The discount rate used for this study is the real interest rate as published by the United States Office of Management and Budget (OMB), currently 2.0% for long-term investments. This rate is published annually for use by federal agencies in evaluating projects. The real interest rate is the effective cost of money that has been adjusted to remove the effect of inflation. The effect of the discount rate on the life cycle cost analysis will be examined in **Section 5 Sensitivity Analyses** below.

A baseline study period of 20 years was selected for this study. This period is the life of the option with the shortest expected service life. The sensitivity of the life cycle cost analysis to the service life assumption is examined in **Section 5 Summary of Sensitivity Analyses** below.

3. Description of Options

The *Bridge Rehabilitation Structure Concept Report* describes five alternatives in detail. These alternatives are as follows.

- Alternative A – 20-Year Design Life
- Alternative B – 20-Year Design Life with Expanded Sidewalks
- Alternative C – Long-Term Design Life
- Alternative D – Long-Term Design Life with 4 Lanes and Bike Lanes
- Alternative E – Long-Term Design Life with 4 Lanes and Light Rail (LRT)

Construction costs and maintenance costs for Alternatives A and B and for Alternatives C and D are very similar. For ease of comparison of life cycle costs, the five alternatives are condensed into the following three distinct options.

- Option A: 20-Year Design Life
- Option B: Long-Term Design Life
- Option C: Long-Term Design Life with 4 Lanes and Multi-Modal Features

3.1 20-Year Design Life

This option consists of strengthening the deck system of existing structure to meet current live load capacity requirements. Strengthening the structure is limited to the deck and floorbeams, as spandrels, arches, and piers currently have sufficient strength. Existing deterioration of the spandrels will be repaired. Limited corrosion mitigation will be included in the deck and spandrel repair procedures. Repairs will include detailing to minimize future corrosion by minimizing exposure of the bridge components to water. No repair or corrosion mitigation will be performed in the piers or in the main arch ribs.

After 20 to 30 years, continuing corrosion in the piers and arches will result in a requirement to either replace the bridge or to perform extensive rehabilitation of the arches. At this time the residual value of the structure is taken to be nil.

Initial costs

The initial costs include construction of the bridge rehabilitation. Design and construction engineering, right of way acquisition, approach roads, traffic control during construction, and user costs are not included in the initial costs. These construction costs were developed as part of the type selection process, and are represented as a single cost at the beginning of year 1 of the study period.

The *Bridge Rehabilitation Structure Concept Report* contains the development of the initial costs. This report presents initial costs as a range of values, as the costs are based on a conceptual design. The single value that formed the basis of the range is used for evaluation of life cycle costs.

Maintenance and Repair Operations

Routine maintenance and repair tasks are considered in this LCCA. These activities are described below.

Biennial Inspection. Standard inspections will be performed biennially. Inspections will include routine evaluation of decks, floorbeams, arches, joints, bearings, and piers.

Joint Replacement. Complete joint replacement is projected at 25-year intervals. As the expected life of the bridge is not greater than this interval, no costs for joint replacement are included.

Deck Repairs. Routine repairs of the deck surface consist of crack sealing and limited pothole repair. Repairs are estimated on a square foot of deck area basis. Costs are likely to be zero at the construction year and increase linearly to a maximum at the year of deck overlay replacement, but for the purposes of this evaluation will be presumed to be an equal cost each year (a uniform series.)

Deck Overlay. Deck deterioration consists of rutting due to tire wear, cracking due to volume changes, and delamination. In general, the deck surface will be milled and an overlay installed at 25 years and again at 50 years. As the expected life of the bridge is not greater than this interval, no costs for routine deck overlays are included.

Residual Value

No terminal costs or salvage value is included. The value of the structure (residual value) is nil at the end of the study period, and demolition costs will be included in the construction of a replacement structure.

3.2 Long-Term Design Life

This option is similar to the 20-Year Design Life Option, and provides the same traffic functionality. This option adds activities intended to halt the progress of corrosion of the arches, ribs, and spandrels.

This option consists of strengthening the existing structure to meet current live load capacity requirements. Strengthening the structure is limited to the deck and floorbeams, as spandrels, arches, and piers currently have sufficient strength. Existing deterioration of the spandrels will be repaired. Corrosion mitigation will be included in the deck and spandrel repair procedures. Repairs will include detailing to minimize future corrosion by minimizing exposure of the bridge components to water.

Minor repair of corrosion-related deterioration of the piers and arch ribs will be performed. In addition, Electrochemical Chloride Extraction and Re-Alkalization (ECE) will be performed in those areas of the piers and arch ribs that are experiencing active corrosion.

After 25 to 35 years, the effects of the ECE may dissipate. A repeat of the ECE process on the arch ribs and piers may be required to prevent re-initiation of corrosion.

Initial costs

The initial costs include construction of the bridge rehabilitation, including the cost of corrosion mitigation at the arch ribs. Design and construction engineering, right of way acquisition, approach roads, traffic control during construction, and user costs are not included in the initial costs. These construction costs were developed as part of the type selection process, and are represented as a single cost at the beginning of year 1 of the study period.

Development of the initial costs is not shown in this memorandum. The *Bridge Rehabilitation Structure Concept Report* contains the development of the initial costs. This report presents initial costs as a range of values, as the costs are based on a conceptual design. The single value that forms the basis of the range is used for evaluation of life cycle costs.

Maintenance and Repair Operations

Biennial Inspection. Standard inspections will be performed biennially. Inspections will include routine evaluation of decks, floorbeams, arches, joints, bearings, and piers.

Joint Replacement. Complete joint replacement is projected at 25-year intervals. As the study period is not greater than this interval, no costs for joint replacement are included.

Deck Repairs. Routine repairs of the deck surface consist of crack sealing and limited pothole repair. Repairs are estimated on a square foot of deck area basis. Costs are likely to be zero at the construction year and increase linearly to a maximum at the year of deck overlay replacement, but for the purposes of this evaluation will be presumed to be an equal cost each year (a uniform series.)

Deck Overlay. Deck deterioration consists of rutting due to tire wear, cracking due to volume changes, and delamination. In general, the deck surface will be milled and an overlay installed at 25 years and again at 50 years. As the study period is not greater than this interval, no costs for deck overlays are included.

The bridge will be restricted to two-lane operation (one lane each direction) during the replacement of the overlay. Road user costs are not included in the cost of the overlay replacement.

Residual Value

At the end of the study period, the bridge will retain significant value. The present worth of this residual value must be included in the life cycle costs.

Residual value is determined by assuming a straight-line depreciation of the cost of the bridge rehabilitation over an assumed life of 75 years. The residual value of the bridge is then

(Initial Cost) x (75 years – study period)/75 years

This option requires significant repeating costs beyond the study period that are not required for a conventional bridge. This cost is the cost of repeating the ECE treatment of the arch ribs at intervals of approximately 35 years. The residual value of the bridge at the end of the study period is reduced by the present worth (calculated at the end of the study period) of the future ECE treatment. The sensitivity of the life cycle costs to the repeating ECE treatment is examined in **Section 5 Summary of Sensitivity Analyses** below.

Other repeating costs beyond the study period, including deck overlays, joint replacement, and maintenance activities, as similar for all options. These costs are excluded from the life cycle cost determination, as these will not materially affect the outcome.

3.3 Long-Term Design Life with 4 Lanes and Multi-Modal Features

This option widens the bridge deck to provide significant traffic functionality that the other options do not provide. This requires replacement of the existing deck system in order to gain the added width.

This option consists of removing the deck and the spandrels from the bridge, and replacing the deck over the piers. The new deck will be wider than the original deck in order to accommodate bicycle lanes and/or light rail transit vehicles.

Design and construction of the deck will minimize future corrosion of the deck, piers, and arch ribs by minimizing exposure of the bridge components to water.

Minor repair of corrosion-related deterioration of the piers and arch ribs will be performed. In addition, Electrochemical Chloride Extraction and Re-Alkalization (ECE) will be performed in those areas of the piers and arch ribs that are experiencing active corrosion.

After 25 to 35 years, the effects of the ECE may dissipate. A repeat of the ECE process on the arch ribs and piers may be required to prevent re-initiation of corrosion.

Initial costs

The initial costs include construction of the bridge rehabilitation, including the cost of corrosion mitigation at the arch ribs and construction of a new and wider deck. Design and construction engineering, right of way acquisition, approach roads, traffic control during construction, and user costs are not included in the initial costs. These construction costs were developed as part of the type selection process, and are represented as a single cost at the beginning of year 1 of the study period.

Development of the initial costs is not shown in this memorandum. The *Bridge Rehabilitation Structure Concept Report* contains the development of the initial costs. This report presents initial costs as a range of values, as the costs are based on a conceptual design. The single value that forms the basis of the range is used for evaluation of life cycle costs.

Maintenance and Repair Operations

Biennial Inspection. Standard inspections will be performed biennially. Inspections will include routine evaluation of decks, floorbeams, arches, joints, bearings, and piers.

Joint Replacement. Complete joint replacement is projected at 25-year intervals. As the study period is not greater than this interval, no costs for joint replacement are included.

Deck Repairs. Routine repairs of the deck surface consist of crack sealing and limited pothole repair. Repairs are estimated on a square foot of deck area basis. Costs are likely to be zero at the construction year and increase linearly to a maximum at the year of deck overlay replacement, but for the purposes of this evaluation will be presumed to be an equal cost each year (a uniform series.)

Deck Overlay. Deck deterioration consists of rutting due to tire wear, cracking due to volume changes, and delamination. In general, the deck surface will be milled and an overlay installed at 25 years and again at 50 years. As the study period is not greater than this interval, no costs for deck overlays are included.

The bridge will be restricted to two-lane operation (one lane each direction) during the replacement of the overlay. Road user costs are not included in the cost of the overlay replacement.

<u>Residual Value</u>

At the end of the study period, the bridge will retain significant value. The present worth of this residual value must be included in the life cycle costs.

Residual value is determined by assuming a straight-line depreciation of the cost of the bridge rehabilitation over an assumed life of 75 years. The residual value of the bridge is then

(Initial Cost) x (75 years – study period)/75 years

This option requires significant repeating costs beyond the study period that are not required for a conventional bridge. This cost is the cost of repeating the ECE treatment of the arch ribs at intervals of approximately 35 years. The residual value of the bridge at the end of the study period is reduced by the present worth (calculated at the end of the study period) of the future ECE treatment. The sensitivity of the life cycle costs to the repeating ECE treatment is examined in **Section 5 Summary of Sensitivity Analyses** below.

Other repeating costs beyond the study period, including deck overlays, joint replacement, and maintenance activities, as similar for all options. These costs are excluded from the life cycle cost determination, as these will not materially affect the outcome.

4. Baseline Life Cycle Costs

The baseline life cycle costs for each of the three bridge rehabilitation options are shown in the table below. These costs are the sum of the initial capital construction costs, the present worth of inspection, maintenance, and repair over the study period, and the present worth of any residual value at the end of the study period. Costs, other than the maintenance costs, are rounded to the nearest $100,000.

All costs are based on constant (2012) dollars and a discount rate of 2.0%. The baseline life cycle costs include the maintenance and repair costs outlined in **Section 3 Description of Options.** See Appendix A for cost details.

	Construction Cost	Present worth of maintenance	Residual Value	Life Cycle Cost
20-Year Design Life	-$15,400,000	-$126,000	$0	-$15,500,000
Long-Term Design Life	-$22,400,000	-$126,000	$9,300,000	-$13,200,000
Long-Term Design Life with 4 Lanes and Multi-Modal Features	-$27,000,000	-$146,000	$11,800,000	-$15,300,000

Negative values represent costs, while positive values represent assets. The Long-Term Design Life option has the lowest life cycle cost at $13.2 million.

5. Summary of Sensitivity Analyses

Any life cycle cost analysis requires use of assumptions regarding future performance of the structure and future costs of maintenance and repair. A baseline analysis is performed with the best available assumptions. Those assumptions are then tested by varying these assumptions and repeating the analysis.

An examination of the baseline analysis suggests that there are several parameters which can materially affect the total life cycle costs. These are 1) the discount rate used for present worth calculations, 2) the service life and resulting study period for the 20-Year Design Life option, and 3) the timing of the repeated ECE treatments for Options B and C. Each parameter is modified and the life cycle cost analysis repeated. Only one parameter is modified for any sensitivity analysis, in order to isolate the effect of that item on the results. Large changes are made in the parameters being examined, so that the significance of changing the item can be assessed.

The following subsections describe the assumptions being evaluated in the sensitivity analysis. Details of life cycle costs for the sensitivity analyses are presented in Appendix B.

5.1 Increase the discount rate

The discount rate currently suggested by the OMB is 2.0%. Discount rates are currently low compared to recent years. Increasing the discount rate generally reduces the significance of future costs. For a test of the sensitivity of the life cycle costs to the discount rate, the discount rate is increased from 2.0% to 3.0%. The results are shown in the table below.

	Construction Cost	Present worth of maintenance	Residual Value	Life Cycle Cost
20-Year Design Life	-$15,400,000	-$114,000	$0	-$15,500,000
Long-Term Design Life	-$22,400,000	-$114,000	$7,900,000	-$14,600,000
Long-Term Design Life with 4 Lanes and Multi-Modal Features	-$27,000,000	-$132,000	$9,900,000	-$17,200,000

5.2 Decrease the discount rate

The discount rate currently suggested by the OMB is 2.0%. Decreasing the discount rate generally increases the significance of future costs. For a test of the sensitivity of the life cycle costs to the discount rate, the rate is decreased from 2.0% to 1.4%. The table below shows the results.

	Construction Cost	Present worth of maintenance	Residual Value	Life Cycle Cost
20-Year Design Life	-$15,400,000	-$134,000	$0	-$15,500,000
Long-Term Design Life	-$22,400,000	-$134,000	$10,300,000	-$12,200,000
Long-Term Design Life with 4 Lanes and Multi-Modal Features	-$27,000,000	-$155,000	$13,200,000	-$14,000,000

5.3 Change the Study Period

The study period corresponds to the expected life of the shortest-lived option. To assess the effect of the existing bridge being extended beyond the initial assumption of 20 years without significant additional maintenance, change the study period from 20 years to 30 years. Considering the extent of the modifications to the bridge proposed for the 20-Year Design Life option, this extended life is not unreasonable. The table below shows the results.

	Construction Cost	Present worth of maintenance	Residual Value	Life Cycle Cost
20-Year Design Life	-$15,400,000	-$174,000	$0	-$15,600,000
Long-Term Design Life	-$22,400,000	-$174,000	$5,600,000	-$16,900,000
Long-Term Design Life with 4 Lanes and Multi-Modal Features	-$27,000,000	-$200,000	$7,500,000	-$19,700,000

5.4 Increased effective life of ECE Treatment of Options B and C

Future costs for re-treatment of the substructure affects the residual value of Options B and C. The life expectancy of this technology is not clearly known, and some early examples of the technology suggest that the benefits are retained for a longer time than was originally assumed. The effect of longer life of the ECE treatment is examined by deferring the re-treatment from the 35th year after construction to the 50th year after construction. Deferring the ECE re-treatment increases the residual value of Options B and C, making them economically more attractive. Results are shown in the table below.

	Construction Cost	Present worth of maintenance	Residual Value	Life Cycle Cost
20-Year Design Life	-$15,400,000	-$126,000	$0	-$15,500,000
Long-Term Design Life	-$22,400,000	-$126,000	$9,800,000	-$12,800,000
Long-Term Design Life with 4 Lanes and Multi-Modal Features	-$27,000,000	-$146,000	$12,200,000	-$14,900,000

6. Discussion and Conclusions

The cost to construct the options being considered varies significantly. The highest-cost option is 175% of the cost of the lowest-cost option. Consideration of life cycle costs minimizes this difference. For the baseline study, the highest-cost option is only 17% more costly than the lowest-cost option.

The baseline analysis predicts that the Long-Term Design Life option (Option B) has the lowest life cycle cost followed by the Long-Term Design Life with 4 Lanes and Multi-Modal Features (Option C). The 20-Year Design Life option (Option A) has the highest life cycle cost. Note that the life cycle cost of Options A and C are almost identical.

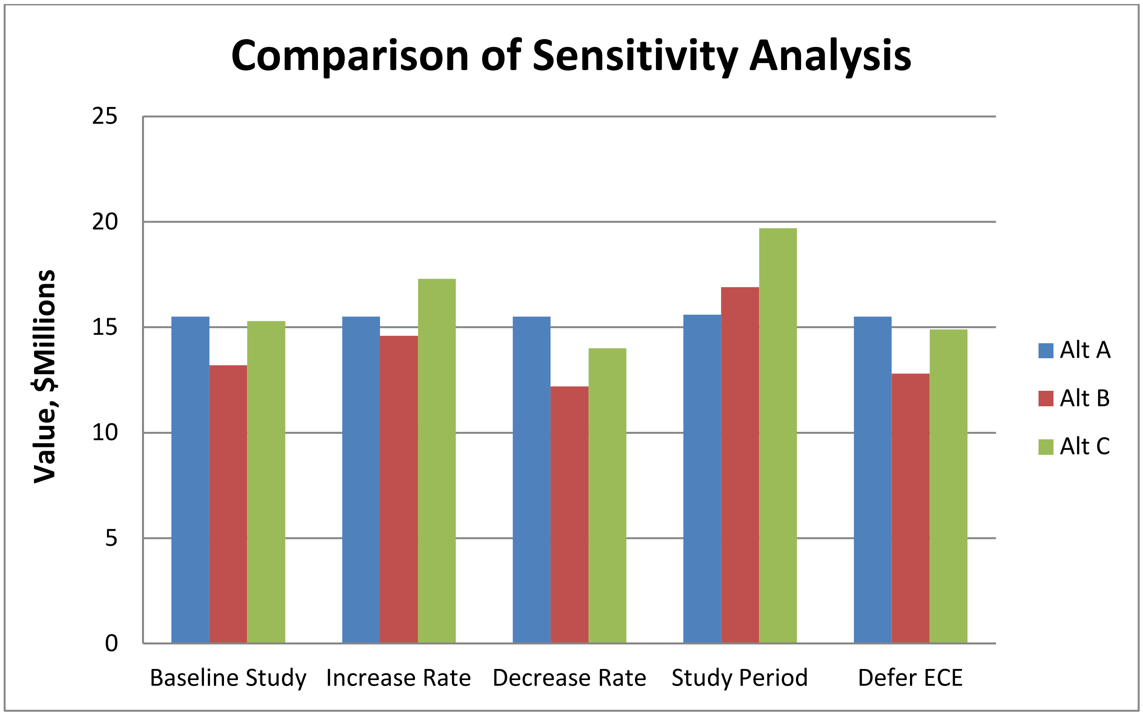
Analysis of the sensitivity of the life cycle costs to the discount rate does not change the prediction of the lowest-cost option (Option B). A decrease in the discount rate, however, makes Option A more attractive than Option C.

Evaluation of the sensitivity of the results to the life of the 20-Year Design Life option changes the ranking of the options. Presuming that the current rehabilitation of the bridge without additional corrosion mitigation will last 30 years instead of the minimum of 20 years required by the design results in the 20-Year Design Life (Option B) being noticeably less costly than the other options.

The ranking of options is not sensitive to the timing of on-going maintenance, most notably the ECE re-treatment that may be needed for Options B and C. Option B remains the least costly, followed by Option A and then by Option C. The difference in life cycle cost between Options A and C is low, as was the case for the baseline study.

The Long-Term Design Life option is always more costly on a life cycle cost basis than is the Long-term Design life with 4 Lanes and Multimodal Features option. This cost difference is 16% in the baseline study, and can be as high as 18% more or as low as 15% more depending on the assumptions made. This difference is due entirely to the added work necessary to accommodate the multi-model features, and can be viewed as the incremental cost of those features.

The table below illustrates the relative magnitudes of the options for the baseline study and for each factor studied in the sensitivity analysis.



The effect of maintenance costs on life cycle costs should be considered. Costs of routine maintenance, which can include both preventive maintenance such as inspection and cleaning and routine repairs such as joint repair, crack repair, and some component patching, are small compared to other life cycle cost elements. These costs can vary widely from the values used in this study without changing the outcome of the study.

The different options include different levels of risk. Options that preserve more of the existing structure have a higher level of risk of poor performance than do options that replace additional components. Risk can include potentially higher maintenance and repair costs, and can also include the risk of impact to traffic operations due to premature component failure. This risk can be reduced by careful design and construction, but cannot be eliminated.

The option with the highest risk is Option A. Extending the life of the structure as suggested in the sensitivity study increases that risk, particularly as the structure ages. The reduction in projected life cycle cost that can be gained by assuming a longer service life for Option A (20-Year Design Life) is offset to some degree by the increased risk. This risk is not quantified in this study, but should be considered in making decisions.

Option B has less risk than does Option A, as proactive measures are taken to preserve key bridge components. Risk in Option B is centered primarily around the performance of original floor beams. Option C has the least risk of any of the options, as the entire deck and spandrel system is replaced with new construction.

Options B and C provide more flexibility for future bridge maintenance than does Option A. Implementation of Option A requires either bridge replacement or a very difficult and potentially expensive rehabilitation of the arch ribs in the relatively near future. Options B and C postpone significant work on the bridge to a more distant future, and allow planners the flexibility to implement either replacement or less extensive bridge preservation measures. This flexibility is not quantified in this study.

References

The following publications were used to identify project requirements, cost parameters, and unit prices. In addition to these publications, CH2M HILL historical records and discussions with specialty construction contractors provided valuable information.

- CH2M HILL Draft *Bridge Rehabilitation Structure Concept Report,* March, 2012
- U.S. Office of Management and Budget *Circular A-94 Guidelines And Discount Rates for Benefit-Cost Analysis Of Federal Programs,* 1992
- U.S. Office of Management and Budget *2012 Discount Rates for OMB Circular No. A-94*, January 2012.
- Transportation Research Board, *NCHRP Report 483 Bridge Life-Cycle Cost Analysis*, 2003
- Utah Department of Transportation *Life Cycle Cost Analysis*, August 2007

Appendix A

Summary of Baseline Life Cycle Costs

The following tables summarize the items that are included in the life cycle cost analysis, the times at which the items occur, the sum of the expenditures, and the present worth of the expenditures. Times for the expenditures are shown as the number of years after the construction. All expenditures are shown in current dollars, without inflation.

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Latah Creek Bridge - Life Cycle Cost Analysis

Alternative A - 20-Year Design Life

Cash Flow Table - Base Conditions

Discount Rate =: 2.00%

Summary

Construction Cost:	$	(15,400,000)
Present Worth of Maintenance:	$	(125,833)
Present Worth of Residual Value:	$	-
Total Life Cycle Cost:	$	(15,525,833)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (15,400,000)	Year 1	$ (15,400,000)	$ (15,400,000)
Biennial Inspection	$ (7,000)	Biennial	$ (70,000)	$ (56,663)
Deck Repairs	$ (4,500)	Annually	$ (85,500)	$ (69,170)
ECE Re-Treatment	$ -	Annually	$ -	$ -
		Subtotal (excluding Construction):	$ (155,500)	$ (125,833)
Residual Value		20	$ -	$ -

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Latah Creek Bridge - Life Cycle Cost Analysis

Alternative B - Long-Term Design Life

Cash Flow Table - Base Condition

Discount Rate =: 2.00%

Summary

Construction Cost:	$	(22,400,000)
Present Worth of Maintenance:	$	(125,833)
Present Worth of Residual Value:	$	9,287,004
Total Life Cycle Cost:	$	(13,238,829)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (22,400,000)	Year 1	$ (22,400,000)	$ (22,400,000)
Biennial Inspection	$ (7,000)	Biennial	$ (70,000)	$ (56,663)
Deck Repairs	$ (4,500)	Annually	$ (85,500)	$ (69,170)
ECE Re-Treatment	$ -	35 Years	$ -	$ -
		Subtotal (excluding Construction):	$ (155,500)	$ (125,833)
Residual Value	$ 13,800,000	30	$ 13,800,000	$ 9,287,004

Latah Creek Bridge - Life Cycle Cost Analysis

Alternative C - Long-Term Design Life with Multi-Modal Features

Cash Flow Table - Base Condition

Discount Rate =: 2.00%

Summary

Construction Cost:	$	(27,000,000)
Present Worth of Maintenance:	$	(145,815)
Present Worth of Residual Value:	$	11,844,295
Total Life Cycle Cost:	$	(15,301,520)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (27,000,000)	Year 1	$ (27,000,000)	$ (27,000,000)
Biennial Inspection	$ (7,000)	Biennial	$ (70,000)	$ (56,663)
Deck Repairs	$ (5,800)	Annually	$ (110,200)	$ (89,152)
ECE Re-Treatment	$ -	35 Years	$ -	$ -
		Subtotal (excluding Construction):	$ (180,200)	$ (145,815)
Residual Value	$ 17,600,000	30	$ 17,600,000	$ 11,844,295

Appendix B
Summary of Sensitivity Analysis

The baseline life cycle cost analyses are repeated with different assumptions about the discount rate, service lives, and timing of maintenance activities after the study period.

Cost summary tables are shown for the following changes in assumptions.

1. Adjusting discount rate up 1%
2. Adjusting discount rate down 0.6%
3. Increasing the service life of Option A by 50%
4. Deferring the ECE re-treatment from year 35 to year 50.

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Latah Creek Bridge - Life Cycle Cost Analysis

Alternative A - 20-Year Design Life

Cash Flow Table - Increase Discount Rate

Discount Rate =: 3.00%

Summary

Construction Cost:	$	(15,400,000)
Present Worth of Maintenance:	$	(113,881)
Present Worth of Residual Value:	$	-
Total Life Cycle Cost:	$	(15,513,881)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (15,400,000)	Year 1	$ (15,400,000)	$ (15,400,000)
Biennial Inspection	$ (7,000)	Biennial	$ (70,000)	$ (51,302)
Deck Repairs	$ (4,500)	Annually	$ (85,500)	$ (62,580)
ECE Re-Treatment	$ -	Annually	$ -	$ -
		Subtotal (excluding Construction):	$ (155,500)	$ (113,881)
Residual Value		20	$ -	$ -

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Latah Creek Bridge - Life Cycle Cost Analysis

Alternative B - Long-Term Design Life

Cash Flow Table - Increase Discount Rate

Discount Rate =: 3.00%

Summary

Construction Cost:	$	(22,400,000)
Present Worth of Maintenance:	$	(113,881)
Present Worth of Residual Value:	$	7,862,196
Total Life Cycle Cost:	$	(14,651,686)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (22,400,000)	Year 1	$ (22,400,000)	$ (22,400,000)
Biennial Inspection	$ (7,000)	Biennial	$ (70,000)	$ (51,302)
Deck Repairs	$ (4,500)	Annually	$ (85,500)	$ (62,580)
ECE Re-Treatment	$ -	35 Years	$ -	$ -
		Subtotal (excluding Construction):	$ (155,500)	$ (113,881)
Residual Value	$ 14,200,000	30	$ 14,200,000	$ 7,862,196

Latah Creek Bridge - Life Cycle Cost Analysis

Alternative C - Long-Term Design Life with Multi-Modal Features

Cash Flow Table - Increase Discount Rate

Discount Rate =: 3.00%

Summary

Construction Cost:	$	(27,000,000)
Present Worth of Maintenance:	$	(131,960)
Present Worth of Residual Value:	$	9,910,796
Total Life Cycle Cost:	$	(17,221,164)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (27,000,000)	Year 1	$ (27,000,000)	$ (27,000,000)
Biennial Inspection	$ (7,000)	Biennial	$ (70,000)	$ (51,302)
Deck Repairs	$ (5,800)	Annually	$ (110,200)	$ (80,658)
ECE Re-Treatment	$ -	35 Years	$ -	$ -
		Subtotal (excluding Construction):	$ (180,200)	$ (131,960)
Residual Value	$ 17,900,000	30	$ 17,900,000	$ 9,910,796

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Latah Creek Bridge - Life Cycle Cost Analysis

Alternative A - 20-Year Design Life

Cash Flow Table - Decrease Discount Rate

Discount Rate =: 1.40%

Summary

Construction Cost:	$	(15,400,000)
Present Worth of Maintenance:	$	(133,853)
Present Worth of Residual Value:	$	-
Total Life Cycle Cost:	$	(15,533,853)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (15,400,000)	Year 1	$ (15,400,000)	$ (15,400,000)
Biennial Inspection	$ (7,000)	Biennial	$ (70,000)	$ (60,265)
Deck Repairs	$ (4,500)	Annually	$ (85,500)	$ (73,588)
ECE Re-Treatment	$ -	Annually	$ -	$ -
		Subtotal (excluding Construction):	$ (155,500)	$ (133,853)
Residual Value		20	$ -	$ -

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Latah Creek Bridge - Life Cycle Cost Analysis

Alternative B - Long-Term Design Life

Cash Flow Table - Decrease Discount Rate

Discount Rate = 1.40%

Summary

Construction Cost:	$	(22,400,000)
Present Worth of Maintenance:	$	(133,853)
Present Worth of Residual Value:	$	10,298,638
Total Life Cycle Cost:	$	(12,235,215)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (22,400,000)	Year 1	$ (22,400,000)	$ (22,400,000)
Biennial Inspection	$ (7,000)	Biennial	$ (70,000)	$ (60,265)
Deck Repairs	$ (4,500)	Annually	$ (85,500)	$ (73,588)
ECE Re-Treatment	$ -	35 Years	$ -	$ -
	Subtotal (excluding Construction):		$ (155,500)	$ (133,853)
Residual Value	$ 13,600,000	30	$ 13,600,000	$ 10,298,638

Latah Creek Bridge - Life Cycle Cost Analysis

Alternative C - Long-Term Design Life with Multi-Modal Features

Cash Flow Table - Decrease Discount Rate

Discount Rate =: 1.40%

Summary

Construction Cost:	$	(27,000,000)
Present Worth of Maintenance:	$	(155,112)
Present Worth of Residual Value:	$	13,176,199
Total Life Cycle Cost:	$	(13,978,913)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (27,000,000)	Year 1	$ (27,000,000)	$ (27,000,000)
Biennial Inspection	$ (7,000)	Biennial	$ (70,000)	$ (60,265)
Deck Repairs	$ (5,800)	Annually	$ (110,200)	$ (94,847)
ECE Re-Treatment	$ -	35 Years	$ -	$ -
		Subtotal (excluding Construction):	$ (180,200)	$ (155,112)
Residual Value	$ 17,400,000	30	$ 17,400,000	$ 13,176,199

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Latah Creek Bridge - Life Cycle Cost Analysis

Alternative A - 20-Year Design Life

Cash Flow Table - Study Period increased to 30 years

Discount Rate = 2.00%

Summary

Construction Cost:	$	(15,400,000)
Present Worth of Maintenance:	$	(173,984)
Present Worth of Residual Value:	$	-
Total Life Cycle Cost:	$	(15,573,984)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (15,400,000)	Year 1	$ (15,400,000)	$ (15,400,000)
Biennial Inspection	$ (7,000)	Biennial	$ (105,000)	$ (77,611)
Deck Repairs	$ (4,500)	Annually	$ (130,500)	$ (96,372)
ECE Re-Treatment	$ -	Annually	$ -	$ -
		Subtotal (excluding Construction):	$ (235,500)	$ (173,984)
Residual Value		20	$ -	$ -

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Latah Creek Bridge - Life Cycle Cost Analysis

Alternative B - Long-Term Design Life

Cash Flow Table - Study Period increased to 30 years

Discount Rate =: 2.00%

Summary

Construction Cost:	$	(22,400,000)
Present Worth of Maintenance:	$	(173,984)
Present Worth of Residual Value:	$	5,631,123
Total Life Cycle Cost:	$	(16,942,861)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (22,400,000)	Year 1	$ (22,400,000)	$ (22,400,000)
Biennial Inspection	$ (7,000)	Biennial	$ (105,000)	$ (77,611)
Deck Repairs	$ (4,500)	Annually	$ (130,500)	$ (96,372)
ECE Re-Treatment	$ -	35 Years	$ -	$ -
		Subtotal (excluding Construction):	$ (235,500)	$ (173,984)
Residual Value	$ 10,200,000	30	$ 10,200,000	$ 5,631,123

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Latah Creek Bridge - Life Cycle Cost Analysis

Alternative C - Long-Term Design Life with Multi-Modal Features

Cash Flow Table - Study Period increased to 30 years

Discount Rate =: 2.00%

Summary

Construction Cost:	$	(27,000,000)
Present Worth of Maintenance:	$	(201,825)
Present Worth of Residual Value:	$	7,452,957
Total Life Cycle Cost:	$	(19,748,868)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (27,000,000)	Year 1	$ (27,000,000)	$ (27,000,000)
Biennial Inspection	$ (7,000)	Biennial	$ (105,000)	$ (77,611)
Deck Repairs	$ (5,800)	Annually	$ (168,200)	$ (124,213)
ECE Re-Treatment	$ -	35 Years	$ -	$ -
	Subtotal (excluding Construction):		$ (273,200)	$ (201,825)
Residual Value	$ 13,500,000	30	$ 13,500,000	$ 7,452,957

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Latah Creek Bridge - Life Cycle Cost Analysis

Alternative B - Long-Term Design Life

Cash Flow Table - Defer ECE Re-Treatment

Discount Rate = 2.00%

Summary

Construction Cost:	$	(22,400,000)
Present Worth of Maintenance:	$	(125,833)
Present Worth of Residual Value:	$	9,758,084
Total Life Cycle Cost:	$	(12,767,749)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (22,400,000)	Year 1	$ (22,400,000)	$ (22,400,000)
Biennial Inspection	$ (7,000)	Biennial	$ (70,000)	$ (56,663)
Deck Repairs	$ (4,500)	Annually	$ (85,500)	$ (69,170)
ECE Re-Treatment	$ -	50	$ -	$ -
		Subtotal (excluding Construction):	$ (155,500)	$ (125,833)
Residual Value	$ 14,500,000	30	$ 14,500,000	$ 9,758,084

Latah Creek Bridge - Life Cycle Cost Analysis

Alternative C - Long-Term Design Life with Multi-Modal Features

Cash Flow Table - Defer ECE Re-Treatment

Discount Rate = 2.00%

Summary

Construction Cost:	$	(27,000,000)
Present Worth of Maintenance:	$	(145,815)
Present Worth of Residual Value:	$	12,248,078
Total Life Cycle Cost:	$	(14,897,737)

Item	Unit Price	Time of Action	Total Expediture	Present Worth
Construction	$ (27,000,000)	Year 1	$ (27,000,000)	$ (27,000,000)
Biennial Inspection	$ (7,000)	Biennial	$ (70,000)	$ (56,663)
Deck Repairs	$ (5,800)	Annually	$ (110,200)	$ (89,152)
ECE Re-Treatment	$ -	50	$ -	$ -
		Subtotal (excluding Construction):	$ (180,200)	$ (145,815)
Residual Value	$ 18,200,000	30	$ 18,200,000	$ 12,248,078

Appendix C

Life Cycle Cost Component Computations

The life cycle cost analysis requires determination of future maintenance and repair costs. For comparisons of options with unequal service life, the residual value of options at the end of the study period is also required. This appendix contains calculations for maintenance costs and residual values.

Task: Develop costs for the maintenance and repair activities for the Latah Creek Bridge alternative structures. Use these costs for the Bridge Life Cycle Cost Analysis (BLCCA)

Assumptions:

1. Three alternatives will be evaluated. These include a 20-Year Design Life, a Long-Term Design Life, and a Long-Term Design Life with a deck widened to provide Multi-Modal capacity..

2. Get cost ranges from available sources. Sources can include Spokane maintenance engineer, other DOT cost estimating guides, and comparisons to other projects. Where necessary, use the cost of new construction with an appropriate factor for rehab/repair projects.

3. Use reasonable cost ranges. A high degree of accuracy in future maintenance and repair costs is not necessary for the following reasons: The probability, timing, and extent of any repair is uncertain; the effective discount rate is variable; and the present worth of work very far in the future is fairly small, so that the error in determining costs is small also. This does not reduce the need to develop reasonable costs, but does suggest that no benefit is to be gained from making small adjustments to costs.

4. Sensitivity to costs will be evaluated by varying the cost parameters.

Alternatives Considered:

A ===> 20-Year Design Life

B ===> Long-Term Design Life

C ===> Long-Term Design Life with Multi-Modal Features

The designations A, B, and C will be included in item descriptions below to distinguish between the alternatives.

Bridge Construction:

Construction costs are estimated by others as part of the alternative analysis.

Construction costs include design, construction, R/W, removal of the existing bridge, maintenance of traffic, and other work. While design and construction costs are spread over several years, they will be represented in the study as a single expenditure during the first year of the study.

$Alt_A := \$ \cdot 15400000$

$Alt_B := \$ \cdot 22400000$

$Alt_C := \$ \cdot 27000000$

Bi-Annual Inspection:

Applies to all alternatives.

$Inspection := \$ \cdot 1000$ per span

$Bi\_Annual\_A := Inspection \cdot 7 = 7000\,\$$

$Bi\_Annual\_B := Inspection \cdot 7 = 7000\,\$$

$Bi\_Annual\_C := Inspection \cdot 7 = 7000\,\$$

Lighting Maintenance:

Not Used

Bearing Replacement:

Not Used

Joint Maintenance:

Not Used

Joint Replacement:

Not Used

Deck Repairs:

Applies to all bridges.

Deck repairs consist of a minimal amount of crack sealing and pothole patching as the deck and overlays age. Assume an average of 0.05% of the deck area per year.

$$Pothole := \frac{\$ \cdot 100}{ft^2}$$

$Area_A := 1000ft \cdot 45ft \cdot 0.0005 = 22.5\,ft^2$

$Deck\_Repair_A := Area_A \cdot Pothole \cdot 2 = 4500\,\$$ per year, where the factor "2" accounts for traffic control. Work is presumed to be done by State forces.

$Deck\_Repair_B := Deck\_Repair_A = 4500\,\$$

$Area_C := 1000ft \cdot 58ft \cdot 0.0005 = 29\,ft^2$

$Deck\_Repair_C := Area_C \cdot Pothole \cdot 2 = 5800\,\$$ per year, where the factor "2" accounts for traffic control. Work is presumed to be done by State forces.

As a reality check, this is approximately the value of a 2-man crew with a truck, compressor, misc air tools, and material for about 4 working days per year. It is sufficient to include additional repairs and cleaning.

Deck Overlay Replacement:

Not Used

Continuing ECE Treatment:

Applies to Alts B and C only.

$ECE_B := \$582000 + \$1961400 + \$984000 = 3527400\,\$$

$ECE_C := \$1961400 + \$984000 = 2945400\,\$$

Compute the present worth of future ECE treatments for three different timing scenarios and three different discount rates. Each timing scenario uses the basic discount rate, and only the standard study period is evaluated with a high and a low bond on the discount rate.

For the base LCCA, the ECE treatment is presumed to occur in year 35, or 15 years after the study period. Using the discount rate of 2.0% determine the value of the ECE treatment 15 years in the future.

$n := 15$ $\qquad$ $r := 0.02$

$$ECE_{B\_15} := ECE_B \cdot \frac{1}{(1+r)^n} = 2620910\,\$$$

$$ECE_{C\_15} := ECE_C \cdot \frac{1}{(1+r)^n} = 2188476\,\$$$

For the evaluation of the sensitivity of the LCCA to a longer life of alternative A, alternative A is presumed to last 30 years. The ECE treatment is presumed to occur in year 35, or 5 years after the study period. Using the discount rate of 2.0% determine the value of the ECE treatment 5 years in the future.

$n := 5$ $\qquad r := 0.02$

$$ECE_{B\_5} := ECE_B \cdot \frac{1}{(1+r)^n} = 3194875\,\$$$

$$ECE_{C\_5} := ECE_C \cdot \frac{1}{(1+r)^n} = 2667740\,\$$$

For the evaluation of the sensitivity of the LCCA to the timing of the ECE re-treatment, alternative is presumed to last 20 years. The ECE treatment is presumed to occur in year 50, or 30 years after the study period. Using the discount rate of 2.0% determine the value of the ECE treatment 30 years in the future.

$n := 30$ $\qquad r := 0.02$

$$ECE_{B\_30} := ECE_B \cdot \frac{1}{(1+r)^n} = 1947375\,\$$$

$$ECE_{C\_30} := ECE_C \cdot \frac{1}{(1+r)^n} = 1626070\,\$$$

For the evaluation of the sensitivity of the LCCA to a higher discount rate, the discount rate must be applied to the future ECE treatments when computing residual values. The ECE treatment is presumed to occur in year 35, or 15 years after the study period. Using the discount rate of 3.0% determine the value of the ECE treatment 15 years in the future.

$n := 15$ $\qquad r := 0.03$

$$ECE_{B\_3\%} := ECE_B \cdot \frac{1}{(1+r)^n} = 2264104\,\$$$

$$ECE_{C\_3\%} := ECE_C \cdot \frac{1}{(1+r)^n} = 1890540\,\$$$

For the evaluation of the sensitivity of the LCCA to a lower discount rate, the discount rate must be applied to the future ECE treatments when computing residual values. The ECE treatment is presumed to occur in year 35, or 15 years after the study period. Using the discount rate of 3.0% determine the value of the ECE treatment 15 years in the future.

$n := 15$ $\qquad r := 0.014$

$$ECE_{B\_1\%} := ECE_B \cdot \frac{1}{(1+r)^n} = 2863422\,\$$$

$$ECE_{C\_1\%} := ECE_C \cdot \frac{1}{(1+r)^n} = 2390975\,\$$$

Residual Value:

Applies to Alts B and C only. Alternative A has no residual value, as the study period is defined by the time at which the bridge must be replaced or undergo a significant rehabilitation.

For the base LCCA, the study period is assumed to be 20 years. The residual value of Alternatives B and C is the cost of those alternatives prorated over the remaining life. The value of the ECE treatment at the end of the study period is subtracted from the residual value of Alternatives B and C.

For each case, the assumed life of Alternatives B and C is 75 years. This is a reasonable estimate in view of the low present worth of items at 75 years and beyond.

$Life := 75$ Years

$Study := 20$ Years

$$Residual_{B\_base} := \frac{Life - Study}{Life} \cdot Alt_B - ECE_{B\_15} = 13805757\,\$$$

$$Residual_{C\_base} := \frac{Life - Study}{Life} \cdot Alt_C - ECE_{C\_15} = 17611524\,\$$$

For the evaluation of the sensitivity of the LCCA to the life of Alternative A, the study period is assumed to be 30 years. The residual value of Alternatives B and C is the cost of those alternatives prorated over the remaining life. The value of the ECE treatment at the end of the study period is subtracted from the residual value of Alternatives B and C.

$\text{Study} := 30$ Years

$$\text{Residual}_{B\_Study\_Period} := \frac{\text{Life} - \text{Study}}{\text{Life}} \cdot \text{Alt}_B - \text{ECE}_{B\_5} = 10245125\ \$$$

$$\text{Residual}_{C\_Study\_Period} := \frac{\text{Life} - \text{Study}}{\text{Life}} \cdot \text{Alt}_C - \text{ECE}_{C\_5} = 13532260\ \$$$

For the evaluation of the sensitivity of the LCCA to the timing of the ECE re-treatment the study period is assumed to be 20 years. The residual value of Alternatives B and C is the cost of those alternatives prorated over the remaining life. The value of the ECE treatment at the end of the study period is subtracted from the residual value of Alternatives B and C.

$\text{Study} := 20$ Years

$$\text{Residual}_{B\_ECE} := \frac{\text{Life} - \text{Study}}{\text{Life}} \cdot \text{Alt}_B - \text{ECE}_{B\_30} = 14479292\ \$$$

$$\text{Residual}_{C\_ECE} := \frac{\text{Life} - \text{Study}}{\text{Life}} \cdot \text{Alt}_C - \text{ECE}_{C\_30} = 18173930\ \$$$

For the evaluation of the sensitivity of the LCCA to a higher discount rate the study period is assumed to be 20 years. The residual value of Alternatives B and C is the cost of those alternatives prorated over the remaining life. The value of the ECE treatment at the end of the study period is subtracted from the residual value of Alternatives B and C.

$Study := 20$ Years

$$Residual_{B\_ECE} := \frac{Life - Study}{Life} \cdot Alt_B - ECE_{B\_3\%} = 14162563 \$$$

$$Residual_{C\_ECE} := \frac{Life - Study}{Life} \cdot Alt_C - ECE_{C\_3\%} = 17909460 \$$$

For the evaluation of the sensitivity of the LCCA to a lower discount rate the study period is assumed to be 20 years. The residual value of Alternatives B and C is the cost of those alternatives prorated over the remaining life. The value of the ECE treatment at the end of the study period is subtracted from the residual value of Alternatives B and C.

$Study := 20$ Years

$$Residual_{B\_ECE} := \frac{Life - Study}{Life} \cdot Alt_B - ECE_{B\_1\%} = 13563244 \$$$

$$Residual_{C\_ECE} := \frac{Life - Study}{Life} \cdot Alt_C - ECE_{C\_1\%} = 17409025 \$$$