Regional District of Okanagan-Similkameen

ISSUED FOR USE

DAM SAFETY REVIEW SUMMARY REPORT — NARAMATA DAMS

K13101459.001

December 21, 2010

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1.0 INTRODUCTION

1.1 GENERAL

EBA, A Tetra Tech Company (EBA) was engaged by the Regional District of Okanagan-Similkameen (RDOS) to undertake dam safety reviews of its four Naramata area dams, namely;

- Big Meadow Lake Dam
- Elinor Lake North (Saddle) Dam
- Elinor (Eleanor) Lake South Dam
- Naramata Lake Dam

The four dams form three interconnected reservoirs that have provided a historical upland source of potable water to the Township of Naramata. The dams were originally constructed during the first half of the twentieth century by the Naramata Irrigation District (NID), which has been subsequently incorporated into the RDOS. With the recent commissioning of a new water treatment facility in the township that draws water from Lake Okanagan, the dams are no longer required for the supply of potable water and the RDOS is considering maintaining these facilities for irrigation purposes only.

This report summarizes the key findings of the four technical reports, namely;

- Dam Safety Review - Big Meadow Lake Dam,
- Dam Safety Reviews for Elinor Lake North (Saddle) Dam and Elinor Lake South Dam,
- Dam Safety Review - Naramata Lake Dam, and
- Hydrotechnical Assessment of the Naramata Dams

The above reports present the results of the Dam Safety Reviews (DSR) of the four Naramata Dams.

The Dam Safety Review was undertaken in general accordance with the requirements of the British Columbia Water Act (1998), the British Columbia Ministry of Environment (BC MoE) Dam Safety Review Guidelines (May 2010), the Canadian Dam Association (CDA) Dam Safety Guidelines (2007), the Interim Consequence Classification Policy For Dams in British Columbia (February 2010) and the BC Dam Safety Regulation (February 2000). It is noted that the BC Regulations take precedence over the CDA Guidelines.

1.2 SITE DESCRIPTION

Big Meadow Lake Dam is situated within a bowl shaped feature near the headwaters of the Chute Creek catchment, approximately 13 km to the northeast of Naramata Township.

Reference to iMap on the BC MoE Water Stewardship website indicates that the dam is approximately 256 m long and 6.7 m high at its maximum height with a design crest elevation of 1613.9 m above mean sea level. Vehicle access to the dam is provided via Arawana Road, which extends off North Naramata Road to the southwest.

A diversion structure is situated downstream of Big Meadow Lake Dam, which can divert flow from Chute Creek into the downstream Elinor Lake reservoir.

The Elinor Lake North and South Dams are situated in a north to south trending valley situated approximately 9.2 km and 8.4 km respectively to the northeast of Naramata Township.

Reference to iMap indicates that the Elinor Lake North Dam is approximately 77.7 m long and approximately 6 m high at its maximum height. It is assumed that it has a crest elevation the same as the Elinor Lake South Dam, while the Elinor Lake South Dam is approximately 83.8 m long and 5.8 m high at its maximum height with a crest elevation of 1278.0 m. Flows from the Elinor Lake Reservoir discharge via a low level conduit through Elinor Lake South Dam into Robinson Creek which in turn discharges into the adjacent Naramata Lake Dam Reservoir. Vehicle access to the dams is provided via Elinor Lake Forestry Service Road, which extends off of Chute Lake Road to the north which in turn extends off of North Naramata Road to the west.

The Naramata Lake Dam is situated in the same north to south trending valley as the Elinor Lake Dams approximately 7.5 km to the northeast of Naramata Township.

Flows from the upstream Elinor Lake discharge into the adjacent Naramata Lake. Naramata Lake is formed by a dam, which iMap indicates is approximately 116 m long and 9.1 m high at it's maximum height and has a crest elevation of 1273 m. Vehicle access to the Naramata Lake Dam is provided via Elinor Lake Forestry Service Road, which extends off of Chute Lake Road to the north which in turn extends off of North Naramata Road to the west.

A location plan showing the position of the dams relative to the other Naramata dams and Lake Okanagan is attached as Figure 1.

2.0 SCOPE OF WORK

2.1 GENERAL

EBA's scope of work for the Dam Safety Review was outlined in our proposal, dated June 30, 2010, which was accepted by the RDOS. In summary, the study included the following tasks:

- Background review;
- Site reconnaissance;
- Review of consequence classification;
- A failures mode assessment;
- Geotechnical assessment, including embankment seepage, static and seismic stability, piping failure and liquefaction potential;
- Hydrotechnical analysis including hydrological analysis, flood routing and hydraulics;
- Review of Operation, Maintenance and Surveillance Manual;

- Review of Emergency Preparedness Plan;
- Review of any public safety management strategies;
- Assessment of compliance with previous reviews;
- Assessment of compliance with CDA Principles; and
- Development of conclusions and recommendations.

2.2 BACKGROUND REVIEW

The following sources of background information were reviewed prior to the site reconnaissance:

- Historic air photos;
- Readily available published sources of geological data;
- RDOS files and discussions with RDOS staff familiar with the site; and
- British Columbia Ministry of the Environment (BC MoE) Dam Safety Branch files;

The search of BC MoE files was undertaken by RDOS and provided to EBA; therefore this has been considered one combined source of information. We understand that this search may have only been of information held at MoE files in Penticton and didn't include a search of MoE files in Victoria, which we understand to be a very good archive of dam information for all of British Columbia.

2.3 SITE RECONNAISSANCE

A site reconnaissance of the four Naramata Dams was conducted by EBA on September 16, 2010. EBA's site representatives were Dr. Adrian Chantler, Ph.D., P.Eng., Mr. Bob Patrick, P.Eng and Mr. Michael J. Laws. They were accompanied by Mr. Alfred E. Hartviksen, P.Eng. and Mr. David Carlson of RDOS.

EBA inspected the crest, upstream slope, downstream slope, downstream toe area and spillway structure of each dam. Photos showing the condition of the four Naramata Dams at the time of the site reconnaissance are appendices to the DSR technical reports along with the observations made during this inspection.

2.4 CONSEQUENCE CLASSIFICATION REVIEW

The Dam Safety Guidelines published by the Canadian Dam Association (CDA Guidelines, 2007) and the Interim Consequence Classification Policy For Dams in British Columbia (February 2010) were reviewed to confirm the current BC MoE consequence classification of High for the four Naramata Dams as found on the BC MoE Water Stewardship website.

2.5 FAILURE MODE ASSESSMENT

The following common modes of failure for earthfill dams was considered with respect to each of the four Naramata dams:

- Embankment overtopping, occurs when the spillway either has insufficient capacity to discharge flood flows, either due to inadequate size or blockage with debris. Embankment overtopping is addressed in the hydrotechnical assessment.
- Piping is the progressive internal erosion of dam fill or foundation materials along preferential seepage paths. The seepage starts to erode finer soil particles at the toe of a dam or at an interface between dissimilar materials that are not compatible from a filtering perspective (such as a silty clay core adjacent to a coarse rock fill shell). With time and continued seepage erosion, "pipes" or voids will be created within the dam that grow in an upstream direction towards the reservoir with acceleration of seepage and rate of erosion. Eventually, collapse of overlying fill, breach of the dam and subsequent uncontrolled discharge of the reservoir will occur. Piping is discussed in the geotechnical assessment.
- Slope instability, gravitational and seepage forces can cause instability in earth dams when they exceed the available shear strength of the soil. Slope stability of the dam is discussed in the geotechnical assessment.
- Other causes of dam failure considered included slope instability due to earthquake forces and liquefaction.

2.6 GEOTECHNICAL ASSESSMENT

The scope of work for the Naramata Dams Safety Review in EBA's proposal did not include a detailed intrusive geotechnical assessment (e.g. drilling, sampling, testing, etc.) to confirm the nature of the existing embankment materials. The geotechnical assessment is based on observations during the site reconnaissance, available data on the existing dam, published geological data, published geotechnical and EBA's engineering judgement and, therefore, is considered to be preliminary in nature. The objective of this approach is to identify potential geotechnical issues so that any detailed geotechnical assessment can be tailored to the particular issue.

The following subjects are covered in the geotechnical assessment;

- Embankment Seepage;
- Embankment Stability;
- Liquefaction; and
- Potential for Piping.

2.7 HYDROTECHNICAL ASSESSMENT

The hydrotechnical assessment included a regional flood frequency assessment to determine the appropriate Inflow Design Flood (IDF), a hydraulic analysis to assess the capacities of the dams to pass the IDF and some additional comments on the downstream effect of decommissioned dams on the Robinson Creek watershed.

2.8 DAM SAFETY MANAGEMENT

EBA undertook a review of RDOS Dam Safety Management documentation and practices with respect to the four Naramata Dams in accordance with the general five components (CDA Guidelines, 2007) of dam safety management, namely:

- Owner commitment to safety;
- Regular inspections and Dam Safety Reviews with proper documentation and follow up;
- Implementation of effective Operations, Maintenance and Surveillance (OMS) practices;
- Preparation of effective Emergency Preparedness Plans; and,
- Management of Public Safety.

3.0 CONCLUSIONS AND RECOMMENDATION

Based on the results of the investigation, analysis and assessments of the four Naramata dams a series of conclusions and recommendations were developed during the Dam Safety Review for each facility as summarized on the attached Tables 1 to 4 in Appendix A.

A priority (high, medium or low) is given in brackets for each recommendation.

4.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of the Regional District of Okanagan-Similkameen and their agents. EBA does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than the Regional District of Okanagan-Similkameen, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the Terms and Conditions stated in EBA's Services Agreement and in the General Conditions provided in Appendix B of this report.

5.0 CLOSURE

EBA trust this report meets your present requirement. Do not hesitate to contact any of the undersigned should there be any questions or comments.

EBA Engineering Consultants Ltd.

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Dec 21, 2010

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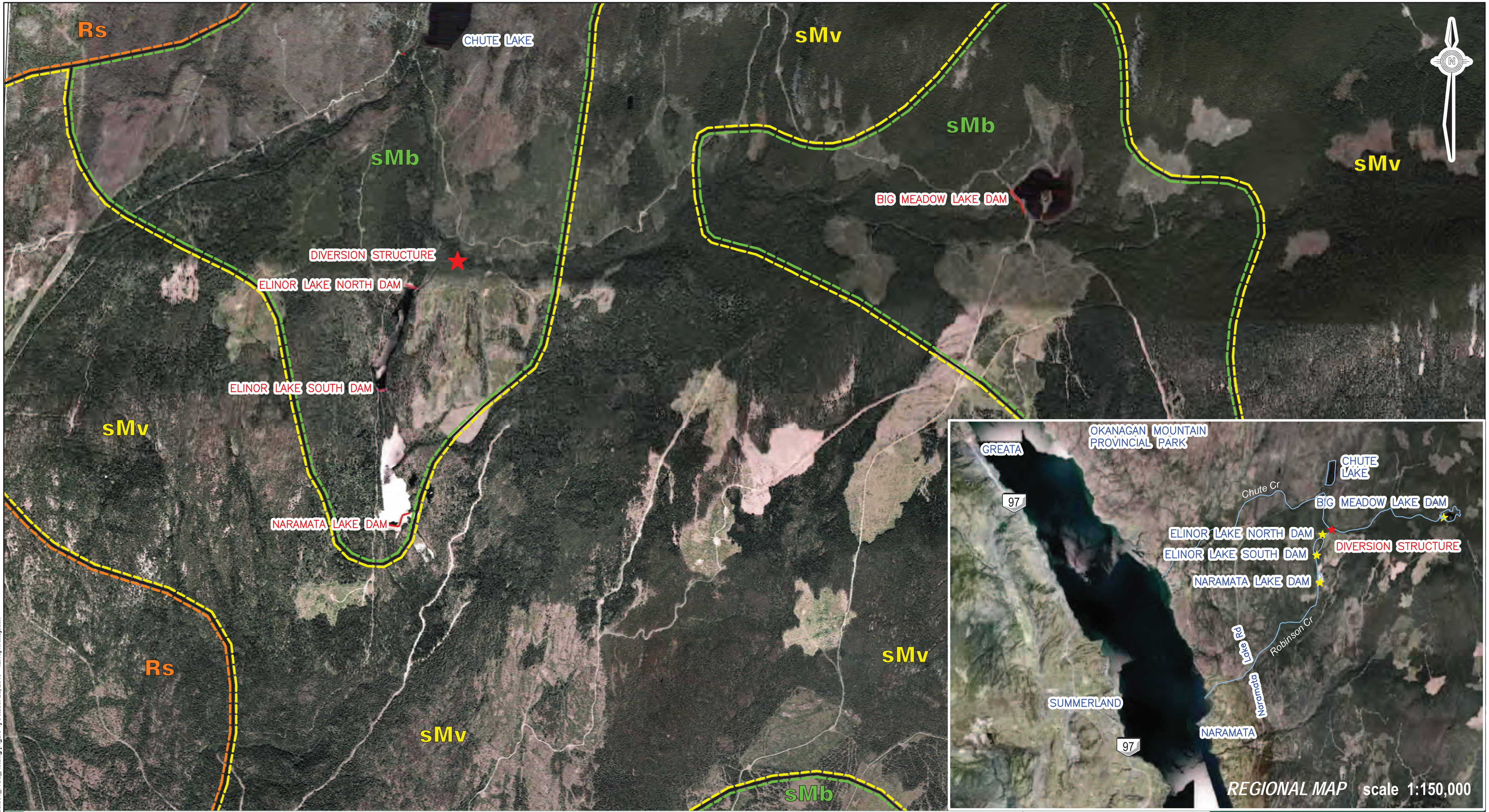
FIGURES



NOTES

Image from Google Earth Pro
Imagery Dates March 4, 2004 - September 26, 2005
Surficial Geology from GEOLOGICAL SURVEY OF CANADA (1984)
Surficial Geology (1984)
Map Kootenay Lake

SCALE 1:30,000

200 0 200 600m 1.2km

SURFICIAL GEOLOGY

Rs , ROCK: Crystalline metamorphic, acidic igneous, quartzite, argillite, marble, greenstone, phyllite, greywacke, limestone, dolomite and sandstone. Areas mapped as rock consist dominantly of rock at the surface but include minor areas of rock covered by a veneer of colluvium and till. Rs: Rock characterized by steep slopes or exposed by modern stream.

sMb ,**sMv**, SANDY TILL: Olive grey, grey and pale grey, weakly calcareous to non-calcareous loamy sand, sandy loam and loam. Generally gravelly, cobbly or bouldery. Mainly massive but locally contains lenses of stratified sediments. Clast lithologies reflect local bedrock which is chiefly crystalline metamorphic and granitic in character. Locally includes unmapped areas of alluvial, glaciofluvial and glaciolacustrine deposits and areas of rock. Locally in valley bottoms till may be as thick as 30 m but generally it is no more than 5 m thick. Occurs as a blanket with surface relief due to the general shape of the underlying surface or deposit; sMb: thickness up to 5 m; sMv: thin and discontinuous with thickness up to 2 m.

CLIENT

REGIONAL DISTRICT RDOS OKANAGAN-SIMILKAMEEN

NARAMATA DAMS SAFETY REVIEW

LOCATION PLAN & SURFICIAL GEOLOGY

EBA Engineering Consultants Ltd.

PROJECT NO.	DWN	CKD	REV
K13101459.001	LM	MJL	0
OFFICE	DATE		
EBA-KELOWNA	October 22, 2010		

Figure 1

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APPENDIX A

APPENDIX A DAM SAFETY REVIEW CONCLUSIONS AND RECOMMENDATIONS

TABLE 1: BIG MEADOW LAKE DAM — SAFETY REVIEW CONCLUSIONS AND RECOMMENDATIONS

Task	Conclusions	Recommendations
Background Review	• There is no site specific subsurface information available for EBA's review. • There is no design information and limited as-built construction documentation. It is probable that the dam was initially constructed in 1933, with major upgrades to the dam completed in 1952. • The dam was designed as a homogenous earthfill dam with a central concrete core wall. • Historical seepage has been observed at the downstream toe of the embankment and has generally been reported as clear; however, the volume of flow has not been quantified.	• RDOS should continue to look for background information on the design and construction of the Big Meadow Lake Dam such as, but not limited to, design reports and construction records including quality control testing results. This should not only include a search of RDOS archives but also BC MoE archives in Victoria (Low).
Site Reconnaissance	• Clear seepage was observed along left hand side of spillway structure on the downstream face. • Clear seepage was observed along right hand side of low level outlet structure on the downstream face. • Woody debris had accumulated in weir downstream of low level outlet structure. • Minor rutting from vehicle movement was noted along the dam crest. • Some loss of freeboard of the embankment was noted at the left abutment most likely due to the construction of the temporary access road during the Okanagan Mountain Park fire. • Erosion and rutting was observed on downstream face above the low level outlet structure from ATV or Skidoo traffic. • Some scrubby vegetation is growing on left hand side of downstream face. • Noticeable clear seepage was observed from the LHS and RHS toe drains (Big-O pipe) into low level outlet channel. • Erosion, over steepening of upstream face of the dam embankment and woody debris accumulation was noted adjacent to the right abutment. • The reservoir side slopes appear stable.	• The area of upstream erosion of the embankment and woody debris accumulation adjacent to the left abutment should be cleaned out and protected with rip-rap (High). • The woody debris should be cleared out of the weir downstream of the low level outlet structure (High). • The scrubby vegetation on the right half of the downstream face of the dam should be cleared (Medium). • RDOS should commission a topographical survey of the dam to confirm that it has sufficient freeboard and that it has maintained its design slopes. At the same time all dam features e.g. spillway structure, locations of seepage etc should also be picked up. The survey could be used to prepare an updated plan of the dam to be incorporated in an OMS manual. Should the survey indicate that there has been a loss of freeboard this will require reinstatement (High).
Consequence Classification	• The Big Meadow Lake Dam is classified as a High Consequence Dam according to CDA Guidelines and High-Low according got BC MoE classification guidelines.	• There are no recommendations from this area of review.
Failure Mode Assessment	• The plausible failure modes for the dam are overtopping, piping through the embankment and foundation, downstream slope instability and soil liquefaction of the upstream slope.	• There are no recommendations from this area of review.
Geotechnical Assessment	• In general, the seepage flow field patterns determined by the steady state seepage analysis assuming a cracked core concur with the historical observations of seepage at the embankment toe. • The results of the preliminary stability analysis indicate that the downstream toe of the dam is marginal stable when subjected to excess seepage or the design seismic event. • The magnitude of potential vertical settlements estimated as a result of soil liquefaction for the design earthquake event is well within the available freeboard for the dam. • Given the depositional nature (e.g. glacial) of the dam foundation there is considered to be no risk of the dam foundation undergoing liquefaction during the design seismic event. • The post seismic residual shear strength stability analysis resulted in a factor of safety just above unity suggesting that the dam is likely to undergo some lateral deformation as a result of the design earthquake, assuming the saturated sands and gravels in the dam's shell are susceptible to liquefaction. • A probabilistic piping risk assessment was conducted using a published method. A probability of piping failure developing of 1.91 x 10-4 was calculated. • Currently seepage monitoring at the dam has been poorly documented. An improved monitoring program where seepage monitoring is well documented would result in a reduction of the probability of piping failure developing by 20% for the dam. • There has been a well documented history of toe seepage at the dam. The construction of a toe berm incorporating a filter and drainage system at the dam or segments of the dam where the seepage has occurred, would likely result in a 40% reduction of the values of the estimated probability of piping failure develop for the dam.	• An intrusive geotechnical investigation and topographical survey of the dam is required to more accurately quantify the liquefaction potential, static stability and seismic stability of the embankment, which is currently not considered within CDA criteria based on the results of the preliminary stability assessment. Should unacceptable factors of safety be obtain following this work it is envisioned that the construction of a toe berm will be required to improve dam stability (High). • Construction of a toe berm incorporating a filter and drainage system at the dam or segment of dam where the seepage has historically occurred should be evaluated (Medium). • An improved seepage monitoring program should be implemented which in conjunction with the construction of a toe berm incorporating a filter and drainage system would reduce the probability of piping failure occurring to within the "ALARP" zone (High).

TABLE 1: BIG MEADOW LAKE DAM — SAFETY REVIEW CONCLUSIONS AND RECOMMENDATIONS

Task	Conclusions	Recommendations
Hydrotechnical Assessment	• Analysis indicates that existing dam is able to pass the IDF with an available freeboard of 1.22 m, which is greater than the minimum requirement of 1.0 m.	• If stop logs are to be utilized, the design flood calculations should be revised. It is recommended that stop logs are not in place during the spring freshet (High).
Dam Safety Management	• A OMS manual needs to be prepared for this facility. • The EPP should be modified to include additional information to ensure that it is reflective of the current state of practice for dam safety management. • The only dam safety security issue appears to be vandalism to the dam downstream face and crest from recreational vehicle traffic. • The potential for piping failure causing loss of life is currently in the unacceptable zone of the ALARP chart suggested by CDA Guidelines. • EBA cannot advise RDOS on what their corporate tolerances are for risk of loss of life. This also applies to the citizens of Naramata and all other stakeholders. • No instrumentation is installed in the dam. • Improving the inspection documentation to include quantify seepage rates and include comments on clarity of seepage would decrease the probability of piping failure.	• A OMS manual needs to be prepared for this facility (High). • The EPP needs updating to conform to current dam safety expectation (Medium). • There is no instrumentation installed to monitor the performance of the dam. As a minimum one piezometer should be installed in the downstream slope and instrumentation installed or a procedure developed to quantify the volume of toe seepage. In-situ testing, sampling, laboratory testing and a formal borehole log should be prepared of the piezometer installed at the dam to provided "as-built" information on the dam and assist in an future engineering assessment (Medium). • RDOS should undertake a review of dam security and implement improvements (Medium).

TABLE 2: ELINOR LAKE NORTH (SADDLE) DAM — SAFETY REVIEW CONCLUSIONS AND RECOMMENDATIONS

Task	Conclusions	Recommendations
Background Review	• There was no site specific subsurface information made available for EBA's review. • There is no design information or as-built construction documentation. The dam was initially constructed in 1946. • There was no indication of water flow at the toe; however, the reservoir was significantly drawn down at the time of inspection and the downstream toe was wet that would suggest seepage occurs. • No recorded historical seepage has been observed at the downstream toe of the embankment, however the downstream toe was wet at the time of the site inspection and, as toe seepage has been reported at the South Dam, it is assumed that it toe seepage is also occurring at the north dam.	• RDOS should continue to look for background information on the design and construction of the Elinor Lake North (Saddle) Dam such as, but not limited to, design reports and construction records including quality control testing results. A particular focus of the search should be to confirm whether there is a low permeability core in the embankment and the geotechnical characteristics of the core material as this has a significance influence on the probability of piping occurring. This should not only include a search of RDOS archives but also BC MoE archives in Victoria (Medium). • Should the records search yield not confirm the presence of a low permeability core or its geotechnical characteristics we would recommend undertaking a field investigation to verify the presence of the a low permeability and its geotechnical characteristics. It is anticipated that at a minimum this would comprise a combination of shallow test pits carefully excavated to expose the top of the core and permit sampling, and a seismic profile of the embankment dam to determine material variability through the embankment. The shear velocities recorded from the seismic profiling could also be used to update any future seismic analyses of the dam (Medium).
Site Reconnaissance	• Rock outcropping was noted adjacent to the right abutment. • Minor rutting from vehicle movement was noted along the crest. • Erosion and heavy rutting was noted on the downstream face from vehicle traffic. • Signs of small burrowing animal activity were noted along the embankment toe. • No indication of toe seepage was noted during the , however the reservoir was significantly drawdown at the time of inspection. • Some scrubby vegetation is growing on the left-hand side of downstream face.	• RDOS should commission a topographical survey of the dam to confirm that it has the sufficient freeboard and it has maintained its design slopes. At the same time, all dam features i.e. spillway structure, locations of seepage etc should also be picked up. The survey could be used to prepare an updated plan of the dam to be incorporated in a OMS manual. Should the survey indicate that there has been a loss of freeboard this will require reinstatement (Medium).
Consequence Classification	• The Elinor Lake North (Saddle) dam is classified as a High Consequence Dam according to CDA Guidelines and High-Low according got BC MoE classification guidelines.	• There are no recommendations from this area of review.
Failure Mode Assessment	• The plausible failure modes for the dam are overtopping, piping through the embankment and foundation, downstream slope instability and soil liquefaction of the upstream slope.	• There are no recommendations from this area of review.
Geotechnical Assessment	• Based on the results of the preliminary stability analysis of the Elinor Lake South Dam the downstream slope of the dam may just be with in the CDA minimum factors of safety criteria for seismic loading. • The magnitude of vertical settlements is estimated to be less than 400 mm as a result of soil liquefaction for the design earthquake event and is well within the available freeboard for the dam. • Given the depositional nature (i.e. glacial) of the dam, foundation there is considered to be no risk of the dam foundation undergoing liquefaction during the design seismic event. • A probabilistic piping risk assessment was conducted using a published method. A probability of piping failure developing of 3.37 x 10-4 was calculated. • There is no information available with respect to the characteristics of the low permeability core material for the Elinor Lake North Dam. In the probabilistic piping risk assessment it was assumed that the core comprise of a low plasticity silt material which is commonly found within the Till deposits in the Okanagan valley. Could it be demonstrated that the core material comprises a low plasticity clay this would result in a reduction of the estimated probability of piping failure to 1.86 x 10-4. If the cores comprise of a high plasticity clay this would result in an even further reduction. • Currently seepage monitoring at the dam has been poorly documented. An improved monitoring program where seepage monitoring is well documented would result in a reduction of the probability of piping failure developing by 20% for the dam. • It is assumed that toe seepage occurs at the dam. The construction of a toe berm incorporating a filter and drainage system at the dam or segment of dam where the seepage has occurred, would likely result in a two-fold reduction of the values of the estimated probability of piping failure develop for the dam.	• The stability of the embankment should be reviewed to confirm that it is within CDA criteria once the results of the piezometer borehole (as recommended below) and topographical survey of the dam are available. Should unacceptable factors of safety be obtained it is envisioned that the construction of a toe berm will be required to improve stability (Medium). • Once the presence and geotechnical characteristics of the low permeability core have been confirmed the probability of piping failure occurring should be reviewed (Medium). • Construction of a toe berm incorporating a filter and drainage system at the dam or segment of dam where the seepage has historically occurred should be evaluated (Medium). • An improved seepage monitoring program should be implemented (High).

TABLE 2: ELINOR LAKE NORTH (SADDLE) DAM — SAFETY REVIEW CONCLUSIONS AND RECOMMENDATIONS

Task	Conclusions	Recommendations
Hydrotechnical Assessment	• No design information was available for the Elinor Lake North Dam. The HEC-HMS modelling was based on the assumption that the dam does not overtop under design flood conditions. Overflows are discharged at the Elinor Lake South Dam.	• Dam design drawings should be obtained for the Elinor North Dam. If design drawings are not available then a topographical survey of the dam should be undertaken to determine the crest elevation. The dam crest should be compared with the maximum water level (1277.7 m) in the reservoir to ensure adequate freeboard (Medium).
Dam Safety Management	• A OMS manual needs to be prepared for this facility. • The EPP manual should be modified to include additional information to ensure that it is reflective of the current state of practice for dam safety management. • The only dam safety security issue appears to be vandalism to the dam downstream face and crest from vehicle traffic. • The potential for piping failure causing loss of life is currently in the unacceptable zone of the ALARP chart suggested by CDA Guidelines. • EBA cannot advise RDOS on what their corporate tolerances are for risk of loss of life. This also applies to the citizens of Naramata and all other stakeholders. • No dam safety instrumentation is installed in the dam. • Improving the inspection documentation to include quantify seepage rates and include comments on clarity of seepage would decrease the probability of piping failure.	• A OMS manual needs to be prepared for this facility (High). • The EPP needs updating to conform to current dam safety expectation (Medium). • There is no dam safety instrumentation installed to monitor the performance of the dam. As a minimum, one piezometer should be installed in the downstream slope and to quantify the volume of toe seepage. In-situ testing, sampling, laboratory testing and a formal borehole log should be prepared of the piezometer installation to provide "as built" information on the dam and assist in an future engineering assessment (Medium). • RDOS should undertake a review of dam security and implement improvements (Medium).

TABLE 3: ELINOR LAKE SOUTH DAM — SAFETY REVIEW CONCLUSIONS AND RECOMMENDATIONS

Task	Conclusions	Recommendations
Background Review	• There was no site specific subsurface information made available for EBA's review. • There was no design information and limited as-built construction documentation available. The dam was initially constructed in 1946, with upgrades completed to the dam in 1959. • The dam was designed as a homogenous earthfill dam with a central clay core. • Historical seepage has been observed at the downstream toe of the embankment and has generally been reported as clear; however it has not been quantified.	• RDOS should continue to look for background information on the design and construction of the Elinor Lake South Dam such as, but not limited to, design reports and construction records including quality control testing results. A particular focus of the search should be to confirm whether there is a low permeability core in the embankment and the geotechnical characteristics of the core material as this has a significance influence on the probability of piping occurring. This should not only include a search of RDOS archives but also BC MoE archives in Victoria (Medium). • Should the records search yield not confirm the geotechnical characteristics of the low permeability core we would recommend undertaking a field investigation to verify its geotechnical characteristics. It is anticipated that at a minimum this would comprise a combination of shallow test pits carefully excavated to expose the top of the low permeability core and permit sampling (Medium).
Site Reconnaissance	• No log boom was present at the spillway channel inlet. • The inlet to the outlet channel has been raised by silt deposition and is probably higher than the spillway weir sill. • Woody debris had accumulated in the spillway channel. • Vegetation was growing over spillway channel. • Signs of camping (fire pit and tin cans) were noted on the reservoir floor adjacent to right abutment of the downstream face. • Signs of animal activity were noted along the embankment toe. • No indication of previously observed toe seepage, no seepage flowing in toe drain (Big-O pipe), however the reservoir was significantly drawdown at the time of inspection.	• A log boom need's to be reinstated at the spillway channel inlet (High). • The silt that has accumulated in the spillway inlet channel should be removed. The inlet to the spillway channel should be at the same elevation as the spillway weir sill (High). • All woody debris that has accumulated in the spillway channel needs to be removed and any overhanging vegetation trimmed back (High). • RDOS should commission a topographical survey of the dam to confirm that it has the sufficient freeboard and it has maintained its design slopes. At the same time, all dam features i.e. spillway structure, locations of seepage etc should also be picked up. The survey could be used to prepare an updated plan of the dam to be incorporated in a OMS manual. Should the survey indicate that there has been a loss of freeboard this will require reinstatement (Medium).
Consequence Classification	• The Elinor Lake South Dam is classified as a High Consequence Dam according to CDA Guidelines and High-Low according got BC MoE classification guidelines.	• There are no recommendations from this area of review.
Failure Mode Assessment	• The plausible failure modes for the dam are overtopping, piping through the embankment and foundation, downstream slope instability and soil liquefaction of the upstream slope.	• There are no recommendations from this area of review.
Geotechnical Assessment	• The results of the preliminary stability analysis indicate that the downstream slope of the dam is just with in the CDA minimum factors of safety criteria for seismic loading. • The magnitude of vertical settlements is estimated to be less than 400 mm as a result of soil liquefaction for the design earthquake event and is well within the available freeboard for the dam. • Given the depositional nature (i.e. glacial) of the dam, foundation there is considered to be no risk of the dam foundation undergoing liquefaction during the design seismic event. • In general, the shape of the seepage, flow fields determined by the steady state seepage analysis concur with the historical observations of seepage at the embankment toe. • A probabilistic piping risk assessment was conducted using a published method. A probability of piping failure developing of 3.28 x 10-4 was calculated. • There is no information available with respect to the characteristics of the low permeability core material for the Elinor Lake South dam. In the probabilistic piping risk assessment it was assumed that the core comprise of a low plasticity silt material which is commonly found within the Till deposits in the Okanagan valley. Could it be demonstrated that the core material for the dam comprise a low plasticity clay this would result in a reduction of the estimated probability of piping failure to 1.83 x 10-4. If the cores comprise of a high plasticity clay this would result in an even further reduction. • Currently seepage monitoring at the dam has been poorly documented. An improved monitoring program where seepage monitoring is well documented would result in a reduction of the probability of piping failure developing by one 20% for the dam. • There has been a well documented history of toe seepage at the dam. The construction of a toe berm incorporating a filter and drainage system at the dam or segment of dam where the seepage has occurred, would likely result in a two-fold reduction of the values of the estimated probability of piping failure develop for the dam.	• Once the results of the piezometer borehole (as recommended below) and topographical survey of the dam are available, the stability of the embankment should be reviewed to confirm that it is within CDA criteria. Should unacceptable factors of safety be obtain it is envisioned that the construction of a toe berm will be required to improve stability (Medium). • Once the characteristics of the low permeability core have been confirmed the probability of piping failure occurring should be reviewed (Medium). • Construction of a toe berm incorporating a filter and drainage system at the dam or segment of dam where the seepage has historically occurred should be evaluated (Medium). • An improved seepage monitoring program should be implemented (High).

TABLE 3: ELINOR LAKE SOUTH DAM — SAFETY REVIEW CONCLUSIONS AND RECOMMENDATIONS

Task	Conclusions	Recommendations
Hydrotechnical Assessment	• Analysis indicates that the existing dam is able to pass the IDF with an available freeboard of 0.30 m, which is lower than the minimum requirement of 1.0 m. However, there are uncertainties with regard to the dam crest elevation. • If the diversion upstream of Elinor Lake is closed, the available freeboard was estimated to be 1.30 m, which is greater than the minimum requirement.	• There are uncertainties with respect to the dam crest elevation. It is recommended that the elevation of the Elinor Lake South Dam crest be surveyed (Medium). • If stop logs are to be utilized, the design flood calculations should be revised. It is recommended that stop logs are not in place during the spring freshet (High). • If the water levels in the Elinor Lake reservoir reaches the spillway crest elevation, the upstream diversion gates should be closed and to direct some or all flow to Chute Creek (High). • RDOS should commission a study of the diversion structure to determine whether it can be modified and/or the gates automated to divert flows down Chute Creek in the event of a significant flood (Medium).
Dam Safety Management	• A OMS manual needs to be prepared for this facility. • The EPP manual should be modified to include additional information to ensure that it is reflective of the current state of practice for dam safety management. • The only dam safety security issue appears to be vandalism to the dam downstream face and crest from vehicle traffic. • The potential for piping failure causing loss of life is currently in the unacceptable zone of the ALARP chart suggested by CDA Guidelines. • EBA cannot advise RDOS on what their corporate tolerances are for risk of loss of life. This also applies to the citizens of Naramata and all other stakeholders. • No dam safety instrumentation is installed in the dam. • Improving the inspection documentation to include quantify seepage rates and include comments on clarity of seepage would decrease the probability of piping failure.	• A OMS manual needs to be prepared for this facility (High). • The EPP needs updating to conform to current dam safety expectation (Medium). • There is no dam safety instrumentation installed to monitor the performance of the dam. As a minimum one piezometer should be installed in the downstream slope and instrumentation installed or a procedure developed to quantify the volume of toe seepage. In-situ testing, sampling, laboratory testing and a formal borehole log should be prepared of the piezometer installed at the dam to provided "as-built" information on the dam and assist in an future engineering assessment (Medium). • RDOS should undertake a review of dam security and implement improvements (Medium).

TABLE 4: NARAMATA LAKE DAM — SAFETY REVIEW CONCLUSIONS AND RECOMMENDATIONS

Task	Conclusions	Recommendations
Background Review	• There was very limited site specific subsurface information available for EBA's review. • There is limited design information and as-built construction documentation. The dam was originally constructed in 1912, raised in 1937 and again in 1967. • The dam was designed as originally as homogenous earthfill dam, however was upgraded to a zoned earthfill dam. • A seepage problem in the form of a boil at the toe of the embankment adjacent to the left abutment resulted in improvements to drainage and flattening of the downstream slope in this area.	• RDOS should continue to look for background information on the design and construction of the Naramata Lake Dam such as, but not limited to, design reports and construction records including quality control testing results. A particular focus of the search should be to confirm the geotechnical characteristics of the embankment fill materials as this has a significance influence on the probability of piping occurring This should not only include a search of RDOS archives but also BC MoE archives in Victoria (Medium). • Should the records search yield confirm the geotechnical characteristics of the shell/core, we would recommend undertaking a field investigation to verify its geotechnical characteristics. It is anticipated that, at a minimum, this would comprise a combination of shallow test pits carefully excavated to expose the top of the shell/core and permit sampling (Medium).
Site Reconnaissance	• Vegetation is growing in and over the spillway channel. • The inlet to the outlet channel has been raised by silt, sand and gravel deposited by vehicle traffic along the dam crest. • Minor rutting from vehicle movement was noted along the dam crest. • A loss of freeboard was observed near the centre of the dam crest due to ATV traffic. • Some silt blockage was observed in toe drainage adjacent to the left abutment, however was flowing clear. • The piezometer installed in the downstream slope adjacent to the left abutment was damaged (bent) due to vehicle traffic. • Heavy rutting from ATV traffic was noted on left-hand side of downstream face. • Some scrubby vegetation is growing on right-hand side of downstream face.	• The silt, sand and gravel that have accumulated in the spillway inlet channel due to vehicle traffic should be removed. The inlet to the spillway channel should be at the same elevation as the spillway weir sill (High). • All significant vegetation growing in the spillway channel needs to be removed and any overhanging vegetation trimmed back (High). • RDOS should commission a topographical survey of the dam to confirm that it has the sufficient freeboard and it has maintained its design slopes. At the same time all dam features i.e. spillway structure, locations of seepage etc should also be picked up. The survey could be used to prepare an updated plan of the dam to be incorporated in an revised OMS manual. Should the survey indicate that there has been a loss of freeboard this will require reinstatement (Medium).
Consequence Classification	• The Naramata Lake dam is classified as a High Consequence Dam according to CDA Guidelines and High-Low according got BC MoE classification guidelines.	• There are no recommendations from this area of review.
Failure Mode Assessment	• The plausible failure modes for the dam are overtopping, and piping through the embankment and foundation.	• There are no recommendations from this area of review.
Geotechnical Assessment	• The results of the preliminary stability analysis indicate that the upstream and downstream slopes of the dam meet the CDA minimum factors of safety criteria for all loading combinations under static and seismic loading. • The upstream slope of the Naramata Lake Dam is constructed from low permeability glacial till and therefore the probability of deformation occurring to the embankment during the design seismic event is considered to be extremely low. • Given the depositional nature (i.e. glacial) of the dam foundation there is considered to be no risk of the dam foundation undergoing liquefaction during the design seismic event. • In general the seepage flow fields determined by the steady state seepage analysis concur with the historical observations of seepage at the embankment toe. • A probabilistic piping risk assessment was conducted using a published method. A probability of piping failure developing of 1.11 x 10-4 was calculated. • There is no information available with respect to the characteristics of the low permeability core material for the Naramata Lake dam. In the probabilistic piping risk assessment it was assumed that the upstream shell/core comprise of a low plasticity silt material which is commonly found within the Till deposits in the Okanagan valley. Could it be demonstrated that the core material for the dam comprise a low plasticity clay this would result in a reduction of the estimated probability of piping failure to 0.98 x 10-4. If the cores comprise of a high plasticity clay this would result in an even further reduction. • Currently seepage monitoring at the dam has been poorly documented. An improved monitoring program where seepage monitoring is well documented would result in a reduction of the probability of piping failure developing by 20% for the dam.	• Once the geotechnical characteristics of the shell/core have been confirmed the probability of piping failure occurring should be reviewed (Medium).

TABLE 4: NARAMATA LAKE DAM — SAFETY REVIEW CONCLUSIONS AND RECOMMENDATIONS

Task	Conclusions	Recommendations
Hydrotechnical Assessment	• Analysis indicates that the existing dam is able to pass the IDF with an available freeboard of 0.45 m, which is lower than the minimum requirement of 1.0 m. • If the diversion upstream of Elinor Lake is closed, the available freeboard was estimated to be 1.05 m, which is greater than the minimum requirement.	• If stop logs are to be utilized, the design flood calculations should be revised. It is recommended that stop logs are not in place during the spring freshet (High). • If the water levels in the Naramata Lake reservoir reaches the spillway crest elevation, the upstream diversion gates should be closed to direct some or all flow to Chute Creek (High). • RDOS should commission a study of the diversion structure to determine whether it can be modified and/or the gates automated to divert flows down Chute Creek in the event of a significant flood (Medium).
Dam Safety Management	• The OMS and EPP manuals should be modified to include additional information to ensure that it is reflective of the current state of practice for dam safety management. • The only dam safety security issue appears to be vandalism to the dam downstream face and crest from vehicle traffic. • The potential for piping failure causing loss of life is currently in the unacceptable zone of the ALARP chart suggested by CDA Guidelines. • EBA cannot advise RDOS on what their corporate tolerances are for risk of loss of life. This also applies to the citizens of Naramata and all other stakeholders. • The only dam safety instrumentation installed in the dam comprises of one piezometer. • Improving the inspection documentation to include quantify seepage rates and include comments on clarity of seepage would decrease the probability of piping failure.	• The OMS manual needs to be revised for this facility conform to current dam safety expectations (Medium). • The EPP needs updating to conform to current dam safety expectations (Medium). • There is currently only one piezometer installed in the dam to monitor the performance of the dam. Given the size of the dam we would recommend the installation of a minimum two additional piezometers in the downstream slope and instrumentation installed or a procedure developed to quantify the volume of toe seepage. In-situ testing, sampling, laboratory testing and a formal borehole log should be prepared of the piezometer installed at the dam to provided "as-built" information on the dam and assist in an future engineering assessment (Medium). • RDOS should undertake a review of dam security and implement improvements were necessary (Medium).

APPENDIX B

APPENDIX B GEOTECHNICAL REPORT — GENERAL CONDITIONS

GEOTECHNICAL REPORT – GENERAL CONDITIONS

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site, a specific development and a specific scope of work. It is not applicable to any other sites nor should it be relied upon for types of development other than that to which it refers. Any variation from the site or development would necessitate a supplementary geotechnical assessment.

This report and the recommendations contained in it are intended for the sole use of EBA's Client. EBA does not accept any responsibility for the accuracy of any of the data, the analyses or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than EBA's Client unless otherwise authorized in writing by EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 ALTERNATE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. EBA's instruments of professional service will be used only and exactly as submitted by EBA.

Electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

3.0 ENVIRONMENTAL AND REGULATORY ISSUES

Unless stipulated in the report, EBA has not been retained to investigate, address or consider and has not investigated, addressed or considered any environmental or regulatory issues associated with development on the subject site.

4.0 NATURE AND EXACTNESS OF SOIL AND ROCK DESCRIPTIONS

Classification and identification of soils and rocks are based upon commonly accepted systems and methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system or method prevail, they are specifically mentioned.

Classification and identification of geological units are judgmental in nature as to both type and condition. EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

Where subsurface conditions encountered during development are different from those described in this report, qualified geotechnical personnel should revisit the site and review recommendations in light of the actual conditions encountered.

5.0 LOGS OF TESTHOLES

The testhole logs are a compilation of conditions and classification of soils and rocks as obtained from field observations and laboratory testing of selected samples. Soil and rock zones have been interpreted. Change from one geological zone to the other, indicated on the logs as a distinct line, can be, in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil or rock zone transition elevations may require further investigation and review.

6.0 STRATIGRAPHIC AND GEOLOGICAL INFORMATION

The stratigraphic and geological information indicated on drawings contained in this report are inferred from logs of test holes and/or soil/rock exposures. Stratigraphy is known only at the locations of the test hole or exposure. Actual geology and stratigraphy between test holes and/or exposures may vary from that shown on these drawings. Natural variations in geological conditions are inherent and are a function of the historic environment. EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of more precise locations of geological units is necessary, additional investigation and review may be necessary.

7.0 SURFACE WATER AND GROUNDWATER CONDITIONS

Surface and groundwater conditions mentioned in this report are those observed at the times recorded in the report. These conditions vary with geological detail between observation sites; annual, seasonal and special meteorologic conditions; and with development activity. Interpretation of water conditions from observations and records is judgemental and constitutes an evaluation of circumstances as influenced by geology, meteorology and development activity. Deviations from these observations may occur during the course of development activities.

8.0 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geological materials to climatic elements (freeze/thaw, wet/dry) and/or mechanical disturbance which can cause severe deterioration. Unless otherwise specifically indicated in this report, the walls and floors of excavations must be protected from the elements, particularly moisture, desiccation, frost action and construction traffic.

9.0 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise specifically advised, support of ground and structures adjacent to the anticipated construction and preservation of adjacent ground and structures from the adverse impact of construction activity is required.

10.0 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and structural performance of adjacent buildings and other installations. The influence of all anticipated construction activities should be considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known.

11.0 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geological deposits, the judgmental nature of geotechnical engineering, as well as the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations may then serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein.

12.0 DRAINAGE SYSTEMS

Where temporary or permanent drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwise specified, it is a condition of this report that effective temporary and permanent drainage systems are required and that they must be considered in relation to project purpose and function.

13.0 BEARING CAPACITY

Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil or rock type and condition. Construction activity and environmental circumstances can materially change the condition of soil or rock. The elevation at which a soil or rock type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geological materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil and/or rock conditions assumed in this report in fact exist at the site.

14.0 SAMPLES

EBA will retain all soil and rock samples for 30 days after this report is issued. Further storage or transfer of samples can be made at the Client's expense upon written request, otherwise samples will be discarded.

15.0 INFORMATION PROVIDED TO EBA BY OTHERS

During the performance of the work and the preparation of the report, EBA may rely on information provided by persons other than the Client. While EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.