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DRAFT ENVIRONMENTAL IMPACT STATEMENT
PUGET SOUND AREA ELECTRIC RELIABILITY PLAN

Appendix E
Transmission Reinforcement Analysis

Bonneville Power Administration
U.S. Department of Energy

Prepared as part of a coordinated plan to address a power system problem in the Puget Sound Area. Utilities participating in planning include: Bonneville Power Administration, Puget Sound Power and Light, Seattle City Light, Snohomish County Public Utility District No. 1, and Tacoma City Light.

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September 1991

MASTER

APPENDIX E

Table of Contents

Transmission System Reinforcement Options Report	page 1-3
Table 1: Comparison of Transmission System Reinforcement Options	page 4
Pre-PSAERP Transmission System Diagram	page 5
Transmission System Reinforcement Options Diagrams	page 6-11
QV Curves of Transmission System Reinforcement Options	page 12-18

Attachment 1: Puget Sound Reinforcement Transmission Alternatives Report

Attachment 2: New Cross Mountain Transmission Line Alternative Memo

PSAERP Transmission System Reinforcement Options

Five transmission line options and several reactive (voltage support) options are presently being considered as possible solutions to the PSAERP by the Transmission Team. The first two line options would be built on new rights-of way adjacent (as much as possible) to existing corridors. The reactive options would optimize the existing transmission system capability by adding new stations for series capacitors and/or switchgear. The other three line options are rebuilds or upgrades of existing cross mountain transmission lines. These options are listed below and include a preliminary assessment of the additional transmission system reinforcement required to integrate the new facilities into the existing transmission system.

These options were derived from earlier study work that was summarized in "Puget Sound Reinforcement Transmission Options" and "New Cross Mountain Transmission Line Alternative: The Crosstie", which are attached. The initial Transmission Options study report recognized the value to system performance of adding an entirely new circuit rather than rebuilding an existing one. However, siting realities require that rebuild options be considered. Typically, the most attractive rebuild options would be the lowest capacity (lowest voltage) circuits. But because of corridor location, length and terminal proximity, the rebuild options listed below appear to be the most promising. Schematic diagrams and QV Curves of each option are also attached. It should be noted that Snoqualmie and Echo Lake refer to the same station east of Puget Sound and Naneum and Kittitas refer to the same station in the Ellensburg area.

OPTION 1: New Chief Joseph-Monroe/Echo Lake line

A new double-circuit 500-kV line would be built on new right-of way from Chief Joseph substation west toward Monroe following the existing Stevens Pass corridor. In the vicinity of Skykomish the double circuit line would split, with one circuit continuing on to Monroe following the existing corridor. The other circuit would head southwest on a new corridor toward Echo Lake substation. A new 500/230-kV transformer would be needed at the existing Snoking substation. The existing 230-kV line that feeds this substation from Monroe was designed for 500-kV operation and would need to be converted at that time. A second Bothell-Snoking 230-kV line would also be needed and this line could be obtained by reconnecting existing lines in the area. A second Chief Joseph 500/230-kV transformer will also be needed and this will be added in the existing substation. This plan is analyzed in detail in "Puget Sound Reinforcement Transmission Options".

OPTION 2: New Chief Joseph-Echo Lake line

A new double-circuit line would be built on new right-of way from Chief Joseph substation southwest by Sickler substation toward Echo Lake substation following the existing Snoqualmie Pass corridor. New transformers would also be needed at Snoking and Chief Joseph as described in Option 1. This plan is also analyzed in detail in "Puget Sound Reinforcement Transmission Options".

OPTION 3: Reactive additions (Voltage Support)

Voltage Support 1

This option includes adding a shunt capacitor bank at Echo Lake substation. This addition, in conjunction with the SVC's and other MSC's proposed to meet the winter 1992-93 load level, will meet the winter 1995-96 load level. QV Curve-0 shows the effect of the addition of Voltage Support 1 (compared to the same system without it).

Voltage Support 2

Voltage support 2 can be accomplished by adding a new 500-kV switchyard in the vicinity of the existing Naneum substation to connect all 4 500-kV lines that go through the Stampede Pass corridor. This station would also include additional series compensation for the existing high-capacity Coulee-Raver lines. This plan would eventually require a Snoking 500/230-kV transformer (discussed in Option 1) and additional series compensation at the new station, either by increasing the size of the banks on the Coulee-Raver lines or by adding new banks on the other 2 lines that head west out of the station.

Another reactive option is to add series capacitor banks on all five cross mountain lines. These additions would require a minimum of 2 new substations, one along the northern (Stevens Pass) corridor and one on the southern (Snoqualmie Pass) corridor. This plan would also eventually require a Snoking 500/230-kV transformer (discussed in Option 1). Many other options were also studied, including the plan described at length in the "Puget Sound Reinforcement Transmission Options" report.

OPTION 4: Chief Joseph-Snohomish 345-kV upgrade with Crosstie

The existing Chief Joseph-Snohomish 345-kV double circuit line (through the Stevens Pass corridor) would be upgraded to a single-circuit 500-kV line in this option (using the existing right-of-way). This upgrade would be accomplished by replacing the top of the existing double circuit towers with new single circuit ones and adding three new conductors. The feasibility of this transmission line upgrade is still being investigated. A new single circuit line would also be needed between Columbia, Sickler and a new substation on the Stevens Pass corridor, tentatively called Mad River (near Chumstick). The rebuilt Chief Joe-Snohomish line would be connected to Monroe substation and a new 500/230-kV transformer would be added at Snohomish to replace the 345/230-kV transformers that will be removed. A second Bothell-Snohomish 230-kV line would be needed with this transformer and could be obtained by connecting one of SCL's Skagit River lines into Snohomish. New transformers would also be needed at Snoking and Chief Joseph as described in Option 1. Additional series compensation would be needed at a new site near Naneum on the existing Coulee-Raver lines. Eventually a second Raver-Echo Lake 500-kV line (adjacent to the existing line) will also be needed. This plan is analyzed in detail in the report entitled "New Cross Mountain Transmission Line Alternative: The Crosstie".

OPTION 5: Chief Joseph-Snohomish 345-kV rebuild

The existing Chief Joseph-Snohomish 345-kV line (through the Stevens Pass corridor) would be replaced by a new double-circuit 500-kV line in this option (using existing right-of-way). This new line would be connected to Monroe substation and a new 500/230-kV transformer would be added at Snohomish to replace the 345/230-kV transformers that will be removed. A second Bothell-Snohomish 230-kV line would be needed with this transformer and could be obtained by connecting one of SCL's Skagit River lines into Snohomish. One of the circuits between Monroe and Snohomish would operate at 500-kV to supply the new transformer, the other would operate at 230-kV. New transformers would also be needed at Snoking and Chief Joseph as described in Option 1.

OPTION 6: Rocky Reach-Maple Valley 345-kV rebuild with Crosstie

The existing Rocky Reach-Maple Valley 345-kV line (through the Snoqualmie corridor) would be replaced by a new double-circuit 500-kV line in this option (using existing right-of-way). This new line would be connected to Echo Lake substation and a new 500/230-kV transformer would be added at Maple Valley or Snoking to replace the 345/230-kV transformer that was removed. Since Sickler substation is not a strong enough source for a new double circuit line, it will have to be reinforced. Many options exist to do this, but the following option has some desirable traits. A double circuit line would be added between a new Columbia switching station (adjacent to the existing series capacitor yard and 230/115-kV substation) and this new line following the Columbia-Rocky Reach 230-kV line. These additions would create a Sickler-Echo Lake line, a Columbia-Echo Lake line and a Columbia-Sickler line. A new single-circuit line would also be needed between Columbia and the Coulee-Hanford line, following the 115-kV right-of-way east toward the old Rocky Ford substation site. A small switching station would be required there. A second Sickler 500/230-kV transformer will also probably be needed.

SUMMARY

The performance of these options is summarized in Table 1. All of these options will solve the voltage stability problems in the Puget Sound Basin beyond the 2003 study period. The two new line options (Options 1 and 2) are somewhat stronger than the other plans for outage conditions since they contain more transmission lines. The upgrade of the Chief Joseph-Snohomish line to single circuit 500-kV (option 4) is the weakest of the transmission options being investigated, however it should be the least expensive. This option would be slightly better than the Reactive Options for solving the voltage stability problems.

All of the transmission line options save a substantial amount of transmission system losses. Option 5, the rebuild of the Chief Joseph-Snohomish 345-kV to 500-kV double-circuit would save the most. The next best loss-saver is Option 1. Options 2, 4 and 6 have similar loss saving that are somewhat lower. The Reactive option saves the least amount of losses.

TABLE 1: COMPARISON OF TRANSMISSION REINFORCEMENT PLANS FOR PSAERP

<u>OPTION</u>	<u>PEAK SYSTEM LOSS SAVINGS</u>		<u>REACTIVE MARGIN</u>
	MW - 2004 BPA	PNW	MVARS - 2004 2-line/1-line/Trojan(1) margins include unused MSC QV curves are attached
1. New Chief Joe-Monroe/Echo Lake 500-kV double circuit	86	108	1100/900/900
2. New Chief Joe-Echo Lake 500-kV double circuit line	72	90	1000/900/900
3. Voltage Support 2 Switchyard and Series caps	6	12	700/400/500 (2)
4. Chief Joe-Snohomish 345-kV upgrade to 500-kV single circuit	75	97	500/800/600
5. Chief Joe-Snohomish 345-kV rebuild to 500-kV double circuit	93	112	800/700/700
6. Rocky Reach-Maple Valley 345-kV rebuild to 500-kV double circuit	73	83	1200/700/800

(1) The Portland area will need to be supported in the early to mid 2000's. Cursory studies indicate that one MSC will provide this support; a 300 MVAR MSC at Marion substation near Salem. All options include this MSC.

(2) This plan includes replacement of the third (PCB) capacitor group at Raver. Another option to this Raver group could be an MSC at Naneum.

QV Curve - 0

PERFORMANCE OF SYSTEM WITH REACTIVE-1 INSTALLED

J97133:2C-R OUT(J9782)MSC @SNOQ(2),MON(1),TAC,OLY

J97EH65:CJ-MON OUT (J97EH63) MSC @ MON(1), OLY

J97EH66:TROJAN SCRAM (J97EH64) MSC @ MON(1), OLY

ALL MSC'S USED

○ J97133QV
+ J97EH66QV

△ J97EH65QV

22-JUL-1991
REACTIVE1.SETUP

PLAN 1: CHIEF JO-MONROE/SNOQUALMIE 500 ADDED

J04663:COUL-RAV 1&2 OUT(J04662)MSC SNOQ(2),RAV(1)
 J04EH426:COULEE-RAVER 500 OUT (J04EH422) NO MSC
 J04EH487:TROJAN SCRAM(J04EH423)MSC MON(1),OLY,MAR

MSC AVAILABU
 MON,OLY
 MON,OLY
 None

○ J04663QV
 + J04EH487QV

△ J04EH426QV

22-JUL-1991
 PLAN1M.SETUP

PLAN 2: CHIEF JOE-SNOQUALMIE 500 ADDED
 J04659:COULEE-RAVER 1&2 OUT(J04656)
 MSC AT MON(1), SNOQ(1), RAV(1)
 J04EH412:COULEE-RAVER 1 OUT(J04EH408)MSC AT MON(1)
 J04EH413:TROJAN SCRAM (J04EH409)
 MSC AT MON(1), OLY(1), MARION(1)

MSC AVAILABLE
 SNOQ, OLY
 OLY
 None

PLAN 3: NANEUM SWYD

ALL MSC'S
USED

20% ON COULE-RAV, 30% ON SICK-RAV, 39% ON VANT-RAV
 o J04826: NAN-RAV 3&4 OUT, MSC 00L, SNQ, MON, RAV (J04825)
 Δ J04827: GC-NAN 1&2 OUT, MSC 00L, SNQ, MON, RAV (J04825)
 + J04EH579: CJ-MON, MSC 0 OLY (J04EH577) MSC RAV
 x J04EH580: TROJAN SCRAM, MSC 0 OLY, MARION (J04EH578) MSC RAV

o J04826QV
 x J04EH580QV

Δ J04827QV

+ J04EH579QV

22-AUG-1991

J04PLAN3-4.SETUP

PLAN 4: UPGRADE CJ-SNOHOMISH 345 TO 500 SSC

ADD CROSSTIE: COLUMBIA-SICKLER-MAD RIVER 500 SSC
 J04651:MADRV-R-MONROE 1&2(J04650)MSC @MON1,SQ2,OLY1
 J04EH416:COLUMB-RAVER 1 OUT(J04EH406)MSC @ MON(1)
 J04EH489:TROJAN SCRAM (J04EH407) MSC @ OLY, MARION

MSC AVAILABL

None
 OLY
 None.

○ J04651QV
 + J04EH489QV

△ J04EH416QV

22-JUL-1991
 PLAN4M.SETUP

PLAN 5: CHIEF JOE-SNOHOMISH REBUILT TO 500 SDC

J04653:COULE-RVR 1&2 OUT(J04652)MSC SNQ(2),MON,RAV

J04EH398:COULE-RVR 1 OUT(J04EH396)MSC @ MON(1)

J04EH490:TROJAN SCRAM (J04EH397)MSC @ OLY,MON,MAR

MSC
OLY
OLY
Non○ J04653QV
+ J04EH490QV

△ J04EH398QV

22-JUL-1991

PLANS5.SETUP

PLAN 6: ROCKY RH-MAPLE VL 345 REBUILD TO 500 SDC

CROSSTIE ADDED: SICKLER-COLUMBIA-ROCKY FORD
 J04658:COL/SICK-SNOQ OUT(J04655)MSC @ SNOQ(2),RAV
 J04EH410:CJ-MON OUT (J04EH404) MSC @ OLY
 J04EH487:TROJAN SCRAM(J04EH423)MSC @ MARION & OLY

MSC AVAILABL
 MON, OLY
 None
 None

○ J04658QV
 + J04EH487QV

△ J04EH410QV

22-JUL-1991
 PLAN 6H.SETUP

PRE-PSAERP SYSTEM
 (EXISTING SYSTEM
 PLUS ECHO LAKE SUB.)

500-KV ———
 345-KV - - - -

ABOUT 50 MI.

OPTION 1.

EXISTING 500-KV

345-KV

OPTION 3

500-KV _____
 345-KV - - - - -

OPTION 4.
EXISTING 500-KV
345-KV

ABOUT 50 MI.

ABOUT 50 MI.

OPTION 5.

EXISTING 500-KV ———
345-KV - - - -

OPTION 6.

EXISTING 500-KV

345-KV

ATTACHMENT 1

Puget Sound Reinforcement Transmission Alternatives Report

PUGET SOUND REINFORCEMENT TRANSMISSION ALTERNATIVES

ASSUMPTIONS

This report uses the the same assumptions as contained in the 1-12-90 memo from Porter to Perry (Table 150).

The line ratings used in this report are included in Table 151. The assumptions include Skagit generation levels prior to and after January 6 of each year. For calculation of loss savings noted in this report, it is assumed that the high and low generation levels will each exist for half the winter peak load period and the loss savings will be the average of these two conditions.

At the time this study was started, there was some concern about the high number of unexplained outages experienced by the new 1.7 pu line designs. Therefore, a 2.0 p.u. line design was used in these studies for calculation of line parameters. Sensitivity of this assumption is tested in Table 310. Due to audible noise constraints, a 4-bittern conductor bundle is assumed.

If an SVC is used in any study, its output is assumed to be zero until a contingency occurs. From that point on, the SVC attempts to maintain the pre-contingency voltage of the bus it is connected to.

NOTE

The January 2004 cases (except Plan 5 and 6) have an error in the compensation level of the Coulee-Raver lines (45% instead of 22.5%). This error improved the performance of the EH winter outages by about 150 MVARs. It was, however, detrimental to the normal winter double line outages of the Coulee-Raver lines, since the system had to withstand the loss of this additional compensation with fewer shunt capacitors energized prior to the outage. This error will be corrected in future cases. It should not have a great effect on the comparison of these alternatives. Refer to Table 310 for more detail.

PROBLEMS

The potential for voltage instability exists in the Puget Sound area for several cross mountain line outages or loss of Trojan generation. This report will analyze the reinforcement of the Cross Mountain (CM) transmission system to relieve these problems. Modifications to the transmission system could cause increased flow in certain areas of the system and require additional facilities. Major areas with transmission problems that are affected by the CM reinforcement are the north Seattle area, Trojan area, Okanogan area and Coulee-Chief Joe area. These will be analyzed individually for each alternative studied.

Reactive support for the maingrid transmission system was studied through 2004. Not all plans are necessarily equal, since additions beyond this time (some of them may be significant) were not considered. Thermal problems in the bulk transmissions system in the Puget Sound area were studied through 2010 to ensure that the plans were equivalent. The other problems were only studied around the 1996 timeframe to measure the impact of the Cross Mountain reinforcement.

Solving the voltage stability problem in the Puget Sound area is a two-tiered problem. The voltages on the 230-kV system need to be supported to preserve the output of the large amount of shunt compensation on the lower voltage system and the reactive losses of the Cross Mountain (CM) transmission needs to be reduced.

There are also three problems that exist prior to the assumed energization of the CM reinforcement (10-96) and will not necessarily be solved by this project. They are: a breaker failure at Raver, the integration of the new PSPL line into Lake Tradition and the Massachusetts-Broadstreet 115-kV line overload.

The breaker failure at Raver could cause loss of the Raver-Snoqualmie and Raver-Tacoma lines, which, prior to the CM additions, would cause the Covington transformers to overload as shown in J96254. Reinforcement of the CM transmission would reduce the severity of this problem. It is assumed that this problem is corrected by rearranging the bus layout at Raver (somehow) and this fix will eliminate the problem in later years. However, the effect of each plan on the existing bus layout is analyzed in Table 170.

There are many line overload problems in the Lake Tradition area that are the result of poor integration of Puget's new 230-kV cross mountain circuit. The heavy loading of the 115-kV lines in this area is further aggravated by external outages. The Massachusetts-Broadstreet overload is caused by throughflow which occurs during maingrid equipment outages. Nothing is assumed to be added to correct these problems, however the effect of each CM reinforcement plan is analyzed with respect to these problems in Table 170.

ALTERNATIVES CONSIDERED

Thirty nine new line options were studied in an attempt to solve the Puget Sound Voltage Stability problem. Five of these are considered technically and economically feasible. Also discussed below are a Reactive Option (no line construction) and two rebuild options. Options that were studied and rejected are included in Tables 302 and 303. The options listed in Table 302 are considered technically feasible, but are too costly. Those options listed in Table 303 are not considered technically feasible or are technically inferior.

The performances of the 500-kV transmission line alternatives are fairly similar. Generic development of these alternatives is included in Table 310. Differences are noted with each plan.

A. Chief Joseph-Monroe 500-kV Double-Circuit Line: Plan 1

1. Puget Sound Area Voltage Stability Performance

This plan assumes a new double circuit Chief Joe-Monroe 500-kV line is built parallel to the existing circuit on new right-of-way (ROW). This new line and the 300 MVAR Static VAR Compensator (SVC) at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe substations in 2002 and 2004, respectively. For more detail on these additions, refer to Table 310.

The voltage stability performance of Plan 1 is shown in QV-110 for 1996 and in QV-111 for 2004 for the 3 critical outages. Since this plan does not have the reactive margins for the double line outage in 2004, an additional 300 MVAR SVC is needed at Covington prior to the 2003-4 winter.

2. Puget Sound Area Thermal Overload Requirements

If the Chief Joe-Monroe 500-kV double-circuit line is added, numerous problems are aggravated in the North Seattle area during winter conditions. These include:

- a. Loss of the Monroe-Sedro-Snohomish 230-kV three terminal line causes the Monroe-Snoking Tap 230-kV line to overload during low Skagit generation (J96M218). This overload will not occur with normal Skagit generation (J96M227).
- b. Loss of the Monroe-Snoking-Sammamish 230-kV three terminal line causes the Monroe-Sedro Tap 230-kV line to overload during low Skagit generation (J96M217). This overload will also not occur with normal Skagit generation (J96M226).
- c. Loss of the Maple Valley 500/230-kV transformer overloads the Monroe transformer beyond its emergency loading and loads the Monroe-Sedro tap line heavily (J96EH554).
- d. Loss of the double-circuit Chief Joe-Snohomish 345-kV lines during normal winter causes the Monroe-Sedro Tap 230-kV line to overload (J96235).
- e. Loss of the Monroe-Snoqualmie 500-kV line also overloads the Monroe 500/230-kV transformer (J96EH555).
- f. The Monroe transformer and the Monroe-Snohomish 230-kV line will overload during cold weather without any outages in 2001 as shown in J00EH32.

This is a difficult set of problems to solve. Since Monroe is strengthened considerably by the addition of the double-circuit CM line, the 230-kV system out of Monroe is stressed heavily as indicated by the fact that there are overloads in the base system without any outages in 2001. To correct these problems, additional 500/230-kV transformation is needed and the 230-kV system into Snohomish needs backup. Since the base system is so heavily stressed, a single reinforcement project will not be able to solve the problems through the study period (2010).

Adding a new Monroe-Snohomish 500-kV line to feed a 500/230-kV transformer at Snohomish would relieve these problems best initially. Case J96EH568 shows that a third Bothell-Snohomish 230-kV line is needed with this plan for the outage of one of the existing lines. This can be accomplished by looping-in or tapping one of SCL's Skagit lines. The worst outage for this plan appears to be the loss of the new transformer and/or the new Monroe-Snohomish 500-kV line (J00EH32) which will cause the Monroe transformer to overload in 2001.

To relieve these later problems, a transformer addition is needed in the Snoking/Snohomish area. Reinforcing Snoking with a 500/230-kV transformer looks attractive at this time since the Monroe-Snoqualmie 500-kV line can be tapped and the existing Snoking Tap 230-kV line can be converted to its design voltage of 500-kV (no new 500-kV line construction is needed). A second Bothell-Snoking 230-kV line is also needed with this transformer (case J00EH113). These additions should solve the area problems well beyond 2010.

If the Snoking transformer were added first, it would require a new circuit to Monroe and not just a tap on the Monroe-Snoqualmie line in order to correct problem 5 above. This line construction (9 miles) can be eliminated by adding the Snohomish transformer first, even though the Snoking project saves about 4

MW more losses than Snohomish.

If the Snoking 500/230-kV transformer is added first, the transmission between Monroe and Snohomish will overload in 1998 for the loss of the new Snoking transformer (J96EH565 and J00EH28). This plan is not as good as Snohomish since the conversion of the existing 230 tap line into Snoking to its design voltage of 500-kV just replaces the existing circuit with one of higher capacity. But since the new line is 500-kV, the system must serve abnormally cold weather loads during that outage instead of moderate loads as was the case prior to the change.

Additional transformation could be added at Monroe with an additional 230-kV circuit added to the Snohomish area. Loss savings would favor the addition of the transformation closer to the load, however, this could aggravate through-flow problems.

Tapping an existing Custer-Monroe 500-kV line to feed a 500/230-kV transformer at Snohomish is another possibility to relieve these problems and would save some line construction. However, loss of the Custer-Monroe line with the new transformer aggravates the overloads that would occur if only the transformer were lost. Additional support would be needed in about 1999 to eliminate the overloads of the Monroe transformer and Monroe-Snohomish line for loss of this new transformer as shown in case J00EH30. As shown above, this overload can be delayed about 2 years if an entirely new line is built from Monroe to Snohomish to supply the new transformer.

The loss savings due to the addition of the recommended Snohomish transformer project is about 13.5 MW on the BPA system and 14.9 MW total for the Northwest in 1996 (compare cases J96248, J96252, J96261 and J96262). These loss savings increase to 21.5 MW on the BPA system and 26.0 MW for the Northwest in 2000 (compare cases J0035, J0036, J0037 and J0038). Note that the 2000 cases have both the Snohomish and the Snoking transformers in service.

A 300 MVAR shunt reactor is required at Monroe to provide voltage control on the 500-kV system during lighter load periods.

Summer and spring conditions were studied (Tables 202-212). The assumed summer conditions include 2000 MW Ingledow to Custer powerflow and 8000 MW total PNW to PSW interchange schedules. The assumed spring conditions include 2000 MW Ingledow to Custer powerflow and 1800 MW Custer to Ingledow powerflow. Eleven transmission lines need upgrading to higher conductor operating temperatures (Table 201).

The Ingledow to Custer powerflow cannot exceed 1000 MW with the Monroe-Snoqualmie 500-kV line permanently out of service during summer. This applies only to Plan 1. The other plans can accommodate 2000 MW Ingledow to Custer during outages.

3. Portland Area Voltage Stability Performance

The critical outage for the Portland area is loss of the Trojan Nuclear plant with one Centralia generating unit previously out of service during abnormally cold weather loads. The addition of the new line into the Puget Sound area, with 300 MVAR SVC's at Maple Valley and Keeler will provide the necessary reactive margins in the Portland area. The Keeler SVC will need to be increased to 500 MVARs in later years to keep up with the load growth. Also, additional 500-kV shunt capacitors will be needed at Ostrander, Keeler and Pearl

substations between 1998 and 2004. The performance of the three critical busses in the Northwest for the Trojan scam is shown in QV-112. For more detail on this plan, refer to Table 310.

4. Portland Area Thermal Overload Requirements

Prior to Puget Sound Reinforcement, the PGE Trojan-Rivergate 230-kV and Trojan-St. Marys 230-kV lines overload following an Allston-Keeler 500-kV line outage during summer conditions (A93194). The severity of the overload increases during off peak Seattle summer loads, very high PNW to PSW schedules over the DC and AC interties (following 3rd AC), and high BCH to PNW schedules (A93160). Adding a cross mountain line increases the severity of the overload by about 4% (A96174, A96175). However, the overload is more sensitive to high area interchange schedules during off peak summer loads than it is to the addition of a new cross mountain line. The overloads slightly decreases in future years as the Seattle summer loads increase.

5. Okanogan Valley Performance/Effects

The new cross mountain line increases loading by about 7%. The Okanogan-Brewster 115-kV line needs upgrading to a higher conductor operating temperature before and after addition of a cross mountain line to prevent overloads following an outage of either Douglas Wells 230-kV line or Sickler 500/230-kV transformer during summer (A96170, A96176). Refer to Table 201.

6. Coulee/Chief Joseph Area Performance/Effects

Loading increases on the 500/230-kV transformers with a new CM line. A second Chief Joe 500/230-kV transformer is needed to prevent overloading the Coulee 500/230kV transformer following an outage of the existing Chief Joe 500/230-kV transformer during spring with 1800 MW Custer to Ingledow powerflow (SPG94116). Refer to Table 201.

7. Plan 1 Summary

1994	Add 300 MVAR SVC on Maple Valley 230-kV bus;
Add 300 MVAR SVC on Keeler 230-kV bus;
Add 500-kV shunt capacitor bank at Ostrander.
1996	Add Chief Joseph-Monroe 500-kV double circuit line;
Add 1300 MVA Snohomish 500/230-kV transformer fed from new 11 mile 500-kV line from Monroe;
Loop-in one SCL Bothell-Diablo line into Snohomish;
Add Monroe 500-kV shunt reactor;
Upgrade 12 transmission lines to higher operating temperatures;
Add second Chief Joe 500/230-kV transformer.
1998	Add 500-kV shunt capacitor bank at Keeler.
2000	Upgrade Keeler SVC to 500 MVAR;
Add Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking;
Add Snoking-Bothell 230-kV #2;
Add MSC to one existing Raver shunt capacitor group;
Add second 500-kV shunt capacitor bank at Ostrander.
2001	Upgrade Maple Valley SVC to 500 MVAR.

- 2002 Add 500-kV shunt capacitor bank at Snoqualmie;
Add second 500-kV shunt capacitor bank at Pearl;
- 2003 Add 300 MVAR SVC on Covington 230-kV bus.
- 2004 Add 500-kV shunt capacitor bank at Monroe;
Add third 500-kV shunt capacitor bank at Ostrander.

8. Loss savings of Plan 1

The loss savings of various options is summarized in Table 100. Plan 1 will save 58.0 MW on the BPA system and 70.2 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 67.9 MW on the BPA system and 82.0 MW in the Northwest in 2004 (compared to the Reactive Plan). This plan has some of the highest loss savings of the 500-kV options studied.

B. Chief Joseph-Snoqualmie 500-kV Double-Circuit Line: Plan 2

1. Puget Sound Area Voltage Stability Performance

This plan assumes a new Chief Joseph-Snoqualmie 500-kV double circuit line is built on new ROW paralleling the existing Chief Joe-Sickler line, on new ROW from Sickler toward the Cascades summit, then paralleling the Rocky Reach-Maple Valley 345-kV line into Snoqualmie. This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Monroe and Snoqualmie substations between 2002 and 2004. For more detail on this and the additions needed through 2004, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 2 in service is shown in QV-120 for 1996 and in QV-121 for 2004 for the 3 critical outages.

2. Puget Sound Area Thermal Overload Requirements

If this line is added, numerous problems are aggravated in the North Seattle area during winter conditions. These include:

- a. Loss of the double-circuit Chief Joe-Snohomish 345-kV lines during normal winter will cause the Monroe-Sedro Tap 230-kV line to overload in 1997 (J96234).
- b. Loss of the Monroe 500/230-kV transformer causes the Maple Valley-Snoking 230-kV line to load beyond the 1275 amp limit (J96EH553).
- c. Loss of the Maple Valley 500/230-kV transformer will cause the Monroe transformer to overload in 2001 (J00EH25).

The 230-kV three-terminal line outages out of Monroe are not serious with this CM plan (J96M219 and J96M220).

Although transformation is not required until 2001, it is advantageous to add a Snoking transformer with the new CM line. This transformer addition solves both

line overloads (problems a and b above) and the eventual 500/230-kV transformer overload (problem c above). It also has loss saving benefits. The Monroe-Snoqualmie line can be tapped and the existing Snoking Tap-Snoking 230-kV line converted to its design voltage of 500-kV to supply the new Snoking transformer. A second Snoking-Bothell 230-kV line is needed with this transformer to prevent overloads during Monroe transformer outages (J00EH26).

When the Lakeside transformer is added (assumed in 2001), the unused 230-kV circuit that is parallel to the existing Bothell-Snoking-Maple Valley 230-kV line will need to be put into service at 230-kV. With the new Chief Joe-Snoqualmie 500-kV line plan, the Maple Valley-Lakeside section of this line will need to be rebuilt to about 1800 amps at -15 degrees Celcius.

The Maple Valley 500/230-kV transformer will overload in about 2007 for loss of the Snoking transformer and Monroe-Snoqualmie line (J04EH97 and 2% load growth). A parallel Maple Valley 500/230-kV transformer will be needed at this time. With these additions, this plan should provide for future load growth beyond 2010.

If a second Maple Valley-Snoking 230-kV line (25 miles) is added to correct problem #2 above instead of the Snoking transformer, it would also delay the Monroe-Snohomish overload in problem #1 until about 1999 (J96236 and J0017). If a second Maple Valley 500/230-kV transformer is then added in 1999, it would delay this overload further until about 2002 (2% load growth applied to case J0018). Additional support would then be needed into the Snohomish area. The Snoking project would be needed at this time.

If the second Maple Valley-Snoking 230-kV line is added in 10-96, followed by a Snoking transformer in 1999, the 230-kV line addition would have limited usefulness until the Lakeside transformer is added (J00EH27). The Snoking transformer addition provides substantial loss savings over the 230-kV line addition (9 MW vs 1.2 MW). If the Snoking 500/230-kV transformer is added in 1996, it would solve all the problems listed above through the year 2007 without the addition of a second Maple Valley-Snoking 230-kV line. This line would not be needed until the Lakeside transformer is added. Therefore, the Snoking transformer is the preferred option.

The loss savings due to the addition of the Snoking project is about 9.0 MW on the BPA system and 14.3 MW total for the Northwest (compare cases J96249, J96253, J96258 and J96259). These loss savings increase to 10.6 MW on the BPA system and 17.0 MW for the Northwest in 2000 (compare cases J0021, J0022, J0025 and J0030).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. Seven transmission lines need upgrading to higher conductor operating temperatures to meet spring and summer loading conditions (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Chief Joseph-Snoqualmie line addition on the Portland system performance is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-122. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: same as Plan 1 (Table 201)
6. Coulee/Chief Joseph Area Performance/Effects: same as Plan 1 (Table 201)
7. Plan 2 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus;
Add 300 MVAR SVC on Keeler 230-kV bus;
Add 500-kV shunt capacitor bank at Ostrander.
- 1996 Add Chief Joseph-Snoqualmie 500-kV double circuit line;
Add 1300 MVA Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking;
Add Snoking-Bothell 230-kV line #2;
Add Snoqualmie 500-kV shunt reactor;
Eight transmission line upgrades to higher operating temperatures
Add second Chief Joe 500/230-kV transformer.
- 1998 Add 500-kV shunt capacitor bank at Keeler.
- 2000 Upgrade Keeler SVC to 500 MVAR;
Add MSC to one existing Raver shunt capacitor group;
Add second 500-kV shunt capacitor bank at Ostrander.
- 2001 Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees (coincides with Lakeside transformer addition).
- 2002 Upgrade Maple Valley SVC to 500 MVAR;
Add 500-kV shunt capacitor bank at Snoqualmie;
Add second 500-kV shunt capacitor bank at Pearl.
- 2004 Add second 500-kV shunt capacitor bank at Monroe;
Add third 500-kV shunt capacitor bank at Ostrander.
- 2006 Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 2

The loss savings of various options is summarized in Table 100. Plan 2 will save 53.6 MW on the BPA system and 66.9 MW in the Northwest in 1996 (compared to the base system). The loss savings will be 53.8 MW on the BPA system and 65.1 MW in the Northwest in 2004 (compared to the Reactive Plan).

C. Chief Joseph-Snoqualmie/Monroe 500-kV Double-Circuit Line: Plan 3

1. Puget Sound Area Voltage Stability Performance

This plan includes a double circuit 500-kV line from Chief Joe west towards Puget Sound using the existing northern corridor to Monroe. At 29 miles outside Monroe, the line will split into two single circuits with one circuit extending southwest to the new Snoqualmie switchyard site and the other circuit line continuing northwest to Monroe. This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Automatic

switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe substations in 2002 and 2004. For more detail on this and the additions needed through 2004, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 3 in service is shown in QV-132 for 1996 and in QV-133 for 2004 for the 3 critical outages.

2. Puget Sound Area Thermal Overload Requirements

If this line is added, the following problems will occur:

- a. The Maple Valley 500/230-kV transformer outage will cause the Monroe 500/230-kV transformer to overload by January 1997 (J96EH328).
- b. The new line addition aggravates the loadings experienced during outages of either 230-kV three-terminal line out of Monroe (J96M147 and J96M148). These lines will overload one or two years after the Cross Mountain line is added.
- c. The loss of the double-circuit Chief Joe-Snohomish 345-kV lines will cause the Monroe-Sedro Tap 230 line to overload (J96260).

The addition of a 500/230-kV transformer at Snoking will solve all the problems listed above. The existing 500-kV constructed tap line presently feeding Snoking should be used to tap the newly formed Snoqualmie-Monroe 500-kV line. A second Bothell-Snoking section is also needed for either the Maple Valley or Monroe 500/230-kV transformer outages as shown in J96EH251 and J96EH252.

The existing Monroe-Snohomish 230-kV line will overload in about 2001 for loss of the new Snoking transformer (J00EH39). A second Snoking-Maple Valley 230-kV line would delay this line overload until about 2006 (case J04EH42 and 2% load growth). This line is assumed to be added in the early 2000's with the Lakeside 230/115-kV transformer. Therefore, if Lakeside is added by 2001, no reinforcement is needed in the Monroe-Snohomish area until 2006.

At this time, additional support will be needed for Snohomish. If a Monroe-Snohomish line is added in 2006, the Monroe 500/230-kV transformer will overload in 2010 for loss of the new Snoking transformer (case J04EH110 and 2% load growth). Since additional 500/230-kV transformation is also needed, this plan will include construction of the Monroe-Snohomish line at 500-kV (operated at 230-kV initially) in 2006 and conversion of this line to 500-kV and a Snohomish 500/230-kV transformer in 2010. As shown with Plan 1, a loop-into Snohomish of one Skagit line is needed with this transformer. This reinforcement will relieve the overload problems in the area beyond 2010.

If the Lakeside transformer is delayed beyond 2001, the Monroe-Snohomish construction will have to be done earlier.

Another solution to these problems would be to reverse the order of the 500/230-kV transformers. If the Snohomish transformer is added first, additional support would be needed to relieve the Monroe transformer and Monroe-Snohomish 230-kV line loadings at about the same time as the Snoking transformer plan (case J00EH35).

Both plans would perform similarly. However, line construction between Monroe and Snohomish can be delayed with the Snoking plan, especially if Lakeside is

added as planned. The BPA loss savings for both plans are almost identical, while the Northwest loss savings favors Snoking by 2.1 MW. Therefore, the Snoking Reinforcement is preferred.

The loss savings due to the addition of the Snoking project (using the existing parallel Bothell-Snoking circuit) is about 10.6 MW on the BPA system and 15.1 MW total for the Northwest in 1996 (compare cases J96241, J96242, J96250, and J96251). The loss savings increases to 12.6 MW for BPA and 17.6 for the Northwest in 2000 (compare cases J0023, J0024, J0027 and J0028).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. During spring and summer conditions, the same seven line upgrades needed for Plan 2 are needed for this plan (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Chief Joseph-Snoqualmie/Monroe line addition on the Portland system performance is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-134. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: same as Plan 1 (Table 201)

6. Coulee/Chief Joseph Area Performance/Effects: same as Plan 1 (Table 201)

7. Plan 3 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus;
 Add 300 MVAR SVC on Keeler 230-kV bus;
 Add 500-kV shunt capacitor bank at Ostrander.
- 1996 Add Chief Joseph-Snoqualmie/Monroe 500-kV double circuit line;
 Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie
 500-kV line and using existing 500-kV constructed line into Snoking;
 Add Snoking-Bothell 230-kV line #2;
 Add Snoqualmie 500-kV shunt reactor;
 Add second Chief Joe 500/230-kV transformer.
 Eight line upgrades.
- 1998 Add 500-kV shunt capacitor bank at Keeler.
- 2000 Upgrade Keeler SVC to 500 MVAR;
 Add MSC to one existing Raver shunt capacitor group;
 Add second 500-kV shunt capacitor bank at Ostrander.
- 2001 Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees
 (coincides with Lakeside transformer addition).
- 2002 Upgrade Maple Valley SVC to 500 MVAR;
 Add 500-kV shunt capacitor bank at Snoqualmie;
 Add second 500-kV shunt capacitor bank at Pearl;
- 2004 Add second 500-kV shunt capacitor bank at Monroe;

Add third 500-kV shunt capacitor bank at Ostrander.

2005 Add Monroe-Snohomish 500-kV line, operate at 230-kV initially.

2010 Add Snohomish 500/230-kV 1800 MVA transformer;
Loop Bothell-Diablo 230-kV line into Snohomish;
Convert Monroe-Snohomish line to 500-kV operation.

8. Loss savings of Plan 3

The loss savings of various options is summarized in Table 100. Plan 3 will save 59.1 MW on the BPA system and 73.9 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 63.6 MW on the BPA system and 77.1 MW in the Northwest in 2004 (compared to the Reactive Plan). This plan has the highest loss savings of the 500-kV options studied.

D. Hanford-Snoqualmie 500-kV Double-Circuit Line: Plan 4

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new 500-kV double circuit line is built from Hanford to Naneum paralleling the existing 500-kV line. From Naneum to Snoqualmie, the new line will parallel the existing Rocky Reach-Maple Valley 345-kV line. The reason for including this plan is the possibility that future resources (eg. the mothballed nuclear plant at Ashe, WNP-1) may be energized in the Hanford area.

This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Monroe and Snoqualmie substations between 2002 and 2004. For more detail on the need for these additions, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 4 in service is shown in QV-140 for 1996 and in QV-141 for 2004 for the 3 critical outages. To meet the reactive requirements for the double line outage in 2004, an additional 300 MVAR SVC is needed at Covington in 2004.

2. Puget Sound Area Thermal Overload Requirements

The thermal requirements of this plan are the same as Plan 2 above. The Snoking and Maple Valley transformer addition projects are similarly proposed to correct these problems. During spring and summer conditions, the same seven line upgrades needed for Plan 2 are needed for this plan (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Hanford-Snoqualmie line addition on the Portland system performance is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-142. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: No impact

6. Coulee/Chief Joseph Area Performance/Effects: No impact

7. Plan 4 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus;
Add 300 MVAR SVC on Keeler 230-kV bus;
Add 500-kV shunt capacitor bank at Ostrander.
- 1996 Add Hanford-Snoqualmie 500-kV double circuit line;
Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking;
Add Snoking-Bothell 230-kV line #2;
Add Snoqualmie 500-kV shunt reactor;
Eight line upgrades.
- 1998 Add 500-kV shunt capacitor bank at Keeler.
- 2000 Upgrade Keeler SVC to 500 MVAR;
Add MSC to one existing Raver shunt capacitor group;
Add second 500-kV shunt capacitor bank at Ostrander.
- 2001 Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees (coincides with Lakeside transformer addition);
Upgrade Maple Valley SVC to 500 MVAR.
- 2002 Add 500-kV shunt capacitor bank at Snoqualmie;
Add second 500-kV shunt capacitor bank at Pearl.
- 2004 Add second 500-kV shunt capacitor bank at Monroe;
Add third 500-kV shunt capacitor bank at Ostrander;
Add 300 MVAR SVC on Covington 230-kV bus.
- 2006 Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 4

The loss savings of various options is summarized in Table 100. Plan 4 will save 39.9 MW on the BPA system and 51.0 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 57.4 MW on the BPA system and 74.2 MW in the Northwest in 2004 (compared to the Reactive Plan). The increase in loss savings in 2004 is largely due to the assumption of WNP-1 operating.

E. Sickler-Snoqualmie Double-Circuit Line & Naneum Switchyard: Plan 5

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new 500-kV double circuit line is built on new ROW from Sickler to Snoqualmie. Mileage for the northern corridor was assumed in the studies, however, the southern corridor is not much longer. Also included in this plan is the development of a major Naneum switchyard (the Coulee-Raver lines will be tied into the existing station with the Sickler-Raver and Vantage-Raver lines). This switchyard development strengthens Sickler as a source for

the new line and reduces the severity of the double-line Coulee-Raver outage.

With this new line added, the three critical outages for the Puget Sound area are 1) loss of the Chief Joe-Monroe 500-kV line during abnormally cold weather, 2) loss of the Trojan nuclear plant with one Centralia unit previously out-of-service, also during abnormally cold weather and 3) simultaneous loss of both Coulee-Naneum 500-kV lines (the compensated section of the old Coulee-Raver lines) during normal winter peak loads.

These new additions and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Also, additional 500-kV shunt capacitors will be needed at Monroe and Snoqualmie substations between 2002 and 2004. For more detail on these additions, refer to Table 310.

The voltage stability performance of Plan 5 is shown in QV-150 for 1996 and in QV-151 for 2004 for the 3 critical outages. To meet the reactive requirements for the single line outage in 2004, an additional 300 MVAR SVC is needed at Covington in 2004. Performance of this plan with the Covington SVC is shown in QV-152.

A Chief Joseph-Sickler 500-kV single circuit and a 300 MVAR SVC at Sickler was investigated as alternatives to the Covington SVC to provide the required reactive margins. Neither performed as well as the Covington SVC during post-transient conditions. However, the transmission between Chief Joe and Sickler will eventually need to be reinforced.

It should be noted that in Plans 1 and 4, a Covington SVC was also proposed, but to correct the double line outage. In Plan 5 this SVC is needed for the cold weather single line outage. The development of the Naneum switchyard in Plan 5 improves the performance of the double line outages. The MSC at Raver is not needed with this plan.

2. Puget Sound Area Thermal Overload Requirements

The thermal requirements of this plan are the same as Plan 2 above. The Snoking and Maple Valley transformer addition projects are similarly proposed to correct these problems. During spring and summer conditions, the same seven line upgrades needed for Plan 2 are needed for this plan (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Sickler-Snoqualmie line and Naneum Switchyard additions on the Portland area performance is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-153. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: No impact

6. Coulee/Chief Joseph Area Performance/Effects: No impact

Although there is no impact in the Coulee/Chief Joseph area, there may be some impact on the Sickler/Douglas transformer. This needs further study.

7. Plan 5 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus and
 Add 300 MVAR SVC on Keeler 230-kV bus.
 Add 500-kV shunt capacitor bank at Ostrander.

- 1996 Add Sickler-Snoqualmie 500-kV double circuit line;
 Expand Naneum 500-kV switchyard;
 Add 300 MVAR 230-kV shunt capacitors at Wells;
 Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie
 500-kV line and using existing 500-kV constructed line into Snoking;
 Add Snoking-Bothell 230-kV line #2;
 Add Snoqualmie 500-kV shunt reactor;
 Eight line upgrades.

- 1998 Add 500-kV shunt capacitor bank at Keeler.

- 2000 Upgrade Keeler SVC to 500 MVAR;
 Add second 500-kV shunt capacitor bank at Ostrander.

- 2001 Rebuild Maple Valley-Lakeside 230-kV line;
 Upgrade Maple Valley SVC to 500 MVAR.

- 2002 Add second 500-kV shunt capacitor bank at Pearl;
 Add 500-kV shunt capacitor bank at Snoqualmie.

- 2003 Add 300 MVAR SVC on Covington (or Snohomish) 230-kV bus.

- 2004 Add second 500-kV shunt capacitor bank at Monroe;
 Add third 500-kV shunt capacitor bank at Ostrander.

- 2006 Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 5

The loss savings of various options is summarized in Table 100. Plan 5 will save 49.6MW on the BPA system and 65.1 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 56.1 MW on the BPA system and 68.7 MW in the Northwest in 2004 (compared to the Reactive Plan).

F. Reactive Alternative Plan 6

1. Puget Sound Area Voltage Stability Performance

The assumed voltage stability criteria can be achieved in 1996 with the addition of three 300 MVAR SVC's and two series capacitor stations on the Coulee-Raver lines (J96EH573QV4, J96EH575QV4, J96275QV4). A possible plan to add five series capacitor stations (one on the Chief Jo-Monroe, one on each Naneum-Raver circuit, and one on each Coulee-Raver line) to reduce the number of SVC's does not meet voltage stability criteria for the Chief Jo-Monroe outage (J96EH581QV). Therefore, reducing the number of SVC's by increasing series compensation is not an alternative.

Distributing the SVC's among different locations provides about 40MVARs of benefits in Q-V performance for the double generator outage during abnormal or double line outage during normal (J96EH573QV4, J96EH573QV5, J96275QV4,

J96275QV5). The single line outage during abnormal shows a 40MVAR disadvantage to distributing SVC's (J96EH575QV4, J96EH575QV5).

The series capacitor stations perform better when located halfway between Columbia and Raver on the Coulee-Raver lines (20% compensation, 2600A continuous). Q-V performance improves by about 30MVARs (J96EH575QV4, J96EH576QV). Voltages are about 4kv less at the stations so criteria levels are not violated when sending end voltages are held high.

System planning assumes that the SVC's can be made equally reliable to transmission lines. If assumptions change and system design assumes the failure of one SVC following the contingency, then one more 300MVAR SVC is needed (assumed at Snohomish J96275QV2, J96275QV3).

In 2000, load growth and system design for the simultaneous loss of both Coulee-Raver 500-kV lines cause the need for three additional series capacitor stations on the other three existing cross Cascades 500-kV lines (25% 3200A midline on Chief Joe-Monroe 500, 35% 2300A on each Naneum-Raver 500 line). These will be switched in service following the double Coulee-Raver line loss during normal winter or double generator loss during abnormal winter. Another 324MVAR 500-kV shunt capacitor bank is needed at Monroe. The plan for 2000 was not studied. It was estimated from 1996 and 2004 studies.

By 2004, load growth causes the need for series compensation to be in service on the Chief Jo-Monroe line (25%) and Naneum-Raver line sections (35%) with no outage during abnormal cold weather (J04EH34). More series compensation on the Chief Jo-Monroe line (25% more for 50% total) and the Naneum-Raver lines (35% more for 70% total) need to be added for the double Coulee-Raver line loss during normal winter. Two 500-kV 324MVAR shunt capacitor banks are needed at Snoqualmie (J0482QV). The assumed voltage stability criteria is achieved for the single line loss (J04EH148QV) and double generator outage (J04EH149QV) with the added series and shunt compensation.

The amounts of series compensation were calculated by considering these factors:

- > series compensation keeps the amount of needed dynamic and switched shunt compensation from dramatically increasing every year with assumed load growth. For example, about 3MVARs of dynamic shunt (SVC's) would be needed for 1MW of load growth without series compensation (3:1 ratio). With the planned series compensation, only about .5-1MVARs per MW of less expensive switched shunt compensation needs to be added. Therefore, adding the series compensation is estimated to be more cost effective than adding more dynamic shunt compensation.

- > series compensation reduces voltage sensitivity to load level (reduces the slope on a Q-V curve). This allows more shunt capacitors to be on line prior to an outage.

- > distributing series compensation along the line improves Q-V performance because reactive power cannot be transmitted over long distances on heavily loaded lines.

- > the amount of series compensation at any specific site is limited by the voltage drop (or rise) that may cause the voltage at the station to exceed 550kv steady state.

> transmission system energy efficiency is best with Coulee-Raver series compensation at about 40-50% (J96279, J96280, J96273).

> the ratio of series compensation between the Chief Jo-Monroe line and the Naneum-Raver lines was sized to keep the powerflow on the lines roughly proportional to the thermal rating of each circuit during the double Coulee-Raver outage.

> voltage stability criteria cannot be met with only series compensation and switched shunt compensation. SVC's are needed too. This is caused by the very high critical voltage (520kv, J96EH577QV). SVC'S provide voltage control in the vicinity of the critical voltage. Also, SVC's lower the critical voltage in this case and the series compensation becomes more effective in Q-V performance. Theoretically, voltage stability could be accomplished with very large amounts of SVC's and no series compensation, regardless of the critical voltage level on a constant power Q-V curve. However, the cost would be much higher with no apparent benefits.

Based on these factors, the maximum compensation is about 50% on Chief Jo-Monroe, 42% on Coulee-Raver #1 & #2, and 70% on Naneum-Raver #1 & #2.

2. Puget Sound Area Thermal Overload Requirements

The loss of both Chief Joe-Snohomish 345-kV lines overloads the Monroe-Sedro Tap 230-kV line section during a 2000 normal winter (J0049). Adding another Monroe-Sedro Tap circuit solves this.

The loss of the Maple Valley 500/230-kV transformer overloads the Covington 500/230-kV transformers during abnormal cold in 2004 (J04EH22). Adding a second Maple Valley transformer solves this.

The loss of the Snoqualmie-Raver 500-kV line overloads the PSP Christopher-Obrien and Covington-Creston 230-kV lines with abnormal cold loads in 2004 (J04EH25). A second Snoqualmie-Raver 500-kV line solves this.

3. Portland Area Voltage Stability Performance

A 300 MVAR SVC is needed at Keeler in 1996 (J96EH573QV3,QV4) and one additional 300

MVAR SVC is needed at Ostrander in 2004 to satisfy voltage stability criteria for the Trojan outage during abnormal cold with one Centralia unit down (J04EH149QV2).

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: see Table 201 (no cross mtn line)

6. Coulee/Chief Joseph Area Performance/Effects: none

7. Reactive Plan 6 Summary

1994 300 MVAR SVC on Maple Valley 230-kV bus and
 300 MVAR SVC on Keeler 230-kV bus.
 8 line upgrades

1996 300 MVAR SVC at Snohomish
 300 MVAR SVC at Covington

20% more series comp on Coulee-Raver #1 and #2 between Columbia and Raver

- 2000 25% series comp on Chief Joe-Monroe 500 midline
 35% series comp on Naneum-Raver #1 and #2 between Naneum and Raver
 3rd parallel circuit from Monroe Tap to Sedro Tap
 Add 500-kV shunt capacitor bank at Monroe
 Add 500-kV shunt capacitor bank at Pearl
 Add 500-kV shunt capacitor bank at Ostrander
- 2004 Add 2-500-kV shunt capacitor banks at Snoqualmie
 Add 500-kV shunt capacitor bank at Ostrander
 25% more series comp on Chief Joe-Monroe 500
 35% more series comp on Naneum-Raver #1 and #2
 2nd Maple Valley 500/230 transformer
 2nd Raver-Snoqualmie 500 line
 300 MVAR SVC at Ostrander

8. Loss savings of Reactive Plan 6

The loss savings of all feasible options are summarized in Table 100. The Reactive Plan will save 2.4 MW in the Northwest in 1996. In the 2004 loss savings case, the reactive plan is used as the base since the powerflow will not solve with just the base system in service.

G. Coulee-Snoqualmie/Olympia 500-kV Double-Circuit Line Rebuild: Plan 7

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new 500-kV double circuit line is built, replacing existing 230-KV and 287-KV lines between Grand Coulee and the Puget Sound area. The Coulee-Columbia 230-kV line, the Columbia-Covington 230-kV line and the Columbia-Olympia portion of the Coulee-Olympia 287-kV line would need to be removed. The remaining section of 287-kV line from Coulee to Olympia would be converted to 230-kV to replace the parallel circuit that was removed. Nothing will be added at Columbia to replace the circuit to Covington, since it is a load line. The Olympia and Covington 230-kV busses will be investigated in the Puget Sound thermal overload section to determine if any reinforcement is needed at these busses to replace the facilities that were removed.

This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe substations in 2002 and 2004. A 300 MVAR SVC is needed at Snohomish in 2004 to strengthen this plan for double line outage. For more detail on these additions, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 7 in service is shown in QV-171 for 2004 for the 3 critical outages.

2. Puget Sound Area Thermal Overload Requirements

The problem areas in the North Seattle area for Plan 7 would be very similar to

Plan 2. Since the Shelton 500/230-kV transformer has been added by this time, additional support is not needed at Olympia to replace the 287-kV circuit. However, at some future time, additional facilities will be needed in this area earlier as compared to the other plans considered (J04EH162). Although a source line was removed from Covington, the addition of the new 500-kV CM lines redistributes the powerflow so that Covington capacity is not a problem. There are no transformer overloads in the Puget Sound area for several years.

As in Plan 2, it is advantageous to add a Snoking transformer with the new CM line since this transformer addition will also alleviate the double 345-kV line outage. The Monroe-Snoqualmie line can be tapped and the existing Snoking Tap-Snoking 230-kV line converted to its design voltage of 500-kV to supply the new transformer. A second Snoking-Bothell 230-kV line is needed with this transformer to prevent overloads during Monroe transformer outages (J00EH26, from Plan 2). With the Snoking Transformer addition, the Covington transformer loadings actually decrease from the pre-CM conditions even though a 230-kV circuit was removed (compare J96EH158 and J96EH582).

When the Lakeside transformer is added (assumed in 2001), the unused 230-kV circuit that is parallel to the existing Bothell-Snoking-Maple Valley 230-kV line will need to be put into service at 230-kV. With a new Chief Joe-Snoqualmie 500-kV line in service, the Maple Valley-Lakeside section of this line will need to be rebuilt to about 1800 amps at -15 degrees Celcius.

This plan has extremely well balanced 500/230-kV transformer loading. The Covington 500/230-kV transformer will overload in about 2011 for loss of the Tacoma transformer (J04EH183 and 2% load growth) and in 2012 for loss of the parallel bank (J04EH165). The Maple Valley 500/230-kV transformer will overload in about 2012 for loss of the Snoking transformer and Monroe-Snoqualmie line (J04EH166). The Tacoma 500/230-kV transformer will overload in 2015 for loss of the Maple Valley transformer (J04EH163). A parallel Maple Valley 500/230-kV transformer will therefore be needed by 10-2010. As can be seen in these outages, the new Snoking transformer is loading in excess of 1600 MVA in these cases. This transformer will need to be a 1800 MVA bank when it is installed in 1996.

The loss savings due to the addition of the Snoking project will be similar to that of Plan 2. The loss savings for Plan 2 are about 9.0 MW on the BPA system and 14.3 MW total for the Northwest (compare cases J96249, J96253, J96258 and J96259). These loss savings increase to 10.6 MW on the BPA system and 17.0 MW for the Northwest in 2000 (compare cases J0021, J0022, J0025 and J0030).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. Seven transmission lines need upgrading to higher conductor operating temperatures to meet spring and summer loading conditions (Table 201). The effect of the new line terminated at Olympia on intertie schedules has not been studied yet.

3. Portland Area Voltage Stability Performance

The effect of the Coulee-Snoqualmie/Olympia 500-kV line addition on the Portland system performance is similar to the other plans. Identical facilities are required in the Portland area. Refer to Table 310 for further information.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: None

6. Coulee/Chief Joseph Area Performance/Effects: Not studied yet.

7. Plan 7 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus and
 Add 300 MVAR SVC on Keeler 230-kV bus.
 Add 500-kV shunt capacitor bank at Ostrander.

- 1996 Replace the existing Coulee-Columbia 230-kV line, Columbia-Covington
 230-kV line and Columbia-Olympia portion of the Coulee-Olympia 287-kV
 line to a new 500-kV double circuit line;
 Convert remaining section of Coulee-Olympia 287-kV line to a 230-kV
 Coulee-Columbia line.
 Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie
 500-kV line and using existing 500-kV constructed line into Snoking;
 Add Snoking-Bothell 230-kV line #2;
 Add Snoqualmie 500-kV shunt reactor;
 Eight transmission line upgrades to higher operating temperatures;
 Add second Chief Joe 500/230-kV transformer.

- 1998 Add 500-kV shunt capacitor bank at Keeler.

- 2000 Upgrade Keeler SVC to 500 MVAR;
 Add MSC to one existing Raver shunt capacitor group;
 Add second 500-kV shunt capacitor bank at Ostrander.

- 2001 Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees
 (coincides with Lakeside transformer addition);
 Upgrade Maple Valley SVC to 500 MVAR.

- 2002 Add 500-kV shunt capacitor bank at Snoqualmie;
 Add second 500-kV shunt capacitor bank at Pearl.

- 2004 Add second 500-kV shunt capacitor bank at Monroe;
 Add third 500-kV shunt capacitor bank at Ostrander;
 Add 300 MVAR SVC on Snohomish 230-kV bus.

- 2012 Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 7

The loss savings of various options is summarized in Table 100. Plan 7 will save 58.2 MW on the BPA system and 69.4 MW in the Northwest in 1996 (compared to the base system). The loss savings will be 54.6 MW on the BPA system and 63.9 MW in the Northwest in 2004 (compared to the Reactive Plan).

H. Chief Joseph-Sickler-Snoqualmie Double-Circuit Line Rebuild: Plan 8

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new Chief Joseph-Sickler-Snoqualmie 500-kV double circuit line is built replacing the existing Chief Joseph-Sickler 500-kV and Rocky Reach-Maple Valley 345-kV lines. This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be

increased to 500 MVARs in later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe in 2002 and 2004. A 300 MVAR SVC is needed at Snohomish in 2002 to strengthen this plan for the double line outage. For more detail on these additions, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 8 in service is shown in QV-180 for 2004 for the 3 critical outages (without the Snohomish SVC).

The exact timing of the need for the Chief Joe-Sickler portion of this plan has not been determined. The 2004 base case with one Centraila unit down would not solve without this reinforcement. A QV curve of this system showed that the 3 shunt capacitor groups at Raver were required to just touch the knee of the QV curve without any outage. It was therefore assumed that this line would be needed immediately.

2. Puget Sound Area Thermal Overload Requirements

If this line is added, numerous problems are aggravated in the North Seattle area during winter conditions. These are very similar but slightly worse than the problems in Plan 2 since the Maple Valley 345/230-kV transformer is removed. If the Snoking transformer is added as in Plan 2, these initial problems are relieved. This transformer will need to be an 1800 MVA bank instead of 1300 MVA as in Plan 2 to make up for the loss of the Maple Valley 345/230-kV transformer (compare cases J04EH163 and J04EH168).

The Maple Valley 500/230-kV transformer will overload in about 2006 for loss of the Snoking transformer and Monroe-Snoqualmie line (J04EH167). A parallel Maple Valley 500/230-kV transformer will be needed at this time. With these additions, this plan should provide for future load growth beyond 2010.

The loss savings due to the addition of the Snoking project will be similar to that of Plan 2. The loss savings for Plan 2 are about 9.0 MW on the BPA system and 14.3 MW total for the Northwest (compare cases J96249, J96253, J96258 and J96259). These loss savings increase to 10.6 MW on the BPA system and 17.0 MW for the Northwest in 2000 (compare cases J0021, J0022, J0025 and J0030).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. Seven transmission lines need upgrading to higher conductor operating temperatures to meet spring and summer loading conditions (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Chief Joseph-Sickler-Snoqualmie line rebuild on the Portland system performance is similar to all the other transmission line options. Identical facilities are required in the Portland area. Refer to Table 310 for further information.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: same as Plan 1 (Table 201)

6. Coulee/Chief Joseph Area Performance/Effects: same as Plan 1 (Table 201)

7. Plan 8 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus and
 Add 300 MVAR SVC on Keeler 230-kV bus.
 Add 500-kV shunt capacitor bank at Ostrander.

- 1996 Rebuild the existing Chief Joseph-Sickler 500-kV and Rocky Reach-Maple
 Valley 345-kV lines to form a Chief Joseph-Sickler-Snoqualmie 500-kV
 double circuit line;
 Add 1800 MVA Snoking 500/230-kV transformer tapping Monroe-Snoqualmie
 500-kV line and using existing 500-kV constructed line into Snoking;
 Add Snoking-Bothell 230-kV line #2;
 Add Snoqualmie 500-kV shunt reactor;
 Eight transmission line upgrades to higher operating temperatures;
 Add second Chief Joe 500/230-kV transformer.

- 1998 Add 500-kV shunt capacitor bank at Keeler.

- 2000 Upgrade Keeler SVC to 500 MVAR;
 Upgrade Maple Valley SVC to 500 MVAR;
 Add MSC to one existing Raver shunt capacitor group;
 Add second 500-kV shunt capacitor bank at Ostrander.

- 2001 Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees
 (coincides with Lakeside transformer addition).

- 2002 Add 500-kV shunt capacitor bank at Snoqualmie;
 Add second 500-kV shunt capacitor bank at Pearl;
 Add 300 MVAR SVC on Snohomish 230-kV bus.

- 2004 Add second 500-kV shunt capacitor bank at Monroe;
 Add third 500-kV shunt capacitor bank at Ostrander.

- 2006 Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 8

The loss savings of various options is summarized in Table 100. Plan 8 will save 50.0 MW on the BPA system and 60.1 MW in the Northwest in 1996 (compared to the base system). The loss savings will be 49.7 MW on the BPA system and 58.2 MW in the Northwest in 2004 (compared to the Reactive Plan).

19-SEPT-1990

QV CURVES

PLAN 1: CJ - MON 2&3, SNOKING, LDC,
COVINGTON-BERRYDALE, 300MVAR SVC AT KEELER,
300MVAR SVC AT MAPLE VL

O J96EH408: COULEE-RAVER OUT (J96EH390)

Δ J96EH418: TROJAN SCRAM (J96EH394)

+ J96179: DOUBLE COULEE-RAVER OUT (J96171)

RAVER VOLTAGE

O J96EH408QV
Δ J96EH418QV
+ J96179QV

30-APR-1990

QV-110

PLAN 1: CHIEF JO-MONROE, SNOK & SNOHOMSH TX, LDC
 500 MVAR SVCS AT MAPLE VALLEY & KEELER
 J04377: DOUBLE COULEE-RAVER OUT (J04376)
 J04EH120: COULEE-RAVER OUT (J04EH119)
 J04EH121: TROJAN SCRAM (J04EH114)

○ J04377QV
 △ J04EH120QV
 + J04EH121QV

28-JUN-1990

QV-111

PLAN 1: CHIEF JOE-MONROE
 TROJAN SCRAM (BASECASE: J04EH114)
 J04EH121: RAVEN
 J04EH141: OSTRANDER
 J04EH145: MARION

O J04EH121QV
 Δ J04EH141QV
 + J04EH145QV

27-JUN-1990

G.V-112

PLAN 2: CJ - SNOQ, SNOKING, LDC,
 COVINGTON-BERRYDALE, 300MVAR SVC AT KEELER
 300MVAR SVC AT MAPLE VL
 J96EH409: COULEE-RAVER OUT (J96EH391)
 J96EH419: TROJAN SCRAM (J96EH395)
 J96180: DOUBLE COULEE-RAVER OUT (J96172)

O J96EH409QV
 Δ J96EH419QV
 + J96180QV

5-MAR-1990

QV-120

PLAN 2: CHIEF JO-SNOQUALMIE, SNOOKING, LDC

500 MVAR SVCS AT MAPLE VALLEY & KEELER

○ J04373: DOUBLE COULEE-RAVER OUT (J04372)

△ J04EH73 : COULEE-RAVER OUT (J04EH71)

+ J04EH82 : TROJAN SCRAM (J04EH81)

28-JUN-1990

QV-121

PLAN 2: CHIEF JOE-SNOQUALMIE
 TROJAN SCRAM (BASECASE: J04EH81)
 J04EH82: RAVEN
 J04EH142: OSTRANDER
 J04EH146: MARION

O J04EH82QV
 Δ J04EH142QV
 + J04EH146QV

27-JUN-1990

SHUNT REACTIVE

QV-12.2

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE ADDED

300 MVAR SVC'S AT MAPLE VALLEY AND KEELER
LDC'S AT COULEE, CENTRALIA, JOHN DAY, DALLES, BONN

SNOKING 500/230 TRANSFORMERS

J96EH378: LDC ADDED AT CHIEF JOE } Based on J96EH332
J96EH500: NO LDC AT CHIEF JOE

O J96EH378QV
Δ J96EH500QV

3-APR-1990

QV-130

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE
 300MVAR SVC AT KEELER, LDC, SNOKING TX
 ○ J96EH367:ONE COULEE-RAVER 500 LINE OUT (J96EH332)
 ▲ J96154:DOUBLE COULEE-RAVER LINE OUT (J96144)
 + J96EH335: TROJAN SCRAM(J96EH332)

RAVER VOLTAGE

RAVER SHUNT REACTIVE - MVARs

○ J96EH367QV
 ▲ J96154QV
 + J96EH335QV

★ amount of
 reactive on in-
 base.

21-FEB-1990

QV-131

PLAN 3: CHIEF JOE - SNOQUALMIE/MONROE
 300MVAR SVC AT KEELER & AT MAPLE VL, LDC, SNOK TXF
 o J96EH378: ONE COULEE-RAVER 500 LINE OUT (J96EH332)
 Δ J96164: DOUBLE COULEE-RAVER LINE OUT (J96164)
 + J96EH379: TROJAN SCRAM (J96EH333)

o J96EH378QV
 Δ J96164QV
 + J96EH379QV

26-FEB-1980

CV-1211

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE
 500 MVAR SVCS AT KEELER AND MAPLE VALLEY
 LDC AND SNOOKING TRANSFORMER
 J04166: DOUBLE COULEE-RAVER LINE OUTAGE (J04165)
 J04EH64: COULEE-RAVER #1 LINE OUT (J04EH26)
 J04EH53: TROJAN SCRAM (J04EH27)

○ J04166QV
 △ J04EH64QV
 + J04EH53QV

11-APR-1990

QU-133

TROJAN SCRAM ON BASE J04EH27
 PLAN 3: CJ-S/M, LDC, SNOKING, 500MVAR SVC'S AT
 KEELER AND MAPLE VALLEY
 O J04EH51: OSTRANDER
 Δ J04EH52: MARION
 + J04EH53: RAVER

O J04EH51QV.
 Δ J04EH52QV.
 + J04EH53QV.

★ reactive on
in base

21-FEB-1990

CV-137

DOUBLE COULEE-RAVER LINE OUT ON CJ-SNOQ/MON PLAN

- ΔJ9642: LINE ADDITION ONLY
- O J9668: LINE AND 2X300 MVAR SVC ADDED
- +J9663: LINE AND 35%/40% COMP ADDED
- xJ9662: LINE, 35%/40% COMP AND 2X300 MVAR SVC

27-DEC-1989

QU-135

COULEE-RAVER LINE OUTAGE ON CJ-SNOQ/MON PLAN

O J96EH46: LINE ADDITION ONLY
 x J96EH88: LINE AND 2X300 MVAR SVC ADDED
 Δ J96EH63: LINE AND 35%/40% COMP ADDED
 + J96EH62: LINE, 35%/40% COMP AND 2X300 MVAR SVC ADD

PLAN 2: CJ-SNOQ, DOUBLE COULEE-RAVER OUTAGE

500 MVAR SVCS AT MAPLE VALLEY & KEELER

J04381QV: WITH SERIES COMP 35% (J04380)

J04318QV: NO SERIES COMP (J04308)

J04373: NO SERIES COMP (J04372)

RAVER VOLTAGE HIGH (549)

RAVER VOLTAGE

○ J04381QV
△ J04318QV
+ J04373QV

19-JUN-1990

QV-127

PLAN 4: HANFORD-SNOO 1&2, SNOKING, LDC, COVINGTON-BERRYDALE, 300MVAR SVC AT KEELER, 300MVAR SVC AT MAPLE VL

No Aske LDC

J96EH410: COULEE-RAVER OUT (J96EH392)

Δ J96EH420: TROJAN SCRAM (J96EH396)

+ J96181: DOUBLE COULEE-RAVER OUT (J96173)

RAVER VOLTAGE

○ J96EH410QV
Δ J96EH420QV
+ J96181QV

RAVER SHUNT REACTIVE - MVARs

6-MAR-1990

QV-140

PLAN 4: HANFORD-SNOQUALMIE, SNOOKING, LDC

500 MVAR SVCS AT MAPLE VALLEY & KEELER

J04379: DOUBLE COULEE-RAVER OUT (J04378)

J04EH122: COULEE-RAVER OUT (J04EH115)

J04EH125: TROJAN SCRAM (J04EH116)

○ J04379QV
 △ J04EH122QV
 + J04EH125QV

PLAN 4: HANFORD-SNOQUALMIE
 TROJAN SCRAM (BASECASE: J04EH116)
 J04EH125: RAVEN
 J04EH143: OSTRANDER
 J04EH147: MARION

O J04EH125QV
 Δ J04EH143QV
 + J04EH147QV

27-JUN-1990

60-147

PLAN 5: SICKLER-SNOQ-NANEUM SY, SNOKING,
 LDC, COV-BERYDL, 300MVAR SVC AT KEELER & MAPLE VL
 O J96182: DOUBLE COULEE-NANEUM OUT (J96174)
 Δ J96EH413: CHIEF JO-MONROE OUT (J96EH393)
 + J96EH421: TROJAN SCRAM (J96EH397)

O J96182QV
 Δ J96EH413QV
 + J96EH421QV

9-MAR-1990

QV-150

PLAN 5: CHIEF JO-SICKLER-SNOQUALMIE, SNOKING, LDC

500 MVAR SVCS AT MAPLE VALLEY & KEELER
 J04315QV: DOULBE COULEE-NANEUM OUT (J043110)
 J04EH126QV: CHIEF JO-MONROE OUT (J04EH118)
 J04EH123QV: TROJAN SCRAM (J04EH117)

○ J04315QV
 △ J04EH126QV
 + J04EH123QV

17-JUL-1990

6V-151

PLAN 5: SICKLER-SNOQUALMIE, SNOOKING, LDC
 500 MVAR SVCS AT MAPLE VL & KEELER, 300 MVAR AT COV
 J04426: DOUBLE COULEE-NANEUM OUT (J04310)
 J04EH150: CHIEF JO-MONROE OUT (J04EH118)
 J04EH151: TROJAN SCRAM (J04EH117)

○ J04426QV
 △ J04EH150QV
 + J04EH151QV

17-JUL-1990

RAVR SHUNT REACTIVE (MVARs)

QV-152

PLAN 5: SICKLER-SNOQUALMIE
 TROJAN SCRAM (BASECASE J04EH117)
 O J04EH151: RAVEN
 Δ J04EH152: OSTRANDER
 + J04EH153: MARION

O J04EH151QV
 Δ J04EH152QV
 + J04EH153QV

18-JUL-1990

SHUNT REACTIVE

QV-153

PLAN 2: CHIEF JO-SNOQUALAMIE, NORMAL WINTER

O J04198: 500-KV LINE, COULEE-RAVER OUT (J04197)
 Δ J04200: 765-KV LINE, OP @ 500, C-R OUT (J04199)
 + J04203: 765-KV LINE, CHIEF JO-SNOQ OUT (J04202) } 2000 MW
 x J04208: 765-KV LINE, COULEE-RAVER OUT (J04202) } PS Setting

O J04198QV.Q
 Δ J04200QV.Q
 + J04203QV.Q
 x J04208QV.Q

RAVER SHUNT REACTIVE - MVAR

10-MAY-1990

QV-1650

PLAN 2: CHIEF JO-SNOQUALAMIE

○ J04EH73: 500-KV LINE, COULEE-RAVER OUT (J04EH71)
 △ J04EH76: 765-KV LINE, OP @ 500, C-R OUT (J04EH74)
 + J04EH78: 765-KV LINE, CHIEF JO-SNOQ OUT (J04EH77) } 2000 MW
 × J04EH88: 765-KV LINE, PS Z=0, CH J-SNOQ OUT (J04EH87) } PS setting
 ◇ J04EH100: 765-KV LINE, COULEE-RAVER OUT (J04EH77)

○ J04EH73QV.
 △ J04EH76QV.
 + J04EH78QV.
 × J04EH88QV.
 ◇ J04EH100QV.

RAVER SHUNT REACTIVE - MVARS

10-MAY-1990

QV-161

PLAN 2: TROJAN SCRAM

○ J04EH82: 500-KV LINE (J04EH81)
 Δ J04EH84: 765-KV LINE, OP AT 500 (J04EH83)
 + J04EH86: 765-KV LINE (J04EH85) - 2000 MW PS setting

○ J04EH820V.
 Δ J04EH840V.
 + J04EH860V.

OSTRANDER SHUNT REACTIVE - MVARs
Rover

26-APR-1990

SV-167

CHIEF JOE - SNOQUALMIE PLAN

WORST SINGLE LINE OUTAGE
 O J96EH26: 500KV LINE ADDED
 Δ J96EH141: 765KV LINE ADDED OPERATED AT 500KV
 + J96EH139: 765KV LINE ADDED
 x J96EH142: 765KV LINE ADDED WITH 35% COMP, 40% IN C-R

O J96EH26QV.
 Δ J96EH141QV
 + J96EH139QV
 x J96EH142QV

12-JAN-1990

QV-163

CHIEF JOE - SNOQUALMIE PLAN

WORST DOUBLE LINE OUTAGE

o J9610: 500KV LINE ADDED

Δ J96104: 765KV LINE ADDED OPERATED AT 500KV

+ J96103: 765KV LINE ADDED

x J96101: 765KV LINE ADDED WITH 35%COMP, 40% IN C-R

12-JAN-1990

QU-164

PLAN 2: CHIEF JOE/COULEE-SNOQUALMIE 765 DOUBLE CIR
 O J04EH102: COULEE-SNOQUALMIE 765 LINE OUT (J04EH101)
 Δ J04EH103: COULEE-RAVER 500 LINE OUT (J04EH101)
 + J04EH105: TROJAN SCRAM (J04EH104)

O J04EH102QV
 Δ J04EH103QV
 + J04EH105QV

10-MAY-1990

CV-165

COULEE - RAVR NO 1&2 OUT

O J96246: 1700MW (J96199)
 Δ J96245: 2000MW (J96191)
 + J96247: 2200MW (J96203)

O J96246QV
 Δ J96245QV
 + J96247QV

9-MAY-1990

QV-166

COULEE - RAVER NO 1 OUT
 O J96EH548: 1800MW (J96EH547)
 Δ J96EH544: 1900MW (J96EH543)
 + J96EH460: 2000MW (J96EH458)
 x J96EH546: 2100MW (J96EH545)
 ◇ J96EH550: 2200MW (J96EH549)

RAVER VOLTAGE

O J96EH548QV
 Δ J96EH544QV
 + J96EH460QV
 x J96EH546QV
 ◇ J96EH550QV

18-APR-1990

RAVER SHUNT REACTIVE - MVARs

CV-167

CHIEF JOE-SNOQUALMIE 765 LINE OUT

○ J96EH559: 1800MW (J96EH547)
 △ J96EH560: 1900MW (J96EH543)
 + J96EH561: 2000MW (J96EH458)
 × J96EH562: 2100MW (J96EH545)
 ◇ J96EH563: 2200MW (J96EH549)

○ J96EH559QV
 △ J96EH560QV
 + J96EH561QV
 × J96EH562QV
 ◇ J96EH563QV

20-APR-1990

QV-167

CHIEF JOE/COULEE-SNOQ 765 DBL CKT PLAN

PHASE SHIFTED TO 2000MW IN BASE (J04EH101)

○ J04EH106:PS ANGLE DECREASED 5° FROM PRE OUTAGE

△ J04EH102:PS SET AT 2000MW PRE OUTAGE ANGLE

+ J04EH107:PS ANGLE INCREASED 5° FROM PRE OUTAGE

RAVER VOLTAGE

○ J04EH106QV
△ J04EH102QV
+ J04EH107QV

11-MAY-1990

QV-169

PLAN 7: GRAND COULEE-OLYMPIA/COVINGTON 500 (Rebuild of 230/287)
 O J04EH171: CHIEF JO-MONROE 500 OUTAGE (J04EH154)
 Δ J04EH175: TROJAN SCRAM (J04EH155)
 + J04492: DOUBLE COULEE-RAVER OUTAGE (J04438)

Smoking, LDC
 500 MVAR SVC @ Keel 1100

8-AUG-1990

QV-171

PLAN 8: CHIEF JOE-SICKLER-SNOQUALMIE 500KV REBUILD

AND ROCKY R-MAPLE VL 345KV
 500MVAR SVCS AT MAPLE VL & KEELER
 O J04EH180: CHIEF JOE-MONROE 500 OUT (J04EH176)
 Δ J04EH179: TROJAN SCRAM (J04EH177)
 + J04495: DOUBLE COULEE-RAVER 500KV OUT (J04494)

RAVER VOLTAGE

O J04EH180QV
 Δ J04EH179QV
 + J04495QV

RAVER SHUNT REACTIVE - MVARs

8-AUG-1990

QV-180

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

300MVAR SVC AT KEELER & MAPLE VALLEY

ADD 35% COMP ON ASHE-MARION

J04EH190: COULEE-RAVER 500 LINE OUT (J04EH186)

J04503: DOUBLE COULEE-RAVER 500 LINES OUT (J04500)

J04EH191: TROJAN SCRAM (J04187)

RAVER VOLTAGE

○ J04EH190QV
△ J04503QV
+ J04EH191QV

9-AUG-1990

RAVER SHUNT REACTIVE - MVAR

CV-215

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

TROJAN SCRAM -- BASED ON J04EH160

o J04EH161: 500 MVAR SVC AT KEELER & MAPLE VL

Δ J04EH192: 300 MVAR SVC AT KEELR, MV & OSTR

+ J04EH198: 500 MVAR AT MV, 300 MVAR AT KEELR & OSTR

x J04EH199: 500MVAR @ MV, 300MVAR @ KEELR (J04EH197) 50% comp on BE-CSTR.

PLAN 3: CHIEF JO-SNOQ/MONROE

TRAJAN SCRAM

o J04EH217:300/300 BE TAP TO HAN-OST(J04EH216)
 Δ J04EH219:300/300 BE TAP TO ASHE/MARION(J04EH218)
 + J04EH185:300MVAR SVC'S - KEELER/MAPLE VL(J04EH160)
 x J04EH161:500MVAR SVC'S - KEELER/MAPLE VL(J04EH160)

o J04EH217QV
 Δ J04EH219QV
 + J04EH185QV
 x J04EH161QV

16-AUG-1990

6V-212

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE
 300MVAR SVC AT KEELER & MAPLE VL, LDC, SNOK TXF
 O J00EH15: ONE COULEE-RAVER 500 LINE OUT (J00EH12)
 Δ J00I100: DOUBLE COULEE-RAVER LINE OUT (J00I10)
 + J00EH16: TROJAN SCRAM (J00EH17)

O J00EH15QV.
 Δ J00I100QV
 + J00EH16QV

8-AUG-1990

2-11-270

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE
 5200MVAR SVC AT KEELER & MAPLE VL, LDC, SNOK TXF
 ○ J04EH159: ONE COULEE-RAVER 500 LINE OUT (J04EH158)
 △ J04441: DOUBLE COULEE-RAVER LINE OUT (J04440)
 + J04EH161: TROJAN SCRAM (J04EH160)

○ J04EH159QV
 △ J04441QV
 + J04EH161QV

8-AUG-1990

QV-221

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

--- BASED ON J04EH160

o J04EH161: 500MVAR SVC AT KEELER & MAPLE VL

Δ J04EH185: 300MVAR SVC AT KEELER & MAPLE VL

+ J04EH192: 300MVAR SVC AT KEELR, MV & OSTRNDR

x J04EH198: 500MVAR AT MV; 300MVAR AT KEELR & OSTR

o J04EH161QV
Δ J04EH185QV
+ J04EH192QV
x J04EH198QV

RAVR SHUNT REACTIVE - MVAR

9-AUG-1990

20-2-2000

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE
 300MVAR SVC AT KEELER & MAPLE VL
 J04EH184: ONE COULEE-RAVER 500 LINE OUT (J04EH158)
 J04499: DOUBLE COULEE-RAVER LINE OUT (J04441)
 J04EH185: TROJAN SCRAM (J04EH160)

○ J04EH184QV
 △ J04499QV
 + J04EH185QV

8-AUG-1990

QV 222

PLAN 8: CJ-SNOQ REPLACING EXISTING LINES

DOUBLE COULEE-RAVER 500 OUTAGE
 J04495: RAVER CHARACTERISTICS
 J04496: MONROE CHARACTERISTICS
 BOTH BASED ON J04494

2-AUG-1990

QV-27E

PLAN 2: CHIEF JO-SNOQUALMIE
 DOUBLE COULEE-RAVER LINE OUTAGE
 500 MVAR SVC'S AT MAPLE VALLEY AND KEELER
 OJ04318: ONE CAP GROUP ON AT RAVER (J04308)
 +J04375: TWO CAP GROUPS ON AT RAVER (J04374)
 ΔJ04373: THREE CAP GROUPS ON AT RAVER (J04372)

O J04318QV
 Δ J04373QV
 + J04375QV

13-JUN-1990

QV-220

CORRECTION OF C-R SERIES COMP LEVEL

J04166, J04EH64 AND J04EH53 - 45% COMP
 J04441, J04EH159 AND J04EH161 - 22% COMP
 2-C-R 1-C-R TROJAN

30723

PLAN 3: CHIEF JO-SNOQ/MON - 35% COMP.

BASED ON J04EH193
 O J04EH195:COULEE-RAVER 500KV LINE 1 OUT
 Δ J04EH207:CHIEF JO-SNOQ 500KV LINE OUT
 + J04EH208:CHIEF JO-MONROE 500KV LINE OUT

QV-231

14-AUG-1990

PLAN 3:CHIEF J-SNOQ/MONROE - 35% COMP.
 300MVAR SVC'S AT KEELER AND MAPLE VL
 J04505:DOUBLE COULEE-RAVER 500KV OUTAGE(J04504)
 Δ J04506:CHIEF J-SNOQ/MON 500KV LINES OUT(J04504)

○ J0450505QV
 Δ J04506QV

13-AUG-1990

PLAN 3: CHIEF JO-SNOQUALMIE/MONROE
 O J04EH195, 2196 + J04506: 35% COMP, 300 MVAR SVC'S
 X J04EH159, 161 + J04441: 500 MVAR SVC'S

O J04EH195QV
 Δ J04EH196QV
 + J04506QV
 x J04EH159QV
 ◇ J04EH161QV
 ▲ J04441QV

14-AUG-1990

6V-223

PLAN 3: CHIEF JO-SNOQUALMIE/MONROE--35% COMP

300 MVAR SVC'S AT KEELER AND MAPLE VALLEY

O J04EH195: COULEE HELD BY EXISTING GENERATION

Δ J04506: COULEE HELD BY EXISTING GENERATION

+ J04EH220: COULEE HELD AT 548 KV

x J04507: COULEE HELD AT 548 KV

O J04EH195QV
Δ J04506QV
+ J04EH220QV
x J04507QV

PLAN 3: CHIEF JO-SNOQ/MON - 35% COMP.
 DOUBLE COULEE-RAVER 500KV OUTAGE
 300MVAR SVC'S AT KEELER AND MAPLE VL
 J04506:COULEE HELD BY EXISTING GENERATION
 J04507:COULEE HELD AT 548KV
 J04512: MSC 300MVAR AT COULEE

QV-235

28-AUG-1980

PLAN 3: CHIEF JO-SNOQ/MON - 35% COMP.
 300MVAR SVC'S AT KEELER AND MAPLE VL
 J04EH195: COULEE HELD BY EXISTING GENERATION
 J04EH220: COULEE HELD AT 548KV
 J04EH223: MSC 300MVAR AT COULEE

Cont. Page out

27-AUG-1990

GV-236

CHIEF JO-MONROE OUT FROM BASE J96EH158

Δ J96EH484A LDC @ PAUL, COULEE, JOHN DAY,
 DALLES, BONNEVILLE
 ○ J96EH484 ADD HOLD AT COULEE 500 E-BUS
 + J96EH484B LDC & 300 MVAR SVC @ MV & KLR
 x J96EH484C LDC, SVC & HOLD AT COULEE

○ J96EH484
 Δ J96EH484A
 + J96EH484B
 x J96EH484C

21-AUG-1980

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

--- BASED ON J04EH160

○ J04EH161: 500MVAR SVC AT MAPLE VL & KEELER

△ J04EH206: 500MVAR e MV: 300MVAR e KLR & OSTR MSC

○ J04EH161QV
△ J04EH206QV

15-AUG-1990

CV-240

PLAN 3: CH JO-SNOQ/MONR TROJAN SCRAM BASE J04EH1

J04EH200: 500 MVAR SVC AT KEELER & MAPLE VALLEY

J04EH201: 300 MVAR SVC AT KEELER & MAPLE VALLEY

J04EH204: 300 MVAR SVC AT KLR & MV: 50% SERIES COMP

ON BE-OSTR IN PRIOR TO OUTAGE (J04EH197)

J04EH205: SAME AS 204, BUT COMP SWITCHED AFTER OUTAGE

OSTRANDER VOLTAGE

○ J04EH200QV
 △ J04EH201QV
 + J04EH204QV
 x J04EH205QV

OSTRANDER SHUNT REACTIVE - MVARS

21-AUG-1990

QV-241

PLAN 3: CHIEF JO-SNOQUALMIE/MONROE
 COMPARISON OF 1.7PU AND 2.0PU LINE DESIGNS
 O J04EH159:1 COULEE-RAVER LINE OUT, 2PU (J04EH158)
 Δ J04EH189:1 COULEE-RAVER LINE OUT, 1.7PU (J04EH188)
 + J04441:DOUBLE COULEE-RAVER OUTAGE, 2PU (J04440)
 x J04502:DOUBLE COULEE-RAVER OUTAGE, 1.7PU (J04501)

O J04EH159QV
 Δ J04EH189QV
 + J04441QV
 x J04502QV

ALTERNATIVE Q-V CURVES

J96EH576QV: C-J-M outage = SUC's @ Snoho, 1 @ MV, 1 @ CV, 1 @ Keeler, series comp, C-R 42%, @ Columbia

J96EH578QV: Trojan outage SUC's @ MV, 1 @ Keeler, series comp 33%, C-J-M, 41%, C-R, 35%, N-X

J96EH579QV: C-J-M outage SUC's @ MV, 1 @ MV, 1 @ Keeler, series comp 46%, C-R, 35%, N-X

J96EH581QV: C-J-M outage SUC's @ MV, 1 @ Keeler, series comp 52%, C-J-M, 70%, N-X

J962822QV: double C-R outage, SUC's @ MV, 1 @ Keeler, series comp + C-R

PSR REACTIVE ALTERNATIVE Q-V CURVES

J96EH575QV: C-J-M outage, SVC's 2E snub, 16 MV, 16 Cov, 20 Keeler, 16 AST
 J96EH575QV4: C-J-M outage, SVC's 2E snub, 16 MV, 16 Cov, Keeler, C-R 42.5% comp
 J96EH575QV5: C-J-M outage, SVC's 3E-MV, 16 Keeler, C-R 42.5% series comp
 J96EH580QV: Trejan outage, SVC's 16 MV, 16 Keeler, series comp all 500 MVES
 J96283QV: double C-R outage, SVC's 16 MV, 16 Keeler, 50% C-J-M, 70% N-R, 42.5% R

○ J96EH575QV
 △ J96EH575QV 4
 + J96EH575QV 5
 x J96EH580QV
 ◇ J96283QV

PSR REACTIVE ALTERNATIVE Q-V CURVES

J96EH573QV3: same as QV except QV at Marion
 J96EH573QV4: Trojan outage, sic's @ Suho, (av, MV, keeler, C-K 42), same
 J96EH573QV5: Trojan outage, sic's @ M6 (3) and keeler
 J04EH149QV: Trojan outage, serves comp as 5-suck lines, sic's same as J96
 J04EH149QV2: same as QV except QV at Marion

2-JUL-1990

PSR REACTIVE ALTERNATIVE Q-V CURVES

J96EH577QV: C.T. - 11.5% voltage, C.R. - 11.5% voltage, no 5.1% S.C.'s

~~J062750V3~~
~~J062750V4~~
~~J062750V5~~
~~J062750V6~~

J96EH577QV

2-JUL-1990

PSR REACTIVE ALTERNATIVE Q-V CURVES

J96275QV2: double C at center sub's 10 MV, 10 Cu, 10 Keeler
 J96275QV3: double C at center sub's 10 MV, 10 Cu, 10 Keeler
 J96275QV4: double C at center sub's 10 MV, 10 Cu, 10 Keeler
 J96275QV5: double C at center sub's 10 MV, 10 Cu, 10 Keeler
 J04EH148QV: C.T. - N. sub's, 5000 Cu, 5000 MV, 5000 Keeler, 6ST, Series Comp. e. 11

J2004 ABNORMAL COLD ALL LINES IN SERVICE

1500 MW added on Conley - King DC line

○ J04EH60QV - all max on
 ▲ J04EH61QV - all max on

DC LINE FROM COULEE TO SNOQUALMIE
 LOADED TO 1500MW PRIOR TO CONTINGENCY
 AFTER CONTINGENCY DC RAMPED TO 3000MW
 TEST OF CJ-MONROE OUTAGE AND TEST OF TROJAN
 OUTAGE (ONE CENTRALIA UNIT ALREADY DOWN)
 KEELER SYNCH CONDENSER WITH GENERATOR OUTAGE

TABLES

TABLE 100: LOSS SAVINGS OF FEASIBLE ALTERNATIVES

(In peak MW's; top number is PNW losses, lower number is BPA losses)

Alternative	1996	2000	2004(1)	2004+(1)
Base System	-0- -0- J96243, J96244	-0- -0- J0037, J0038	N/A	N/A
Plan 1	70.2	91.5	82.0	82.0
Chief Joe-Monroe	58.0 J96261, J96262	73.7 J0035, J0036	67.9 J04343	67.9 J04343
Plan 2	66.9	78.3	65.1	69.3
Chief Joe-Snoqualmie	53.6	62.2	53.8	58.0
500-kV	J96258, J96259	J0022, J0021	J04226	J04347
Plan 2	77.7	90.6	76.9	
Chief Joe-Snoqualmie	64.3	74.0	65.0	
765-kV line op @ 500	J96271, J96272	J0046, J0047	J04227	
Plan 2			141.5	141.5
Coulee/Chief Joe-			122.6	122.6
Snoqualmie 765-kV line			J04228	J04228
Plan 3	73.9	86.1	77.1	84.9
Chief Joe-Snoq/Mon	59.1	68.2	63.6	70.4
4-Bunting	J96241, J96242	J0023, J0024	J04345	J04348
Plan 3	Older J96 studies showed an additional 6.6 MW BPA and 6.9 MW PNW losses are available if 4-Seahawk conductor is used.			
Chief Joe-Snoq/Mon				
4-Seahawk				
Plan 4	51.0	71.6	74.2(2)	78.7(2)
Hanford-Snoqualmie	39.9 J96267, J96268	54.5 J0042, J0043	57.4 J04344	61.1 J04349
Plan 5	65.12	77.73	68.7	73.4
Sickler-Snoqualmie	49.6 J96269, J96270	59.5 J0044, J0045	56.1 J04346	60.9 J04350
Plan 6	2.4	10.13	-0-	-0-
Reactive Alternative	xxx J96273, J96273loss	xxx J0040, J0041	-0- J04370	-0- J04370
Plan 7	69.4	82.4	63.9	67.8
Coulee-Olympia/Snoq	58.2	68.2	54.6	58.1
500-kV	J96289, J96290	J00104, J00105	J04508	J04510
Plan 8	60.1	73.5	58.2	63.7
Chief Joe-Sickler-	50.0	59.7	49.7	53.9
Snoqualmie 500-kV	J96291, J96292	J00106, J00107	J04509	J04511

(1) Loss savings for 2004 are referenced against loss of Reactive Alternative, not base system without additions as is the case for 1996 and 2000.

(2) 2004 base has WNP-1 in operation which increases the loss savings of Plan 4.

TABLE 15C.

.....1/09/90.....
PUGET SOUND VOLTAGE PLANNING ASSUMPTIONS
.....

RESOURCES

1. The Puget Sound area hydro generation will generate at median water firm peaking levels for winter prior to January 6 (reduced generation on the Skagit River). Snoqualmie Falls will be assumed frozen with no generation during abnormal cold.
2. The PSP&L combustion turbines will be generating during abnormal cold except Whitehorn unit #3 and Shuffleton units are off.
3. The PSP&L combustion turbines are off during normal winter peak load.
4. PGE's Beaver combustion turbine/combined cycle plant is off.
5. Coulee serves as a baseload generator with 4500MW generation.
6. Snake River projects provide peaking generation.

.....

INTERTIE SCHEDULES

7. BCH to PNW schedule is 250MW during normal and abnormal cold. After the BCH-WWP intertie is completed in the mid 1990's, the total BCH-PNW schedule will be 850MW. Phase shifters on the eastern BCH system will cause 600MW to flow directly to the WWP system. The Nelway phase shifter will be adjusted to minimize inadvertent flow. This assures the Ingledow to Custer powerflow will consistently be about 250MW.
8. BCH is using two Burrard units as synchronous condensers for normal and abnormal winter loads. Zero reactive is generated prior to a contingency.
9. PNW-PSW interchange is zero during abnormal cold if PNW resources are sufficient to meet the load cold weather load.
10. PNW imports from the PSW on the DC intertie if PNW resources are insufficient to meet the assumed cold weather load.
11. PNW-PSW interchange during normal peak is 1000MW DC and 2000MW AC export to PSW in 1996. Export in later years decreases to allow PNW resources to meet the assumed normal load.
12. Transmission additions to return the Canadian Entitlement (1400MW firm in 2003) will be addressed in a separate planning study.

.....

SYSTEM DESIGN

13. The operating point will be planned to provide 500MVARs shunt reactive margin from the voltage instability point.
14. The newly revised Reliability Criteria is applied.

TABLE 150

15. The system will be designed to restore full load immediately following the contingency unless a detailed system study shows the load cannot be fully restored with a 95% voltage level at BPA delivery points. The system will not be designed to use the direct load trip scheme now being installed at Intalco and Kaiser.

.....

LOAD LEVEL ASSUMPTIONS

16. The CY89 load forecasts and power factors for normal peak are reasonable.

17. The peak load level above the PNUCC forecast experienced during the February 1989 cold snap is the abnormal cold load level for planning. Snohomish PUD abnormal cold load for planning is slightly higher due to their own 1987 study. Multipliers for abnormal cold load for the four major utilities are: PSP&L 116%, SCL 111%, SPD 123%, TCL 120%. The utilities report that the February 1989 conditions reflect reduced school and business loads. The power factor for abnormal is the same as normal weather.

.....

SYSTEM ADDITION ASSUMPTIONS

Prior to 1993

Raver 500kv shunt capacitors (brings total to 952MVARs)
Columbia series capacitor upgrade (2400A, 22.5%)
Olympia-Port Angeles 230kv loop-in at Shelton
Shelton-Port Angeles 230KV loop-in at Fairmount
Port Angeles 115kv terminals in advance of added Daishowa load
(assumed schedule: phase 1 - fall 1993, phase 2 - fall 1995)
Olympia 230kv shunt capacitors (2-150MVAR banks, remove old 100MVAR bank)
Custer-Bellingham 230kv #2 line
BCH Nelway phase shifter
BCH Nicola-Meridian series capacitors (50%)
BCH Nicola-Ingledow series capacitors (50%)
TCL shunt capacitors at Southwest (100MVARs), Pearl (60MVARs), Northeast (80)
and Cowlitz (60MVARs)

Prior to 1996

Cowlitz-Olympia 230kv line
Cowlitz Falls Integration (Mayfield-Mossyrock 230kv loop-in)
Port Angeles 115kv shunt capacitors (Daishowa phase 1, 2-23.7MVAR banks)
Shelton 230kv shunt capacitors (Daishowa phase 1, 1-114MVAR bank)
Fairmount-Port Angeles 230kv line (3rd line, Daishowa phase 1)
Shelton-Fairmount 230kv line (3rd line, Daishowa phase 2)
Olympic Peninsula Reinforcement with 500kv to Shelton
Allston 500/230kv transformer #2
Ostrander 500kv shunt capacitors (1-312MVAR bank)
Keeler 500kv shunt capacitors (1-312MVAR bank)
BCH Williston-Kelly Lake 500kv #3 line with series capacitors
BCH Kelly Lake-Cheekye 500kv #2 line with series capacitors
BCH Ingledow static var device (150MVAR)
BCH-WWP intertie (600MW added import assumed for both normal and abnormal)

Prior to 2004

No assumed additions after 1996.

.....

TABLE 151: LINE AND TRANSFORMER RATINGS

The new reliability criteria requires that abnormally cold weather loads must be served during maingrid outages using -15 deg C ambient equipment limits. Main grid outages include the 500-kV system, 345-kV system and the transformers from these systems to the 230-kV grid. Moderate cold weather loads must be served during 230-kV system outages using a -10 deg C ambient. The ratings of critical lines are as follows:

	Owner	Conductr	Max Oper Temp	Rating at Ambient Temperature				
				-15 C	-10 C	-5 C	20 C	35 C
Bellingham-Sedro	BPA	Drake	60	1124	1082	1037	776	357
Berrydale-Talbot Hill	PSPL							
Bothell-Sammamish	SCL	Tern	100	1363	1333	1303	1133	1015
	PSPL	Tern	100	1363	1333	1303	1133	1015
Bothell-Snohomish #1	BPA	Drake	90	1308	1275	1271	1083	948
Bothell-Snohomish #2	BPA	Drake	100	1391	1361	1329	1156	1035
	SCL	Mallard		1377	1347	1345	1170	1048
Bothell-Snoking	SCL	Mallard	100	1377	1347	1345	1170	1048
	BPA	Drake	100	1391	1361	1329	1156	1035
Broadstreet-Massachusetts	SCL							
Christopher-Obrien*	PSPL	Bittern		1616	1567	1517	1228	1011
Cottage Br-Snoqualmie	PSPL	2/0 cu7						
Covington-Creston	BPA	Drake	80	1252	1217	1180	1000	847
Covington-Obrien	PSPL							
Covington-Tacoma A	BPA	Drake	80	1252	1217	1180	1000	847
Lakeside-Talbot Hill #1	PSPL	Tern						
Lakeside-Talbot Hill #2	PSPL	4/0 cu7						
Monroe Tap-Sedro Tap #1	BPA	Drake	70	1191	1153	1113	907	728
Monroe Tap-Sedro Tap #2	BPA	Drake	70	1191	1153	1113	907	728
Monroe-Snoking Tap	BPA	Chukar	70	1942	1879	1813	1434	1139
Snohomish-Murray	BPA	Drake	50	1049	1001	952	644	357
Snohomish-Murray+	BPA	Drake	100	1391	1361	1329	1156	1035
Snoking-Maple Valley	SCL	Mallard						
Talbot Hill-Obrien	PSPL	Tern						

*Estimated using 75 deg C bittern with BPA Assumptions

+Upgraded in BPA line sag program

Transformers

Station	voltage	nominal rating	thermal summer	emergency summer	thermal winter	emergency winter
Covington #1	500/230	1008	1107	1317	1256	1512
Covington #2	500/230	1008	1087	1317	1236	1512
Maple Valley	500/230	1792	1862	2136	2089	2523
Monroe	500/230	1008	1177	1353	1325	1512
Tacoma	500/230	1344	1429	1665	1621	1983

The above emergency ratings are based on 60% load factor.
No transformer can be loaded above emergency rating at any time.
No transformer can be loaded above thermal without an outage.

TABLE 170

OTHER THERMAL PROBLEMS IN THE PUGET SOUND AREA

As mentioned in the main text, there are three problems that exist prior to the assumed energization of the CM reinforcement (10-96) and will not necessarily be solved by this project. They are: a breaker failure at Raver, the integration of the new PSPL line into Lake Tradition and the Massachusetts-Broadstreet 115-kV line overload.

A breaker failure at Raver could cause loss of the Raver-Snoqualmie and Raver-Tacoma lines, which, prior to the CM additions, would cause the Covington transformers to overload as shown in J96254. Reinforcement of the CM transmission would reduce the severity of this problem. It is assumed that this problem is corrected by rearranging the bus layout at Raver (somehow) and this fix will eliminate the problem in later years. However, the effect of each plan on the existing bus layout is analyzed below.

There are also many line overload problems in the Lake Tradition area that are the result of poor integration of Puget's new 230-kV cross mountain circuit. The heavy loading of the 115-kV lines in this area are further aggravated by external outages. The Massachusetts-Broadstreet overload is caused by throughflow which occurs during maingrid equipment outages. Nothing is assumed to be added to correct these problems, however the effect of each CM reinforcement plan is analyzed with respect to these problems below.

Plan 1

This CM line addition alleviates the breaker failure problem at Raver until about 2004 (J04232).

Terminating the new CM line at Monroe improves (but does not correct) the Massachusetts-Broadstreet overload and Lake Tradition integration problems.

Plan 2

This CM line addition will alleviate the breaker failure problem at Raver (J96257), however, by about 2005 the problem will reoccur (J04216). The addition of the second Maple Valley 500/230-kV transformer (in 2006) will delay this even further.

Terminating the new CM line at Snoqualmie aggravates the Massachusetts-Broadstreet overload and Lake Tradition integration problems.

Plan 3

This CM line addition will alleviate the breaker failure problem at Raver (J96255), however, by about 2003 the problem will reoccur (J04207). The addition of the Snohomish 500/230-kV transformer (in 2010) will delay this even further.

Terminating the new CM line at both Monroe and Snoqualmie does not change the Massachusetts-Broadstreet overload and Lake Tradition integration problems significantly.

Plan 4: same as Plan 2.

Plan 5: same as Plan 2.

Plan 7

This CM line addition alleviates the breaker failure problem at Raver (J96287), however, by about 2002 the problem will reoccur (J04497). The addition of the second Maple Valley 500/230-kV transformer (in 2012) will again delay the problem.

Terminating a new CM line at Snoqualmie aggravates the Massachusetts-Broadstreet overload and Lake Tradition integration problems.

Plan 8

This CM line addition alleviates the breaker failure problem at Raver (J96288), however, by about 2003 the problem will reoccur (J04498). The addition of the second Maple Valley 500/230-kV transformer (in 2006) will again delay this problem.

Terminating the new CM line at Snoqualmie aggravates the Massachusetts-Broadstreet overload and Lake Tradition integration problems.

TABLE 201 - LINE UPGRADES

PUGET SOUND AREA LINE	Upgrade BEFORE XMTN PLAN	Upgrade AFTER XMTN PLAN	PLAN
PSP Bellingham-Sedro 230-kV	970A	1020A spring	all
PSP Blumaer-Electron Heights 115	440A	470A summer	all
PSP Electron Hgths-Krain Corner Tap (on Elct Hts-White Rv 115-kV line)	340A	360A summer	all
PSP St Clair-White River 115 line	720A	760A summer	all
PSP Obrien-Talbot Hill 230 line	700A	860A summer	all
BPA Covington-Tacoma A 230 line	600A	630A summer	all
PSP Maple Valley-Talbot Hill 230 #1&2	---	1900A summer	all
SCL Bothell-Snohomish 230 #3 (created from loopin)	---	1200A summer	plan 1
PSP Beverly Park-Hilton 115	---	600A summer	plan 1
SCL Maple Valley-Snoking 230	---	950A summer	plan 1
PSP Lakeside-Sammamish 115 #1&2	---	650A summer	plan 1
OKANOGAN AREA LINES			
BPA Brewster-Ophir Tap 115	280A	300A summer	all
	310A	330A spring	all
BPA Ophir Tap-Okanogan 115	250A	270A summer	all
	280A	300A spring	all

Table 202

A96CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING			
				250MW INGLEDOW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A			
			RAVER-SNOQ 500	N/A	N/A	90%	92%
			TACOMA 500/230	98%	110%	112%	111%
			CHRIS-COVINGTN 230	92%	102%	104%	103%
BREWSTER- OPHIR T 115	180A	(353A)	CHRIS-OBRIEN 230	100%	103%	105%	106%
			DOUGLAS-WELLS 230	151%	158%	161%	162%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	137%	144%	147%	148%

Table 203

A96CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 1000MW INGLEDCW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER- ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	94%	100%	102%	103%
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	93%	98%	99%	99%
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE RAVER-SNOQ 500 TACOMA 500/230 CHRIS-COVINGTN 230 CHRIS-OBRIEN 230	N/A N/A 106% 99% 103%	86% 100% 118% 109% 106%	89% 111% 120% 112% 108%	N/A 113% 120% 111% 109%
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	148%	154%	157%	158%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	134%	140%	143%	144%
HOLCOMB- NASELLE 115	420A		LONGVW-LONGVW T 230	120%	123%	125%	125%

Table 204

A96CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 2000MW INGLENDOW>CUSTER TROJAN OFF								A96 CASE #'S
				FO	PFLOW	FO	PFLOW	FO	PFLOW	FO	PFLOW	
				NO	MONROE	MON-SNOQ	SNOQ					
				PLAN	PLAN	PLAN	PLAN					
BLUMAER- ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	142	147	147	153	149	155	151	155	141,142,143,144
ELECTHTS- WR KC TP 115	306A	(447A)	RAVER-PAUL 500 ELECTHTS-WHITE RV 115	110 97	112 96	113 100	115 99	114 102	117 100	115 102	116 100	SAME AS ABOVE 145,146,147,148
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	63 129		66 134		67 137		67 138		SAME AS ABOVE
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	90		101		104		104		
			RAVER-SNOQ 500	112	112	137	139	148	149	154	153	149,150,151,152
			TACOMA 500/230	125	124	134	135	138	139	138	139	153,154,155,156
			CHRIS-COVINGTN 230 CHRIS-OBRIEN 230	114 114	115 115	123 123	127 127	126 126	127 127	126 126	130 130	157,158,159,160
MAPLE VL- TALBOT H 230	1767A	(3304A)	MAPLE VL-TALBOT H 230	95	95	102	103	107	107	108	108	161,162,163,164
LAKESIDE- SAMMAMISH 115	552A	(1015A)	LAKESIDE-SAMMAMISH MONROE-SNOQ 500 SNOK TP-SNOQUALM 500	N/A 95 N/A	87 95	114 116	114 118	106 N/A 100	106 N/A 87	97 N/A	98	165,166,167,168 173,135,134,133 134
MAPLE VL- SNOKING 230	890A	(1035A)	MONROE-SNOQ 500 MAPLE VL 500/230	N/A N/A		106 N/A	108 N/A	N/A N/A		N/A		SAME AS ABOVE
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	142	138	147	142	150	146	152	148	169,170,171,172
OKANOGAN- R T 115	180A	(353A)	DOUGLAS-WELLS 230	128	130	133	135	137	139	138	140	SAME AS ABOVE
ERLY PK- ILTON 115	552A		MONROE-SNOQUALM 500	N/A	87	107	107	N/A		N/A		SAME AS ABOVE
BOTHELL- SNOHOSH 3 230			MONROE-SNOQUALM 500	N/A		112	113 (N)	N/A		N/A		SAME AS ABOVE

Table 205

A00CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 250MW INGLENDOW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A			
			RAVER-SNOQ 500	N/A			
			TACOMA 500/230	101%	110%	115%	114%
			CHRIS-COVINGTON 230	95%	109%	107%	106%
			CHRIS-OBRIEN 230	106%	110%	111%	112%
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	152%	160%	162%	163%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	138%	146%	148%	149%
HOLCOMB- NASELLE 115	420A		LONGVW-LONGVW T 230	112%	116%	117%	117%

Table 206
A00CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 100% MW IN GLEADOW CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	91%	97%	98%	98%
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A	92%	N/A	N/A
			RAVER-SNOQ 500	N/A	101%	108%	111%
			TACOMA 500/230	108%	124%	122%	122%
			CHRIS-COVINGTN 230	100%	116%	113%	113%
LAKESIDE- SAMMAMISH 115	552A	(1015A)	LAKESIDE-SAMMAMISH	N/A	102%	N/A	N/A
			MONROE-SNOQ 500				
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	150%	156%	160%	161%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	136%	142%	146%	147%
TROJAN- ST MARYS 230	1315A	(1507A)	ALLSTON-KEELER 500	96%	99%	100%	100%
TROJAN- RIVERGATE 230	1315A	(1507A)	ALLSTON-KEELER 500	97%	100%	101%	101%
BOTHELL- SNOHOMH 3 230			MONROE-SNOK TAP 500	N/A	107%	N/A	N/A

Table 207

A00CY89 STUDIES

LOAD	RATING	100 DEG RATING	OUTAGE	% LINE LOADING 2000MW INGLEDOVE>CUSTER TROJAN OFF			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER- ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	138	145	146	147
ELECTHTS- WR KC TP 115	306A	(447A)	RAVER-PAUL 500 ELECTHTS-WHITE RV 115	109 98	114 103	114 103	115 102
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	62 128	67 134	67 134	67 135
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	93	108	108	108
			RAVER-SNOQ 500	111	138	149	153
			TACOMA 500/230	128	142	143	143
			CHRIS-COVINGTN 230 CHRIS-OBRIEN 230	118 115	131 117	131 120	131 121
MAPLE VL- TALBOT H 230	1767A	(3304A)	MAPLE VL-TALBOT H 230	97	107	110	110
LAKESIDE- SAMMAMISH 115	552A	(1015A)	LAKESIDE-SAMMAMISH	93	126	107	99
			MONROE-SNOK TP 500	N/A	104	N/A	N/A
			SNOK TP-SNOQ 500	N/A	123	97	N/A
MAPLE VL- SNOKING 230	890A	(1035A)	MONROE-SNOQ 500	N/A			
			MAPLE VL 500/230	N/A			
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	144	150	153	155
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	131	136	139	141
RLY PK- ON 115	552A		SNOK TP-SNOQ 500	N/A	103	N/A	N/A
ROTHELL- 1,2,3 SNOHOMSH 230			MONROE-SNOK TP 500	N/A	140	100	N/A
ROTHELL- SNOKING 230	1048A		MONROE-SNOK TP 500	92	111	N/A	N/A

Table 209

AO4CY89 STUDIES

3 LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 250MW INGLEDOVE>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A			
			RAVER-SNOQ 500	N/A			
			TACOMA 500/230	95%	114%	112%	111%
			CHRIS-COVINGTN 230	N/A	106%	104%	102%
			CHRIS-OBRIEN 230	102%	107%	108%	109%
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	153%	161%	164%	164%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	139%	147%	149%	150%
HOLCOMB- NASELLE 115	420A		LCNGVW-LONGVW T 230	111%	115%	116%	116%

Table 209
A04CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 1000MW INGLEWOOD>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER- ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	N/A	96%	96%	97%
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	91%	98%	98%	98%
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A	N/A	87%	N/A
			RAVER-SNOQ 500	N/A	N/A	102%	104%
			TACOMA 500/230	104%	121%	121%	120%
			CHRIS-COVINGTN 230	96%	117%	111%	110%
BREWSTER- OPHIR T 115	180A	(353A)	CHRIS-OBRIEN 230	105%	108%	111%	111%
			DOUGLAS-WELLS 230	152%	159%	162%	163%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	138%	145%	147%	148%
BOTHELL- SNOHOMH 3 230			MONROE-SNOK TAP 500	N/A	113%	N/A	N/A
HOLCOMB- NASELLE 115	420A		LONGVW-LONGVW T 230	120%	124%	125%	125%

Table 210
A04CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 2000MW INGLEDOVE>CUSTER TROJAN OFF			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER- ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	132	140	141	142
ELECTHTS- WR KC TP 115	306A	(447A)	RAVER-PAUL 500 ELECTHTS-WHITE RV 115	108 99	113 105	114 105	114 104
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	62 125	67 132	67 132	66 133
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE RAVER-SNOQ 500 TACOMA 500/230 CHRIS-COVINGTON 230 CHRIS-OBRIEN 230	87 101 124 113 112	107 132 142 129 115	105 142 141 129 117	103 145 140 127 117
MAPLE VL- TALBOT H 230	1767A	(3304A)	MAPLE VL-TALBOT H 230	90	105	105	105
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	145	151	155	156
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	131	136	140	142
COVINGTON- WHITE RV 230	730A		COVINGTON-WHITE RV 230	93	97	99	100
BOTHELL- 1,2,3 SNOHOMSH 230			MONROE-SNOK TP 500	N/A	147	N/A	N/A
WELL- ING 230	1048A		MONROE-SNOK TP 500	108	127	N/A	N/A
AKESIDE- SNOKING 230	980A		SNOK TP-SNOQ 500	N/A	116	N/A	N/A

Table 211

SPG94CY89 STUDIES

: RLOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 1800MW CUSTER>INGLEDOW					FO	PF	PF #
				NO	MONROE	MON-SNOQ	SNOQ				
				PLAN	PLAN	PLAN	PLAN				
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230 DOUGLS-SICKLR 500/230	170% 159%	182% 185%	185% 188%	185% 186%				
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230 DOUGLS-SICKLR 500/230	156% 147%	168% 170%	171% 173%	171% 172%				
HOLCOMB- NASELLE 115	420A		LONGVW-LONGVW T 230	105% 105%	111% 111%	111% 111%	111% 111%				
BELLNGHM- SEDRO 230	660A		MONROE-SNOK TP 500 SNOK TP 500				113 106			SPG94114	
BELNGH P- SEDRO 1 115	387A		BELLNGHM-SEDRO 230	109% 109%	105% 105%	106% 106%	115% 115%				
BEV PK- GOLDBART 115	276A		SNOK TAP-SNOQUALM 500 SNOK TP 500				103 106			SPG94114	

Table 212
SPG94CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 2000MW INGLEDOW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER- ELECTHTS 115	387A	(587A)	RAVER-PAUL 500	136%	142%	144%	144%
ELECTHTS- WR KC TP 115	387A	(447A)	RAVER-PAUL 500 ELECTHTS-WHITE RV 115	104% 91%	108% 95%	109% 96%	109% 96%
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500				
				157%	162%	164%	164%
O BRIEN- TALBOT H 230	723A	(1015A)	NO OUTAGE RAVER-SNOQ 500 TACOMA 500/230 CHRIS-COVINGTON 230 CHRIS-OBRIEN 230	N/A 91% 108% 100% 100%	88% 116% 117% 108% 101%	90% 125% 119% 110% 103%	N/A 129% 119% 110% 104%
MAPLE VL- SNOKING 230	890A	(1035A)	MONROE-SNOQ 500 MAPLE VL 500/230		102%		
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	156%	163%	167%	169%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	143%	149%	154%	155%
BOTHELL- SNOHOMH 3 230			MONROE-SNOQUALM 500		121%		
BOTHELL- SAMMASH 230	1015A		MONROE-SNOQUALM 500	74%	101%	91%	
BELL- ING 230	1048A		MONROE-SNOK TP 230 MONROE-SNOQUALM 500	103% 126%	133% 126%		
SAMMASH 115/230			SAMMASH 115/230 1	96%	107%	106%	103%
CHWALIS- TACOMA A 230	1070A		PAUL-RAVER 500	97%	101%	102%	103%

TABLE 302

TECHNICALLY FEASIBLE TRANSMISSION ALTERNATIVES REJECTED FOR ECONOMIC REASONS

1. CHIEF JOE-SNOQUALMIE 765-KV LINE

Assumptions used for 765-kV study:

- a. 765/500-kV transformers will be 500 MVA/phase, 10.5% impedance.
- b. Phase shifting transformers will be on 500-kV sending end and have same size and impedance as step-up transformers.
- c. 765-kV transmission line will be 6-Seahawk, 2 PU, double circuit design.
- d. Plan 2, the Chief Joe and Snoqualmie terminations, will be tested to determine the feasibility of this voltage class.
- e. If a 765-kV line is built, it will initially operate at 500-kV until 2004 and then converted to its design voltage.
- f. The 765-kV plan will have same SVC's added as the 500-kV Plan 2: at Maple Valley and Keeler.

Results of 765-kV study

- a. Operating a 765-kV line at 500-kV provides about 50 MVARs additional reactive over a 500-kV line for the three critical outages (compare J04198QV and J04200QV in QV-160, J04EH73QV and J04EH76QV in QV-161, and J04EH82QV and J04EH84QV in QV-162). Upgrading this line to 765-kV operation does not provide an appreciable improvement due to the additional impedance of the transformation at each end (compare J96EH26QV and J96EH139QV in QV-164 and J9610QV and J96103QV in QV-164). Also voltage control for all operating conditions is much more difficult than 500-kV lines. Several switched and fixed shunt reactors will be required.
- b. To make the first 765-kV line attractive (without a 765-kV grid), the line must be force-loaded. Adding phase shifters to the sending end would enable the line to be loaded to a predetermined level. Loss savings favor about 2000 MW loading on each line (Table 350). Surge Impedance Loading (SIL), with terminating transformer impedance added, is also about 2000 MW.
- c. The voltage stability performance of several line loadings were studied. For the worst double line outage, the performance was better for lower initial loadings as shown in QV-166 (probably due to problems at Chief Joe). For the single Coulee-Raver line outage, performance was better for higher pre-outage flows as shown in QV-167. The single Chief Joe-Snoqualmie 765-kV line outage also is better for higher pre-outage loadings, but the differences are not as great as shown in QV-168. This makes sense since one of the phase shifted lines is removed in this case.
- d. 2000 MW pre-loading of the new 765-kV line appears to be optimal.
- e. Adjusting the phase shift of the new line after an outage occurs was investigated. QV-169 shows the effect of increasing and decreasing the phase shift angle after the worst single line outage occurs. From these studies it appears to be beneficial to decrease the angle after a single line outage

occurs and detrimental to increase the angle. Adjusting the phase shift after double line outages was not investigated at this time since a phase shift adjustment will not help for a double 765-kV line outage.

f. The remaining studies assume that each new line is loaded to 2000 MW prior to any outage and the pre-outage phase shift angle is held after the outages occurs.

g. The phase shifter impedance does not have an appreciable difference in the performance (compare J04EH78QV and J04EH88QV in QV-161.).

h. Performance of the 765-kV line plan with 2000 MW loading (as compared to the 500-kV line) appears to be better at the start of the QV curves for the three critical outages. But as the voltage drops through the QV curve, the performance drops off sharply apparently due to voltage collapse at Chief Joe. This is especially true for the double Coulee-Raver line outage where most of the power must go through Chief Joe. QV-160 compares the double line outages, QV-161 the single line outages and QV-162 the Trojan scram.

i. From the performance of the above, at least one of the 765-kV lines will need to be extended to Coulee.

j. The performance of a Chief Joe/Coulee-Snoqualmie 765-kV double circuit line is shown in J04EH102QV, J04EH103QV and J04EH105QV in QV-165. J04203QV in QV-160 gives a good indication of how this plan would operate during the loss of the new double circuit line. This plan has 500 MVAR SVC's at Keeler and Maple Valley like the 500-kV plans and is not necessarily optimized. Comparing these curves with those in QV-121 (the same plan at 500-kV), it is estimated that this line addition would last only about 2 years longer than a 500-kV double circuit line.

k. The loss savings of this plan are as follows (with Snoking Reinforcement): These also included in Table 100.

	1996*	2004+
Chief Joe-Snoqualmie 500-kV SDC	66.9	65.1
Chief Joe-Snoqualmie 765-kV SDC operated at 500-kV	77.7	76.9
Chief Joe/Coulee-Snoqualmie 765-kV SDC phase shifted to 2000 MW		141.5

* 1996 losses compared to base system
+ 2004 losses compare to reactive plan

l. There is a benefit of a 765-kV line as part of a future 765-kV grid that is hard to evaluate at this time.

Conclusion

The additional expense of constructing the new line to 765-kV does not appear to but justified by the QV performance. There is a significant loss savings though.

TABLE 303 Continued

TRANSMISSION ALTERNATIVES REJECTED DUE TO POOR TECHNICAL PERFORMANCE

25. Raver-Snoqualmie 500-kV single circuit line, Snoqualmie switchyard.	Surprisingly effective, but not nearly enough to correct problem. This will be investigated in conjunction with CM alternatives.
26. Raver-Snoqualmie 500-kV single circuit line, Raver-Covington 500-kV single circuit line.	Similar to #25.
27. Raver-Snoqualmie, Raver-Covington and Raver-Tacoma 500-kV single circuit lines.	Similar to #25.
28. Covington-Maple Valley 500-kV single circuit line, Covington and Maple Valley switchyards.	Most effective of westside line construction, but still not enough to correct problem. This will be investigated in conjunction with CM alternatives.

TABLE 303

TRANSMISSION ALTERNATIVES REJECTED DUE TO POOR TECHNICAL PERFORMANCE

Alternative	Comments
1. Chief Joe-Raver 500-kV double circuit line.	Voltage Stability performance was inferior to northern termination plans, 4 of 5 existing 500-kV CM lines already terminated at Raver.
2. Chief Joe-Raver 500-kV double circuit and Raver-Snoqualmie 500-kV #2 lines.	Performance is similar to preferred plans, however, 4 of 5 existing 500-kV CM lines already terminated at Raver.
3. Coulee-Raver 500-kV double circuit line.	Coulee termination does not improve performance of the critical single line outage, 4 of 5 existing 500-kV lines already terminated at Raver
4. Ashe-Snoqualmie 500-kV double circuit line.	Performance is OK, but not any better than a Hanford termination.
5. Chief Joe-Monroe/Snoqualmie 500-kV double circuit, add Raver-Snoqualmie #2 and use with one existing Coulee-Raver line to form Coulee-Snoqualmie 500-kV line.	Tying existing line into Snoqualmie degrades performance.
6. Chief Joe-Coulee 500-kV single circuit line.	Slight improvement in performance, not enough to justify 30 miles of line construction and terminations.
7. Monroe-Raver-Paul 500-kV single circuit line.	Improvement is small, comparable to a 500-kV shunt capacitor group, not economic.
8. Monroe-Raver-Olympia 500-kV single circuit line.	Not quite as good at Monroe-Raver-Paul (#7).
9. Naneum Switchyard (tie Coulee-Raver lines, Vantage-Raver and Sickler-Raver lines together near Ellensburg).	Little effect on performance for abnormally cold weather conditions.
10. Naneum Switchyard and Grand Coulee-Naneum 500-kV double circuit line.	Little improvement in system performance when compared to existing system.
11. Naneum Switchyard with shunt capacitors.	Cap group is effective addition.
12. Naneum Switchyard with series capacitors within station.	Shunt caps more effective per MVAR.

TABLE 303 Continued

TRANSMISSION ALTERNATIVES REJECTED DUE TO POOR TECHNICAL PERFORMANCE

13. Naneum Switchyard, Naneum-Snoqualmie 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
14. Naneum Switchyard, Naneum-Monroe 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
15. Naneum Switchyard, 500-kV single-circuit tap line to Hanford-Grand Coulee.	Little improvement in system performance when compared to existing system.
16. Naneum Switchyard, Naneum-Hanford 500-kV single circuit line.	Little improvement in system performance when compared to existing system.
17. 500-kV single circuit tap line from Sickler to existing Grand Coulee-Hanford 500-kV line.	Little improvement in system performance when compared to existing system.
18. Sickler-Monroe 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
19. Sickler-Monroe 500-kV double circuit line, 500-kV single circuit tap line from Sickler to existing Grand Coulee-Hanford 500-kV line.	Not enough improvement for Coulee-Raver outage.
20. Sickler-Snoqualmie 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
21. John Day-Paul 500-kV double circuit line.	Little improvement in system performance when compared to existing system.
22. John Day-Allston 500-kV double circuit line.	Little improvement in system performance when compared to existing system.
23. John Day-Allston 500-kV Raver-Olympia 500-kV single circuit line.	Better than #22 but still mediocre.
24. Lower Monumental-Hanford 70% Series Compensation - 136 MVAR.	These additions are ineffective in correcting the problem.

TABLE 302 Continued

TECHNICALLY FEASIBLE TRANSMISSION ALTERNATIVES REJECTED FOR ECONOMIC REASONS

2. COULEE-SNOQUALMIE DIRECT CURRENT LINE

A Coulee-Snoqualmie DC line was modeled for abnormal cold 2004 system conditions. A 1500MW power schedule is needed with all lines in service (J04EH60QV, J04EH61QV). The base case with one Centralia unit down needs one SVC at Maple Valley for the reactive margin (J04EH61QV). Normal winter conditions were not modeled.

The post transient outage of the Chief Jo-Monroe 500kv line needs DC fast ramping to 3000MW. One SVC at Maple Valley is needed to provide reactive margin (J04EH62QV).

The post transient Trojan outage with one Centralia unit down and an SVC at Keeler is slightly less severe than the Chief Jo-Monroe outage (J04EH63QV). This also needs DC fast ramping to 3000MW.

The estimated cost of this plan is 3 times the cost of the comparable AC plan.

A Celilo-Snoqualmie DC line was not studied because the area interchange assumptions for normal winter do not allow full use of the existing Celilo DC terminal for scheduling power to Snoqualmie. Another Celilo terminal is needed in addition to longer line length (290 miles vs. 190 miles). This provides no apparent benefit for the increased cost.

3. HIGH-PHASE-ORDER TRANSMISSION LINE (SIX-PHASE, 500-kV+)

Similar problems to 765-kV analysis listed above. Reliability is reduced from standard double-circuit lines: would need to plan for loss of entire circuit during abnormally cold weather (presently just plan for one circuit on double-circuit towers). These requirements would make this alternative even more expensive than a similar 765-kV AC three-phase alternative. And like the 765-kV plan, there does not appear to be any justification for additional cost.

TABLE 310

INVESTIGATIONS OF QV PERFORMANCE FOR TRANSMISSION LINE ALTERNATIVES

The general development of the transmission line options is detailed in this table. Most of this development was done on Plans 2 and 3. This discussion covers many of the options and refinements that were investigated in this study.

1996 QV PERFORMANCE

With a new Chief Joe-Snoqualmie/Monroe or Chief Joe-Snoqualmie line added, the three critical outages for the Puget Sound area are 1) loss of one Coulee-Raver 500-kV line during abnormally cold weather, 2) loss of Trojan with one Centralia unit previously out-of-service, also during abnormally cold weather and 3) loss of both Coulee-Raver 500-kV lines during normal winter peak loads.

The new line with the LDC's proposed in the assumptions and the Snoking Reinforcement project do not provide the necessary reactive margins in either the Puget Sound or Portland areas without SVC's. A 300 MVAR SVC is required on the Keeler 230-kV bus to provide the necessary reactive margins in the Portland area for the Trojan scram. The QV performance of these additions are shown in the attached QV-131. The required 500 MVAR on-line margin cannot be obtained without switching the existing shunt capacitors at Raver or adding additional high-speed reactive. A 300 MVAR SVC is therefore required on the Maple Valley 230-kV bus to provide this margin. The performance of these additions is shown in QV-132, which has the required margins without switching capacitors after the outage.

Additions of series compensation were studied in 1996 as an alternative to SVC additions. As shown in QV135 (Normal winter outages) and QV-136 (abnormal cold weather outages), the addition of SVC's is much more effective at this time. However, once these SVC's are added, the addition of series comp becomes much more effective (QV-137). Series capacitor additions may be more appropriate rather than the increases in SVC size due to performance and loss savings. This will be discussed later.

2000 QV PERFORMANCE - SOLVING PROBLEMS IN THE PORTLAND AREA

With Plan 3, the QV-outages for 2000 (QV-220) were compared with 1996 (QV-132). The line outages are marginal in 2000, but since additional cap groups are available at Raver during these outages, that group can be switched automatically (MSC) after the outage in conjunction with the Maple Valley SVC. The Trojan Scram outage, however, has just a 500 MVAR margin in 2000, and the base system already has all three caps groups energized. Therefore, system reinforcement will be needed by 10-2000 in the Portland area. Increasing the SVC at Keeler to 500 MVAR will provide enough support for this outage through 2004, as shown in study QV-221 and will be assumed as the long range support for this initial planning process. Other options exist, which include:

1. 300 MVAR SVC at Ostrander

This is about equally effective per MVAR as Keeler (QV-222) and would provide additional reliability due to the different location. Also MSC switching a 300 MVAR capacitor group at Ostrander was nearly as effective as the SVC (QV-240).

2. Series compensation on Ashe-Marion and Big Eddy-Ostrander lines

Ashe-Marion compensation didn't seem to help much (compare QV-215 with QV-223) but the Big Eddy-Ostrander line, which is heavily loaded during these conditions, seems to help as much as a 300 MVAR SVC at Ostrander (QV-216). Because this is an old line with small conductor, continuous series compensation is probably not desirable, however, switching the comp after outages is actually better (QV-241).

3. Tap lines from Big Eddy to the Hanford-Ostrander and the Ashe-Marion

These tap lines were studied to relieve the bottleneck between Big Eddy and Ostrander. These were not very effective as shown in QV-218.

2004 QV PERFORMANCE - SOLVING PROBLEMS IN PUGET SOUND AREA

After the Portland reactive problems are solved (by increasing the SVC at Keeler to 500 MVAR), the Puget Sound area again experiences problems. QV-223 shows the 2004 system with only a 300 MVAR SVC at Maple Valley. The double Coulee-Raver line outage does not have sufficient margin in these cases. To meet the reactive margins for this critical double line outage, the operating voltage at Raver must be nearly 550-kV or the existing 500-kV shunt capacitors at Raver must be automatically switched with the outage. As discussed below, to maintain reactive margins at Monroe and prevent overvoltages at Raver, MSC at Raver is favored.

Comparing QV-223 with QV-220, the critical single line outage will not have the required 500 MVAR margin (even with MSC at Raver) in 2003. Support will be needed by 10-2002. Increasing the SVC at Maple Valley will correct the system through 2004 as shown in QV-221 and will be the assumed long range plan. Again other options exist:

1. An additional 300MVAR SVC at Snohomish

An additional SVC in the North Puget Sound area (as opposed to increasing the size of the Maple Valley SVC) would provide some additional reliability by separating the facilities. This also more effective for the CM plans that have lines terminated south of Monroe.

2. Series compensation of the new line

Compensation of the new lines was investigated as a second phase reinforcement (as an alternative to the SVC increases at Maple Valley). Previous loss savings studies indicated that the optimal compensation level for the future system with a new 4-bunting conductor line into the Snoqualmie/Monroe area would be 35% on the new line and 40% total on the Coulee-Raver lines. Since these J96 studies showed only about a 2 MW loss savings for all this compensation and due to the need for some variable reactive supply in the load area, SVC's were selected as the best reinforcement initially. However, once SVC's are installed in the load area, series comp becomes more attractive.

As noted earlier, the J04 cases contain an error in the Coulee-Raver series compensation. 45% comp was inadvertently used instead of the planned 22.5%. This error results in slightly over-optimistic QV curves. As shown in QV-230, the EH winter QV curves for Plan 3 with the corrected impedances have about 150 MVARs less margin. With the lower compensation levels, more shunt reactive can be on in the base. The double line outage shows the largest difference,

2

obviously since a larger amount of series reactive is lost with these outages. All three curves for Plan 3 (with the correct compensation level) still have the required 500 MVAR margin.

If 35% compensation is added on the new circuits, the critical outages change. The worst single line outage becomes the new Chief Joe-Monroe circuit and the worst double line outage becomes loss of the new double circuit line (QV-231 and QV-232).

If the compensation is added in lieu of the 200 MVAR additions to the SVC's at Maple Valley and Keeler, performance is improved for the line outages as shown in QV-233. For the single and double line outages, the knees of the QV curves move to the left by about 125 to 250 MVARs. The Trojan scam, however, appears to get worse if the series comp is added (compare J04EH196QV and J04EH161QV). In fact the curve for the series comp case (J04EH196) will not solve below 1.05 pu voltage. The reason for this appears to be that the Keeler SVC is hitting the ceiling and the system collapses in the Portland area (note that the J04EH196 curve starts to solve better than 161 at Raver but drops off sharply below 1.08 pu voltage). Although series comp improves the Puget Sound area line outages, separate reinforcement, such as the Keeler SVC increase or others mentioned above, will also be needed in the Portland area. Otherwise this option looks attractive, especially since the series comp should "grow" with the load, that is, it will provide increasing MVARs to the system as the line loadings increase. Series compensation, as a second phase reinforcement to the transmission line options, should be studied further.

3. Mechanically Switched Capacitors at Grand Coulee

A general observation from the QV curves of the transmission line options is that the knees tend to coincide with the Coulee generators reaching Q_{max} . Curves were run with an infinite VAR source at Coulee as a comparison (QV-234). These cases were run on Plan 3 with 35% compensation. Included on this curve is the unscheduled reactive required at Coulee to hold the pre-fault voltage. These numbers show that initially it doesn't take much reactive to make a significant difference at Raver. However, larger reactive additions at the source have a diminishing effect at the receiving end. Limited reactive additions may be beneficial. Due to the large number of machines at Coulee to provide VAR regulation, shunt capacitor additions at Coulee are all that is needed to provide this benefit.

Curves QV-235 and QV-236 show the addition of a 300 MVAR MSC at Coulee for the double and single line outages respectively. These curves show that a 300 MVAR shunt capacitor addition at Coulee provides about 200 MVARs at Raver. In other words, a 300 MVAR MSC at Coulee is equivalent to a 200 MVAR SVC in Puget Sound. These capacitors can either be energized prior to outage or mechanically switched after outages occur.

Similar studies were run in J96 without any system reinforcement beyond LDC's at Paul, Coulee, John Day, Dalles and Bonneville and the 300 MVAR SVC's at Maple Valley and Keeler (QV-237). This addition is not quite as effective at moving the curves to the left but it does drop the knees considerably. Apparently with the reduced system impedance from the line additions, supporting the sending end of the transmission lines becomes more effective.

MSC's at Coulee (and other generating plants such as Chief Joe) should be investigated in more detail.

DOUBLE LINE OUTAGE

To obtain adequate reactive margins at Raver for the double Coulee-Raver line outage, all three capacitor groups are required on line or MSC switched after the outage. If the capacitors are on line prior to the outage, overvoltages may exist on the system (J04440) and adequate margins might not exist at Monroe, since having all 3 cap groups on at Raver do not allow any capacitors on at Monroe. As an example, refer to QV-225 which shows no margin at Monroe for the double Coulee-Raver line outage. QV-226 shows the performance at Raver for the double Coulee-Raver line outage with one, two and three cap groups on at Raver prior to the outage.

Another option to improve the double line outage performance would be to develop the Naneum switchyard, as in Plan 5. The switchyard development may also have some loss savings benefits. Series comp on the new lines would also improve the double line outage.

LDC AT CHIEF JOE

With new circuits terminated at Chief Joe, the additional charging current reduces the reactive output of the generators at that dam. The addition of an LDC at Chief Joe to control the 500-kV bus, however, does not help much in addition to the other LDC's previously proposed. Refer to QV-130. The addition of shunt capacitors at Chief Joe could make an LDC there beneficial.

LINE DESIGN

As mentioned in the assumptions, a 2.0 p.u. line design was used in these studies due to poor experience on lines of the 1.7 design. Recent information indicates that the poor experience is due to 60hz withstand and that a 1.7 p.u. design would perform more favorably if additional bells were added in place of spacers on the existing tower designs. QV-250 compares the outage performance of the two designs for the single and double Coulee-Raver line outages. As can be seen, the 1.7 p.u. design is about 25-50 MVARs better than the 2.0 design. If a 1.7 p.u. line design is used, the system performance would be slightly better than shown in this study.

SHUNT REACTIVE ADDITIONS

To maintain adequate voltages on the system throughout the study period, it is assumed that shunt capacitors will be added on the 500-kV system. In reality, some capacitors will be needed on the lower voltage systems to maintain voltages for outages on these systems. However, the assumption of 500-kV capacitor additions will provide an approximation of the total shunt compensation required.

By the year 2000, additional shunt capacitor groups will be needed at Keeler and Ostrander (refer to case J00EH17). Going out to 2004, a second capacitor group is needed at Pearl and a third is needed at Ostrander (refer to case J04EH160). Because of the transmission line addition into the Puget Sound area, additional capacitors will not be required until 2002. One capacitor group is needed at Snoqualmie by 2002 and a second capacitor group at Monroe is needed by 2004. The following shunt compensation plan is assumed as a starting point for the Transmission line options:

1998 Add 500-kV shunt capacitor bank at Keeler.

- 2000 Add second 500-kV shunt capacitor bank at Ostrander.
- 2002 Add 500-kV shunt capacitor bank at Snoqualmie;
 Add second 500-kV shunt capacitor bank at Pearl;
- 2004 Add second 500-kV shunt capacitor bank at Monroe;
 Add third 500-kV shunt capacitor bank at Ostrander.

TABLE:

LOSS SAVINGS OF VARIOUS
765-KV LINE LOADINGS

Phase shifted Load (MW) on each new CJ-Sung 765 line

PF CASES

Powerflow Cases for North Seattle Studies

BASES	PLAN 1	PLAN 2	PLAN 3	REACTIVE PLAN	PLAN 7 & 8
J96122	J96171	J96172	J96144	A93160	J96287
J96152	J96235	J96234	J96241	A93194	J96288
J96243	J96248	J96236	J96250	SPG94116	J96EH582
J96254	J96261	J96239	J96251	A96170	J00EH17
J0008	J96262	J96249	J96255	A96174	
J00EH11	J96EH502	J96253	J96260	A96175	J04497
	J96EH554	J96257	J96EH206	J96273	J04498
	J96EH555	J96259	J96EH251	J96279	J04EH160
	J96EH565	J96EH503	J96EH252	J96280	J04EH162
	J96EH566	J96EH553	J96EH315	J0049	J04EH163
	J96EH568	J96M216	J96EH328	J04EH22	J04EH165
	J96M215	J96M219	J96M146	J04EH25	J04EH166
	J96M217	J96M220	J96M147	J04EH34	J04EH167
	J96M218	J0017	J96M148		J04EH168
	J96M221	J0018	J0023		J04EH183
	J96M226	J0021	J0024		
	J96M227	J0022	J0027		
	J0035	J0025	J0028		
	J0036	J0030	J00EH34		
	J0037	J00EH25	J00EH35		
	J0038	J00EH26	J00EH39		
	J00EH28	J00EH27	J04165		
	J00EH29	J04197	J04207		
	J00EH30	J04216	J04EH26		
	J00EH31	J04EH94	J04EH42		
	J00EH32	J04EH97	J04EH110		
	J00EH112		J04440		
	J00EH113				
	J04196				
	J04232				

PF - BASES

J96244 5/ 8/90 PF 4.020
 CY89 MJL
 Base for Loss savings
 Normal Profit Gen

PF - PLAN 1

S:PQ R- PLOTTED 13-APR-90 AT 08:31:40 HOURS

Low Skagit Gen

LOSSES BPA= 602.80
 PNW= 940.57
 SYSTEM= 3536.73

J96M217 4/13/90 PF 4.020
 CY89 MJL-ALH
 BASED ON J96M215
 SNOKING TP 230KV BUS OUT

PF - PLAN 2

LOSSES
 BPA= 627.45
 PNW= 957.25
 SYSTEM= 3583.95

J96239 5/ 8/90 PF 4.020
 CY89 MJL
 Based on J96122
 Dia 2
 Low Stage Gen

LOSSES
 BPA= 628.71
 PNW= 958.63
 SYSTEM= 3585.56

J96253 5/ 9/90 PF 4.020
 CY89 MJL Based on J96122
 Plan 2
 No Scheduling
 Long Scheduling Gen

J0022 5/11/90 FF 4.020
 C189 MJL
 BASED ON J0008
 PLAN 2 WITH SNOOKING
 NORMAL SPAGIT GEN

PF - PLAN 3

LOSSES
 BPA= 695.78
 PNW= 1032.98
 SYSTEM= 3610.19

J0028 5/ 9/90 PF 4.020
 CY89 MJL
 Bas : on J0028
 Plan 2
 Low Skop

INGLEDOW
528 -50

528 -51
CUSTER

LOSSES BPA= 898.17
PNW= 1329.52
SYSTEM= 3975.91

J04EH42 2/ 7/90 PF 4.020
CY89 ALH-MJL
BASED ON J04EH26
SNOKING 500KV BUS OUT
SNOK TAP 500KV BUS OUT

PF - REACTIVE PLAN

AB3194 6/25/90 PF 4.020
CY88 GLC
BASED ON AB3198
GEN PATTERN SIMILAR TO AB3159
ALLSTON-KEELER OUTAGE WITH
100% NORMAL SUMMER PEAK LOAD

LOSSES
BPA= 1046.80
PMA= 1360.07
SYSTEM= 4376.01

LOSSES

BPA= 1015.02
 PNM= 1200.00
 SYSTEM= 3707.30

BPA= 1006.01
 PNW= 1370.77
 SYSTEM= 4389.13

A96174 6/25/90 PF 4.020
CY88 GLC
BASED ON A9687
NO XMTN PLAN
ALLSTON-KELLER OUTAGE WITH
100% NORMAL SUMMER PEAK LOAD

LOSSES
BPA= 1009.41
PMA= 1407.35
SYSTEM= 4427.78

A96175 6/25/90 PF 4.020
CY89 GLC
BASED ON A9688
MONROE XMTN PLAN
ALLSTON-KEELER OUTAGE WITH
100% NORMAL SUMMER PEAK LOAD

LOSSES
BPA= 992.13
PNA= 1396.08
SYSTEM= 4412.40

LOSSES BPA= 674.58
 PNW= 1009.75
 SYSTEM= 3637.39

LOSSES BPA= 777.97
PNW= 1153.08
SYSTEM= 3741.77

O.L.
1190A
rated 113A

J0049 5/30/90 PF 4.020
CY89 SEATTLECAPS GLC
Based on J0049
all CJ-Like 345 outage

S:PG R- PLOTTED 5-FEB-90 AT 13:21:39 HOURS

500MG

500BUES

J04EH34 2/ 5/90 PF 4.019

CY89 PAL-GLC

BASED ON J04EHY89 BASE FOR ABNORMAL CO

SERIES COMP IN:25X CJ-MONROE

42X COULEE-RAVER

352 NANEUM-RAVER

SNOKING 500 REMOVED

SNOD 500 ADDED, 2ND MV 500/230 ADDED

2ND RAVEN-SNOUWALHE 500 ADDED

CANADA TO PMA

(BCH & HKOOT)

529 -56

ING

529 -56

CUST

260(-141)

(2)

881(33)

(2)

540 -52

MMROE

1802(-6)

(2)

536 -39

SICKLER

579 -34

(147)

(2)

540 -52

MMROE

1802(-6)

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CANADA TO PMA

(BCH & HKOOT)

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SICKLER

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CANADA TO PMA

(BCH & HKOOT)

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CUST

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MMROE

1802(-6)

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536 -39

SICKLER

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CANADA TO PMA

(BCH & HKOOT)

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CUST

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MMROE

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SICKLER

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CANADA TO PMA

(BCH & HKOOT)

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529 -56

CUST

260(-141)

(2)

881(33)

(2)

540 -52

MMROE

1802(-6)

(2)

536 -39

SICKLER

579 -34

(147)

PF - PLANS 7 + 8

500BUSNORTHWEST

INTERTIE SCHEDULE

AC= 0. AC= -370.
DC= 0. DC= 0.

LOSSES

BPA= 662.53
PNW= 1034.61
SYSTEM= 3823.38

CANADA TO PNW
(BCH & WKOOT)
SI= 850.
AI= 850.

MONT TO PNW
SI= 1310.
AI= 994.

IDAHO TO PNW
SI= 700.
AI= 646.

J96EH582 7/24/90 PF 4.020
CY89 MJL
BASED ON J96EH158
PLAN 7 230/287 REBUILD
GC-OLY AND GC-SNOQ 500 ADDED
SMOKING TX ADDED

500BUSNORTHWEST

INTERTIE SCHEDULE

AC= -730.
DC= -1640.

ACTUAL

AC= -815.
DC= -2013.

LOSSES

BFA= 1052.34
PINW= 1478.35
SYSTEM= 4133.36

CANADA TO PINW
(BCH & WKOOT)

SI= 850.
AI= 850.

MONT TO PINW
SI= 1300.
AI= 1011.

IDAHO TO PINW
SI= 480.
AI= 512.

J04EH160 7/26/90 PF 4.020
CY89 MJL
BASED ON J04EH70
PLAN 3 CJ-S/M
C-R COMP CORRECTED

S:PO R- , PLOTTED 27-JUL-90 AT 15:37:42 HOURS

LOSSES
 BPA= 886.87
 PNW= 1306.73
 SYSTEM= 3955.61

J04EH165 7/27/90 PF 4.020
 CY89 MJL-ALH
 BASED ON J04EH154
 PLAN 7
 COVINGTON 500/230KV TXF OUT

S:PO F- , PLOTTED 27-JUL-90 AT 15:52:16 HOURS

ATTACHMENT 2

New Cross Mountain Transmission Line Alternative Memo

U.S. DEPARTMENT OF ENERGY - BONNEVILLE POWER ADMINISTRATION

TE OCT 12 1990

Memorandum

FROM : Marv Landauer, Electrical Engineer
Project Studies Section - EOFB

Marv Landauer

SUBJECT New Cross Mountain Transmission Line Alternative

TO : Dennis Porter, Assistant Director
Division of System Planning - EO

I have recently been studying a new cross mountain transmission line alternative for the Puget Sound Area Electric Reliability Project that shows some promise. This alternative consists of rebuilding the double-circuit Chief Joe-Snohomish 345-kV Line to single-circuit 500-kV, using as much of the existing tower structures and conductor as possible. The new line would be looped into Monroe and terminated at Snohomish with a new 500/230-kV autotransformer. New 500-kV switching stations would be added at Columbia and Mad River (my name for a new station along the Stevens Pass corridor), with a new single circuit 500-kV line connecting these new stations to the existing Sickler switchyard. Refer to Attachment A.

Only 2004 studies of this plan have been run and these are not complete. A step plan between 1996 and 2004 has not been developed. There are also many potential variations to this plan that have not yet been explored.

It is assumed that the addition of the Snohomish 500/230-kV transformer (to replace the existing 345/230-kV transformers) and a Snoking 500/230-kV transformer will provide adequate support to the North Seattle area through 2004. A second Chief Joe 500/230-kV transformer will be needed because of the removal of the 345-230-kV transformers there. 500 MVAR SVCs are assumed at Maple Valley and Keeler in the 2004 studies, as in the other plans.

The addition of the new east side crosstie reduces the severity of the outages that can occur by providing a more integrated transmission system. The post-transient performance of the three worst outages for this alternative is shown in the Q-V curves in Attachment B. These curves can be compared to the three worst outages for the Chief Joe-Snoqualmie/Monroe plan ~~we~~ submitted as the budget plan (Plan 3 shown in Attachment C). This new plan will require additional reinforcement for the single line outage in 2004 to provide the necessary 500 MVAR margin, whereas the budget plan does not require additional reinforcement until 2005. It should be noted that this new plan, like the Reactive Alternative, does not have the same ultimate capacity that the new 500-kV double-circuit Line plans do. The crosstie plan and the Reactive Alternative make better use of existing system capacity, especially during outages.

The loss savings for this plan is lower than the new double circuit line plans in the most recent engineering report. As compared to the Reactive Alternative (since the base system will not solve without reinforcement in later years), this new alternative will save about 57 MW in losses in 2004. For comparison, the Chief Joe-Snoqualmie 500-kV double circuit line alternative saves about 65 MW and the Chief Joe-Snoqualmie/Monroe 500-kV double circuit Line plan saves about 77 MW.

Even though the post-transient performance and loss savings are inferior to the better double-circuit plans, this new plan should be considerably cheaper. The rebuild of the 345-kV line will be less expensive than a new single-circuit line since the conductor and much of the existing towers, can be reused. This savings should more than offset the additional cost of the extra losses, east side line construction and switchyard development at Columbia and Mad River.

This crosstie concept could also be applied to many of the other plans documented in the engineering report. It would also allow for a staged development of these alternatives that could reduce the overall cost.

5 Attachments

MLandauer:zb:3887 (VS16-EOFB-6844L)

cc:

A. Courts - E

M. Raschio - EOF

A. Rodrigues - EOFA

M. Bond - EOFB

G. Comegys - EOFC

Official File - EOF (FY 91 BI 14)

Viles

Taylor

Attachment A: Cross tie Plan

Attachment B

PLAN 10: CROSS TIE COLUMBIA-SICKLER-MADRIVER
 CHIEF JO-SNOHOMISH 345 REBUILD TO 500
 O J04541 BOTH COLUMBIA-RAVER 500 OUT (J04534)
 Δ J04EH244 MADRIVER-MONROE #2 500 OUT (J04EH238)
 + J04EH240 TROJAN SCRAM (J04EH239)

Attachment C

PLAN 3 CHIEF JOE-SNOQ/MON correct C-R
 O J04EH159: COULEE-RAVER OUT (J04EH158) Series comp
 Δ J04441: BOTH COULEE-RAVER LINES OUT (J04440)
 + J04EH161: TROJAN SCRAM (J04EH160)

O J04EH159
 Δ J04441
 + J04EH161

INTERTIE SCHEDULE

AC= -730.
DC= -1200.

ACTUAL

AC= -909.
DC= -1261.

LOSSES

BPA= 876.75
PNW= 1291.90
SYSTEM= 3938.84

CANADA TO PNW
(BCH & WKOOT)
SI= 850.
AI= 650.

MONT TO PNW
SI= 1300.
AI= 1012.

IDAHO TO PNW
SI= 480.
AI= 528.

500BUSNORTHWEST

J04EH158 7/26/90 PF 4.020
CY89 MJL
BASED ON J04EH69
PLAN 3 CJ-S/M
C-R COMP CORRECTED

500BUSNORTHWEST

INTERIE	SCHEDULE	ACTUAL	LOSSES
AC=	-730.	AC= -909.	EFA= 893.69
DC=	-1200.	DC= -1261.	PNW= 1311.66
			SYSTEM= 3958.77

CANADA TO PNW	MONT TO PNW	IDAHO TO PNW
(BCH & WKOOT)	SI= 1300.	SI= 480.
SI= 850.	AI= 1013.	AI= 527.
AI= 850.		

J04EH238 9/28/90 PF 4.020
CY89 MJL-ALH
BASED ON J04EH69
PLAN 10 - CROSSTIE
CJ-SNOH 345 REBUILT TO 500 SSC
COLUMBIA-SICKLER-MAD RIVER 500 SSC ADDED

END

**DATE
FILMED**

01 / 16 / 92