Department of Fisheries and Oceans

ISSUED FOR USE

2007 INSPECTION
FULTON DAM

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EXECUTIVE SUMMARY

EBA Engineering Consultants Ltd. (EBA) was requested by the Department of Fisheries and Oceans (DFO) to conduct the 10 year Dam Safety Review (DSR) of Fulton Dam. Fulton Dam is a concrete gravity dam approximately 12 m high that is used to supply water to the Fulton River Spawning Channel facility operated by DFO. The last DSR was conducted by UMA Engineering Ltd. (UMA) in 1997 with geotechnical input from EBA. Fulton Dam was classified as a High Consequence dam in the 1997 DSR. Fulton Dam was constructed in 1968.

Upon review of the UMA DSR report and after limited discussion with DFO, EBA was able to conclude that the majority of the recommendations made in the 1997 DSR report had not yet been followed. The general areas requiring further study were hydrotechnical, geotechnical, mechanical/gate revisions and dam safety management.

The site inspection was conducted on October 9 and 10, 2007. The EBA representatives mobilized to site were Mr. Scott Sylte, P.Eng. and Mr. Chris Gräpel, P.Eng. They were accompanied to site by Sam McNeil, Senior Engineering Technician with DFO. Mr. Dennis Merkly, Maintenance Supervisor of the Fulton River facility, also accompanied the inspection team during their time on site.

The site inspection included the dam, the low level outlet sluiceway, the Regulating Outlet structure, two concrete tunnel bulkheads accessed from Beaver Creek near the Beaver Creek valve house, the downstream portal of the eastern tunnel, and a section of the pipeline that crosses a landslide that was initiated during construction. The portions of the inspection that addressed tunnel issues will be presented in a separate report.

Aside from leakage observed through the low level outlet, all visible components of the dam and associated appurtenances were observed to be in good condition. EBA reviewed the 1997 DSR report and generally agreed with the methodology employed and findings of that DSR.

The geotechnical stability analysis conducted in 1997 was reviewed upon completion of the 2007 inspection and compared to the latest version of the Canadian Dam Association Guidelines (CDA Guidelines, 2007). The 1997 calculated factors of safety for the loading conditions recommended by the CDA were found to meet or exceed the corresponding minimum factors of safety. However, the geotechnical stability analysis requires refinement with regards to update flood and seismic events.

EBA confirmed that current Consequence Classification of the dam (High) was appropriate.

A hydrotechnical assessment was not conducted as part of the 2007 annual inspection. The hydrotechnical/hydrolic data should be updated with current data so that the flood routing analysis and geotechnical stability analyses can be updated/refined.

Dam safety management practices presented in the Operations, Maintenance and Surveillance Manual or the Emergency Preparedness/Response Plan were not reviewed as it understood they are out of date and not consistent with current operating practices at Fulton Dam. Additionally, Public Safety Management should be considered with regard to site operations. Several recommendations were made with regard to the current dam safety management practices at Fulton Dam.

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1.0 INTRODUCTION

1.1 GENERAL

EBA Engineering Consultants Ltd. (EBA) was requested by the Department of Fisheries and Oceans (DFO) to conduct the 10 year Dam Safety Review (DSR) of Fulton Dam. Fulton Dam is a concrete gravity dam approximately 12 m high that is used to supply water to the Fulton River Spawning Channel facility operated by DFO. The last DSR was conducted by UMA Engineering Ltd. (UMA) in 1997 with geotechnical input from EBA. Fulton Dam was classified as a High Consequence dam in the 1997 DSR. Fulton Dam was constructed in 1968.

A site location plan of the Fulton Spawning Channel facility is presented in Figure 1.

This report is subject to the General Terms and Conditions presented in Appendix A.

1.2 BACKGROUND INFORMATION FROM 1997 DAM SAFETY REVIEW

Upon review of the UMA DSR report and after limited discussion with DFO, EBA was able to conclude that the majority of the recommendations made in the 1997 DSR report had not yet been followed. The general studies/activities that need to be conducted as part of the recommendations of the 1997 DSR are presented as follows:

- Hydrotechnical study – Assess the Inflow Design Flood (IDF) for this dam according to the 2007 Canadian Dam Association - Dam Safety Guidelines (CDA Guidelines, 2007). This is required to assess the water levels associated with the IDF. Additionally, the assessment of the degree of inundation for various flood and failure scenarios needs to be conducted;
- Geotechnical study – Assess the stability of the dam during the IDF as well as during the Maximum Design Earthquake (MDE) and more accurately define the various geotechnical parameters used in these assessments. Additionally, a slope stability assessment of a section of slope along the pipeline that conveys water to the spawning channels was recommended;
- Mechanical/Gate revisions and maintenance – various elements of the gates and water flow control structures required maintenance in 1997; and
- Dam Safety Management – The Operations, Maintenance and Surveillance (OMS) Manual and the Emergency Preparedness Plan needed updating or significant revisions.

The reader is referred to Section 4.9 – Summary of Recommendations in the 1997 DSR report which is attached in Appendix B.

2.0 SCOPE OF WORK

The scope of work conducted by EBA was presented in our proposal letter dated July 13, 2007. In that proposal, EBA recommended a phased approach to the completion of a DSR beginning with a review of the geotechnical aspects of the Fulton Dam and associated appurtenances. At the time of preparation, EBA recommended a Dam Safety Audit (DSA). However, upon further review of the 1997 DSR report, it was recognized that since very little of the work recommended in 1997 had been completed, the DSA would basically repeat the deficiencies and non-conformances requiring additional work, in addition to any new deficiencies observed in 2007. As a result, EBA recommended that a geotechnical inspection be conducted to assess if there were any obvious indicators of an impending failure or deterioration of the dam or its foundation since 1997 and then assess the site with regard to planning a series of engineering studies to address the outstanding items from the 1997 DSR.

3.0 SITE DESCRIPTION

The Fulton River Spawning Channel is operated by DFO to supplement natural sockeye salmon spawning areas around Babine Lake. Two spawning channels are operated by DFO; both are located on the north side of the Fulton River valley. A site plan for the Fulton Lake facility is presented in Figure 2.

Spawning Channel No. 1 is located furthest upstream and is fed by river water. Spawning Channel No. 2 is located approximately 800 m downstream of Channel No. 1 and is fed by a pipeline from the reservoir.

The reservoir is impounded by a concrete gravity dam that is approximately 12 m high at the spillway section and 16.5 m at the non-overflow section on the left side of the dam. The right spillway wall has a maximum height of approximately 14 m above the base of the dam. Left and right are defined from the perspective of looking downstream. The dam is approximately 60 m long. The spillway section of the dam is located on the right side of the dam and is approximately 34 m wide. The spillway section of the dam is curved and has been constructed to Elevation 776.32 m (2547'). A plan and section drawing of Fulton Dam is presented in Figure 3.

A gate house is located on the left side of the dam which controls an upper gate and a lower gate. The inlets for both gates are protected by trash racks. The discharge from both gates passes through a rectangular low level portal that exits at the toe of the left abutment. The trash rack, gates and low level portal are illustrated in Figure 3.

The regulating intake structure for the pipeline that supplies water to Channel No. 2 is located approximately 200 m to the left (north) of the dam. The regulating intake structure is a three level gated concrete intake tower equipped with trash racks. The three levels of intake were designed to provide a varying temperature of water; however, it is understood this system was not used as it did not work. There is also a main gate that controls water flow into the tunnel as well as a smaller tunnel flooding gate that is used to fill the tunnel before the main gate is opened. The inlet channel and location of the regulating intake structure is presented on Figure 2. A plan and section of the regulating intake structure is presented in Figure 4.

Water flow is routed from the intake tower through a 3.7 m diameter, 150 m long tunnel to the Regulating Outlet Structure that is used to regulate river flow (and water supply to Channel No. 1) when the reservoir level is below spillway invert elevation. The Regulating Outlet Structure has three hollow cone discharge valves (two 2.1 m and one 0.76 m diameter valves). The Regulating Outlet is operated from the valve house located above the three hollow cone valves. A plan and section of the Regulating Outlet Structure is presented in Figure 5 and 6.

The 2.3 m diameter water supply tunnel and pipeline that supplies water to Spawning Channel No. 2 branches off the tunnel that leads to the Regulating Outlet Structure. The pipeline daylights at Beaver Creek where a valve house and two access portals are located. The pipeline daylights downstream of the valve house at a shaft access to the water supply tunnel known as the east portal. A landslide approximately 670 m downstream from the east portal occurred during construction, which resulted in construction of the pipeline on a trestle with sliding bearings with the capacity for the landslide and pipeline foundation to move without stressing the pipeline. The pipeline then passes down the north bank of the Fulton River valley, passes underneath the river in two locations and terminates at a terminal structure at the head of Spawning Channel No.2. Plans and profiles of the pipeline are presented in Figures 7 and 8.

4.0 SITE INSPECTION

4.1 GENERAL

The site inspection was conducted on October 9 and 10, 2007. The EBA representatives mobilized to site were Mr. Scott Sylte, P.Eng. and Mr. Chris Gräpel, P.Eng. They were accompanied to site by Sam McNeil, Senior Engineering Technician with DFO. Mr. Dennis Merkly, Maintenance Supervisor of the Fulton River facility, also accompanied the inspection team during their time on site.

The site inspection included the dam, the low level outlet sluiceway, the Regulating Outlet structure, two concrete tunnel bulkheads accessed from Beaver Creek near the Beaver Creek valve house, the downstream portal of the eastern tunnel, and a section of the pipeline that crosses a landslide that was initiated during construction. The portions of the inspection that addressed tunnel issues will be presented in a separate report.

4.2 DAM

The reservoir level at the time of inspection was just below crest elevation and was observed on the staff gauge on the side of the gate house to be 46.6’, which corresponds to a reservoir elevation of 2546.6’. The left crest of the dam is the walkway to the gate house from the left abutment. The concrete on the walking surface was in good condition. The concrete at the crest of the spillway section was viewed from the gate house window and appeared to be in good condition with some exposed aggregate areas, but no indication of significant or widespread concrete deterioration was observed. Photographs of the crest of the dam, downstream face and gatehouse taken from the crest of the dam or the left abutment are presented in Photos 1 through 9.

The downstream face of the dam and spillway was viewed from the downstream toe of the dam. Access to the downstream toe of the dam was achieved by walking down the left abutment with the assistance of a rope tied to the guardrail at the crest of the dam. The downstream face of the dam to the left of the gate house and on the spillway surface was in generally good condition. However, some minor weathering or deterioration of the concrete was observed at construction joints. These areas were not widespread and do not appear to be actively degrading. Some efflorescence and/or mineralization was observed at a vertical construction joint to the left of the gate house from approximately mid-height to the downstream toe. The downstream flip bucket/energy dissipation structure at the toe of the dam was in good condition with minimal areas where exposed aggregate was visible. The downstream toe of the dam was observed to be in contact with the bedrock.

The right abutment was viewed from the toe to near the crest by climbing up the natural ground (or talus that has built up over the face of the dam) along the slope of the dam. Although seepage was reported for this area in the 1997 Dam Safety Review report, the only possible visible signs of seepage were wet areas on the natural rock slope adjacent to the dam.

The channel downstream of the dam was generally horizontal for a distance of about 10 to 15 m beyond which there was a near vertical drop of about 10 m in height. The bedrock at the toe of the dam was very rough with asperities varying between 0.15 m to 0.5 m with inclinations of 20° to near vertical. The bedrock downstream of the dam was observed to be a very strong chert with chaotic discontinuity orientations. Discontinuities were observed to be dipping steeply upstream and downstream with a small number of sub-horizontal joints dipping in a generally downstream direction. The discontinuity surfaces were undulating and smooth; however, the smoothness of the exposed joints was most likely due to exposure to running water. The joints were generally tight and the persistence of the joints, including the sub-horizontal ones, varied from 0.2 to 1.0 m. The drop off beyond the toe of the dam appears to be due to a steeply dipping to near vertical shear zone approximately 10 to 15 m wide that extends up the valley slopes. This feature is most visible from the channel downstream of the drop off. EBA observed two other such features further downstream to a distance of about 100 m downstream of the dam.

The concrete structure at the flip bucket/energy dissipation structure is completely founded on the bedrock. Voids or erosion beneath the concrete were not observed.

Photographs of the downstream face of the dam, flip bucket/energy dissipation structure, right abutment area and the bedrock channel bottom downstream of the dam are presented in Photos 10 through 21.

The low level outlet was discharging water at a rate of approximately 7 gallons per second (approximately 0.03 m^3/s, based on visual estimate). It is understood that the flow was due to the seals on the gate being worn out as discussed in the 1997 DSR report. The gates and seals were not inspected by EBA. Discussions with DFO site staff indicate the lower gate was opened last about four years ago and the gate seal is damaged with a missing length of seal. It is understood that the gates have been leaking since approximately 1988. Site staff also report that, at high reservoir levels, one or both gates have insufficient weight to close once they have been opened.

The reservoir immediately upstream of the dam is confined to a long narrow channel that constitutes the pre-impoundment river valley. An arm of the reservoir upstream of the dam extends off to the left towards the penstock tunnel intake structure. There is a narrow spit of land with an elevation just above the reservoir level at the time of the inspection between the reservoir upstream of the dam and the reservoir upstream of the penstock tunnel intake structure. A photograph of the reservoir upstream of the intake structure is presented in Photo 23.

Lead line soundings of the reservoir depth at the upstream face of the dam to the left of the gate house and out the window of the gate house at the left flank of the overflow spillway indicated that a firm to hard bottom was present. Review of the recorded depths indicated that the elevation of the lead line was generally below the design heel elevation shown on the design drawings presented in the 1997 DSR report. These observations appear to indicate that significant sediment build up to the left of the overflow spillway are not present. The flow of water through the gate seals may be preventing any build up of sediment in the vicinity of the gate house. The depth of sediment upstream of the overflow spillway can not be inferred or estimated based on the lead line soundings conducted in October 2007.

4.3 REGULATING OUTLET STRUCTURE

The Regulating Outlet Structure was viewed during the dam inspection. In general, the concrete structure is in good condition and the valve operation house is neat and orderly. The smallest of the three outlets, the 30 inch (0.76 m) diameter outlet, at this facility was in operation. The two 84 inch (2.13 m) diameter outlets were covered. All three outlets consist of cone valves. Although the valve mechanisms were not observed during the inspection, site personnel indicated that the epoxy coating on the valves were overdue for repair. A photograph of the Regulating Outlet Structure in operation is presented in Photo 22.

The Regulating Outlet Structure is accessed via a set of stairs from the bluff located downstream of the left abutment of the dam. This route is also used to access the river downstream of the dam and is occasionally used by the public to access the river for recreation purposes.

The 1997 DSR report indicated that the stability of the rock bluff near the Regulating Outlet Structure should be evaluated to verify that it is stable.

This concern was raised due to the unlined or practically unlined nature of the tunnel, which would cause water pressure to build up in the bedrock. EBA inspected the rock bluff slope from the toe of the slope during the October 2007 inspection. There was no sign of any recent movements or increased rock block accumulation at the toe of the slope. Additionally, seepage was not observed on the slope. The slope appeared to be stable, notwithstanding the potential for ongoing fragmental rockfall.

4.4 REGULATING INTAKE STRUCTURE

The penstock intake structure was observed to be in good condition. The gates, lifting apparatus, and other mechanical and structural elements of the facility were not inspected by EBA. A series of log booms were observed upstream of the intake structure as shown in Photo 23. The amount of debris that is retained by these booms is understood to be relatively minor based on the annual expenditures for debris removal (approximately $2,000 to $5,000).

The electrical gate lifting winches are understood to be operated via electricity from the nearby BC Hydro grid. There is an emergency generator at the intake structure to provide power for gate operation during power outages. The generator was not tested during the inspection but it is understood that it is tested regularly.

The power poles on site that supported the electrical lines running to the intake structure were recently replaced as they had become weakened by carpenter ants.

4.5 REGULATING AND SPAWNING CHANNEL #2 TUNNELS

The tunnel inspections were conducted by Mr. Scott Sylte, P.Eng. of EBA. The results of these inspections are presented in a separate report(s).

4.6 FACILITIES DOWNSTREAM OF FULTON RIVER DAM

EBA reviewed the site plans, toured the entire site and discussed the layout and operation of the site with DFO staff on site. The following infrastructure is located downstream of Fulton River Dam:

- Spawning Channels 1 and 2 (approximately 3 km to 5 km downstream of dam);
- Highway bridge (Provincial Route 118, approximately 5 km downstream of dam) ; and
- Fish counting fence and various DFO facilities (approximately 5 km downstream of dam).

It is understood that there is not a permanent population downstream of the dam; however, there are a significant number of DFO workers at the various spawning channels and fish counting station during spawning season.

4.7 OPERATIONS, MAINTENANCE AND SURVEILLANCE MANUAL

It is understood that an Operations, Maintenance and Surveillance Manual exists for the Fulton River Dam and associated appurtenances. However, it is also understood that it has not been kept up to date and is not viewed to be an accurate representation of current operating procedures. Operating knowledge has been transferred from the original engineering and operations staff to the existing staff through primarily verbal communications and some overlap between engineering and operations staff.

4.8 EMERGENCY PREPAREDNESS/RESPONSE PLAN

It is understood that an Emergency Preparedness/Response Plan does not exist for Fulton River Dam. It is further understood that DFO has started to consider potential modes of failure and how such emergencies would be managed with regard to downstream stakeholders.

4.9 PUBLIC SAFETY MANAGEMENT

Historically, public safety management has not been a traditional dam safety topic. However, an increasing number of hazardous incidents, injuries and fatalities due to public interaction with dams have resulted in additional attention to this matter in the national and international dam safety community. Consequently, the 2007 CDA Guidelines have been issued with a draft Technical Bulletin - Public Safety Management. Consequently, EBA reviewed public safety management measures in place at the site while conducting the dam inspection. It is understood that there is an original Emergency Preparedness Plan that was reviewed in the 1997 DSR. However, the extent of deficiencies noted and recommendations made on this document combined with the age of the document suggest that it requires complete re-writing in order to meet the BCMOE-Dam Safety Branch requirements for such documents.

Access to the facility is generally unrestricted with the exception of access to key valve and gate control equipment in the dam, penstock tunnel intake structure and the Regulating Outlet Structure where doors are locked. The public is able to readily access the downstream toe of the dam and various pools and fishing locations (such as Millionaire's Pool downstream of the dam) as well as the reservoir upstream of the dam.

Various signs communicating information to the public are in place at the facility, as shown in Photos 24 through 27 and briefly described as follows from the fish counting fence to the dam:

- Fish Counting Fence – There are a series of informative/interpretative signs that explain to the public the nature and purpose of the Fulton River facility. Brochures are available that present a map of the facility, including the dam;
- Access road to dam, just off the highway – there is a sign that advises the public to stay off the Fulton River facility property. However, there is no gate to control public access;
- Various locations around dam and access to Regulating Outlet Structure – Signs advising the public that the site is a work area, to keep a distance from all work activities, to keep away from open water, have children attended at all times and to obey all signs;
- Access road to dam and penstock intake structure, just before fork in road – Water-intake, no swimming, keep off the ice in the winter and no unauthorized vehicles;
- Upstream face of dam – A sign that says "Danger – Water Intake"; and
- Downstream of the dam – There is one sign immediately downstream of the dam that warns the public that water levels in the river can rise rapidly. The water level rapidly rises due to operation of the Regulating Outlet Structure. It is also understood that signs are posted downstream at one location, Millionaire's Pool, to advise of times when the Regulating Outlet Structure will be operated. It is understood that the river channel narrows significantly well downstream of the dam. There are no alarms or horns to announce the release of water via this appurtenance.

Although not visible from the dam crest, there is a boom in place upstream of the dam. However, this boom is in place for the purposes of debris management. Therefore, it is not likely that there are any warning signs to prevent people from crossing the boom to access the forebay upstream of the dam. The overflow spillway on the dam is particularly hazardous to boaters and swimmers as strong currents can be set up by the spillway or low level conduit discharge.

It is understood that the local residents have made inquiries if the dam and associated facilities could be used as a tourist attraction. By its very nature, the site is already an area of attraction which is accentuated by the interpretive nature of the fish counting fence.

It is further understood that operation of the Regulating Control Outlet Structure valves can result in a rapid increase of water level in the river downstream of the dam, especially at areas where the river is constrained by the bedrock valley slopes.

At present, the posted signs are the only means DFO has implemented to minimize the potential for injury or loss of life due to public interaction with the dam and appurtenances.

5.0 GEOTECHNICAL ASSESSMENT

5.1 DAM

EBA was responsible for conducting the geotechnical engineering component of the 1997 DSR. The geotechnical stability assessment presented in the 1997 DSR report was reviewed as part of this assignment based on the observations made at the toe of the dam in October 2007 and with consideration of the 2007 CDA Guidelines.

A failure mode assessment is required to guide stability analysis so that likely modes of failure are considered. For gravity dams, the most likely modes of failure (with percentage of total failures in brackets) are presented as follows (Foster et al., 2000):

- Overtopping height exceeds design limits (32%);
- Shear failure through foundation (22%);
- Piping through foundation (19%);
- Shear failure through dam body (19%); and
- Other causes.

The aforementioned statistics indicate that overtopping and shear failure through the dam foundation are the two most common modes of failure for a gravity dam.

The stability assessment conducted by EBA in 1997 considered the following loading cases:

- Normal (usual) loading – Reservoir at dam crest, static conditions, grout curtain assumed to reduce uplift pressures somewhat;
- Flood (Probable Maximum Flood, PMF) loading – Maximum reservoir elevation, uplift pressures reduced by intact grout curtain, tail water depth at toe of dam unknown and, therefore, not included in calculations;
- Extreme (Earthquake) loading – Reservoir at dam crest elevation, seismic loading applied using pseudo-static method of analysis with a horizontal seismic force of 0.12g; and
- Post Earthquake (unusual) loading – Reservoir at dam crest, static loading, grout curtain has cracked with full uplift pressure.

The stability analysis conducted by EBA in 1997 focused on the overflow section of the dam. Stability analysis calculations were not conducted on the non-overflow section of the dam. However, with a greater height and mass of concrete being present at this section, there would be a general tendency for the factors of safety against sliding to increase due to increased normal stress on the concrete – bedrock contact.

The calculated factors of safety against sliding from the 1997 stability analysis are presented as follows:

- Normal (usual) Loading – 3.2, in excess of the CDA recommended value of 3.0 for conditions where tests to assess rock-concrete contact shear strength parameters are not available;
- Extreme (PMF) Loading – 1.9, less than the minimum of 2.0 suggested by the 1995 CDA Guidelines. A residual sliding factor of safety of 0.7 was calculated which indicates mathematical prediction of instability under certain limited conditions;
- Extreme (Earthquake) Loading - 1.3, exceeding the 1995 CDA Guidelines suggestion of 1.1; and
- Post Earthquake (unusual) Loading – 2.5, exceeding the minimum of 2.0 suggested by the 1995 CDA Guidelines.

The recently issued 2007 CDA Guidelines and associated Technical Bulletin – Structural Considerations for Dam Safety indicates the following terminology and required factors of safety:

- Unusual Loading – includes loading due to a flood event established by the Consequence Classification. The 2007 CDA Guidelines and Technical Bulletin – Hydrotechnical Considerations for Dam Safety indicate that an inflow design flood (IDF) event with a return period 1/3 between a 1/1000 year event and the PMF is suggested for a High Consequence Dam. The suggested minimum factor of safety against sliding (without shear strength testing) for Unusual Loading is 1.3; and
- Extreme Loading – includes loading due to the PMF event. The suggested minimum factor of safety against sliding (without shear strength testing) for Extreme Flood (PMF) Loading is 1.1.

The Technical Bulletin-Structural Considerations for Dam Safety (CDA, 2007) indicates that the Extreme Flood Loading case can be used in lieu of the Unusual Flood Loading case when the return period of the IDF exceeds 1:1,000 years, which is the case for Fulton River Dam.

Upon consideration of the aforementioned points, the calculated factor of safety against sliding for the Extreme Flood (PMF) Loading condition is found to meet the requirements of the 2007 CDA Guidelines and Technical Bulletin – Structural Considerations for Dam Safety. This analysis addresses the most common mode of failure for a gravity dam (overtopping exceeds design limits) discussed earlier in this section. However, it is not known if the PMF flows used in this analysis meet the flows that would be predicted by current PMF models. This must be confirmed.

Additionally, EBA has reviewed the estimation of the concrete-bedrock interface shear strength with the benefit of recent research into the shear strength mobilized at the concrete-bedrock interface of a concrete gravity dam (Rigby and Donnelly, 2007). The Barton and Choubey (1997) formula was used in 1997 to estimate the effective basal friction and dilation angle of the bedrock beneath the concrete dam, based on observations made by

EBA at the downstream toe of the dam during our 1997 inspection. The effective basal friction angle was estimated to be 27°. This value could be increased to 30°. The dilation angle was estimated using Joint Roughness coefficients and Joint Wall Strength which were indicated to be conservative in the 1997 report. The overall basal friction and dilation angle estimated using the Barton and Choubey approach was conservatively estimated to be 34.5°. This is judged to be quite low, with a more reasonable value for the quality, strength and roughness of bedrock observed at the downstream toe of the dam being between 40° and 50°. Even this assessment may prove to be conservative upon completion of a detailed investigation and testing program. By way of comparison, the friction angle for rock fill excavated from such a bedrock mass would be in excess of 40°.

Another element of conservatism in the analysis conducted by EBA is that zero concrete-bedrock bond strength was included in our analysis. This is a reasonable assumption as current practice neglects this additional shear strength contribution along the concrete-bedrock interface. It is not possible to accurately estimate what percentage of the concrete is bonded to the bedrock without a detailed and specialized coring and laboratory testing program.

The analysis conducted by EBA in 1997 to assess the shear failure through the concrete – bedrock contact partially addresses the second most likely mode of failure discussed earlier in this section – shear through dam foundation. It does not address the potential for failure along a plane of weakness in the dam foundation. Based on observations of the exposed bedrock at the toe of the dam, this mode of foundation failure is judged to be unlikely.

Piping failure of the foundation is judged to be unlikely due to the competency of the rock mass and the lack of reported joint infilling in the records reviewed by EBA in 1997. It was not possible to assess if subsurface seepage was exiting downstream of the dam during the October 2007 inspection. However, the age of the structure and good performance since construction suggests that development of a piping failure mechanism in the bedrock is unlikely.

The seismic analysis conducted by EBA was pseudo-static in nature which means that the time dependant accelerations associated with the maximum design earthquake (MDE) were not considered on the structure. Additionally, the impact of acceleration of the top of the dam due to ground accelerations was not considered. The curved nature of the overflow spillway introduces a complication in that rocking motion caused by seismic accelerations perpendicular to the dam crest could cause concrete blocks within the structure to open at the joints when the structure deflects in an upstream direction under seismic loading. Conversely, seismic accelerations causing the blocks to return to their normal position after deflecting upstream could result in high compressive stresses as the structure deflects in a downstream direction and compresses the curved overflow spillway crest.

5.2 SLOPE ABOVE REGULATING OUTLET STRUCTURE

A stability analysis was not undertaken for the rock bluff in the vicinity of the Regulating Outlet Structure. It is important to note that the operation of the Regulating Structure is not deemed critical for flood conveyance during a major flood. The 1997 DSR recommended that the regulating Outlet Structure not be operated during the design flood or PMF due to the potential for damaging the cone valves should they be submerged.

The only impact of a rock slope failure on the safe operation of the dam would be potentially impedance of the flood routing downstream of the dam. The volume of rock that could be mobilized by a failure is unknown; therefore, the degree of impedance of flood routing, with corresponding increase in tail water level at the dam and consequential decrease in the stability of the dam is unknown. However, based on our judgment, a rock slope failure volume in the order of 1,000 m^3 would likely have minimal impact on the tail water level at the toe of the dam. Therefore, a failure that could impact the operation of or cause significant damage to the Regulating Outlet Structure may not be cause for dam safety concerns.

Separate from the potential for a large slope failure, the slope has a moderate to high potential for fragmental rockfall, which is discussed under separate cover. This does not pose a dam safety concern but does pose a potential hazard to employees.

6.0 DISCUSSION

6.1 1997 DAM SAFETY REVIEW RECOMMENDATIONS

Discussions with DFO staff indicate that very few to none of the recommendations presented in UMA's 1997 DSR report have been completed. EBA has recommended to DFO that the 2007 Dam Safety Review consist of a detailed inspection of the dam to identify if there are any obvious concerns about the safety of the dam. A brief review of the 1997 DSR report has been undertaken and, based on the areas of the facility inspected in October 2007, EBA generally agrees with the findings of that report. The recommendations relating to the mechanical, structural and hydrotechnical elements of the facility have not been confirmed since 1997. However, the performance and stability of the dam appears to be within the requirements of BCMOE-Dam Safety Branch and the suggestions of the CDA Guidelines.

6.2 CONSEQUENCE CLASSIFICATION

EBA agrees with the High Consequence classification recommended by UMA in the 1997 DSR report from the perspectives of economics and environmental issues. Our rationale is presented in the following paragraphs.

The CDA Guidelines (CDA, 2007) indicate (in Table 2-1 the Technical Bulletin for Inundation, Consequences and Classification for Dam Safety) that a High Consequence Dam would have high economic losses affecting infrastructure, public transportation and commercial facilities. Additionally, the BC Water Act (Reg 44/2000) indicates in Schedule 1 (Sections 2(1)(d) and 3(2)) that a High Consequence Dam would have estimated direct and indirect costs that could exceed $1,000,000. Given that the dam would likely cost about $10 to $20 million to reconstruct, not including repair/replacement costs for the spawning channels, Fulton Dam is clearly a High Consequence Dam based on the CDA and BC Water Act criteria. The costs presented in the BC Water Act have not been adjusted for inflation.

From an environmental perspective, Fulton Dam is used to impound water for use in improving the quantity of salmon fry that return to the ocean and the Skeena River. It is further understood from DFO that the quality of the man made spawning channels is so high that the Skeena River sockeye salmon fishery would be significantly impacted by destruction of this facility to the point where there would be a corresponding year after dam failure when salmon returns to the river would be very low. This constitutes an economic impact; however, according to the corresponding CDA Technical Bulletin, it also constitutes significant loss or deterioration of critical fish habitat where restoration or compensation in kind is viewed to be highly possible which also justifies a High Consequence classification. From the perspective of the BC Water Act, a High Consequence dam is one where loss or significant deterioration of nationally or provincially important fish habitat with the feasibility and practicality of restoration and/or compensation is high. Therefore, by both CDA and BC Water Act criteria, from an environmental perspective, Fulton River Dam is a High Consequence dam.

From a loss of life perspective, the only people that would be within the inundation area appear to be the DFO facility workers, public visitors to the fish counting fences or motorists traveling on the highway. As this only qualifies as temporary occupation of the potential area of inundation, the consequence classification with regard to loss of life has been judged to be Significant according to the corresponding 2007 CDA Technical Bulletin. However, the extent of flood inundation from dam break or the IDF/PMF should be assessed to verify no permanent residents, including the DFO offices and residences, are impacted/inundated. As the consequence classification of a dam is to be taken as the highest incremental consequence, the aforementioned High Consequence Classifications apply. It is unlikely that DFO staff would be downstream of the dam during the design flood event. Therefore, the only way they could be impacted by a dam failure is if there was a latent defect in the dam or foundation that caused a sudden “sunny day” failure. Mis-operation of the dam during non-flooding conditions is not likely to cause failure due to the presence of an un-gated overflow spillway. A “sunny day” failure due to latent defect is not considered likely due to the good performance of the dam over the past 30 years and the recent observations on the condition of the dam. However, a “sunny day” failure could occur due to seismic loading.

Downstream of the dam at the outlet of Fulton River into Babine Lake, there are a series of cottages. The 1997 DSR report indicated these cottages were above the potential zone of inundation during the dam break and PMF flows. This should be verified with updated flood forecasts and inundation mapping.

A consequence classification is based on the incremental consequences of dam failure. A key consideration is the difference in inundation extent associated with the design flood event without dam failure and the extent of inundation that occurs upon dam failure. If the extent of inundation during a design storm event during which the dam remains stable is such that the spawning facilities are damaged or destroyed, the incremental consequence of the dam failing is limited to economic consequences, which still justifies the High Consequence classification.

6.3 HYDROTECHNICAL CONSIDERATIONS

The hydrology used in the original design calculations should be reviewed against the updated database of precipitation and stream gauging data in the general region of the dam. This data can be used to estimate the IDF and the PMF reservoir levels and tail water depths. The estimation of high return period events such as the IDF and PMF will result in some statistical uncertainty since the length of time the various precipitation and stream gauging databases have been in service lacks statistical power for long term predictions. The flows associated with the current PMF for the project site are likely higher than those used during the original design work.

Based on EBA's review of the 1997 DSR report, it is understood that inundation mapping was completed by Patrick Fawkes & Associates in 1986. The fundamental assumption behind this analysis is that it was conducted for a dam breach. The mapping of inundation associated with the IDF was not conducted. As such, the impact of such a flood event occurring without a dam breach are unknown with regards to potential inundation of the highway bridge and the various facilities such as the spawning channels and the fish counting fence. Consequently, flood inundation mapping for the IDF should be conducted.

The flood inundation mapping should be updated to permit comparison of the IDF, PMF and the flood wave associated with dam failure to allow for incremental consequences to be determined. The extent of inundation associated with these flood events could then be reviewed against current maps of local development to better assess their impact.

Flood inundation mapping will require that the release of water over the crest of the dam and through the low level conduit be modelled. The peak discharge rates should be determined by reviewing the hydrology of the reservoir catchment and then routing the spillway and low level outlet discharge through the Fulton River channel downstream of the dam.

The impact of a rock bluff failure should be the subject of a simplified sensitivity analysis in which various degrees of obstruction are placed in the river channel downstream of the dam at the Regulating Outlet Structure. This would be accomplished by creating a berm of material of varying height that extends across the river channel. EBA anticipates that this material would be quickly eroded during a high return period flood event.

The reservoir levels and tail water levels predicted by the hydrological/hydraulic modelling and flood routing serve yet another purpose in the geotechnical stability analysis which is discussed in the next section.

6.4 GEOTECHNICAL STABILITY CONSIDERATIONS

The analysis conducted by EBA in 1997 requires refinement due to the following:

- Improvement in the understanding of concrete – bedrock friction at the base of the dam;
- Inadequate information on the tail water depth during the PMF flood event;
- Additional analysis to assess the dynamic interaction of the concrete blocks in the curved overflow spillway during a seismic event;
- Assessment of the stability of the non-overflow section of the dam under all relevant loading conditions; and
- Assessment of the development of tensile stresses in the heel or high compressive stresses at the toe. Due to the moderate height of the dam, EBA does not anticipate the development of high compressive stresses at the toe of the dam. However, tensile stresses could develop at the upstream toe.

The analysis would require input from the hydrotechnical assessment in the form of current IDF or PMF reservoir elevations, flow rates and tail water elevations.

6.5 OPERATIONS MAINTENANCE AND SURVEILLANCE

An updated OMS Manual should be prepared. The BCMOE-Dam Safety Branch has prepared an OMS Manual template to guide preparation of such documents to their requirements. It is presented in the document "Inspection and Maintenance of Dams – Dam Safety Guidelines". A copy of the OMS template has been included in Appendix C.

DFO should implement regular and documented operator inspections of the various elements of the facility that relate directly or indirectly to the safe operation of the dam. The completed inspection forms should be filed in a dam log book that will serve at the archive for all such inspections.

6.6 EMERGENCY RESPONSE PLAN

The Emergency Preparedness/Response plan was not reviewed while on site; however, based on the comments from the 1997 DSR, it requires significant revision. The BCMOE-Dam Safety Branch has prepared an Emergency Preparedness Plan template to guide preparation of such documents to their requirements. It is presented in the document "Inspection and Maintenance of Dams – Dam Safety Guidelines". A copy of the EPP template has been included in Appendix C.

The inundation maps for IDF, PMF and dam break events should be prepared prior to preparing the EPP so that affected areas can be clearly identified. In the short term, DFO may use the inundation mapping prepared by Patrick Fawkes & Associates for an interim document and then refine it further so that an appropriate level of response can be implemented in the event of the IDF, a seismic event (i.e., potential dam breach) or the PMF (including potential dam breach as well).

6.7 PUBLIC SAFETY MANAGEMENT

A Public Safety Management plan should be prepared to mitigate any risks associated with dam operation and public interaction. This would include, but not be limited to, the following measures:

- Conducting a risk assessment according to the Ontario Power Generation procedures (CDA, 2004) which are briefly outlined in the draft Technical Bulletin – Public Safety Around Dams (CDA, 2007);
- Improve signage to specifically state the hazards, include cartoons or illustrations showing the hazard that is easily understood and incorporate large, easily read text that is visible from an appropriate distance. This would include signs or buoys on the log booms warning the public on watercraft upstream of the dam;
- Install alarms (warning horns or sirens) to warn of impending release of water through the Regulating Structure Outlet, with signage stating what the alarm means at various places where the public interacts with the river downstream of the dam;
- Implement a public education program that reaches out to outdoor groups and the general public to educate them of the specific hazards associated with the dam; and
- Install barriers to access such as locked gates and other access restrictions to the stairwell leading down to the Regulating Structure Outlet.

The nature of what elements of Public Safety Management are required would be more specifically identified during the risk assessment.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Based on EBA's review of the 1997 DSR report and our October 2007 site inspection, the following conclusions have been reached:

General

- None of the recommendations from the 1997 DSR report have been implemented. DFO should start commissioning the various studies and activities required to meet the recommendations of the 1997 DSR;

Dam and Appurtenant Structures

- The concrete structure of the dam and appurtenance structures is in generally good condition. There was some efflorescence at one construction joint on the dam and some evidence of erosion at construction joints and exposed aggregate at the spillway. However, these deteriorated conditions were judged to be minor in nature;

- Seepage immediately beneath the dam appears to be minimal. Deeper seepage exiting further downstream was not observed and could not be inspected for in detail for accessibility reasons;
- The gate seals at the dam were sufficiently worn or damaged that a significant volume of water was passing through the low level outlet at the time of inspection. The poor condition of the seals do not impact safe operation of the dam as poor seals do not inhibit gate opening during a flood event to pass flood water;
- Sediment build up behind the dam does not appear to have occurred to the left of the overflow spillway. The leaking gate seal may be preventing sediment build up around the gate house. The presence or absence of sediment build up upstream of the overflow spillway was not verified during the October 2007 inspection;
- The Regulating Outlet Structure appears to be in good condition. The state of the cone valve operating apparatus was not assessed during the inspection. It is understood that these valves are not to be operated during a high return period flood event due to the potential for damage caused by back pressure (submergence) from a high tail water level. Therefore, lack of confirmation of their operability will not impact dam safety;
- The Penstock Intake Structure appears to be in good condition. Mechanical systems and the back up generator were not operated during the October 2007 inspection;

Consequence Classification

- The consequences of failure for Fulton Dam are such that the High Consequence classification assigned in 1997 still applies to the structure under the requirements of the 2007 CDA Guidelines and associated Technical Bulletins;

Geotechnical Assessment

- The calculated factors of safety against sliding under various loading conditions from the 1997 DSR meet or exceed the suggested minimum factors of safety presented in the 2007 CDA Guidelines and associated Technical Bulletins;
- The stability analysis for static, flood and seismic loading conditions needs to be refined further to meet the requirements of the 2007 CDA Guidelines;
- The consequences of failure of the rock bluff adjacent to the Regulating Outlet Structure could directly impact the safe operation of the dam by impeding the flood routing downstream of the dam. However, the impact of any potential rock bluff failure on tail water level at the dam is unknown. Loss of the Regulating Outlet Structure will not impact the conveyance of the IDF or PMF from the reservoir as the 1997 DSR recommended that this structure not be operated during high return period flood events;

- The rock slope in the vicinity of the Regulating Outlet Structure was viewed form the toe of the slope. Excess seepage or evidence of large-scale instability was not observed. As such, it appears that this slope is stable, at least in the short term; however fragmental rockfall may pose a hazard to personnel;

Hydrotechnical Assessment

- A hydrologic evaluation of the IDF has not been conducted;
- The PMF flood rate assessed in 1997 has likely increased due to advances in knowledge about extreme precipitation events;
- The hydraulic assessment on how the dam discharges the IDF or PMF event should be updated to assess the tail water depth at the downstream toe of the dam;
- The extent of flood inundation from the PMF and the IDF should be assessed with regards to the infrastructure downstream of the dam;

Emergency Preparedness Plan

- The EPP has not been regularly updated and was found to be insufficient during the 1997 DSR;

Operations, Maintenance and Surveillance Manual

- The OMS Manual has not been regularly updated. As such, operations information/procedures are verbally transferred;

Public Safety Management

- There is regular public interaction with the dam and downstream environment. Although signs are present in various locations, the nature of hazards posed by the dam is not clearly illustrated to the public and public access to potentially dangerous locations is not restricted.

7.2 RECOMMENDATIONS

Based on EBA's review of the 1997 DSR report, our October 2007 site inspection, and the aforementioned conclusions, the following recommendations are made:

General

- DFO should commission the various studies and inspections required to address the recommendations made in the 1997 DSR report;

Dam and Appurtenant Structures

- DFO should adopt a regular operator inspection program complete with photographs and documentation of the various features observed during the 2007 dam inspection, as well as other key components that were not inspected;

- DFO should rehabilitate the gate seals at the dam and, if necessary, at the penstock intake structure;
- The mechanical condition of all outlet control works (Regulating Outlet Structure, Penstock Intake Structure, Dam Outlet Gates) should be inspected by a qualified mechanical/hydraulic systems engineer;

Consequence Classification

- There are no recommendations relating to Consequence Classification;

Hydrotechnical Assessment

- The hydrologic calculation of the IDF and PMF should be verified using the latest hydrologic data available in the area of the dam;
- The tail water depth at the downstream toe of the dam should be verified for the IDF and PMF. This information is required for a refined stability analysis of the dam;
- Flood routing analysis should be conducted to assess the area of inundation due to the IDF and PMF. This information is required to assess the relative safety of the spawning channels during a significant flood event as well as to provide guidance on what areas will be impacted by the IDF and PMF. This will guide the preparation of the EPP;

Geotechnical Assessment

- The stability analysis conducted in 1997 should be re-done using more appropriate shear strength parameters to assess sliding at the base of the dam, sliding along any potential discontinuities within the bedrock, sliding along construction joints and development of tensile or high compressive stresses;
- The pseudo-static stability assessment should be updated with the latest seismic data. Additionally, a more rigorous seismic analysis should be conducted due to the curved nature of the overflow spillway crest;
- The tail water depth from the hydrotechnical assessment should be used in the stability analysis for the IDF or PMF;

Emergency Preparedness Plan

- The EPP should be updated/re-written using the Guidelines for such documents issued by BCMOE-Dam Safety Branch;

Operations, Maintenance and Surveillance Manual

- The OMS should be updated using the Guidelines for such documents issued by BCMOE-Dam Safety Branch;

Public Safety Management

- DFO should conduct a risk assessment to understand all of the potential hazards associated with public interaction with the dam and river channel downstream of the dam so that appropriate mitigative measures can be implemented.

7.3 PRIORITIES OF FURTHER WORK

Based on the findings of the inspection and the conclusions and recommendations reached herein, EBA recommends the following order of priority for the recommended actions:

High Priority (To be initiated in the next three months)

- Commission an inspection of the various gates and mechanical/electric equipment with the goal of following up that task with initiation of rehabilitation designs and construction works as appropriate;
- Commission an experienced dam safety/engineering consultant to prepare an inspection guideline to be reviewed and ultimately used by DFO site staff in conducting and documenting regular operations inspections. The surveillance monitoring schedule and checklist presented in Appendix II in the 1997 DSR report will be used to prepare new guidelines for operations inspections;
- Implement dam inspection guidelines and start documentation in a dam log book specifically created to track the results of inspections and flood events or operation and maintenance activities at the dam;
- Commission an experienced dam safety/engineering consultant to start work on revising the OMS and EPP documents to meet BCMOE – Dam Safety Branch requirements for such documents. Initial versions of these documents will not include the results of subsequent analyses. However, these documents are "living" documents in that they change frequently. Therefore, they could be easily updated with the results of future analyses;
- Commission the recommended hydrologic/hydraulic and flood routing (hydrotechnical) modelling studies recommended herein;

Medium Priority (to be initiated or completed in the next year)

- Upon completion of the aforementioned hydrotechnical studies, commission a refined geotechnical stability study, including seismic assessment;
- Start construction/rehabilitation works for gate seal repair and any other recommendations from the mechanical/electrical inspections recommended earlier in this section;
- Complete a Public Safety Management Plan risk assessment and begin implementation of any improvements or additions to the existing public safety management measures in place;

- Complete OMS and EPP documents with the results of the High priority analyses discussed earlier in this section; and
- Commission a detailed inspection of the site by a qualified dam safety/engineering consultant in the fall of 2008. Annual inspections by qualified third parties should be conducted once a year.

8.0 CLOSURE

Please do not hesitate to contact the undersigned if you have any questions regarding this report.

EBA Engineering Consultants Ltd.

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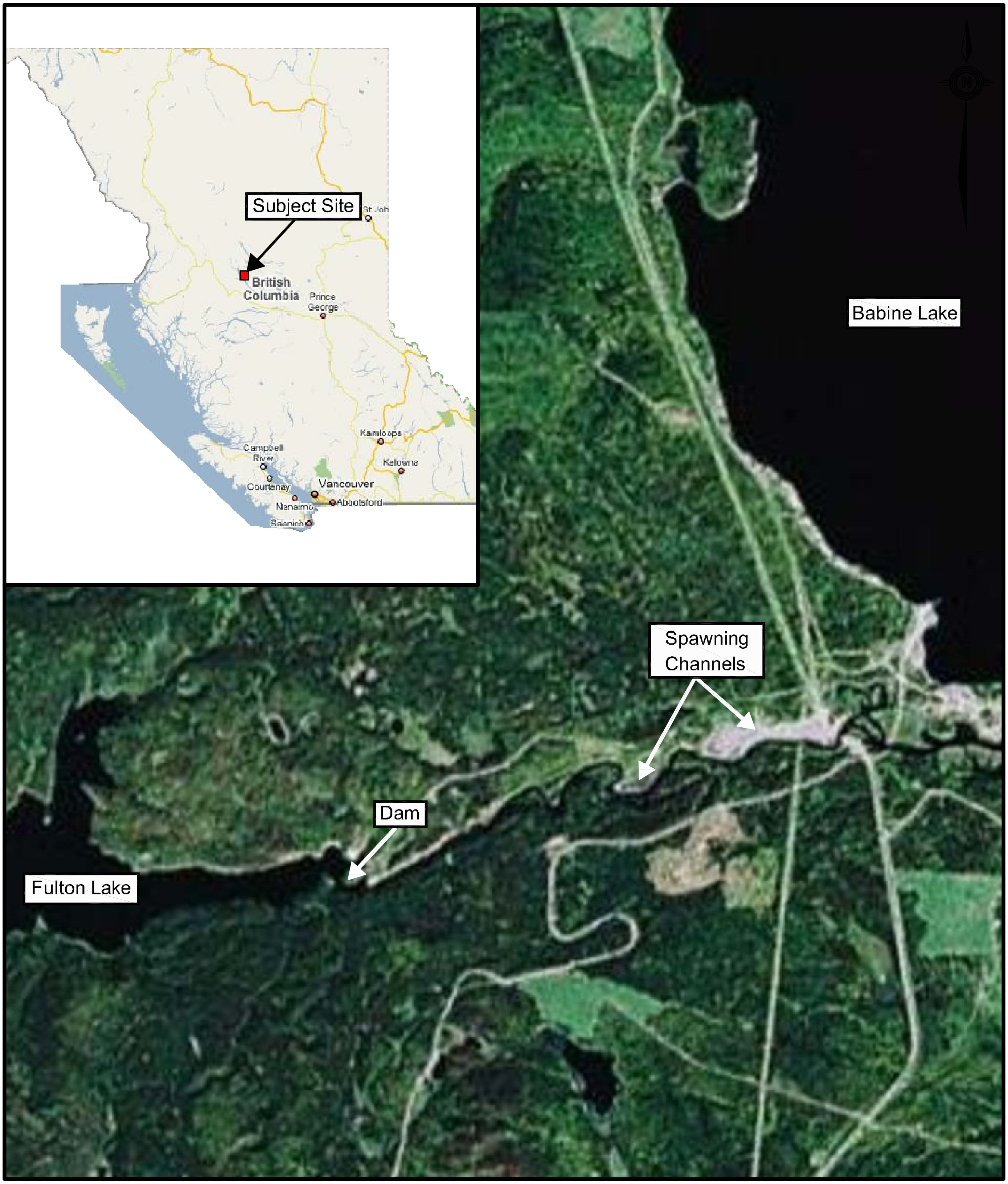
FIGURES



CLIENT

Department of Fisheries and Oceans

EBA Engineering Consultants Ltd.

2007 Inspection, Fulton Dam
Granisle, British Columbia

Site location plan

PROJECT NO./FILE NO.	DWN	CKD	REV
V13101063 V13101063H01a.dwg	RH	CKG	0

OFFICE	DATE
EBA-EDM	December 2007

Figure 1

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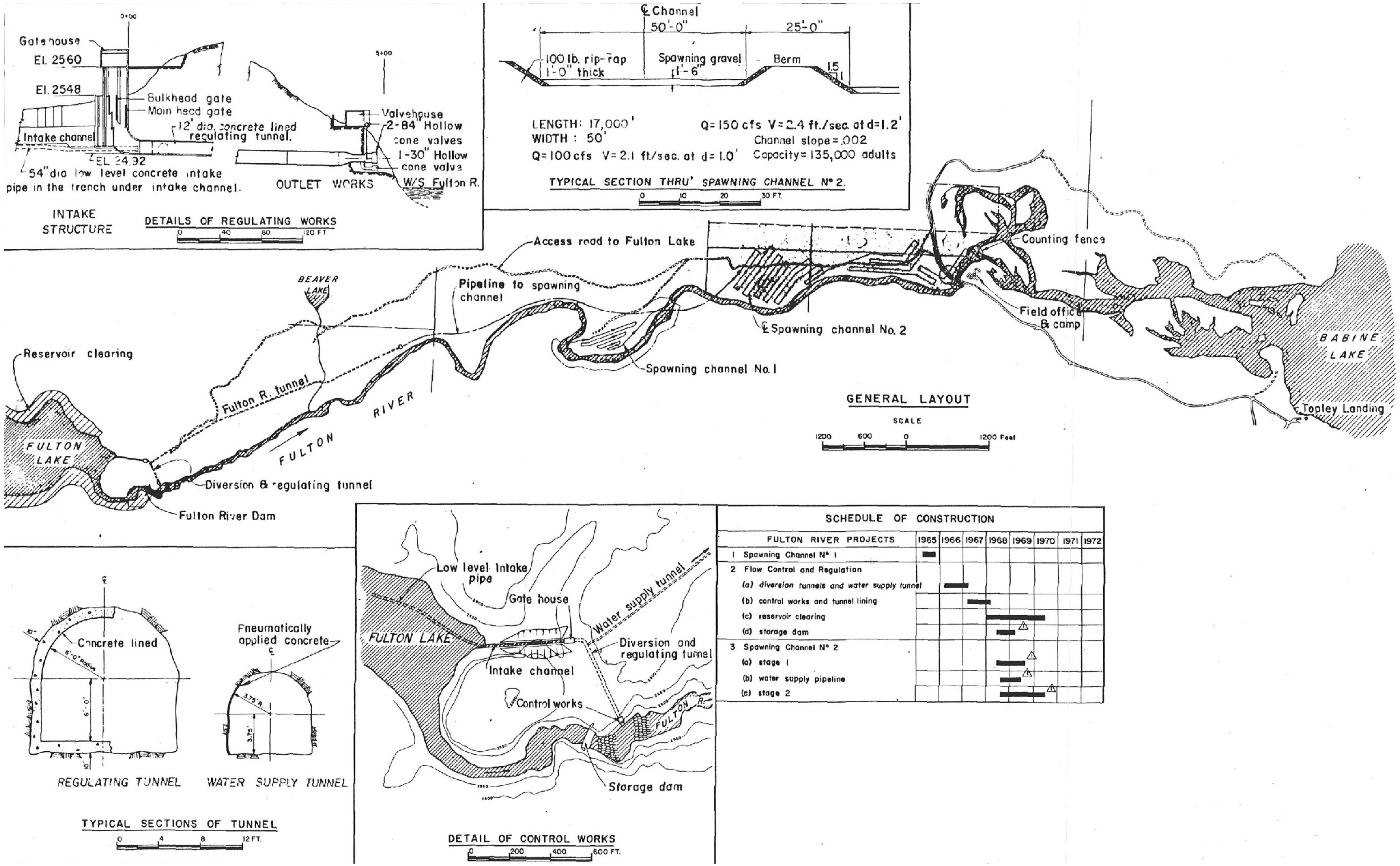

Note: Base drawing provided by UMA Engineering Ltd, Fulton Dam Safety Review report (2507-0175-001-00-01), dated August 1997.

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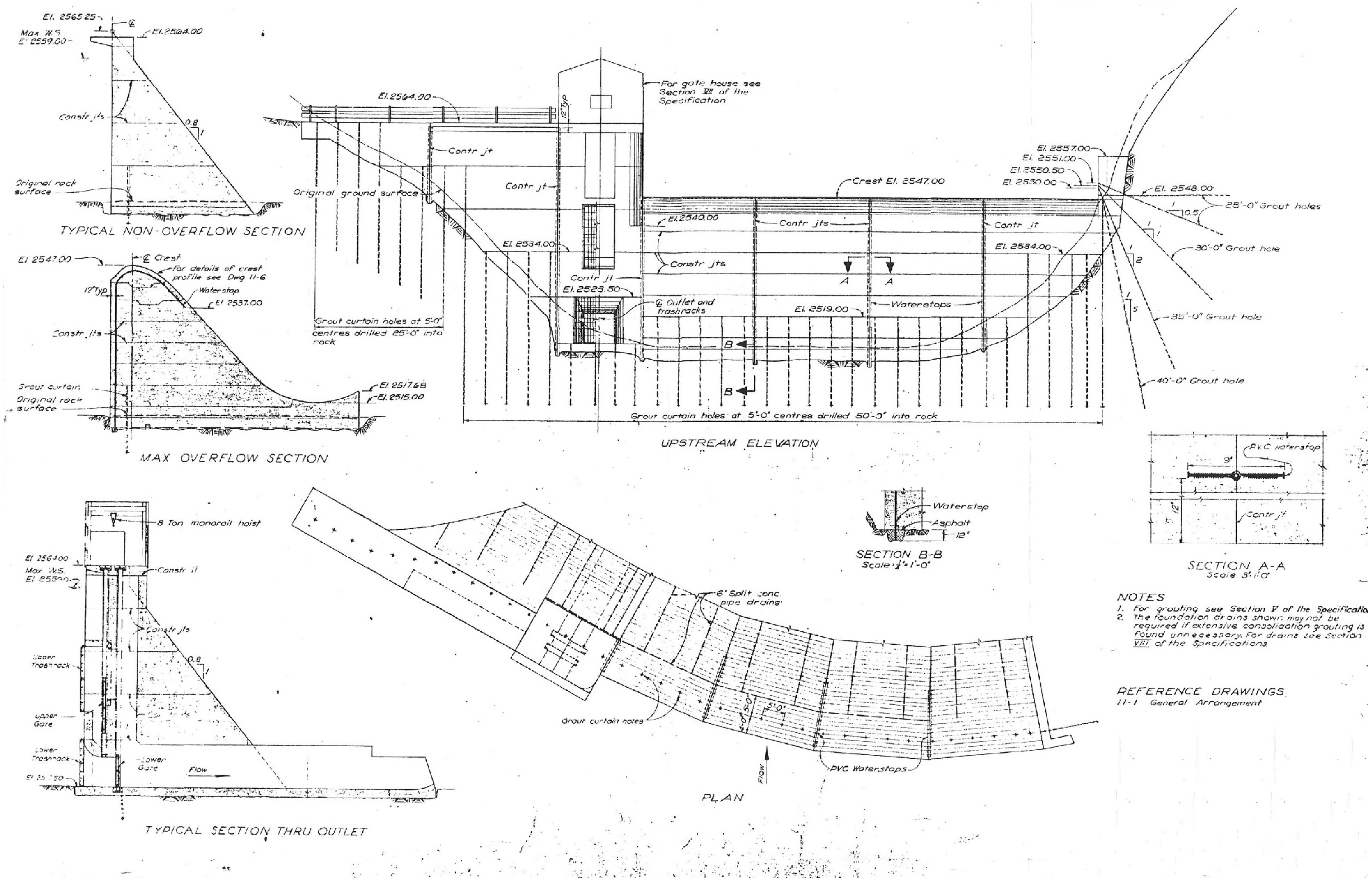
2007 Inspection, Fulton Dam
Granisle, British Columbia

Site Plan

PROJECT NO./FILE NO.	DWN	CKD	REV
V13101063 V13101063H01a.cdr	RH	CKG	1
OFFICE: EBA-EDM	DATE: December 2007		

Figure 2



Note: Base drawing provided by UMA Engineering Ltd, Fulton Dam Safety Review report (2507-0175-001-00-01), dated August 1997.

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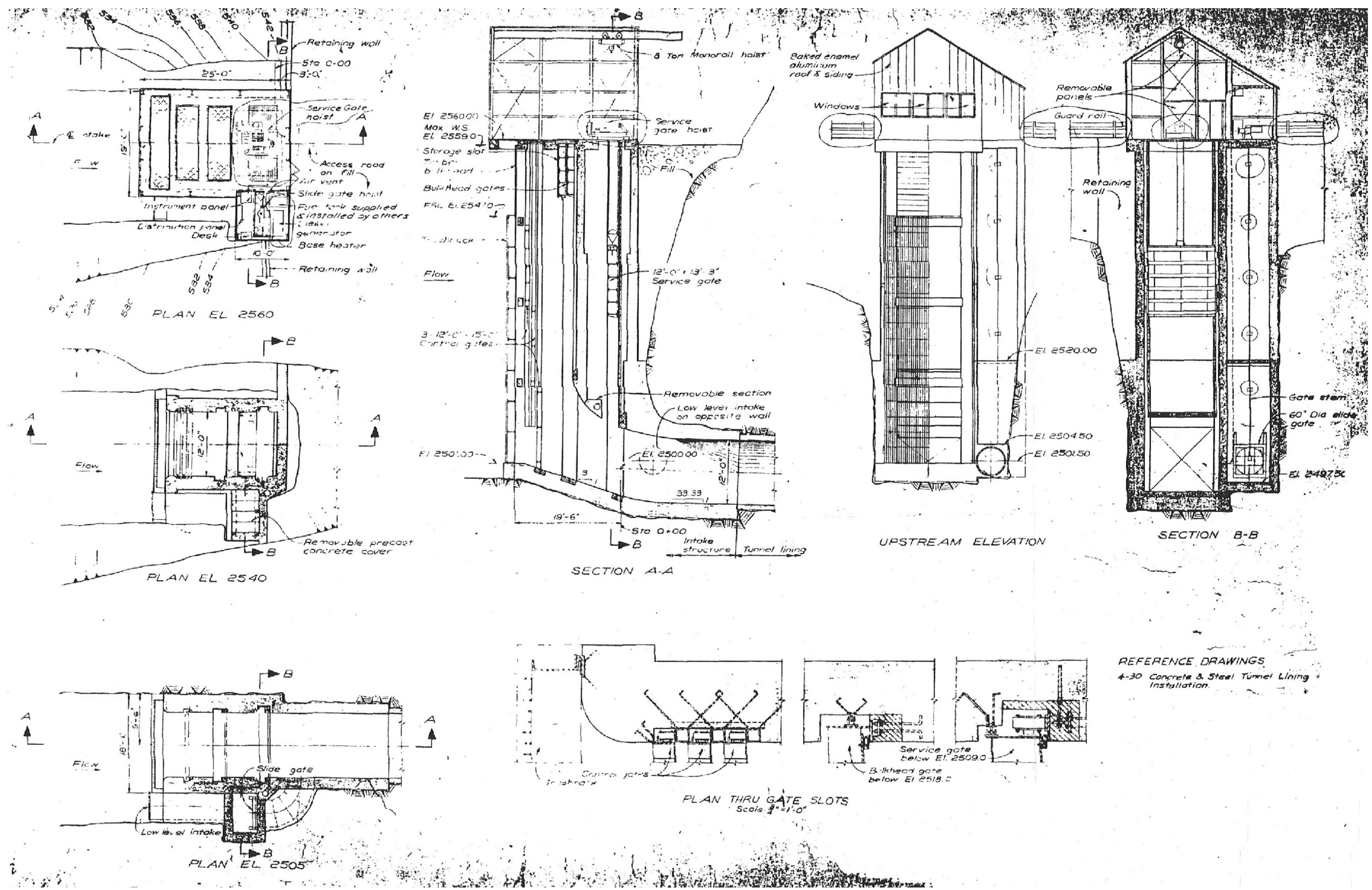
2007 Inspection, Fulton Dam
Granisle, British Columbia

Plan and Sections of Dam

PROJECT NO./FILE NO.	DWN	CKD	REV
V13101063 V13101063H01a.cdr	RH	CKG	1

OFFICE	DATE
EBA-EDM	December 2007

Figure 3



Note: Base drawing provided by UMA Engineering Ltd, Fulton Dam Safety Review report (2507-0175-001-00-01), dated August 1997.

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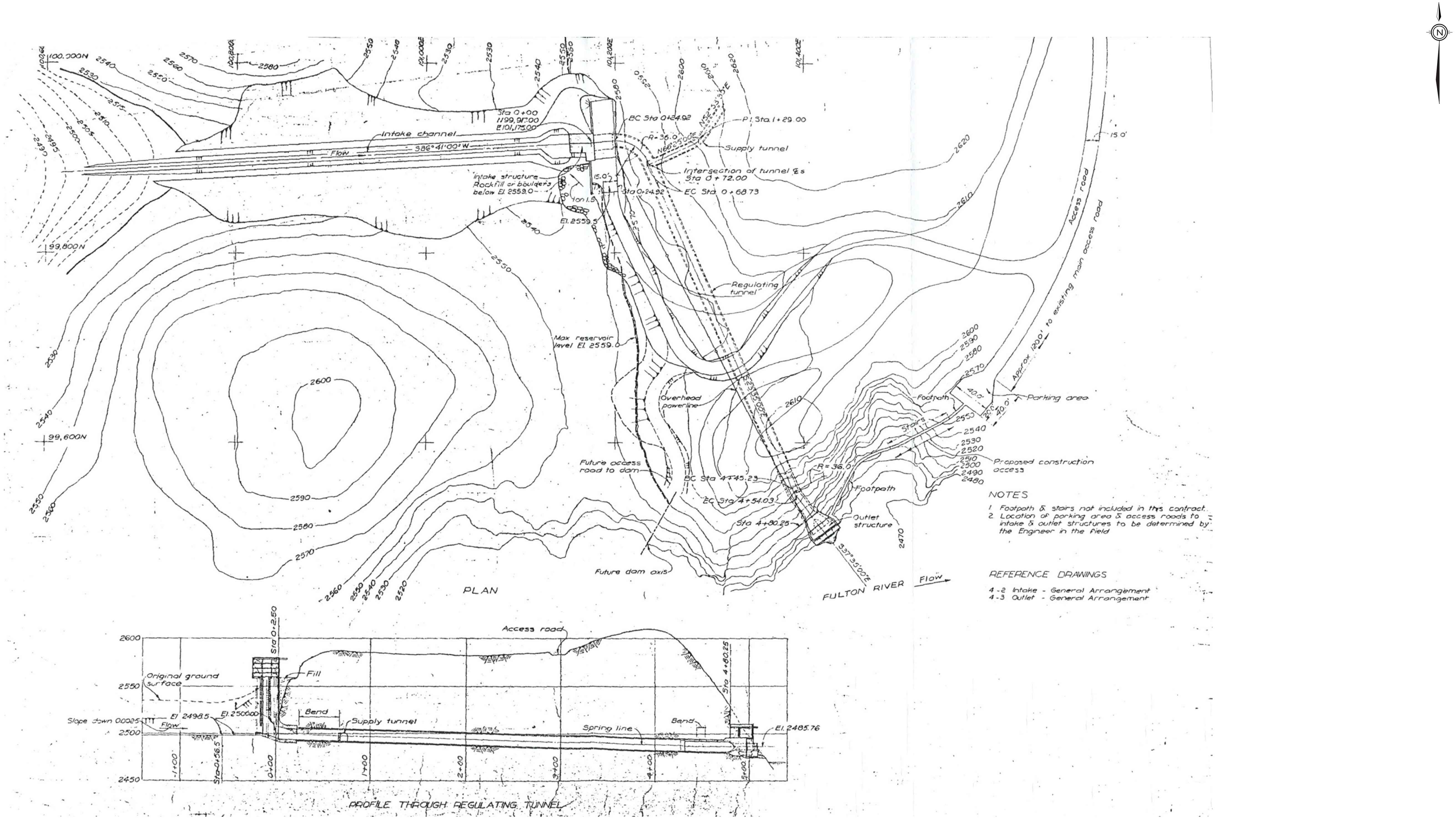
2007 Inspection, Fulton Dam
Granisle, British Columbia

Regulating Works Intake

EBA Engineering Consultants Ltd.

PROJECT NO./FILE NO.	DWN	CKD	REV
V13101063 V13101063H01a.cdr	RH	CKG	1
OFFICE: EBA-EDM	DATE: December 2007		

Figure 4



Note: Base drawing provided by UMA Engineering Ltd,
Fulton Dam Safety Review report (2507-0175-001-00-01),
dated August 1997.

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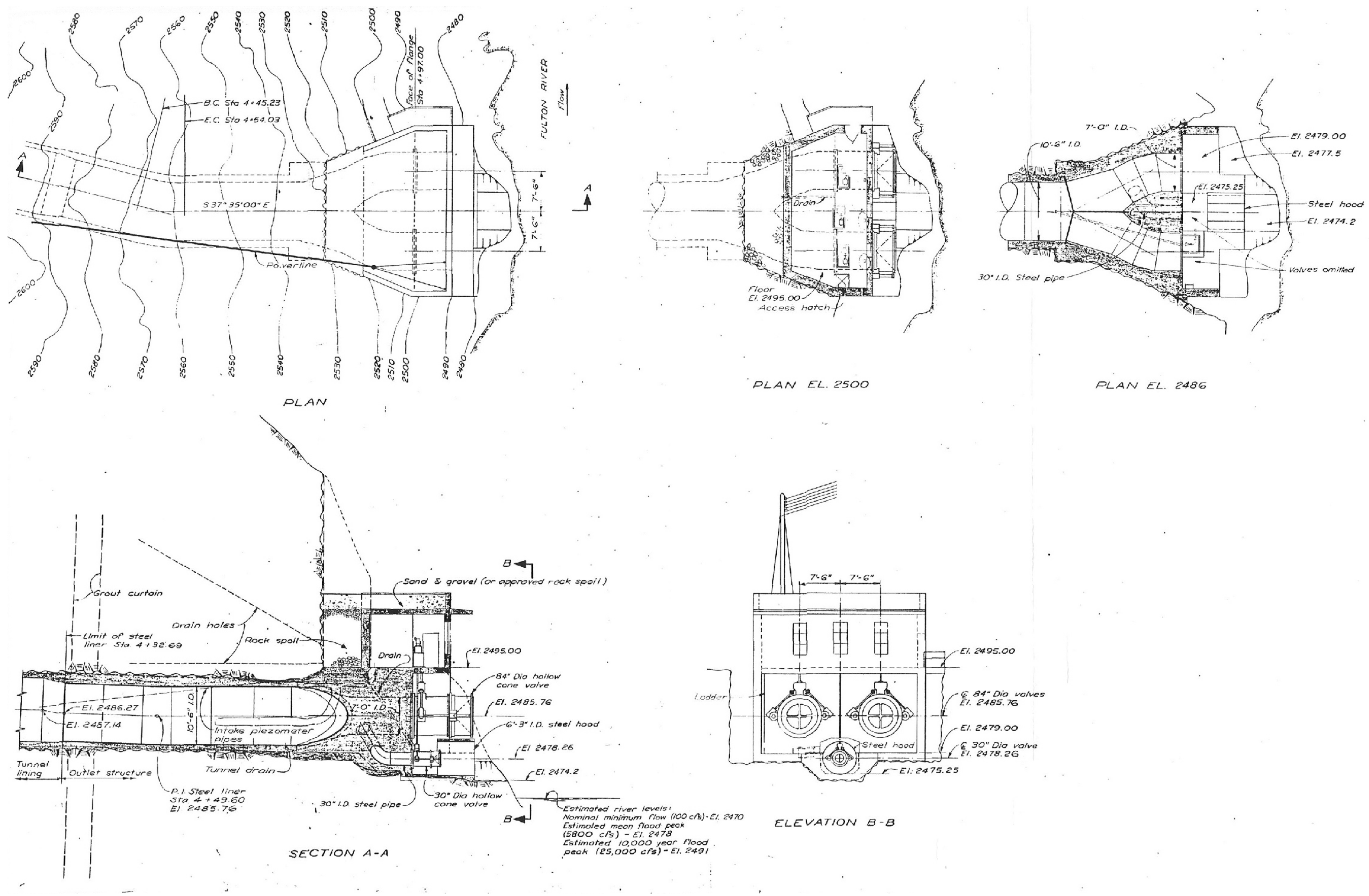
2007 Inspection, Fulton Dam
Granisle, British Columbia

Plan and Section of Regulating Works

PROJECT NO./FILE NO.	DWN	CKD	REV
V13101063 V13101063H01a.cdr	RH	CKG	1
OFFICE: EBA-EDM	DATE: December 2007		

Figure 5



Note: Base drawing provided by UMA Engineering Ltd,
Fulton Dam Safety Review report (2507-0175-001-00-01),
dated August 1997.

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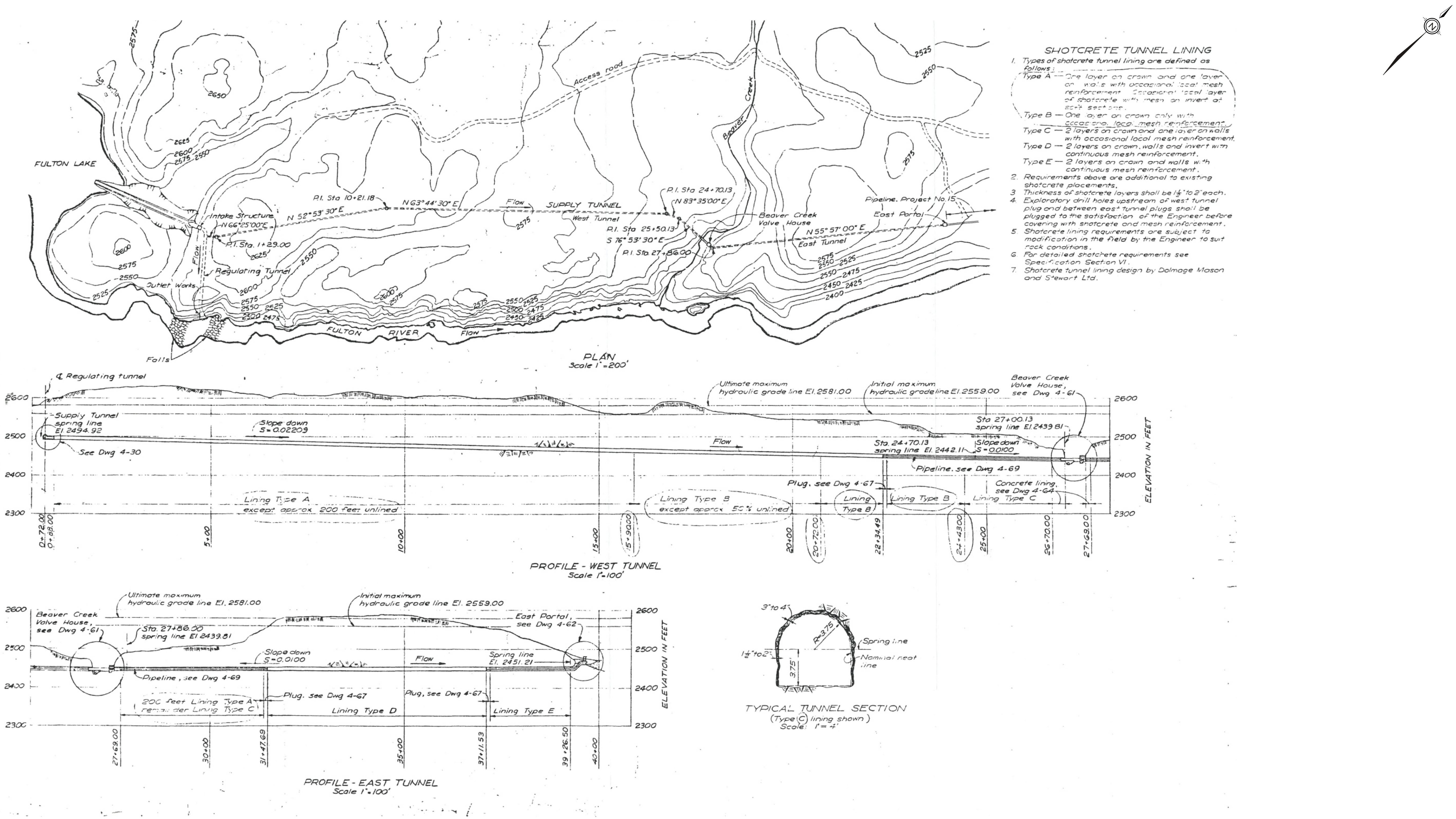
2007 Inspection, Fulton Dam Granisle, British Columbia

Regulating Outlet Structure

PROJECT NO./FILE NO.	DWN	CKD	REV
V13101063 V13101063H01a.cdr	RH	CKG	1

OFFICE	DATE
EBA-EDM	December 2007

Figure 6



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Department of Fisheries and Oceans

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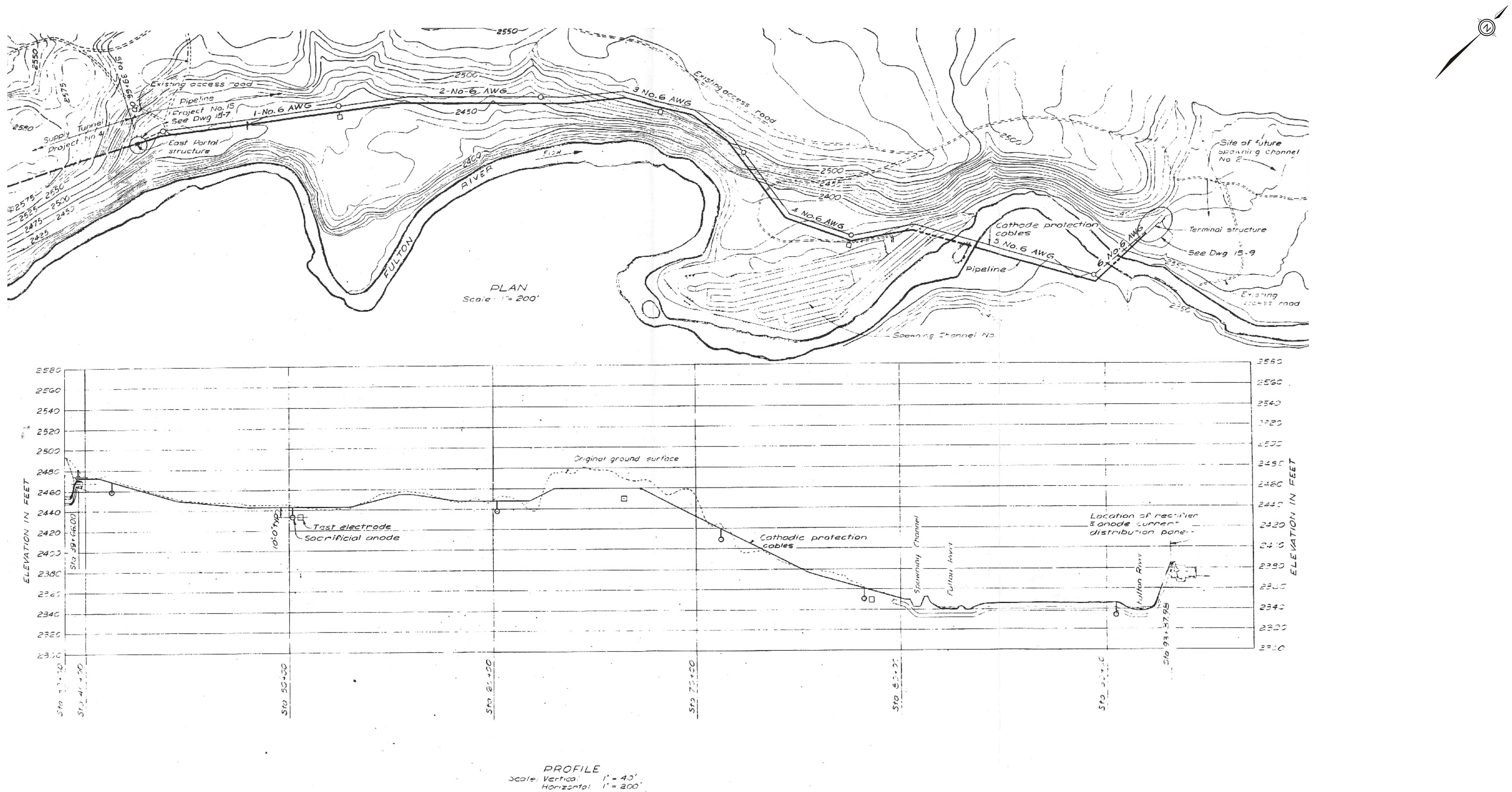
2007 Inspection, Fulton Dam
Granisle, British Columbia

Plan and Profile of Supply Pipeline for Spawning Channel #2 (1 of 2)

PROJECT NO./FILE NO.	DWN	CKD	REV
V13101063 V13101063H01a.cdr	RH	CKG	1
OFFICE: EBA-EDM	DATE: December 2007		

Figure 7



Note: Base drawing provided by UMA Engineering Ltd, Fulton Dam Safety Review report (2507-0175-001-00-01), dated August 1997.

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Department of Fisheries and Oceans

EBA Engineering Consultants Ltd.

2007 Inspection, Fulton Dam
Granisle, British Columbia

Plan and Profile of Supply Pipeline for Spawning Channel #2 (2 of 2)

PROJECT NO./FILE NO.	DWN	CKD	REV
V13101063 V13101063H01a.cdr	RH	CKG	1
OFFICE: EBA-EDM	DATE: December 2007		

Figure 8

PHOTOGRAPHS

Photo 1
Crest of dam viewed from left abutment.

Photo 2
Upstream face of dam viewed from left abutment.

Photo 3
Inside of gatehouse on crest of dam. Note two portals in floor beneath which the two gates are located.

Photo 4
Upper downstream face, crest of dam and gatehouse.

Photo 5
Crest of spillway section.

Photo 6
Downstream face of spillway section viewed from gatehouse.

Photo 7
Downstream face of non-overflow and spillway viewed from crest of dam near left abutment.

Photo 8
Downstream face of spillway viewed from bluff downstream of left abutment.

Photo 9
Downstream face of dam viewed from bluff downstream of left abutment.

Photo 10
Downstream face of dam viewed from toe of dam. Note minor deterioration of concrete at construction joint.

Photo 11
Mineral build up on downstream face of dam near toe of dam.
Very small amounts of seepage appears to be passing through
a crack/ construction joint in the dam

Photo 12
Mineral build up on downstream toe of dam at toe of dam (different view of site shown in Photo 11).

Photo 13
Mineral build up on a construction joint on downstream face of dam, viewed from downstream toe. Mineralization is due to very small amount of seepage passing through dam along the construction joint.

Photo 14
Spillway section viewed from downstream toe. Note deterioration of concrete at construction joints and patches applied sometime in the past. Note toe of flip bucket/energy dissipation structure is in contact with the bedrock foundation.

Photo 15
Concrete bedrock contact at downstream toe of dam.

Photo 16
Left (non-overflow) portion of dam and spillway gatehouse. Red arrow indicates zone of mineralization presented in photos 11, 12 and 13.

Photo 17
Left portion (non-overflow) of dam and low level outlet structure. Note minor deterioration of concrete at construction joints.

Photo 18
Condition of bedrock immediately downstream of dam.

Photo 19
Right abutment between spillway wingwall and rock abutment.

Photo 20.
Bedrock downstream of spillway section. Photo taken from bluff downstream of left abutment.

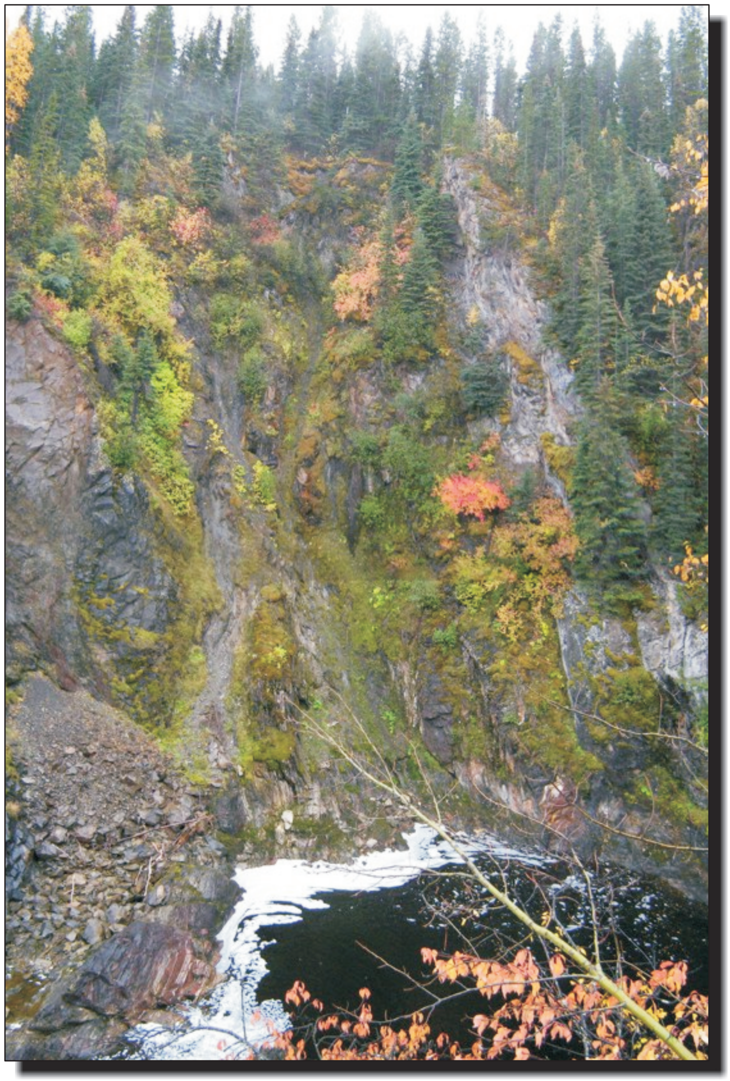

Photo 21
Shear zone downstream of drop off.

Photo 22
30 inch outlet at Regulating Outlet Structure in operation. Note the dam to the left of the structure.

Photo 23
Log booms upstream of the regulating intake structure.

Photo 24
Warning sign for regulating intake structure.

Photo 25
Warning sign on road before dam.

Photo 26
Warning sign for regulating intake structure. Note that sign says no unauthorized vehicles.

Photo 27
Warning sign for stairway access to Regulating Outlet Structure and Fulton River downstream of dam.

APPENDIX

APPENDIX A EBA TERMS AND 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 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.

3.0 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.

4.0 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.

5.0 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 judgmental 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.

6.0 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.

7.0 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.

8.0 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.

9.0 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.

10.0 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.

11.0 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.

12.0 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.

13.0 STANDARD OF CARE

Services performed by EBA for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practising under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

14.0 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.

15.0 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), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by EBA shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by EBA shall be deemed to be the overall original for the Project.

The Client agrees that 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. The Client warrants that EBA's instruments of professional service will be used only and exactly as submitted by EBA.

The Client recognizes and agrees that 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.

APPENDIX

APPENDIX B SUMMARY OF 1997 DAM SAFETY REVIEW RECOMMENDATIONS (SECTION 4.9)

References are made to page numbers in the 1997 DSR report for Fulton Dam.

4.9 SUMMARY OF RECOMMENDATIONS

This is a compilation of all recommendations made in Sections 3 and 4 of this report. Not all of these recommendations are necessarily Dam Safety concerns. However, some of these Operation and Maintenance concerns could become Dam Safety concerns if not addressed.

4.9.1 Further analysis and Investigation Recommendations

- Seismic Analysis – Further seismic analysis will be required to determine the magnitude of the MCE (Page 3.6).
- Failure Scenarios – Further study is required to determine if these scenarios are possible or need to be analyzed (Page 3.8).
- Seismic Assessment – Further seismic analysis based on comprehensive historic seismic data for the region is warranted (Page 4.31).
- Seismic Assessment – A more thorough examination of the earthquake analysis would be appropriate (Page 4.32).
- Foundation Tests – If foundations are randomly fractured, methods and programs should be established for determining strength data for critically oriented parts of the rock foundations (Page 4.38).
- Outlet Slope Stability – Further investigation and more detailed analysis of the stability of the slope adjacent to the Outlet Structure is recommended (Page 4.49).
- Trestle Survey – It is recommended that if sufficient existing information can not be found, then field investigations should be undertaken to collect the necessary information (Page 4.49).

4.9.2 Operation and Maintenance Recommendations

The following O&M recommendations are grouped by facility.

A) Fulton Dam

- No Spillway Work – No repair work is deemed necessary at this time (Page 4.6).
- Spillway wall leakage during spillway operation – It would be useful to inspect leakage at this location on the backside of the wall during spillway operation (Page 4.6).

- Overflow – No repair work is required at this time (Page 4.6).
- Abutments – No repair is warranted, but this area should be inspected particularly at high reservoir levels (Page 4.7).
- Plunge Pool Stability – Further assessment of the consequences of instability of the Plunge Pool should be addressed when the detailed stability analysis for the dam is undertaken (Page 4.8).
- Gate Leakage/Undermining – Some consideration should be made for either minimizing the gate leakage or possibly reinforcing the rock at this location so that the foundation does not eventually become undermined (Page 4.9).
- Terrain Mapping – It is recommended that terrain mapping of the reservoir rim using air photographs be carried out, followed by ground truthing only if areas of concern are detected during terrain mapping (Page 4.10).

B) Outlet Works

- Hoist Review – It is recommended that the entire system be reviewed to ensure is safe (Page 4.11).
- Chain Capacity/Wear – Chain load versus capacity should be checked by operation personnel and the chain should be replaced if the chain capacity factor of safety is below 6 (Page 4.11).
- Skin Plate Repair – An annual review of these defects should be made. A stainless steel (say E309) weld repair is recommended when the maximum depth reaches 3/8 inch (Page 4.12).
- Greasing the Rollers 0 the bearings could not be greased and replacement must be considered in the near future even though the wheel roller bearings still have alignment and rotation capability (Page 4.12).
- Seal Replacement – The possibility of the bottom seal being replaced by one having fabric reinforcement to stiffen the stem of the seal might be considered (Page 4.12).
- Minor Joint Seepage – None of this should be of concern at this time, no remedial action is required (Page 4.13).

C) Regulating Works

- Fan Break Test – Carry out the procedure for setting the rate of emergency closure to 7 f.p.m. under full flow conditions as suggested (Page 4.14).
- Bypass Gate Check – The condition of this gate should be checked more thoroughly when convenient (Page 4.15).

- Bypass Hoist Capacity Settings – To avoid damage by buckling of the operating stem during gate closure, the maximum pressure of the hoist equipment should not exceed the maximum safe compression load on the operating stem with reference to its support spacing (Page 4.15).
- Inoperative Equipment Removal – It is recommended that all inoperative equipment be removed from the facility (Page 4.15).
- Rock Scaling – The slope above and adjacent to the stairway can be expected to deteriorate quickly and should probably be scaled at intervals of not more than every 5 to 10 years. Accumulations of ravelled rock resting against the stairway or its support posts (noted in one area) should be removed periodically (Page 4.16).
- Vegetated Slopes – Possible reclamation with vegetation should be considered to minimize the potential rock fall and slide hazard to operations personnel (Page 4.16).
- Valve Concrete Repair – Some more extensive repairs to the concrete should be considered to avoid having to replace the reinforced concrete supports if further deterioration is allowed to occur (Page 4.16).
- Remove In-stream Wires – The inoperative control system for monitoring tunnel water pressures should be removed (Page 4.17).

D) Supply Tunnel and Pipeline

- Bypass Gate Leakage – The gate coating should be repaired, otherwise the entire gate will need major repair work in the future (Page 4.18).
- Watering Up – All bulkheads in the western (upstream) tunnel section should be checked on a yearly basis when the tunnel is watered up (Page 4.19).
- Replace Drain – The drain pipe should be replaced before it begins leaking (Page 4.19).
- Bulkheads – All bulkheads in the eastern (downstream) tunnel section should be checked on a yearly basis when the tunnel is watered up (Page 4.19).
- Cleaning Drains – Any blocked drain pipes in the eastern tunnel section should be cleaned to prevent build up of water pressures behind the lining upon tunnel drainage that could cause failure of the shotcrete lining or debonding (Page 4.20).
- Eastern Tunnel Drain Rehabilitation – If this drain system is required, it should be rehabilitated. If it is not required (i.e. pump tunnel out when required), then this system should be decommissioned by plugging it off permanently (Page 4.21).
- Eastern Tunnel Plugs – No repair work is required at this time (Page 4.21).
- Pipe Insulation – More repair work to the insulation is required (Page 4.21).

- Survey Monuments on the Pipeline – Frequent monitoring with survey monuments on the pipeline, the trestle supports accompanied by ambient temperature, pipeline, and water temperature should be done to determine if there is any significant movement of the pipeline over time (Page 4.21).
- Scour Survey – It is suggested that a survey of the river at the pipeline crossing location would be appropriate to verify that the pipe cover has not been scoured and is still adequate. Ground Penetrating Radar (GPR) Survey may be required to locate the buried pipe (Page 4.22).
- Pipe Flow Monitor – Non-intrusive form of flow measurement (clamp on ultrasonic) could be considered as a method for initiating the service gate closure or an alarm (at remote location) (Page 4.22).
- Beaver Creek Inspection – Recommended that the entire Beaver Creek channel be inspected yearly and that debris and potential obstructions in the channel be removed (Page 4.23).
- Slope Stability/Erosion Control – Although not an immediate concern, a surface drainage plan needs to be developed to stabilize the ravine slopes in the vicinity of the pipeline crossing for the long term (Page 4.23).
- Outlet Slope Scaling – It is recommended that the rock bluff be check scaled the next time scaling work is carried out on the slopes above the outlet structure (within 5 to 10 years) (Page 4.23).
- Soil Movement Relative to the Steel Piles – Past survey monitoring records which are understood to exist, should be reviewed and compared against results of a new survey (Page 4.24).
- Slope Erosion near Pipe – Should be ground proofed to check for any evidence of instability and assess the actual topographic and geologic conditions (Page 4.24).
- No Open Valve in Flood – The 30 m hollow-cone valve should not be opened at the river levels above el. 775.9 m (2,380 ft) (Page 4.36.).

APPENDIX

APPENDIX C BCMOE DAM SAFETY BRANCH TEMPLATES FOR PREPARING OMS MANUAL AND EPP

BRITISH COLUMBIA

GUIDE FOR PREPARING AN OPERATION, MAINTENANCE AND SURVEILLANCE PLAN

Dam Name: ______________________ *Water Licence No.:* ____________

Owner's Name: ____________________ *Phone #:* ____________________

Stream Name: ____________________ *Reservoir Name:* ____________________

Dam Location: ***Latitude:*** ____________ ***Longitude:*** ____________ ***Map Sheet No.:*** ____________

LIST INDIVIDUALS WHO ARE RESPONSIBLE FOR:

	Name	Title	Phone #
Operation:			
Maintenance:			
Inspections:			
Instrumentation:			

PHYSICAL DESCRIPTION:

Dam Height: ____________ *Dam Type:* ____________________

Length: ____________ *Crest Width:* ____________________

Reservoir Capacity: ____________ *Reservoir Area:* ____________________

Spillway Capacity: ____________ *Design Flood Inflow:* ____________________

Watershed Area: ____________ *Purpose of Dam:* ____________________

Consequence Classification: ________

ACCESS TO DAM: *(describe road access to dam from nearest center, attach map to this Plan)*

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LIST SIGNIFICANT STRUCTURES DOWNSTREAM OF DAM: *(i.e., access road, railroad, subdivision etc.)*

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