SEISMIC MITIGATION PROJECTS

FEASIBILITY STUDY GUIDELINES

July 28 2005

Funding Department

British Columbia
Ministry of Education

1.0 INTRODUCTION

In 2004 the Ministry of Education (MEd) undertook an assessment of existing schools located in high-risk seismic zones of the Province to determine the potential risk of structural damage or failure that could result from a significant seismic event. Over 850 schools located in 37 school districts were assessed over a three-month period. About 750 schools were found to have one or more building components rated at moderate to high risk.

In November 2004, government announced a $1.5 billion plan to make BC schools earthquake safe over the next 15 years. MEd announced the first three years of its Seismic Mitigation Program (SMP) on March 7, 2005. Eighty schools in 29 school districts were approved for upgrading, with additional schools to be included in three school districts, following further consultation with their boards. Seismic upgrading of 95 schools is now expected to commence between 2005/06 and 2007/08 in 30 school districts.

In 2004, MEd retained the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) and the Department of Civil Engineering, University of British Columbia (UBC) to develop new seismic assessment tools. The outcome was UBC-100, a performance-based assessment tool. APEGBC has been subsequently retained to develop a set of interim "bridging" guidelines to enable the design of cost-effective seismic upgrades for seismic risk mitigation of BC schools to commence in 2005. While it is understood that the development of cost-effective retrofit strategies is a multi-year task, the *Bridging Guidelines for the Performance Based Seismic Retrofit of British Columbia School Buildings (Bridging Guidelines)* present a modified approach to determine seismic demand that complements the requirements specified in the 2005 National Building Code of Canada (NBC 2005), with the intent to still achieve a life safety level of performance of the school buildings.

2.0 FEASIBILITY STUDY PROCESS

The feasibility study is the first step in the MEd project procurement process, following the initial approval or support for a capital project. A team of consultants will be required to undertake the feasibility study. The feasibility study typically consists of two stages – the first stage to test and confirm some of the project assumptions that led to the initial support of the project, and the second stage to carry out a more detailed evaluation of seismic deficiencies and develop a preferred retrofit option.

2.1 Consultant Selection

Given the highly technical nature of the work it is recommended that the consultants be hired with the expectation that they will continue with the detailed design and execution of the project, assuming that they continue to meet the district's performance expectations.

2.1.1 Qualification of Consultants

Considerable engineering judgement and experience is required to properly apply the requirements of the new *Bridging Guidelines* and proposed new building code requirements to existing school facilities. Engineers selected to conduct feasibility studies and develop detailed design solutions must attend the APEGBC workshop on Seismic Assessments and

Retrofit Design Concepts Using a Performance Based Approach, presented July 14, 2005, or be trained in the use of the *Bridging Guidelines* by some other means to the satisfaction of the school district, and be able to demonstrate that they are fully conversant with seismic design issues and have considerable experience in undertaking seismic upgrading projects. The qualifications of individuals and firms should match the scope and complexity of the assignment.

Successful consulting engineers should be willing to consider innovative analysis techniques or mitigation concepts. MEd is establishing a peer review process, in partnership with APEGBC, that will enable highly qualified and independent engineers to participate in the review of proposed unique design solutions, at the request of a school district or the Ministry. A peer review should also be considered for all schools situated on Site Class E.

Consideration should also be given to who is designated as the prime consultant for a project. A structural engineer, with experience in project management and coordination of sub-consultants, may be qualified to lead all phases of the project. For projects with significant architectural, renovation, heritage, or building envelope components an architect may be more qualified to lead the project.

2.1.2 Specialist Requirements

The prime consultant will be required to develop scope for, and coordinate specialists or sub-consultants as outlined below.

Architectural

An architect (if not the prime consultant) should be retained in each stage of the feasibility study to provide direction in matters of fire and life safety, building envelope integrity and functionality. Existing building systems and finishes may be disturbed as a direct result of the proposed seismic upgrade and would need to be restored or replaced to maintain the integrity of the existing school.

Geotechnical

Soil conditions are an important variable in the seismic response of buildings. For the first stage of the feasibility study, geotechnical parameters may be derived using existing geotechnical reports or the soils maps provided in the *Bridging Guidelines*. For the second stage of the feasibility study, the services of a geotechnical engineer may be required, with the scope of the geotechnical work to be developed by the prime consultant in conjunction with the geotechnical engineer.

Mechanical and Electrical

Mechanical and electrical components may be disturbed as a result of the proposed seismic upgrade. Engineers in each discipline should be retained in each stage to provide input regarding the cost implications associated with the removal and replacement of these components. The engineers should also comment on the cost-effectiveness of proposed alterations to existing systems in relation to their anticipated service life.

Asbestos
Asbestos and other hazardous materials may be disturbed during a seismic upgrade. For the first stage of the feasibility study the prime consultant may rely on the district's current documentation regarding asbestos. For the second stage of the feasibility study, the services of a qualified asbestos abatement consultant may be required to test possible asbestos-containing materials and determine abatement procedures and costs.

Cost consultant or quantity surveyor
A cost consultant or quantity surveyor shall be required to prepare capital cost estimates in the second stage of the feasibility study process. The consultant should be experienced in seismic mitigation costing.

2.2 Seismic Design Objectives

The **primary objective** of the Seismic Mitigation Program is to reduce life-safety risk to the occupants of schools. The objective is to minimize the probability of local or global structural collapse. Buildings meeting this objective may experience extensive damage to structural and non-structural components and may not be fully accessible after a significant earthquake. Subsequent repairs may be required before the building can be reoccupied, and these repairs may or may not be economical. It is **not** the specific intent of a seismic upgrade to control property damage or to maintain the ability of a building to function immediately after an earthquake.

The feasibility study will need to consider four major categories of seismic hazards:
- structural, including foundations;
- non-structural;
- geologic/site hazards, including liquefaction; and
- adjacency.

The seismic upgrade design shall follow the recommendations in the *Bridging Guidelines*. However, if a building does not fall within the scope of the *Bridging Guidelines*, the building shall be upgraded to the full intent of the NBC 2005 requirements, with an importance factor of 1.0 (not 1.3 as specified for the design of new buildings).

Heavy partition walls shall be assessed and upgraded per the *Bridging Guidelines.* All other non-structural hazards shall be assessed per the 'parts and portions' seismic requirements of NBC 2005 using an importance factor of 1.0.

There may be some buildings or portions of schools that are intended to function as post disaster emergency shelters for the community. Such buildings shall be upgraded to the full intent of the NBC 2005 requirements, including an importance factor of 1.5, but only after a decision has been made by both the district and the Ministry.

2.3 Seismic Project Assumptions

The initial step of the feasibility study will be to test the project assumptions to confirm that the project should proceed. These assumptions must be well documented as they may be revisited in the second stage of the feasibility study. They are outlined in Table 1.

Table 1. Seismic Project Assumptions

Assumption	Testing Procedure
1. That the school, or specific blocks of the school, continues to be a high seismic risk	Each block or building of the school shall be evaluated to determine whether its capacity meets the seismic demand as outlined in the *Bridging Guidelines,* including the effects of any renovations or modifications that have occurred since the 2004 assessments, or were not considered in the original assessment.
2. That the school, or specific blocks of the school, will continue to be required for instructional purposes	The capacity and enrolment of the existing schools and surrounding schools, as well as ten-year enrolment projections, should be reviewed by the school district. Where there is current or forecast surplus capacity in the system, and seismic risks are high, alternative solutions should be considered. **Structural upgrading is not the only means of seismic risk reduction – other methods for specific blocks or buildings include vacating, change of use, partial or total demolition, or disposal.**
3. That value can be achieved through a stand-alone seismic upgrade	Based on the re-assessment, the consultant shall determine an order-of-magnitude capital cost to upgrade the building per the *Bridging Guidelines* such that the LDRS shall be satisfactory for an Intensity of 130% of the design ground motion (a ground motion 1.3 times larger than that specified in NBC 2005). This cost estimate may be based on the consultant's past experience in similar upgrades. **If it is determined that seismic upgrading can proceed at a cost that does not exceed 70% of replacement cost (as determined by the school district), this project assumption has been confirmed.**
4. That voluntary stand-alone seismic upgrading can proceed	The local government approval authority should be consulted to determine what conditions may be applied to a stand-alone seismic upgrading project.

Project Assumption Notes

1. Seismic Risk Assessments

Seismic mitigation projects were approved by MEd based on the 2004 structural assessments and school board priorities. The seismic demand used in the assessments was based on the requirements of the draft NBC 2005, where the design seismic event has a probability of exceeding of 2% in 50 years, and included an importance factor of 1.3 per the requirements for the design of new schools.

Every effort should be made to evaluate the building per the *Bridging Guidelines*. However, if the consultant can demonstrate that the building falls outside the scope of the *Bridging Guidelines,* then the evaluation shall be carried out using the same procedures as the 2004 assessments, but using 80% of the demand based on an importance factor of 1.0, combined with any new information regarding the building.

The *Bridging Guidelines* outline all structural components that are considered to contribute to the Lateral Deformation Resisting System (LDRS) of the building. The total LDRS shall be checked for an Intensity of 110% of the design ground motion (a ground motion 1.1 times larger than that specified in NBC 2005). If the LDRS is not satisfactory for that Intensity then the building shall continue to be considered medium to high risk in need of upgrading.

If the LDRS is satisfactory for that Intensity, **and** all load paths are complete between components, **and** all connections between components meet the overstrength requirements outlined in the *Bridging Guidelines,* **and** all non-structural, geologic and adjacency hazards are low risk, only then shall the building be deemed low to medium risk. As a result, consideration should be given to deferring any upgrading to a later date.

2. Continued Use for Instructional Purposes

Schools known to be closed were not approved for seismic upgrading. If there is any indication that the school may not be required for instructional purposes beyond five to ten years, consideration should be given to deferring any upgrading.

3. Value for Money

The 2004 seismic assessments included an estimated cost to remediate the deficiencies. The budget model used in the seismic assessments assumed that there would be minimal renovation costs associated with the seismic upgrading. Typically, renovations would be limited to the repair of existing systems or removal of hazardous materials that are disrupted in the mitigation process.

If other significant renovations are required in a school, which should proceed concurrently, or if the seismic remediation cost estimate exceeds 70% of replacement cost, other alternatives should be considered, including:

- Securing other sources of funding for the required renovations, such as the Annual Facility Grant (AFG);
- Closing the school and relocating students to a school with a lower seismic risk;
- Deferral of the seismic mitigation project and requesting a major renovation or replacement project in a future capital plan;

- Other risk reduction alternatives (see item 2 in Table 1).

4. Local Authorities Having Jurisdiction
Local governments generally have jurisdiction over the scope of renovations that may be required when a building owner wishes to undertake a “voluntary” upgrade. MEd is encouraging local authorities to take a risk management rather than a prescriptive approach to stand-alone seismic upgrades.

2.4 Feasibility Study Stages

2.4.1 First Stage of the Feasibility Study

The first stage should commence with a review of existing documentation, and a review of any previous seismic mitigation work, as outlined in Table 2. The review must include a site visit to the school to confirm the relevance of the existing documentation. Such reviews shall be carried out prior to the seismic risk re-assessment per the *Bridging Guidelines*.

Table 2. Stage One Review Requirements

1. Structural	• Review the 2004 structural seismic assessment • Review existing drawings • Review any previous structural seismic upgrades • Site inspection
2. Non-structural	• Review any major non-structural issues identified in the 2004 assessment • Review the non-structural assessment previously completed by the Ministry of Finance Seismic Mitigation Program; • Review any previous non-structural seismic upgrades • Site inspection to identify and list those items that pose a real life safety risk (as opposed to damage control or items needed for immediate operation such as boilers, small mechanical or electrical units) • Assess with the district the remaining service life of the listed items
3. Geological/site hazards	• Review any potential hazards identified in the 2004 assessment • Review any available soils maps or soils investigation reports
4. Adjacency	• Review issues including potential pounding between buildings/blocks and any resulting falling objects

The first stage must also test the project assumptions that the school continues to be rated as medium to high risk based on a new evaluation per the *Bridging Guidelines;* the school will continue to be required for instructional purposes; and that seismic upgrading is a preferred means of seismic risk reduction.

A brief report summarizing the conclusions reached at the end of the first stage of the feasibility study must be completed by the prime consultant for the district to review and submit to MEd.

2.4.2 Second Stage of the Feasibility Study

The second stage of the feasibility study should proceed only if supported by the conclusions reached in the first stage.

The second stage of the seismic feasibility includes a more detailed evaluation of the seismic deficiencies and a conceptual upgrade design of alternatives per the *Bridging Guidelines.* It also includes preparation of capital cost estimates for at least two alternatives with a recommendation of the preferred upgrade design, as well as an associated construction schedule and procurement process.

The intent of the *Bridging Guidelines* is to make full use of the capacity of the existing structural components in the LDRS, and only add additional structural components or enhance existing components to make up the "balance of capacity" required. The upgrade design shall use this philosophy unless it can be demonstrated that the cost of a completely new LDRS to meet either the seismic demand per the *Bridging Guidelines* or NBC 2005 (I=1.0) is equivalent to the cost of a "balance of capacity" upgrade. If the cost of a completely new LDRS is developed it shall be compared to the "balance of capacity" upgrade cost.

The upgrade design of the LDRS per the *Bridging Guidelines* shall be satisfactory for an Intensity of 130% of the design ground motion (a ground motion 1.3 times larger than that specified in NBC 2005). In addition, it shall ensure:

- a complete load path exists between all structural components
- all connections between components meet the overstrength requirements outlined in the *Bridging Guidelines*
- all life-safety risk non-structural hazards have been addressed
- all geologic hazards have been addressed
- all adjacency hazards have been addressed

Additional structural analysis may also be required in the following situations:

- heritage designated buildings; or
- any building (or portion) where the post-disaster performance objective has been confirmed.

Further detailed evaluation of geologic/site hazards may be required at this time. If existing soils maps or geotechnical reports are insufficient, further subsurface investigation by a geotechnical engineer may be necessary. Particular attention will need to be paid to any soil liquefaction conditions and any sloping site conditions. This information is essential in order to develop realistic cost estimates.

For schools located on soils designated Site Class E, a site specific response analysis is strongly recommended as a means to minimize the upgrade cost. The site-specific response analysis shall as a minimum verify the Site Class. If confirmed to be Site Class E, the district may choose to carry out further site specific analysis as a means to further minimize the upgrade cost; in such a case a site specific response spectra shall be developed and the services of UBC retained to develop specific seismic demand parameters consistent with the *Bridging Guidelines*.

An implementation strategy should be developed as part of the detailed evaluation giving consideration to the potential phasing or staging of the remediation work. The continued operation of a school during an upgrade project may require the use of any existing "swing" space or the provision of temporary accommodation (e.g. portables).

The second stage will also require the development of plans and written descriptions of proposed scope of work of each upgrade alternative to a level of detail that will enable a cost consultant or quantity surveyor to develop cost estimates. The cost estimate will need to consider all costs associated with the project, including:

- any alterations to mechanical and electrical systems and removal of any hazardous materials resulting from the structural mitigation work;
- any restoration or replacement of building systems or finishes directly affected by the structural mitigation work;
- the costs of project phasing and any temporary accommodation;
- design fees;
- suitable contingencies; and
- construction cost escalation.

There may be some alternative or unusual retrofit concepts considered in the second stage and subsequent detailed design stage. MEd will be establishing an ongoing arrangement with APEGBC and UBC to enable a peer review committee to consider these concepts, at the request of the Ministry or a school district.

2.5 Feasibility Study Reporting Requirements

A concise report should be prepared at the end of both the first and second stage of the feasibility study process. The purpose of the report is to summarize the evaluation, analysis, design and recommendations from the feasibility study, and to prepare some of the documentation required for the Project Agreement (refer to the MEd *Project Procurement Procedures and Guidelines* for further information). The suggested contents of the feasibility study reports are outlined in Table 3.

Table 3. Contents of a Seismic Mitigation Feasibility Study Report

Stage One Summary Report	Confirmation of project assumptions outlined in Table 1.
Stage Two Report	Shall include the following items covered in Stage One: • determination of seismic risk (based on *Bridging Guidelines*) • current and forecast school capacity and utilization
Description of mitigation concept(s)	Written description of recommended mitigation approach(es), with floor plans to illustrate the scope and any proposed phasing. Make reference to: • the project seismic design objective (primary or post-disaster) • design guidelines (per *Bridging Guidelines*, or per NBC 2005 I=1.0 or any alternatives)
Cost estimate	Estimate of project costs that follows the format of the Project Agreement Schedule B.
Procurement process	Recommended project procurement and project management process, based on consultation with the district.
Risk management	Identify any seismic issues that may not be completely resolved.
Project milestones and schedule and expenditure forecasts	• project timelines to tender, construction award and completion • estimates of quarterly cash flow requirements
Concurrent projects	Description of any other self-funded renovations to be undertaken concurrently by the school district.