Dam and Canal Safety Guidelines

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Alberta
ENVIRONMENT

WATER ACT

WATER (MINISTERIAL) REGULATION
PART 6

DAM AND CANAL SAFETY

GUIDELINES

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THE WATER ACT

DAM AND CANAL SAFETY GUIDELINES

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INTRODUCTION

On September l9, l978, Alberta became the first province to establish a Dam and Canal Safety Regulation.
On January 1, 1999 the Water Act came into force. The Dam and Canal Safety Regulations under Water Resources Act were incorporated into the Water (Ministerial) Regulation Part 6.

The purpose of the Regulation is to promote the safety of dams and canals primarily to prevent loss of life, and secondly, economic losses due to failure of these structures.

These Guidelines provide information as to how the Regulation is administered by the Dam Safety and Water Projects Branch of Alberta Environmental Protection. The Guidelines were originally published in February 1979 and updated in January 1983.

LICENSING

Before any water retaining structure is constructed the person, agency or company undertaking the project requires authorization pursuant to Part 4 of the Water Act. To obtain authorization, the applicant must apply to the Director. The application will state the quantity of water that can be diverted and used and include plans of the project (drawings and specifications).

The Director has certain requirements before an application can be processed. Further details can be obtained from the Department Regional office.

The Director will always refer the application to the Dam Safety and Water Projects Branch for review and advice if the structure meets or exceeds the following criteria.

In the case of a dam, the structure should be at least 2.5 meters high and have at least 30,000 cubic meters or more in reservoir capacity.

In the case of a canal, the conveying capacity should be 15 cubic meters or more per second and the embankments should be at least 2.5 high.

Other structures may be referred at the discretion of the Director.

For the Dam Safety and Water Projects Branch to complete a review, certain additional information is required as discussed later in the Guidelines.

The approval holder is responsible for the construction of a new structure, and the operation and maintenance of an existing structure in a manner such that the structure is, and remains, stable and safe. The approval holder is also responsible for the cost of any repair work required to meet the requirements of the regulation and is expected to keep

any works in good condition.

DELEGATION OF POWERS

Some of the powers of the Minister in the Regulation have been delegated to the Dam Safety and Water Project Branch Head. Therefore, a notification, direction, or other order prescribed in the Regulation signed by the Dam Safety and Water Projects Branch Head has the same authority as if it had been signed by the Minister.

UNDERSTANDING THE REGULATION

Part 6 (Dam and Canal Safety) of the Water (Ministerial) Regulation must be read in conjunction with the Water Act to obtain a full understanding of the legislation. Copies of the Act and Regulation are available from the Queen's Printer.

APPLYING FOR A LICENCE

The Director will refer the application to the Head of the Dam Safety and Water Projects Branch before granting or refusing an application for a licence or approval or for an amendment of an approval involving the construction, repair, improvement, change, alteration, replacement, suspension, abandonment, or removal of a dam or canal as defined in the Part 6 of the Water (Ministerial) Regulations.

When an application is referred to the Dam Safety and Water Projects Branch, the drawings and other documents related to the proposed structure will be evaluated to ensure that the structure has been fully detailed and sufficient design analysis has been undertaken by the applicant and/or the applicant's engineering representative.

To enable the Dam Safety and Water Projects Branch to evaluate the proposed structure, the following list of information (List A) must generally be provided when filing an application with the Director. List A is meant to cover all types of structures. Variations in the content of the information is left to the discretion of the individual engineer submitting the information.

While the Dam Safety and Water Projects Branch does not expect to receive highly detailed information on each project, inevitable delay will occur in the processing of an application if insufficient information is presented. Applicants should contact the Dam Safety and Water Projects Branch prior to submission of an application that involves a dam or canal affected by the Act to ensure that the applicant has a good understanding of what is required to meet the regulation and what the Dam Safety and Water Projects Branch requires to review the project.

REQUIRED INFORMATION TO BE SUBMITTED WITH AN APPLICATION FOR A LICENCE - LIST A

l. Key plan showing principal topographic features of the drainage area (watershed) and downstream channel at an appropriate scale.

2. General plan of dam and adjacent areas at an appropriate contour

interval showing location of all appurtenant structures and reference bench marks.

3. General plan of dam and reservoir at an appropriate scale showing borrow areas, extent of reservoir, water surface and reservoir capacity curves.

4. Centerline profile of dam showing the following:

   a) crest elevation
   b) FSL (full supply level) and MWL (maximum water level)
   c) natural ground surface
   d) depth and nature of underlying strata as shown by test pits or borings
   e) probable depth of excavation for foundation or cut-off
   f) location and dimensions of conduit outlets.

5. Typical cross-section(s) of dam at maximum section showing:

   a) embankment slopes and dimensions
   b) position, dimensions and material of any cut-off
   c) position and dimensions of any zoned material, filter layers, rock toes, etc.
   d) nature and dimensions of any slope protection

6. Gradation curves of granular filter materials and the base material being protected.

7. Calculations showing analysis of embankment stability including the effect of rapid drawdown of the reservoir.

8. Details of the hydrologic studies carried out to establish the size of the spillway(s).

9. Detailed plan(s) of spillway showing:

   a) width and shape of crest
   b) length of spillway (centerline profile)
   c) grade and shape of approach and discharge channels
   d) layout of upstream and downstream erosion protection
   e) dimensions of floors, walls
   f) under-drainage beneath the slab and location of any cut-offs
   g) spillway rating curve and design discharge (flood discharge and frequency of event)
   h) tailwater rating curve.

10. Detailed plan(s) of outlet works showing locations and dimensions of all valves or sluice gates, intakes, trash racks, outlet towers, gate houses and appurtenant structures.

11. Discharge rating curve for the outlet works.

12. Sub-surface exploration results showing (as necessary):

    a) depth to bedrock (where exploration taken to bedrock)
    b) classification of both rock and soil underneath the dam and its appurtenant structures
    c) illustrated logs of all holes with depth to water table and dates of measurement recorded
    d) results of other tests performed
    e) all unusual surface and sub-surface geological features
    f) classification and strength

parameters of construction materials.

13. Miscellaneous plans of construction features not covered above such as pilings, fish ladders, flash boards, timber details, radial gates or mechanical operating devices, fuse plug spillways, etc.

14. Construction specifications.

15. Proposed construction schedule.

Certain structures may be subjected to an in-depth evaluation by the Director depending on the consequences of failure, location, or other factors. In these cases, the Dam Safety and Water Projects Branch may ask for additional information regarding the project. List B includes some of the areas for which additional information may be required.

ADDITIONAL INFORMATION - LIST B

l. Spillway and outlet model studies.

2. Plans for handling river diversion during construction.

3. Flood inundation maps, flood action plans, and emergency preparedness plans.

4. Instrumentation drawings, reports and reading schedules.

5. Schedule of first filling of reservoir, operating methodology.

6. Design reports covering.
   - Hazard Assessment.
   - Freeboard Selection etc.

7. Additional information required at discretion of the Dam Safety and Water Projects Branch.

After receiving the required information, the Dam Safety and Water Projects Branch will evaluate the proposed structure and recommend to the Director that the application be approved or rejected. Approval may have certain conditions attached to it. These may include the following items:

a) inspection of the works during and after construction
b) notification of the Dam Safety and Water Projects Branch prior to start of construction
c) provision of Emergency Preparedness Plans (EPP's)
d) provision of Operations and Maintenance and Surveillance (OMS) Manuals
e) instrumentation readings
f) visual inspections
g) first filling schedules, and
h) future reporting.

EXISTING STRUCTURES

Part 6 of Water (Ministerial) Regulations allows inspections of dams and canals and their associated appurtenant structures to determine if they are safe.

The administrative process associated with operation of Part 6 of Water (Ministerial) Regulations is detailed below. Parts and Sections referred to are parts and sections in the Regulation.

1. Interpretation defines various terms used in the Regulation:

   In Section (e), "canal" also includes:

syphons, flumes, ditches, aquaducts, etc. that are capable of conducting 5 cubic metres/sec. or more.

In Section (h), "dam" also includes the foundations and abutments, the reservoir and its outer perimeter and works related to the barrier such as spillways, penstocks, conduits, outlet works, and other flood or riparian controls.

2. The Minister has delegated the powers under the Water Act for sections 97, 98, 99, 100, 101, 103, 104, 105, 107, 115(1)(m), 157(b), 160 and 167 to the Head of the Dam Safety and Water Projects Branch.

3. Part 6 of the regulation allows the Dam Safety and Water Projects Branch Head to obtain existing information on individual structures, arrange an initial site inspection and proceed to obtain extra information, if required, to determine the condition of the structure.

4. Section 29 of the Regulation requires that within 90 days of receiving a request from the Head of the Dam Safety and Water Projects Branch, the Licensee must supply all existing data on the dam or canal and arrange a site inspection. The Licensee and any person giving technical advice to the Licensee may accompany the Dam Safety and Water Projects Branch staff during this inspection. Formal Dam Safety Inspections will normally be required every five years for major dams with a Dam Safety Report being prepared.

5. Section 33(1) of the Regulation requires that the Licensee supply additional information, as requested, to the Dam Safety and Water Projects Branch Head so that the condition of the dam or canal may be evaluated. For larger structures, mainly dams, the Dam Safety and Water Projects Branch Head will require that the Licensee report on the condition of the structure. The report must identify any deficiencies and make recommendations regarding repairs, modifications, etc. to ensure the project is safe. The report must contain a recommended date for future inspections and reports.

   The Licensee may notify the Dam Safety and Water Projects Branch Head that he is engaging an independent professional engineer to obtain the information or prepare the reports.

   The Dam Safety and Water Projects Branch Head may determine that the information or report is sufficient to determine the condition of the dam or canal. If no further work is required on the dam or the canal, the Dam Safety and Water Projects Branch Head will inform the Licensee accordingly and may prescribe a date when a further inspection will be required.

6. The Dam Safety and Water Projects Branch Head may decide that the information or report is inadequate and that further information or work is required. The Dam Safety and Water Projects Branch Head may direct the Licensee to obtain further information or do such other and further things as necessary.

7. Section 32(1) of the Regulation allows the Dam Safety and Water Projects Branch Head to direct the Licensee to make such repairs, improvements, changes to, or replacements of all or part of the dam or canal as he considers necessary for the safety of any person or property affected or likely to be affected by the dam or canal.

8. Section 32(3) requires that a person who has obtained the Directors authorization must submit a schedule for completion of the work to the Director at least 14 days before commencing.

APPENDIX I - DEFINITIONS

Dam:

A barrier constructed for the purpose of storing water or water containing any other substance, e.g. oil sand tailings, coal waste. For the purpose of this Guideline, a dam is limited to those structures at least 2.5m high and is at least 30,000 cubic meters or more in reservoir capacity.

Freeboard:

The vertical distance between the Full Supply Level and the lowest elevation of the crest of the dam.

Incremental Consequences of Failure. Classification of Dams.

This is a measure of the increase in loss of life and economic damage attributable to dam failure caused by a specific natural event (flood) over and above that which would have occurred due to the natural event (flood) without dam failure.

Each dam is assessed and placed in one of four categories related to their incremental consequences of failure: very high, high, low, very low.

Inflow Design Flood: (I.D.F.)

The flood hydrograph used to design or assess the discharge capacity of the dam.

For each individual project the selected inflow design flood should be developed using recognized hydrologic methods applicable to local conditions used to estimate the shape volume and frequency of the selected inflow design flood.

Probable Maximum Precipitation: (P.M.P.)

The greatest depth of precipitation for a given duration that is physically possible over a given area at a particular geographic location at the most critical time of the year.

Probable Maximum Flood: (P.M.F.)

A hypothetical flood for a selected location on a given stream whose magnitude is maximized according to accepted methods. It is estimated by combining the most critical meteorological and hydrological conditions considered reasonably possible for the particular location under consideration.

APPENDIX II - SPILLWAYS

Spillway Capacity:

Each dam must be provided with a spillway or spillways sized to accommodate the passage of floods. The spillway must be capable of discharging extreme floods without causing failure of the dam. Limited

damage may be sustained provided it does not affect the integrity of the dam.

When routing the inflow design flood through the reservoir the level of the reservoir prior to the flood should be assumed to be full supply level or the normal operating level for that time of year.

Service Spillways, Emergency Spillways and Outlets:

The sizing of the various outlets is left to the judgment of the design engineer. In general, the operating or service spillway should be large enough so that the emergency spillway operates infrequently.

In all cases, specific data must be supplied for the reservoir showing details of the freeboard calculations. Also rating curves must be supplied for the full range of operation of each spillway and/or outlet.

Minimum Freeboard Required:

Freeboard is the minimum allowable difference in elevation between the lowest elevation of the crest of the dam and the maximum flood level attained when routing the Inflow Design Flood through the reservoir.

Some of the factors to be considered in determining the freeboard required are:

- Extreme floods
- Wave run-up due to wind generated waves and wind set-up
- Settlement of the crest of the dam.

Selection of the Magnitude of the Inflow Design Flood (I.D.F.):

In order to select the appropriate IDF for a project, it is necessary to assess the incremental consequences of failure, i.e., loss of life, damage and environmental and social impacts due to dam failure arising from a flood that exceeds the IDF to those losses that would occur for the IDF routed through the reservoir and outlets without dam failure.

The most important decision to be made in selection of the IDF is whether there would be potential for incremental loss of life. No incremental loss of life is acceptable.

If a dam is designed to pass a large flood (for example, the 1 in 5000 year event), then the spillway discharge during this event may cause considerable downstream damages and potential loss of life, in fact, all of the habitation may be flooded in which case no further potential loss of life is possible due to dam failure as a result of a larger flood. In this case, increasing the spillway capacity would not be required to satisfy the “no incremental loss of life requirements”. It would then require an economic risk analysis to determine if the economic losses, including loss of the dam, could be tolerated if a larger flood occurred and caused the failure of the dam.

The incremental consequences of failure for the dam can be selected using Table 1. From this category the recommended spillway I.D.F. can be obtained from Table 2.

Both new and existing spillways are treated equally and the same analysis can be applied to both. In general, where a potential for incremental loss of life exists, the PMF should be used as the IDF. Where no incremental loss of life due to dam failure could occur, then the IDF should be selected based on economic or risk analysis with a minimum of the 1 in 100 year event. A number of organizations have attempted to address the question of spillway adequacy and especially the adequacy of existing spillways using risk-based analysis. References 5, 6, 7 & 8 provide some insight into this subject.

TABLE 1
CLASSIFICATION OF DAMS IN TERMS OF CONSEQUENCES OF FAILURE

CONSEQUENCE CATEGORY	**POTENTIAL INCREMENTAL CONSEQUENCES OF FAILURE [a]**	
	LIFE SAFETY[b]	**SOCIO-ECONOMIC FINANCIAL ENVIRONMENTAL[b] [c]**
VERY HIGH	Large number of fatalities	Extreme damages
HIGH	Some fatalities	Large damages
LOW	No fatalities anticipated	Moderate damages
VERY LOW	No fatalities	Minor damages beyond owner's property

[a] Incremental to the impacts which would occur under the same natural conditions (flood, earthquake or other event) but without failure of the dam. The consequence (i.e. loss of life, or economic losses) with the higher rating determines which category is assigned to the structure. In the case of tailings dams, consequence categories should be assigned for each stage in the life cycle of the dam.

[b] The criteria which define the Consequence Categories should be established between the Owner and regulatory authorities, consistent with societal expectations. Where regulatory authorities do not exist, or do not provide guidance, the criteria should be set by the Owner to be consistent with societal expectations. The criteria may be based on levels of risk which are acceptable or tolerable to society.

[c] The Owner may wish to establish separate corporate financial criteria which reflect their ability to absorb or otherwise manage the direct financial loss to their business and their liability for damage to others.

TABLE 2
USUAL MINIMUM CRITERIA FOR INFLOW DESIGN FLOODS

CONSEQUENCE CATEGORY	INFLOW DESIGN FLOOD (IDF)
Very High	Probable Maximum Flood (PMF)[a]
High	Annual Exceedance Probability (AEP) between 1/1000 and the PMF[b]
Low	AEP between 1/100 and 1/1000[b] [c]

[a] An appropriate level of conservatism shall be applied to loads from this event, to reduce the risks of dam failure to tolerable values. Thus, the probability of dam failure could be much lower than the probability of extreme event loading.

[b] Within the High Consequence category, the IDF is based on the consequences of failure. For example, if one incremental fatality would result from failure, an AEP of 1/1000 could be acceptable, but for consequences approaching those of a Very High Consequence dam, design floods approaching the PMF would be required.

[c] If a Low Consequence structure cannot withstand the minimum criteria, the level of upgrading may be determined by economic risk analysis, with consideration of environmental and social impacts.

McLennan Girouxville Canal

Drop Inlet Structure Figure 8 Lake

APPENDIX III - DESIGN

Stability:

Designs presented for new dams or calculations provided during the assessment of existing dams and structures should include stability analysis. This analysis should be in sufficient detail to enable the calculations to be verified. Details of cross-sections analysed, parameters used including strength of individual materials and foundation and piezometric assumptions must be provided.

Outlets:

In general, each dam should be provided with a riparian outlet. This should be sized to pass any discharge that is required by the licence. Control valves should be located upstream of the dam centre line and should be accessible either through an access well or shaft, or as part of a drop inlet spillway arrangement. Surface mounted slide gates have proved to be inadequate due to ice action on the gate operating stem and are to be avoided.

Outlet pipes should be suitable for long term operation and should be protected from erosion and corrosion. Lock-seam types of corrugated metal pipes (CMP) have proven to be unsatisfactory. Annular CMP is acceptable. Cathodic protection or some other form of corrosion protection should be considered. Outlet pipes should be large enough so that regular internal inspection can be made to determine their condition. When CMP is used, care should be taken when attaching flexible CMP to rigid concrete structures. Also, the use of rigid seepage cut-offs with CMP is not recommended.

Gates:

Gates should be designed such that they are easily operated. When electrical or mechanical operation is provided, they should be exercised regularly and appropriate and adequate back-up systems provided. Where winter operation is required, bubbler or heater systems should be installed.

Staged Construction:

Where the construction of a dam is staged over a number of years, full details should be supplied with the application for licence. The use of long term construction for oil sands dykes, coal waste ponds, etc. is acceptable, provided details are provided on the final height and slopes of the facility. Design changes and modifications based on performance of a staged construction project are acceptable but will be subject to special operating requirements. These may include performance reports at the end of each construction season or construction lift, as appropriate.

APPENDIX IV - INSTRUMENTATION

Instrumentation is provided in dams to monitor behavior both during the construction and operational life of the structure. These may consist of slope indicators, piezometers, settlement gauges, measuring weirs, surface survey

monuments, etc.

The extent and variety of instrumentation should be based on the hazard posed by the dam. The spacing and distribution of instrumentation should be so designed that the behavior of the dam can be effectively evaluated even when individual instruments fail.

Where instrumentation is proposed, drawings should be submitted with the application for licence giving depths, type of instrument and the reading schedule to be followed.

Instrumentation readings and plots will be required by the Dam Safety and Water Projects Branch during construction, during the first filling and for the operational life of the project.

APPENDIX V - DIVERSION

Where diversion of a river or stream is required, full details are to be provided at the time of application. Details of the cofferdam(s) to be used, the diversion method, e.g. tunnels, and the frequency of flood to be handled, must be provided.

The risk of cofferdam overtopping and failure during flooding should be fully evaluated. An Emergency Preparedness Plan may be required for substantial cofferdams.

APPENDIX VI - OPERATION AND MAINTENANCE MANUAL

Each major project must have an Operation Maintenance and Surveillance Manual detailing the operation of the project including gates, outlets, back-up equipment, emergency generators, etc. and the maintenance schedule required to ensure that each item requiring long term maintenance is maintained.

Copies of this manual may be required during an annual inspection of the project and one should be available on site. Operational tests of flood handling capabilities including gate operation and stop log removal, should be carried out as required by the engineer reviewing the safety of the project. These tests also may be required during the five year joint safety review carried out in conjunction with the Dam Safety and Water Projects Branch.

APPENDIX VII - EMERGENCY PREPAREDNESS

INUNDATION STUDIES

Inundation studies are required to determine the consequences of dam failure. These studies model the formation of a dambreak and the rapid passage of the resulting floodwave downstream.

EMERGENCY PREPAREDNESS

If inundation studies show that the consequence category is high or very high then the dam owner and other emergency responders must ensure that appropriate actions will be taken to manage an emergency situation and mitigate the effects if the dam were to fail.
The dam owner is responsible for ensuring that all emergency responders are able to develop co-ordinated plans for such emergencies by:

- identifying all emergency responders with the resources to assist during an

emergency
- making them aware of the areas that would be inundated
- making them aware of the amount of time available to warn local residents if the dam were to unexpectedly breach
- assisting stakeholders in clarifying their emergency roles
- assisting emergency responders in preparing emergency communications procedures between themselves
- facilitating agreement between all the emergency information sources on how to organize the task of supplying information needed during an emergency
- preparing an emergency notification fanout procedure satisfactory to all.

During any emergency, the dam owner is responsible for:
- initiating the notification fanout
- providing the information needed to keep all stakeholders up-to-date on the situation at the source of the emergency
- providing the information needed to keep all stakeholders up-to-date on the progress of the flood wave if the dam does breach.
- supporting the emergency operations of municipalities

Each emergency responder must have an emergency operations plan. The dam owner must have an On-Site plan for action that would be taken at the dam. In addition and most importantly, the owner must also create, distribute and periodically test the Emergency Preparedness Plan for notifying and coordinating the response of stakeholders to the emergency situation created downstream by problems at the dam.

Dickson Dam Spillway

Oldman Dam Spillway

GENERAL INFORMATION

Licensees or other persons requiring further information on the working of the Regulation or the application of this guideline should contact the Dam Safety and Water Projects Branch.

Alberta Environmental Protection
Dam Safety and Water Projects Branch
8th Floor, Oxbridge Place
9820 - 106 Street
Edmonton, Alberta
T5K 2J6

Phone: (780) 422-1355

The Dam Safety and Water Projects Branch will also give general engineering advice but for particular problems will refer the Licensee to one of the other agencies listed below:

a) Prairie Farm Rehabilitation Administration (P.F.R.A.)
Agriculture Canada
632, 220 - 4 Ave S.E.
Calgary, Alberta
T2G 4X3
Phone: (403) 292-5638

P.F.R.A. will give design and construction advice to farmers and ranchers in the prairie provinces.

b) Consulting Engineers of Alberta
Suite 505, 22 Sir Winston Churchill Ave
St. Albert, Alberta T8N 1B4
Phone: (780) 458-1852

For names of consulting engineers.

OTHER PUBLICATIONS BY DAM SAFETY AND WATER PROJECTS BRANCH

D.S. 5 Inspection of Small Dams
This is a booklet designed to help the owners of small dams recognize problems occurring at their dams.

D.S. 6 A Dam Owners Guidelines for the Preparation of Emergency Preparedness Plans

Details the required process for preparing Inundation Studies and Emergency Plans.

These publications are available through the Dam Safety and Water Projects Branch.

REFERENCES

1. "Dam Safety Guidelines" Canadian Dam Safety Association, January 1999.

2. "National Dam Safety Program, A Progress Report",
Federal Emergency Management Agency, U.S.A. FEMA 103/April 1986.

3. "Regulations Governing Safety of Water Power Projects and Project Works", Federal Emergency Regulatory Commission, June 1980.

4. "Federal Guidelines for Dam Safety".
Prepared by the AD Hoc Interagency Committee on Dam Safety of the Federal Co-ordinating Council for Science Engineering and Technology, Washington, D.C. 20500, June 25, 1979.

5. Von Thun, J.L. "Application of Decision Analysis Techniques in Dam Safety Evaluation and Modification", Proceedings of the International Conference on Safety of Dams, Coimbra, 23-29, April 1984.

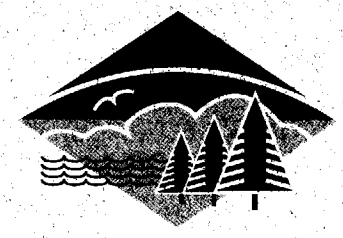
6. "Safety of Dams, Flood and Earthquake Criteria", Committee of Safety Criteria for Dams, U.S. National Research Council, 1985.

7. "Interim Guidelines on Design Floods for Dams",
Australian National Committee on Large Dams, 1984.

RELATED WEB SITES

1. Canadian Dam Safety Association	http://www.cda.ca/
2. Alberta Queen's Printer	http://www.gov.ab.ca/qp/ascii/regs/98_205.txt
3. Alberta Environmental Protection	http://www.gov.ab.ca/env/water/reports.html http://www.gov.ab.ca/env/water/basins.html
4. P.F.R.A.	http://www.agr.ca/pfra/pfintroe.htm

Alberta
ENVIRONMENTAL PROTECTION
Natural Resources Service
Water management Division
Dam Safety and Water Projects Branch



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