MEMO

TO: British Columbia Ministry of Transportation and Infrastructure

FROM: WSP Canada Group Ltd.

SUBJECT: **Island Rail Corridor Bridge Assessment – Seismic Condition Memorandum**

DATE: **March 12, 2019**

1. GENERAL

WSP Canada Group Ltd. (WSP) has prepared this Seismic Condition Memorandum for the British Columbia Ministry of Transportation and Infrastructure (MoTI) to supplement the Island Rail Corridor: Bridge Assessment report. The intent of this memo is to present a strategy with rationale, methodology, and order of magnitude costs for a seismic retrofit program for the bridges and structures on the Victoria and Port Alberni Subdivisions.

No detailed seismic calculations were performed as part of this assessment.

2. BACKGROUND

There are 67 bridge and trestle structures identified on the subdivisions comprising the Island Rail Corridor. Of these bridges, there are 48 bridges on the Victoria Subdivision (seven of which are between Victoria and Langford) and 19 on the Port Alberni Subdivision. The bridges vary widely in age and configuration from newer steel girder bridges to aging and heavily deteriorated timber trestles.

3. METHODOLOGY

Development of the seismic retrofit strategy included review of previous detailed inspection reports and record drawings, completion of cursory field-level seismic vulnerability assessments, identification of key seismic parameters, and compilation of available information for developing estimated costs for a seismic retrofit strategy and design implementation (construction) program.

As part of the retrofit strategy development, a desktop study was performed to interpret the susceptibility of the bridge sites to geotechnical concerns such as liquefaction, strain-softening, or amplification. The Site Class for each bridge site was also interpreted to assist with categorization of bridges and development of the strategy.

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Factors affecting the resiliency of a bridge include the span configuration, superstructure geometry and connections to substructure, bearing support length at piers and abutments, strength and ductility of substructures, strength and stability of foundations, ground conditions, embankment stability and local seismicity. A high-level cursory assessment of bridges was carried out to identify bridges that are highly susceptible to severe structural damages or potentially loss of supports or totally collapse under design earthquakes.

4. RECOMMENDED SEISMIC RETROFIT STRATEGY

The seismic retrofit strategy comprises two primary components, namely Seismic Vulnerability Rating followed by Retrofit Strategy Development. The Seismic Vulnerability Rating is carried out to identify seismically deficient bridges and prioritize them in order of vulnerability. After identifying vulnerable bridges, a concept-level Retrofit Strategy is developed for each vulnerable bridge. A brief description of these two analyses is provided below.

4.1 SEISMIC VULNERABILITY RATING

The process of the Seismic Vulnerability Rating of existing bridges involves a systematic assessment of a multitude of variables and requires a consistent application of engineering judgement to identify and rank bridges from low to high risk. The United States Federal Highway Administration (FHWA) has developed a Seismic Vulnerability Rating procedure that is intended to be used in conjunction with the American Association of State Highway and Transportation Officials (AASHTO) Specifications. The FHWA procedure requires a vulnerability assessment of a bridge structure in four areas:

a. Connections, bearings and seat widths;
b. Columns, piers and foundations;
c. Abutments, and;
d. Soil liquefaction.

Following ranking of the bridges, the final bridge retrofit priorities should be determined by considering such factors as importance, network redundancy, non-seismic deficiencies, remaining useful life, and other peripheral issues.

The Seismic Vulnerability Rating is the first step towards the development of an efficient and comprehensive retrofitting program. The following step comprises a detailed evaluation of the seismic capacity of the high-risk bridges identified and assessment of potential retrofit measures in accordance with the determined priority index.

4.2 RETROFIT STRATEGY DEVELOPMENT

Retrofit Strategy Development comprises two phases of work namely, Seismic Analysis and Strategy Development.

Following the Seismic Vulnerability Rating exercise, the highly vulnerable bridges would generally be subjected to a further assessment to determine whether the bridge should be considered as a candidate for replacement or retrofit. This would involve evaluation of overall condition of the bridge, remaining service life, and cost of seismic retrofit versus cost of replacement of the bridge.

For those bridges selected for retrofit, detailed seismic analysis will be performed to identify major seismic deficiencies associated with the existing bridge and then a concept-level retrofit strategy will be developed to mitigate all identified major seismic deficiencies together with a budgetary level of cost estimates. Depending on the complexity, configuration, or other specific characteristics of the structure, the scope of the retrofit strategy development could be limited to

structural elements only or could be expanded to include geotechnical investigation and upgrades. At the current stage, we do not have sufficient information to determine the level of effort that would be required for developing a retrofit strategy for each structure. Therefore, some general assumptions have been made based on our general observations of the structure configurations and conditions and an assumed level of effort that would be required for similar structures based on our past experience.

Upon completion of the retrofit strategy development and acceptance by the Ministry, detailed seismic retrofit design can proceed.

5. SEISMIC RETROFIT PROGRAM DEVELOPMENT AND BUDGET ESTIMATES

The following is a summary of the budget estimates for development of a seismic retrofit program comprising the Seismic Vulnerability Rating and Retrofit Strategy Development phases.

5.1 SEISMIC VULNERABILITY RATING

As a first step in the program, it is envisaged that all 67 bridges and trestles will be ranked in accordance to the Seismic Vulnerability Rating system discussed above. It is estimated that the order of magnitude budget for completion and reporting for this phase of the work would be in the range of $150,000 to $200,000 and would require approximately six months to complete.

5.2 RETROFIT STRATEGY DEVELOPMENT

The order of magnitude budget for development of seismic retrofit strategy for those bridges that are selected for retrofitting as discussed above varies depending on the level of structural complexity and local geotechnical susceptibility.

For this estimate, the following general assumptions have been made in terms of budget estimates for seismic analysis and retrofit strategy development based on our general observations of the complexity of the bridge structure. For each structure, a complexity rating has been assigned for the purpose of assessing the extent of analysis required. Assuming that the level of analysis for each interpreted complexity is more or less the same, it is possible to estimate the total budget for the retrofit strategy development.

Bridge complexities and associated costs are generally summarized as follows:

INTERPRETED COMPLEXITY	GEOTECHNICAL AND STRUCTURAL CHARACTERISTICS	ESTIMATED BUDGET FOR SEISMIC ANALYSIS	ESTIMATED BUDGET FOR RETROFIT STRATEGY DEVELOPMENT
Low	- Low geotechnical risk - Single span - Built after 1990 - Evidence of good seismic details incorporated	$ 5,000	$ 7,500

Medium	- Moderate to high geotechnical risk - Single span - Built between 1980 and 1990 - Evidence of minimum seismic details incorporated	$ 30,000	$ 60,000
Moderate	- High geotechnical risk - Multiple spans - Built before 1980 - No evidence of seismic details incorporated	$ 60,000	$ 100,000
High	- High geotechnical risk - Multiple spans - Mixed superstructure composition - Built before 1980 - No evidence of seismic details incorporated	$ 100,000	$ 225,000

For bridge sites identified as having an interpreted geotechnical susceptibility of moderate to very-high, we have assumed that a geotechnical evaluation will be required. The estimated cost for each geotechnical evaluation is estimated to be $25,000.

For timber trestle structures, it is assumed that as these are approaching the end of their practical service life and therefore development of a seismic retrofit strategy is not considered economically viable. Similarly, for large or complex structures with severe seismic deficiencies requiring significant upgrade, no budgets have been developed since the seismic retrofitting of these structures is considered cost prohibitive. Typical features for structures in this list include liquefiable soils, unreinforced masonry foundations, non-redundant superstructure elements, slender columns or otherwise non-ductile substructure elements, or a combination of these features.

Structures that are considered to be cost prohibitive for retrofitting include:
- Mile 14.00 Niagara Canyon
- Mile 14.90 Arbutus Canyon
- Mile 29.80 Koksilah Road
- Mile 39.30 Cowichan River
- Mile 40.6 Unnamed Waterway
- Mile 46.80 Whitehouse Creek
- Mile 47.90 Chemainus River
- Mile 79.90 Green Lake
- Mile 98.60 French Creek
- Mile 103.70 Little Qualicum River
- Mile 110.70 Big Qualicum River
- Mile 123.00 Coal Creek
- Mile 124.10 Mill Creek
- Mile 125.50 Tsable River
- Mile 135.10 Trent River

The following table identifies the number of bridges for each section of the corridor that are considered to be candidates for retrofitting.

SUBDIVISION	SECTION	NUMBER OF BRIDGES IN SECTION	NUMBER OF BRIDGES IDENTIFIED FOR RETROFIT STRATEGY DEVELOPMENT
Victoria	Victoria to Langford	7	7
	Langford to Duncan	12	7
	Duncan to Nanaimo*	9	5
	Nanaimo to Parksville	5	3
	Parksville to Courtenay	15	7
	Subdivision Total	**48**	**22**
Port Alberni	Parksville to Port Alberni	19	7
	Subdivision Total	**19**	**7**

* Including Wellcox Spur

The estimated budget is summarized as follows for each section of the rail corridor.

SUBDIVISION	SECTION	ESTIMATED COST OF SEISMIC ANALYSIS AND RETROFIT STRATEGY DEVELOPMENT
Victoria	Victoria to Langford	$ 345,000
	Langford to Duncan	$ 680,000
	Duncan to Nanaimo*	$ 970,000
	Nanaimo to Parksville	$ 555,000
	Parksville to Courtenay	$ 870,000
	Subdivision Total	**$ 3,420,000**
Port Alberni	Parksville to Port Alberni	$ 1,237,500
	Subdivision Total	**$ 1,237,500**

* Including Wellcox Spur

6. SEISMIC RETROFIT PROGRAM IMPLEMENTATION COSTS

The following is a summary of the estimated costs for implementation of a seismic retrofit program based on the assumed seismic condition of the structures. Order of magnitude costs for seismic rehabilitation have been developed and are presented below. These costs are estimates for implementation, or construction, of seismic rehabilitation strategies developed for the structures in each section. Costs have not been developed for timber trestle structures since these structures are approaching their functional service life and would likely require replacement within the foreseeable future and therefore a seismic rehabilitation program is unnecessary.

It is estimated that a substantial component of a seismic retrofit program will be strengthening and reconstruction of the bridge substructures and ground improvements.

The costs shown in the table below include those for construction works related to seismic improvement of the structures and include a 20% administration contingency and 10% engineering contingency.

SUBDIVISION	SECTION	ESTIMATED COST OF SEISMIC RETROFIT PROGRAM IMPLEMENTATION
Victoria	Victoria to Langford	$ 1,267,500
	Langford to Duncan	$ 4,875,000
	Duncan to Nanaimo*	$ 7,410,000
	Nanaimo to Parksville	$ 3,120,000
	Parksville to Courtenay	$ 4,972,500
	Subdivision Total	**$ 21,645,000**
Port Alberni	Parksville to Port Alberni	$ 6,922,500
	Subdivision Total	**$ 6,922,500**

* Including Wellcox Spur

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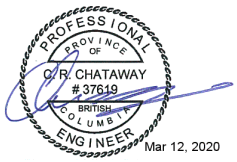

WSP Canada Group Ltd. has prepared this Seismic Condition Memorandum as a component of the Island Rail Corridor: Bridge Assessment report solely for the use of the intended recipient, the British Columbia Ministry of Transportation and Infrastructure, in accordance with the professional services agreement.