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INTERIM GUIDELINES
REV 1: Issued November 9/10
Seismic Design Requirements for High Consequence Dikes

1. Application

These interim guidelines apply to the design and construction of new and major upgrades to high consequence dikes. More comprehensive guidelines are under development. However, until these are available, designs must generally be consistent with these interim guidelines to obtain *Dike Maintenance Act* approval.

2. Definitions

High Consequence Dikes are flood protection works where the consequences of failure during a major flood are very high. These works typically protect urban or urbanizing areas, and failure could result in large economic losses and/or significant loss of life.

Major Dike Upgrade - a project involving the raising of the design crest elevation of a high consequence dike, or where the dike is being significantly reconstructed, or widened to meet provincial dike standards.

3. Background and Policy Considerations

The west coast of British Columbia including Vancouver Island is an earthquake prone region because of the location of and movement at tectonic plate boundaries. Seismic risks are generally lower in the BC interior. The Lower Mainland is a high seismic risk area where there is a significant potential for extensive damage to the Fraser River and sea dike system in a large earthquake.

The Fraser River Flood Control Program (FRFCP) reconstructed approximately 250 km of river and sea dikes between 1968 and 1994. Except for the Barrowtown Pump Station in Abbotsford, the Fraser River Flood Control Program design criteria (developed 40 years ago) did not address seismic design issues, given the cost constraints of the program.

Current projects to upgrade dikes, through raising and widening to meet new design flood levels, without commensurate design and construction measures to address other modes of dike failure, including seismic, lead to a false sense of security.

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Other jurisdictions (i.e. California Department of Water Resources and US Army Corps of Engineers) are specifically addressing seismic issues in their current flood protection projects.

Seismic strengthening measures are most efficiently incorporated into a structure at the same time as upgrading of the works for other reasons (i.e. raising and widening to meet higher design flood levels).

Dikes that have a high likelihood of co-incident (or near co-incident) high water and earthquake loading should be subject to higher standards of seismic design and construction than those dikes that only infrequently experience loading from high water. Examples of the former include the Vedder Canal dikes and dikes subject to high tides (e.g. many of the Richmond, Surrey, and Delta dikes). Examples of the latter include the Chilliwack East Dike and most other Fraser River dikes upstream from the Fraser Estuary.

The likelihood of flooding from failure of a dike from a seismic event, or from combinations of seismic and high water events should be approximately equivalent to the likelihood of failure of the dike from the design flood event.

Dikes that only infrequently experience loading from high water should be evaluated for seismic stability using typical water surface elevations. Flood risk should be addressed through a combination of seismic strengthening prior to the earthquake, emergency planning and response, and both short and long term repairs following the earthquake.

4. Fraser River Dikes – River Dikes Not Influenced by Ocean Storm Surge

Fraser River dikes, upstream of the tidal estuary, generally have a low likelihood of co-incident high water and earthquake loading. Design flood events are restricted to the May, June, July freshet period. Dike crest elevations for these Fraser River Dikes are based on flow for the 1894 flood of record which is estimated to have an annual exceedance probability of approximately 1 in 500.

The seismic design of the dikes shall meet the following requirements and criteria:

- Completion of detailed subsurface investigations, laboratory testing and analyses of the seismic stability of the dike materials and foundation soils. The analyses shall include the estimation of permanent displacements (settlement and lateral spreading) caused by ground shaking and liquefaction.

- Assessment of the probable damage to the dike and appurtenant structures for the the 1 in 500 annual exceedence probability seismic event at the mean annual water level.

    - Post seismic event damage must be limited such that the dike will remain capable of providing flood protection for the mean annual water level, plus 0.6 m freeboard.

- Completion of a post earthquake remediation plan, based on the estimated probable damage.

- Post seismic event damage must be limited so that the dike and appurtenant structures can be rebuilt within 4 to 6 months to provide flood protection for the 1 in 10 annual exceedence probability peak water level plus 0.6 m freeboard.

- If the above remediation appears infeasible to implement, the dike design and construction shall incorporate further seismic strengthening measures to a point where the dike can be remediated to the 1:10 level within 4-6 months. The remediation plan should allow for possible limitations in the availability of heavy equipment and materials following a large regional earthquake.

5. <u>Sea and River Dikes within the Fraser Estuary – Subject to Ocean Storm Surge but not Ocean Waves</u>

The seismic design of these dikes shall meet the following requirements and criteria:

- Completion of detailed subsurface investigations, laboratory testing and analyses of the seismic stability of the dike materials and foundation soils. The analyses shall include the estimation of permanent displacements (settlement and lateral spreading) caused by ground shaking and liquefaction.

- Assessment of the probable damage to the dike and appurtenant structures for the the 1 in 500 annual exceedence probability seismic event at the mean annual water level.

  - Post seismic event damage must be limited such that the dike will remain capable of providing flood protection for the estimated flood level resulting from higher high water large tide (HHWLT) during mean annual flows on the Fraser River, plus 0.6 m freeboard. (HHWLT is the average of the highest high waters, one from each of 19 years of predictions.)

  - Complete sensitivity analyses to determine the worst case damage for the range of tidal variation. (This information will assist with emergency response planning.)

- Completion of a post earthquake remediation plan, based on the estimated probable damage.

  - Post seismic event damage must be limited so that the dike and appurtenant structures can be rebuilt within 4 to 6 months to provide flood protection for the 1 in 10 annual exceedence probability peak water level plus 0.6 m freeboard.

  - If the above remediation appears infeasible to implement, the dike design and construction shall incorporate further seismic strengthening measures to a point where the dike can be remediated to the 1:10 level within 4-6 months. The remediation plan should allow for possible limitations in the availability of heavy equipment and materials following a large regional earthquake.

6. Sea Dikes – Subject to Ocean Storm Surge and Waves

As per section 5. above, except that:

- Post seismic event damage must be limited such that the dike will remain capable of providing flood protection for the estimated flood level resulting from higher high water large tide (HHWLT) plus the wave and wind set up, and wave run up associated with a "mean annual storm", plus 0.6 m freeboard;

And:

- Post seismic event damage must be limited so that the dike and appurtenant structures can be rebuilt within 4 to 6 months to provide flood protection for the 1 in 10 annual exceedence probability peak water level plus the wave and wind set up, and wave run up associated with a 1 in 10 annual exceedence probability storm, plus 0.6 m freeboard.

If the levels determined from the above criteria are higher than the dike crest design elevation before the seismic event, the level criteria default to the pre-seismic event dike design elevation.

7. Other High Consequence Dikes in BC

To be developed – guidance should be obtained directly from the Inspector and Deputy Inspectors of Dikes.

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