REPORT ON

LOWER CHASE RIVER DAM
2003 DAM SAFETY REVIEW

Submitted to:

City of Nanaimo
455 Wallace Street
Nanaimo, B.C. V9R 5J6

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OFFICES ACROSS NORTH AMERICA, SOUTH AMERICA, EUROPE, AFRICA, ASIA AND AUSTRALIA
SUMMARY

This report presents an assessment of the Dam Safety Review (DSR) of the Lower Chase River water-retaining dam. The assessment included review of instrumentation data, as well as a site inspection. The findings are as follows.

DAM SAFETY

Condition of Dam

- The dam is a HIGH consequence dam;

- The dam’s configuration is essentially unknown upstream. The upstream slope is underwater, and appears to have never been surveyed. Whether the concrete core wall is supported or not in the central area is questionable, and the transition of this core wall into the abutments is unknown;

- The upper downstream slope is oversteep and is slipping gradually. There is the risk of more rapid settlement or slope failure in wetter conditions, but such slope movement would be unlikely to be a threat to the dam safety in the short term;

- Minimal seepage was evident from the dam, and appears to be less than reported in the past. The remedial works constructed in 1980 and 1981 appear to be functioning as intended;

- The hydrology of the catchment has been determined as has the spillway capacity. Because of changing standards, the spillway cannot pass the appropriate design storm for the dam’s current hazard rating;

- No detailed seismic stability assessment has been carried out. A reasonable assessment cannot be done without knowledge of the upstream configuration of the dam (Point 2 above), which is presently being determined; and

- Two wood stave offtake pipes are recorded to have been backfilled with concrete in 1980 and that remediation appears to be functioning as intended given the minimal seepage through the dam.

Operations and Maintenance of Dam

- The dam been well maintained, with recent substantial clearing of vegetation;
• The 1992 dam safety recommendation for installation of a flow monitoring weir is being undertaken concurrent with this safety review;

• Detailed surveys of the dam, and in particular its condition upstream below water surface, are being undertaken concurrent with this safety review; and

• A start has been made at resolving issues associated with bringing the dam into line with current safety standards for extreme events (storm, earthquake), but work remains to be accomplished.

Emergency Preparedness

• The emergency preparedness plan (EPP) has been recently updated and is appropriate.

Conclusion

• There are no present Actual Deficiencies at Lower Chase Dam; and

• There are fifteen instances of Potential Deficiencies and Non-Conformances with regard to accepted dam safety principles.

RECOMMENDATIONS

Work is recommended to:

• Reconstruct or otherwise reinstate the upper part of the downstream slope; and

• Automate reading of the V-notch weir that is presently being constructed and incorporate measurements into the City’s real time monitoring (SCADA) system. Store weir flow data as ASCII files for future analysis.

The upper slope repair is not urgent as a current dam safety issue, but the slope will continue to degrade and slip further until the present over-steep condition is eliminated.

Weir flow is a crucial validation of ongoing dam safety given the uncertainty over details of the dam’s construction and tracking this should give advance warning of a deteriorating situation. An automated system is low-cost and will substantially enhance public safety. It ought to be implemented within a year, and preferably sooner.
Automation of the V-notch weir will not eliminate the need to inspect the toe of the dam. At present access is difficult, and in our view is an impediment to effective inspection. We therefore recommend that:

- A path be constructed down through the left abutment to provide safe and easy access to the downstream toe and berm.

Part of the reasons for the findings in this DSR is that the dam is nearly 100 years old and was likely never formally designed. However, societal expectations have changed and old dam’s are required to be comparable to new dams in terms of safety for potentially affected people downstream. In the longer term, say within the next three years, the dam needs to be brought up to date from its current design of 1 in 100 year rare event (storm, earthquake) capability to something better than a 1 in 1000 year standard. Further engineering studies, and likely some construction upgrading are required. Specifically:

- Spillway modification is needed so that the dam can safely pass about a 3000 year return period storm. The exact design criteria needs to be established with the Water Comptroller, but is likely to lead to a doubling of present spillway capacity. Alternatively, a second emergency spillway may be added; and

- The seismic resistance of the dam is uncertain, and needs to be determined by further studies. These were also recommended in the 1992 DSR.

The above five recommendations are the principal items requiring attention, and the thirteen action items identified in Appendix A relate to aspect of these three recommendations. Addressing these actions items will bring the City’s management of Lower Chase dam into conformance with current standards of dam safety. A detailed explanation and expansion of these recommendations is given in the report.

This DSR has been carried out in accordance with the recommendations of the Canadian Dams Association and in compliance with the Water Act of the Province of British Columbia, BC Reg 44/2000. It was carried out by H. Hawson, P. Eng and M. Jefferies, P.Eng, over the period July-November, 2003.
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Appendix B  Dam Inspection Report, July 2003
Appendix C  Follow-up Dam Inspection Report, October 2003
1.0 INTRODUCTION

1.1 Purpose

This report presents a Dam Safety Review (DSR) of the safety of the Lower Chase River dam, and was carried out for the City of Nanaimo (City) who own the dam. The dam lies in the south part of the city, see Figure 1.1 for location, and is accessed by way of Nanaimo Lakes Road. The dam has also been known by the former names Lower Harewood Dam and Lower Colliery Dam.

Under the British Columbia Provincial Water Act, it is the responsibility of dam owners to ensure that dams and appurtenant works are inspected to evaluate compliance with acceptable standards of public safety. In practice for a dam like Lower Chase this takes the form of a DSR about every seven or so years. The last review of the dam was in 1992 by EBA. No unusual events triggered the present inspection.

It is understood that this report will be forwarded to the Water Management Branch of Land and Water British Columbia Inc. in compliance with the City’s responsibilities under its dam license, #61423 (issued 27 Sept 1985).

1.2 Background

Although constructed in 1910 for water supply to the then Harewood Colliery, it is understood that Lower Chase River dam was decommissioned in about 1945 and the lake is now used solely as a recreational resource for the city. A layout of the dam and its lake is provided as Figure 1-2.

Lower Chase River dam is an earthfill structure some 77 m in length and with a maximum height of 23.3 m. Key dam statistics and data are summarized on Table 1.1, while Photograph 1.1 shows a view of the dam. The spillway for the impounded lake is located in the right abutment, and is a two channel converging into one arrangement. The spillway is used to discharge water under operating conditions, not only during extreme events, and is uncontrolled in that there are no mechanical gates, sluices or stop-logs used to control the water level. The spillway discharges into a plunge pool downstream of the dam. The spillway is illustrated in Photograph 1.2.
Figure 1.1: Site Location Plan
Figure 1.2: Plan of Lower Chase Dam and Reservoir
(with location of movement cracks observed July/03 sketched)
Lower Chase dam appears to have been an engineered structure when constructed nearly a hundred years ago, but no records of its design and construction survive. Accordingly, part of this assessment includes estimates of the dam’s expected performance. These estimates are compared to the dam’s actual behaviour for various potential failure modes defined in the ICOLD study of dam safety. This then provides the context for the DSR.

Photograph 1-1: View Lower Chase River Dam 24 July 03 (composite photo) from upstream (remediated discharge valve control tower in left foreground of dam face, spillway entrance under footbridge to right)

Table 1-1: Lower Chase River Dam Statistics

<table>
<thead>
<tr>
<th>Type of Dam</th>
<th>• Concrete core, rockfill/ granular shell</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• 1 filter zone on downstream toe</td>
</tr>
<tr>
<td>Maximum Height</td>
<td>23.3 m</td>
</tr>
<tr>
<td>Width of Crest</td>
<td>10 m approximately</td>
</tr>
<tr>
<td>Length along Crest</td>
<td>77 m</td>
</tr>
<tr>
<td>Catchment Area</td>
<td>2600 Ha approximately</td>
</tr>
<tr>
<td>Upstream Sideslope</td>
<td>About 1V:1H, but no detailed survey data</td>
</tr>
<tr>
<td>Downstream Sideslope</td>
<td>2.0 H:1V nominal</td>
</tr>
<tr>
<td>Retained Water (normal pool)</td>
<td>173,000 m³</td>
</tr>
<tr>
<td>Normal Water Level</td>
<td>71.8 m</td>
</tr>
<tr>
<td>Freeboard, 1:100 year storm</td>
<td>About 0.3 m (midway along crest)</td>
</tr>
<tr>
<td>Offtake works</td>
<td>None working; backfilled with concrete in 1980</td>
</tr>
<tr>
<td>Type of Spillway</td>
<td>• Unregulated spillway designed to discharge under normal operating conditions</td>
</tr>
<tr>
<td></td>
<td>• Concrete walled channel</td>
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1.3 History of Dam Safety Activities

Since acquisition of the dam by the City in 1975, there have been five principal safety related activities:

- 1978-80 Testing of the dam’s condition followed by remedial works;

- 1987 Development of a dam “Data File”;

- 1992 A first DSR;

- 1992 Development of a “Data Book” which included Operations & Maintenance requirements together with an emergency response plan; and

- 2002 Hydrology study for the Chase River.

The City has also undertaken monthly inspections of the dam using their own staff and which are documented as paper records held in files at the water supply office (Public Works Yard, 2020 Labieux Road, Nanaimo, BC).

Inundation estimates in the event of dam failure were originally based on modelling undertaken by the Water Management Branch and sent to the City in 1977 as a map of potential flooded land. This study has recently been supplemented by further estimates as part of the 2002-3 hydrology studies.
1.4 Authorization

Golder Associates Ltd were retained for this DSR by the City of Nanaimo by letter dated July 07, 2003 based on our proposal P32-1198 dated May 26, 2003.

2.0 SAFETY REVIEW PROCESS

2.1 Standard of Assessment

This DSR was carried out in accordance with BC Dam safety Regulation (BC Reg 44/00) and follows the Dam Safety Guidelines published by the Canadian Dam Association.

A comprehensive list of dam safety requirements has been developed by BC Hydro for DSR audits, and these requirements have been used as the basic checklist for this DSR.

2.2 Methodology

A DSR is a means for a dam owner to determine compliance with requirements, to improve the understanding of existing risks and identify opportunities for risk reduction.

This assessment is based on a review of existing reports and drawings provided by the City and a site inspection. Further, approximate calculations or other estimates have been made to provide a context for the review as there is no design and construction report. Archives and books on Nanaimo have been searched for historic information, although little was discovered other than a brief entry recording the use of the dam for water supply in 1915. Finally, considerable useful information has been provided by the Dams’ Branch in Victoria from the records of their various inspectors during the 1975-85 period.

The completed DSR pro-forma of the Canadian Dam Association is included in Appendix A.

The site inspection was completed by H. Hawson and M. Jefferies of Golder Associates Ltd. on July 23-24, 2003 and October. The report is included as Appendix B. Areas inspected include:

- Dam;
- Spillway; and
- Reservoir slopes.

The dam is in an active seismic zone and has experienced strong ground motion in the past. We have estimated the maximum ground acceleration experienced by the dam to date.
Because the dam is a historic structure for which no detailed records survive, we have also estimated the expected performance of the dam. This is in part based on prior stability calculations (Golder Associates, 1978b), part on prior hydraulic studies (Willis, Cunliffe & Tait, 1978; Dayton & Knight, 1987; and Water Management Consultants, 2002) and part on new calculations.

2.3 Deficiencies and Non-Conformances

During the review, the dam safety requirements assessed as not being met were assigned with a particular deficiency or non-conformance type in accordance with definitions in BC Hydro's dam safety procedures as follows.

**Actual deficiency:** An unacceptable dam performance condition which has been confirmed based on BC Hydro's dam safety standards and criteria. There are two types of Actual Deficiencies: under normal loads expected during the lifetime of the dam (denoted as \( An \)) and under unlikely loads that are not expected to occur (denoted as \( Au \)).

**Potential deficiency:** A potentially unacceptable dam performance condition which has not yet been confirmed. Potential deficiencies are separated into those which, on more detailed investigation, are expected to be confirmed as actual deficiencies and those that are not (including those where it may not be possible to demonstrate that they are not deficiencies). There are four types of Potential Deficiencies.

- **\( Pn \):** *is a potential deficiency under normal loads*, a potentially unacceptable dam performance condition under normal loads, that has not yet been confirmed.

- **\( Pu \):** *is a potential deficiency under unlikely loads*, a potentially unacceptable dam performance condition under unlikely loads, that has not yet been confirmed.

- **\( Pq \):** *is a potential deficiency expected to be readily demonstrated not to be a deficiency*. A potentially unacceptable dam performance condition may exist, but it is expected that with some investigation, the potential deficiency will be demonstrated as being not a deficiency.

- **\( Pd \):** *is a potential deficiency expected not to be deficient, but difficult to prove*, a potentially unacceptable dam performance condition that is not expected to be deficient, however it would be difficult or impossible to demonstrate.

**Non-conformances:** Failure to establish or to follow appropriate policies, procedures, operating instructions, maintenance requirements, or surveillance plans. The following are the non-conformance categories: **NCi** indicates that required information is not
available; $NCo$ is an operational non-conformance; $NCm$ is a maintenance non-conformance; $NCs$ is a surveillance non-conformance; and $NCp$ is a non-conformance in other procedures.

*A non-conformance in itself is not indicative of unacceptable dam performance.*

### 3.0 LOWER CHASE RIVER DAM & RELATED STRUCTURES

#### 3.1 History

The history of the dam is obscured by the lack of records and documentation before 1977. Important dates are:

- ~1910: constructed by Harewood Colliery;
- ~1945: taken out of service with Colliery;
- 1975 ownership passed to City of Nanaimo (Parks & Recreation);
- 1977 Inspection by Province leading to requirement for licensing;
- 1978 Investigation of dam’s condition and design of remedial work (Willis, Cunliffe & Tait + Golder Associates);
- 1980 Remediation of dam (directed by Willis, Cunliffe & Tait);
- 1981 Remediation of concentrated seepage/washout from left abutment;
- 1987 Dayton & Knight produced dam “data file”;
- 1992 Inspection by EBA and development of “data book”; and,
- 1993 Responsibility for the dam transferred to Engineering & Public Works from Parks & Recreation.

#### 3.2 Description

##### 3.2.1 Foundation Conditions

Lower Chase Dam lies in a narrow steep sided ravine, with both abutment thought to be founded on silty overburden. The dam foundation is believed to comprise glacial soil based on the single 1978 boring that penetrated the foundation. Some weathered siltstone is exposed on the lower part of the right abutment.

There have been no hydrogeological studies nor are there any piezometers in the abutments. The groundwater movement in the abutments is thus unknown, as is the influence of the retained reservoir. What can be inferred is that the reported abutment seepage is more likely from precipitation flowing into the abutment than the reservoir. This follows from the absence of seepage zones during the current inspection which was in a dry period but with full reservoir retained.
Bedrock may be overlain by a veneer of till (or possibly channel fill) in the centre of the ravine.

The dam was originally constructed to supply water to a colliery. This raised concerns about whether mining operations might underlie the dam's foundations. These concerns were addressed in a 1992 study by Westwater Mining Ltd. and which found that no documented mineworking approached the dam foundation area.

### 3.2.2 Earthfill Dam

As noted above, Lower Chase Dam is an historic structure nearly 100 years old. No records appear to have survived from when it was constructed, and the understanding of the dam is based on work carried out over the past twenty years as now documented. Figure 3.1 shows the best estimate of the internal configuration of the dam (after EBA, 1992; there is no more recent information).

A concrete wall provides the impervious barrier, and also forms the front face of the dam at normal pool level in the reservoir (Photograph 1-1). This wall is 0.3m thick at the top and extend at this thickness for 0.6m. It then thickens to a reported 1.2m (EBA, 1992), and a horizontal construction joint is evident. It is unclear whether the wall thickens with depth. There is no data or test results to show whether or not the concrete wall is reinforced, although this would be likely. There are no expansion or other movement joints apparent in the concrete wall.

The concrete core wall is presumed to extend to full depth and be founded in dense till. Evidence for this presumption comes from the concrete valve tower on the front face of the dam that extended to a measured depth of 15m, which ought to be original valley bottom as estimated from the depth to till-like material found in the nearby borehole 9 (put down as part of the 1978 investigation).

There have apparently been no concrete cores taken over the years and the strength of the concrete is unknown. However, the concrete is weathering well and there are no apparent signs of deterioration (see Appendix B).

On the upstream side, the core wall support is unknown. No contour drawings or other surveys in the reservoir are available, and the upstream slope shown on Figure 3.1 seems to be only schematic. Nevertheless, it would not have been unusual to have placed rockfill upstream of the concrete when this dam was built as there are other examples of such a configuration being built within the Province around that period. There are no boreholes extending through the upstream shell.
NOTE

1. This figure is taken from 1987 "Data File", but it does not match the details shown on Sheet 8 of the As-Built drawings from 1980. It appears to be a schematic section.

2. The downstream slope is now eroded/slumped in the upper part.

3. The downstream shell is what was believed to exist but involves much extrapolation of limited data.

4. It is not known where the information on core wall thickness came from.

Figure 3.1: Schematic cross-section of Lower Chase Dam
The downstream shell has stabilized by a compacted sand and gravel berm in 1980. The upper slope above the berm was left in place at an average slope of about 1.5H:1V. The berm comprised compacted sandy gravel and included to drain ditches that extended up the fill/abutment contact on either side.

The berm slope is covered with grass, while the upper slope that comprises the pre-1980 conditions is heavily vegetated.

A gravel filter drain to intercept seepage through the dam and abutment was installed in the 1980 remediation.

The dam is not straight in plan at present, with what appear to be non-structural extension of the dam upstream in both abutments. These are seemingly only to provide better recreational access.

According to photographs taken during a 1981 inspection there was washout/erosion incident in the contact of the dam with the Left Abutment, as illustrated on Figure 3.2. There were no notes about the remediation of this area.

3.2.3 Spillway

The spillway is concrete sided and floored channel, split into two channels near the entrance and which are spanned by the footbridge (Photograph 1-2). Water level is controlled by the spillway inlet lip elevation, stop logs not being used by the City. There are no gates or other mechanical means of water level control.

3.2.4 Offtake Works

There are no presently working offtake works, the dam being used to only retain water for recreation.

The dam was built for water supply and a low-level outlet arrangement comprising an upstream inlet with control valves at the concrete dam face existed until 1980. At that time the two pipes passing through the body of the dam were backfilled with concrete, the valves removed and the control chamber backfilled. The old valve chamber can be seen on the front face of the dam in Photograph 1-1.
Figure 3.2: Photographs of Left Abutment/Dam washout recorded during inspection by Dam Safety Branch 24 Feb 81. (from Water Management Branch, 1982)
3.2.5 Remedial Work 1978-80

The 1978 investigations and studies of the dam identified three aspects requiring remediation:

- Installation of a seepage collection and filter system;
- Installation of a stabilizing berm for the lower downstream slope; and
- Backfilling of the low-level offtake pipes through the dam.

The progress of the remedial works is documented in photographs and notes by the Provincial inspectors (some of which have been copied into this report as noted); nothing apparently remains of notes from the engineering company directing the work, Willis Cunliffe & Tait. However, this company did provide As-Built drawings of the works.

3.3 Safety Standard

3.3.1 Consequence Classification

The Canadian Dam Safety Association guidelines are used by the Water Management Branch in assessing the required standards of dams. Determination of the required safety level and appropriate engineering standards are based on the consequence classification of the dam.

Consequence categories are based on the incremental losses that a failure of the dam might inflict on downstream or upstream areas, or at the dam location itself. Incremental losses are those over and above losses which might have occurred in the same natural event or condition had the dam not failed. Incremental losses are evaluated in terms of:

- Loss of life;
- Economic losses or damage to property; and
- Other less quantifiable consequences related to social, cultural and environmental damage.

Table 3.1 shows the classification of dams in terms of these loss categories. The highest consequence category of the three considerations is the governing rating for the dam.
Table 3-1: Classification of Dams in Terms of Consequences of Failure
(after Table 1.1 – CDA Guidelines)

<table>
<thead>
<tr>
<th>CONSEQUENCE CATEGORY</th>
<th>POTENTIAL INCREMENTAL CONSEQUENCES OF FAILURE[a]</th>
<th>LIFE SAFETY[b]</th>
<th>SOCIOECONOMIC</th>
<th>FINANCIAL</th>
<th>ENVIRONMENTAL[b][c]</th>
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<tr>
<td>Very High</td>
<td>Large number of fatalities</td>
<td></td>
<td>Extreme damages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Some fatalities</td>
<td></td>
<td>Large damages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>No fatalities anticipated</td>
<td></td>
<td>Moderate damages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very Low</td>
<td>No fatalities</td>
<td></td>
<td>Minor damages beyond owner’s property</td>
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[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 the 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.

3.3.2 Hazard Rating

The Dam Safety Branch presently rate Lower Chase Dam as a HIGH hazard structure.

The dam failure inundation study of 1977 suggested that flooding in the event of dam failure could be extensive. The 2002 hydrology study produced similar estimates, and is the basis of the emergency plan. Figure 3.2 shows the extent of the present estimate of possible flooding.

The potential inundation area comprises older houses and one school. Stored chemical or other possible environmental contaminants have not been evaluated or inventoried. Possible economic losses in the flooded area have not been quantified.

The warning time would depend on whether failure arose from deterioration of the dam (which might be undetected between monthly inspections), earthquake (no warning) or storm flooding (likely anticipated from forecasts with an inspector assigned to the dam with a radio). Although storm flooding seems the more likely extreme event failure (discussed below) and the City’s procedures should provide substantial warning for this case, no warning has been adopted for the present hazard assessment pending further earthquake resistance estimates.
Based on the above, and in comparison to Table 3-1, it is difficult to argue for a LOW rating. The fact the dam is old with unknown features would suggest that a risk of some fatalities cannot ever be discounted. Conversely, the dam is patently not in the same consequence class as the large BC Hydro dams such as Mica, Revelstoke or Bennett and which comprise the VERY HIGH rating.

We conclude that the present HIGH rating is reasonable and appropriate.

### 3.3.3 Required Safety Criteria

The required design/assessment criteria for dam safety depend on the consequence category. Tables 3.2 and 3.3 show the safety criteria published by the Canadian Dam Safety Association for earthquake and flood situations respectively. Based on these tables and the HIGH consequence category, it follows that Lower Chase Dam should:

- Withstand about a 3,000 year return period earthquake; and
- Safely pass about a 3000 year flood.

In choosing these targets, the range of standard given in the tables has been recognized as follows. At the upper end (less likely, or longer return period) Lower Chase Dam is obviously much different from the very large BC Hydro dams and thus the values used at Lower Chase should not approach those indicated as appropriate for VERY HIGH consequence dams. Equally, on the other hand, some conservatism is warranted at the lower end as the dam is not a modern engineered structure and aspects of potential damage remain unquantified. Therefore a reasonable risk for the Lower Chase dam would be mid-way between the two extremes, and this is 3000 years because the underlying risk scale in the tables is order of magnitude (logarithmic).
Figure 3.3: Present estimate of possible inundation area.

Note: this figure was extracted from the new plan of the potentially impacted area and which is presented in full in the EPP and OMS manual.
Table 3.2: Usual Minimum Criteria For Design Earthquakes  
(after Table 5.1-CDA Guidelines)

<table>
<thead>
<tr>
<th>CONSEQUENCE CATEGORY</th>
<th>MAXIMUM DESIGN EARTHQUAKE (MDE)</th>
<th>DETERMINISTICALLY DERIVED</th>
<th>PROBABILISTICALLY DERIVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>MCE</td>
<td></td>
<td>1/10,000</td>
</tr>
<tr>
<td>High</td>
<td>50% to 100% MCE</td>
<td>1/1000 to 1/10,000</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Building Code</td>
<td></td>
<td>1/100 to 1/1000</td>
</tr>
</tbody>
</table>

Table 3.3: Usual Minimum Criteria for Design Inflow Floods  
(after Table 6.1-CDA Guidelines)

<table>
<thead>
<tr>
<th>CONSEQUENCE CATEGORY</th>
<th>INFLOW DESIGN FLOOD (IDF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>Probable Maximum Flood (PMF)</td>
</tr>
<tr>
<td>High</td>
<td>Annual exceedance probability between 1/1000 and the PMF (depends on consequences)</td>
</tr>
<tr>
<td>Low</td>
<td>Annual exceedance probability between 1/100 and 1/1000</td>
</tr>
</tbody>
</table>

3.4 Hydrology

There is no design report as such for the Lower Chase dam, but the hydrology of the Chase watershed has been assessed in three studies while the dam has been owned by the City. These studies were:

- 1978: by Willis, Cunliffe & Tait in connection with the 1980 dam;
- 1987: by Dayton & Knight in connection with the dam’s Data File; and

The results of these studies have been plotted as storm flow versus the associated estimated return period on Figure 3.4. Also shown on this figure is the probable maximum flood (PMF) which is only quoted by Water Management Consultants.
There is some difference between the 1978 study and the other two. A trend line has been drawn through the results of these studies, weighted to the 1987/2002 results, to indicate a present best-estimate of how the flood increases with increasing return period. A 3000 year return period event, the appropriate risk standard for the dam as discussed above, corresponds with about a 85 m$^3$/sec flood inflow to the reservoir.

Figure 3.4: Summary of hydrological studies for Lower Chase showing estimated flood flow versus return period

The PMF represents something in excess of a 10,000 year event which is, in our opinion, unwarrantedly conservative for the dam.

There has been no systematic measurement of spillway flows over the life of the dam, and thus no measured data on which the hydrological estimates can be improved.

3.5 Earthquakes

With the exception of very low consequence situations, dams are held to a higher standard of public safety than implied by the National Building Code. This requires an assessment of the possible loadings caused by earthquakes.
No site specific seismic hazard assessments have been undertaken for this dam, or the Chase River watershed. However, a detailed earthquake hazard assessment was undertaken recently in connection with the City’s South Forks Dam (Sandwell, 2002). In addition, BC Hydro (1992) carried out a systematic assessment of earthquake risk and which included the John Hart Dam. Both dams are in a comparable earthquake risk situation to the Chase River dams. The results of these seismic hazard estimates are plotted in Figure 3.5.

![Figure 3.5: Horizontal Peak Ground Acceleration versus Estimated Return Period](image)

A 3000 year return period event, the appropriate risk standard for the dam as discussed above, corresponds with about a 0.5g peak ground acceleration at the dam site, depending on assumptions in the seismic model.

### 4.0 FAILURE MODE ANALYSIS

#### 4.1 Potential Failure Modes

The causes of water-retaining earthfill dam failures have been investigated and summarized by the International Committee on Large Dams (ICOLD). Some of the potential failure mechanisms are relevant to Dam D. The most common primary failure mechanisms for water retaining earthfill dams are summarized in Figure 4.1.
Based on the site specific study, as well as the overall statistical analyses of dam failures, the most common modes of failure that are considered in this report are presented in Table 4-1, with comments regarding the relevance of each mechanism to Lower Chase Dam.

These potential failure modes are discussed further in the following sections, and considered with respect to the monitoring information available, and the observations made during a site inspection.
Table 4-1: Relevance of Most Common Failure Modes to Lower Chase Dam

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Comments/Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope Instability</td>
<td>Instability of compacted downstream shell is unlikely. Stability of upstream fill is unknown.</td>
</tr>
<tr>
<td>Earthquake</td>
<td>Dam is in an area of high seismicity. It has not been designed to resist earthquakes, but is unlikely to show liquefaction failure. The core wall may be vulnerable to cracking or toppling. Crest settlement/slumping would be expected in a substantial earthquake, but is unlikely to exceed normal dam freeboard.</td>
</tr>
<tr>
<td>Overtopping</td>
<td>Dam operating freeboard is quite low. Spillway is uncontrolled, with uncertainties on the design storm. Ongoing dam safety requires spillway be kept clear of all debris. Dam crest is somewhat erodable.</td>
</tr>
<tr>
<td>Seepage within embankment</td>
<td>The downstream shell is permeable. A seepage collection and drainage system was designed and constructed in 1980. The core wall is concrete.</td>
</tr>
<tr>
<td>Internal erosion</td>
<td>Internal erosion is a potential mode of failure if drainage filters does not perform as designed and the concrete core wall is cracked by slope movement or an earthquake. Internal erosion is not a credible mechanism under present minimal seepage through the dam.</td>
</tr>
<tr>
<td>Foundation seepage and internal erosion of foundation</td>
<td>Seepage from both abutments is intercepted and carried to filter. Dam is founded on low permeability till with little seepage apparent. Uplift from foundation seepage is not a credible failure mechanism even though there is no grout curtain.</td>
</tr>
<tr>
<td>Rupture of conduits</td>
<td>The two old conduits were backfilled with concrete and are not likely to be a threat to the dam.</td>
</tr>
</tbody>
</table>

4.2 Seepage within Foundation/Abutments

4.2.1 Design Basis and Expected Behaviour

There is no design report for the dam, nor has expected foundation seepage been evaluated to date.

Golder Associates
There is no indication that a grout curtain was ever constructed in the rock beneath the dam. Seepage through the foundation should not be large because of the low permeability of the till underlying the dam and presumed to extend upstream into the reservoir. It is estimated that foundation seepage should be less than about 1 litre/min at normal reservoir level.

4.2.2 Performance Review

There is no seepage monitoring weir and seepage was only estimated from flow in the base of the ditch downstream of the dam. There has been seepage in the past from both abutments, but this seems seasonal and related to rainfall rather than retained water.

On balance it appears that the foundation is behaving as expected.

4.3 Slope Instability

4.3.1 Design Basis and Expected Behaviour

**Downstream Slope.** The stability of the downstream shell was investigated in 1978 as part of the work leading up to the 1980 remediation. The safety factor for slope stability computed as low as 1.2 under long term conditions, although 1.4 was regarded as more representative, and without an earthquake loading. This resulted in construction of the stabilizing berm. No calculations have been discovered for the effect of the as-built berm, but the investigation report (Golder Associates, 1978b) indicated that at least a factor of safety of 1.5 was required. These values may be compared with a conventional upper bound of 1.5 required by design code (Canadian Foundation Manual) for long term stability.

**Upstream Slope.** The upstream slope stability has not been addressed in any study to date. As noted earlier, there seem to be no records of the dams configuration upstream of the concrete wall.
4.3.2 Performance Review

There are no slope movement monitoring records.

**Downstream Slope.** The site inspection (Appendix B) found substantial evidence of slope movement in the upper part of the downstream shell above the stabilizing berm. This is unsurprising given the loose fill that apparently was placed above the lower rockfill and the very steep slope. What was left in place in 1980 at 1V:1.5H has now steepened to as much as 1V:0.8H, and which far exceeds the credible friction angle of the fill. The slope is only stable in the upper part because of the tension reinforcement provided by the fibrous roots of the large amount of vegetation on this part of the slope.

There is also evidence of possible subsidence in the lower part of the downstream slope. This area was not readily inspected in July/03, but once the vegetation had been cleared in this years maintenance, a small scarp-like feature some 150mm high was evident in the follow-up October/03 inspection (Appendix C), illustrated on Photograph 4-1. This feature may be the remains from the abutment washout incident in 1981 and which is shown on Figure 3-2, but it also appears close to the location of the old woodstave pipe. As can be seen, grass is well established and continuous so that the scarp is not recent. But, it requires careful surveillance over the next few years to verify that it does not indicate a more serious underlying movement.

![Photograph 4-1: Scarp in lower downstream slope](image)

The **upstream slope** was underwater and could not be inspected (See Photograph 1-1). However, there we no signs of distress in the concrete core wall that would infer loss of upstream support.
4.4 Earthquake

4.4.1 Design Basis and Expected Behaviour

The dam remediation in 1978 explicitly excluded seismic stability as an issue. It is thought that the view taken then was that, as the dam had survived the 1946 Comox earthquake and was then 75 years old, it was likely adequate given the safety standards of the day.

To date, no studies have been undertaken of the behaviour of the dam during an earthquake.

The appropriate site ground motion for the appropriate earthquake risk is so strong (0.5g) that slope movement will occur under this condition and this cannot be prevented by even substantial remedial works. However, slope movement does not necessarily represent failure provided that the associated crest settlement is less than the freeboard of the reservoir.

Downstream, the foundation appears to be dense till and most of the dam fill to be free draining rockfill. Neither give any hazard for catastrophic (liquefaction) failure even during an earthquake. However, the fill beneath the toe berm may be loose and saturated and this part could be prone to substantial slumping in an earthquake. Although settlement under the design earthquake motion needs to be formally computed, we would be surprised if it would exceed about 0.5 m at the dam crest for the downstream slope. What is more problematic is the upstream slope.

Under earthquake motion, the retained fill of the dam could impose a substantial load on the concrete wall of the dam and the dam's integrity would depend on how much support was available to the core wall from the upstream shell. However, practically nothing is known about the upstream shell in terms of its configuration or materials.

If the upstream comprises a substantial rockfill shell, then it may provide sufficient support during the MDE. Under this scenario, only minor cracking of the concrete wall might be expected. On the other hand, if the dam face comprises a freestanding wall over much of the central section or if the upstream fill is loose, then far greater movement of the core wall would arise. Much would then depend on the amount and brittleness of the reinforcement. A situation with the wall failing in slabs and leaving the loose downstream fill exposed to the full reservoir is conceivable.

Because of this wide range of uncertainty on possible outcomes for the concrete wall, the present assessment can only regard the dam as vulnerable to the MDE. Further, we are unable to estimate the level of safe ground motion.

Golder Associates
4.4.2 Performance Review

There is no strong motion instrumentation on or near the dam. However, the historical record of earthquakes has been used to estimate the ground motions that the dam has experienced in its near hundred year life. The results are shown on Figure 4.2.

![Figure 4.2: Estimated peak ground acceleration experienced by Lower Chase Dam](image)

The maximum peak ground acceleration experienced by the dam was about 0.03g, which would have been quite widely felt in Nanaimo, in 1946. This was caused by a M7.3 event some 120 km distant. A second event, which had only slightly less ground motion, occurred in 1976 from a M5.4 event at the much closer distance of 60 km.

The experienced peak acceleration of 0.03g corresponds to about a 20-year return period event based on the ground motion studies plotted in Figure 3.4. However, there is 95% confidence that the dam has actually experienced its 30 year return period event in its 90 year history. This suggests that the design trends shown on Figure 3.4 are conservatively biased for the Chase River area, and that a peak ground acceleration of 0.2g would be a better estimate of the appropriate motion for the 3000 year return period standard of care.

Comparison of dam performance at 0.03g, which is presumed adequate as no records or articles have been found indication otherwise, provides no assurance of adequacy at even the reduced 0.2g ground motion level. This aspect requires further evaluation.
4.5 Overtopping

4.5.1 Design Basis and Expected Behaviour

The spillway capacity has been evaluated concurrently with each of the hydrological studies discussed earlier. There are discrepancies in the estimated capacity of the spillway as follows:

- 1978, Willis, Cunliffe & Tait: 55 m$^3$/sec;
- 1987, Dayton & Knight: 35-42 m$^3$/sec; and

The 1987 and 2002 estimates may in fact be closer than they appear as the upper end of the 2002 estimates allow water flowing over the spillway wall part way down the slope.

Comparing these estimates of spillway capacity to the hydrology discussed earlier indicates that the spillway does not have the capacity to pass the appropriate flood. Broadly, the spillway capacity needs to more than double to meet current dam safety standards, or else an alternative emergency spillway needs to be provided in addition.

4.5.2 Performance Review

Comparing the storm recurrence plot, Figure 3.4, with the spillway capacity shows that the 2002 estimate of capacity corresponds to about a 30 year return period event. There is a 95% chance that such an event has already occurred in the dam’s life.

The elevation of the surface of the water impounded in the reservoir has been monitored, but only recently. The results are shown on Figure 4.3. Retained water levels were much below the dam crest, at which level there is 1.8 m depth of water at the spillway.

As an index of hydraulic performance, Figure 4.4 plots daily precipitation at Departure Bay for the period 1913-1993 and indicates that the Nanaimo area experienced a maximum 24-hr precipitation of slightly more than 100 mm in the period 1913-1993. The maximum storm was in Jan/68, with a second storm in Feb/68. This actual rainfall can be compared to a 1-hour duration “probable maximum” storm of 60mm and a 24-hour duration storm of 200 – 300 mm used in the recent hydrological study for the nearby Chase river watershed, although there is some uncertainty when comparing measurements at Departure Bay to the watershed because of topography.
Figure 4.3: Measured water depths at spillway

Figure 4.4: Daily rainfall at Departure Bay 1913-1993
No evidence is apparent today of any damage caused by excess flows down the Lower Chase spillway nor is there any record of the dam overtopping. These factors suggest that the spillway has a better performance than the 25 m$^3$/sec assessed in 2002. Nevertheless, this is less than half what is needed by current standards and also has the dam with minimal to no freeboard.

4.6 Seepage within Embankment

4.6.1 Design Basis and Expected Behaviour

The dam was constructed with what appears to be an engineered concrete wall. It is assumed that this engineering attention extended to how the wall met the till foundation or bedrock (as the case was) and that the engineers who directed construction endeavoured to ensure a good contact. The wall also has little obvious cracking. In this situation, very little flow would be expected through the dam.

4.6.2 Seepage Performance Review

Seepage is not measured. No seepage estimates are available from any of the dam's inspection records over the years.

Seepage was estimated at less than 5 litre/min during our site inspection (Appendix B). This seems less than would be inferred from the stated need in 1978 to install drainage ditches. It is in accord with what would be expected for this dam in good condition. It also suggests that flows reporting to the base of the dam may derive from the abutments.

4.7 Internal Erosion in Embankment (Piping)

4.7.1 Design Basis and Expected Behaviour

The dam is a composite structure with a concrete wall providing the impervious barrier. This wall is apparently continuous and therefore there should be no seepage through the dam as such, and hence no expectation of any internal erosion even in the absence of filters.

4.7.2 Performance Review

The exposed concrete is in apparently excellent condition. Seepage downstream is minimal, and patently there is no concentrated seepage that might lead to erosion of the dam fill.
4.8 Rupture of Conduits

4.8.1 Design Basis and Expected Behaviour

The two woodstave pipes pass through the concrete core wall. These are recorded to have been backfilled with concrete in 1980, and with their upstream end in the valve chamber further put under mass concrete (see Appendix B). The expectation is that any vulnerability of the dam to internal conduits was eliminated by these remedial actions.

4.8.2 Performance Review

There is no evidence in terms of concentrated seepage or surface expression that the remedial work is anything other than effective.

5.0 SAFETY REVIEW

5.1 Dam Safety

5.1.1 Implementation of 1992 Recommendations

The 1992 DSR recommended twelve actions. Of these, nine have been implemented to date. (see Table 5.1).

The recommendations regarding concentrated seepage in the 1992 DSR have no paper trail in the City’s file. We therefore contacted R. Patrick, P.Eng. of EBA (Nanaimo office) who made these recommendations. In the subsequent telephone conversation on 29-Sept-03, Mr. Patrick indicated that the seepage was located and turned out to be “not a problem” with no requirement for further work. Our inspection (Appendix B) searched for concentrated seepage and found none, confirming the adequacy of the judgement made ten years earlier.

The recommendation for the earthquake risk assessment and dam upgrading as needed is reiterated in this DSR as appropriate and requiring action.

Of the remaining actions, the addition of the log boom to the spillway, is regarded as undesirable because there is more likelihood of an accident to the public while swimming than any spillway blockage risk reduction to the dam.
Table 5.1: 1992 DSR Recommendations and Status

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construct flow measurement weir at toe of dam</td>
<td>Under construction</td>
</tr>
<tr>
<td>Install reservoir level staff gauge</td>
<td>Done</td>
</tr>
<tr>
<td>Install log boom at spillway inlet</td>
<td>Not carried out to date</td>
</tr>
<tr>
<td>Remove trees prior to toppling in reservoir</td>
<td>Done, and ongoing</td>
</tr>
<tr>
<td>Remove dead trees from reservoir</td>
<td>Done</td>
</tr>
<tr>
<td>Repair path erosion</td>
<td>Done</td>
</tr>
<tr>
<td>Clear vegetation from upper slope, regrade, and hydroseed</td>
<td>Not carried out to date</td>
</tr>
<tr>
<td>Collect surface water flowing down left abutment</td>
<td>Done</td>
</tr>
<tr>
<td>Determine source of existing seepage</td>
<td>Done</td>
</tr>
<tr>
<td>Remediate seepage</td>
<td>Not required</td>
</tr>
<tr>
<td>Carry out earthquake resistance/upgrading study</td>
<td>Not carried out to date</td>
</tr>
<tr>
<td>Upgrade the hydrology of the Chase River system</td>
<td>Study completed 2002; follow on work ongoing. Used in this DSR.</td>
</tr>
</tbody>
</table>

5.1.2 Results of July 2003 Site Inspection

Appendix B provides a detailed record of the inspection of the dam on July 23-24, 2003. Generally:

- In July the dam had considerable vegetation growth and which prevented a thorough inspection to be made of the downstream slope;

- Access to the downstream slope and the toe of the dam is very difficult, and likely constrains the effectiveness of the monthly inspections and compromises effective surveillance;

- Slope instability and crest settlement are occurring in the upper part of the downstream slope. This slope was left oversteep in the 1980 remediation, and further remediation was recommended in the 1992 DSR. This has not been carried out to date. This instability is not viewed as a risk to the dam’s integrity at present, but the slope will continue to deteriorate;
• The upstream slope could not be assessed as it was underwater and with no survey drawings on record. However, there was no evidence of core-wall instability in an upstream direction;

• No zones of concentrated seepage or other indications of internal erosion/piping were found;

• The downstream toe area where flow from the dam’s drainage ditches collects into the old river channel is severely overgrown and it is at the stage where sensible monitoring of the seepage through the dam is impossible;

• The spillway was clear, but a tree growing in the central concrete walled island in the upper part will become a hazard to the spillway integrity in the future; and

Comparison of the recent inspection with that reported in 1992 indicates that the dam is in much the same condition as it was then, but is requiring further maintenance.

5.1.3 Results of October 2003 Site Inspection

According to photographs taken during a 1981 inspection there was washout/erosion incident in the contact of the dam with the Left Abutment, as illustrated on Figure 3.2. There were no notes about the remediation of this area. We specifically inspected the washout area in July/03 and found a restored slope in good condition with the drainage trench apparently performing as intended, see Appendix B. However, vegetation in July precluded as thorough inspection as was warranted.

Substantial clearing of vegetation was undertaken around the dam in the Fall 2003, and a further inspection of the slope and toe areas was then carried out. This additional inspection is detailed in Appendix C. The lower downstream slope was found to be in the condition as generally indicated above, but a small scarp feature was discovered towards the base. This scarp feature most likely related to the 1981 abutment washout incident. This scarp feature requires monitoring in case it indicates some deeper seated movement.

5.1.4 CDA Standard Evaluation

Based on the above review of dam design/performance, and the site inspection, the dam safety review database has been used to assess the Lower Chase Dam. The detailed results are given in Appendix A on an issue by issue basis. For each issue, the following is given:
The dam safety principle;
The rating of Lower Chase dam with respect to that principle;
A description of why that rating was assigned; and
A recommendation to address the shortfall if the dam is non-compliant.

The descriptions of the various ratings was provided in Section 2 above.

Because the standard safety review database was used, not all questions are relevant to Lower Chase dam. In these instances Not Applicable has been shown for the relevant issue in Appendix A.

No Actual Deficiencies were identified.

Fifteen instances of Potential Deficiencies and Non-Conformances were identified, and these are summarized on Table 5.2. The numbers shown within the [ ] refer to the dam safety principles in Appendix A.

<table>
<thead>
<tr>
<th>Deficiency Type</th>
<th>Instances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential Deficiency</td>
<td></td>
</tr>
<tr>
<td>Expected to be deficient under unlikely loads</td>
<td>6</td>
</tr>
<tr>
<td>[Principles: 5.1, 7.1, 7.2, 7.3, 8.6, 9.5]</td>
<td></td>
</tr>
<tr>
<td>Expected not to be deficient, quickly demonstrated</td>
<td>2</td>
</tr>
<tr>
<td>[Principles: 8.7, 9.7]</td>
<td></td>
</tr>
<tr>
<td>Expected not to be deficient, difficult to demonstrate</td>
<td>1</td>
</tr>
<tr>
<td>[Principle: 8.3]</td>
<td></td>
</tr>
<tr>
<td>Non-Conformance</td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td>1</td>
</tr>
<tr>
<td>[Principles: 6.1]</td>
<td></td>
</tr>
<tr>
<td>Surveillance</td>
<td>2</td>
</tr>
<tr>
<td>[Principle: 3.4, 8.9]</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>2</td>
</tr>
<tr>
<td>[Principle 8.1, 8.5]</td>
<td></td>
</tr>
<tr>
<td>Other Procedures</td>
<td>1</td>
</tr>
<tr>
<td>[Principles: 10.2]</td>
<td></td>
</tr>
</tbody>
</table>

Potential deficiencies largely relate to two issues: the changing standard of care which means that Lower Chase dam no longer meets the public's view of required safety in regard to (1) extreme storms and (2) earthquakes.
Non-conformances relate to information on the likelihood of extreme events, the need to maintain (possibly reconstruct) the upper part of the downstream slope, and the implementing automatic seepage weir monitoring as a surveillance improvement.

5.2 Operations & Maintenance

The dam is used passively to retain a recreational lake, so that the only operational issue as such is clearing the spillway to ensure it retains its full capacity. No issues in this regard were apparent during our review and the potential debris conditions in the reservoir were excellent.

The lack of maintenance of the dam apparent in the July/03 inspection has now been largely addressed. However, work is require to reinstate the upper part of the downstream slope. This is oversteep and slipping/ravelling.

The new weir (presently being tendered for construction this year) will be a substantial addition to effective dam condition surveillance.

The Operations, Maintenance And Surveillance (“OMS”) manual is being updated concurrently with this DSR.

5.3 Emergency Preparedness

The Emergency Preparedness Plan (EPP) has been recently updated and is appropriate.

6.0 CONCLUSIONS & RECOMMENDATIONS

The Lower Chase dam is in as good a condition today as it was at the last DSR in 1992. No evidence of any form of distress was observed. There are no Actual Deficiencies.

However, the dam is likely rather vulnerable to “unlikely” situations (storm, earthquake), and may contain a decaying pipe which is a well-recognized threat to dam safety. There are a total of twelve Potential Deficiencies and Non-Conformances with regard to dam safety.

Work is recommended to:

• Reconstruct the upper portion of the downstream slope; and
Automate reading of the V-notch weir that is presently being constructed and get the measurements into the City’s real time monitoring (SCADA) system. Weir flow is a crucial validation of ongoing dam safety given the uncertainty over details of the dam’s construction and tracking this should give useful advance warning of a deteriorating situation.

The upper part of the downstream slope needs cutting back with removal of roots and other vegetation. It must be then be reconstructed with new compacted fill (possibly with the addition of geogrids) to the original design profile followed by hydroseeding to stabilize the surface.

Although automation of the V-notch weir is recommended, this will not preclude the need to inspect the toe of the dam. At present access is difficult, and in our view is an impediment to effective inspection. We therefore also recommend that:

- A path be constructed down through the left abutment to provide safe and easy access to the downstream toe and berm.

Part of the reasons for the findings in this DSR is that the dam is nearly 100 years old and was likely never formally designed. However, societal expectations have changed and old dam’s are required to be comparable to new dams in terms of safety for potentially affected people downstream. In the longer term, say within the next three years, the dam needs to be brought up to date from its current design of 1 in 100 year rare event (storm, earthquake) capability to something better than a 1 in 1000 year standard. Further engineering studies, and likely some construction upgrading are required. Specifically:

- Spillway modification is needed so that the dam can safely pass a 2-3000 year return period storm. The exact design criteria needs to be agreed with the Water Comptroller, but is likely to lead to either at least doubling the spillway capacity or provision of a second emergency spillway; and

- The seismic resistance of the dam is uncertain and but needs formal documenting, in particular with attention to core cracking during shell movement. The extent of any upgrading would need to be defined by further studies. A precursor of any study will be a full survey of the dam and in particular establishing an engineering record of the upstream configuration of the dam.

The above five recommendations are the principal items requiring attention over the next few years.
Because of the dam’s age, and the way it came into the City’s ownership, records for the dam are far more sketchy than desirable and it must be recognized that aspects of the dam will remain uncertain despite the best efforts of the City. The emphasis on routine surveillance in the City’s operation of the dam is appropriate for the circumstances and necessary for public safety.

This dam safety review is submitted by Golder Associates Ltd.

M. Jefferies, P. Eng.
Associate

H. Hawson, P. Eng.
Principal
## 7.0 REFERENCES

<table>
<thead>
<tr>
<th>Reference Type</th>
<th>Document Description</th>
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</thead>
<tbody>
<tr>
<td>Library #713</td>
<td>Dayton &amp; Knight (1987); Data File: Lower Harewood Colliery Dam (a.k.a. Lower Chase River Dam and Harewood No. 1 Dam)</td>
</tr>
<tr>
<td>Library #189</td>
<td>Willis, Cunliffe &amp; Tait (1979). Contact documents for Dam Rehabilitation Program, issued for Tender.</td>
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APPENDIX A

DETAILED RESULTS OF DAM SAFETY REVIEW
1.0 DAM SAFETY MANAGEMENT SYSTEM

1.1 The dam system, its functions and responsibilities shall be identified.
Type: Cnf Conformance: Conforms
Description: The acceptance of responsibility for the dam by the Engineering Dept of the City is clear, and individuals have been tasked. Surveys are being done both of the dam and of the underwater upstream slope, with revised OMS manual in draft awaiting this survey data.

1.2 The dam shall be classified in terms of the reasonably foreseeable consequences of failure for consideration in design, evaluation and management of dam safety.
Type: Cnf Conformance: Conforms
Description: The dam's classification of HIGH in current Provincial records has been reviewed during this inspection and found consistent with the present circumstances.

1.3 The dam safety management system shall include a process so that reported potential and actual deficiencies are followed up until resolution.
Type: Cnf Conformance: Conforms
Description: A list of outstanding dam safety issues is maintained by Engineering and used to track progress in resolving those issues. Part of the current backlog of issues relates to the dam originally being operated by the Parks & Recreation rather than Engineering group within the City, and what was found during interviews with the Engineering group was an awareness of issues and how to get dam safety on track.

1.4 Documentation shall be maintained so that a permanent record exists of the design and performance of the dam, and the management of its safety.
Type: Cnf Conformance: Conforms
Description: Files are maintained and were made available to the Inspection team; the City's filing system for reports and drawings was thorough. These included prior safety reviews. However, because the dam is a historic structure nearly 100 years old, there are neither design reports nor construction records. Paper records of the dams performance and condition are kept.

1.5 All staff with responsibilities for dam safety activities shall be adequately qualified and trained.
Type: Cnf Conformance: Conforms
Description: Training videos are available and some staff have attended dam safety conferences. Training videos and the OMS manual are scheduled to be reviewed with each new employee in this area of work and every two years for the experienced Watershed Inspectors. Training and reviews is documented within Engineering (as a sign-off sheet within the corresponding dam operating log) as well as with Human Resources.

2.0 DAM SAFETY REVIEW

2.1 The dam safety management system shall include a process for independent periodic review ("Dam Safety Review") of safety management at a dam.
Type: Cnf Conformance: Conforms
Description: Implemented. Reviews carried out in 1978, 1992 and 2003 (this review).

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November 2003
3.0 OPERATION, MAINTENANCE AND SURVEILLANCE

3.1 Operation, maintenance and surveillance requirements for dam safety shall be documented in procedures ("OMS Manual") that allow the operators to operate the dam in a safe manner, maintain it in safe condition, and monitor its performance well enough to provide early identification of any conditions which might threaten dam safety.

Type: Cnf  
Conformance: Conforms

Description: CMS manual ("Data Book") created in 1992 and updated. The dam and reservoir is a passive system with no operation as such - the only operation is to ensure that the spillway is kept free of debris. The OMS manual is being revised concurrent with this DSR and includes updates of procedures to present standards.

3.2 Operating procedures shall be followed to ensure that the dam, together with applicable structures and equipment required for flood discharge, is operated safely.

Type: Cnf  
Conformance: Conforms

Description: The key operating requirement is that the spillway be kept debris free. This requirement is emphasized in the revised OMS manual. Procedures are in place to ensure that debris can be rapidly removed, either using City resources or external contractors, as required.

3.3 Maintenance procedures shall be followed to ensure that the dam, together with applicable structures and equipment required for flood discharge, is maintained in a safe and fully operable condition.

Type: Cnf  
Conformance: Conforms

Description: There are no moveable gates or machinery required for safe operation of the dam, and which require maintenance. Maintenance is primarily the routine clearing of debris from the spillway and cutting of grass on the downstream slope of the dam (to allow identification of any slope movements). Excess vegetation was thoroughly cleared from the downstream toe area in Fall/2003.

3.4 Surveillance procedures shall be followed to monitor dam performance well enough to provide early identification of any conditions which might threaten dam safety.

Type: NCs  
Non-conformance: Surveillance

Description: Surveillance is presently monthly and based on the Watershed Inspector noting observations against a check list, with these observations being coordinated against potential failure modes in the recently revised OMS manual. A seepage monitoring weir is being tendered, although this will be read only manually at monthly intervals. However, because of the crucial importance of the weir flow to dam safety (given the possibly decaying outtake pipe within the dam) more than monthly inspections are needed as a piping-related failure would likely develop far faster.

Recommend: Implement automated weir flow readings on the City's SCADA system and with an appropriate alarm level set. To avoid false alarms, the reservoir level should be similarly monitored. These automated readings should also be stored at daily intervals in perpetuity as minimum, average and maximum values for the 24 hour period.

3.5 The dam owner shall ensure that the dam is adequately safeguarded to prevent unauthorized modifications or operation of the dam by someone other than the dam owner or an agent of the dam owner.

Type: Cnf  
Conformance: Conforms
Description: There are no operable valves or gates, and the only credible deliberate hazarding of the dam would be for someone to block the spillway. However, the dam is on a foot track and it would be difficult to get something large to the dam without alerting members of the public who walk the trail across the dam for at least most of the daylight hours. It is considered that the dam complies with the intent of this Dam Safety Principle.

4.0 EMERGENCY PREPAREDNESS

4.1 An emergency plan shall be established and maintained for any dam whose failure could be expected to result in loss of life, as well as for any dam where advanced warning would reduce upstream or downstream damage.

Type: Cnf  Conformance: Conforms

Description: The EPP has been recently revised and its distribution includes identified responders to possible emergency situations.

4.2 Appropriate procedures and resources shall be available and documented in the emergency plan to support the actions to be taken in the event of an emergency at the dam.

Type: Cnf  Conformance: Conforms

Description: The EPP defines a list of emergency scenarios. The actions to be taken in these situations are defined and appropriate. The EPP includes notification of other public agencies, but relies on these agencies to warn potentially affected residents. Given the historic nature of the dam, the EPP appropriately emphasizes public safety over immediate emergency repairs at the dam.

4.3 A program shall be in place to maintain emergency preparedness at the dam so that the operators and other responders are always prepared to act appropriately in the case of a dam safety emergency.

Type: Cnf  Conformance: Conforms

Description: Program implemented as part of recent EPP revision.

5.0 EARTHQUAKES

5.1 The Maximum Design Earthquake (MDE) selected for design or evaluation of the dam and appurtenant structures shall be consistent with accepted practice for structures with similar consequences of failure.

Type: Pu  Potential Deficiency: Expected to be deficient under unlikely loads

Description: An earthquake hazard assessment was recommended in the 1992 inspection by EBA but has not been implemented. Estimates of an appropriate MDE are given in the main text of this Inspection & Review. The ability of the dam to withstand the estimated MDE is uncertain, the principal vulnerability being failure of the concrete core wall because of temporary loss of support. It is thought that such failure would result in accelerated erosion of the dam rather than a quick failure, but this needs to be fully reviewed in a detailed study.

Recommend: Perform a seismic assessment of the dam. This will involve some additional physical testing. However, study results may be constrained by lack of knowledge of the internal configuration of the dam and the study will require the prior documentation of the upstream configuration of the dam.
Appendix A: Detailed Results of Dam Safety Review (Continued)

6.0 FLOODS

6.1 The Inflow Design Flood (IDF) selected for design or evaluation of the dam and appurtenant structures shall be consistent with accepted practice for structures with similar consequences of failure.

Type: NCI Non-conformance: Information

Description: Studies are underway to revise the IDF. Estimates have been developed for this Inspection & Review based on this recent work together with prior studies for the City that were done in 1978 and 1987. A PMF event is viewed as excessively conservative and unlikely, see the text of the report.

Recommend: Complete the Chase River hydrology study and review the estimated IDF used in this assessment.

7.0 DISCHARGE FACILITIES

7.1 The discharge facilities shall be capable of passing the IDF without exceeding any structural limitations on the dam.

Type: Pu Potential Deficiency: Expected to be deficient under unlikely loads

Description: About a doubling in spillway capacity is required to pass the IDF estimated in this study.

Recommend: Investigate options for upgrading the spillway and/or providing a second emergency spillway.

7.2 The approach and exit channels of discharge facilities shall be adequately protected against erosion and shall be free of any obstructions that could adversely affect the discharge capacity of the facilities.

Type: Pu Potential Deficiency: Expected to be deficient under unlikely loads

Description: The spillway was presently clear, although the tree growing in the central island is a future hazard. No log boom has been installed to protect the spillway entrance, but the reservoir is debris clear and the adjacent park maintenance suggests that the intent of the Safety Principle is met by the current actions. The spillway discharge is in the same condition as it was remediated to in 1980 and is performing as intended.

Recommend: Cut down the tree in the spillway island, and remove all vegetation. Change the island surface from soil to masonry/stone/concrete (although this action may be delayed until after evaluation of the necessary spillway upgrade).

7.3 Sufficient freeboard shall be provided for all operating conditions including extreme floods, wind conditions and earthquakes.

Type: Pu Potential Deficiency: Expected to be deficient under unlikely loads

Description: Freeboard under the IDF may be compromised as the spillway has inadequate capacity. Freeboard under earthquake induced dam movement is uncertain. However, the reservoir is small with a short fetch and is also sheltered. Waves are not expected to present any additional concerns for the dam's integrity.

Recommend: This likely freeboard deficiency will be resolved with upgrading of the spillway, see 7.1 and 7.2, and any earthquake related dam stability enhancement, see 8.6.

7.4 The dam outflow structures shall be capable of handling ice and debris.

Type: Cnf Conformance: Conforms

Description: There are no trash racks or other debris screens, but these would interfere with the
recreational use of the dam. Further, given the small size of the dam it is unlikely that large logs could ever pass through the spillway. However, there is little decayed timber around the reservoir waiting to wash into the reservoir. Ongoing maintenance is keeping debris under control, and this appears to be a practical way of complying with the intent of this dam safety principle at Middle Chase.

7.5 All flow control equipment shall be capable of opening and closing under required operating conditions.
Type: N/A Other: Not Applicable
Description: There is no flow control equipment at the dam

8.0 GEOTECHNICAL STRUCTURES

8.1 The slopes of an embankment dam and its abutments shall ensure that the dam, foundation and abutments are stable under all reservoir levels and operating conditions.
Type: NCm Non-conformance: Maintenance
Description: The downstream shell was upgraded during the 1980 remediation by a stability berm and the slope now meets the then design intent with regard to overall stability. However, the upper slope was left oversteep and is now slipping, with tension cracks and settlement apparent in the central part of the dam. The upstream slope condition/geometry is unknown, being below water during this inspection and with no underwater survey data for review. However, no indications were found of any upstream movement of the concrete core wall.
Recommend: The upper part of the downstream slope should be cleared of vegetation, reconstructed, and hyroseeded.

8.2 Adequate filter and drainage facilities shall be provided in an embankment to intercept and control the maximum anticipated seepage, and to prevent significant migration of particles.
Type: Cnf Conformance: Conforms
Description: An engineered filter and drainage system was installed during the 1980 remediation of the dam. As discussed in the main report, outflows from the dam during our inspection were minimal and comparable to what might be expected the dam in good condition with its best estimated internal configuration. Correspondingly, the principal role of the seepage collection system is for inflows from the abutments as the concrete core wall in itself is a satisfactory hydraulic barrier and immune to deterioration from internal erosion.

8.3 The hydraulic gradients in an embankment dam, in its foundation abutments, and along embedded conduits and other appurtenant structures, shall be sufficiently low to prevent piping and heave in the existing material.
Type: Pd Potential Deficiency: Expected not to be deficient, difficult to demonstrated
Description: There are no piezometers in the abutments or embankment with which to establish hydraulic gradients.
Recommend: This deficiency would require the installation of piezometers to prove the existence of what are estimated to be very low hydraulic gradients (based on the low seepage flow and types of material). Installation of piezometers is a low priority and it is more important to address spillway capacity and earthquake stability aspects.

8.4 An embankment dam shall retain the reservoir safely in spite of any cracking that may be induced by settlement, hydraulic fracturing or frost action.
Appendix A: Detailed Results of Dam Safety Review (Continued)

Type: Cnf  Conformance: Conforms
Description: There are no signs of ongoing foundation settlements, consistent with the dam having been in place for nearly 100 years. Measured seepage is consistent with excellent condition of the internal concrete wall and which precludes hydrofracturing.

8.5 The slopes of an embankment dam and its abutments shall be provided with adequate protection against erosion, seepage, traffic, frost and burrowing animals.

Type: NCm  Non-conformance: Maintenance
Description: The upstream slope is below normal reservoir pool level, so that the concrete core wall forms the exposed upstream slope of the dam. No evidence of concrete deterioration was found during the site inspection. The downstream slope is grassed in the lower part and vegetated above. The upper part was eroding from precipitation moving soil down an oversteep slope, the vegetation providing an incomplete surface protection. However, the actions taken against concentrated flows/seepage in 1981 appear effective and the remainder of the slope was in good condition.

Recommend: See Recommendation 8.1.

8.6 All embankment and foundation materials susceptible to liquefaction shall be identified, and the post-liquefaction stability of the embankment dam shall be evaluated. If appropriate, remedial measures shall be undertaken to protect against failure of the embankment dam.

Type: Pu  Potential Deficiency: Expected to be deficient under unlikely loads
Description: The downstream slope was tested with boreholes in 1978 and which revealed predominantly rockfill underlain by dense till. This would not be liquefiable. Downstream, rockfill was overlain by loose sand fill, and this may be saturated and liquefaction prone under the DBE where confined by the new stability berm. Nevertheless, it is thought that limited liquefaction in this toe area would not cause significantly more crest settlement than would otherwise occur, and that this settlement would be in the order of 0.5m. The uncertain issue is the upstream slope and the degree of support it would provide to the central concrete core. The range of scantious credible range from no support to comparable support to the downstream shell, but there is no information to make a judgement within this range. Accordingly, earthquake response has been rated as a potential deficiency, expected to be real. The dam has withstood a modest earthquake shock in 1946.

Recommend: Once the dam has been properly surveyed and documented (Recommendation 1.1), carry out a seismic response study. This will require testing of the concrete core to ascertain rebar spacing/type and likely boreholes to determine the abutment foundation conditions and depth to bedrock. Testing of the upstream shell in the reservoir may also be needed.

8.7 Embankment dams and appurtenant structures, foundation and abutments shall be capable of resisting the forces associated with the Maximum Design Earthquake (MDE).

Type: Pq  Potential Deficiency: Expected not to be deficient, quickly demonstrated
Description: The earthquake vulnerability of the dam was identified as a potential deficiency in 1992 and remains to be addressed. See 8.6 above. The spillway is unlikely to fail during the MDE, but requires checking of reinforcement arrangement to confirm this opinion. Such checking requires tests, as there are no construction records. The bridge over the spillway is likely to topple into the spillway under the MDE, but this is not viewed as a dam safety issue assuming that there would be prompt removal of the bridge debris.

Recommend: See Recommendation 8.6
Appendix A: Detailed Results of Dam Safety Review (Continued)

8.8 Rock foundations shall have sufficient strength, watertightness and stiffness to provide adequate stability under design loads for the dam, appurtenances, abutments and foundation.
Type: Cnf Conformance: Conforms
Description: The rock is sound, and issues of potential undermining were addressed in the 1992 investigation. Foundation conditions are excellent.

8.9 In situ foundations and abutments as well as embankments and backfill, shall be free from gravity-driven movement that would impair the operational capability of appurtenant hydraulic structures or threaten their structural integrity and hydraulic performance.
Type: NCs Non-conformance: Surveillance
Description: No recent movements were apparent during the inspection of the dam and the spillways integrity appeared excellent. However, it would be helpful to install several inexpensive settlement monitoring pins and monitor settlement formally.
Recommend: Install settlement monitoring pins in concrete blocks at three locations along the dam crest. Also place three pins on the concrete wall. Record elevations every six months.

8.10 Fill surrounding appurtenant hydraulic structures shall be free of localized concentrations of seepage that could lead to piping. The foundations and embankment shall be protected from potential adverse effects of any leakage from conduits or structures.
Type: Cnf Conformance: Conforms
Description: The spillway is subject to minimal hydraulic gradient and has a long seepage path. No localized seepage was evident.

9.0 CONCRETE (AND OTHER RIGID) STRUCTURES

9.1 The analysis and evaluation of the strength and condition of a concrete dam (or other rigid structure), its foundation and appurtenances shall be consistent with accepted practice for structures with similar consequences of failure.
Type: Cnf Conformance: Conforms
Description: Not a concrete dam.

9.2 Concrete dams, their foundations and appurtenant structures shall have adequate resistance to sliding at the dam-foundation interface, within the dam and at any plane in the foundation, to withstand all reasonable loads and load combinations to achieve adequate dam safety.
Type: N/A Other: Not Applicable
Description: Not applicable.

9.3 If required to achieve dam stability, foundation drainage systems shall be designed, maintained and operated to achieve their purpose during and after all reasonable loading conditions.
Type: N/A Other: Not Applicable
Description: Not applicable.

9.4 The concrete shall have sufficient strength that the loads will not result in excessive deformations or overstressing.
Type: N/A Other: Not Applicable
Description: Not applicable.
Appendix A: Detailed Results of Dam Safety Review (Continued)

9.5 During and after extreme events such as the IDF and the MDE, the dam shall continue to safely retain the reservoir water.
Type: Pu  Potential Deficiency: Expected to be deficient under unlikely loads
Description: There have been no evaluations of possible damage to the present spillway during the IDF.
Recommend: This deficiency is expected to be addressed in the upgrading of the spillway for hydraulic capacity and does not require specific attention here.

9.6 Structural integrity and functionality of support structures for mechanical and electrical equipment that relate to dam safety shall be preserved during and after extreme events including the IDF and MDE.
Type: N/A  Other: Not Applicable
Description: There is no installed electrical or mechanical equipment.

9.7 Appurtenant structures shall be capable of withstanding all reasonable loads and load combinations.
Type: Pq  Potential Deficiency: Expected not to be deficient, quickly demonstrated
Description: It is anticipated that the pedestrian footbridge is not earthquake resistant and may topple into the spillway. Provided that this debris was cleared in a timely manner, loss of the footbridge would not be a dam safety issue. The spillway walls require chacking for earthquake resistance; in our opinion they are likely adequate.
Recommend: Need to check overturning loads versus reinforcing bar spacing and capacity during earthquake loading scenarios.

10.0 RESERVOIR AND ENVIRONMENT

10.1 The stability of reservoir slopes shall be evaluated under all conditions, if any potential slope failure poses an unacceptable risk to public safety, the dam or its appurtenant structures. If necessary, such slopes shall be stabilized or the public otherwise protected from the effects of slope failure.
Type: Cnf  Conformance: Conforms
Description: Reservoir slopes are low and surrounded by largely flat ground; instability of these slopes is not a threat to the dam or spillway.

10.2 The need for reservoir evacuation or emergency drawdown capability as a dam safety risk control measure shall be assessed on a case-by-case basis. If appropriate, alternative safety measures shall be taken to reduce the risks.
Type: NCp  Non-conformance: Other Procedures
Description: Emergency reservoir drawdown is a possible action in a post earthquake situation.
Recommend: There is no low level outlet. Use of a siphon should be evaluated in detail.

10.3 The reservoir shall be monitored for potential dam safety hazards which should be remedied or considered in the evaluation of dam safety.
Type: Cnf  Conformance: Conforms
Description: The reservoir is monitored, with action as required.
APPENDIX B

DAM INSPECTION REPORT, JULY 2003
Lower Chase Dam (City of Nanaimo)

1 Introduction

Lower Chase dam was inspected by H. Hawson and M. Jefferies during the afternoon 23 July 03 and the following morning 24 July 03. The purpose of the inspection was to be part of a 7-10 years Dam Safety Review (DSR) of the dam, the last such DSR having been carried out by EBA Ltd in 1992, in accordance with regulatory requirements. The inspection was not carried out because of some identified potential problem with the dam.

The inspection comprised a walk-over of the dam and the surrounding reservoir slopes after review the previous week of documentation about the dam that was provided by the City.

The dam comprises a concrete core structure with the core exposed on the upstream side in the upper part, see Figure 1. The dam crest is part of a trail in the City’s park system and is asphalt surfaced with a pedestrian bridge crossing the spillway. Photograph 1 shows a picture of the upstream side of the dam taken during the inspection; the upstream projection from the face is the old valve chamber tower that extended to a depth of 15 m and which was decommissioned and backfilled in 1980. Photograph 2 shows a view of the spillway channel with its footbridge and which are located in the right abutment of the dam.

The dam is nearly one hundred years old, and is believed to have been constructed in about 1910 to provide a water supply to the then Harewood Colliery. The dam was evidently an engineered structure from the concrete core and the draw-off tower,
with evidence of care in the finishing of the concrete (Photograph 3). No photographs have been found of the dam during its construction or in its early years.

The dam was acquired by the City in 1975 and is now part of the City’s parks. The reservoir is used for swimming and fishing, with no offtake of the impounded water. All net inflow is simply allowed to flow down the spillway into the Chase river.

2 Watershed & Reservoir Conditions

2.1 Weather

The weather during both days of the inspection was bright, sunny and dry. Air temperatures were warm.

2.2 Watershed

Dry conditions had existed for well before the inspection and there was minimal inflow into the reservoir at the time of the inspection. This is consistent with the time of year of the inspection.

2.3 Reservoir

2.3.1 Level

Reservoir level is uncontrolled as the dam is operated solely as a recreation resource with a passive spillway. At the time of the inspection the reservoir was very slightly above the lowest part of the spillway crest with only a few inches of water in the spillway (Photograph 4).

2.3.2 Debris

The reservoir was free of debris, Photograph 5 (taken from the dam) showing a view of the conditions in the reservoir.

2.3.3 Bank Stability

The banks around the reservoir only rise a few metres above the water surface, and the ground is generally flat lying as illustrated on Photograph 5. The whole surrounding
area is part of the park system and readily accessible. No substantive bank erosion was observed while walking around the reservoir.

2.4 Discharges

The reservoir water is not discharged, the outlet works having been taken out of commission during remediation of the dam in 1980.

Flows down the spillway were only a few gallons per second during the inspection, reflecting the dry conditions in the watershed during the previous weeks.

3 Embankment Condition

3.1 Upstream Slope

The upstream earthworks are poorly defined and lie below the normal reservoir surface. The record drawing from the dam remediation in 1980 suggests that the central part of the dam is an unsupported vertical face (see Figure 1) while the dam Data File indicates a sloping fill (see Figure 2); the upstream slope was not visible at the time of inspection. No underwater survey records were available from the City for review.

The concrete core wall was inspected. No settlement or shrinkage cracks were seen in the wall itself, although there was one large crack where the wall joined the spillway structure, Photograph 6. This crack appeared old and there no sign of recent movement was seen.

The concrete wall appears to have been raised in the past, as it does not extend monolithically to the crest (Photograph 3). Some surface weathering of the concrete was evident, but nothing substantive to the dam’s function was observed.

No signs of any movement in an upstream direction were evident in the dam crest.

3.2 Downstream Slope

The downstream slope was found inadequate during the 1978 inspection/investigation of the dam, and a stabilizing berm was constructed in 1980 together with drainage
trenches. Details are contained on Sheet 3 of the As-Built Drawings produced by the engineer, Willis, Cunliffe & Tait.

The downstream slope comprises two parts, an original and steeper upper slope with the lower shallower berm. Photograph 7 is taken from the toe of the dam and predominantly shows conditions on the berm.

Access to the downstream slope, the berm, and the to of the dam was inadequate, involving relatively dangerous scrambling. There were no steps or other pathways, and effective routine monthly surveillance of the dam has been severely compromised by the constraint that this imposes on inspecting the important downstream toe area.

The upper slope was also poorly maintained with extensive vegetation. It was difficult to inspect for signs of movement, but these were found. Figure 2 shows the cross-section of the dam from the data book with conditions found during the present inspection; the slope has been over-steepened to as much as 52 deg (measured using handheld clinometer). Cracks indicating more deep-seated movement were found in the asphalt surfacing on the dam crest, Figure 3 showing a sketch of their location.

Trees that are apparent in photographs of the Right side of the upper part of the slope in the 1980 photographs are still there, but have now grown substantially. Tree roots likely intrude into the right hand side of the upper slope.

The berm slope, although now covered with uncut grass, appeared to be in much the condition as recorded on the 1980 as built drawings. No signs of instability were observed, and the movement crack that was noted in 1980-2 was not found.

3.3 Seepage/Piping

Erosion of the Left abutment was an issue during a dam inspection in 1981. This area was inspected, and although now much obstructed by vegetation, no signs of erosion were seen. Photograph 8 illustrates this lower slope/abutment area. However, although no daylighting seepage was found, there was a distinctly damp area in the lower slope and which may correspond to the location of the gravel drain installed in 1980 – it is difficult to be precise because there are no markers from which to determine the gravel drain location according to the 1980 As-Built Drawings.
Seepage was an issue with the right hand abutment/dam intersection during the 1978 inspection, and drains were installed during the 1980 remediation. These drainage trenches appears to be working as intended. The area is now well covered with ferns, although it is unclear whether this is more attributable to shade than ongoing dam conditions.

The 1992 inspection report recommended that a source of concentrated seepage should be investigated. However, the report provides no sketch as to where this was and presumes that the reader already knows. No concentrated flows were observed daylighting from the lower part of the berm slope, although this was very heavily covered with brambles that obscured much.

In the original channel downstream of the dam there was no weir or any attempt at seepage monitoring. There was heavy vegetation here (Photograph 9), however. Only an extremely small trickle of water was flowing in the base of the channel (Photograph 10). Given the heavy vegetation, the best estimate was that seepage through the dam’s drain system installed in 1980 was no more than about 5 L/min at the time of this inspection. No evidence was seen that seepage had been much more in the recent past, although the vegetation also makes clear that the area does remain permanently damp.

The heavily vegetated conditions in the toe area made it impossible to assess whether or not there were any fines in the seepage.

3.4 Crest

The dam crest comprises an approximately level path, part paved with asphalt.

There is evidence of downstream slope movement (as noted above) with longitudinal cracks, Photograph 11. However, there is no pattern of general crest settlement and the cracks appear related to shallow slips in the downstream slope as a consequence of it being too steep rather than any a general instability of the dam.

4 Outlet Works

The dam was originally provided with outlet works in the form of two wood stave pipes passing through the dam, each controlled by a valve at the upstream end. The
valves were located in a concrete chamber on the upstream face of the concrete water barrier (Figure 1 and Photograph 1).

According to the As-Built Drawings by Willis, Cunliffe & Tait, both pipes were filled with concrete during the 1980 remediation, with the valve chamber backfilled. This took the pipes out of service and sealed the concrete face of the dam. The lack of seepage at the downstream toe confirms that there has been no deterioration in the old wood staves.

There are no other offtake works, the dam remaining in service solely to provide a recreational lake.

5 Spillway

The spillway was last repaired in the 1980 reconstruction works. Details of repairs to the spillway channel and is restored condition are contained on Sheet 6 of the As-Built Drawings produced by the engineer, Willis, Cunliffe & Tait.

5.1 Spillway Control

The spillway is a flat-lying concrete channel, split into two in the upstream side (see Photograph 2). Although the 1992 DSR recommended installation of a log boom, there was no evidence that this had ever been done. As a result the entrance to the spillway is open, Photograph 4. The spillway was clear of debris.

The spillway was originally equipped with stop-logs and which were retained in channels cast into the concrete, Photograph 12. It is understood that stop-logs have never been used by the City, and there were none on site.

There are no gates or other devices to control spillway flow.

5.2 Channel

The spillway channel is concrete as are the walls on both sides for the full length of the channel. The upstream part of the spillway has an island area between the two channels and this is becoming overgrown. Upstream of the footbridge this takes the
form of grass, but downstream a large tree has become established and is threatening the integrity of the spillway concrete wall, see Photograph 13.

A visual survey of the spillway concrete found no signs of concrete spalling, although there were numerous surface cracks in the exposed concrete walls (see Photograph 12). However, shallow water in the channel prevented a clear view of the channel bottom and which may have lead to some cracks being missed. None of the observed cracks has any significance for the integrity of the spillway.

The channel was clear of any substantive debris that would impede flow.

Downstream of the footbridge, no evidence was apparent of bank erosion caused by water flows exceeding the channel capacity.

5.3 Energy Dissipation

The spillway is not provided with any energy dissipation structure, with flows being discharged in a free drop from the end of the concrete channel into a plunge pool below. No evidence was seen of the spillway end being undermined, and the discharge arrangements appear in complete accord with the record of 1980 reconstruction.

5.4 Bridge

A footbridge has been provided over the spillway (Photograph 2). It is not known when this bridge was built, but it is not original. The concrete appears in good condition, in particular with no evidence of spalling on where the beams meet the abutments.

6 Instrumentation

The dam has no piezometers, movement gauges, settlement monitoring points, or weirs. Earlier recommendations to install a weir at the toe of the dam have not been followed.
Figure 1: Cross-section of Lower Chase Dam from *As-Built* Record
Figure 2: Cross-section of Lower Chase dam from the dam’s Data File with current upper slope condition sketched
Figure 3: Plan of dam with location of downstream movement cracks sketched
Photograph 1: View of upstream side of dam 24 July 03 (composite photo)
Photograph 2: View of spillway from upstream (one channel either side of bridge pier)

Photograph 3: Bullnose on top of original core wall shows care taken in finishing concrete
Photograph 4: Entrance to Left channel of spillway

Photograph 5: Conditions in reservoir as observed from dam crest
Photograph 6: Crack in dam wall at junction between dam and spillway
Photograph 7: Composite photograph showing a view of the downstream slope taken from the toe of the dam

(note the top of the berm where vegetation changes from grass to shrubs)
Photograph 8: View of lower Left slope/abutment area which had suffered concentrated seepage and was repaired in 1981
Photograph 9: Conditions downstream of dam where filter drains discharge

Photograph 10: Ditch downstream of dam showing minimal water flow
(boot is just to right side of ditch base)
Photograph 11: View from Left along dam crest showing cracks from slope movement
Photograph 12: Stop-log slots in spillway concrete walls
Photograph 13: View of spillway showing tree in middle of flow splitter immediately downstream of footbridge
APPENDIX C

FOLLOW-UP DAM INSPECTION REPORT, OCTOBER 2003
1 Introduction

Lower Chase dam was inspected by H. Hawson on Monday morning of October 20, 2003 following a weekend of heavy rainfall. The purpose of this additional inspection was to review the dam after the vegetation was removed and to inspect the spillway flow.

The inspection comprised a walk-over of the dam and the surrounding reservoir slopes and review the dam after the vegetation was removed and to inspect the spillway flow.

2 Watershed & Reservoir Conditions

2.1 Weather

The weather was raining at the time of the visit and visibility was poor because of fog.

2.2 Watershed

As a result of the heavy rain water was ponded throughout the watershed area on the ground surface.

2.3 Reservoir

2.3.1 Level

The reservoir level was within 1 ft of the top of the spillway sill, as illustrated on Photograph 1.
2.3.2 Debris

The reservoir and spillway was free of debris.

2.4 Discharges

A considerable flow was occurring in the spillway structure. The flow was being directed towards the south wall of the spillway down the chute and was splashing above the wall. Photographs 2 and 3 show the flow at the time.

3 Embankment Condition

3.1 Downstream Slope

The vegetation was cleared from the downstream slope which allowed the slope to be more easily inspected.

Precipitation was running down the face of the dam and ponding on the surface of the lower berm. Also water was visible at the toe of the dam which was flowing into the creek.

A small scarp feature was evident at the toe of the slope (see Photograph 4). This feature is quite visible. However, there is no indication that the feature is recent as the scarp appears to be well grassed. There was no evidence of seepage occurring at this feature and there did not appear to be any visible cause for this to have occurred.
Photograph 1: Conditions at spillway inlet

Photograph 2: Flow in spillway looking downstream from pedestrian bridge
Photograph 3: Flow in spillway looking upstream from near discharge point

Photograph 4: Old scarp approximately 150 – 200 mm high on lower slope