North Pacific Region
Spare Transformer Project

Updated Spare Transformer Plan

Final Report

24 September 2012

Prepared By: Hydroelectric Design Center
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SPARE TRANSFORMER PLAN
Hydroelectric Design Center
24 September 2012

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1.0 INTRODUCTION

In 2002, a Spare Transformer Plan was developed as part of the North Pacific Region (NPR) Spare Transformer Project involving the main unit transformers at the Portland, Seattle, and Walla Walla district projects. The projects have a combined 157 main unit transformers (including spares) whose age varies from less than 10 to more than 50 years old. The majority of these projects do not have spare main unit transformers, although spare transformers were added to four projects as a result of the 2002 study.

This report describes the efforts undertaken to update the 2002 study to consider the changes in energy values, the presence of new spare transformers, the widespread use of hydroAMP for power plant equipment condition assessment, and to consider changes in transformer procurement costs. The final result of this work includes recommended actions for the existing main unit spare transformers as well as an updated sparing and placement plan. Future work to minimize the possible impacts on unit availability related to transformer failures could include an additional study to identify appropriate projects for multiple spares, and long-term refurbishment and replacement plans for the main unit transformers.

Updating this study included the following major steps: gather updated Condition Assessments, update Economic Consequences of Failure Analysis, and update the Sparing and Placement Plan. Each of the following steps is described in greater detail below. The *NPR Main Unit Transformers* workbook was updated to organize the data and other information produced during the course of this work. References to various spreadsheets in the description of the work performed below are to individual spreadsheets in the workbook (spreadsheet names in italics).

1.1 SUMMARY OF SYSTEM AND STUDY CHANGES

1.1.1 System Changes

A total of 29 main unit transformers have been replaced since 2002, improving the Condition Index (CI) and reducing the probability of failure of those units. The units that were replaced consist of The Dalles T2 and T4, McNary T1-T7 and Green Peter, which was replaced at the time of the 2002 study. Additionally, both The Dalles 230kV (single-phase) and McNary 230kV spares were salvaged by the contractor along with the replaced transformers, as they were of no more use as spares, Ice Harbor T6 is currently in the process of being replaced. The Dalles and McNary transformers were replaced due to their poor condition, and the Green Peter and Ice Harbor replacements were due to internal faults.

Four new spare main unit transformers were procured as a result of the recommendations of the 2002 study: Detroit 230kV single-phase, Dworshak 500kV single-phase, Libby 230kV three-phase, and a Little Goose 230kV single-phase spare for bank T2 (and Lower Granite and Lower Monumental T2 banks). These changes bring the system spare transformer total to nine spares, compared to seven spares in 2002.

1.1.2 Study Changes

Recent experience has shown the estimated durations to install, or obtain and install, a new transformer in the 2002 study were optimistic, as such these durations have been increased for this study. To install an existing spare transformer that is stored on site is estimated to require an outage of approximately four months. Based on recent transformer procurements, the time to procure and install a new transformer to replace a failed transformer is estimated to be twenty-four months. The economic cost of a transformer outage is based on the number of generators each transformer outage would affect while out of service; how this cost was calculated will be discussed further in section 3.1. The methods used to estimate the cost of a new transformer have been refined and the costs of materials that constitute a transformer have increased in the intervening 10 years. Further discussion on how these costs were developed may be found in section 3.2.1.

2.0 CONDITION ASSESSMENT OF MAIN UNIT TRANSFORMERS

As was the case in the first spare transformer study, the first critical factor in the analysis is the condition of the existing main unit transformers. The development of an NPR-wide method to determine transformer condition was completed by the representatives from several large hydro-power owners shortly after the 2002 study was completed. The resulting hydroAMP Hydro Plant Risk Assessment Guide: Transformers (Sept. 2006) is used by the NPR operating project staffs to evaluate the condition of their transformers. This information is saved in a hydroAMP database maintained by BPA. The Tier 1 Condition Index for each of the transformers in the study was gathered in May 2012. The transformer CI was used to determine whether each particular transformer is currently in Good, Fair, Marginal, or Poor condition, based on a one-to-ten rating scale. Note that these condition ratings are intended to indicate the overall condition of the transformers based on available test data and maintenance records, as well as age. The CI is based on Insulating Oil Analysis, Power Factor and Excitation Current Tests, Operation and Maintenance History and Age. In some cases, there are remedial measures that can be employed to improve the condition of transformers rated below Good. These are addressed in section 4.3.1 and discussed further in Phase 1: NPR Spare Transformer Plan (Oct. 2002).

The following process was followed for each main unit transformer.

1. A hydroAMP Tier 1 Condition Assessment datasheet was gathered for each transformer, which provided the transformer CI and the Data Quality Indicator (DQI), which were recorded in the *Condition Assessment* spreadsheet. The age of the transformer was automatically calculated in the *Condition Assessment* spreadsheet.
2. The *Nameplate Information* spreadsheet (Attachment B) was updated to capture the nameplate information for all of the main unit transformers and spares, including the new main unit transformers at The Dalles and McNary power plants and the four spare transformers obtained for Detroit, Dworshak, Libby and Little Goose projects. The spreadsheet includes the following information:
    - Location of transformer
    - Transformer identification
    - Units served
    - Number of phases (single- or three-phase)
    - Manufacturer
    - Serial number
    - Date manufactured
    - Voltage ratings
    - MVA rating(s)
    - Cooling method(s)
    - Oil preservation method
    - Percent impedance at rated MVA (all windings)
    - Base information (rail/wheels or flat)
3. The percent impedance at rated MVA was more completely recorded in the *Nameplate Information* spreadsheet to include the values found in the original transformer test reports where available.

A probability of failure was calculated for each transformer (or a representative transformer in a family) based on the transformer's CI and current age. The probability of failure for the transformers and the probability of failure curves, from which the information was gathered, are discussed further in section 3.2.1.

3.0 ECONOMIC ANALYSIS

The economic analysis described below was used to determine for which projects at least one spare transformer appears to be economically justified. For the purposes of this analysis, the economic benefit of having a spare transformer available is the difference in revenue lost between a long outage without a spare and a short outage with a spare. It is recognized that there are other costs involved with a transformer failure, possibly even including damage to adjacent equipment (e.g., bus work, structures, etc.), detrimental environmental impacts, and there could be a significant safety hazard to personnel. Having a spare main unit transformer available does not mitigate these possible consequences of a transformer failure. Nor do these consequences influence which projects should have spare transformers. Accordingly, these factors were not included in the analysis.

3.1 REVENUE LOST AS A CONSEQUENCE OF FAILURE

The economic costs of a transformer outage were provided by BPA's Federal Projects Office and were based on the number of generators each transformer outage would affect. For the base condition, or no transformer outage, unit availability was the 90% typically used in economic studies in the BPA service territory. This indirectly takes into account normal maintenance outages that reduce plant availability. The costs of an outage were derived from the difference in annual value of the plant's output at 90% availability and the availability resulting from a transformer outage.

This information was incorporated into the *Economic Impacts* spreadsheet (Attachment D). Added to the spreadsheet were calculations of the economic consequence of failure for two different scenarios. The first scenario was a four month outage, which assumes that an unplanned failure occurs and there is a spare transformer available to replace the damaged one. The second scenario was a twenty-four month outage, which assumes an unplanned failure occurs, there is no spare transformer available, and one must be procured and installed. An additional column calculates the savings realized by having a spare available before an unplanned failure.

3.2 ECONOMIC ANALYSIS INCLUDING PROBABILITY OF FAILURE

3.2.1 Methodology

An evaluation of the need for spare transformers must take into account some element of risk or probability of failure to properly balance the revenue saved by having a spare against the costs of procuring a spare. The following calculations were performed and the results are displayed in the *Economic Analysis* spreadsheet (Attachment E) for each project and type of transformer.

One measurement of the exposure to an extreme and relatively improbable event is the product of the potential cost of the event and the probability of that event occurring. For this analysis, the revenue expected to be saved by having a spare transformer is used instead of the potential additional cost of the outage by not having a spare.

The probability of failure for each grouping of similar transformers, as entered in the *Economic Analysis* spreadsheet, is based on the transformer survivor curves developed for the previously completed Phase 1B: Multiple, Shared, and Spare Transformer Procurement Timing Analysis final report (May 2005), which were improved in support of a similar report completed for Omaha District in 2007. The survivor curves are based on a Weibull distribution and can be used to develop a hazard function with the transformer CI and age as parameters.

It is necessary to take into account the fact that the probability of a transformer failure in any time period at a particular project increases with the number of transformers at the project. Several columns of the *Economic Analysis* spreadsheet are used to calculate that increased probability of any failure occurring. The Expected Benefit (the product of the probability of a transformer failure and the revenue saved by having a spare transformer) is tabulated for each project.

The estimated costs for spare transformers were estimated based on system-wide transformer costs over the last five years (10 transformers), and assume the same configuration (single- or three-phase) and MVA ratings of the transformer to be replaced. The estimates include design, manufacturing, shipping, erecting, testing costs, and all appurtenances. The estimates do not have allowances for constructing storage facilities, removing or repairing a damaged transformer or any internal costs associated with procuring a spare transformer. Installation costs are not included as they are expected to be the same whether installing a spare or a new transformer, for the purposes of this study.

To reflect the fact that a single spare transformer can serve as the spare for several banks of transformers, the estimated cost of the spare was divided by the number of transformers for which it would be a direct replacement.

3.2.2 Results

A column in the *Economic Analysis* spreadsheet also tabulates the ratio of the Expected Benefits to the Spare Transformer Costs per unit (B/C ratio) for each project or type of transformer. The greater the resulting ratio, the more likely that one or more spare transformer may be economically justified.

Based on the simple analysis performed herein, the results for each project were divided into four categories as follows:

A – Project where one or more spare transformers appear justified and none exists

B – Projects where one or more spare transformers appear justified and one exists

C – Projects where no spare transformers appear justified and none exists

D – Projects where no spare transformers appear justified and one exists

Category A	B/C ratio
McNary 230kV	16.24
The Dalles 230kV (single-phase, existing units)	13.54
Bonneville PH1 230kV (no transfer bus)	3.42
Bonneville PH1 230kV (transfer bus)	1.53
Bonneville PH1 115kV (no transfer bus)	1.35
The Dalles T1 (existing units)	1.22

Category B	B/C ratio
Little Goose, Lower Granite, Lower Monumental T1	60.94
Chief Joseph 230kV	44.67
John Day	41.26
Chief Joseph 500kV, T5-T6	27.11
Detroit	17.60
Little Goose, Lower Granite, Lower Monumental T2	12.92
Dworshak 500kV	12.86
Chief Joseph 500kV, T7	5.14
Libby	1.40

Category C	B/C ratio
McNary 115kV	0.65
Albeni Falls	0.61
Bonneville PH1 115kV (transfer bus)	0.61
Cougar	0.49
Hills Creek	0.48
Dexter	0.45

Ice Harbor T1-T3	0.32
Foster	0.31
The Dalles 230kV (three-phase)	0.28
The Dalles 230kV (single-phase, new units)	0.27
Lost Creek	0.26
Lookout Point	0.21
The Dalles 115kV (new units)	0.15
Dworshak 115kV	0.15
Ice Harbor T4-T5	0.08
The Dalles T2	0.07
Ice Harbor T6	0.06
Green Peter	0.05
The Dalles T4	0.03

Category D	B/C ratio
Bonneville PH2	0.16
The Dalles TA (fish attraction units)	0.11

3.2.2.1 Notes for Results

The following paragraphs notate various aspects for consideration of the above categorized list. These notes are valid for both the previous list and the following bar chart.

The Dalles T2 and T4 are new units and consequently are of a very different condition than that of their respective families, as such, the B/C ratios for these units have been listed independently. The process of replacing The Dalles T1, T3 and T5-T7 is intended to begin in the coming year. Special analyses was performed for these units (the B/C ratios are shown above), the results of which are discussed further in section 4.4.

It should be noted that The Dalles TA bank is included in Category D although no data was available for outage cost information for this bank. To arrive at The Dalles TA bank B/C ratio above, an average factor of outage cost increase for The Dalles from 2002 to 2012 was calculated based on data provided by BPA for the T1-T11 banks. This average factor of increase was then used with the outage cost data for TA from 2002 to arrive at an estimated annual cost of outage for the TA bank. This value was then entered in the *Economic Impacts* spreadsheet as the annual revenue lost, at which point calculations were made as for other projects in the study.

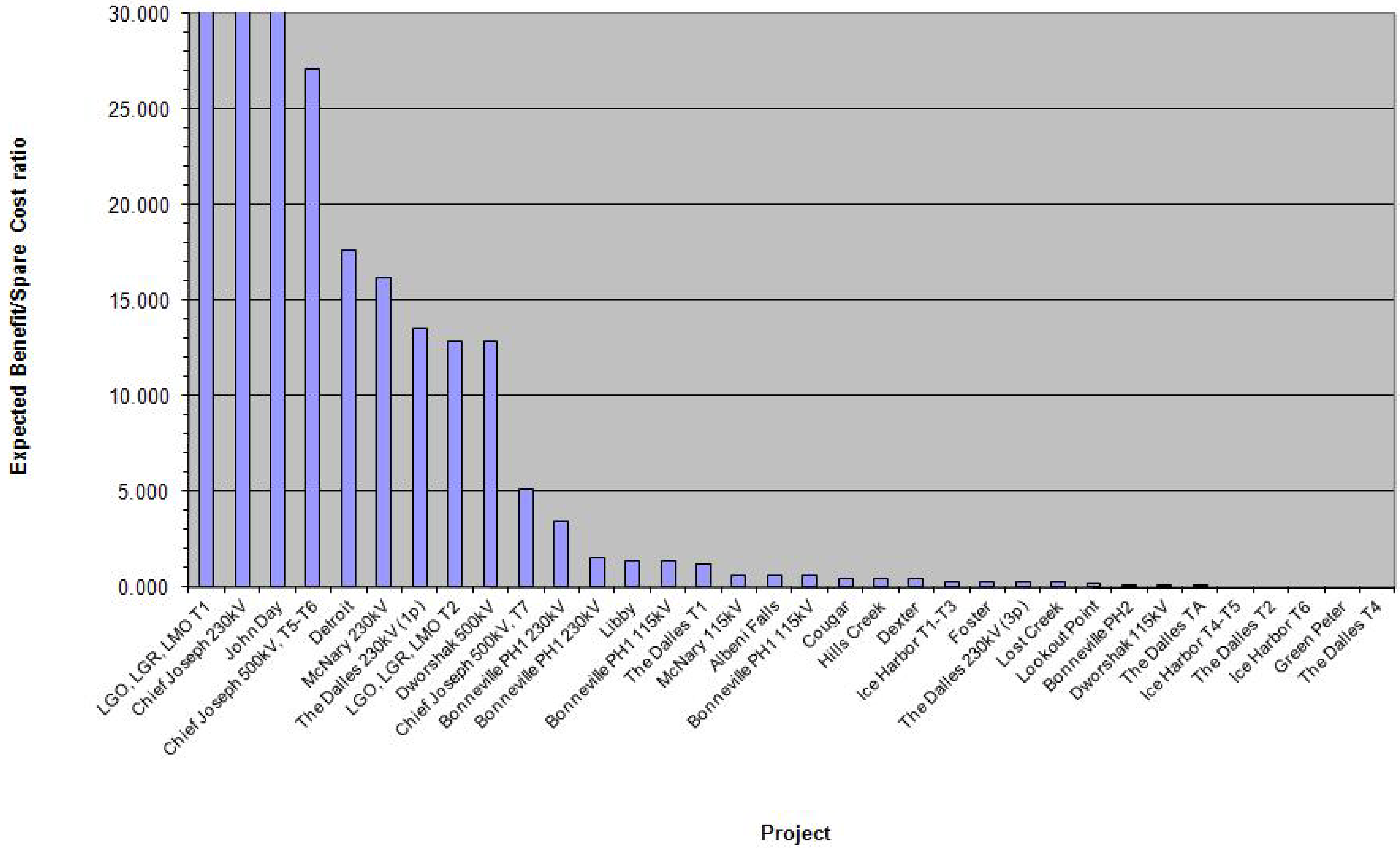
For Bonneville 1st Powerhouse, B/C ratios for two bus configurations are listed: with and without a transfer bus. The significance of analyses of Bonneville 1st Powerhouse for these two cases is discussed further in section 4.1.2.

The Ice Harbor T6 bank has a B/C ratio listed independently of Ice Harbor T4 and T5 as it is currently in the process of being replaced. The Chief Joseph T7 units are not identical, although similar, to the T5 and T6 units, and so the B/C ratio for the T7 bank is listed independently.

Additionally, John Day (and Little Goose, Lower Granite and Lower Monumental T1), which is listed in Category B, has a spare transformer which is of unknown serviceability. The CI for the spare at John Day is 7.8 (Fair), with a DQI of 0. The very low DQI could indicate that the information used to calculate the CI was very old and/or of questionable integrity or incomplete. The uncertain condition of the spare will be discussed further in section 5.1.

The bar chart on the following page summarizes the ranking of the projects in order of decreasing B/C ratio. Note that the ordinate scale has been reduced to enable the ratios for the Category C and D projects to be discernible.

Economic Analysis Results Summary



3.3 ADDITIONAL CONSIDERATIONS

There are indirect consequences of unit outages caused by main unit transformer failures that are not addressed in this analysis. One is that at numerous projects specific units must run to provide fish attraction water. A failure of a main unit transformer serving the fish attraction or priority dispatch units could result in additional units at the plant being severely curtailed to maintain compliance with the current fish passage plan. Thus, a failure of a main unit transformer could produce a disproportionately large economic impact, much larger than indicated in this report.

There may be local system impacts that would occur if a particular project's output were reduced due to a main unit transformer failure. These impacts may be seasonal in nature and could range from reduced bulk power transfers in an area due to the loss of local generation support to problems maintaining local voltage levels without the area generators.

4.0 RECOMMENDED SPARE TRANSFORMER PLAN

The recommended spare transformer plan is based on the results of the condition assessment and economic analysis results for each of the main unit transformers. The first section describes the configuration of each plant's generators and main unit transformers and the recommended course of action to be followed in the case of a transformer failure today. The existing spare main unit transformers and the sites at which they can directly replace in-service transformers are discussed in the second section. The third section describes some recommended actions to be taken on the existing main unit transformers and, where appropriate, a summary of the equipment or repairs needed to make the spares fully functional. The last section describes the recommended order of detailed evaluation and procurement of new spare transformers.

The details of each type of transformer and a summary of the short term and long term sparing options is included in the *Sparing Plan Summary* spreadsheet (Attachment F).

4.1 PROJECT SPECIFIC INFORMATION AND EMERGENCY FAILURE PLAN

For most projects, the emergency failure plan remains the same as that outlined in the 2002 study report. However, as Detroit, Dworshak 500kV, Libby and Little Goose (and Lower Granite and Lower Monumental) have all procured spares since 2002, the emergency failure plan for those projects has changed accordingly.

4.1.1 Albeni Falls

Albeni Falls has three main unit transformers each connecting one generator to the area 115kV system. The transformers are rated 13.2-115kV, 13.75/18.3 MVA, and are three-phase units.

There is no spare main unit transformer for Albeni Falls, nor are any of the existing spare transformers suitable for use at Albeni Falls. In the case of a transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

4.1.2 Bonneville 1st Powerhouse

The first powerhouse at Bonneville has 5 main unit transformer banks, each of which connects two generators to the area system. Each of the transformer banks consists of three single-phase units. The single-phase units in two of the banks are rated 13.2-115kV and 69 MVA, and the single-phase units in the other three banks are rated 13.2-230kV and 42 MVA.

There are no spare main unit transformers for Bonneville 1st powerhouse. However, the 13.8kV electrical system includes a transfer bus that can be used to transfer any single generator to any main unit transformer. Transformer banks T1/2 and T9/10 are oversized to take advantage of the transfer bus. Thus a main unit transformer failure at Bonneville 1st powerhouse will only remove one unit from service as the other can be transferred to T1/2 or T9/10. However, it may be that should any significant work be done on the transformers or bus system, in the future, the transfer bus may be removed. Removing the transfer bus would force two generators out of service in the event of a transformer failure; this would increase the expected benefit of having a spare for both families of transformers at the project and place both in Category A.

4.1.3 Bonneville 2nd Powerhouse

The second powerhouse at Bonneville has two main unit transformers, each of which connects four generators to the area 230kV system. The transformers are rated 13.8-13.8-230kV, 344/385 MVA, and are three-phase units.

There is a spare main unit transformer (three-phase unit) for Bonneville 2nd powerhouse. However, at present it is not operational. Auxiliary components have been removed to replace failed components on transformers T11 and T12. In its present condition, the Bonneville 2nd Powerhouse spare is not serviceable.

4.1.4 Chief Joseph

Chief Joseph has seven main unit transformer banks, each of which consists of three single-phase units. Each transformer bank connects four generators to the area system, except bank T7, which only connects three generators to the system. The single-phase units that comprise the main unit transformers for units 1-16 are rated 13.2-13.2-230kV, 124 MVA. The single-phase units that comprise the main unit transformers for units 17-24 are rated 13.8-13.8-500kV, 115/153.3 MVA. The single-phase units that comprise the main unit transformers for units 25-27 are rated 13.8-13.8-500kV, 86.2/115 MVA.

There are two spare main unit transformers (single-phase units) for Chief Joseph. The first is a direct replacement for the single-phase units in the 230kV banks, and the second is a direct replacement for the single-phase units in the 115/153.3 MVA 500kV banks. The second spare can also be used as a replacement for the single-phase units in the 86.2/115 MVA 500kV bank.

4.1.5 Cougar

Cougar has one main unit transformer connecting the two generators to the area 115kV system. The transformer is rated 6.6 –115kV, 30 MVA, and is a three-phase unit.

There is no spare main unit transformer for Cougar, nor are any of the existing spare transformers suitable for use at Cougar. In the case of a transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

4.1.6 The Dalles

The Dalles has seven main unit transformer banks consisting of three banks of single-phase units and four banks consisting of three-phase units. Each transformer bank connects two generators to the area system. The ratings of the banks appear below.

TA (Fish Water units)	13.2-115kV, 8.72/10.9 MVA, single-phase units
T1 (Units 1-2)	13.2-115kV, 63 MVA, single-phase units
T2 (Units 3-4)	13.2-115kV, 37.8/50.4/63 MVA, single-phase units
T3, T5-T7 (Units 5, 6, 9-14)	13.2-230kV, 63 MVA, single-phase units
T4 (Units 7-8)	13.2-230kV, 37.8/50.4/63 MVA, single-phase units
T8-T11 (Units 15-22)	13.2-230kV, 208/233 MVA, three-phase units

It is intended that the process of replacing The Dalles T1, T3, and T5-T7 banks begin in the coming year. As T2 and T4 have also recently been replaced, it could be useful to consider the affect of all new spare transformers on the economic analysis of this study, which is further discussed in section 4.4.

There is one spare main unit transformer for the TA bank at The Dalles. None of the existing spare transformers are suitable for use at The Dalles T1-T11 banks. In the case of a transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

4.1.7 Detroit

Detroit has two main unit transformer banks, each connecting one generator to the area 115kV system. The output of the Big Cliff generator is connected to the area 115kV system through these two banks also. The transformers are rated 13.2-230kV, 29 MVA, and are single-phase units.

There is a spare main unit transformer (single-phase unit) for Detroit powerhouse.

4.1.8 Dexter

Dexter has one main unit transformer connecting the generator to the area 115kV system. The transformer is rated 13.2 –115kV, 13/17.3 MVA, and is a three-phase unit.

There is no spare main unit transformer for Dexter, nor are any of the existing spare transformers suitable for use at Dexter. In the case of a transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

4.1.9 Dworshak

Dworshak has two main unit transformers connecting the three generators to the area 115kV and 500kV systems. Due to the configuration of the 13.8kV system at Dworshak, generators 1 and 2 are connected to both main unit transformers. The connection to the 115kV system is through a three-phase transformer rated 13.2-115kV, 150 MVA. The connection to the 500kV system is through a bank of three single-phase transformers. Each single-phase unit is rated 13.2-500kV, 121.5/162 MVA.

There is no spare 115kV main unit transformer at Dworshak, nor are any of the existing spare transformers suitable for use at Dworshak to replace the 115kV transformer should a failure occur. In the case of a 115kV transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

There is a spare 500kV main unit transformer (single-phase unit) for Dworshak powerhouse.

4.1.10 Foster

Foster has one main unit transformer connecting the two generators to the area 115kV system. The transformer is rated 4-115kV, 18/24 MVA, and is a three-phase unit.

There is no spare main unit transformer for Foster, nor are any of the existing spare transformers suitable for use at Foster. In the case of a transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

4.1.11 Green Peter

Green Peter has one main unit transformer connecting the two generators to the area 115kV system. The transformer is rated 13.2-115kV, 73.5/98 MVA, and is a three-phase unit.

There is no spare main unit transformer for Green Peter, nor are any of the existing spare transformers suitable for use at Green Peter. In the case of a transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

4.1.12 Hills Creek

Hills Creek has one main unit transformer connecting the two generators to the area 115kV system. The transformer is rated 6.6 –115kV, 27/36 MVA, and is a three-phase unit.

There is no spare main unit transformer for Hills Creek, nor are any of the existing spare transformers suitable for use at Hills Creek. In the case of a transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

4.1.13 Ice Harbor

Ice Harbor has six main unit transformer banks connecting the six generators to the area 115kV system. Each transformer bank is a three-phase unit. The T1-T3 banks for units 1-3 are rated 13.2-115kV, 109 MVA. The T4-T6 banks for units 4-6 are rated 13.2-115kV, 134 MVA.

There are no spares for main unit transformers at Ice Harbor, nor are any of the existing spare transformers suitable for use at Ice Harbor. In the case of a transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

4.1.14 John Day

John Day has four main unit transformer banks, each of which consists of three single-phase units. Each transformer bank connects four generators to the area system. The single-phase units that comprise the main unit transformers are rated 13.2-13.2-500kV, 164/218.6 MVA.

There is a spare main unit transformer (single-phase unit) for John Day. It is also a direct replacement for the T1 main unit transformers at Lower Monumental, Little Goose, and Lower Granite. See section 5.1 for further discussion about this spare.

4.1.15 Libby

Libby has three main unit transformers each connecting two generators to the area 230kV system, except bank T3 that only connects one generator to the 230kV system. The transformers are rated 13.2-230kV, 192/256 MVA, and are three-phase units.

There is a spare main unit transformer (three-phase unit) at Libby powerhouse.

4.1.16 Little Goose

Little Goose has two main unit transformer banks, each of which consists of three single-phase units. The T1 transformer bank connects four generators to the area 500kV system and the T2 transformer bank connects two units to the area 500kV system. The single-phase units that comprise the T1 main unit transformer bank for units 1-4 are rated 13.2-13.2-500kV, 164/218.6 MVA. The single-phase units that comprise the T2 main unit transformer bank for units 5-6 are rated 13.2-13.2-500kV, 82/109 MVA.

The spare single-phase transformer at John Day is a direct replacement for the units that make up the T1 bank. See section 5.1 for further discussion about this spare.

There is a spare main unit transformer (single-phase unit) for the T2 bank at Little Goose powerhouse. It is also a direct replacement for the T2 main unit transformers at Lower Monumental and Lower Granite powerhouse.

4.1.17 Lookout Point

Lookout Point has three main unit transformers connecting the three generators to the area 115kV system. Each transformer is rated 13.2-15kV, 48 MVA, and is a three-phase unit.

There is no spare main unit transformer for Lookout Point, nor are any of the existing spare transformers suitable for use at Lookout Point. In the case of a transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

4.1.18 Lost Creek

Lost Creek has one main unit transformer connecting the two generators to the area 115kV system. The transformer is rated 13.2-15kV, 45/60 MVA, and is a three-phase unit.

There is no spare main unit transformer for Lost Creek, nor are any of the existing spare transformers suitable for use at Lost Creek. In the case of a transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

4.1.19 Lower Granite

Lower Granite has two main unit transformer banks, each of which consists of three single-phase units. The T1 transformer bank connects four generators to the area 500kV system and the T2 transformer bank connects two units to the area 500kV system. The single-phase units that comprise the T1 main unit transformer bank for units 1-4 are rated 13.2-13.2-500kV, 164/218.6 MVA. The single-phase units that comprise the T2 main unit transformer bank for units 5-6 are rated 13.2-13.2-500kV, 82/109 MVA.

The spare single-phase transformer at John Day is a direct replacement for the units that make up the T1 bank. See section 5.1 for further discussion about this spare.

The spare single-phase main unit transformer at Little Goose is a direct replacement for the T2 bank serving units 5 and 6.

4.1.20 Lower Monumental

Lower Monumental has two main unit transformer banks, each of which consists of three single-phase units. The T1 transformer bank connects four generators to the area 500kV system and the T2 transformer bank connects two units to the area 500kV system. The single-phase units that comprise the T1 main unit transformer bank for units 1-4 are rated 13.2-13.2-500kV, 164/218.6 MVA. The single-phase units that comprise the T2 main unit transformer bank for units 5-6 are rated 13.2-13.2-500kV, 82/109 MVA.

The spare single-phase transformer at John Day is a direct replacement for the units that make up the T1 bank. See section 5.1 for further discussion about this spare.

The spare single-phase main unit transformer at Little Goose is a direct replacement for the T2 bank serving units 5 and 6.

4.1.21 McNary

McNary has seven main unit transformer banks, each of which consists of three single-phase units. Each transformer bank connects two generators to the area system. The single-phase units that comprise the main unit transformers for units 1-12 are rated 13.2-13.2-230kV, 40/53/66.7 MVA. The single-phase units that comprise the main unit transformers for units 13-14 are rated 13.2-115kV, 40/53/66.7 MVA.

There is no spare main unit transformer for McNary. In the case of a transformer failure, the two options would be an expedited repair of the failed transformer or the purchase of an adaptable spare from the used equipment market.

4.2 EXISTING SPARE MAIN UNIT TRANSFORMERS

The electrical and physical features of the existing main unit transformer spares were reviewed to determine their applicability to multiple projects. Information regarding the results of that review as well as information on the condition of each spare appears below. Where restrictions on storage and movement allow, spare transformers should be stored “fully dressed” and filled with oil to allow periodic electrical testing to insure the transformer remains suitable for service.

4.2.1 Bonneville 2nd Powerhouse Spare

The spare transformer at the Bonneville 2nd powerhouse is a three-phase unit rated 13.8-13.8-230kV, 344/385 MVA. It is a direct replacement for T11 and T12 at the Bonneville 2nd powerhouse. The spare transformer not equipped with all of its required ancillary components and is not suitable for service at this time. Refurbishment of the spare is planned for 2014.

4.2.2 Chief Joseph 230kV Spare

The spare 230kV transformer at the Chief Joseph powerhouse is a single-phase unit rated 13.2-13.2-230kV, 124 MVA. It is a direct replacement for the single-phase units of banks T1 –T4 at Chief Joseph.

This transformer was in service as A phase of T1. The GE Type U 230kV bushing failed and the transformer was removed from service and replaced with the spare. This phase has been repaired by Powertech Labs in British Columbia and was refitted with a new 230kV bushing.

4.2.3 Chief Joseph 500kV Spare

The spare 500kV transformer at the Chief Joseph powerhouse is a single-phase unit rated 13.8-13.8-500kV, 115/153.3 MVA. It is a direct replacement for the single-phase units of banks T5 and T6 at Chief Joseph. It can also be used to replace one of the phases of T7 at Chief Joseph.

This transformer has never been in service. It is equipped with bushings but not with coolers or fans.

4.2.4 The Dalles 115kV Spare (TA)

The Dalles 115kV spare is a single-phase unit is rated 13.2-115kV, 8.72/10.9 MVA. It is a direct replacement for the single-phase units of bank TA at The Dalles. It is not suitable for service in any other location.

4.2.5 Detroit 230kV Spare

The Detroit 230kV spare is a single-phase unit rated 13.2-230kV, 29 MVA. It is a direct replacement for the Detroit transformers T1 and T2. The spare transformer is fully assembled and properly stored. It is not suitable for service in any other location.

4.2.6 Dworshak 500 kV Spare

The Dworshak 500kV spare is a single-phase unit rated 13.8-13.8-500kV, 121.5/162 MVA. It is a direct replacement for the Dworshak T1 transformers. The spare transformer is fully assembled and properly stored. It is not suitable for service in any other location.

4.2.7 John Day 500kV Spare

The John Day 500kV spare transformer is a single-phase unit rated 3.2-13.2-500kV, 164/218.6 MVA. It is a direct replacement for the single-phase units in banks T1-T4 at John Day, and bank T1 at Little Goose, Lower Granite, and Lower Monumental. The spare was not purchased with the coolers and fans or the low voltage bushings. A spare high voltage bushing was purchased but it has been stored improperly and is not suitable for service at this time.

4.2.8 Libby 230kV Spare

The Libby 230kV spare transformer is a three-phase unit rated 13.2-13.2-230kV, 192/256 MVA. It is a direct replacement for all Libby transformers and would be a suitable replacement for the T1 banks at Little Goose, Lower Granite or Lower Monumental powerhouses. The spare transformer is fully assembled and properly stored.

4.2.9 Little Goose, Lower Granite, Lower Monumental 500kV Spare

The Little Goose, Lower Granite, Lower Monumental joint 500kV spare is a single-phase unit rated 13.2-13.2-500kV, 82/109 MVA. It is a direct replacement for the units in the T2 banks at Little Goose, Lower Granite and Lower Monumental powerhouses. The spare transformer is fully assembled and properly stored at Little Goose Dam.

4.3 RECOMMENDED ACTION FOR EXISTING TRANSFORMERS

4.3.1 Existing Main Unit Transformers

Improving the condition of the existing main unit transformers should be included in the plan to minimize the risk of loss of revenue due to forced transformer outages. Recommendations and guidance regarding practices designed to mitigate the probability of failure of a transformer currently in service may be found in the previous report Phase 1: NPR Spare Transformer Plan (Oct. 2002).

4.3.2 Existing Spare Transformers

Another step that should be taken to minimize the risk of lost revenue is to insure that the existing spare transformers are actually capable of being placed into service. Some of the existing spare transformers were purchased without low voltage bushings or ancillary equipment and spare high voltage bushings were shipped and stored separately. If the transformer failure that requires the use of the spare is violent, it is possible that these other components will not be reusable from the failed unit. The majority of the recommended steps below are necessary to insure that the spare transformers are serviceable without relying on scavenging parts from the failed unit.

4.3.2.1 Detroit 230kV Spare

The new Detroit spare should remain stored filled with oil and properly dressed and occasionally tested to insure its reliability as a spare.

4.3.2.2 Dworshak 500kV Spare

The new Dworshak 500kV spare should remain stored filled with oil and properly dressed and occasionally tested to insure its reliability as a spare.

4.3.2.3 Libby 230kV Spare

The new Libby spare should remain stored filled with oil and fully dressed and occasionally tested to insure its reliability as a spare.

4.3.2.4 Little Goose, Lower Granite and Lower Monumental T2 Spare

The new shared Little Goose, Lower Granite and Lower Monumental T2 Spare should remain stored filled with oil and properly dressed and should be tested occasionally to insure its reliability as a spare.

4.3.2.5 John Day 500kV Spare

There is a spare 500kV bushing on site at John Day. It has been stored horizontally for an extended time, which may have allowed gas to displace oil from the paper condenser layers in the bushing. It should be reprocessed by the manufacturer or repaired by a qualified facility. After the bushing is made ready for service it should be installed in the transformer. Radiators, fans, and other cooling equipment should be procured. Suitable low voltage bushings should be located or procured and installed on the transformer. The spare transformer should then be electrically tested to ascertain its condition. If necessary, the oil should be degassed and filtered. A nitrogen blanket should be maintained above the oil in the tank. Auxiliary equipment should be located and stored in an accessible location for possible use in the future.

4.4 PRIORITIZED SPARING AND PLACEMENT PLAN

4.4.1 General

The results of the economic analysis summarized in section 4 provides a ranking of the projects for which one or more multiple spare transformers appear to be justified. The four categories into which the results were divided are repeated here for convenience.

A – Project where one or more spare transformers appear justified and none exists

B – Projects where one or more spare transformers appear justified and one exists

C – Projects where no spare transformers appear justified and none exists

D – Projects where no spare transformers appear justified and one exists

One possible course of action based on the results of the analysis is to not consider the possible need for additional spare transformers for Category B projects and pursue only the Category A projects in order of decreasing Benefit/Cost ratio. More detailed analyses should be performed before setting aside the Category B projects in the list, as John Day and Little Goose, Lower Granite and Lower Monumental T1 banks have a spare of unreliable serviceability and two of the highest B/C ratios. Of the Category B projects, priority should be given to John Day and Little Goose, Lower Granite and Lower Monumental T1 banks.

The economic analysis results for the Category C projects could be more favorable if projects were to be grouped together for the purposes of spare transformers. As an example, it may be possible to purchase a spare transformer with multiple voltages that could fit several projects. Such a transformer would not be a direct or simple replacement for any of the related projects, but it would bring down the per-unit cost of a spare for them. In the cases where proposed groupings still fail to justify a spare on lost revenue alone, additional issues like those mentioned in section 3.3 should be considered.

4.4.2 Category A Projects

The projects in Category A have no spare transformer available and one or more spare appears to be justified based on the economic analysis of section 3.

4.4.2.1 McNary (230kV)

The additional analysis described in section 5 should be performed for McNary to determine whether more than one spare is justified and the optimum timing of procurement. Consideration should be given to storing the first spare on the transformer (intake) deck to minimize weather related transportation concerns if and when the spare is needed.

4.4.2.2 The Dalles 230kV (single-phase)

The process of replacing The Dalles T3, T5-T7 is planned to begin in the coming year. As such, economic analysis was performed to determine the affect of all new transformers on the project’s need for a spare.

For this analysis transformer banks T3-T7 were treated as a group, despite the modest difference in age of the T4 transformers, in order to account for this difference, an average age of the group was determined to be 1.5 years. This additional economic analysis provides a B/C ratio of less than one, theoretically placing the project in Category C, provided the transformers are replaced as scheduled. If possible, it may be wise to procure an additional single-phase 230kV transformer, while these units are being replaced, to be retained as a spare. Procuring a spare along with the replacement transformers may reduce the individual cost of the spare and make the procurement more economically justifiable. Otherwise, in the event that one or more of the T3-T7 bank transformers should fail, the failed transformer should be repaired for use as a spare, which could be more economical than purchasing a new spare transformer.

If The Dalles T3, T5-T7 transformers are not to be replaced, the project remains in Category A. As such, the additional analysis described in section 5 should be performed for The Dalles to determine whether more than one spare is justified and the optimum timing of procurement. Consideration should be given to storing the first spare on or near the transformer deck to minimize weather related transportation concerns if and when the spare is needed.

4.4.2.3 Bonneville 1st Powerhouse 230kV

The additional analysis described in section 5 should be performed for Bonneville 1st Powerhouse 230kV to determine whether more than one spare is justified and the optimum timing of procurement. Consideration should be given to storing the first spare on or near the transformer deck to minimize weather related transportation concerns if and when the spare is needed.

4.4.2.4 The Dalles 115kV

The process of replacing The Dalles T1 bank is planned to begin in the coming year. As such, economic analysis was performed to determine the affect of all new transformers on the project's need for a spare. For this analysis transformer banks T1 and T2 were treated as a group, despite the difference in age of the T2 transformers, in order to account for this difference, the average age of the group, 4 years, was used. This additional economic analysis provides a B/C ratio of less than one, theoretically placing the project in Category C, provided the transformers are replaced as scheduled. If possible, it may be wise to procure an additional 115kV transformer, while the T1 units are being replaced, to be retained as a spare. Procuring a spare along with the replacement transformers may reduce the individual cost of the spare and make the procurement more economically justifiable. Otherwise, in the event that one or more of the T1 and T2 bank transformers should fail, the failed transformer should be repaired for use as a spare, which could be more economical than purchasing a new spare transformer.

If The Dalles T1 bank is not to be replaced, the project remains in Category A. As such, the additional analysis described in section 5 should be performed for The Dalles to determine whether more than one spare is justified and the optimum timing of procurement. Consideration should be given to storing the first spare on or near the transformer deck to minimize weather related transportation concerns if and when the spare is needed.

4.4.3 Category B Projects

The projects in Category B have one spare transformer available and additional spares may be justified based on the large B/C ratios from the economic analysis of section 3. Note that John Day and Little Goose, Lower Granite and Lower Monumental T1 banks have a spare transformer of unknown reliability. As such, it is recommended that they be treated as Category A projects for future work and considerations should be made for purchasing additional spares.

4.4.3.1 John Day and Little Goose, Lower Granite and Lower Monumental T1

The additional analysis described in section 5 should be performed for John Day and Little Goose, Lower Granite and Lower Monumental T1 banks to determine the number of 164 MVA spares that are justified and the optimum timing of their procurement. If three additional spares can be justified and the existing spare is serviceable, then storing one at each project would be recommended. There is one existing spare stored at John Day which is a direct replacement for these projects. The spare transformer(s) should be stored on the transformer decks if possible to minimize weather related transportation concerns if and when the spare is needed.

4.4.3.2 Chief Joseph 230kV

Chief Joseph currently has one 230kV spare transformer. The additional analysis described in section 5 should be performed for Chief Joseph to determine the number of spares that are justified and the optimum timing of their procurement. Consideration should be given to storing the spare(s) on or near the transformer deck to minimize weather related transportation concerns if and when the spare is needed.

4.4.3.3 Chief Joseph 500kV

Chief Joseph currently has one 500kV spare transformer that is a direct replacement for the T5 and T6 banks and may also be used as a replacement for the T7 transformers. The additional analysis described in section 5 should be performed for Chief Joseph to determine the number of spares that are justified and the optimum timing of their procurement. Consideration should be given to storing the spare(s) on or near the transformer deck to minimize weather related transportation concerns if and when the spare is needed.

4.4.3.4 Detroit

Detroit currently has one spare transformer. The additional analysis described in section 5 should be performed for Detroit to determine whether additional spares that are justified and the optimum timing of their procurement.

4.4.3.5 Little Goose, Lower Granite, Lower Monumental T2 banks

The additional analysis described in section 5 should be performed for Little Goose, Lower Granite, and Lower Monumental to determine whether additional 82 MVA spares are justified and the optimum timing of their procurement. If two more spares can be justified, then storing one at each project would be recommended (the existing spare is stored at Little Goose which is between the other two projects). The spare transformer(s) should be stored on the transformer decks if possible to minimize weather related transportation concerns if and when the spare is needed.

4.4.3.6 Dworshak 500kV bank

The additional analysis described in section 5 should be performed for Dworshak to determine whether an additional spares are justified and the optimum timing of their procurement. Consideration should be given to storing the spare(s) on or near the transformer deck to minimize weather related transportation concerns if and when the spare is needed.

4.4.3.7 Libby

The additional analysis described in section 5 should be performed for Libby to whether additional spares are justified and the optimum timing of their procurement. Consideration should be given to storing the spare(s) on or near the transformer deck to minimize weather related transportation concerns if and when the spare is needed.

4.4.4 Category C Projects

The projects in Category C have no spare transformer available and no spare appears to be justified based on the economic analysis of section 3.

Many of the projects in Category C have relatively small three-phase transformers, or similarly sized single-phase transformers. One possibility that would reduce the effective cost of a spare would be to purchase a spare that is capable of fitting several locations. A disadvantage of that approach is that the spare transformer may not fit any of the sites without modification to existing equipment.

Below are some possible groupings for common spares that cover most Category C transformers.

4.4.4.1 McNary (115kV)

The existing McNary 115kV transformers are unique in the system. If one of these units should fail, the replaced transformer should be repaired for use as a spare, which could be more economical than purchasing a new spare transformer. It would need to be stored at McNary.

4.4.4.2 Albeni Falls and Dexter

A common spare transformer could be used for Albeni Falls and Dexter. The existing transformers at the two projects have the same voltage ratings, practically identical MVA ratings and impedances, and have the same rail wheel spacing. The lost revenue costs at Dexter are higher than Albeni Falls so the spare would be better stored at Dexter. Another consideration is that the cost to transport the spare from Dexter to Albeni Falls may approach the cost of a second spare. Transportation would also only be possible in good weather.

4.4.4.3 Bonneville 1st Powerhouse 115kV

If one of the Bonneville 1st Powerhouse 115kV transformers should fail, the replaced transformer should be repaired for use as a spare, which could be more economical than purchasing a new spare transformer. It would need to be stored at Bonneville 1st Powerhouse.

4.4.4.4 Foster, Hills Creek, and Cougar

A common spare transformer could be used for Foster, Hills Creek, and Cougar. It is possible that a transformer could be obtained with both 4.16kV and 6.6kV low voltage windings and an 115kV high side winding. A rating of 36MVA at 6.6kV would cover both Hills Creek and Cougar. That same transformer would be rated approximately 22.7MVA at 4.16kV which is close to the top rating of the Foster transformer (24 MVA). The spare could be stored near either Hills Creek or Cougar. The lost revenue costs are higher at Hills Creek but the Cougar transformer has a lower condition rating than the Hills Creek transformer.

4.4.4.5 Ice Harbor

The two types and sizes of transformers at Ice Harbor are not an optimal match, but it may be possible to obtain a single transformer that could substitute for either. Such a spare would have a top rating of approximately 135MVA with a flat base. The spare would be placed at Ice Harbor.

Another option would be to purchase two spare transformers, one for Ice Harbor TW1-TW3 and the other for TW4-TW6. These spares could be shared with Green Peter T1 and Dworshak TW1 and have a top rating of 109MVA and 150MVA, respectively, with a flat base. There are more similar units at Ice Harbor, so consideration should be given to storing both spares at Ice Harbor.

4.4.4.6 The Dalles (3 phase 230kV)

It may be possible to use the Bonneville 2nd Powerhouse spare for one of the three-phase 230kV units at The Dalles. That would require significant 13.2 bus work and inventive connections.

4.4.4.7 Lookout Point and Lost Creek

The Lookout Point and Lost Creek transformers are not an optimal match, but it may be possible to obtain a single transformer that could substitute for either. Such a spare would have a top rating of approximately

45MVA with a flat base. The lost revenue costs are higher at Lost Creek and the condition of both transformers is comparable, so consideration should be given to storing the spare at Lost Creek.

4.4.4.8 Dworshak 115kV

As noted above, Dworshak TW1 (115kV) could share a spare with Ice Harbor TW4-TW6. This spare would have a top rating of 150MVA and have a flat base. Such a transformer would be stored at Ice Harbor.

Otherwise, the Dworshak 115kV transformer is unique in the system. It is the largest three-phase 115kV bank and the only one with a load tap changer. If it fails, consideration should be given to replacing it with 3 single-phase units so they could be replaced with spares from other projects. This would involve considerable expense at the project to rebuild the isophase bus and other control and hardware connections that may render this option uneconomical.

4.4.4.9 Green Peter

As noted above, Green Peter could share a spare with Ice Harbor TW1-TW3. This spare would have a top rating of 109MVA and have a flat base. Such a transformer would be stored at Ice Harbor, due to higher lost revenue costs.

Otherwise, should the existing Green Peter transformer fail, it could be repaired for use as a spare, possibly much less expensively than obtaining a new spare transformer. It would need to be stored at Green Peter.

4.4.5 Category D Projects

The projects in Category D have a spare transformer available and no spare appears to be justified based on the economic analysis of section 3. The projects in this category are Bonneville 2nd Powerhouse and The Dalles fishwater units (TA). The spare for The Dalles fishwater units can be justified on the criticality of The Dalles TA to the operation of the remainder of the plant to stay in compliance with environmental regulations. The spare transformer at Bonneville 2nd Powerhouse was obtained when a transformer bound for Libby 7-8 was reconfigured for Bonneville (after the Libby expansion was canceled).

5.0 RECOMMENDATIONS

5.1 ADDITIONAL SPARE TRANSFORMERS

The work performed for the updated study resulted in, among other things, a prioritized ranking of NPR COE projects for which spare main unit transformers should be considered. Procurement of spare transformers for Category A projects should be given highest priority and should ideally be procured in order of decreasing B/C ratio. All Category A and B projects should have available one or more (if justified by further analysis) serviceable spares. It would be impractical to procure all the spare transformers in a short time frame and so, an overall procurement plan needs to be developed.

John Day and Little Goose, Lower Granite and Lower Monumental T1 banks share a single spare stored at John Day, which constitutes the greatest number of transformers dependent on one spare of the projects studied. Although the CI indicates that the spare is in Fair condition, the cooling fans and bushings are not installed and insulation testing cannot be performed. As such, the placement of John Day and Little Goose, Lower Granite and Lower Monumental T1 banks in Category B is questionable because this classification is based solely on the availability of a spare to the projects. The 21 total transformers of these projects are identical units, but were not studied all together as the energy values between John Day and the Lower Snake projects differ significantly. However, if all four projects are treated as one family for the purpose of this study, the B/C ratio ranges from above 70 to over 280, depending upon the assumptions made for the CI and revenue lost. This range far surpasses the B/C ratios of all other projects studied, including that of John Day and the Little Goose, Lower Granite and Lower Monumental T1 banks considered separately.

Regardless of the results of this added analysis, the uncertain state of the John Day spare supports considering John Day and Little Goose, Lower Granite and Lower Monumental as Category A projects.

Although not a good match, The Dalles and Bonneville 1st Powerhouse should be considered high priority among the Category A projects, as it could be possible to procure two shared spares (115kV single-phase and 230kV single-phase) able to replace the units at both projects. These spares could be specially designed for use at either plant, reducing the cost of supplying a spare for the individual projects.

5.2 FURTHER ANALYTICAL WORK

The Phase 1B work completed in 2005 developed the methodology for evaluating the need for multiple spares. A description of the method can be found in the Phase 1B: Multiple, Shared, and Spare Transformer Procurement Timing Analysis final report (May 2005). This updated ranking can be used as a starting point for future work addressing possible multiple spares and procurement timing. The work should include a detailed analysis for each project to identify if, and how many, multiple spares are justified, as well as the optimal purchase timing. The detailed analyses should take into account the probabilities of multiple failures. The analyses to determine the optimum timing for spare transformer procurement should also take into account the effects of time on transformer condition as well as projected changes in the value of the generation. Additional consideration should be given to the thus far unaccounted for considerations described in section 3.3, particularly the ramifications of the loss of fish attraction water or priority units needs to be determined. The results of individual project studies should then be analyzed as a whole to determine the overall sparing and purchasing schedule.

North Pacific Region
Spare Transformer Project

Updated Spare Transformer Plan

Attachment A

Scope of Work

24 September 2012

Prepared By: Hydroelectric Design Center
CENWP-HDC-E

NPR SPARE TRANSFORMER STUDY UPDATE PROJECT
SCOPE AND SCHEDULE OR HDC WORK
28 JUNE 2012

SCOPE

Update Transformer Sparing Study

Step 1 Gather Updated Condition Assessments

The original study included gathering all the information required to perform a condition assessment on the main unit transformers in the NPR. This study will rely on the availability of the current and accurate hydroAMP-based condition assessment data for the transformers. The Scope does not include obtaining original test data and repeating the hydroAMP assessment.

Step 2 Update Economic Consequences of Failure Analysis

The original study used annual generation and revenue information from BPA and estimated generator outage durations (with and without a spare transformer) to develop a difference in lost generation costs. These costs were multiplied by the transformer's assumed probability of failure to arrive at an Expected Benefit cost. For this study update, the transformer survivor curve data developed for the Phase 1B NPR Transformer Study and the Omaha District Transformer Study will be used to determine probability of failures for each transformer based on its current condition index. The remainder of the Economic Analysis from Phase 1 will be repeated with updated cost and failure data. It is assumed that BPA will provide similar updated revenue information for this study.

Step 3 Update Sparing and Placement Plan

An updated sparing and placement plan will be developed reflecting the new information and method described above. The plan will follow the form produced in the Phase 1 report; a combination of written summary and tabular presentations of results.

North Pacific Region
Spare Transformer Project

Updated Spare Transformer Plan

Attachment B

Nameplate Information

24 September 2012

Prepared By: Hydroelectric Design Center
CENWP-HDC-E

Location	XFMR	Unit	Phase	OEM	Serial No.	New In:	Votage		MVA	Cooling	Oil Prot.	Z (%) @ MVA				Base	Tap
							Nominal	2.5% Taps				H-X/Y	H-X	H-Y	X-Y		
Albeni Falls	T1	1	three	Penn	23525-1	1952	13.2-115kV	+1, -3	13.75/18.3	OA/FA	N2 Blanket	-	7.9@13.75	-	-	wheels	B
Albeni Falls	T2	2	three	Penn	23525-2	1952	13.2-115kV	+1, -3	13.75/18.3	OA/FA	N2 Blanket	-	7.8@13.75	-	-	wheels	B
Albeni Falls	T3	3	three	Penn	23525-3	1952	13.2-115kV	+1, -3	13.75/18.3	OA/FA	N2 Blanket	-	8.0@13.75	-	-	wheels	B
Bonneville PH1	T1/2 A	1-2	single	ABB	LNM 60071	1995	13.2-115kV	+2, -2	69	FOA	COPS	-	11.1@69	-	-	wheels	3
Bonneville PH1	T1/2 B	1-2	single	ABB	LNM 60072	1995	13.2-115kV	+2, -2	69	FOA	COPS	-	11.1@69	-	-	wheels	3
Bonneville PH1	T1/2 C	1-2	single	ABB	LNM 60073	1995	13.2-115kV	+2, -2	69	FOA	COPS	-	11.2@69	-	-	wheels	3
Bonneville PH1	T3/4 A	3-4	single	ABB	MNM 60061	1995	13.2-230kV	+2, -2	46	FOA	COPS	-	11.6@46	-	-	wheels	3
Bonneville PH1	T3/4 B	3-4	single	ABB	MNM 60062	1995	13.2-230kV	+2, -2	46	FOA	COPS	-	11.6@46	-	-	wheels	3
Bonneville PH1	T3/4 C	3-4	single	ABB	MNM 60063	1995	13.2-230kV	+2, -2	46	FOA	COPS	-	11.6@46	-	-	wheels	3
Bonneville PH1	T5/6 A	5-6	single	ABB	MNM 60064	1995	13.2-230kV	+2, -2	46	FOA	COPS	-	11.6@46	-	-	wheels	3
Bonneville PH1	T5/6 B	5-6	single	ABB	MNM 60065	1995	13.2-230kV	+2, -2	46	FOA	COPS	-	11.6@46	-	-	wheels	3
Bonneville PH1	T5/6 C	5-6	single	ABB	MNM 60066	1995	13.2-230kV	+2, -2	46	FOA	COPS	-	11.6@46	-	-	wheels	3
Bonneville PH1	T7/8 A	7-8	single	ABB	MNM 60067	1995	13.2-230kV	+2, -2	46	FOA	COPS	-	11.7@46	-	-	wheels	3
Bonneville PH1	T7/8 B	7-8	single	ABB	MNM 60068	1995	13.2-230kV	+2, -2	46	FOA	COPS	-	11.8@46	-	-	wheels	3
Bonneville PH1	T7/8 C	7-8	single	ABB	MNM 60069	1995	13.2-230kV	+2, -2	46	FOA	COPS	-	11.7@46	-	-	wheels	3
Bonneville PH1	T9/10 A	9-10	single	ABB	LNM 60074	1995	13.2-115kV	+2, -2	69	FOA	COPS	-	11.2@69	-	-	wheels	3
Bonneville PH1	T9/10 B	9-10	single	ABB	LNM 60075	1995	13.2-115kV	+2, -2	69	FOA	COPS	-	11.3@69	-	-	wheels	3
Bonneville PH1	T9/10 C	9-10	single	ABB	LNM 60076	1995	13.2-115kV	+2, -2	69	FOA	COPS	-	11.3@69	-	-	wheels	3
Bonneville PH2	T11	11-14	three	GE	M101696	1980	13.8-13.8-230kV	+2, -2	344/385	FOA	Atmoseal		14.56@172	14.62@172	27.46@172	flat	1
Bonneville PH2	T12	15-18	three	GE	M101695	1980	13.8-13.8-230kV	+2, -2	344/385	FOA	Atmoseal		14.48@172	14.52@172		flat	1
spare			three	GE	M102120	1980	13.8-13.8-230kV	+2, -2	344/385	FOA	Atmoseal		14.41@172	14.58@172	27.54@172	flat	1
Chief Joseph	T1A	1-4	single	GE	M102269	1986	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.37@124	12.29@62	12.34@62		wheels	3
Chief Joseph	T1B	1-4	single	GE	M102266	1986	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.42@124	12.29@62	12.42@62		wheels	3
Chief Joseph	T1C	1-4	single	GE	M102267	1986	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.37@124	12.28@62	12.36@62		wheels	3
Chief Joseph	T2A	5-8	single	GE	M102276	1984	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.28@124	12.12@62	12.36@62		wheels	3
Chief Joseph	T2B	5-8	single	GE	M102273	1984	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.42@124	12.23@62	12.40@62		wheels	3
Chief Joseph	T2C	5-8	single	GE	M102277	1984	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.20@124	12.10@62	12.24@62		wheels	3
Chief Joseph	T3A	9-12	single	GE	M102274	1984	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.42@124	12.22@62	12.12@62		wheels	3
Chief Joseph	T3B	9-12	single	GE	M102272	1984	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.42@124	12.41@62	12.55@62		wheels	3
Chief Joseph	T3C	9-12	single	GE	M102271	1984	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.42@124	12.38@62	12.49@62		wheels	3
Chief Joseph	T4A	13-16	single	GE	M102270	1985	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.42@124	12.31@62	12.20@62		wheels	3
Chief Joseph	T4B	13-16	single	GE	M102275	1984	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.42@124	12.31@62	12.24@62		wheels	3
Chief Joseph	T4C	13-16	single	GE	M102268	1984	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.43@124	12.24@62	12.49@62		wheels	3
Chief Joseph	T5A	17-20	single	GE	M100578	1976	13.8-13.8-500kV	+4, -0	115/153.3	OA/FA	Atmoseal	11.38@115	11.44@575	11.34@575		flat	2
Chief Joseph	T5B	17-20	single	GE	M100577	1976	13.8-13.8-500kV	+4, -0	115/153.3	OA/FA	Atmoseal	11.54@115	11.39@575	11.47@575		flat	2
Chief Joseph	T5C	17-20	single	GE	M100581	1976	13.8-13.8-500kV	+4, -0	115/153.3	OA/FA	Atmoseal	11.37@115	11.58@575	11.39@575		flat	2
Chief Joseph	T6A	21-24	single	GE	M100580	1978	13.8-13.8-500kV	+4, -0	115/153.3	OA/FA	Atmoseal	11.56@115	11.47@575	11.44@575		flat	2
Chief Joseph	T6B	21-24	single	GE	M100579	1978	13.8-13.8-500kV	+4, -0	115/153.3	OA/FA	Atmoseal	11.54@115	11.45@575	11.42@575		flat	2
Chief Joseph	T6C	21-24	single	GE	M100576	1978	13.8-13.8-500kV	+4, -0	115/153.3	OA/FA	Atmoseal	11.51@115	11.10@575	11.47@575		flat	2
Chief Joseph	T7A	25-27	single	GE	M100574	1978	13.8-13.8-500kV	+4, -0	86.2/115	OA/FA	Atmoseal	5.59@575	11.23@575	5.47@287.5		flat	2
Chief Joseph	T7B	25-27	single	GE	M100573	1978	13.8-13.8-500kV	+4, -0	86.2/115	OA/FA	Atmoseal	5.82@575	11.23@575	5.49@287.5		flat	2
Chief Joseph	T7C	25-27	single	GE	M100572	1978	13.8-13.8-500kV	+4, -0	86.2/115	OA/FA	Atmoseal		8.59@86.25			flat	2
spare			single	GE	M102265	1984	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.42@124	12.15@62	12.34@62		wheels	
spare			single	GE	M100575	1977	13.8-13.8-500kV	+4, -0	115/153.3	OA/FA	Atmoseal	11.57@115	11.50@575	11.41@575		flat	
Cougar	T1	1-2	three	A-C	20-01270-27762	1963	6.6-115kV	+4, -0	30	FOA	N2 Blanket	-	10.1@30	-	-	flat	D

Location	XFMR	Unit	Phase	OEM	Serial No.	New In:	Votage		MVA	Cooling	Oil Prot.	Z (%) @ MVA				Base	Tap
							Nominal	2.5% Taps				H-X/Y	H-X	H-Y	X-Y		
The Dalles	TA-a	FW1-2	single	Central	2638-3	1956	13.2-115kV	+2, -2	8.72/10.9	OA/FA	N2 Blanket	-	7.4@8.72	-	-	wheels	B
The Dalles	TA-b	FW1-2	single	Central	2638-4	1956	13.2-115kV	+2, -2	8.72/10.9	OA/FA	N2 Blanket	-	7.5@8.72	-	-	wheels	B
The Dalles	TA-c	FW1-2	single	Central	2638-2	1956	13.2-115kV	+2, -2	8.72/10.9	OA/FA	N2 Blanket	-	7.4@8.72	-	-	wheels	B
spare			single	Central	2638-1	1956	13.2-115kV	+2, -2	8.72/10.9	OA/FA	N2 Blanket	-	7.4@8.72	-	-	wheels	B
The Dalles	T1A	1-2	single	Ferranti	140808	1956	13.2-115kV	+2, -2	63	FOW	N2 Blanket	-	12.5@63	-	-	wheels	2
The Dalles	T1B	1-2	single	Ferranti	140806	1956	13.2-115kV	+2, -2	63	FOW	N2 Blanket	-	12.4@63	-	-	wheels	2
The Dalles	T1C	1-2	single	Ferranti	140807	1956	13.2-115kV	+2, -2	63	FOW	N2 Blanket	-	12.4@63	-	-	wheels	2
The Dalles	T2A	3-4	single	VA Tech	TP 648	2005	13.2-115kV	+2, -2	37.8/50.4/63	OA/FA/FA	COPS	-	7.43@37.8	-	-	flat	2
The Dalles	T2B	3-4	single	VA Tech	TP 646	2005	13.2-115kV	+2, -2	37.8/50.4/63	OA/FA/FA	COPS	-	7.46@37.8	-	-	flat	2
The Dalles	T2C	3-4	single	VA Tech	TP 647	2005	13.2-115kV	+2, -2	37.8/50.4/63	OA/FA/FA	COPS	-	7.49@37.8	-	-	flat	2
The Dalles	T3A	5-6	single	Ferranti	140793	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	16.9@63	-	-	wheels	3
The Dalles	T3B	5-6	single	Ferranti	140792	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	16.91@63	-	-	wheels	3
The Dalles	T3C	5-6	single	Ferranti	140791	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	17.32@63	-	-	wheels	3
The Dalles	T4A	7-8	single	Hyundai	*-001	2009	13.2-230kV	+2, -2	37.8/50.4/63	OA/FA/FA	COPS	-	10.147@37.8	-	-	flat	3
The Dalles	T4B	7-8	single	Hyundai	*-002	2009	13.2-230kV	+2, -2	37.8/50.4/63	OA/FA/FA	COPS	-	10.234@37.8	-	-	flat	3
The Dalles	T4C	7-8	single	Hyundai	*-003	2009	13.2-230kV	+2, -2	37.8/50.4/63	OA/FA/FA	COPS	-	10.113@37.8	-	-	flat	3
The Dalles	T5A	9-10	single	Ferranti	140799	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	16.66@63	-	-	wheels	3
The Dalles	T5B	9-10	single	Ferranti	140798	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	16.68@63	-	-	wheels	3
The Dalles	T5C	9-10	single	Ferranti	140800	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	16.65@63	-	-	wheels	3
The Dalles	T6A	11-12	single	Ferranti	140796	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	17.05@63	-	-	wheels	3
The Dalles	T6B	11-12	single	Ferranti	140802	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	16.85@63	-	-	wheels	3
The Dalles	T6C	11-12	single	Ferranti	140801	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	16.72@63	-	-	wheels	3
The Dalles	T7A	13-14	single	Ferranti	140794	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	17.25@63	-	-	wheels	3
The Dalles	T7B	13-14	single	Ferranti	140805	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	16.99@63	-	-	wheels	3
The Dalles	T7C	13-14	single	Ferranti	140804	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	16.72@63	-	-	wheels	3
The Dalles	T8	15-16	three	GE	H409355	1972	13.2-230kV	+2, -2	208/233	FOA	N2 Blanket	-	12.9@208	-	-	flat	3
The Dalles	T9	17-18	three	GE	H409356	1972	13.2-230kV	+2, -2	208/233	FOA	N2 Blanket	-	12.89@208	-	-	flat	3
The Dalles	T10	19-20	three	GE	H409357	1972	13.2-230kV	+2, -2	208/233	FOA	N2 Blanket	-	12.88@208	-	-	flat	3
The Dalles	T11	21-22	three	GE	H409358	1972	13.2-230kV	+2, -2	208/233	FOA	N2 Blanket	-	12.96@208	-	-	flat	3
Detroit	T1A	1	single	Penn	16326-1	1951	13.2-230kV	+2, -2	29	FOW	N2 Blanket	-	7.18@29	-	-	wheels	C
Detroit	T1B	1	single	Penn	16326-5	1951	13.2-230kV	+2, -2	29	FOW	N2 Blanket	-	7.19@29	-	-	wheels	C
Detroit	T1C	1	single	Penn	16326-6	1951	13.2-230kV	+2, -2	29	FOW	N2 Blanket	-	7.21@29	-	-	wheels	C
Detroit	T2A	2	single	Penn	16326-4	1951	13.2-230kV	+2, -2	29	FOW	N2 Blanket	-	7.18@29	-	-	wheels	C
Detroit	T2B	2	single	Penn	16326-2	1951	13.2-230kV	+2, -2	29	FOW	N2 Blanket	-	7.07@29	-	-	wheels	C
Detroit	T2C	2	single	Penn	16326-3	1951	13.2-230kV	+2, -2	29	FOW	N2 Blanket	-	7.20@29	-	-	wheels	C
spare			single	HICO	TM80097201	2006	13.2-230kV	+2, -2	29	ODAF	N2 Blanket	-	7.18@29	-	-	flat	
Dexter	T1	1	three	Moloney	911268	1955	13.2-115kV	+2, -2	13/17.3	OA/FA	N2 Blanket	-	7.41@13	-	-	wheels	3
Dworshak	TW1	1	three	West	7001766	1971	13.2-115kV	+16, -16	150	FOA	N2 Blanket	-	15.1@150	-	-	flat	2R
Dworshak	T1A	2-3	single	West	7001743	1971	13.8-13.8-500kV	+4, -0	121.5/162	OA/FA	N2 Blanket	11.24@109.5	15.66@66.75	13.45@54.75	30.22@54.75	flat	3
Dworshak	T1B	2-3	single	West	7001742	1971	13.8-13.8-500kV	+4, -0	121.5/162	OA/FA	N2 Blanket	11.17@109.5	15.63@66.75	13.41@54.75	30.14@54.75	flat	3
Dworshak	T1C	2-3	single	West	7001744	1971	13.8-13.8-500kV	+4, -0	121.5/162	OA/FA	N2 Blanket	11.15@109.5	15.56@66.75	13.35@54.75	30.03@54.75	flat	3
spare			single	HICO	TA80097203	2007	13.8-13.8-500kV	+4, -0	121.5/162	OA/FA	COPS		16.02@66.75	13.74@54.75		flat	
Foster	T1	1-2	three	West	RBR 67511	1966	4-115kV	+2, -2	18/24	OA/FA	N2 Blanket	-	9.83@18	-	-	flat	3
Green Peter	T1	1-2	three	HICO	TP80009203	2002	13.2-115kV	+2, -2	75/100	OA/FA	N2 Blanket	-	7.89@75	-	-	flat	3

Location	XFMR	Unit	Phase	OEM	Serial No.	New In:	Votage		MVA	Cooling	Oil Prot.	Z (%) @ MVA				Base	Tap
							Nominal	2.5% Taps				H-X/Y	H-X	H-Y	X-Y		
Hills Creek	T1	1-2	three	West	6991866	1961	6.6-115kV	+2, -2	27/36	OA/FA	N2 Blanket	-	6.97@27	-	-	flat	3
Ice Harbor	TW1	1	three	Wagner	9P2922	1960	13.2-115kV	+2, -2	109	FOW	N2 Blanket	-	10.94@109	-	-	flat	C
Ice Harbor	TW2	2	three	Wagner	9P2923	1960	13.2-115kV	+2, -2	109	FOW	N2 Blanket	-	10.90@109	-	-	flat	C
Ice Harbor	TW3	3	three	Wagner	9P2924	1960	13.2-115kV	+2, -2	109	FOW	N2 Blanket	-	10.80@109	-	-	flat	C
Ice Harbor	TW4	4	three	FPE	50142-1	1975	13.2-115kV	+2, -2	134	FOA	N2 Blanket	-	10.05@134	-	-	wheels	3
Ice Harbor	TW5	5	three	FPE	50142-2	1975	13.2-115kV	+2, -2	134	FOA	N2 Blanket	-	10.03@134	-	-	wheels	3
Ice Harbor	TW6	6	three	FPE	50142-3	1975	13.2-115kV	+2, -2	134	FOA	N2 Blanket	-	9.98@134	-	-	wheels	3
John Day	T1A	1-4	single	West	700894	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.49@82	17.66@82	40.45@82	flat	3
John Day	T1B	1-4	single	West	700895	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.42@82	17.38@82	40.07@82	flat	3
John Day	T1C	1-4	single	West	7000973	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.49@82	1.66@82		flat	3
John Day	T2A	5-8	single	West	7001000	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.83@82	17.94@82	42.12@82	flat	3
John Day	T2B	5-8	single	West	7001750	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.38@82	17.57@82	40.55@82	flat	3
John Day	T2C	5-8	single	West	700972	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.66@82	17.87@82	41.28@82	flat	3
John Day	T3A	9-12	single	West	7001223	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.77@82	17.94@82	41.07@82	flat	3
John Day	T3B	9-12	single	West	7001197	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.60@82	17.60@82		flat	3
John Day	T3C	9-12	single	West	7001001	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.83@82	17.94@82	41.51@82	flat	3
John Day	T4A	13-16	single	West	7001244	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.40@82	17.50@82		flat	3
John Day	T4B	13-16	single	West	7001246	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.66@82	17.70@82	41.43@82	flat	3
John Day	T4C	13-16	single	West	7001186	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.77@82	17.80@82	40.45@82	flat	3
spare			single	West	7000893	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.63@82	17.66@82	40.53@82	flat	3
Libby	T1	1-2	three	West	7002149	1974	13.2-13.2-230kV	+2, -2	192/256	OA/FA	N2 Blanket		7.52@96	7.55@96	17.81@96	flat	3
Libby	T2	3-4	three	West	7002299	1974	13.2-13.2-230kV	+2, -2	192/256	OA/FA	N2 Blanket		7.49@96	7.60@96	17.74@96	flat	3
Libby	T3	5	three	GE	M102119	1974	13.2-13.2-230kV	+2, -2	192/256	OA/FA	Atmoseal		7.65@96	7.71@96	15.34@96	flat	3
spare			three	Hyundai	20061367TID009	2007	13.2-13.2-230kV	+2, -2	192/256	OA/FA	COPS		7.59@96	7.607@96		flat	
Little Goose	T1A	1-4	single	West	7001429	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.56@82	17.66@82	41.51@82	flat	3
Little Goose	T1B	1-4	single	West	7001428	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.83@82	17.66@82	40.53@82	flat	3
Little Goose	T1C	1-4	single	West	7001427	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.63@82	17.70@82	40.45@82	flat	3
Little Goose	T2A	5-6	single	West	7002545	1978	13.2-13.2-500kV	+3, -1	82/109	OA/FA	N2 Blanket		9.20@41	9.30@41		flat	3
Little Goose	T2B	5-6	single	West	7002546	1978	13.2-13.2-500kV	+3, -1	82/109	OA/FA	N2 Blanket		9.20@41	9.40@41		flat	3
Little Goose	T2C	5-6	single	West	7002548	1978	13.2-13.2-500kV	+3, -1	82/109	OA/FA	N2 Blanket		9.30@41	9.50@41		flat	3
spare			single	HICO	TA80097205	2007	13.2-13.2-500kV	+3, -1	82/109	OA/FA	COPS		9.68@41	9.64@41		flat	
Lookout Point	T1	1	three	Penn	23561-3	1954	13.2-115kV	+2, -2	48	FOW	N2 Blanket	-	11.3@48	-	-	wheels	B
Lookout Point	T2	2	three	Penn	23561-2	1954	13.2-115kV	+2, -2	48	FOW	N2 Blanket	-	11.3@48	-	-	wheels	B
Lookout Point	T3	3	three	Penn	23561-1	1954	13.2-115kV	+2, -2	48	FOW	N2 Blanket	-	11.3@48	-	-	wheels	B
Lost Creek	T1	1-2	three	FPE	50312-1	1976	13.2-115kV	+2, -2	45/60	OA/FA	N2 Blanket	-	7.1@45	-	-	flat	1
Lower Granite	T1A	1-4	single	West	7002007	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.44@82	17.70@82	40.89@82	flat	3
Lower Granite	T1B	1-4	single	West	7001968	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.56@82	17.82@82	41.10@82	flat	3
Lower Granite	T1C	1-4	single	West	7002026	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.59@82	17.74@82	40.80@82	flat	3
Lower Granite	T2A	5-6	single	West	7002549	1978	13.2-13.2-500kV	+3, -1	82/109	OA/FA	N2 Blanket		9.10@41	9.40@41		flat	3
Lower Granite	T2B	5-6	single	West	7002544	1978	13.2-13.2-500kV	+3, -1	82/109	OA/FA	N2 Blanket		9.10@41	9.40@41		flat	3
Lower Granite	T2C	5-6	single	West	7002547	1978	13.2-13.2-500kV	+3, -1	82/109	OA/FA	N2 Blanket		9.10@41	9.30@41		flat	3
Lower Mon.	T1A	1-4	single	West	7000942	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.83@82	17.66@82	41.28@82	flat	3

Location	XFMR	Unit	Phase	OEM	Serial No.	New In:	Votage		MVA	Cooling	Oil Prot.	Z (%) @ MVA				Base	Tap
							Nominal	2.5% Taps				H-X/Y	H-X	H-Y	X-Y		
Lower Mon.	T1B	1-4	single	West	7000734	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.49@82	17.63@82	40.05@82	flat	3
Lower Mon.	T1C	1-4	single	West	7000943	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.35@82	17.42@82	41.16@82	flat	3
Lower Mon.	T2A	5-6	single	West	7002634	1978	13.2-13.2-500kV	+3, -1	82/109	OA/FA	N2 Blanket		9.20@41	9.60@41	20.90@41	flat	3
Lower Mon.	T2B	5-6	single	West	7002633	1978	13.2-13.2-500kV	+3, -1	82/109	OA/FA	N2 Blanket		9.30@41	9.60@41	21.30@41	flat	3
Lower Mon.	T2C	5-6	single	West	7002635	1978	13.2-13.2-500kV	+3, -1	82/109	OA/FA	N2 Blanket		9.10@41	9.50@41	20.70@41	flat	3
McNary	T1A	1-2	single	ABB	LN9629-7	2008	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.47@20	5.49@20	11.06@20	wheels	4
McNary	T1B	1-2	single	ABB	LN9629-8	2008	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.42@20	5.41@20	10.93@20	wheels	4
McNary	T1C	1-2	single	ABB	LN9629-9	2008	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.45@20	5.46@20	10.99@20	wheels	4
McNary	T2A	3-4	single	ABB	LN9629-18	2009	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.36@20	5.42@20	10.87@20	wheels	4
McNary	T2B	3-4	single	ABB	LN9629-14	2009	13.2-13.2-230kV	+3, -1	40/3/66.7	OA/FA/FA	COPS		5.49@20	5.44@20	10.98@20	wheels	4
McNary	T2C	3-4	single	ABB	LN9629-16	2009	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.43@20	5.40@20	10.92@20	wheels	4
McNary	T3A	5-6	single	ABB	LNL9629-1	2004	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.42@20	5.45@20	10.96@20	wheels	4
McNary	T3B	5-6	single	ABB	LNL9629-2	2004	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.41@20	5.48@20	11.06@20	wheels	4
McNary	T3C	5-6	single	ABB	LNL9629-3	2004	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.53@20	5.52@20	11.06@20	wheels	4
McNary	T4A	7-8	single	ABB	LNL9629-10	2009	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.44@20	5.43@20	10.96@20	wheels	4
McNary	T4B	7-8	single	ABB	LNL9629-11	2009	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.44@20	5.43@20	10.94@20	wheels	4
McNary	T4C	7-8	single	ABB	LNL9629-12	2009	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.45@20	5.47@20	11.16@20	wheels	4
McNary	T5A	9-10	single	ABB	LNL9629-13	2009	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.44@20	5.45@20	10.98@20	wheels	4
McNary	T5B	9-10	single	ABB	LNL9629-15	2009	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.43@20	5.41@20	10.92@20	wheels	4
McNary	T5C	9-10	single	ABB	LNL9629-17	2009	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.43@20	5.45@20	10.96@20	wheels	4
McNary	T6A	11-12	single	ABB	LNL9629-4	2006	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.54@20	5.52@20	11.15@20	wheels	4
McNary	T6B	11-12	single	ABB	LNL9629-5	2006	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.50@20	5.52@20	11.10@20	wheels	4
McNary	T6C	11-12	single	ABB	LNL9629-6	2006	13.2-13.2-230kV	+3, -1	40/53/66.7	OA/FA/FA	COPS		5.53@20	5.50@20	11.12@20	wheels	4
McNary	T7A	13-14	single	ABB	LNL9628-1	2004	13.2-13.2-115kV	+2, -2	40/53/66.7	OA/FA/FA	COPS		8.24@20	8.18@20	16.48@20	wheels	4
McNary	T7B	13-14	single	ABB	LNL9628-2	2006	13.2-13.2-115kV	+2, -2	40/53/66.7	OA/FA/FA	COPS		8.16@20	8.13@20	16.34@20	wheels	4
McNary	T7C	13-14	single	ABB	LNL9628-3	2006	13.2-13.2-115kV	+2, -2	40/53/66.7	OA/FA/FA	COPS		8.28@20	8.17@20	16.50@20	wheels	4

North Pacific Region
Spare Transformer Project

Updated Spare Transformer Plan

Attachment C

Condition Assessment

24 September 2012

Prepared By: Hydroelectric Design Center
CENWP-HDC-E

Location	Transformer	OEM	Years Old	HydroAMP Condition Index (May 2012)		Data Quality Indicator (note 1)	Evaluation Date
Albeni Falls	T1	Penn	60	8.3	Good	10	9/7/2011
Albeni Falls	T2	Penn	60	8.3	Good	10	9/7/2011
Albeni Falls	T3	Penn	60	8.3	Good	10	9/7/2011
Bonneville PH1	T1/2 A	ABB	17	10	Good	10	12/19/2011
Bonneville PH1	T1/2 B	ABB	17	10	Good	10	12/19/2011
Bonneville PH1	T1/2 C	ABB	17	10	Good	10	12/19/2011
Bonneville PH1	T3/4 A	ABB	17	10	Good	10	12/19/2011
Bonneville PH1	T3/4 B	ABB	17	9.2	Good	10	12/19/2011
Bonneville PH1	T3/4 C	ABB	17	10	Good	10	12/19/2011
Bonneville PH1	T5/6 A	ABB	17	10	Good	10	12/19/2011
Bonneville PH1	T5/6 B	ABB	17	10	Good	10	12/19/2011
Bonneville PH1	T5/6 C	ABB	17	10	Good	10	12/19/2011
Bonneville PH1	T7/8 A	ABB	17	9.2	Good	10	12/19/2011
Bonneville PH1	T7/8 B	ABB	17	10	Good	10	12/19/2011
Bonneville PH1	T7/8 C	ABB	17	10	Good	10	12/19/2011
Bonneville PH1	T9/10 A	ABB	17	10	Good	10	12/19/2011
Bonneville PH1	T9/10 B	ABB	17	9.2	Good	10	12/19/2011
Bonneville PH1	T9/10 C	ABB	17	10	Good	10	12/19/2011
Bonneville PH2	T11	GE	32	8.8	Good	10	12/19/2011
Bonneville PH2	T12	GE	32	8.8	Good	10	12/19/2011
spare		GE	32	6.5	Fair	10	12/19/2011
Chief Joseph	T1A	GE	26	10	Good	10	9/24/2011
Chief Joseph	T1B	GE	26	10	Good	10	9/24/2011
Chief Joseph	T1C	GE	26	10	Good	10	9/24/2011
Chief Joseph	T2A	GE	28	10	Good	10	9/24/2011
Chief Joseph	T2B	GE	28	10	Good	10	9/24/2011
Chief Joseph	T2C	GE	28	10	Good	10	9/24/2011
Chief Joseph	T3A	GE	28	10	Good	10	9/24/2011
Chief Joseph	T3B	GE	28	10	Good	10	9/24/2011
Chief Joseph	T3C	GE	28	10	Good	10	9/24/2011
Chief Joseph	T4A	GE	27	10	Good	10	9/24/2011
Chief Joseph	T4B	GE	28	10	Good	10	9/24/2011
Chief Joseph	T4C	GE	28	10	Good	10	9/24/2011
Chief Joseph	T5A	GE	36	9.5	Good	10	9/24/2011
Chief Joseph	T5B	GE	36	8.4	Good	10	9/24/2011
Chief Joseph	T5C	GE	36	8.4	Good	10	9/24/2011
Chief Joseph	T6A	GE	34	8.4	Good	10	9/24/2011
Chief Joseph	T6B	GE	34	8.4	Good	10	9/24/2011
Chief Joseph	T6C	GE	34	8.4	Good	10	9/24/2011
Chief Joseph	T7A	GE	34	8.4	Good	10	9/24/2011
Chief Joseph	T7B	GE	34	8.4	Good	10	9/24/2011
Chief Joseph	T7C	GE	34	8.4	Good	10	9/24/2011
spare	230kV	GE	28	10	Good	10	9/24/2011
spare	500kV	GE	35	6.9	Fair	10	9/24/2011
Cougar	T1	A-C	49	7.3	Fair	7	9/28/2011
The Dalles	TA-a	Central	56	8.1	Good	10	6/14/2011
The Dalles	TA-b	Central	56	7	Fair	10	6/14/2011
The Dalles	TA-c	Central	56	7	Fair	10	6/14/2011
spare		Central	56	5.4	Marginal	7	6/30/2011
The Dalles	T1A	Ferranti	56	6.4	Fair	10	6/29/2011

Location	Transformer	OEM	Years Old	HydroAMP Condition Index (May 2012)		Data Quality Indicator	Evaluation Date
						(note 1)	
The Dalles	T1B	Ferranti	56	5.2	Marginal	10	6/29/2011
The Dalles	T1C	Ferranti	56	6.4	Fair	10	6/29/2011
The Dalles	T2A	VA Tech	7	8.3	Good	10	6/15/2011
The Dalles	T2B	VA Tech	7	8.3	Good	10	6/15/2011
The Dalles	T2C	VA Tech	7	8.3	Good	10	6/15/2011
The Dalles	T3A	Ferranti	56	7.3	Fair	7	6/29/2011
The Dalles	T3B	Ferranti	56	7.3	Fair	7	6/29/2011
The Dalles	T3C	Ferranti	56	7.1	Fair	7	6/29/2011
The Dalles	T4A	Hyundai	3	8.3	Good	10	6/15/2011
The Dalles	T4B	Hyundai	3	9.2	Good	10	6/15/2011
The Dalles	T4C	Hyundai	3	9.2	Good	10	6/15/2011
The Dalles	T5A	Ferranti	56	6.6	Fair	10	6/29/2011
The Dalles	T5B	Ferranti	56	6.2	Fair	10	6/29/2011
The Dalles	T5C	Ferranti	56	6.6	Fair	10	6/29/2011
The Dalles	T6A	Ferranti	56	6.6	Fair	10	6/29/2011
The Dalles	T6B	Ferranti	56	6.2	Fair	10	6/29/2011
The Dalles	T6C	Ferranti	56	6.2	Fair	10	6/29/2011
The Dalles	T7A	Ferranti	56	5.8	Marginal	10	6/29/2011
The Dalles	T7B	Ferranti	56	6.2	Fair	10	6/29/2011
The Dalles	T7C	Ferranti	56	4.7	Marginal	10	6/29/2011
The Dalles	T8	GE	40	7.4	Fair	7	6/15/2011
The Dalles	T9	GE	40	8.6	Good	7	6/15/2011
The Dalles	T10	GE	40	8.6	Good	7	6/15/2011
The Dalles	T11	GE	40	7.8	Fair	10	6/15/2011
Detroit	T1A	Penn	61	7	Fair	4	9/29/2011
Detroit	T1B	Penn	61	6	Fair	4	9/29/2011
Detroit	T1C	Penn	61	6.8	Fair	7	9/29/2011
Detroit	T2A	Penn	61	7.3	Fair	7	9/29/2011
Detroit	T2B	Penn	61	6.4	Fair	7	9/29/2011
Detroit	T2C	Penn	61	8.1	Good	7	9/29/2011
spare (note 2)		HICO	6				
Dexter	T1	Moloney	57	7.3	Fair	7	9/28/2011
Dworshak	TW1	West	41	9.5	Good	10	3/5/2012
Dworshak	T1A	West	41	7.2	Fair	10	9/7/2011
Dworshak	T1B	West	41	9.5	Good	10	9/7/2011
Dworshak	T1C	West	41	9.5	Good	10	9/7/2011
spare (note 2)		HICO	5				
Foster	T1	West	46	8.6	Good	7	9/29/2011
Green Peter	T1	GE	10	9	Good	10	9/29/2011
Hills Creek	T1	West	51	8.1	Good	4	9/29/2011
Ice Harbor	T1	Wagner	52	9	Good	10	6/7/2011
Ice Harbor	T2	Wagner	52	9	Good	10	6/7/2011
Ice Harbor	T3	Wagner	52	9	Good	10	6/7/2011
Ice Harbor	T4	FPE	37	9.5	Good	10	6/7/2011
Ice Harbor	T5	FPE	37	9.5	Good	10	6/7/2011
Ice Harbor	T6	FPE	37	2.7	Poor	10	6/7/2011
John Day	T1A	West	45	6.7	Fair	10	4/24/2012

Location	Transformer	OEM	Years Old	HydroAMP Condition Index (May 2012)		Data Quality Indicator (note 1)	Evaluation Date
John Day	T1B	West	45	6.7	Fair	10	4/24/2012
John Day	T1C	West	45	6.7	Fair	10	4/24/2012
John Day	T2A	West	45	7.8	Fair	10	4/24/2012
John Day	T2B	West	45	7.4	Fair	10	4/24/2012
John Day	T2C	West	45	7.8	Fair	10	4/24/2012
John Day	T3A	West	45	7.4	Fair	10	4/24/2012
John Day	T3B	West	45	8.6	Good	10	4/24/2012
John Day	T3C	West	45	8.6	Good	10	4/24/2012
John Day	T4A	West	45	7.4	Fair	10	4/24/2012
John Day	T4B	West	45	7.4	Fair	10	4/24/2012
John Day	T4C	West	45	7.4	Fair	10	4/24/2012
spare		West	45	7.8	Fair	0	4/24/2012
Libby	T1	West	38	7.6	Fair	7	7/26/2011
Libby	T2	West	38	7.6	Fair	10	7/26/2011
Libby	T3	GE	38	8.9	Good	10	7/26/2011
spare (note 2)		Hyundai	5				
Little Goose	T1A	West	45	9.5	Good	10	9/8/2011
Little Goose	T1B	West	45	9.5	Good	10	9/8/2011
Little Goose	T1C	West	45	9.5	Good	10	9/8/2011
Little Goose	T2A	West	34	9.5	Good	10	9/8/2011
Little Goose	T2B	West	34	9.5	Good	10	9/8/2011
Little Goose	T2C	West	34	9.5	Good	10	9/8/2011
spare (note 2)		HICO	5				
Lookout Point	T1	Penn	58	8.1	Good	7	9/29/2011
Lookout Point	T2	Penn	58	8.1	Good	7	9/28/2011
Lookout Point	T3	Penn	58	9	Good	7	9/28/2011
Lost Creek	T1	FPE	36	5.3	Marginal	10	8/27/2012
Lower Granite	T1A	West	45	9.5	Good	10	9/8/2011
Lower Granite	T1B	West	45	9.5	Good	10	9/8/2011
Lower Granite	T1C	West	45	9.5	Good	10	9/8/2011
Lower Granite	T2A	West	34	9.5	Good	10	9/8/2011
Lower Granite	T2B	West	34	9.5	Good	10	9/8/2011
Lower Granite	T2C	West	34	9.5	Good	10	9/8/2011
Lower Monumental	T1A	West	45	8.8	Good	10	8/16/2011
Lower Monumental	T1B	West	45	8.8	Good	10	8/16/2011
Lower Monumental	T1C	West	45	8.8	Good	10	8/16/2011
Lower Monumental	T2A	West	34	8.8	Good	10	8/16/2011
Lower Monumental	T2B	West	34	8.8	Good	10	8/16/2011
Lower Monumental	T2C	West	34	8.8	Good	10	8/16/2011
McNary	T1A	ABB	4	10	Good	7	9/8/2011
McNary	T1B	ABB	4	10	Good	7	9/8/2011
McNary	T1C	ABB	4	10	Good	7	9/8/2011
McNary	T2A	ABB	3	9.2	Good	10	9/8/2011
McNary	T2B	ABB	3	10	Good	10	9/8/2011
McNary	T2C	ABB	3	10	Good	10	9/8/2011
McNary	T3A	ABB	8	10	Good	10	9/8/2011
McNary	T3B	ABB	8	10	Good	10	9/8/2011
McNary	T3C	ABB	8	10	Good	10	9/8/2011

Condition Assessment

Location	Transformer	OEM	Years Old	HydroAMP Condition Index (May 2012)		Data Quality Indicator (note 1)	Evaluation Date
McNary	T4A	ABB	3	8.9	Good	10	9/8/2011
McNary	T4B	ABB	3	10	Good	10	9/8/2011
McNary	T4C	ABB	3	10	Good	10	9/8/2011
McNary	T5A	ABB	3	10	Good	10	9/8/2011
McNary	T5B	ABB	3	10	Good	10	9/8/2011
McNary	T5C	ABB	3	10	Good	10	9/8/2011
McNary	T6A	ABB	6	8.9	Good	10	9/8/2011
McNary	T6B	ABB	6	10	Good	10	9/8/2011
McNary	T6C	ABB	6	8.9	Good	10	9/8/2011
McNary	T7A	ABB	8	10	Good	10	9/8/2011
McNary	T7B	ABB	6	10	Good	10	9/8/2011
McNary	T7C	ABB	6	10	Good	10	9/8/2011
Notes:	1. DQI is a measure of the integrity, availability and age of the data provided to determine the CI. A DQI of 4 or less usually indicates that the data is more than two years old.						
	2. There is no hydroAmp data available for this spare as of May 2012.						

North Pacific Region
Spare Transformer Project

Updated Spare Transformer Plan

Attachment D

Economic Impacts

24 September 2012

Prepared By: Hydroelectric Design Center
CENWP-HDC-E

Location	Transformer	OEM	Phase	Tx Failure Affects		Annual Revenue Lost for Tx outage ($)	Revenue Lost per Failure (M$)		Saved by having spare ($)	Est. Cost of Spare ($)
				# of Units	MW		with spare (4 mo outage)	without spare (24 mo outage)		
Albeni Falls	T1	Penn	three	1	14.2	$ 590,000	$ 194,700	$ 1,180,000	$ 985,300	$ 764,500
Albeni Falls	T2	Penn	three	1	14.2	$ 590,000	$ 194,700	$ 1,180,000	$ 985,300	$ 764,500
Albeni Falls	T3	Penn	three	1	14.2	$ 590,000	$ 194,700	$ 1,180,000	$ 985,300	$ 764,500
Bonneville PH1 (note 1)	T1/2 A	ABB	single	1	51.35	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 1,111,000
Bonneville PH1 (note 1)	T1/2 B	ABB	single	1	51.35	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 1,111,000
Bonneville PH1 (note 1)	T1/2 C	ABB	single	1	51.35	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 1,111,000
Bonneville PH1 (note 1)	T3/4 A	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 973,000
Bonneville PH1 (note 1)	T3/4 B	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 973,000
Bonneville PH1 (note 1)	T3/4 C	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 973,000
Bonneville PH1 (note 1)	T5/6 A	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 973,000
Bonneville PH1 (note 1)	T5/6 B	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 973,000
Bonneville PH1 (note 1)	T5/6 C	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 973,000
Bonneville PH1 (note 1)	T7/8 A	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 973,000
Bonneville PH1 (note 1)	T7/8 B	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 973,000
Bonneville PH1 (note 1)	T7/8 C	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 973,000
Bonneville PH1 (note 1)	T9/10 A	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 1,111,000
Bonneville PH1 (note 1)	T9/10 B	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 1,111,000
Bonneville PH1 (note 1)	T9/10 C	ABB	single	1	54	$ 1,095,000	$ 361,350	$ 2,190,000	$ 1,828,650	$ 1,111,000
Bonneville PH1 (note 2)	T1/2 A	ABB	single	2	102.7	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 1,111,000
Bonneville PH1 (note 2)	T1/2 B	ABB	single	2	102.7	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 1,111,000
Bonneville PH1 (note 2)	T1/2 C	ABB	single	2	102.7	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 1,111,000
Bonneville PH1 (note 2)	T3/4 A	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 973,000
Bonneville PH1 (note 2)	T3/4 B	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 973,000
Bonneville PH1 (note 2)	T3/4 C	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 973,000
Bonneville PH1 (note 2)	T5/6 A	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 973,000
Bonneville PH1 (note 2)	T5/6 B	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 973,000
Bonneville PH1 (note 2)	T5/6 C	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 973,000
Bonneville PH1 (note 2)	T7/8 A	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 973,000
Bonneville PH1 (note 2)	T7/8 B	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 973,000
Bonneville PH1 (note 2)	T7/8 C	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 973,000
Bonneville PH1 (note 2)	T9/10 A	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 1,111,000
Bonneville PH1 (note 2)	T9/10 B	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 1,111,000
Bonneville PH1 (note 2)	T9/10 C	ABB	single	2	108	$ 2,439,000	$ 804,870	$ 4,878,000	$ 4,073,130	$ 1,111,000

Economic Impacts

Location	Transformer	OEM	Phase	Tx Failure Affects		Annual Revenue Lost for Tx outage ($)	Revenue Lost per Failure (M$)		Saved by having spare ($)	Est. Cost of Spare ($)
				# of Units	MW		**with spare** (4 mo outage)	**without spare** (24 mo outage)		
Bonneville PH2	T11	GE	three	4	266	$ 6,783,000	$ 2,238,390	$ 13,566,000	$ 11,327,610	$ 6,842,500
Bonneville PH2	T12	GE	three	4	266	$ 6,783,000	$ 2,238,390	$ 13,566,000	$ 11,327,610	$ 6,842,500
spare		GE	three							
Chief Joseph	T1A	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T1B	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T1C	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T2A	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T2B	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T2C	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T3A	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T3B	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T3C	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T4A	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T4B	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T4C	GE	single	4	353	$ 21,999,000	$ 7,259,670	$ 43,998,000	$ 36,738,330	$ 1,792,000
Chief Joseph	T5A	GE	single	4	380	$ 35,419,000	$ 11,688,270	$ 70,838,000	$ 59,149,730	$ 2,099,650
Chief Joseph	T5B	GE	single	4	380	$ 35,419,000	$ 11,688,270	$ 70,838,000	$ 59,149,730	$ 2,099,650
Chief Joseph	T5C	GE	single	4	380	$ 35,419,000	$ 11,688,270	$ 70,838,000	$ 59,149,730	$ 2,099,650
Chief Joseph	T6A	GE	single	4	380	$ 35,419,000	$ 11,688,270	$ 70,838,000	$ 59,149,730	$ 2,099,650
Chief Joseph	T6B	GE	single	4	380	$ 35,419,000	$ 11,688,270	$ 70,838,000	$ 59,149,730	$ 2,099,650
Chief Joseph	T6C	GE	single	4	380	$ 35,419,000	$ 11,688,270	$ 70,838,000	$ 59,149,730	$ 2,099,650
Chief Joseph	T7A	GE	single	3	285	$ 21,524,000	$ 7,102,920	$ 43,048,000	$ 35,945,080	$ 1,697,500
Chief Joseph	T7B	GE	single	3	285	$ 21,524,000	$ 7,102,920	$ 43,048,000	$ 35,945,080	$ 1,697,500
Chief Joseph	T7C	GE	single	3	285	$ 21,524,000	$ 7,102,920	$ 43,048,000	$ 35,945,080	$ 1,697,500
spare		GE	single							
spare		GE	single							
Cougar	T1	A-C	three	2	25	$ 5,579,000	$ 1,841,070	$ 11,158,000	$ 9,316,930	$ 940,000
The Dalles	TA-a	Central	single	2	27	$ 154,937	$ 51,129	$ 309,873	$ 258,744	$ 1,151,500
The Dalles	TA-b	Central	single	2	27	$ 154,937	$ 51,129	$ 309,873	$ 258,744	$ 1,151,500
The Dalles	TA-c	Central	single	2	27	$ 154,937	$ 51,129	$ 309,873	$ 258,744	$ 1,151,500
spare		Central	single							

Location	Transformer	OEM	Phase	Tx Failure Affects		Annual Revenue Lost for Tx outage ($)	Revenue Lost per Failure (M$)		Saved by having spare ($)	Est. Cost of Spare ($)
				# of Units	MW		with spare (4 mo outage)	without spare (24 mo outage)		
The Dalles	T1A	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,057,000
The Dalles	T1B	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,057,000
The Dalles	T1C	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,057,000
The Dalles	T2A	VA Tech	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,057,000
The Dalles	T2B	VA Tech	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,057,000
The Dalles	T2C	VA Tech	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,057,000
The Dalles	T3A	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T3B	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T3C	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T4A	Hyundai	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T4B	Hyundai	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T4C	Hyundai	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T5A	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T5B	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T5C	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T6A	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T6B	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T6C	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T7A	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T7B	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T7C	Ferranti	single	2	156	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 1,151,500
The Dalles	T8	GE	three	2	172	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 4,334,500
The Dalles	T9	GE	three	2	172	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 4,334,500
The Dalles	T10	GE	three	2	172	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 4,334,500
The Dalles	T11	GE	three	2	172	$ 1,225,000	$ 404,250	$ 2,450,000	$ 2,045,750	$ 4,334,500
Detroit	T1A	Penn	single	1	50	$ 3,760,000	$ 1,240,800	$ 7,520,000	$ 6,279,200	$ 794,500
Detroit	T1B	Penn	single	1	50	$ 3,760,000	$ 1,240,800	$ 7,520,000	$ 6,279,200	$ 794,500
Detroit	T1C	Penn	single	1	50	$ 3,760,000	$ 1,240,800	$ 7,520,000	$ 6,279,200	$ 794,500
Detroit	T2A	Penn	single	1	50	$ 3,760,000	$ 1,240,800	$ 7,520,000	$ 6,279,200	$ 794,500
Detroit	T2B	Penn	single	1	50	$ 3,760,000	$ 1,240,800	$ 7,520,000	$ 6,279,200	$ 794,500
Detroit	T2C	Penn	single	1	50	$ 3,760,000	$ 1,240,800	$ 7,520,000	$ 6,279,200	$ 794,500
spare		HICO	single							
Dexter	T1	Moloney	three	1	15	$ 3,394,000	$ 1,120,020	$ 6,788,000	$ 5,667,980	$ 749,500

Economic Impacts

Location	Transformer	OEM	Phase	Tx Failure Affects		Annual Revenue Lost for Tx outage ($)	Revenue Lost per Failure (M$)		Saved by having spare ($)	Est. Cost of Spare ($)
				# of Units	MW		**with spare** (4 mo outage)	**without spare** (24 mo outage)		
Dworshak	TW1	West	three	1	90	$ 8,152,000	$ 2,690,160	$ 16,304,000	$ 13,613,840	$ 2,740,000
Dworshak	T1A	West	single	2	310	$ 47,533,000	$ 15,685,890	$ 95,066,000	$ 79,380,110	$ 2,191,000
Dworshak	T1B	West	single	2	310	$ 47,533,000	$ 15,685,890	$ 95,066,000	$ 79,380,110	$ 2,191,000
Dworshak	T1C	West	single	2	310	$ 47,533,000	$ 15,685,890	$ 95,066,000	$ 79,380,110	$ 2,191,000
spare		HICO	single							
Foster	T1	West	three	2	20	$ 4,095,000	$ 1,351,350	$ 8,190,000	$ 6,838,650	$ 850,000
Green Peter	T1	GE	three	2	80	$ 10,503,000	$ 3,465,990	$ 21,006,000	$ 17,540,010	$ 1,990,000
Hills Creek	T1	West	three	2	30	$ 6,329,000	$ 2,088,570	$ 12,658,000	$ 10,569,430	$ 1,030,000
Ice Harbor	T1	Wagner	three	1	90	$ 1,108,000	$ 365,640	$ 2,216,000	$ 1,850,360	$ 2,125,000
Ice Harbor	T2	Wagner	three	1	90	$ 1,108,000	$ 365,640	$ 2,216,000	$ 1,850,360	$ 2,125,000
Ice Harbor	T3	Wagner	three	1	90	$ 1,108,000	$ 365,640	$ 2,216,000	$ 1,850,360	$ 2,125,000
Ice Harbor	T4	FPE	three	1	111	$ 1,108,000	$ 365,640	$ 2,216,000	$ 1,850,360	$ 2,500,000
Ice Harbor	T5	FPE	three	1	111	$ 1,108,000	$ 365,640	$ 2,216,000	$ 1,850,360	$ 2,500,000
Ice Harbor	T6	FPE	three	1	111	$ 1,108,000	$ 365,640	$ 2,216,000	$ 1,850,360	$ 2,500,000
John Day	T1A	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
John Day	T1B	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
John Day	T1C	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
John Day	T2A	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
John Day	T2B	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
John Day	T2C	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
John Day	T3A	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
John Day	T3B	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
John Day	T3C	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
John Day	T4A	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
John Day	T4B	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
John Day	T4C	West	single	4	540	$ 10,917,000	$ 3,602,610	$ 21,834,000	$ 18,231,390	$ 2,785,300
spare		West	single							
Libby	T1	West	three	2	210	$ 12,798,000	$ 4,223,340	$ 25,596,000	$ 21,372,660	$ 4,714,000

Location	Transformer	OEM	Phase	Tx Failure Affects		Annual Revenue Lost for Tx outage ($)	Revenue Lost per Failure (M$)		Saved by having spare ($)	Est. Cost of Spare ($)
				# of Units	MW		with spare (4 mo outage)	without spare (24 mo outage)		
Libby	T2	West	three	2	210	$ 12,798,000	$ 4,223,340	$ 25,596,000	$ 21,372,660	$ 4,714,000
Libby	T3	GE	three	1	105	$ 3,782,000	$ 1,248,060	$ 7,564,000	$ 6,315,940	$ 4,714,000
spare		Hyundai	three							
Little Goose	T1A	West	single	4	540	$ 42,715,000	$ 14,095,950	$ 85,430,000	$ 71,334,050	$ 2,785,300
Little Goose	T1B	West	single	4	540	$ 42,715,000	$ 14,095,950	$ 85,430,000	$ 71,334,050	$ 2,785,300
Little Goose	T1C	West	single	4	540	$ 42,715,000	$ 14,095,950	$ 85,430,000	$ 71,334,050	$ 2,785,300
Little Goose	T2A	West	single	2	270	$ 8,262,000	$ 2,726,460	$ 16,524,000	$ 13,797,540	$ 1,634,500
Little Goose	T2B	West	single	2	270	$ 8,262,000	$ 2,726,460	$ 16,524,000	$ 13,797,540	$ 1,634,500
Little Goose	T2C	West	single	2	270	$ 8,262,000	$ 2,726,460	$ 16,524,000	$ 13,797,540	$ 1,634,500
spare		HICO	single							
Lookout Point	T1	Penn	three	1	40	$ 325,000	$ 107,250	$ 650,000	$ 542,750	$ 1,210,000
Lookout Point	T2	Penn	three	1	40	$ 325,000	$ 107,250	$ 650,000	$ 542,750	$ 1,210,000
Lookout Point	T3	Penn	three	1	40	$ 325,000	$ 107,250	$ 650,000	$ 542,750	$ 1,210,000
Lost Creek	T1	FPE	three	2	49	$ 4,404,000	$ 1,453,320	$ 8,808,000	$ 7,354,680	$ 1,390,000
Lower Granite	T1A	West	single	4	540	$ 41,510,000	$ 13,698,300	$ 83,020,000	$ 69,321,700	$ 2,785,300
Lower Granite	T1B	West	single	4	540	$ 41,510,000	$ 13,698,300	$ 83,020,000	$ 69,321,700	$ 2,785,300
Lower Granite	T1C	West	single	4	540	$ 41,510,000	$ 13,698,300	$ 83,020,000	$ 69,321,700	$ 2,785,300
Lower Granite	T2A	West	single	2	270	$ 7,392,000	$ 2,439,360	$ 14,784,000	$ 12,344,640	$ 1,634,500
Lower Granite	T2B	West	single	2	270	$ 7,392,000	$ 2,439,360	$ 14,784,000	$ 12,344,640	$ 1,634,500
Lower Granite	T2C	West	single	2	270	$ 7,392,000	$ 2,439,360	$ 14,784,000	$ 12,344,640	$ 1,634,500
Lower Monumental	T1A	West	single	4	540	$ 34,059,000	$ 11,239,470	$ 68,118,000	$ 56,878,530	$ 2,785,300
Lower Monumental	T1B	West	single	4	540	$ 34,059,000	$ 11,239,470	$ 68,118,000	$ 56,878,530	$ 2,785,300
Lower Monumental	T1C	West	single	4	540	$ 34,059,000	$ 11,239,470	$ 68,118,000	$ 56,878,530	$ 2,785,300
Lower Monumental	T2A	West	single	2	270	$ 4,190,000	$ 1,382,700	$ 8,380,000	$ 6,997,300	$ 1,634,500
Lower Monumental	T2B	West	single	2	270	$ 4,190,000	$ 1,382,700	$ 8,380,000	$ 6,997,300	$ 1,634,500
Lower Monumental	T2C	West	single	2	270	$ 4,190,000	$ 1,382,700	$ 8,380,000	$ 6,997,300	$ 1,634,500
McNary	T1A	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T1B	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T1C	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350

Economic Impacts

Location	Transformer	OEM	Phase	Tx Failure Affects		Annual Revenue Lost for Tx outage ($)	Revenue Lost per Failure (M$)		Saved by having spare ($)	Est. Cost of Spare ($)
				# of Units	MW		with spare (4 mo outage)	without spare (24 mo outage)		
McNary	T2A	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T2B	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T2C	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T3A	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T3B	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T3C	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T4A	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T4B	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T4C	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T5A	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T5B	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T5C	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T6A	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T6B	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T6C	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,190,350
McNary	T7A	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,090,300
McNary	T7B	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,090,300
McNary	T7C	ABB	single	2	140	$ 16,657,000	$ 5,496,810	$ 33,314,000	$ 27,817,190	$ 1,090,300
Notes:	1. Assuming the transfer bus remains.									
	2. Assuming no transfer bus.									

North Pacific Region
Spare Transformer Project

Updated Spare Transformer Plan

Attachment E

Economic Analysis

24 September 2012

Prepared By: Hydroelectric Design Center
CENWP-HDC-E

This analysis is intended to indicate the relative ranking of projects that merit further study to determine the appropriate number of spare transformers for each. It does not address the economics study required to evaluate spare transformer purchase options and timing. This study does not address the probability of failures involving multiple phases (of a bank of single phase transformers) that could require there to be more than one spare transformer available.

Probabilities are based on HydroAMP CI score and Weibull reliability analysis and are for failure during the next year.

Project		Transformer Condition Index (lowest of group)	Transformer Condition Rating (lowest of group)	Probability of Failure for Individual Transformers	Probability of No Failure for Individual Transformers	Number of Identical Transformers	Probability of No Transformer Failure at Project	Probability of Failure for Any Transformer at Project	Revenue saved by having spare	Expected Benefit (revenue saved times probability of failure)	Est. cost of spare	Spare cost per unit	Expected Benefit/Spare cost per unit ratio	Category*
				(Pf)	(1-Pf)	(n)	(1-Pf)^n	1-(1-Pf)^n	($000)	($000)	($000)	($000)		
LGO, LGR, LMO T1	(note 1)(note 2)	8.8	Good	0.0368	0.9632	9	0.7136	0.2864	$ 65,844,760	$ 18,858,651	$ 2,785,300	$ 309,478	60.937	B
Chief Joseph 230kV	(note 3)	10	Good	0.01656	0.9834	12	0.8184	0.1816	$ 36,738,330	$ 6,671,071	$ 1,792,000	$ 149,333	44.672	B
John Day		6.7	Fair	0.04898	0.9510	12	0.5474	0.4526	$ 18,231,390	$ 8,252,193	$ 2,785,300	$ 232,108	35.553	B
Chief Joseph 500kV, T5-T6	(note 4)	8.4	Good	0.02871	0.9713	6	0.8396	0.1604	$ 59,149,730	$ 9,485,207	$ 2,099,650	$ 349,942	27.105	B
Detroit		6	Fair	0.0744	0.9256	6	0.6288	0.3712	$ 6,279,200	$ 2,330,589	$ 794,500	$ 132,417	17.600	B
McNary 230kV	(note 5)	8.9	Good	0.0022	0.9978	18	0.9614	0.0386	$ 27,817,190	$ 1,073,966	$ 1,190,350	$ 66,131	16.240	A
The Dalles 230kV (1p)		4.7	Marginal	0.08057	0.9194	12	0.3649	0.6351	$ 2,045,750	$ 1,299,170	$ 1,151,500	$ 95,958	13.539	A
LGO, LGR, LMO T2	(note 2)(note 6)	8.8	Good	0.0262	0.9738	9	0.7877	0.2123	$ 11,046,493	$ 2,345,421	$ 1,634,500	$ 181,611	12.915	B
Dworshak 500kV		7.2	Fair	0.0411	0.9589	3	0.8817	0.1183	$ 79,380,110	$ 9,388,620	$ 2,191,000	$ 730,333	12.855	B
Chief Joseph 500kV, T7		8.4	Good	0.02773	0.9723	3	0.9191	0.0809	$ 35,945,080	$ 2,908,117	$ 1,697,500	$ 565,833	5.140	A
Bonneville PH1 230kV	(note 7)	9.2	Good	0.0105	0.9895	9	0.9093	0.0907	$ 4,073,130	$ 369,471	$ 973,000	$ 108,111	3.418	A
Bonneville PH1 230kV	(note 8)	9.2	Good	0.0105	0.9895	9	0.9093	0.0907	$ 1,828,650	$ 165,876	$ 973,000	$ 108,111	1.534	A
Libby	(note 9)	7.6	Fair	0.0355	0.9645	3	0.8971	0.1029	$ 21,372,660	$ 2,198,726	$ 4,714,000	$ 1,571,333	1.399	B
Bonneville PH1 115kV	(note 7)	9.2	Good	0.0105	0.9895	6	0.9386	0.0614	$ 4,073,130	$ 250,197	$ 1,111,000	$ 185,167	1.351	A
The Dalles T1	(note 10)	5.2	Marginal	0.0755	0.9245	3	0.7901	0.2099	$ 2,045,750	$ 429,311	$ 1,057,000	$ 352,333	1.218	A
McNary 115kV	(note 11)	10	Good	0.0028	0.9972	3	0.9916	0.0084	$ 27,817,190	$ 234,919	$ 1,090,300	$ 363,433	0.646	C
Albeni Falls		8.3	Good	0.0554	0.9446	3	0.8429	0.1571	$ 985,300	$ 154,747	$ 764,500	$ 254,833	0.607	C
Bonneville PH1 115kV	(note 8)	9.2	Good	0.0105	0.9895	6	0.9386	0.0614	$ 1,828,650	$ 112,327	$ 1,111,000	$ 185,167	0.607	C
Cougar		7.3	Fair	0.0496	0.9504	1	0.9504	0.0496	$ 9,316,930	$ 461,840	$ 940,000	$ 940,000	0.491	C
Hills Creek		8.1	Good	0.0468	0.9532	1	0.9532	0.0468	$ 10,569,430	$ 494,438	$ 1,030,000	$ 1,030,000	0.480	C
Dexter		7.3	Fair	0.0589	0.9412	1	0.9412	0.0589	$ 5,667,980	$ 333,561	$ 749,500	$ 749,500	0.445	C
Ice Harbor T1-T3		9	Good	0.0428	0.9572	3	0.8770	0.1230	$ 1,850,360	$ 227,613	$ 2,125,000	$ 708,333	0.321	C
Foster		8.6	Good	0.0388	0.9612	1	0.9612	0.0388	$ 6,838,650	$ 265,203	$ 850,000	$ 850,000	0.312	C
The Dalles 230kV (3p)		7.4	Fair	0.0388	0.9612	4	0.8536	0.1464	$ 2,045,750	$ 299,568	$ 4,334,500	$ 1,083,625	0.276	C
Lost Creek		5.3	Marginal	0.0484	0.9516	1	0.9516	0.0484	$ 7,354,680	$ 355,967	$ 1,390,000	$ 1,390,000	0.256	C
Lookout Point		8.1	Good	0.0545	0.9456	3	0.8454	0.1546	$ 542,750	$ 83,918	$ 1,210,000	$ 403,333	0.208	C
Bonneville PH2		8.8	Good	0.02431	0.9757	2	0.9520	0.0480	$ 11,327,610	$ 544,054	$ 6,842,500	$ 3,421,250	0.159	D
Dworshak 115kV		9.5	Good	0.0300	0.9700	1	0.9700	0.0300	$ 13,613,840	$ 408,007	$ 2,740,000	$ 2,740,000	0.149	C
The Dalles TA		7	Fair	0.0599	0.9401	3	0.8308	0.1692	$ 258,744	$ 43,767	$ 1,151,500	$ 383,833	0.114	D
Ice Harbor T4-T5		9.5	Good	0.0264	0.9736	2	0.9480	0.0520	$ 1,850,360	$ 96,301	$ 2,500,000	$ 1,250,000	0.077	C
The Dalles T2		8.3	Good	0.0043	0.9957	3	0.9872	0.0128	$ 2,045,750	$ 26,155	$ 1,057,000	$ 352,333	0.074	C
Ice Harbor T6	(note 12)	2.7	Poor	0.0799	0.9201	1	0.9201	0.0799	$ 1,850,360	$ 147,825	$ 2,500,000	$ 2,500,000	0.059	C
Green Peter		9	Good	0.0057	0.9943	1	0.9943	0.0057	$ 17,540,010	$ 99,627	$ 1,990,000	$ 1,990,000	0.050	C
The Dalles T4		8.3	Good	0.00156	0.9984	3	0.9953	0.0047	$ 2,045,750	$ 9,559	$ 1,151,500	$ 383,833	0.025	C

Notes
1. Existing John Day spare fits Lower Monumental, Lower Granite, and Little Goose T1 phases.
2. Revenue Saved by Spare for LGO, LGR, LMO T1 and T2 are averages of values from the three plants.
3. Group includes units of age 26-28 years, for calculations, 27 years was used.
4. Group includes units of age 34-36 years, for calculations, average of 35 was used.
5. Group age ranges from 3-8 years, with average age of 4.5 years. The probability of failure value is the average between the probability of failure for 4 and 5 years.
6. A spare could replace any of the Lower Monumental, Lower Granite, or Little Goose T2 phases.
7. Assuming no transfer bus.
8. Assuming the transfer bus remains.
9. Revenue saved is based on the loss of either T1 or T2 at Libby.
10. Assumes a new spare could be used for both The Dalles T1 and T2 transformers.
11. Group includes units of age 6 and 8 years. This value is the average of the probability of failure for the group of transformers.
12. T6 is about to be replaced.

* Category A - No spare exists and one or more appears justified
Category B - Spare exists and one or more appears justified
Category D - Spare exists and no spare appears justified
Category C - No spare exists and no spare appears justified

North Pacific Region
Spare Transformer Project

Updated Spare Transformer Plan

Attachment F

Spare Transformer Plan

24 September 2012

Prepared By: Hydroelectric Design Center
CENWP-HDC-E

Location	XFMR	Phase	OEM	New In:	Voltage		MVA	Cooling	Oil Prot.	~Z (%) @ MVA				Base			Spare Plan	
					Nominal	2.5% Taps				H-X/Y	H-X	H-Y	X-Y	Type	Rail	Rail/Wheels	Now	Future
															Gauge	Centers		
Albeni Falls	T1-T3	three	Penn	1952	13.2-115kV	+1, -3	13.75/18.3	OA/FA	N2 Blanket	-	8@13.75	-	-	wheels	56.5"		expedited repair/used market	Category C - evaluate shared spare (ALF and DEX)
Bonneville PH1	T1/2, T9/10	single	ABB	1995	13.2-115kV	+2, -2	69	FOA	COPS	-	11@69	-	-	wheels	84.375"	87"	transfer one unit/ expedite repair	Category A - evaluate spare purchase timing
	T3/4, T5/6, T	single	ABB	1995	13.2-230kV	+2, -2	46	FOA	COPS	-	11.5@46	-	-	wheels	87"		transfer one unit/ expedite repair	Category A - evaluate spare purchase timing
Bonneville PH2	T11, T12	three	GE	1980	13.8-13.8-230kV	+2, -2	344/385	FOA	Atmoseal		14.5@172	14.6@172	27.5@172	flat			use existing Bon PH2 500kV spare	Category D - take no action
Chief Joseph	T1-T4	single	GE	1986	13.2-13.2-230kV	+2, -2	124	FOW	Atmoseal	12.4@124	12.3@62	12.3@62		wheels		88"	use existing CJ 230kV spare	Category B - evaluate additional spare purchase timing
	T5-T6	single	GE	1976	13.8-13.8-500kV	+4, -0	115/153.3	OA/FA	Atmoseal	11.5@115	11.5@575	11.4@575		flat			use existing CJ 500kV spare	Category B - evaluate additional spare purchase timing
	T7	single	GE	1978	13.8-13.8-500kV	+4, -0	86.2/115	OA/FA	Atmoseal	5.7@575	11.2@575	5.5@287.5		flat			use existing CJ 500kV spare (for T5-T6)	Category A - evaluate spare purchase timing
Cougar	T1	three	A-C	1963	6.6-115kV	+4, -0	30	FOA	N2 Blanket	-	10.1@30	-	-	flat			expedited repair/used market	Category C - evaluate shared spare (COU, FOS, HCR)
The Dalles	TA	single	Central	1956	13.2-115kV	+2, -2	8.72/10.9	OA/FA	N2 Blanket	-	7.4@8.72	-	-	wheels		84.25"	use existing TDA 115kV spare	Category D - take no action
	T1	single	Ferranti	1956	13.2-115kV	+2, -2	63	FOW	N2 Blanket	-	12.4@63	-	-	wheels		84.25"	expedited repair/used market	Category A - evaluate spare purchase timing
	T2	single	VA Tech	2005	13.2-115kV	+2, -2	37.8/50.4/63	OA/FA/FA	COPS	-	7.5@37.8	-	-	flat			expedited repair/used market	Category C - evaluate shared spare (BON and TDA)
	T3, T5-T7	single	Ferranti	1956	13.2-230kV	+2, -2	63	FOW	N2 Blanket	-	17@63	-	-	wheels		84.25"	use existing TDA 230kV spare	Category A - evaluate spare purchase timing
	T4	single	Hyundai	2009	13.2-230kV	+2, -3	37.8/50.4/63	OA/FA/FA	COPS	-	10.2@37.8	-	-	flat			use existing TDA 230kV spare	Category C - evaluate need for spare
	T8-T11	three	GE	1972	13.2-230kV	+2, -2	208/233	FOA	N2 Blanket	-	12.9@208	-	-	flat			expedited repair/used market	Category C - evaluate need for spare
Detroit	T1, T2	single	Penn	1951	13.2-230kV	+2, -2	29	FOW	N2 Blanket	-	7.2@29	-	-	wheels		84"	use existing DET 230kV spare	Category B - evaluate additional spare purchase timing
Dexter	T1	three	Moloney	1955	13.2-115kV	+2, -2	13/17.3	OA/FA	N2 Blanket	-	7.41@13	-	-	wheels	56.5"	56.125"	expedited repair/used market	Category C - evaluate shared spare (ALF and DEX)
Dworshak	TW1	three	West	1971	13.2-115kV	+8, -8 (LTC)	150	FOA		-	15.1@150	-	-				expedited repair/used market	Category C - evaluate need for spare
	T1	single	West	1971	13.8-13.8-500kV	+4, -0	121.5/162	OA/FA	N2 Blanket	11.2@109.5	15.6@66.75	13.5@54.75	30.1@54.75	flat			use existing DWK 500kV spare	Category B - evaluate additional spare purchase timing
Foster	T1	three	West	1966	4-115kV	+2, -2	18/24	OA/FA	N2 Blanket	-	9.83@18	-	-	flat			expedited repair/used market	Category C - evaluate shared spare (COU, FOS, HCR)
Green Peter	T1	three	GE	1966	13.2-115kV	+2, -2	73.5/98	OA/FA	N2 Blanket	-	7.89@75	-	-	flat			expedited repair/used market	Category C - evaluate need for spare
Hills Creek	T1	three	West	1961	6.6-115kV	+2, -2	27/36	OA/FA	N2 Blanket	-	6.97@27	-	-	flat			expedited repair/used market	Category C - evaluate shared spare (COU, FOS, HCR)
Ice Harbor	TW1-TW3	three	Wagner	1960	13.2-115kV	+2, -2	109	FOW	N2 Blanket	-	10.9@109	-	-	flat			expedited repair/used market	Category C - evaluate shared spare (IHR)
	TW4-TW6	three	FPE	1975	13.2-115kV	+2, -2	134	FOA	N2 Blanket	-	10@109	-	-	wheels		84"	expedited repair/used market	Category C - evaluate shared spare (IHR)
John Day	T1-T4	single	West	1967	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.5@82	17.7@82	41@82	flat			use existing JDA 500kV spare/expedited repair/used market	Category B - evaluate additional spare purchase timing
Libby	T1-T3	three	West/GE	1974	13.2-13.2-230kV	+2, -2	192/256	OA/FA	N2 Blanket		7.5@96	7.6@96	16.9@96	flat			use existing LIB 230kV spare	Category B - evaluate additional spare purchase timing
LMN, LGS, LGR	T1	single	West	1978	13.2-13.2-500kV	+3, -1	164/218.6	OA/FA	N2 Blanket		17.6@82	17.7@82	41@82	flat			use existing JDA 500kV spare/expedited repair/used market	Category B - evaluate additional spare purchase timing
	T2	single	West	1978	13.2-13.2-500kV	+3, -1	82/109	OA/FA	N2 Blanket		9.2@41	9.4@41	21@41	flat			use existing LGS, LMN, LGR 500kV spare	Category B - evaluate additional spare purchase timing
Lookout Point	T1-T3	three	Penn	1954	13.2-115kV	+2, -2	48	FOW	N2 Blanket	-	11.3@48	-	-	wheels	84"		expedited repair/used market	Category C - evaluate shared spare (LOP and LCR)
Lost Creek	T1	three	FPE	1976	13.2-115kV	+2, -2	45/60	OA/FA	N2 Blanket	-	7.1@45	-	-	flat			expedited repair/used market	Category C - evaluate shared spare (LOP and LCR)
McNary	T1-T6	single	ABB	2004-2009	13.2-13.2-230kV	+2, -2	40/53/66.7	OA/FA/FA	COPS		5.5@20	5.5@20	11@20	wheels			expedited repair/used market	Category A - evaluate spare purchase timing
	T7	single	ABB	2004-2006	13.2-13.2-115kV	+2, -2	40/53/66.7	OA/FA/FA	COPS		8.2@20	8.15@20	16.4@20	wheels			expedited repair/used market	Category C - evaluate shared spare (MCN)
Category A - No spare exists and one or more appears justified																		
Category B - Spare exists and one or more appears justified																		
Category C - No spare exists and no spare appears justified																		
Category D - Spare exists and no spare appears justified																		