REPORT ON

UPPER CHASE RIVER DAM
2003 DAM SAFETY REVIEW

Submitted to:
Greater Nanaimo Water District
455 Wallace Street
Nanaimo, B.C. V9R 5J6

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March, 2004

03-1411-103
This report presents an assessment of the Dam Safety Review (DSR) of the Upper 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 currently rated a HIGH consequence dam but it appears that a LOW consequence rating is appropriate.

- The dam appears to be in comparable condition to that in its last major inspection in 1992.

- No seepage or signs of instability were evident during this inspection.

- Spillway capacity is limited by the two culverts downstream of the concrete spillway channel, these culverts having about than half the capacity of the channel.

- The spillway cannot pass the appropriate design storm for the dam’s current hazard rating. The principal limitation is the culverts, but additional capacity is also needed in the concrete channel.

- No detailed seismic stability assessment has been carried out. However, the dam is so low and massive that although the main concrete wall might crack under the design earthquake, outright and rapid loss of the reservoir is not anticipated. Some remedial work to the dam might be found necessary following a full seismic assessment.

Operations and Maintenance of Dam

- Recommendations from the 1992 dam safety inspection have largely been carried out; and

- The dam is adequately maintained.

Emergency Preparedness

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

- There are no present Actual Deficiencies at Upper Chase Dam; and

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

RECOMMENDATIONS

Part of the reasons for the findings in this DSR is that the dam is some seventy years old. The dam needs to be brought up to date from its current design of 1 in 50 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 3000 year return period storm. The exact design criteria needs to be agreed with the Water Comptroller, but may lead to about a tripling of the spillway capacity (it is actually the culverts beneath Nanaimo Lakes road that is the problem).

- The seismic resistance of the dam is probably adequate but needs formal documenting, in particular with attention to toppling. The extent of any upgrading would need to be defined by this study.

Neither of these recommended upgrades is urgent, but should be considered within the next five years.

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.
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LIST OF APPENDICES

Appendix A  Detailed Results of Dam Safety Review
Appendix B  Dam Inspection Report, July 2003
1.0 INTRODUCTION

1.1 Purpose

This report presents a Dam Safety Review (DSR) of the safety of the Upper Chase River dam, and was carried out for the Greater Nanaimo Water District (District) who own the dam. The dam lies in the south part of the Greater Nanaimo Water District, see Figure 1.1 for location, and is accessed by way of Nanaimo Lakes Road. The dam has also been known by the former name No 2 Reservoir 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 Upper 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.

Upper Chase dam appears to have been an engineered structure when constructed some seventy 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.

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 Greater Nanaimo Water District’s responsibilities under its conditional dam license (# 22585, issued July 1955).

1.2 Background

Upper Chase dam is believed to be about seventy years old, but little is known of its history or even, surprisingly, the reason for its construction. No photographs have been found of the dam during its construction or in its early years. The dam comprises a mass concrete wall further supported by earthfill downstream, with Photograph 1.1 showing a picture of the upstream side of the dam taken during the inspection. On the left of the concrete dam is an earthfill dam that leads to the spillway in the left abutment, Photograph 1-2. Photograph 1.3 shows a view of the spillway channel, which is a concrete and leads to two culverts passing under the road shown in Photograph 1.4. Figure 1.2 gives a sketch plan of the dam layout.

No maximum height has been determined for the 64m long concrete section, but it appears to be about 6 m. The earthfill section is both lower, 2.5m, and shorter, 33m.
The dam is evidently an engineered structure from the carefully formed buttresses and care in the finishing of the concrete. However, the buttresses are on the upstream side of the dam and give the impression that the dam was first engineered to act as a retaining wall for the fill bringing Nanaimo Lakes Road to its current level.

The District constructed a pipe at the dam in 1998/9 to divert water to the No 1 Reservoir that is just the other side of the road, when required.

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 at the junction of the dam with the left abutment, and is founded on rock. The spillway is designed to spill 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 lined channel with a bedrock base, illustrated on Figure 1.2.

### Table 1-1: Upper Chase River Dam Statistics

| Type of Dam | • Part concrete with granular downstream shell  
| • Part earthfill with unknown zonation |
| Maximum Height | • Concrete section: about 6 m, but not established by survey  
| • Earthfill section: about 3 m, but not established by survey |
| Width of Crest | Varies depending on location |
| Length along Crest | • Concrete section 64 m  
| • Earthfill section 33 m |
| Catchment Area | • 2600 Ha approximately |
| Retained Water (normal pool) | • 61,000 m³ |
| Freeboard, 1:100 year storm | None |
| Offtake works | • Pipe attached to concrete section and with valve in road. Discharges to No 1 Reservoir |
| Type of Spillway | • Unregulated spillway designed to discharge under normal operating conditions  
| • Concrete walled channel |
| • CapaGreater Nanaimo Water District may be limited by twin culverts under road |
Figure 1.1: Site location plan
Figure 1.2: Plan of Upper Chase Dam and Reservoir

Extracted from Drawing of Reservoirs N° 1 & 2 by City Engineer (Dated 31 Oct 1944)

Golder Associates
Photograph 1-1: View of concrete part of Upper Chase River Dam 24 July 03

Photograph 1-2: View of earthfill part of Upper Chase River Dam (spillway entrance at left end of embankment)
Photograph 1-3: View of spillway looking upstream from road

Photograph 1-4: Culvert entrance downstream of spillway channel
1.3 History of Dam Safety Activities

Since acquisition of the dam by the Greater Nanaimo Water District in 1955, there have been six principal safety related activities:

- 1978: Dam Safety Inspection (Golder Associates);
- 1987 Development of a dam “Data File” (Dayton & Knight);
- 1992: Dam Safety Inspection (EBA);
- 1992: Development of a “Data Book” which included Operations & Maintenance requirements together with an emergency response plan (EBA);
- 1998-9: Construction of offtake pipe to Nº 1 Reservoir (Reid Crowther); and
- 2002-3 Hydrology study for the Upper Chase River (Water Management Consultants).

The District 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 Lobieux Road, Nanaimo, BC).

Inundation estimates in the event of dam failure are essentially based on modelling undertaken by the Water Management Branch and sent to the Greater Nanaimo Water District 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 acting as agent for the Greater Nanaimo Water District 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 District and a site inspection. Archives and books on Nanaimo have been searched for historic information, but nothing was found for this dam.

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. The report is included as Appendix B. Areas inspected include:

- Dam, both earthfill and concrete sections;
- 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 based on prior hydraulic studies (Willis, Cunliffe & Tait, 1978; Dayton & Knight, 1987; and Water Management Consultants, 2002) supplemented with additional 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 $A_n$) and under unlikely loads that are not expected to occur (denoted as $A_u$).

**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. But, importantly, a non-conformance in itself is not indicative of unacceptable dam performance. The following are the non-conformance categories: $NC_i$ indicates that required information is not available; $NC_o$ is an operational non-conformance; $NC_m$ is a maintenance non-conformance; $NC_s$ is a surveillance non-conformance; and $NC_p$ is a non-conformance in other procedures.
3.0 UPPER CHASE RIVER DAM & RELATED STRUCTURES

3.1 History

The history of the dam is obscured by the lack of records and documentation before 1955, at which time GNWD acquired the dam from Canadian Collieries Ltd. The original purpose for the dam is unclear, and it may have been constructed as a buttress for the Nanaimo Lakes road rather than as a dam. Important dates are:

- 1920? Believed constructed in period 1911-1940, but actual date, design and details unknown;
- 1955 Ownership passed to Greater Nanaimo Water District;
- 1978 Inspection by Golder Associates found dam in excellent condition, with clearly adequate stability;
- 1992 Inspection by EBA found dam in good condition but with some concrete spalling;
- 1998/9 Offtake pipe to Reservoir #1 constructed as engineered by Reid Crowther; and
- 2002-3 2002 Hydrology study for the Chase River, including Upper Chase dam.

3.2 Description

3.2.1 Foundation Conditions

There are no boreholes or exposures directly indicating foundation conditions. The 1992 DSR reports that both parts of the dam are founded on till. However, substantial bedrock was encountered during excavations for the new offtake pipe in 1998/9 and it appears possible that the concrete section of the dam is founded directly on bedrock.

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. But, no abutment seepage has been reported in the various inspections over the past twenty five years. Seepage conditions are unknown earlier than this because of an absence of inspection reports.

Concerns about whether mining operations might underlie the dams foundations 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 Concrete Dam

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 0.9m thick at the top. It is unclear whether the wall thickens with depth, but the external buttresses on the upstream side of the concrete wall suggest that it does not. There is no data or test results to show whether or not the concrete wall is reinforced, and there are no expansion or other movement joints apparent in the concrete wall.

There appears to have been no surveys of the reservoir upstream of the concrete wall.

The concrete wall is supported on the downstream side by earthfill.

The concrete core wall is presumed to extend to full depth and be founded on bedrock, not the dense till overlying bedrock as thought in the 1992 DSR.

There have apparently been no concrete cores taken over the years and the strength of the concrete is unknown.

3.2.3 Earthfill Dam

The southern section of the dam comprises a short earth embankment that links the concrete section to the spillway in the left abutment. There are no available details on how it was built, nor has any subsequent testing been carried out. There also appear to be no survey drawings.

To some extent the lack of attention to the earthfill section is understandable as it is barely a dam. Its height is only 2.5m and it only retains water when the spillway has about a 0.3m depth at the entrance.

3.2.4 Spillway

The spillway comprises a rectangular concrete channel with a horizontal base leading, by way of a short but rather steeply sloped section, to a pair of 1800 mm diameter (6ft) culverts in a headwall. These culverts pass under the road and discharge freely into the old Chase River at about 1.5m above the base of the channel.
3.2.5 Offtake Works

Outlet works comprise a 450 mm diameter discharge pipe set in the dam face about 1m below normal pool level (see Photograph 4). The pipe continues under the Nanaimo Lakes Road to the Emergency Water Intake tank and then onto Reservoir #1. Diversion of water is controlled by a valve set in the roadbase.

The original license for the dam included a condition that a water offtake pipe was to be constructed in 1955-6. However, this appears to have be cancelled as there are no records (or recollections amongst the older GNWD employees) of any construction from that time. The present offtake work were engineered by Reid Crowther and Partners Ltd. (their project number 37065-00) in 1998 and constructed in 1999. Figure 3.1 shows a section taken from the As-Built record showing the new offtake pipe.

The new offtake is for emergency use only, with no normal diversion of water to Reservoir #1.

3.2.6 Prior Dam Safety Inspections

The dam has had two prior DSR inspections, one in 1978 and one in 1992.

The 1978 inspection (Golder Associates, 1978) concluded that the dam was obviously safe based on a walkover survey. Although this conclusion was not substantiated with detailed notes or reasoning, why the engineers took that view in 1978 was apparent on visiting the site: Upper Chase is a very massive dam in proportion to its very low height and with no signs of anything untoward.

The 1992 DSR reported no safety issues, but did highlight the spalling of the concrete. It also identified marginal capability to handle a 100 year return period storm, the then design standard.

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.
Figure 3.4: Section taken from Reid Crowley as-Built showing intake pipe.

- ROUND ALUMINUM HOOD TO PROTECT INTAKE SCREEN 800mm CLEAR ALL AROUND FOR DETAIL SEE THIS SHEET
- EXIST. 200# WATERMAIN
- EXIST. 750# WATERMAIN
- EXIST. 450# WATERMAIN
- CONCRETE LOCK BLOCKS
- NEW CHAINLINK FENCE
- ORIGINAL GROUND
- APPROX. ORIGINAL ROCK PROFILE
- EXISTING 450# WATERMAIN SLOPED AT 4.9% TO DAYLIGHT
- EXISTING SIDERAIL AROUND RESERVOIR
- EXISTING RESERVOIR
- ORIGINAL GROUND
- EXISTING UPPER CHASE RIVER DAM (RESERVOIR #2)
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**

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<tr>
<th>CONSEQUENCE CATEGORY</th>
<th>POTENTIAL INCREMENTAL CONSEQUENCES OF FAILURE[a]</th>
<th>LIFE SAFETY[b]</th>
<th>SOCIOECONOMIC &amp; ENVIRONMENTAL[b,c]</th>
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<tr>
<td>Very High</td>
<td>Large number of fatalities</td>
<td>Extreme damages</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Some fatalities</td>
<td>Large damages</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>No fatalities anticipated</td>
<td>Moderate damages</td>
<td></td>
</tr>
<tr>
<td>Very Low</td>
<td>No fatalities</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 Upper Chase Dam as a HIGH hazard structure.

In developing the HIGH rating, it appears that failure of the Upper Chase dam has been taken to result in failure of the two downstream dams. Thus, there is no distinction in the inundation study of 1977 between the three dams. And, the inundation study suggests that flooding in the event of dam failure could be extensive. The 2002 hydrology study produced similar estimates, and is the basis of the present emergency plan. The potentially area is shown on Figure 3.2.
However, the reservoir volume retained by the Upper Chase dam is small. Further, failure of the concrete section of Upper Chase dam would direct water primarily to the immediately adjacent Reservoir N° 1 rather than to the River Chase itself, a conclusion also reached by Water Management Consultants (2002b).

It is noteworthy that there are no people living in the Chase valley between the Upper and Middle Chase dams. Nor are there any industrial plants or chemical storage facilities. The case for rating the Upper Chase dam as HIGH consequence depends entirely on the assumption that failure at Upper Chase causes a failure downstream. This is questionable. The Reservoir N° 1 dam is a concrete gravity dam and the overtopping would be limited because of the low volume of water retained by the Upper Chase; failure of the Reservoir N° 1 dam as a consequence of Upper Chase failure is a very conservative scenario.

Failure modes for Upper Chase dam are discussed in Section 4 below, but the effect on the hazard assessment is this. Under an earthquake loading scenario, a rapid release of water from Upper Chase is not credible. Under a severe storm scenario, a washout of the earthfill section of Upper Chase is credible, and possibly with subsequent erosion of the foundation and adjacent roadway. An internal erosion scenario (internal defect) is not credible.

Thus, the only credible failure scenario involves an extreme storm and for which there should be adequate warning. Given the vulnerability of the downstream dams to this storm, it is difficult to understand where there is any increased risk contribution from the Upper Chase dam. This mitigates against assigning a HIGH rating to the Upper Chase dam.

Based on the above, and in comparison to Table 3-1, in our opinion a LOW rating is reasonable and appropriate for the Upper Chase dam.
Figure 3.2: 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.

Golder Associates
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 LOW consequence category, it follows that Upper Chase Dam should:

- Withstand about a 1000 year return period earthquake; and
- Safely pass about a 1000 year flood.

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>
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<td><strong>DETERMINISTICALLY</strong></td>
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</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 Upper Chase dam, but the hydrology of the Chase watershed has been assessed in three studies. These studies were:

- 1978: by Willis, Cunliffe & Tait in connection with the 1978 dam safety review;
- 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 3.3. Also shown on this figure is the probable maximum flood (PMF) which is only quoted by Water Management Consultants for the Lower Chase dam and has been scaled using relative catchment area.

![Figure 3.3: Summary of hydrological studies for Upper Chase showing estimated flood flow versus return period](image)

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 as these are consistent with each other, to indicate a present best-estimate of how the flood...
increases with increasing return period. A 1000 year return period event, the appropriate risk standard for the dam as discussed above, corresponds with about a 60 m$^3$/sec flood inflow to the reservoir. The PMF represents well 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 Greater Nanaimo Water District’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 3.4.

![Figure 3.4: Horizontal peak ground acceleration versus estimated return period](images/earthquakes.png)

Figure 3.4: Horizontal peak ground acceleration versus estimated return period
A 1000 year return period event, the appropriate risk standard for the dam as discussed above, corresponds with about a 0.3g 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.

![Figure 4.1: Summary of Failures in Water Retaining Earthfill Dams (ICOLD, 1995)](image)

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 Upper Chase Dam. The table is split into two parts, 4-1(a) dealing with the concrete section and 4-1(b) dealing with the earthfill section.

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 4-1a: Relevance of Most Common Failure Modes to Upper Chase Dam

*Concrete Section*

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Comments/Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope Instability</td>
<td>Instability of downstream shell is unlikely.</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, but is backed by fill and which would provide temporary containment on its own in the absence of the concrete wall.</td>
</tr>
<tr>
<td>Overtopping</td>
<td>Spillway is uncontrolled, with uncertainties on the design storm. Ongoing dam safety requires spillway be kept clear of all debris. Spillway can pass only about a 50 year storm because of the constrain of the downstream culverts. Dam crest is not erodabile.</td>
</tr>
<tr>
<td>Seepage within embankment</td>
<td>The core wall is concrete and there is no normal seepage flow.</td>
</tr>
<tr>
<td>Internal erosion</td>
<td>Internal erosion could only arise if the core wall is cracked or toppled by an earthquake, so exposing the downstream shell to seepage. This might represent a delayed failure mode post earthquake, but only if there was also substantial retained water in the reservoir and which is not usually the case.</td>
</tr>
<tr>
<td>Foundation seepage and internal erosion of foundation</td>
<td>Details to intercept foundation seepage are unknown, and there may not be any drains. However, there is no evidence of seepage after some seventy years of operation.</td>
</tr>
<tr>
<td>Rupture of conduits</td>
<td>There is an offtake pipe with an engineered connection to the concrete wall of the dam. Rupture of this pipe would be unlikely to cause dam failure because of the substantial concrete wall thickness that would allow it to bridge between the uneroded parts of the downstream shell.</td>
</tr>
</tbody>
</table>
**Table 4-1b: Relevance of Most Common Failure Modes to Upper Chase Dam Earthfill Section**

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Comments/Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope Instability</td>
<td>No evidence of slope instability in seventy years and the slope is less than 3m high. On the other hand, details of the earthfill construction are 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 because the geometry suggests that most of the embankment will not be saturated.</td>
</tr>
<tr>
<td>Overtopping</td>
<td>Spillway is uncontrolled, with uncertainties on the design storm. Ongoing dam safety requires spillway be kept clear of all debris. Spillway can pass only about a 50 year storm because of the constrain of the downstream culverts. Dam crest is erodable.</td>
</tr>
<tr>
<td>Seepage within embankment</td>
<td>The core wall is concrete and there is no normal seepage flow.</td>
</tr>
<tr>
<td>Internal erosion</td>
<td>Internal erosion is unlikely because the retained head of water is small, and often none. There are minimal hydraulic gradients to drive the development of internal erosion even in the likely absence of engineered filters within the embankment.</td>
</tr>
<tr>
<td>Foundation seepage and internal erosion of foundation</td>
<td>Details to intercept foundation seepage are unknown, and there may not be any drains. However, there is no evidence of seepage after some seventy years of operation.</td>
</tr>
<tr>
<td>Rupture of conduits</td>
<td>There is no offtake pipe or conduit in this section.</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.

Because the dam is founded on low permeability till (or possibly on tight bedrock) and the retained head is small, seepage through the foundation should be minimal.

4.2.2 Performance Review

There is no seepage monitoring weir nor any seepage collection system. Seepage can only be evaluated from leaks to surface in the downstream toe area of the dam. None were evident during the inspection, nor was evidence found of past seepage.

It appears that the foundation is behaving as expected.

4.3 Slope Instability

4.3.1 Design Basis and Expected Behaviour

The stability of the dam was investigated in 1978 and at which time it was concluded that stability was clearly more than adequate. We concur with this view because of the dams width compared to its low height – even loose end dumped fill would be expected to be stable in the long term for this geometry. Further, the earthfill section is largely above pond level.

4.3.2 Performance Review

There are no slope movement monitoring records. The site inspection (Appendix B) found no sign of movement; the same result was found in the two prior inspections.

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 earthquake and was some fifty years old by 1978, it was likely adequate given the safety standards of the day.
The site ground motion for the appropriate earthquake risk is so strong (0.3g) 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. Settlement under the design earthquake motion needs to be formally computed; but, we would be surprised if it would exceed about 0.5 m for the earthfill section itself or the fill forming the downstream shell to the concrete section.

What is more problematic is the behaviour of the concrete wall itself. Our expectation is that the concrete wall might crack, but this would only lead to seepage through the earthfill section and no impoundment release. More uncertain is whether or not the concrete wall might topple forward into the reservoir. However, even under a toppling situation there is sufficient freeboard to the earthfill that outright dam failure does not seem a likely consequence.

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 Upper Chase Dam](image-url)
Upper Chase Dam Safety Review
March, 2004

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.

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 estimates as follows:

- 1978, Willis, Cunliffe & Tait : 49 m³/sec; and
- 2002, Water Management Consultants : 18 m³/sec

The difference between these two estimates is the capacity of the two culverts downstream of the spillway channel itself. We have checked the culvert capacity using the American Iron & Steel Institute Handbook for Steel Drainage Products and estimate a 20 m³/sec culvert capacity. At this flow level, there would be a 1.5 m head of water above the culvert and which corresponds to the dam crest elevation. Flow through the culvert would be inlet controlled and the culvert slope relied on by Willis, Cunliffe & Tait would be of no benefit. This is essentially the same conclusion as Water Management Consultants.

Comparing these estimates of spillway capacity to the hydrology discussed earlier indicates that the spillway likely does not have the capacity to pass the appropriate flood. At present the spillway has an effective capacity about equal to the fifty year return period storm. Whereas, the dam’s hazard rating indicates that at least a 1000 year event should be safely passed. The chief restriction is the culverts. However, even the spillway channel itself will only pass about 32 – 40 m³/sec at full pool (again there is a difference in the estimates between Willis, Cunliffe & Tait and Water Management Consultants). This is less than the appropriate design storm event that requires about a 60 m³/sec capacity.
4.5.2 Performance Review

The elevation of the surface of the water impounded in the reservoir has been monitored only since 2003, and are measured as depths over the spillway entrance. The results are shown on Figure 4.3. The dam crest elevation is also shown on the figure. Retained water levels were much below the dam crest.

![Figure 4.3: Measured water depths at spillway 2003](image)

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 foundation and that the engineers who directed construction endeavoured to ensure a good contact. The wall has only minor cracking, and in this situation, very little flow would be expected through the dam under the small retained head.

For the short earthfill section, there is normally minimal retained water at normal pond levels and hence no expected seepage.
4.6.2 Seepage Performance Review

There is no seepage monitoring weir nor any seepage collection system. Seepage can only be evaluated from leaks to surface in the downstream toe area of the dam. None were evident during the inspection, nor was evidence found of past seepage.

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

4.7 Internal Erosion in Embankment (Piping)

4.7.1 Design Basis and Expected Behaviour

The main part of the dam is a composite structure with a concrete wall providing the impervious barrier. This wall is continuous and with only minor cracking. The retained head is typically no more than about 2m. Seepage downstream of the wall should be minimal with low hydraulic gradients. Correspondingly, there is no expectation of any internal erosion even in the absence of filters in the downstream shell.

In the case of the earthfill part of the dam, there is little retained water under normal pond levels. The hydraulic gradients are small in the lower part of the dam, and no internal erosion would be expected even in the absence of filters.

4.7.2 Performance Review

For the concrete section of the dam, no evidence was seen of fines loss features either in the top of the dam fill (as sinkholes) or in erosion at the dam toe. See Appendix B.

Vegetation covered the earthfill section to the extent that it precluded inspection.

4.8 Rupture of Conduits

4.8.1 Design Basis and Expected Behaviour

The original offtake pipe passes through the core wall in an engineered junction. The pipe is steel and permanently underwater. As such, rupture of the pipe is unlikely either by corrosion or differential movements. If pipe rupture did occur, because the dam wall is thick concrete, only minor washout of the embankment and adjacent road might be expected.
4.8.2 Performance Review

There is no evidence in terms of concentrated seepage or surface expression that any rupture has formed in the offtake pipe or that the pipe has moved and allowed settlement.

5.0 SAFETY REVIEW

5.1 Dam Safety

5.1.1 Implementation of 1992 Recommendations

The 1992 DSR recommended ten actions. Of these, five have been implemented and which includes the important hydrological study that has been used as information for this DSR. Table 5.1 summarizes the situation.

Table 5.1: Comparison of 1992 DSR Recommendations with Action

<table>
<thead>
<tr>
<th>Recommendation</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install reservoir level staff gauge</td>
<td>Not carried out to date</td>
</tr>
<tr>
<td>Install log boom at spillway inlet</td>
<td>Not carried out to date</td>
</tr>
<tr>
<td>Fence of access to culvert inlets</td>
<td>Carried out, but low standard</td>
</tr>
<tr>
<td>Remove vegetation and reconstruct embankment</td>
<td>Not carried out to date</td>
</tr>
<tr>
<td>Remove trees leaning over reservoir</td>
<td>Completed</td>
</tr>
<tr>
<td>Remove dead trees from reservoir</td>
<td>Completed</td>
</tr>
<tr>
<td>Core concrete wall to determine depth of deterioration</td>
<td>Not carried out to date</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>
<tr>
<td>Research archives to determine history and construction information</td>
<td>Done for this DSR.</td>
</tr>
</tbody>
</table>

5.1.2 Results of July 2003 Site Inspection

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

- No indications of slope instability and/or crest settlement were found;
- No zones of concentrated seepage or other indications of internal erosion/piping were found; and
- The spillway was clear, and in good condition.

Comparing what was found in this inspection with that reported in 1992 indicates that the dam is in much the same condition as it was then. The 1992 DSR reported somewhat extensive surface weathering and spalling of the exposed concrete. However, comparing the 1992 photographs with conditions during our inspection, the weathering does not appear to have accelerated. We place less emphasis than EBA on the concrete deterioration and do not concur with their recommendation to core the concrete wall – in our view, ongoing visual inspection is sufficient for dam safety at present.

On the other hand, the earthfill section is now well covered with small bushes and trees. For inspection to be effective the downstream slope requires regrading to an normal engineering finish and possibly a grass protection re-established. This will allow the Watershed Inspector to evaluate the dam condition on a walkover survey and without difficulty.

5.1.3 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 Upper 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 Upper 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 given in Section 2 above.

Because the standard safety review database was used, not all questions are relevant to Upper Chase dam. In these instances Not Applicable has been shown for the relevant issue in Appendix A.
No Actual Deficiencies were identified. Nine 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. Potential deficiencies largely relate to two issues: the changing standard of care which means that Upper 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 the spillway and to the desirability of establishing survey markers so that the lack of movement in the dam can be confirmed by measurements in future.

Table 5.2: Summary of Identified Deficiencies & Non-Compliances

<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>4</td>
</tr>
<tr>
<td>[Principles: 7.1, 7.2, 7.3, 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>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>1</td>
</tr>
<tr>
<td>[Principle: 8.9]</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>1</td>
</tr>
<tr>
<td>[Principle: 3.5]</td>
<td></td>
</tr>
<tr>
<td>Other Procedures</td>
<td>6</td>
</tr>
<tr>
<td>[Principles: 1.1, 1.2, 1.5, 4.1, 4.2, 4.3, 10.2]</td>
<td></td>
</tr>
</tbody>
</table>

5.2 Emergency Preparedness

The emergency preparedness plan (EPP) has been revised recently and is appropriate for the dam.
6.0 CONCLUSIONS & RECOMMENDATIONS

The Upper 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.

There are a total of nine Potential Deficiencies and Non-Conformances with regard to dam safety and which relate to “unlikely” situations. For storms, the spillway does not meet the standard of care expected twenty years ago, although this was not recognized in the two prior DSRs. The spillway is now substantially deficient with regard to current expectations for dam safety. For earthquakes, there may be a vulnerability to toppling of the concrete wall.

Part of the reasons for the findings in this DSR is that the dam is some seventy years old. The dam needs to be brought up to date from its current design of 1 in 50 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 1000 years return period storm. The exact design criteria needs to be agreed with the Water Comptroller, but may lead to about a tripling of the spillway capacity (it is actually the culverts beneath Nanaimo Lakes road that is the problem).

- The seismic resistance of the dam is probably adequate but needs formal documenting, in particular with attention to toppling. The extent of any upgrading would need to be defined by this study.

This dam safety review is submitted by Golder Associates Ltd.

M. Jefferies, P. Eng.  
Associate

H. Hawson, P. Eng.  
Principal
7.0 REFERENCES

City Document Reference

Library Dayton & Knight (1987); Data File: Upper Chase River Dam


Willis, Cunliffe & Tait (1979). Contact documents for Dam Rehabilitation Program, issued for Tender.

Golder Associates
APPENDIX A

DETAILED RESULTS OF DAM SAFETY REVIEW
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: NCi  Non-conformance: Information
Description: The drawing of the dam in the existing Data Book is incomplete, only comprising a plan. There are no detailed profiles of the dam and spillway. Details from the 1956-7 construction of an offtake pipe to Reservoir #1 are missing.

   The acceptance of responsibility for the dam by the Engineering Dept is clear, and individuals have been tasked.
Recommend: Update the drawings of the dam based on the 1955 as-constructed record (both drawings and photographs) supplemented by a new survey of the dam. Report this information as a 1-2 drawing set at reasonable scale, showing the dam as it exists and including the offtake works.

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. A LOW rating would be more consistent with downstream incremental risk from this dam, although the spillway should be rated to the same 3000-year return period standard as the downstream dams.

1.3 The dam safety management system shall include a process so that reported potential and actual deficiencies are followed up until resolution.
Type: NCp  Non-conformance: Other Procedures
Description: There is no formal documentation system operated by the District for resolution of potential and actual deficiencies. However, it is a small group of people and discussion with them revealed clear knowledge of how the District worked to resolve dam safety issues.
Recommend: Document the District's present informal system adopted by Engineering when revising the dam's Data Book.

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: NCi  Non-conformance: Information
Description: Files are maintained and were made available to the Inspection team. These included prior safety reviews. However, because the dam is an historic structure believed to be some seventy five years old, there are neither design reports nor construction records. Paper records of the dams performance and condition are kept.
Recommend: A "design" report should be developed. Part of this will require information from further studies (earthquake, spillway) and part will require the new drawing set recommended in 1.1.

   Documentation of the dam's condition could be usefully improved by adding digital pictures (taken from the same selected place on each inspection) to the monthly reports. The monthly reports should also include a plan of the dam so the location of observations can be easily and precisely noted.

1.5 All staff with responsibilities for dam safety activities shall be adequately qualified and trained.

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July 2003
Appendix A: Detailed Results of Dam Safety Review (Continued)

Type: NCp  Non-conformance: Other Procedures
Description: Training videos have been purchased, but there were no records within Engineering of who had received what training. Discussions with some personnel also indicated that training was incomplete.
Recommend: Update the training of Tenders.

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).

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: OMS 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.

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: Pu  Potential Deficiency: Expected to be deficient under unlikely loads
Description: The key operating requirement is that the spillway be kept debris free. At present this is done by Engineering requesting Parks & Recreation to clear logs. Based on discussions during the inspection, it is unclear that Parks & Recreation appreciate the possibly critical importance of such a request and would respond promptly.
Recommend: Establish procedures/budget authority for Engineering to issue an immediate task order to external contractors if required. Ensure that this authority is included in the dam's Data Book.

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: NCm  Non-conformance: Maintenance
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). The dam was found to be poorly maintained during the July 2003 site inspection, with much vegetation preventing a thorough inspection as required.
Recommend: An immediate (2003) maintenance campaign is needed to clear bushes on the embankment section.

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 Tender noting observations against a check list. These required observations have not been coordinated against potential failure modes.

**Recommend:** Upgrade the Tender's inspection check list, and add a drawing so that the location of observations can be indicated.

### 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:** NCm  
**Non-conformance:** Maintenance

**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. Because of the road crossing the spillway, this would be rather easy.

**Recommend:** Nothing recommended now, as the whole spillway needs upgrading. The upgraded spillway should be screened to prevent debris blocking it.

### 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:** NCp  
**Non-conformance:** Other Procedures

**Description:** The Data Book contains an emergency plan and updated contact people.

The distribution of the plan is very limited and in particular the "Dam Tender", who is the likely first responder, does not have a copy. Two of the three issued copies are in library files, which raises questions about out of hours access in an emergency.

**Recommend:** Widen the distribution of the revised Data Book to include the "Dam Tender", Supervisor, and responsible manager in Engineering.

#### 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:** NCp  
**Non-conformance:** Other Procedures

**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.

The EPP does not catalogue available resources and their location to the emergency responders with the exception of sandbags.

**Recommend:** Further actions to dewater the reservoir in an emergency (eg using a siphon) should be evaluated and added to the action list (this might be an essential rapid action after a large earthquake). Equipment available for emergencies need to be identified and this should include local contractors who could contribute to an emergency response. Estimate the effect of other concurrent emergencies on the viability of the action plan as may happen in a severe earthquake.

#### 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: NCp  Non-conformance: Other Procedures

Description: It is understood that no coordination meetings have taken place with other public agencies and nor has the District implemented any dry-run training simulations. Staff appear untrained in the range of possible emergency actions, relying solely on the text in the Data Book.

Recommend: It is understood that the City will implement a dry-run of a dam failure incident. Coordination meeting with other public agencies are required. Staff training is required.

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: Cnf  Conformance: Conforms

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, and the scale of the dam does not warrant further work.

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 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 with a tripping of the culvert capacity beneath the Nanaimo Lakes road.

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
Appendix A: Detailed Results of Dam Safety Review (Continued)

Description: The spillway was presently clear, but no log boom as been instlled to protect the spillway entrance.
Recommend: Do nothing now pending design of the upgraded spillway in the near future.

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 opacity.
Freeboard under earthquake induced dam movements is likely adequate.

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 deficiency will be resolved with upgrading of the spillway, see 7.1 and 7.2, and any earthquake related dam stability enhancement, see 8.5.

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

Type: Cnf Conformance: Conforms
Description: Ongoing maintenance by the Parks & Recreation department is keeping debris under control, and this appears to be a practical way of complying with the intent of this dam safety principle at Upper Chase given the small scale of the dam and pending revisions to the spillway.

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: Cnf Conformance: Conforms
Description: The embankment sections of the dam are stable, with no evidence of movements.

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: The retained head is so low (about 2m), and the seepage path relatively long, that internal erosion is not a threat to the dam even in the absence of engineered filters (and they are likely absent given the dam's age)

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: Cnf Conformance: Conforms
Description: There are no piezometers in the abutments or embankment with which to establish hydraulic gradients. However the retained head is so low that large gradients are
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.

Type: Cnf  Conformance: Conforms
Description: There are no signs of ongoing foundation settlements, consistent with the dam having been in place for some seventy five years. There is no apparent seepage consistent with excellent condition of the 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 embankment section is not well protected against erosion, and the vegetation prevented a thorough inspection. The fill behind the concrete section is protected in part by the roadway.
Recommend: See Recommendation 3.3. Some reconstruction of the embankment section may be needed.

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: Cnf  Conformance: Conforms
Description: It is unlikely that there are saturated and loose soils at either dam section.

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. The ability of the dam to withstand the estimated MDE is uncertain, the principal vulnerability being toppling of the concrete core wall. It is thought that such failure would result in accelerated erosion of the dam rather than a quick failure, but this need to be fully reviewed in a detailed study.
Recommend: Carry out a full seismic response assessment of the dam, with design of remedial works as required.

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 at three locations along the dam crest. 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: There spillway is subject to minimal hydraulic gradient and has a long seepage path. No localized seepage was evident.

No localized seepage or settlement was evident around the offtake pipe.

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: The concrete wall section in the dam is spalling, but does not appear to have deteriorated significantly since 1992. Such reduction in concrete section that has occurred is not a dam safety issue because of the massive size of the wall with respect to the retained head.

Need to further check the spillway when dry - it was obscured by flowing water during the inspection.

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. Supported by earthfill downstream shell.

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: Cnf
Conformance: Conforms

Description: See 9.1

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
Appendix A: Detailed Results of Dam Safety Review (Continued)

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: The spillway walls require checking for earthquake resistance; in our opinion they are likely adequate.
Recommend: Need to check overturning loads versus reinforcing bar spacing and capacity.

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. This scenario has not been addressed by the District.
Recommend: There is a low level outlet that could be readily used. This scenario should be evaluated in detail, and included in the EPP.

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 by the Parks & Recreation department as required.
APPENDIX B

DAM INSPECTION REPORT, JULY 2003
1 Introduction

Upper 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 after review the previous week of documentation about the dam that was provided by the City. The surrounding reservoir slopes were inaccessible and were only viewed from the dam crest.

The dam comprises a mass concrete wall further supported by earthfill downstream, see Figure 1. The dam is adjacent to Nanaimo Lakes Road. Photograph 1 shows a picture of the upstream side of the dam taken during the inspection; the upstream projections are buttresses that appear configured to resist the thrust from the roadway fill. On the left of the concrete dam is an earthfill dam that leads to the spillway in the left abutment, Photograph 2.

Photograph 3 shows a view of the spillway channel, which is concrete and leads to two culverts passing under the road and which are illustrated on Photograph 4. Figure 1 gives a sketch plan of the dam layout. Exit conditions for the culverts are shown on Photograph 5.
The dam is believed to be about seventy years old, but little is known of its history. No photographs have been found of the dam during its construction or in its early years. The dam is evidently an engineered structure from the carefully formed buttresses and care in the finishing of the concrete.

Upper Chase dam was brought into service as a water diversion structure about fifty years ago. Water Licence #22585 was issued to the Greater Nanaimo Water District in 1955 for construction of a pipe at the dam and noted that “construction shall be completed and the water beneficially used on or before 30 Dec 1957”. The Upper Chase dam is still used to divert water to the No 1 Reservoir that is just the other side of the road, when required.

The Upper Chase reservoir, although small, is stocked with fish and it is understood to be popular with anglers.

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 outflow from the reservoir at the time of the inspection. This is consistent with the time of year.

2.3 Reservoir

2.3.1 Level

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 3). The freeboard exceeded 2.5 m (see Photograph 1)
2.3.2 Debris

The reservoir was free of debris.

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. No substantive bank erosion was observed.

2.4 Discharges

There is no low-level discharge facility. Water not diverted to Reservoir #1 using the outlet pipe (see below) flows down the spillway. No controls are used on reservoir level, the spillway having neither gates or stop-logs. 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 Dam Condition

3.1 Concrete Section

The concrete wall was inspected. There are some shrinkage cracks evident, but these appear old. No evidence was seen of recent settlement cracks, with the wall being straight and with no indication of movement. Some weathering and spalling of the concrete is now evident (Photograph 6), but nothing substantive to the dam's function was observed. The concrete condition appeared unchanged from that reported in the 1992 DSR by EBA.

The concrete section is supported in the downstream side by earthfill and the Nanaimo Lake Road on that fill. The downstream slope is in effect a gentle slope over a few metres to the roadway, then the width of the roadway, then a further slope to original ground. Practically, these are such flat and wide slopes for the size of the dam that they have a large reserve of resistance. Unsurprisingly, there was no evidence of slope movements or other distress.
3.2 Earthworks Section

The southern section of the dam comprises a short earth embankment that links the concrete section to the spillway in the left abutment. This area could not be assessed close up because of the heavy vegetation there. However, nothing untoward was observed looking from the dam crest.

3.3 Seepage/Piping

No evidence of seepage and/or piping were seen. This is unsurprising given the dam’s geometry and size, and the low retained head of water (<2m).

4 Outlet Works

Outlet works comprise a discharge pipe set in the dam face about 1m below normal pool level (see Photograph 4). The pipe continues under the Nanaimo Lakes Road to Reservoir #1. Diversion of water is controlled by a valve set in the roadbase.

The entrance to the discharge pipe was underwater at the time of inspection and we were unable to investigate the conditions around the pipe in a walk-over survey. But there were no cracks on the dam crest to indicate any movement of the dam caused by or associated with the offtake pipe.

5 Spillway

5.1 Spillway Control

There are no gates or other devices to control spillway flow. Stop logs are also not used, and there is no provision for them.

5.2 Channel

The spillway comprises a rectangular concrete channel with a horizontal base, leading to a pair of culverts in a headwall. These culverts pass under the road and discharge into the Chase River.

The channel was clear of any substantive debris that would impede flow.
The spillway base was covered with shallow water during the inspection and this prevented direct inspection of cracks. However, no evidence of spillway settlement or concrete failure was observed in the channel sidewalls.

Similarly, the headwall where the spillway transitions to a twin-culvert structure was also in good condition (Photograph 4).

5.3 Energy Dissipation

The spillway is not provided with any energy dissipation structure, with flows being discharged into the Chase River with a free drop, shown on Photograph 5.

6 Instrumentation

The dam has no piezometers, movement gauges, settlement monitoring points, or weirs.
Figure 1: Schematic Plan of Upper Chase Dam
Photograph 1: View of concrete part of dam 24 July 03

Photograph 2: View of embankment section of dam (spillway entrance far left)
Photograph 3: View of spillway looking upstream from road

Photograph 4: Culvert entrance downstream of spillway channel
Photograph 5: Culvert discharge into channel
Photograph 6: View of offtake pipe below water surface. Note spalling of concrete.