Dam Safety Management in BC for Small Dams

Dr. Dwayne D. Tannant
School of Engineering

Background

• Dam owner is directly responsible for dam safety
• Government functions as a regulator and licensing body and oversees all dams in the province
  – Dam Safety Program established in 1967 by the Comptroller of Water Rights to ensure that major dams in BC were designed, constructed, operated, and maintained to acceptable standards for public safety
  – regulations have evolved over time
  – now includes a stronger 'watch-dog' component than it did before 2010

• Today, dam safety includes a strong emphasis on a dam safety management system
Small Dams in US

- A study of 23 dam failures, which resulted in fatalities from 1960 to 1998, demonstrated that the failure of dams between 6.1 and 15 m high represented 18 of the dam failures and caused 86% of deaths; 5 dams <6.1 m high failed and caused 2% of deaths
- Average age of the dams that failed was only 40 years
- Poorly managed small dams pose significant individual and cumulative threats that cause catastrophic human, property, and environmental losses

Small Dams in Australia

- Surveys of farmer practices provide empirical evidence of the importance of policy and its proper implementation
- A purely voluntary/educative mechanism was found to be unacceptable as a minimum benchmark for dam safety management
- Cost burdens to small dam owners can be minimized by making available affordable design/review processes such as the cost-effective spillway designs
**Canadian Record on Dam Failures**

- Approximately 1 to 3 small dams fail in BC every year
- 5 recorded dam failures resulting in 11 fatalities in Canada since 1908
- No failures of “large” dams in Canada
- June 2010 failure of Testalinden dam, British Columbia

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**Testalinden Dam Failure (June 13, 2010)**

[Image of dam breach]
Before

Testalinden Dam

Testalinden Creek

100 m

4 Hrs After Dam Breached

Metal culvert

High water mark prior to dam breach

Photo: Chris Jentsch
Breach

Consequences

overall losses and compensation to land owners estimated at ~$20 million
Consequences

- Comprehensive review of over 1000 dams in BC
- Evaluation of dam management practices
- Changes to the *Water Act* and the associated *Dam Safety Regulation*
- Hiring of more dam safety officers (still not enough)
- Improvements in how data on dams are collected and archived
- Improvements in dam safety education materials
- Creation of professional guidelines for dam safety reviews in BC
Some Consequences for You

- Increased pressure to report/comply is now being placed
  on all dam water license holders (owners)
  - watch-dog showing/using its teeth (enforcement)
  - recent regulatory changes are minor, but the emphasis on
    compliance and tracking of compliance is certainly much higher
- Dam classification changed to match Canadian Dam
  Association (2007) guidelines
  - dictates required frequency and complexity of dam safety
    management activities required by owner
- New signage requirements for dams on Crown Land
  classified as significant, high, very high or extreme

Some Consequences for You

- Dams are becoming increasingly regulated across
  Canada (and the world)
  - to protect the public, infrastructure, and the environment
  - once regulations are established, they stay forever – a reality
    you must face
- Dams exceeding their life-span or dams with poor safety
  management systems are more likely to fail
  - Small earth dams are exposed to gradual deterioration; owners
    need to be aware of these changes
- Climate change is causing more precipitation extremes
  - increased risk for dam failure (e.g. insufficient spillway capacity)
**Dams in BC**

- **Regulated dams**
- **OR**
  - Downstream consequence classification of Significant, High, Very High, or Extreme

**Dam Classification** *(in Terms of Consequence of Failure)*

<table>
<thead>
<tr>
<th>Dam class</th>
<th>Population at risk</th>
<th>Loss of life</th>
<th>Environmental and cultural values</th>
<th>Infrastructure and economics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>None</td>
<td>0</td>
<td>Minimal short-term loss</td>
<td>Low economic losses; area contains limited infrastructure or services</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No long-term loss</td>
<td></td>
</tr>
<tr>
<td>Significant</td>
<td>Temporary only</td>
<td>Unspecified</td>
<td>No significant loss or deterioration of fish or wildlife habitat</td>
<td>Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Loss of marginal habitat only</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Restoration or compensation in land highly possible</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Permanent</td>
<td>10 or fewer</td>
<td>Significant loss or deterioration of important fish or wildlife habitat</td>
<td>High economic losses affecting infrastructure, public transportation and commercial facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Restoration or compensation in land highly possible</td>
<td></td>
</tr>
<tr>
<td>Very High</td>
<td>Permanent</td>
<td>100 or fewer</td>
<td>Significant loss or deterioration of critical fish or wildlife habitat</td>
<td>Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities for dangerous substances)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Restoration or compensation in land possible but impractical</td>
<td></td>
</tr>
<tr>
<td>Extreme</td>
<td>Permanent</td>
<td>More than 100</td>
<td>Major loss of critical fish or wildlife habitat</td>
<td>Extreme losses affecting critical infrastructure or services (e.g., hospital, major industrial complex, major storage facilities for dangerous substances)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Restoration or compensation in land impossible</td>
<td></td>
</tr>
</tbody>
</table>
### Frequency of Activities Based on Classification

<table>
<thead>
<tr>
<th>Activity</th>
<th>Extreme</th>
<th>Very High &amp; High</th>
<th>Significant</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site surveillance</td>
<td>Weekly</td>
<td>Weekly</td>
<td>Monthly</td>
<td>Quarterly</td>
</tr>
<tr>
<td>Formal inspection</td>
<td>Semi-Annually</td>
<td>Annually</td>
<td>Annually</td>
<td>Annually</td>
</tr>
<tr>
<td>Monitor instrumentation</td>
<td>Annually unless otherwise specified in OMS</td>
<td>Annually unless otherwise specified in OMS</td>
<td>Annually unless otherwise specified in OMS</td>
<td>If and when required by Dam Safety Officer</td>
</tr>
<tr>
<td>Test operation of outlet facilities, spillway gates and other mechanical components</td>
<td>Annually</td>
<td>Annually</td>
<td>Annually</td>
<td>Annually</td>
</tr>
<tr>
<td>Update emergency contact information in EPP</td>
<td>Annually</td>
<td>Annually</td>
<td>Annually</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Review and revise, if necessary, OMS and EPP</td>
<td>Every 7 years</td>
<td>Every 10 years</td>
<td>Every 10 years</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Conduct Dam Safety Review and submit report</td>
<td>Every 7 years</td>
<td>Every 10 years</td>
<td>Not Applicable</td>
<td>Not Applicable</td>
</tr>
<tr>
<td>Review downstream conditions and notify Dam Safety Officer of any changes</td>
<td>Annually</td>
<td>Annually</td>
<td>Annually</td>
<td>Annually</td>
</tr>
</tbody>
</table>
Critical Components for Dam Safety

- Owner commitment to dam safety
- Effective operations, maintenance, and surveillance practices (OMS)
- Effective emergency preparedness planning (EPP)
- Regular dam safety reviews, if needed

- These components are part of a dam safety management system
  - a system your DSO would like to see you develop and use

Dam Safety Management System (CDA 2007)

- **Dam Safety Policy**
  - Reporting
    - Periodic reporting to management and regulator
  - Corrective Actions
    - Peer reviews and audits
    - Incident investigations
    - Respond to deficiencies and non-conformances identified during Dam Safety Reviews
    - Respond to inspections, monitoring, equipment testing or emergency preparedness tests

- **Planning**
  - Work program components
  - Execution responsibilities
  - Standards and procedures
  - Resources
  - Schedules

- **Implementation**
  - Operation
  - Maintenance
  - Surveillance
  - Emergency preparedness

- **Supporting Processes**
  - Staff training and qualification
  - Program communication
  - Record keeping and management

- **Checking and Reviewing**
  - Dam surveillance and Dam Safety Reviews
  - Program peer reviews or review boards
  - Program audits
  - Incident Investigations
  - Testing of emergency preparedness
  - Equipment tests
Effective OMS Practices

- Effective OMS practices include
  - operating rules that do not compromise safety
  - maintenance schedules
  - multi-level surveillance and monitoring
  - complete life-cycle management
  - Writing records/documentation
- Dams can fail if allowed to deteriorate
- Regular surveillance can detect a deficiency prior to a catastrophic event

Operations

- Dams need safe operating criteria:
  - maximum safe discharge rates
  - highest safe reservoir levels
  - seasonal constraints
- Dams need monitoring to verify safe operations
- For extreme inflow conditions
  - have procedures and equipment to ensure gates are operational
  - have redundancies and back-up systems
Maintenance

- Adequate financial resources are essential for an effective maintenance program
  - issue of relevance to some of you today
- Testing of flow control equipment should be part of inspection and maintenance
- Owners should have
  - accurate inventory of the dam components and their maintenance requirements
  - schedule of maintenance activities and a tracking system

Surveillance

- Routine surveillance performed according to schedule
  - driven by the dam classification
  - tempered by issues of practicality (e.g. dam access)
- Special surveillance done after unusual or extreme events
- Maintain records/documentation of surveillance
  - instrumentation, if any, regularly monitored and results recorded
Effective Emergency Preparedness

- Effective Emergency Preparedness Plan (EPP) involves a written plan in the event of an emergency situation
- EPP doesn’t need to be a long document; a 2-page template appropriate for small dams is available from MFLNRO
- Experience has shown that emergency plans save lives during dam failures
Formal Annual Inspection
It is recommended that you customize this form to fit your dam.

Pre-inspection information
Name of Dam: ___________________________ Inspection Date: ______________________________
Current Elevation: ___________________________ Weather During Last Week: _______________________
Name of Owner: ___________________________ Water Licence #: _______________________________
Date of Dam: ___________________________ Phone #: _______________________________
E-mail: ___________________________
City, Province: ___________________________ Post Office Code: _______________________________
Name of Principal Contact Person: ___________________________ Principal Contact's Cell Phone: _______________________________
Principle Contacts: ___________________________ Other Inspection Participants: _______________________________
Person Responsible for this Inspection: ___________________________ Phone #: _______________________________

Date of Last Annual Inspection: ___________________________
Was last Annual Inspection Report reviewed? ___________________________
Vore dam deficiency identified that required follow-up? ___________________________
Date of Last Dam Safety Report (DSR): ___________________________
Was last DSR Report reviewed? ___________________________
Vore recommendations from the last DSR Report implemented? ___________________________
Repairs or modifications done in last formal inspection? ___________________________
Factual discrepancies/revisions since last formal inspection? ___________________________
Is the Works Currently Fully Operational? ___________________________

Dam Information
Type of Dam: ___________________________ Max. Height of Dam: _______________________________
Are date materials well known? Are foundation conditions well known? ___________________________
Are date construction details well known? Construction Date: _______________________________

Failue Consequence Classification
Circle current Failure Consequence Classification (based on BC Dam Safety Regulation):
Low Significan High Very High Extreme

Hydrology
Discharge Area: ___________________________ Reservoir Area: _______________________________
Inflow Design Flood (IDF): ___________________________ IDF Return Period: _______________________________
Discharge Flood: ___________________________ (if available)
Discharge Flood: ___________________________ (if available)
Spillway Crest Elevation: ___________________________
Spillway Width: ___________________________
Spillway Capacity: ___________________________
Gates (if spillway is equipped) ___________________________
Reservoir Storage Volume: ___________________________
Licensed Storage Volume: ___________________________

Emergency Preparedness Plan (EPP)
Is the emergency contact information in the EPP been updated this year and distributed as required? ___________________________

Embankment Dam
1. Upstream Slope

   DATE: ___________________________ LOCATION: ___________________________.

   VERTICAL VEGETATION: ___________________________.
   DATE: ___________________________.
   REQUIREMENTS: ___________________________.
   LOCATION: ___________________________.
   SLOPE PROTECTION:
   DATE: ___________________________.
   RECOMMENDATIONS: ___________________________.
   LOCATION: ___________________________.

   SLOPE:
   DATE: ___________________________.
   NOTES: ___________________________.
   LOCATION: ___________________________.
   LENGTH: ___________________________.
   WIDTH: ___________________________.

   INUNDATION:
   DATE: ___________________________.
   WATERLINES: ___________________________.
   LOCATION: ___________________________.
   LENGTH: ___________________________.
   WIDTH: ___________________________.

   CREEK:
   DATE: ___________________________.
   TRAVELING VEGETATION:
   LOCATION: ___________________________.
   LENGTH: ___________________________.
   WIDTH: ___________________________.
   VEGETATION:
   DATE: ___________________________.
   LOCATION: ___________________________.
   SURFACE:
   DATE: ___________________________.
   LOCATION: ___________________________.

   GROUND COVER:
   DATE: ___________________________.
   NOTES: ___________________________.
   LOCATION: ___________________________.

   EROSION:
   DATE: ___________________________.
   LOCATION: ___________________________.
   LENGTH: ___________________________.
   WIDTH: ___________________________.

   SEDIMENT:
   DATE: ___________________________.
   LOCATION: ___________________________.
   NOTES: ___________________________.

2. Crest

   AREAS:
   DATE: ___________________________.
   IS THERE PUBLIC ACCESS TO THE CREST? (CHECK)
   IS THERE MARKED OR SIGN Điểm: ___________________________.
   IS THERE ACCESS TO THE CREST MARKED? (CHECK)
   VEGETATION:
   DATE: ___________________________.
   VEGETATION:
   DATE: ___________________________.
   LOCATION: ___________________________.
   NOTES: ___________________________.
   BRUSH:
   DATE: ___________________________.
   LOCATION: ___________________________.
   NOTES: ___________________________.
   GROUND COVER:
   DATE: ___________________________.
   LOCATION: ___________________________.
   NOTES: ___________________________.
   EROSION:
   DATE: ___________________________.
   LOCATION: ___________________________.
   NOTES: ___________________________.
**Dam Safety Review**

- For High, Very High, and Extreme dams
- Dam safety review involves six components:
  - site visit and dam inspection
  - review dam classification
  - review design and construction
  - review operations, maintenance and surveillance practices
  - review emergency preparedness
  - review previous reports and implementation of recommendations

- Canadian Dam Association has dam safety review guidelines outlining the recommended content of a review
- APEGBC now has professional practice guidelines

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**LEGISLATED DAM SAFETY REVIEWS IN BC**

APEGBC PROFESSIONAL PRACTICE GUIDELINES

12/11/15
Review Engineer

- Review engineer should be a registered professional engineer with appropriate experience
  - Review engineer cannot carry out two consecutive safety reviews of the same dam

Dam Safety Management System

- The regulated approach for dams in BC requires a level of diligence on the part of the dam owner
- Dam owner should develop and implement a Dam Safety Management System
- Required complexity for an effective dam safety management system should match the size, type, and risks associated with the dam
  - more templates/training needed to assist in development of an effective system
  - best practices; pragmatic and realistic
  - sharing the effort/cost
  - partnerships and support
Could This Have Been Prevented?

Action Items For You

- Be more aware of the regulatory requirements that come attached to your water licence
- Buy into the notion of being a responsible owner in an regulated environment
- Work with others to minimize the effort and cost to develop and implement a simple, effective, dam safety management system
- Respond in a timely manner to the dam information requests from your DSO – they have a job to do too
  - keep e-copies of the information you assemble and submit so it is easier to submit subsequent documents
Dam Safety Education

- Online resources
- Workshops
- Sharing best practices
- Roles for government (DSO), educational institutions, consultants
Unit 1 Inspection of Embankments
Unit 2 Inspection of Deficiencies:
   Part 1- Steepness
   Part 2- Cracks, Depressions, Sinkholes, Maintenance Concerns

Manual on small earth dams
A guide to siting, design and construction