000	$65,400	$369,484
20% Pipe Pile Fdn	26	ea	$960	$6,000	$6,960	$180,878
10% Special Foundations	13	ea	$3,000	$8,000	$11,000	$142,935
Drake Conductor	11	crkt mi	$22,176	$63,360	$85,536	$915,235
OPGW	11	mi	$10,000	$22,000	$32,000	$342,400
OHSW	11	mi	$2,000	$18,000	$20,000	$214,000
Dampers	169	ea	$50	$600	$650	$110,167
Aerial Balls/Bird Diverters	11	ea	$300	$2,000	$2,300	$25,988
Structure Signs	56	ea	$100	$500	$600	$33,898
20% Clearing	2	mi	$0	$25,000	$25,000	$53,500
Remove H-Structure	71	ea		$4,000	$4,000	$282,480
Remove Conductor	11	crkt mi		$31,680	$31,680	$338,976
Subtotal						$4,374,884
Mob/Demob						$87,498
Engineering, Management, Permitting @20%						$874,977
Subtotal						$5,337,358
Contingency @20%						$1,067,472
Access @20%						$1,067,472
Total Construction						$7,472,302

Table C-10: Indian - University 230kV Line

115 & 230KV TRANSMISSION LINES - KENAI PENINSULA

Indian - University (230KV) 16.5 MILES

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Tangent Structure	61	ea	$14,400	$5,800	$20,200	$1,231,877
Medium Angle	17	ea	$19,300	$30,800	$50,100	$872,942
DE/Large Angle	9	ea	$23,400	$42,000	$65,400	$569,765
20% Pipe Pile Fdn	40	ea	$960	$6,000	$6,960	$278,923
10% Special Foundations	20	ea	$3,000	$8,000	$11,000	$220,414
Drake Conductor	17	crkt mi	$22,176	$63,360	$85,536	$1,411,344
OPGW	17	mi	$10,000	$22,000	$32,000	$528,000
OHSW	17	mi	$2,000	$18,000	$20,000	$330,000
Dampers	261	ea	$50	$600	$650	$169,884
Aerial Balls/Bird Diverters	17	ea	$300	$2,000	$2,300	$40,075
Structure Signs	87	ea	$100	$500	$600	$52,272
20% Clearing	3	mi	$0	$25,000	$25,000	$82,500
Remove H-Structure	109	ea		$4,000	$4,000	$435,600
Remove Conductor	17	crkt mi		$31,680	$31,680	$522,720
Subtotal						$6,746,316
Mob/Demob						$202,389
Engineering, Management, Permitting @25%						$1,686,579
Subtotal						$8,635,285
Contingency @20%						$1,727,057
Access @15%						$1,295,293
Winter Construction @15%						$1,295,293
Total Construction						$12,952,927

Table C-11: Dave's Creek Substation

Kenai Transmission Upgrades

230kV Daves Creek

Scope: Convert 115kV line position to transformer, add 230/115kV transformer, add 230kV breaker bay and controls

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	A-frame 230kV	1	$5,000	$31,500	$36,500	$5,000	$31,500	$36,500
A-2	230kV 3-ph disconnect support	1	$3,000	$3,500	$6,500	$3,000	$3,500	$6,500
I-A-1	115kv line Terminal	1	$15,000		$15,000	$15,000	$0	$15,000
	Total A. Structures					$8,000	$35,000	$43,000
	B. Disconnects							
B-1	230kV 3-ph V switch	1	$10,000	$12,000	$22,000	$10,000	$12,000	$22,000
					$0	$0	$0	$0
	Total B. Disconnects					$10,000	$12,000	$22,000
	C. Arresters							
C-1	230kv arrestor	3	$1,500	$2,000	$3,500	$4,500	$6,000	$10,500
C-2	115kv arrestor	3	$1,200	$1,500	$2,700	$3,600	$4,500	$8,100
	Total C. Arresters					$8,100	$10,500	$18,600
	E. Circuit Breakers							
E-1	230kv GCB	1	$8,000	$80,000	$88,000	$8,000	$80,000	$88,000
					$0	$0	$0	$0
	Total E. Circuit Breakers					$8,000	$80,000	$88,000
	G. Protection and Control							
G-1	Modify Univ. line to xformer controls	1	$30,000	$10,000	$40,000	$30,000	$10,000	$40,000
G-2	230kV Univ. Line controls	1	$5,000	$80,000	$85,000	$5,000	$80,000	$85,000
G-3	230kV PT	3	$3,000	$10,000	$13,000	$9,000	$30,000	$39,000
I-G-1	115kV PT		$2,000		$2,000	$0	$0	$0
	Total G. Protection And Control					$35,000	$90,000	$125,000
	H. Power Transformers							
H-1	160MVA 230/115kV Xformer	1	$15,000	$2,500,000	$2,515,000	$15,000	$2,500,000	$2,515,000
					$0	$0	$0	$0
	Total H. Power Transformers					$15,000	$2,500,000	$2,515,000
H-1	SVC Integration	1	$3,800,000	$275,000	$4,075,000	$3,800,000	$275,000	$4,075,000
	J. SCADA and Communications							
J-1	Add 230kV bay	1	$10,000	$5,000	$15,000	$10,000	$5,000	$15,000
					$0	$0	$0	$0
	Total J. Scada and Communications					$10,000	$5,000	$15,000
	K. Conduit and Cables							
K-1	RGS & Cables	1	$60,000	$20,000	$80,000	$60,000	$20,000	$80,000
	Total K. Conduits and Cables					$60,000	$20,000	$80,000
	L. Foundations							
L-1	A-Frame	4	$2,500		$2,500	$10,000	$0	$10,000
L-2	Switch Support	2	$5,000		$5,000	$10,000	$0	$10,000
L-3	Xformer w. oil containment	1	$120,000	$30,000	$150,000	$120,000	$30,000	$150,000
L-4	230kV GCB	1	$3,000		$3,000	$3,000	$0	$3,000
	Total L. Foundations					$143,000	$30,000	$173,000
	M. Site Work							
M-1	Excavation	1	$80,000		$80,000	$80,000	$0	$80,000
M-2	Backfill	1	$80,000		$80,000	$80,000	$0	$80,000
	Total M. Site Work					$160,000	$0	$160,000
	N. Fence							
N-1	Expand existing	1	$20,000		$20,000	$20,000	$0	$20,000
					$0	$0	$0	$0

Kenai Transmission Upgrades

230kV Daves Creek

Scope: Convert 115kV line position to transformer, add 230/115kV transformer, add 230kV breaker bay and controls

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	Total N. Fence					$20,000	$0	$20,000
	O. Grounding							
O-1	Expand groundgrid	1	$15,000		$15,000	$15,000	$0	$15,000
					$0	$0	$0	$0
	Total O. Grounding					$15,000	$0	$15,000
	P. Building							
	?				$0	$0	$0	$0
					$0	$0	$0	$0
	Total P. Building					$0	$0	$0
	Location Adder for Labor	30%				$147,630		
	Total Construction					$4,439,730	$3,057,500	$7,497,230
	Land Rights and Permits	1%*						$74,972
	Design	13%*						$974,640
	Construction Management	9%*						$674,751
	Overheads	20%*						$1,499,446
	* of Total Construction $							
	Total Project Costs (+10%)							$11,793,143

Assumption:
Existing control building has sufficient room for 230kV controls

Table C-12: Summit & Hope Substations

Kenai Transmission Upgrades

230kV Summit and Hope

Scope: Replace 115/14.4kV single phase transformer and associated switches with equivalent 230/14.4kV unit

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	H- frame Sw. support	3	$10,000	$9,000	$19,000	$30,000	$27,000	$57,000
I-A-1	115kv line Terminal	1	$15,000		$15,000	$15,000	$0	$15,000
	Total A. Structures					$45,000	$27,000	$72,000
	B. Disconnects							
B-1	3 pole centerbreak V switch 230kV	2	$10,000	$12,000	$22,000	$20,000	$24,000	$44,000
B-2	230kv Circuit switcher w. stand	1	$15,000	$50,000	$65,000	$15,000	$50,000	$65,000
	Total B. Disconnects					$35,000	$74,000	$109,000
	C. Arresters							
C-1	230kv Arrestor	2	$1,500	$2,000	$3,500	$3,000	$4,000	$7,000
C-2	14.4 kv arrestor	2	$1,200	$1,500	$2,700	$2,400	$3,000	$5,400
	Total C. Arresters					$5,400	$7,000	$12,400
	E. Circuit Breakers							
					$0	$0	$0	$0
					$0	$0	$0	$0
	Total E. Circuit Breakers					$0	$0	$0
	G. Protection and Control							
G-1	Transformer protection	1	$20,000	$40,000	$60,000	$20,000	$40,000	$60,000
G-1	230kv Pt	1	$3,000	$10,000	$13,000	$3,000	$10,000	$13,000
	Total G. Protection And Control					$23,000	$50,000	$73,000
	H. Power Transformers							
H-1	230/14.4kV 2MVA 1-phase	1	$20,000	$500,000	$520,000	$20,000	$500,000	$520,000
					$0	$0	$0	$0
	Total H. Power Transformers					$20,000	$500,000	$520,000
	J. SCADA and Communications							
J-1	Upgrade existing	1	$15,000	$5,000	$20,000	$15,000	$5,000	$20,000
					$0	$0	$0	$0
	Total J. Scada and Communications					$15,000	$5,000	$20,000
	K. Conduit and Cables							
K-1	RGS and Cables	1	$30,000	$20,000	$50,000	$30,000	$20,000	$50,000
					$0	$0	$0	$0
	Total K. Conduits and Cables					$30,000	$20,000	$50,000
	L. Foundations							
L-1	230kv Circuit Switcher Stand	2	$5,000		$5,000	$10,000	$0	$10,000
L-2	Transformer w. Oil containment	1	$60,000	$15,000	$75,000	$60,000	$15,000	$75,000
	Total L. Foundations					$70,000	$15,000	$85,000
	M. Site Work							
M-1	Excavation and backfill	1	$40,000		$40,000	$40,000	$0	$40,000
					$0	$0	$0	$0
	Total M. Site Work					$40,000	$0	$40,000
	N. Fence							
N-1	New Fence	1	$15,000		$15,000	$15,000	$0	$15,000
					$0	$0	$0	$0
	Total N. Fence					$15,000	$0	$15,000
	O. Grounding							
O-1	Groundgrid	1	$35,000	$15,000	$50,000	$35,000	$15,000	$50,000
					$0	$0	$0	$0

Kenai Transmission Upgrades

230kV Summit and Hope

Scope: Replace 115/14.4kV single phase transformer and associated switches with equivalent 230/14.4kV unit

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	Total O. Grounding					$35,000	$15,000	$50,000
	Location Adder for Labor	30%				$100,020		
	Total Construction					$433,420	$713,000	$1,146,420
	Land Rights and Permits	1%*						$11,464
	Design	13%*						$149,035
	Construction Management	9%*						$103,178
	Overheads	20%*						$229,284
	* of Total Construction $							
	Total Project Costs (+10%)							$1,803,319

Table C-13: Portage Substation

Kenai Transmission Upgrades

230kV Portage

Scope: Replace 115/24.9kV transformer and associated switches with equivalent 230/24.9kV unit
Replace in line circuit switchers with 230kv units

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	H-frame Terminal	3	$10,000	$9,000	$19,000	$30,000	$27,000	$57,000
A-2	bus work	1	$10,000	$3,000	$13,000	$10,000	$3,000	$13,000
I-A-1	115kv line Terminal	3	$15,000		$15,000	$45,000	$0	$45,000
	Total A. Structures					$85,000	$30,000	$115,000
	B. Disconnects							
B-1	230kv Circuit Switcher, 3-phase	3	$15,000	$50,000	$65,000	$45,000	$150,000	$195,000
	w. stand				$0	$0	$0	$0
	Total B. Disconnects					$45,000	$150,000	$195,000
	C. Arresters							
C-1	230kv arrestor	3	$1,500	$2,000	$3,500	$4,500	$6,000	$10,500
C-2	24.9kv arrestor	3	$1,200	$1,500	$2,700	$3,600	$4,500	$8,100
	Total C. Arresters					$8,100	$10,500	$18,600
	E. Circuit Breakers							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total E. Circuit Breakers					$0	$0	$0
	G. Protection and Control							
G-1	New Xformer and line controls	1	$20,000	$60,000	$80,000	$20,000	$60,000	$80,000
G-2	230kV PT	2	$3,000	$10,000	$13,000	$6,000	$20,000	$26,000
G-3	Voltage sensors at tap	2	$10,000	$8,000	$18,000	$20,000	$16,000	$36,000
	Total G. Protection And Control					$26,000	$80,000	$106,000
	H. Power Transformers							
H-1	230/24.9kV - 10 MVA	1	$20,000	$1,500,000	$1,520,000	$20,000	$1,500,000	$1,520,000
					$0	$0	$0	$0
	Total H. Power Transformers					$20,000	$1,500,000	$1,520,000
	J. SCADA and Communications							
J-1	Upgrade existing	1	$15,000	$5,000	$20,000	$15,000	$5,000	$20,000
					$0	$0	$0	$0
	Total J. Scada and Communications					$15,000	$5,000	$20,000
	K. Conduit and Cables							
K-1	RGS and Cables	1	$60,000	$20,000	$80,000	$60,000	$20,000	$80,000
					$0	$0	$0	$0
	Total K. Conduits and Cables					$60,000	$20,000	$80,000
	L. Foundations							
L-1	230kv Circuit Switcher Stand	3	$5,000		$5,000	$15,000	$0	$15,000
L-2	Transformer w. Oil containment	1	$80,000	$20,000	$100,000	$80,000	$20,000	$100,000
	Total L. Foundations					$95,000	$20,000	$115,000
	M. Site Work							
M-1	Excavation & Backfill	1	$50,000	$50,000	$100,000	$50,000	$50,000	$100,000
					$0	$0	$0	$0
	Total M. Site Work					$50,000	$50,000	$100,000
	N. Fence							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total N. Fence					$0	$0	$0
	O. Grounding							

Kenai Transmission Upgrades

230kV Portage

Scope: Replace 115/24.9kV transformer and associated switches with equivalent 230/24.9kV unit
Replace in line circuit switchers with 230kv units

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
O-1	Expand existing	1	$15,000		$15,000	$15,000	$0	$15,000
					$0	$0	$0	$0
	Total O. Grounding					$15,000	$0	$15,000
	P. Building							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total P. Building					$0	$0	$0
	Location Adder for Labor	25%				$125,730		
	Total Construction					$544,830	$1,865,500	$2,410,330
	Land Rights and Permits	1%*						$24,103
	Design	13%*						$313,343
	Construction Management	9%*						$216,930
	Overheads	20%*						$482,066
	* of Total Construction $							
	Total Project Costs (+10%)							$3,791,449

Table C-14: Girdwood Substation

Kenai Transmission Upgrades

230kV Girdwood

Scope: Install 230kV GIS Ringbus and 230/24.9kV Transformer
Install 2 - 230kV Circuit Switchers at the tap

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	230kV OH/Cable Terminal	2	$7,500	$33,000	$40,500	$15,000	$66,000	$81,000
I-A-1	115kv line Terminal retire	1	$15,000		$15,000	$15,000	$0	$15,000
	Total A. Structures					$30,000	$66,000	$96,000
	B. Disconnects							
	N/A				$0	$0	$0	$0
	Total B. Disconnects					$0	$0	$0
	C. Arresters							
C-1	230kv arrestors at Xformer	3	$1,500	$2,000	$3,500	$4,500	$6,000	$10,500
C-2	24.9kV arrestor at xformer	3	$1,200	$1,500	$2,700	$3,600	$4,500	$8,100
C-3	230kv arrestors at terminal	6	$1,500	$2,000				
	Total C. Arresters					$8,100	$10,500	$18,600
	E. Circuit Breakers							
E-1	230kV ringus Gis w/ 4 positions	1		$4,000,000	$4,000,000	$0	$4,000,000	$4,000,000
					$0	$0	$0	$0
	Total E. Circuit Breakers					$0	$4,000,000	$4,000,000
	G. Protection and Control							
G-1	Panels for Xformer and lines	3	$20,000	$80,000	$100,000	$60,000	$240,000	$300,000
	Total G. Protection And Control					$60,000	$240,000	$300,000
	H. Power Transformers							
H-1	230/24.9kV 10 MVA	1	$20,000	$1,500,000	$1,520,000	$20,000	$1,500,000	$1,520,000
					$0	$0	$0	$0
	Total H. Power Transformers					$20,000	$1,500,000	$1,520,000
	J. SCADA and Communications							
J-1	Upgrade to ringbus	1	$15,000	$10,000	$25,000	$15,000	$10,000	$25,000
					$0	$0	$0	$0
	Total J. Scada and Communications					$15,000	$10,000	$25,000
	K. Conduit and Cables							
K-1	230kV XLPE w. terminations	2			$0	$0	$0	$0
K-2	RGS and 600V cables	1	$65,000	$25,000	$90,000	$65,000	$25,000	$90,000
	Total K. Conduits and Cables					$65,000	$25,000	$90,000
	L. Foundations							
L-1	Transformer w. oil containment	1	$80,000	$20,000	$100,000	$80,000	$20,000	$100,000
L-2	GIS Building	1	$60,000		$60,000	$60,000	$0	$60,000
L-3	Terminal	6	$3,500		$3,500	$21,000	$0	$21,000
	Total L. Foundations					$80,000	$20,000	$100,000
	M. Site Work							
M-1	Excavation and backfill	1	$100,000	$100,000	$200,000	$100,000	$100,000	$200,000
M-2	Road at Substation	1		$1,000,000	$1,000,000	$0	$1,000,000	$1,000,000
	Total M. Site Work					$100,000	$1,100,000	$1,200,000
	N. Fence							
N-1	Perimeter fence	1	$80,000	$50,000	$130,000	$80,000	$50,000	$130,000
					$0	$0	$0	$0
	Total N. Fence					$80,000	$50,000	$130,000
	O. Grounding							
O-1	New groundgrid	1	$50,000	$25,000	$75,000	$50,000	$25,000	$75,000
					$0	$0	$0	$0

Kenai Transmission Upgrades

230kV Girdwood

Scope: Install 230kV GIS Ringbus and 230/24.9kV Transformer
Install 2 - 230kV Circuit Switchers at the tap

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	Total O. Grounding					$50,000	$25,000	$75,000
	P. Building							
P-1	GIS Enclosure	1	$20,000	$100,000	$120,000	$20,000	$100,000	$120,000
P-2	Lighting	1	$20,000	$8,000	$28,000	$20,000	$8,000	$28,000
	Total P. Building					$40,000	$108,000	$148,000
	Location Adder for Labor	15%				$164,430		
	Total Construction					$712,530	$7,154,500	$7,867,030
	Land Rights and Permits	1%*						$78,670
	Design	9%*						$708,033
	Construction Management	9%*						$708,033
	Overheads	20%*						$1,573,406
	* of Total Construction $							
	Total Project Costs (+10%)							$12,028,689
	$per/Terminal							$2,602,172

Assumption:
No station upgrade prior to 230kV conversion
Double circuit from existing tap location to sub is constructed with conversion
2nd xformer not needed
Road will be permit condition

Table C-15: Indian Substation

Kenai Transmission Upgrades

230kV Indian

Scope: Replace 115/24.9kV transformer and associated switches with equivalent 230/24.9kV unit
Replace in line circuit switchers with 230kv units

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	H-frame Terminal	3	$10,000	$9,000	$19,000	$30,000	$27,000	$57,000
A-2	bus work	1	$10,000	$3,000	$13,000	$10,000	$3,000	$13,000
I-A-1	115kv line Terminal	3	$15,000		$15,000	$45,000	$0	$45,000
	Total A. Structures					$85,000	$30,000	$115,000
	B. Disconnects							
B-1	230kv Circuit Switcher, 3-phase	3	$15,000	$50,000	$65,000	$45,000	$150,000	$195,000
	w. stand				$0	$0	$0	$0
	Total B. Disconnects					$45,000	$150,000	$195,000
	C. Arresters							
C-1	230kv arrestor	3	$1,500	$2,000	$3,500	$4,500	$6,000	$10,500
C-2	24.9kv arrestor	3	$1,200	$1,500	$2,700	$3,600	$4,500	$8,100
	Total C. Arresters					$8,100	$10,500	$18,600
	E. Circuit Breakers							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total E. Circuit Breakers					$0	$0	$0
	G. Protection and Control							
G-1	New Xformer and line controls	1	$20,000	$60,000	$80,000	$20,000	$60,000	$80,000
G-2	230kV PT	3	$3,000	$10,000	$13,000	$9,000	$30,000	$39,000
G-3	Voltage Sensors at Tap	2	$10,000	$8,000	$18,000	$20,000	$16,000	$36,000
	Total G. Protection And Control					$29,000	$90,000	$119,000
	H. Power Transformers							
H-1	230/24.9kV - 5 MVA	1	$20,000	$1,000,000	$1,020,000	$20,000	$1,000,000	$1,020,000
					$0	$0	$0	$0
	Total H. Power Transformers					$20,000	$1,000,000	$1,020,000
	J. SCADA and Communications							
J-1	Upgrade existing	1	$15,000	$5,000	$20,000	$15,000	$5,000	$20,000
					$0	$0	$0	$0
	Total J. Scada and Communications					$15,000	$5,000	$20,000
	K. Conduit and Cables							
K-1	RGS and Cables	1	$60,000	$20,000	$80,000	$60,000	$20,000	$80,000
					$0	$0	$0	$0
	Total K. Conduits and Cables					$60,000	$20,000	$80,000
	L. Foundations							
L-1	230kv Circuit Switcher Stand	3	$5,000		$5,000	$15,000	$0	$15,000
L-2	Transformer w. Oil containment	1	$80,000	$20,000	$100,000	$80,000	$20,000	$100,000
	Total L. Foundations					$95,000	$20,000	$115,000
	M. Site Work							
M-1	Excavation & Backfill	1	$50,000	$50,000	$100,000	$50,000	$50,000	$100,000
					$0	$0	$0	$0
	Total M. Site Work					$50,000	$50,000	$100,000
	N. Fence							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total N. Fence					$0	$0	$0
	O. Grounding							

Kenai Transmission Upgrades

230kV Indian

Scope: Replace 115/24.9kV transformer and associated switches with equivalent 230/24.9kV unit
Replace in line circuit switchers with 230kv units

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
O-1	Expand existing	1	$15,000		$15,000	$15,000	$0	$15,000
					$0	$0	$0	$0
	Total O. Grounding					$15,000	$0	$15,000
	P. Building							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total P. Building					$0	$0	$0
	Location Adder for Labor	25%				$126,630		
	Total Construction					$548,730	$1,375,500	$1,924,230
	Land Rights and Permits	1%*						$19,242
	Design	13%*						$250,150
	Construction Management	9%*						$173,181
	Overheads	20%*						$384,846
	* of Total Construction $							
	Total Project Costs (+10%)							$3,026,814

Table C-16: University Substation

Kenai Transmission Upgrades

230kV University

Scope: Add 230kv PT and controls for line terminal

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	230kV PT Stand	3	$1,500	$1,500	$3,000	$4,500	$4,500	$9,000
A-2	Bus work	1	$5,000	$3,000	$8,000	$5,000	$3,000	$8,000
I-A-1	115kv line Terminal	1	$15,000		$15,000	$15,000	$0	$15,000
	Total A. Structures					$24,500	$7,500	$32,000
	G. Protection and Control							
G-1	line panel	1	$20,000	$80,000	$100,000	$20,000	$80,000	$100,000
G-2	230kv Pt	3	$3,000	$10,000	$13,000	$9,000	$30,000	$39,000
	Total G. Protection And Control					$29,000	$110,000	$139,000
	K. Conduit and Cables							
K-1	RGS and cables	1	$15,000	$5,000	$20,000	$15,000	$5,000	$20,000
					$0	$0	$0	$0
	Total K. Conduits and Cables					$15,000	$5,000	$20,000
	L. Foundations							
L-1	230kV PT Stand	3	$2,500		$2,500	$7,500	$0	$7,500
					$0	$0	$0	$0
	Total L. Foundations					$7,500	$0	$7,500
	O. Grounding							
O-1	Pt grdg	1	$5,000	$2,000	$7,000	$5,000	$2,000	$7,000
					$0	$0	$0	$0
	Total O. Grounding					$5,000	$2,000	$7,000
	Location Adder for Labor	0%				$24,300		
	Total Construction					$105,300	$124,500	$229,800
	Land Rights and Permits	1%*						$2,298
	Design	13%*						$29,874
	Construction Management	9%*						$20,682
	Overheads	20%*						$45,960
	* of Total Construction $							
	Total Project Costs (+10%)							$361,475

Assumption:
Control house has sufficient space for new line controls and protection

Table C-17: Quartz Creek Substation

Kenai Transmission Upgrades

115kV Quartz Creek Station

Scope: Add 1 breaker position to existing switchyard
Note: ring bus has 556 MCM ACSR - replace with 795 or larger

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	A-frame terminal	1	$4,000	$36,500	$40,500	$4,000	$36,500	$40,500
I-A-2	3-phase bus support	2	$1,500	$4,000	$5,500	$3,000	$8,000	$11,000
A-3	ring bus cond.& conn. repl.	1	$30,000	$33,050	$63,050	$30,000	$33,050	$63,050
A-4	115kv post insulator assbly	6	$1,000	$2,000	$3,000	$6,000	$12,000	$18,000
A-5	115kV suspension insulator assbly	3	$2,000	$3,000	$5,000	$6,000	$9,000	$15,000
	Total A. Structures					$49,000	$98,550	$147,550
	B. Disconnects							
B-1	115kv 3-ph V Switch	1	$10,000	$10,000	$20,000	$10,000	$10,000	$20,000
					$0	$0	$0	$0
	Total B. Disconnects					$10,000	$10,000	$20,000
	E. Circuit Breakers							
E-1	115kv GCB	1	$7,000	$55,000	$62,000	$7,000	$55,000	$62,000
					$0	$0	$0	$0
	Total E. Circuit Breakers					$7,000	$55,000	$62,000
	G. Protection and Control							
G-1	115kv PT	3	$1,500	$6,000	$7,500	$4,500	$18,000	$22,500
G-2	Relay Panel	1	$30,000	$80,000	$110,000	$30,000	$80,000	$110,000
G-3	Control Mods.	1	$6,000	$20,000	$26,000	$6,000	$20,000	$26,000
	Total G. Protection And Control					$40,500	$118,000	$158,500
	H. Power Transformers							
					$0	$0	$0	$0
					$0	$0	$0	$0
	Total H. Power Transformers					$0	$0	$0
	J. SCADA and Communications							
J-1	Add new equipment	1	$10,000	$5,000	$15,000	$10,000	$5,000	$15,000
					$0	$0	$0	$0
	Total J. Scada and Communications					$10,000	$5,000	$15,000
	K. Conduit and Cables							
K-1	RGS + cables	1	$65,000	$25,000	$90,000	$65,000	$25,000	$90,000
	Total K. Conduits and Cables					$65,000	$25,000	$90,000
	L. Foundations							
L-1	A-frame	4	$1,500		$1,500	$6,000	$0	$6,000
L-2	GCB	1	$2,500		$2,500	$2,500	$0	$2,500
I-L-3	Insulator Support	4	$5,500		$5,500	$22,000	$0	$22,000
	Total L. Foundations					$30,500	$0	$30,500
	M. Site Work							
M-1	Excav. & Backfill	1	$150,000		$150,000	$150,000	$0	$150,000
M-2	Surface Course	1	$10,000		$10,000	$10,000	$0	$10,000
	Total M. Site Work					$160,000	$0	$160,000
	O. Grounding							
O-1	Expand groundgrid	1	$35,000	$20,000	$55,000	$35,000	$20,000	$55,000
					$0	$0	$0	$0
	Total O. Grounding					$35,000	$20,000	$55,000
	Location Adder for Labor	30%				$122,100		

Kenai Transmission Upgrades

115kV Quartz Creek Station

Scope: Add 1 breaker position to existing switchyard
Note: ring bus has 556 MCM ACSR - replace with 795 or larger

Total Construction		$529,100	$331,550	$860,650
Land Rights and Permits	1%*			$8,607
Design	15%*			$111,885
Construction Management	9%*			$77,459
Overheads	20%*			$172,130
* of Total Construction $				
Total Project Costs (+10%)				$1,353,802

Assumption:
Control building has space for additional Relay panel
Station service is adequate to supply additional load

Table C-18: Dave's Creek - Quartz Creek Upgrade

Line Section	Existing Structure Type	Existing Framing	Existing Line Miles	Proposed Structure Type	Proposed Framing	Proposed Location	Total Costs
Quartz Ck - Davis Ck	STH-1A	115kV	14.5	STH-1D	115kV DBL	Existing Alignment	$ 13,650,000
Quartz Creek Sub	Add breaker position, increase bus ampacity						$ 1,353,802
Total							$ 15,003,802

C.2 Southcentral / Overall

Table C-19: Fossil Creek Substation

South Central Alaska Transmission Plans

115kv Fossil Creek

Scope: Install a new Substation
with 115kV ring bus & terminals for OH lines to Eklutna 2, P2 and Raptor

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-2	A-Frame 115kV	4	$5,000	$30,000	$35,000	$20,000	$120,000	$140,000
A-4	115kV 3-ph bus support	8	$1,500	$3,500	$5,000	$12,000	$28,000	$40,000
A-5	115kV 3-ph disconnect support	8	$2,500	$2,800	$5,300	$20,000	$22,400	$42,400
A-7	115kV bus work	1	$60,000	$90,000	$150,000	$60,000	$90,000	$150,000
A-8	230/115kv PT stand	3	$1,000	$1,500	$2,500	$3,000	$4,500	$7,500
	Total A. Structures					$115,000	$264,900	$379,900
	B. Disconnects							
B-1	115kV 3-ph disconnect	8	$10,000	$10,000	$20,000	$80,000	$80,000	$160,000
B-3	115kV 3-ph V switch	3	$10,000	$10,000	$20,000	$30,000	$30,000	$60,000
	Total B. Disconnects					$110,000	$110,000	$220,000
	C. Arresters							
C-2	115kv arrestor	3	$1,200	$1,500	$2,700	$3,600	$4,500	$8,100
	Total C. Arresters					$3,600	$4,500	$8,100
	E. Circuit Breakers							
E-2	115kV GCB	4	$7,000	$55,000	$62,000	$28,000	$220,000	$248,000
	Total E. Circuit Breakers					$28,000	$220,000	$248,000
	G. Protection and Control							
G-2	115kV PT	12	$2,000	$7,000	$9,000	$24,000	$84,000	$108,000
	Total G. Protection And Control					$24,000	$84,000	$108,000
	H. Power Transformers							
H-2	Sta. Service Xformer 24.9/.24kV, 300M	1	$2,000	$15,000	$17,000	$2,000	$15,000	$17,000
	Total H. Power Transformers					$2,000	$15,000	$17,000
	J. SCADA and Communications							
J-1	115kV facilities	1	$100,000	$100,000	$200,000	$100,000	$100,000	$200,000
J-2	Microwave Tower	1	$40,000	$40,000	$80,000	$40,000	$40,000	$80,000
J-3	cables, connections etc.	1	$70,000	$40,000	$110,000	$70,000	$40,000	$110,000
	Total J. Scada and Communications					$210,000	$180,000	$390,000
	K. Conduit and Cables							
K-1	RGS & Cables	1	$750,000	$400,000	$1,150,000	$750,000	$400,000	$1,150,000
	Total K. Conduits and Cables					$750,000	$400,000	$1,150,000
	L. Foundations							
L-1	A-Frame	16	$2,500		$2,500	$40,000	$0	$40,000
L-2	Switch Support	16	$5,000		$5,000	$80,000	$0	$80,000
L-3	Bus Support	8	$5,000		$5,000	$40,000	$0	$40,000
L-5	PT Support	3	$2,500		$2,500	$7,500	$0	$7,500
L-6	Control Enclosure	1	$80,000		$80,000	$80,000	$0	$80,000
L-7	Conduit Vault	6	$3,000	$7,000	$10,000	$18,000	$42,000	$60,000
L-8	Sta. Service Xformer	1	$1,500	$3,000	$4,500	$1,500	$3,000	$4,500
L-9	Light Pole	20	$2,000	$2,000	$4,000	$40,000	$40,000	$80,000
L-10	Microwave tower	1	$25,000		$25,000	$25,000	$0	$25,000

South Central Alaska Transmission Plans

115kv Fossil Creek

Scope: Install a new Substation
with 115kV ring bus & terminals for OH lines to Eklutna 2, P2 and Raptor

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
L-11	115kV GCB	4	$2,500		$2,500	$10,000	$0	$10,000
	Total L. Foundations					$342,000	$85,000	$427,000
	M. Site Work							
M-1	Excavation	1	$750,000		$750,000	$750,000	$0	$750,000
M-2	Backfill	1	$600,000	$200,000	$800,000	$600,000	$200,000	$800,000
	Total M. Site Work					$1,350,000	$200,000	$1,550,000
	N. Fence							
N-1	Perimeter Fence	1	$100,000	$150,000	$250,000	$100,000	$150,000	$250,000
					$0	$0	$0	$0
	Total N. Fence					$100,000	$150,000	$250,000
	O. Grounding							
O-1	Groundgrid	1	$200,000	$200,000	$400,000	$200,000	$200,000	$400,000
					$0	$0	$0	$0
	Total O. Grounding					$200,000	$200,000	$400,000
	P. Building							
P-1	230kV/115 Control Enclosure & Contr	1	$300,000	$500,000	$800,000	$300,000	$500,000	$800,000
					$0	$0	$0	$0
	Total P. Building					$300,000	$500,000	$800,000
	V. Station Lighting							
V-1	Light Pole	10	$1,000	$5,000	$6,000	$10,000	$50,000	$60,000
V-2	Lights, receptacles, J-boxes	1	$5,000	$40,000	$45,000	$5,000	$40,000	$45,000
	Total V. Yard Lights					$15,000	$90,000	$105,000
	Location Adder for Labor	20%				$1,064,880		
	Total Construction					$4,614,480	$2,503,400	$7,117,880
	Land Rights and Permits	1%**						$571,179
	Design	13%*						$925,324
	Construction Management	9%*						$640,609
	Overheads	20%*						$1,423,576
	* of Total Construction $							
	** includes land purchase $500,000							
	Total Project Costs							$10,678,568
	$/terminal							$2,669,642

Assumption:
Land is available in the area - 10 to 15 acres @$50,000

Table C-20: Eklutna Hydro Substation

South Central Alaska Transmission Plans

115kv Eklutna Hydro Plant

Scope: Install a new Substation
with 115kV ring bus & terminals for OH lines to Eklutna 2, Dow, 2-Xformers (existing)

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-2	A-Frame 115kV	5	$5,000	$30,000	$35,000	$25,000	$150,000	$175,000
A-4	115kV 3-ph bus support	10	$1,500	$3,500	$5,000	$15,000	$35,000	$50,000
A-5	115kV 3-ph disconnect support	10	$2,500	$2,800	$5,300	$25,000	$28,000	$53,000
A-7	115kV bus work	1	$60,000	$90,000	$150,000	$60,000	$90,000	$150,000
A-8	115kv PT stand	6	$1,000	$1,500	$2,500	$6,000	$9,000	$15,000
	Total A. Structures					$131,000	$312,000	$443,000
	B. Disconnects							
B-1	115kV 3-ph disconnect	10	$10,000	$10,000	$20,000	$100,000	$100,000	$200,000
B-3	115kV 3-ph V switch	3	$10,000	$10,000	$20,000	$30,000	$30,000	$60,000
	Total B. Disconnects					$130,000	$130,000	$260,000
	C. Arresters							
C-2	115kv arrestor	6	$1,200	$1,500	$2,700	$7,200	$9,000	$16,200
	Total C. Arresters					$7,200	$9,000	$16,200
	E. Circuit Breakers							
E-2	115kV GCB	5	$7,000	$55,000	$62,000	$35,000	$275,000	$310,000
	Total E. Circuit Breakers					$35,000	$275,000	$310,000
	G. Protection and Control							
G-2	115kV PT	15	$2,000	$7,000	$9,000	$30,000	$105,000	$135,000
	Total G. Protection And Control					$30,000	$105,000	$135,000
	H. Power Transformers							
H-2	Sta. Service Xformer 24.9/.24kV, 300N	1	$2,000	$15,000	$17,000	$2,000	$15,000	$17,000
	Total H. Power Transformers					$2,000	$15,000	$17,000
	J. SCADA and Communications							
J-1	115kV facilities	1	$100,000	$100,000	$200,000	$100,000	$100,000	$200,000
J-2	Relais and Controls	5	$15,000	$80,000	$95,000	$75,000	$400,000	$475,000
J-3	cables, connections etc.	1	$70,000	$40,000	$110,000	$70,000	$40,000	$110,000
	Total J. Scada and Communications					$245,000	$540,000	$785,000
	K. Conduit and Cables							
K-1	RGS & Cables	1	$750,000	$400,000	$1,150,000	$750,000	$400,000	$1,150,000
	Total K. Conduits and Cables					$750,000	$400,000	$1,150,000
	L. Foundations							
L-1	A-Frame	20	$2,500		$2,500	$50,000	$0	$50,000
L-2	Switch Support	20	$5,000		$5,000	$100,000	$0	$100,000
L-3	Bus Support	10	$5,000		$5,000	$50,000	$0	$50,000
L-5	PT Support	6	$2,500		$2,500	$15,000	$0	$15,000
L-7	Conduit Vault	6	$3,000	$7,000	$10,000	$18,000	$42,000	$60,000
L-8	Sta. Service Xformer	1	$1,500	$3,000	$4,500	$1,500	$3,000	$4,500
L-9	Light Pole	20	$2,000	$2,000	$4,000	$40,000	$40,000	$80,000

South Central Alaska Transmission Plans

115kv Eklutna Hydro Plant

Scope: Install a new Substation
with 115kV ring bus & terminals for OH lines to Eklutna 2, Dow, 2-Xformers (existing)

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
L-11	115kV GCB	5	$2,500		$2,500	$12,500	$0	$12,500
	Total L. Foundations					$287,000	$85,000	$372,000
	M. Site Work							
M-1	Excavation	1	$750,000		$750,000	$750,000	$0	$750,000
M-2	Backfill	1	$600,000	$200,000	$800,000	$600,000	$200,000	$800,000
	Total M. Site Work					$1,350,000	$200,000	$1,550,000
	N. Fence							
N-1	Perimeter Fence	1	$100,000	$150,000	$250,000	$100,000	$150,000	$250,000
					$0	$0	$0	$0
	Total N. Fence					$100,000	$150,000	$250,000
	O. Grounding							
O-1	Groundgrid	1	$200,000	$200,000	$400,000	$200,000	$200,000	$400,000
					$0	$0	$0	$0
	Total O. Grounding					$200,000	$200,000	$400,000
	P. Building							
					$0	$0	$0	$0
	Total P. Building					$0	$0	$0
	V. Station Lighting							
V-1	Light Pole	10	$1,000	$5,000	$6,000	$10,000	$50,000	$60,000
V-2	Lights, receptacles, J-boxes	1	$5,000	$40,000	$45,000	$5,000	$40,000	$45,000
	Total V. Yard Lights					$15,000	$90,000	$105,000
	Location Adder for Labor	20%				$984,660		
	Total Construction					$4,266,860	$2,511,000	$6,777,860
	Land Rights and Permits	10%						$67,779
	Design	13%*						$881,122
	Construction Management	9%*						$610,007
	Overheads	20%*						$1,355,572
	* of Total Construction $							
	Total Project Costs							$9,692,340
	$/terminal							$2,423,085

Assumption:
Land is available w/o costs

C.3 Northern System

Table C-21: Lorraine Substation

South Central Alaska Transmission Plans

230kv Switchyard Lorraine

Scope: Install a new breaker and a half switchyard with 8 terminals: 2 OH from Pt. Mac, , 2 OH to Douglas, Teeland ,
& 1 OH to E.Terminal, SVC, fut. Xformer to 115kV

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	A-frame 230kV	7	$5,000	$31,500	$36,500	$35,000	$220,500	$255,500
A-3	230kv 3-ph bus support	18	$1,500	$4,000	$5,500	$27,000	$72,000	$99,000
A-6	230kV Bus work	1	$300,000	$450,000	$750,000	$300,000	$450,000	$750,000
A-8	230kv PT stand	2	$1,000	$1,500	$2,500	$2,000	$3,000	$5,000
A-9	230kV 3-ph disconnect support	23	$3,000	$3,500	$6,500	$69,000	$80,500	$149,500
	Total A. Structures					$433,000	$826,000	$1,259,000
	B. Disconnects							
B-2	230kV 3-ph V switch	6	$12,000	$15,000	$27,000	$72,000	$90,000	$162,000
B-3	230kV 3-ph disconnect	23	$12,000	$15,000	$27,000	$276,000	$345,000	$621,000
	Total B. Disconnects					$348,000	$435,000	$783,000
	C. Arresters							
C-1	230kv arrestor	3	$1,500	$2,000	$3,500	$4,500	$6,000	$10,500
	Total C. Arresters					$4,500	$6,000	$10,500
	E. Circuit Breakers							
E-1	230kv GCB	11	$8,000	$80,000	$88,000	$88,000	$880,000	$968,000
	Total E. Circuit Breakers					$88,000	$880,000	$968,000
	G. Protection and Control							
G-1	230kV PT	12	$3,000	$10,000	$13,000	$36,000	$120,000	$156,000
	Total G. Protection And Control					$36,000	$120,000	$156,000
	H. Power Transformers							
H-1	SVC Transformer & Controls	1	$13,465,000	$15,000	$13,480,000	$13,465,000	$15,000	$13,480,000
H-2	Sta. Service Xformer 24.9/.24kV, 300M	1	$2,000	$15,000	$17,000	$2,000	$15,000	$17,000
	Total H. Power Transformers					$13,467,000	$30,000	$13,497,000
	J. SCADA and Communications							
J-1	230kV facilities	1	$70,000	$70,000	$140,000	$70,000	$70,000	$140,000
J-2	Microwave Tower	1	$80,000	$120,000	$200,000	$80,000	$120,000	$200,000
J-3	cables, connections etc.	1	$60,000	$30,000	$90,000	$60,000	$30,000	$90,000
	Total J. Scada and Communications					$210,000	$220,000	$430,000
	K. Conduit and Cables							
K-1	RGS & Cables	1	$1,100,000	$500,000	$1,600,000	$1,100,000	$500,000	$1,600,000
	Total K. Conduits and Cables					$1,100,000	$500,000	$1,600,000
	L. Foundations							
L-1	A-Frame	14	$2,500		$2,500	$35,000	$0	$35,000
L-2	Switch Support	23	$5,000		$5,000	$115,000	$0	$115,000
L-3	Bus Support	18	$5,000		$5,000	$90,000	$0	$90,000
L-4	230kV GCB	11	$3,000		$3,000	$33,000	$0	$33,000
L-5	230kV PT Support	2	$2,500		$2,500	$5,000	$0	$5,000
L-6	Control Enclosure	1	$80,000		$80,000	$80,000	$0	$80,000
L-7	Conduit Vault	5	$3,000	$7,000	$10,000	$15,000	$35,000	$50,000
L-8	Sta. Service Xformer	1	$1,500	$3,000	$4,500	$1,500	$3,000	$4,500

South Central Alaska Transmission Plans

230kv Switchyard Lorraine

Scope: Install a new breaker and a half switchyard with 8 terminals: 2 OH from Pt. Mac, , 2 OH to Douglas, Teeland , & 1 OH to E.Terminal, SVC, fut. Xformer to 115kV

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
L-9	Light Pole	20	$2,000	$2,000	$4,000	$40,000	$40,000	$80,000
L-10	Microwave tower	1	$25,000		$25,000	$25,000	$0	$25,000
L-11	SVC Foundations	1	$175,000	$35,000	$210,000	$175,000	$35,000	$210,000
	Total L. Foundations					$614,500	$113,000	$727,500
	M. Site Work							
M-1	Excavation	1	$1,500,000		$1,500,000	$1,500,000	$0	$1,500,000
M-2	Backfill	1	$1,200,000	$400,000	$1,600,000	$1,200,000	$400,000	$1,600,000
	Total M. Site Work					$2,700,000	$400,000	$3,100,000
	N. Fence							
N-1	Perimeter Fence	1	$100,000	$150,000	$250,000	$100,000	$150,000	$250,000
					$0	$0	$0	$0
	Total N. Fence					$100,000	$150,000	$250,000
	O. Grounding							
O-1	Groundgrid	1	$300,000	$300,000	$600,000	$300,000	$300,000	$600,000
					$0	$0	$0	$0
	Total O. Grounding					$300,000	$300,000	$600,000
	P. Building							
P-1	230kV/115 Control Enclosure & Contr	1	$600,000	$1,300,000	$1,900,000	$600,000	$1,300,000	$1,900,000
					$0	$0	$0	$0
	Total P. Building					$600,000	$1,300,000	$1,900,000
	V. Station Lighting							
V-1	Light Pole	20	$1,000	$5,000	$6,000	$20,000	$100,000	$120,000
V-2	Lights, receptacles, J-boxes	1	$5,000	$40,000	$45,000	$5,000	$40,000	$45,000
	Total V. Yard Lights					$25,000	$140,000	$165,000
	Location Adder for Labor	20%				$4,005,200		
	Total Construction					$24,031,200	$5,420,000	**$29,451,200**
	Land Rights and Permits	1%**						$877,757
	Design	8%*						$2,356,096
	Construction Management	9%*						$2,650,608
	Overheads	20%*						$5,890,240
	* of Total Construction $							
	** includes land purchase $600,000							
	Total Project Costs							**$41,225,901**

TableC-22: Douglas Substation

South Central Alaska Transmission Plans

230kV Douglas

Scope: Install a new breaker and a half switchyard with4(6) terminals: 2 Xformer 230/138kV 150MVA(fut OH to north), 2 OH to Lorraine, fut OH to north
fut 3rd line north; 138kV single & xfer bus w. 6 terminals
2-138/230kV xformers, 2 lines north, T-land line and 138/24.9kV xformer

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
I	**230kV Yard**							
	A. Structures							
A-1	A-frame 230kV	4	$5,000	$31,500	$36,500	$20,000	$126,000	$146,000
A-3	230kv 3-ph bus support	18	$1,500	$4,000	$5,500	$27,000	$72,000	$99,000
A-6	230kV Bus work	1	$300,000	$450,000	$750,000	$300,000	$450,000	$750,000
A-8	230kv PT stand	2	$1,000	$1,500	$2,500	$2,000	$3,000	$5,000
A-9	230kV 3-ph disconnect support	14	$3,000	$3,500	$6,500	$42,000	$49,000	$91,000
	Total A. Structures					$391,000	$700,000	$1,091,000
	B. Disconnects							
B-3	230kV 3-ph V switch	4	$15,000	$20,000	$35,000	$60,000	$80,000	$140,000
B-4	230kV 3-ph disconnect	14	$15,000	$20,000	$35,000	$210,000	$280,000	$490,000
	Total B. Disconnects					$270,000	$360,000	$630,000
	C. Arresters							
C-1	230kv arrestor	6	$1,500	$2,000	$3,500	$9,000	$12,000	$21,000
C-2	138kv arrestor	6	$1,200	$1,500	$2,700	$7,200	$9,000	$16,200
	Total C. Arresters					$16,200	$21,000	$37,200
	E. Circuit Breakers							
E-1	230kv GCB	6	$15,000	$110,000	$125,000	$90,000	$660,000	$750,000
	Total E. Circuit Breakers					$90,000	$660,000	$750,000
	G. Protection and Control							
8	230kV PT	8	$3,000	$10,000	$13,000	$24,000	$80,000	$104,000
	Total G. Protection And Control					$24,000	$80,000	$104,000
	H. Power Transformers							
H-1	150MVA 230/138/115kV Xformer	2	$15,000	$2,500,000	$2,515,000	$30,000	$5,000,000	$5,030,000
H-2	Sta. Service Xformer 24.9/.24kV, 300N	1	$2,000	$15,000	$17,000	$2,000	$15,000	$17,000
	Total H. Power Transformers					$32,000	$5,015,000	$5,047,000
	J. SCADA and Communications							
J-1	Add 230kV facilities	1	$60,000	$60,000	$120,000	$60,000	$60,000	$120,000
J-2	Fiberoptic cables	1	$50,000	$20,000	$70,000	$50,000	$20,000	$70,000
	Total J. Scada and Communications					$110,000	$80,000	$190,000
	K. Conduit and Cables							
K-1	RGS & Cables	1	$750,000	$400,000	$1,150,000	$750,000	$400,000	$1,150,000
	Total K. Conduits and Cables					$750,000	$400,000	$1,150,000
	L. Foundations							
L-1	A-Frame	16	$2,500		$2,500	$40,000	$0	$40,000
L-2	Switch Support	14	$5,000		$5,000	$70,000	$0	$70,000
L-3	Xformer w. oil containment	2	$120,000	$30,000	$150,000	$240,000	$60,000	$300,000
L-4	230kV GCB	6	$3,000		$3,000	$18,000	$0	$18,000
L-5	230kV PT Support	2	$2,500		$2,500	$5,000	$0	$5,000
L-6	Control Enclosure	1	$80,000		$80,000	$80,000	$0	$80,000
L-7	Conduit Vault	4	$3,000	$7,000	$10,000	$12,000	$28,000	$40,000
L-8	Sta. Service Xformer	1	$1,500	$3,000		$1,500		
L-9	Bus Support	18	$5,000		$5,000	$90,000	$0	$90,000
L-10	Light Pole	20	$2,000	$2,000		$40,000		
	Total L. Foundations					$596,500	$88,000	$643,000

South Central Alaska Transmission Plans

230kV Douglas

Scope: Install a new breaker and a half switchyard with4(6) terminals: 2 Xformer 230/138kV 150MVA(fut OH to north), 2 OH to Lorraine, fut OH to north
fut 3rd line north; 138kV single & xfer bus w. 6 terminals
2-138/230kV xformers, 2 lines north, T-land line and 138/24.9kV xformer

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	M. Site Work							
M-1	Excavation	1	$900,000		$900,000	$900,000	$0	$900,000
M-2	Backfill	1	$900,000	$400,000	$1,300,000	$900,000	$400,000	$1,300,000
	Total M. Site Work					$1,800,000	$400,000	$2,200,000
	N. Fence							
N-1	Expand existing	1	$100,000	$150,000	$250,000	$100,000	$150,000	$250,000
					$0	$0	$0	$0
	Total N. Fence					$100,000	$150,000	$250,000
	O. Grounding							
O-1	Expand groundgrid	1	$300,000	$150,000	$450,000	$300,000	$150,000	$450,000
					$0	$0	$0	$0
	Total O. Grounding					$300,000	$150,000	$450,000
	P. Building							
P-1	230kV Control Enclosure & Controls	1	$400,000	$750,000	$1,150,000	$400,000	$750,000	$1,150,000
					$0	$0	$0	$0
	Total P. Building					$400,000	$750,000	$1,150,000
	V. Station Lighting							
V-1	Light Pole	20	$1,000	$5,000	$6,000	$20,000	$100,000	$120,000
V-2	Lights, receptacles, J-boxes	1	$5,000	$40,000	$45,000	$5,000	$40,000	$45,000
	Total V. Yard Lights					$25,000	$140,000	$165,000
	Total Construction							$13,857,200
II	**138kV Yard**							
	A. Structures							
A-2	A-Frame 138kV	3	$5,000	$30,000	$35,000	$15,000	$90,000	$105,000
A-4	138kV 3-ph bus support	16	$1,500	$3,500	$5,000	$24,000	$56,000	$80,000
A-5	138kV 3-ph disconnect support	14	$2,500	$2,800	$5,300	$35,000	$39,200	$74,200
A-7	138kV bus work	1	$120,000	$180,000	$300,000	$120,000	$180,000	$300,000
A-8	138kv PT stand	2	$1,000	$1,500	$2,500	$2,000	$3,000	$5,000
	Total A. Structures					$196,000	$368,200	$564,200
	B. Disconnects							
B-1	138kV 3-ph disconnect	14	$10,000	$15,000	$25,000	$140,000	$210,000	$350,000
B-3	138kV 3-ph V switch	6	$10,000	$15,000	$25,000	$60,000	$90,000	$150,000
	Total B. Disconnects					$200,000	$300,000	$500,000
	C. Arresters							
C-2	138kv arrestor	3	$1,200	$1,500	$2,700	$3,600	$4,500	$8,100
	Total C. Arresters					$3,600	$4,500	$8,100
	E. Circuit Breakers							
E-2	138kV GCB	7	$7,000	$65,000	$72,000	$49,000	$455,000	$504,000
	Total E. Circuit Breakers					$49,000	$455,000	$504,000
	G. Protection and Control							

South Central Alaska Transmission Plans

230kV Douglas

Scope: Install a new breaker and a half switchyard with4(6) terminals: 2 Xformer 230/138kV 150MVA(fut OH to north), 2 OH to Lorraine, fut OH to north
fut 3rd line north; 138kV single & xfer bus w. 6 terminals
2-138/230kV xformers, 2 lines north, T-land line and 138/24.9kV xformer

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
G-2	138kV PT	8	$2,000	$7,000	$9,000	$16,000	$56,000	$72,000
	Total G. Protection And Control					$16,000	$56,000	$72,000
	H. Power Transformers							
	None							
	Total H. Power Transformers					$0	$0	$0
	J. SCADA and Communications							
J-1	138kV facilities	1	$100,000	$100,000	$200,000	$100,000	$100,000	$200,000
J-2	Relais and Controls	7	$15,000	$80,000	$95,000	$105,000	$560,000	$665,000
J-3	cables, connections etc.	1	$70,000	$40,000	$110,000	$70,000	$40,000	$110,000
	Total J. Scada and Communications					$275,000	$700,000	$975,000
	K. Conduit and Cables							
K-1	RGS & Cables	1	$750,000	$400,000	$1,150,000	$750,000	$400,000	$1,150,000
	Total K. Conduits and Cables					$750,000	$400,000	$1,150,000
	L. Foundations							
L-1	A-Frame	12	$2,500		$2,500	$30,000	$0	$30,000
L-2	Switch Support	14	$5,000		$5,000	$70,000	$0	$70,000
L-3	Bus Support	16	$5,000		$5,000	$80,000	$0	$80,000
L-5	PT Support	3	$2,500		$2,500	$7,500	$0	$7,500
L-7	Conduit Vault	6	$3,000	$7,000	$10,000	$18,000	$42,000	$60,000
L-11	138kV GCB	7	$2,500		$2,500	$17,500	$0	$17,500
	Total L. Foundations					$223,000	$42,000	$265,000
	M. Site Work							
M-1	Excavation	1	$750,000		$750,000	$750,000	$0	$750,000
M-2	Backfill	1	$600,000	$200,000	$800,000	$600,000	$200,000	$800,000
	Total M. Site Work					$1,350,000	$200,000	$1,550,000
	N. Fence							
N-1	Perimeter Fence	0	$100,000	$150,000	$250,000	$0	$0	$0
					$0	$0	$0	$0
	Total N. Fence					$0	$0	$0
	O. Grounding							
O-1	Groundgrid	1	$200,000	$200,000	$400,000	$200,000	$200,000	$400,000
					$0	$0	$0	$0
	Total O. Grounding					$200,000	$200,000	$400,000
	P. Building							
					$0	$0	$0	$0
	Total P. Building					$0	$0	$0
	V. Station Lighting							
V-1	Light Pole	0	$1,000	$5,000	$6,000	$0	$0	$0
V-2	Lights, receptacles, J-boxes	0	$5,000	$40,000	$45,000	$0	$0	$0
	Total V. Yard Lights					$0	$0	$0
	Construction Total							$5,980,200

South Central Alaska Transmission Plans

230kV Douglas

Scope: Install a new breaker and a half switchyard with4(6) terminals: 2 Xformer 230/138kV 150MVA(fut OH to north), 2 OH to Lorraine, fut OH to north
fut 3rd line north; 138kV single & xfer bus w. 6 terminals
2-138/230kV xformers, 2 lines north, T-land line and 138/24.9kV xformer

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	Location Adder for Labor	20%				$1,264,920		
	Total Construction					$10,697,140	$11,719,700	$22,416,840
	Land Rights and Permits	1%*						$224,168
	Design	13%*						$2,914,189
	Construction Management	9%*						$2,017,516
	Overheads	20%*						$4,483,368
	* of Total Construction $							
	Total Project Costs							$32,056,081

Assumption:
138kV controls fit in new 230kV control building; sufficient real estate next to existing is available

Table C-23: Healy Substation

Alaska Transmission Plans

230kv Switchyard Healy

Scope: Install a new breaker and a half switchyard with 6 terminals: 2 OH from Gold Creek, , 2 OH to Fbks, 1-OH to Healy Plant, 1-OH Gold Creek (fut)
Note: the "future" terminal can be used for either Gold Creek or a 3rd line to Faitbanks

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	A-frame 230kV	5	$5,000	$31,500	$36,500	$25,000	$157,500	$182,500
A-3	230kv 3-ph bus support	18	$1,500	$4,000	$5,500	$27,000	$72,000	$99,000
A-6	230kV Bus work	1	$300,000	$450,000	$750,000	$300,000	$450,000	$750,000
A-8	230kv PT stand	2	$1,000	$1,500	$2,500	$2,000	$3,000	$5,000
A-9	230kV 3-ph disconnect support	23	$3,000	$3,500	$6,500	$69,000	$80,500	$149,500
	Total A. Structures					$423,000	$763,000	$1,186,000
	B. Disconnects							
B-2	230kV 3-ph V switch	5	$15,000	$20,000	$35,000	$75,000	$100,000	$175,000
B-3	230kV 3-ph disconnect	23	$15,000	$20,000	$35,000	$345,000	$460,000	$805,000
	Total B. Disconnects					$420,000	$560,000	$980,000
	C. Arresters							
	Total C. Arresters					$0	$0	$0
	E. Circuit Breakers							
E-1	230kv GCB	8	$15,000	$110,000	$125,000	$120,000	$880,000	$1,000,000
	Total E. Circuit Breakers					$120,000	$880,000	$1,000,000
	G. Protection and Control							
G-1	230kV PT	11	$3,000	$10,000	$13,000	$33,000	$110,000	$143,000
	Total G. Protection And Control					$33,000	$110,000	$143,000
	H. Power Transformers							
H-2	Sta. Service Xformer 24.9/.24kV, 300M	1	$2,000	$15,000	$17,000	$2,000	$15,000	$17,000
	Total H. Power Transformers					$2,000	$15,000	$17,000
	J. SCADA and Communications							
J-1	230kV facilities	1	$70,000	$70,000	$140,000	$70,000	$70,000	$140,000
J-2	Microwave Tower	1	$40,000	$40,000	$80,000	$40,000	$40,000	$80,000
J-3	cables, connections etc.	1	$60,000	$30,000	$90,000	$60,000	$30,000	$90,000
	Total J. Scada and Communications					$170,000	$140,000	$310,000
	K. Conduit and Cables							
K-1	RGS & Cables	1	$500,000	$300,000	$800,000	$500,000	$300,000	$800,000
	Total K. Conduits and Cables					$500,000	$300,000	$800,000
	L. Foundations							
L-1	A-Frame	20	$2,500		$2,500	$50,000	$0	$50,000
L-2	Switch Support	23	$5,000		$5,000	$115,000	$0	$115,000
L-3	Bus Support	18	$5,000		$5,000	$90,000	$0	$90,000
L-4	230kV GCB	8	$3,000		$3,000	$24,000	$0	$24,000
L-5	230kV PT Support	2	$2,500		$2,500	$5,000	$0	$5,000
L-6	Control Enclosure	1	$80,000		$80,000	$80,000	$0	$80,000

Alaska Transmission Plans

230kv Switchyard Healy

Scope: Install a new breaker and a half switchyard with 6 terminals: 2 OH from Gold Creek, , 2 OH to Fbks, 1-OH to Healy Plant, 1-OH Gold Creek (fut)
Note: the "future" terminal can be used for either Gold Creek or a 3rd line to Faitbanks

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
L-7	Conduit Vault	5	$3,000	$7,000	$10,000	$15,000	$35,000	$50,000
L-8	Sta. Service Xformer	1	$1,500	$3,000	$4,500	$1,500	$3,000	$4,500
L-9	Light Pole	20	$2,000	$2,000	$4,000	$40,000	$40,000	$80,000
L-10	Microwave tower	1	$25,000		$25,000	$25,000	$0	$25,000
	Total L. Foundations					$445,500	$78,000	$523,500
	M. Site Work							
M-1	Excavation	1	$800,000		$800,000	$800,000	$0	$800,000
M-2	Backfill	1	$1,000,000	$400,000	$1,400,000	$1,000,000	$400,000	$1,400,000
	Total M. Site Work					$1,800,000	$400,000	$2,200,000
	N. Fence							
N-1	Perimeter Fence	1	$100,000	$150,000	$250,000	$100,000	$150,000	$250,000
					$0	$0	$0	$0
	Total N. Fence					$100,000	$150,000	$250,000
	O. Grounding							
O-1	Groundgrid	1	$300,000	$150,000	$450,000	$300,000	$150,000	$450,000
					$0	$0	$0	$0
	Total O. Grounding					$300,000	$150,000	$450,000
	P. Building							
P-1	230kV Control Enclosure & Controls	1	$400,000	$750,000	$1,150,000	$400,000	$750,000	$1,150,000
					$0	$0	$0	$0
	Total P. Building					$400,000	$750,000	$1,150,000
	V. Station Lighting							
V-1	Light Pole	20	$1,000	$5,000	$6,000	$20,000	$100,000	$120,000
V-2	Lights, receptacles, J-boxes	1	$5,000	$40,000	$45,000	$5,000	$40,000	$45,000
	Total V. Yard Lights					$25,000	$140,000	$165,000
	Location Adder for Labor	30%				$1,421,550		
	Total Construction					$6,160,050	$4,436,000	$10,596,050

Land Rights and Permits	1%**	$705,961
Design	13%*	$1,377,487
Construction Management	9%*	$953,645
Overheads	20%*	$2,119,210
* of Total Construction $		
** includes land purchase $600,000		
Total Project Costs		$15,752,352
$/bay		$3,938,088
$/terminal		$2,250,336

Assumption:
Land is available in the area - 10 to 15 acres @$50,000

Alaska Transmission Plans

230kv Substation Healy

Scope: Install a new230kV breaker and a half switchyard (operated initially as ring bus) with 4 terminals: 2 -150MVA Xformers, 2 OH to Fbks
Note: operated at 230kV

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	A-frame 230kV	4	$5,000	$31,500	$36,500	$20,000	$126,000	$146,000
A-3	230kv 3-ph bus support	18	$1,500	$4,000	$5,500	$27,000	$72,000	$99,000
A-4	138kV 3-ph bus support	4	$1,500	$4,000	$5,500	$6,000	$16,000	$22,000
A-5	138kV switch support	2	$3,000	$3,500	$6,500	$6,000	$7,000	$13,000
A-6	230kV Bus work	1	$300,000	$450,000	$750,000	$300,000	$450,000	$750,000
A-7	138kV A-frame	1	$5,000	$31,500	$36,500	$5,000	$31,500	$36,500
A-8	230kv PT stand	2	$1,000	$1,500	$2,500	$2,000	$3,000	$5,000
A-9	230kV 3-ph disconnect support	14	$3,000	$3,500	$6,500	$42,000	$49,000	$91,000
	Total A. Structures					$408,000	$754,500	$1,162,500
	B. Disconnects							
B-1	138kV 3-ph switch	3	$12,000	$15,000	$27,000	$36,000	$45,000	$81,000
B-2	230kV 3-ph V switch	2	$15,000	$20,000	$35,000	$30,000	$40,000	$70,000
B-3	230kV 3-ph disconnect	14	$15,000	$20,000	$35,000	$210,000	$280,000	$490,000
	Total B. Disconnects					$276,000	$365,000	$641,000
	C. Arresters							
C-1	230kV Arrestor	6	$1,500	$2,000	$3,500	$9,000	$12,000	$21,000
C-2	138kV Arrester	6	$1,200	$1,500	$2,700	$7,200	$9,000	$16,200
	Total C. Arresters					$16,200	$21,000	$37,200
	E. Circuit Breakers							
E-1	230kv GCB	4	$15,000	$110,000	$125,000	$60,000	$440,000	$500,000
E-2	138kV GCB	1	$15,000	$90,000	$105,000	$15,000	$90,000	$105,000
	Total E. Circuit Breakers					$75,000	$530,000	$605,000
	G. Protection and Control							
G-1	230kV PT	8	$3,000	$10,000	$13,000	$24,000	$80,000	$104,000
G-2	138kV PT	1	$3,000	$10,000	$13,000	$3,000	$10,000	$13,000
	Total G. Protection And Control					$27,000	$90,000	$117,000
	H. Power Transformers							
H-1	150MVA Xformer 138/230kV	2	$15,000	$2,500,000	$2,515,000	$30,000	$5,000,000	$5,030,000
H-2	Sta. Service Xformer 24.9/.24kV, 300N	1	$2,000	$15,000	$17,000	$2,000	$15,000	$17,000
	Total H. Power Transformers					$32,000	$5,015,000	$5,047,000
	J. SCADA and Communications							
J-1	230kV facilities	1	$70,000	$70,000	$140,000	$70,000	$70,000	$140,000
J-2	Microwave Tower	1	$40,000	$40,000	$80,000	$40,000	$40,000	$80,000
J-3	cables, connections etc.	1	$60,000	$30,000	$90,000	$60,000	$30,000	$90,000
	Total J. Scada and Communications					$170,000	$140,000	$310,000
	K. Conduit and Cables							
K-1	RGS & Cables	1	$500,000	$300,000	$800,000	$500,000	$300,000	$800,000
	Total K. Conduits and Cables					$500,000	$300,000	$800,000
	L. Foundations							
L-1	A-Frame	20	$2,500		$2,500	$50,000	$0	$50,000
L-2	Switch Support	16	$5,000		$5,000	$80,000	$0	$80,000
L-3	Bus Support	20	$5,000		$5,000	$100,000	$0	$100,000
L-4	230/138kV GCB	5	$3,000		$3,000	$15,000	$0	$15,000
L-5	230kV PT Support	2	$2,500		$2,500	$5,000	$0	$5,000
L-6	Control Enclosure	1	$80,000		$80,000	$80,000	$0	$80,000

Alaska Transmission Plans

230kv Substation Healy

Scope: Install a new230kV breaker and a half switchyard (operated initially as ring bus) with 4 terminals: 2 -150MVA Xformers, 2 OH to Fbks
Note: operated at 230kV

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
L-7	Conduit Vault	5	$3,000	$7,000	$10,000	$15,000	$35,000	$50,000
L-8	Sta. Service Xformer	1	$1,500	$3,000	$4,500	$1,500	$3,000	$4,500
L-9	Light Pole	20	$2,000	$2,000	$4,000	$40,000	$40,000	$80,000
L-10	Microwave tower	1	$25,000		$25,000	$25,000	$0	$25,000
L-11	Xformer & Oil Containment	2	$120,000	$30,000	$150,000	$240,000	$60,000	$300,000
	Total L. Foundations					$651,500	$138,000	$789,500
	M. Site Work							
M-1	Excavation	1	$800,000		$800,000	$800,000	$0	$800,000
M-2	Backfill	1	$1,000,000	$400,000	$1,400,000	$1,000,000	$400,000	$1,400,000
	Total M. Site Work					$1,800,000	$400,000	$2,200,000
	N. Fence							
N-1	Perimeter Fence	1	$100,000	$150,000	$250,000	$100,000	$150,000	$250,000
					$0	$0	$0	$0
	Total N. Fence					$100,000	$150,000	$250,000
	O. Grounding							
O-1	Groundgrid	1	$300,000	$150,000	$450,000	$300,000	$150,000	$450,000
					$0	$0	$0	$0
	Total O. Grounding					$300,000	$150,000	$450,000
	P. Building							
P-1	230kV Control Enclosure & Controls	1	$400,000	$400,000	$800,000	$400,000	$400,000	$800,000
					$0	$0	$0	$0
	Total P. Building					$400,000	$400,000	$800,000
	V. Station Lighting							
V-1	Light Pole	20	$1,000	$5,000	$6,000	$20,000	$100,000	$120,000
V-2	Lights, receptacles, J-boxes	1	$5,000	$40,000	$45,000	$5,000	$40,000	$45,000
	Total V. Yard Lights					$25,000	$140,000	$165,000
	Location Adder for Labor	30%				$1,434,210		
	Total Construction					$6,214,910	$8,593,500	$14,808,410

Land Rights and Permits	1%**	$748,084
Design	13%*	$1,925,093
Construction Management	9%*	$1,332,757
Overheads	20%*	$2,961,682
* of Total Construction $		
** includes land purchase $600,000		
Total Project Costs		$21,776,026
$/bay		$5,444,007
$/terminal		$3,110,861

Assumption:
Land is available in the area - 10 to 15 acres @$50,000

Assumptions:
existing Healy 138kV can accommodate one more 138kV terminal for 2nd line to Gold Creek
distance bvetween existing 138kV and new 230kV is short and allows xformer 138kV switching in existing yard

Table C-24: Gold Creek Substation

South Central Alaska Transmission Plans

230kv Switchyard Gold Creek

Scope: Install a new breaker and a half switchyard with 8 terminals: 2 OH from Healy , 2 OH to Douglas, 1-Reactor/SVC, 2- Watana (fut), 1-OH to Dougla (fut)

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	A-frame 230kV	5	$5,000	$31,500	$36,500	$25,000	$157,500	$182,500
A-3	230kv 3-ph bus support	18	$1,500	$4,000	$5,500	$27,000	$72,000	$99,000
A-6	230kV Bus work	1	$300,000	$450,000	$750,000	$300,000	$450,000	$750,000
A-8	230kv PT stand	2	$1,000	$1,500	$2,500	$2,000	$3,000	$5,000
A-9	230kV 3-ph disconnect support	16	$3,000	$3,500	$6,500	$48,000	$56,000	$104,000
	Total A. Structures					$402,000	$738,500	$1,140,500
	B. Disconnects							
B-2	230kV 3-ph V switch	4	$12,000	$15,000	$27,000	$48,000	$60,000	$108,000
B-3	230kV 3-ph disconnect	16	$12,000	$15,000	$27,000	$192,000	$240,000	$432,000
	Total B. Disconnects					$240,000	$300,000	$540,000
	C. Arresters							
C-1	230kv arrestor	3	$1,500	$2,000	$3,500	$4,500	$6,000	$10,500
	Total C. Arresters					$4,500	$6,000	$10,500
	E. Circuit Breakers							
E-1	230kv GCB	8	$8,000	$80,000	$88,000	$64,000	$640,000	$704,000
	Total E. Circuit Breakers					$64,000	$640,000	$704,000
	G. Protection and Control							
G-1	230kV PT	10	$3,000	$10,000	$13,000	$30,000	$100,000	$130,000
	Total G. Protection And Control					$30,000	$100,000	$130,000
	H. Power Transformers							
H-2	Sta. Service Xformer 24.9/.24kV, 300k	1	$2,000	$15,000	$17,000	$2,000	$15,000	$17,000
	Total H. Power Transformers					$2,000	$15,000	$17,000
	J. SCADA and Communications							
J-1	230kV facilities	1	$70,000	$70,000	$140,000	$70,000	$70,000	$140,000
J-2	Microwave Tower	1	$40,000	$40,000	$80,000	$40,000	$40,000	$80,000
J-3	cables, connections etc.	1	$60,000	$30,000	$90,000	$60,000	$30,000	$90,000
	Total J. Scada and Communications					$170,000	$140,000	$310,000
	K. Conduit and Cables							
K-1	RGS & Cables	1	$1,100,000	$500,000	$1,600,000	$1,100,000	$500,000	$1,600,000
	Total K. Conduits and Cables					$1,100,000	$500,000	$1,600,000
	L. Foundations							
L-1	A-Frame	14	$2,500		$2,500	$35,000	$0	$35,000
L-2	Switch Support	16	$5,000		$5,000	$80,000	$0	$80,000
L-3	Bus Support	18	$5,000		$5,000	$90,000	$0	$90,000
L-4	230kV GCB	8	$3,000		$3,000	$24,000	$0	$24,000
L-5	230kV PT Support	2	$2,500		$2,500	$5,000	$0	$5,000
L-6	Control Enclosure	1	$80,000		$80,000	$80,000	$0	$80,000
L-7	Conduit Vault	5	$3,000	$7,000	$10,000	$15,000	$35,000	$50,000
L-8	Sta. Service Xformer	1	$1,500	$3,000	$4,500	$1,500	$3,000	$4,500

South Central Alaska Transmission Plans

230kv Switchyard Gold Creek

Scope: Install a new breaker and a half switchyard with 8 terminals: 2 OH from Healy , 2 OH to Douglas, 1-Reactor/SVC, 2- Watana (fut), 1-OH to Dougla (fut)

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
L-9	Light Pole	20	$2,000	$2,000	$4,000	$40,000	$40,000	$80,000
L-10	Microwave tower	1	$25,000		$25,000	$25,000	$0	$25,000
	Total L. Foundations					$395,500	$78,000	$473,500
	M. Site Work							
M-1	Excavation	1	$1,500,000		$1,500,000	$1,500,000	$0	$1,500,000
M-2	Backfill	1	$1,200,000	$400,000	$1,600,000	$1,200,000	$400,000	$1,600,000
	Total M. Site Work					$2,700,000	$400,000	$3,100,000
	N. Fence							
N-1	Perimeter Fence	1	$100,000	$150,000	$250,000	$100,000	$150,000	$250,000
					$0	$0	$0	$0
	Total N. Fence					$100,000	$150,000	$250,000
	O. Grounding							
O-1	Groundgrid	1	$300,000	$300,000	$600,000	$300,000	$300,000	$600,000
					$0	$0	$0	$0
	Total O. Grounding					$300,000	$300,000	$600,000
	P. Building							
P-1	230kV Control Enclosure & Controls	1	$400,000	$900,000	$1,300,000	$400,000	$900,000	$1,300,000
					$0	$0	$0	$0
	Total P. Building					$400,000	$900,000	$1,300,000
	V. Station Lighting							
V-1	Light Pole	20	$1,000	$5,000	$6,000	$20,000	$100,000	$120,000
V-2	Lights, receptacles, J-boxes	1	$5,000	$40,000	$45,000	$5,000	$40,000	$45,000
	Total V. Yard Lights					$25,000	$140,000	$165,000
	Location Adder for Labor	30%				$1,779,900		
	Total Construction					$7,712,900	$4,407,500	$12,120,400

Land Rights and Permits	1%**	$721,204
Design	13%*	$1,575,652
Construction Management	9%*	$1,090,836
Overheads	20%*	$2,424,080
* of Total Construction $		
** includes land purchase $600,000		
Total Project Costs		$17,932,172
$/bay		$4,483,043
$/terminal		$2,561,739

Assumption:
Land is available in the area - 10 to 15 acres @$50,000

Table C-25: Lorraine-Douglas 230 kV Line

230kV LORRAINE TO DOUGLAS

COST ESTIMATE - Line Sections

			DOUBLE CIRCUIT			
Lorraine to Douglas	42	MILES				
Parallel to CEA Line & MEA Line						
	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Tangent Structure	314	ea	$22,800	$11,000	$33,800	$10,618,608
Medium Angle	37	ea	$26,400	$19,000	$45,400	$1,677,984
DE/Large Angle	18	ea	$44,400	$54,000	$98,400	$1,818,432
Driven Pipe Pile	375	ea	$7,200	$6,000	$13,200	$4,951,901
Auggered Ground Sleeve	31	ea	$5,600	$3,000	$8,600	$270,178
OPGW	42	mi	$15,840	$21,120	$36,960	$1,552,320
OHSW	42	mi	$5,280	$10,560	$15,840	$665,280
Drake Conductor	84	crkt mi	$19,008	$63,360	$82,368	$6,918,912
Dampers	1109	ea	$50	$600	$650	$720,720
Aerial Balls/Bird Diverters	370	ea	$300	$2,000	$2,300	$850,080
Structure Signs	370	ea	$100	$500	$600	$221,760
90% Clearing	38	mi	$0	$25,000	$25,000	$945,000
Subtotal						$31,211,174
Mob/Demob @+6%						$1,872,670
Engineering, Management, Permitting @+20%						$6,242,235
Subtotal						$39,326,080
Contingency @+20%						$7,865,216
80% Winter Construction @+35%						$8,739,129
Permitting						$150,000
Total Construction Estimate						$56,080,425

Table C-26: Douglas – Healy 230 kV line

Line Section	Line Miles	Cost ($/mile)	Proposed Framing	Total Costs
Douglas - Healy	171	$1,100,000	230kV	$ 188,100,000
Total				$ 188,100,000

Table C-27: Healy – Gold Hill 230 kV Line

230kV HEALY TO GOLD HILL

COST ESTIMATE - Line Sections

Replace Existing 138kV Line 103 SINGLE CIRCUIT MILES

	Qty	Unit	Material Cost	Labor Cost	Material & Labor Cost	Total Cost
Tangent Structure	423	ea	$15,900	$11,500	$27,400	$11,601,087
Medium Angle	121	ea	$17,520	$13,500	$31,020	$3,752,510
DE/Large Angle	60	ea	$22,200	$27,000	$49,200	$2,975,878
Driven Pipe Pile	1137	ea	$1,200	$6,000	$7,200	$8,187,295
Direct Embedment	254	ea	$200	$2,000	$2,200	$558,884
OPGW	103	mi	$15,840	$21,120	$36,960	$3,810,576
OHSW	103	mi	$5,280	$10,560	$15,840	$1,633,104
Cardinal Conductor	103	ckt mi	$22,176	$79,200	$101,376	$10,451,866
Dampers	1815	ea	$50	$600	$650	$1,179,464
Aerial Balls/Bird Diverters	544	ea	$300	$2,000	$2,300	$1,252,046
Structure Signs	605	ea	$100	$500	$600	$362,912
60% Clearing	62	mi	$0	$25,000	$25,000	$1,546,500
Remove Existing Conductor	103	ckt mi		$15,840	$15,840	$1,633,104
Remove Existing Twrs & Fnd	605	ea		$3,000	$3,000	$1,814,560
Remove Existing Anchors	2722	ea		$300	$300	$816,552
Subtotal						$51,576,339
Mob/Demob @+6%						$3,094,580
Engineering, Management, Permitting @+20%						$10,315,268
Subtotal						$64,986,187
Contingency @+20%						$12,997,237
60% Winter Construction @+25%						$7,736,451
Total Construction Estimate						$85,719,875

Table C-28: Clear and Eva Creek Substations

North Central Transmission Upgrades

230kV Transformer Installations at Clear or Eva Creek

Scope: Replace 138kV transformer with equivalent 230 unit
Replace in line circuit switchers with 230kv units

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
I	**Cleary Station**							
	C. Arresters							
C-1	230kv arrestor	3	$1,500	$2,000	$3,500	$4,500	$6,000	$10,500
C-2	12.5kv or 24,9kV arrestor	3	$1,200	$1,500	$2,700	$3,600	$4,500	$8,100
	Total C. Arresters					$8,100	$10,500	$18,600
	G. Protection and Control							
G-1	New Xformer and line controls	1	$20,000	$60,000	$80,000	$20,000	$60,000	$80,000
G-2	230kV PT	3	$3,000	$10,000	$13,000	$9,000	$30,000	$39,000
	Total G. Protection And Control					$29,000	$90,000	$119,000
	H. Power Transformers							
H-1	230/24.9kV - 10 MVA	1	$20,000	$1,500,000	$1,520,000	$20,000	$1,500,000	$1,520,000
I-H-2	retire 139/24.9kV -10MVA	1	$15,000		$15,000	$15,000	$0	$15,000
	Total H. Power Transformers					$35,000	$1,500,000	$1,535,000
	K. Conduit and Cables							
K-1	RGS and Cables	1	$25,000	$20,000	$45,000	$25,000	$20,000	$45,000
					$0	$0	$0	$0
	Total K. Conduits and Cables					$25,000	$20,000	$45,000
	L. Foundations							
L-1	230kv Circuit Switcher Stand	0	$5,000		$5,000	$0	$0	$0
L-2	Transformer w. Oil containment	0	$80,000	$20,000	$100,000	$0	$0	$0
	Total L. Foundations					$0	$0	$0
	Location Adder for Labor	25%				$24,275		
	Total Construction					$121,375	$1,620,500	$1,741,875
	Construction Management	9%*						$156,769
	Overheads	20%*						$348,375
	* of Total Construction $							
	Total Project Costs							$2,247,019

Assumption:
Foundations and oil containment will not have to be replacec

Table C-29: Nenana Substation

North Central Transmission Upgrades

230kV Nenana

Scope: Replace 138/24.9kV transformer and associated switches with equivalent 230/24.9kV unit
Replace in line circuit switchers with 230kv units

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	H-frame Terminal	3	$10,000	$9,000	$19,000	$30,000	$27,000	$57,000
A-2	bus work	1	$10,000	$3,000	$13,000	$10,000	$3,000	$13,000
I-A-1	138kv line Terminal	3	$15,000		$15,000	$45,000	$0	$45,000
	Total A. Structures					$85,000	$30,000	$115,000
	B. Disconnects							
B-1	230kv Circuit Switcher, 3-phase	3	$15,000	$50,000	$65,000	$45,000	$150,000	$195,000
	w. stand				$0	$0	$0	$0
I-B-2	retire 138kV CS	3	$5,000		$5,000	$15,000	$0	$15,000
	Total B. Disconnects					$60,000	$150,000	$210,000
	C. Arresters							
C-1	230kv arrestor	3	$1,500	$2,000	$3,500	$4,500	$6,000	$10,500
C-2	24.9kv arrestor	3	$1,200	$1,500	$2,700	$3,600	$4,500	$8,100
	Total C. Arresters					$8,100	$10,500	$18,600
	E. Circuit Breakers							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total E. Circuit Breakers					$0	$0	$0
	G. Protection and Control							
G-1	New Xformer and line controls	1	$20,000	$60,000	$80,000	$20,000	$60,000	$80,000
G-2	230kV PT	3	$3,000	$10,000	$13,000	$9,000	$30,000	$39,000
G-3	Voltage Sensors at Tap	2	$10,000	$8,000	$18,000	$20,000	$16,000	$36,000
	Total G. Protection And Control					$29,000	$90,000	$119,000
	H. Power Transformers							
H-1	230/24.9kV - 5 MVA	1	$20,000	$1,000,000	$1,020,000	$20,000	$1,000,000	$1,020,000
I-H-2	retire 139/24.9kV -2.5MVA	1	$15,000		$15,000	$15,000	$0	$15,000
	Total H. Power Transformers					$35,000	$1,000,000	$1,035,000
	J. SCADA and Communications							
J-1	Upgrade existing	1	$15,000	$5,000	$20,000	$15,000	$5,000	$20,000
					$0	$0	$0	$0
	Total J. Scada and Communications					$15,000	$5,000	$20,000
	K. Conduit and Cables							
K-1	RGS and Cables	1	$60,000	$20,000	$80,000	$60,000	$20,000	$80,000
					$0	$0	$0	$0
	Total K. Conduits and Cables					$60,000	$20,000	$80,000
	L. Foundations							
L-1	230kv Circuit Switcher Stand	3	$5,000		$5,000	$15,000	$0	$15,000
L-2	Transformer w. Oil containment	1	$80,000	$20,000	$100,000	$80,000	$20,000	$100,000
	Total L. Foundations					$95,000	$20,000	$115,000
	M. Site Work							
M-1	Excavation & Backfill	1	$50,000	$50,000	$100,000	$50,000	$50,000	$100,000
					$0	$0	$0	$0
	Total M. Site Work					$50,000	$50,000	$100,000
	N. Fence							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total N. Fence					$0	$0	$0

North Central Transmission Upgrades

230kV Nenana

Scope: Replace 138/24.9kV transformer and associated switches with equivalent 230/24.9kV unit
Replace in line circuit switchers with 230kv units

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	O. Grounding							
O-1	Expand existing	1	$15,000		$15,000	$15,000	$0	$15,000
					$0	$0	$0	$0
	Total O. Grounding					$15,000	$0	$15,000
	P. Building							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total P. Building					$0	$0	$0
	Location Adder for Labor	25%				$135,630		
	Total Construction					$587,730	$1,375,500	$1,963,230
	Land Rights and Permits	1%*						$19,632
	Design	13%*						$255,220
	Construction Management	9%*						$176,691
	Overheads	20%*						$392,646
	* of Total Construction $							
	Total Project Costs							$2,807,419

Table C-30: Ester Substation

North Central Transmission Upgrades

230kV Ester

Scope: Replace 138/12.5kV transformer and associated switches with equivalent 230/12.5kV unit
Replace in line circuit switchers with 230kv units

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	H-frame Terminal	3	$10,000	$9,000	$19,000	$30,000	$27,000	$57,000
A-2	bus work	1	$10,000	$3,000	$13,000	$10,000	$3,000	$13,000
I-A-1	138kv line Terminal	3	$15,000		$15,000	$45,000	$0	$45,000
	Total A. Structures					$85,000	$30,000	$115,000
	B. Disconnects							
B-1	230kv Circuit Switcher, 3-phase	3	$15,000	$50,000	$65,000	$45,000	$150,000	$195,000
	w. stand				$0	$0	$0	$0
I-B-2	retire 138kV CS	3	$5,000		$5,000	$15,000	$0	$15,000
	Total B. Disconnects					$60,000	$150,000	$210,000
	C. Arresters							
C-1	230kv arrestor	3	$1,500	$2,000	$3,500	$4,500	$6,000	$10,500
C-2	12.5kv arrestor	3	$1,200	$1,500	$2,700	$3,600	$4,500	$8,100
	Total C. Arresters					$8,100	$10,500	$18,600
	E. Circuit Breakers							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total E. Circuit Breakers					$0	$0	$0
	G. Protection and Control							
G-1	New Xformer and line controls	1	$20,000	$60,000	$80,000	$20,000	$60,000	$80,000
G-2	230kV PT	3	$3,000	$10,000	$13,000	$9,000	$30,000	$39,000
G-3	Voltage Sensors at Tap	2	$10,000	$8,000	$18,000	$20,000	$16,000	$36,000
	Total G. Protection And Control					$29,000	$90,000	$119,000
	H. Power Transformers							
H-1	230/12.5kV - 10 MVA	1	$20,000	$1,500,000	$1,520,000	$20,000	$1,500,000	$1,520,000
I-H-2	retire 139/24.9kV -2.5MVA	1	$15,000		$15,000	$15,000	$0	$15,000
	Total H. Power Transformers					$35,000	$1,500,000	$1,535,000
	J. SCADA and Communications							
J-1	Upgrade existing	1	$15,000	$5,000	$20,000	$15,000	$5,000	$20,000
					$0	$0	$0	$0
	Total J. Scada and Communications					$15,000	$5,000	$20,000
	K. Conduit and Cables							
K-1	RGS and Cables	1	$60,000	$20,000	$80,000	$60,000	$20,000	$80,000
					$0	$0	$0	$0
	Total K. Conduits and Cables					$60,000	$20,000	$80,000
	L. Foundations							
L-1	230kv Circuit Switcher Stand	3	$5,000		$5,000	$15,000	$0	$15,000
L-2	Transformer w. Oil containment	1	$80,000	$20,000	$100,000	$80,000	$20,000	$100,000
	Total L. Foundations					$95,000	$20,000	$115,000
	M. Site Work							
M-1	Excavation & Backfill	1	$50,000	$50,000	$100,000	$50,000	$50,000	$100,000
					$0	$0	$0	$0
	Total M. Site Work					$50,000	$50,000	$100,000
	N. Fence							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total N. Fence					$0	$0	$0

North Central Transmission Upgrades

230kV Ester

Scope: Replace 138/12.5kV transformer and associated switches with equivalent 230/12.5kV unit
Replace in line circuit switchers with 230kv units

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	O. Grounding							
O-1	Expand existing	1	$15,000		$15,000	$15,000	$0	$15,000
					$0	$0	$0	$0
	Total O. Grounding					$15,000	$0	$15,000
	P. Building							
	N/A				$0	$0	$0	$0
					$0	$0	$0	$0
	Total P. Building					$0	$0	$0
	Location Adder for Labor	25%				$135,630		
	Total Construction					$587,730	$1,875,500	$2,463,230
	Land Rights and Permits	1%*						$24,632
	Design	13%*						$320,220
	Construction Management	9%*						$221,691
	Overheads	20%*						$492,646
	* of Total Construction $							
	Total Project Costs							$3,522,419

Table C-31: Gold Hill and Wilson Substations

North Central Transmission Upgrades

230kV Gold Hill or Wilson

Scope: Convert 138kV line position to transformer, add 150 MVA 230/138kV transformer, 230kV breaker bay and controls

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	A. Structures							
A-1	A-frame 230kV	1	$5,000	$31,500	$36,500	$5,000	$31,500	$36,500
A-2	230kV 3-ph disconnect support	2	$3,000	$3,500	$6,500	$6,000	$7,000	$13,000
A-3	230kV buswork and supports	1	$50,000	$40,000	$90,000	$50,000	$40,000	$90,000
I-A-1	138kv line Terminal	1	$15,000		$15,000	$15,000	$0	$15,000
	Total A. Structures					$11,000	$38,500	$154,500
	B. Disconnects							
B-1	230kV 3-ph V switch	1	$15,000	$20,000	$35,000	$15,000	$20,000	$35,000
					$0	$0	$0	$0
	Total B. Disconnects					$15,000	$20,000	$35,000
	C. Arresters							
C-1	230kv arrestor	3	$1,500	$2,000	$3,500	$4,500	$6,000	$10,500
C-2	138kv arrestor	3	$1,200	$1,500	$2,700	$3,600	$4,500	$8,100
	Total C. Arresters					$8,100	$10,500	$18,600
	E. Circuit Breakers							
E-1	230kv GCB	1	$20,000	$125,000	$145,000	$20,000	$125,000	$145,000
					$0	$0	$0	$0
	Total E. Circuit Breakers					$20,000	$125,000	$145,000
	G. Protection and Control							
G-1	Modify Healy line to xformer controls	1	$30,000	$10,000	$40,000	$30,000	$10,000	$40,000
G-2	230kV Healy Line controls	1	$5,000	$80,000	$85,000	$5,000	$80,000	$85,000
G-3	230kV PT	3	$3,000	$10,000	$13,000	$9,000	$30,000	$39,000
I-G-1	138kV PT	1	$2,000		$2,000	$2,000	$0	$2,000
	Total G. Protection And Control					$35,000	$90,000	$166,000
	H. Power Transformers							
H-1	150MVA 230/138kV AutoXformer	1	$15,000	$2,500,000	$2,515,000	$15,000	$2,500,000	$2,515,000
	Total H. Power Transformers					$15,000	$2,500,000	$2,515,000
	J. SCADA and Communications							
J-1	Add 230kV bay	2	$10,000	$5,000	$15,000	$20,000	$10,000	$30,000
					$0	$0	$0	$0
	Total J. Scada and Communications					$20,000	$10,000	$30,000
	K. Conduit and Cables							
K-1	RGS & Cables	1	$70,000	$30,000	$100,000	$70,000	$30,000	$100,000
	Total K. Conduits and Cables					$70,000	$30,000	$100,000
	L. Foundations							
L-1	A-Frame	4	$2,500		$2,500	$10,000	$0	$10,000
L-2	Switch Support	2	$5,000		$5,000	$10,000	$0	$10,000
L-3	Xformer w. oil containment	1	$120,000	$30,000	$150,000	$120,000	$30,000	$150,000
L-4	230kV GCB	1	$3,000		$3,000	$3,000	$0	$3,000
	Total L. Foundations					$143,000	$30,000	$173,000
	M. Site Work							
M-1	Excavation	1	$80,000		$80,000	$80,000	$0	$80,000
M-2	Backfill	1	$80,000		$80,000	$80,000	$0	$80,000
	Total M. Site Work					$160,000	$0	$160,000
	N. Fence							
N-1	Expand existing	1	$30,000	$30,000	$60,000	$30,000	$30,000	$60,000
					$0	$0	$0	$0
	Total N. Fence					$30,000	$30,000	$60,000

North Central Transmission Upgrades

230kV Gold Hill or Wilson

Scope: Convert 138kV line position to transformer, add 150 MVA 230/138kV transformer, 230kV breaker bay and controls

Item	Description	Quantity	Unit Labor $	Unit Material $	Unit $	Ext.Lab. $	Ext. Mat.$	Extended $
	O. Grounding							
O-1	Expand groundgrid	1	$35,000	$20,000	$55,000	$35,000	$20,000	$55,000
					$0	$0	$0	$0
	Total O. Grounding					$35,000	$20,000	$55,000
	P. Control Enclosure							
P-1	Pre Fab Enclosure	0	$15,000	$150,000	$165,000	$0	$0	$0
					$0	$0	$0	$0
	Total P. Building					$0	$0	$0
	Location Adder for Labor	20%				$112,420		
	Total Construction					$674,520	$2,904,000	$3,578,520
	Land Rights and Permits	1%*						$35,785
	Design	13%*						$465,208
	Construction Management	9%*						$322,067
	Overheads	20%*						$715,704
	* of Total Construction $							
	Total Project Costs							**$5,117,284**

Assumptions: Controls and protection can be added in existing building
Land (approx. 2 acres is available at existing site.

D Appendix D: Economic Analysis Sensitivity

Add PDF Economic Sensitivities Appendix page 1

Add PDF Economic Sensitivities Appendix page 2

Add PDF Economic Sensitivities Appendix page 3

Add PDF Economic Sensitivities Appendix page 4

E Appendix E: Production Modeling Presentation

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F Appendix F: Pre-Watana Simulation Results

The contents of Appendix G can be found in a separate document titled *Appendix G: Pre-Watana Simulation Results*.