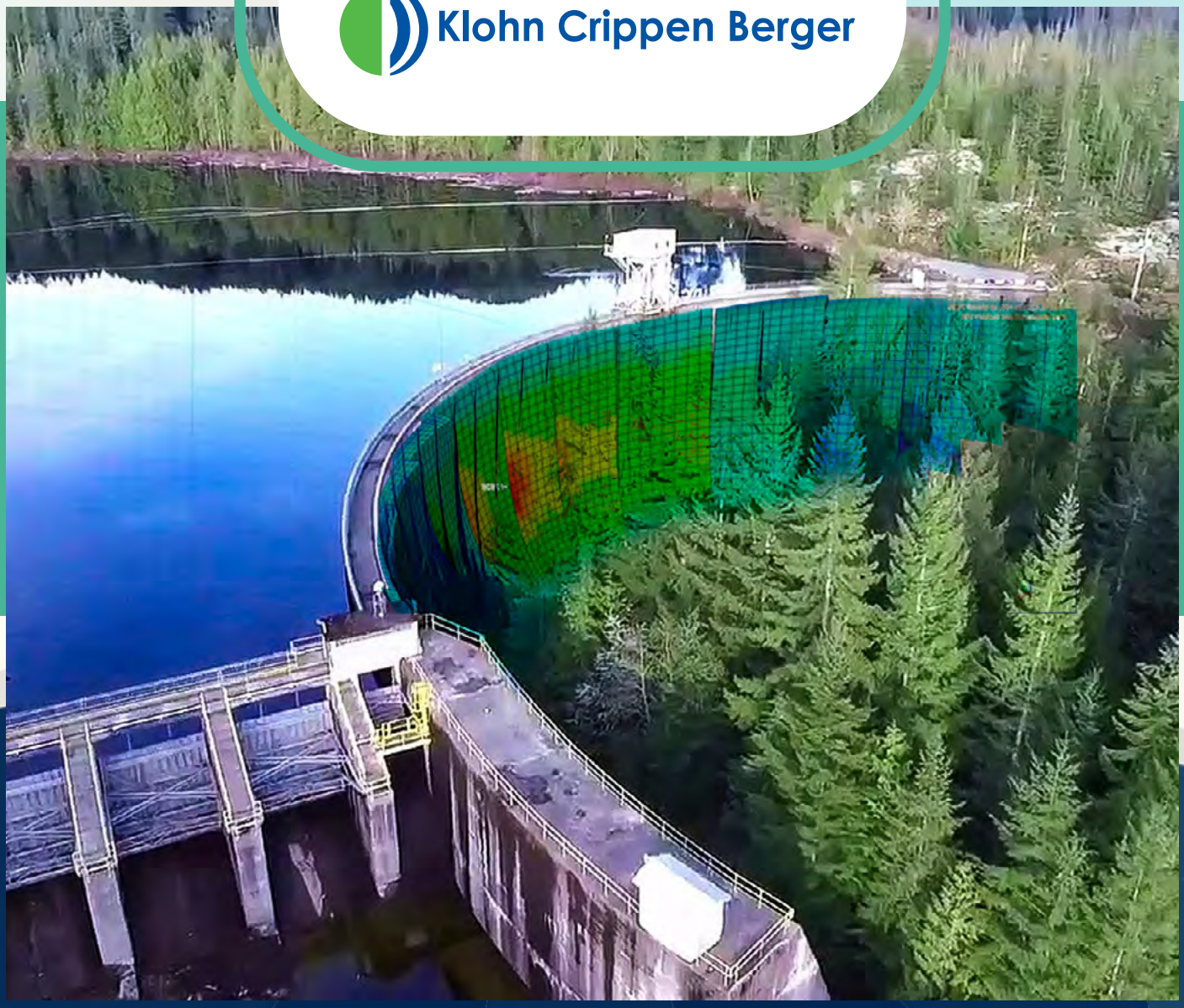
Klohn Crippen Berger



LOIS LAKE DAM STRUCTURAL EVALUATION

BC, CANADA

ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | CANADA

ASSOCIATION DES FIRMES D'INGÉNIEURS-CONSEILS | CANADA

AWARD SUBMISSION

Evolugen by Brookfield Renewable

CANADIAN CONSULTING ENGINEERING AWARDS 2020

Klohn Crippen Berger

500 – 2955 Virtual Way
Vancouver, BC
604.669.3800
www.klohn.com

CONTACT NAME	Sahar Pakzad
EMAIL	spakzad@klohn.com
TEL	604.251.8590
PROJECT NAME	Lois Lake Dam Structural Evaluation
LOCATION OF PROJECT	20 km south of Powell River, B.C.
YEAR COMPLETED	2019
CATEGORY OF ENTRY	F. Special Projects
ROLE IN PROJECT	Prime Consultant
PROJECT OWNER / CLIENT	Evolugen (by Brookfield Renewable)
PROJECT SUMMARY	Klohn Crippen Berger was retained by Evolugen in 2018 to conduct a complex engineering study to confirm the structural integrity of the Lois Lake dam, spillway and foundations. KCB used state-of-the-art earthquake engineering computer simulations. The dam's powerhouse provides clean electricity to a local mill that distributes its excess power to communities through the BC grid. The dam's safety is key to keeping the 14 km reservoir open to the public for recreational use.

INNOVATION

Lois Lake Dam is a double curvature concrete arch dam with a crest length of 200 m and a height of 59 m at the deepest point. Klohn Crippen Berger (KCB) was retained by the dam owner/client, Evolugen (by Brookfield Renewable), in September 2018 to conduct a structural performance study of the dam and spillway structures. Evolugen's objectives were to confirm the integrity of the dam, spillway and abutments during a potential earthquake.

KCB used advanced meshing and Finite Element simulation software to analyze the dam and spillway. The forces induced by the water and earthquakes, and the geology of each abutment, were considered. KCB verified the strength and stability of the dam and the spillway and obtained the dam's seismic response at the hoist tower. Contacts between vertical concrete contraction joints and between the structure and foundation were included in the model. KCB applied historic earthquake records to the model at the base of the foundation and used specialized simulation techniques to ensure proper propagation of the seismic waves.

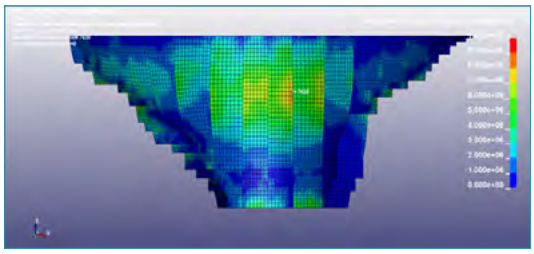
Another objective of this study was to estimate the earthquake response at the crest of the dam so that the resistance of the hoist tower at this location could be verified. KCB also verified the strength and stability of the spillway's concrete piers in order to verify that the spillway gates would be operational after the design earthquake.

KCB considered the construction sequence of the dam, locations of the expansion and construction joints of the dam, and conditions of the interface between the concrete and bedrock. Hydrostatic loads corresponding to seasonal levels of the reservoir and temperatures of the water were considered, as well as a set of earthquake records that were representative of the site and the dam safety classification.

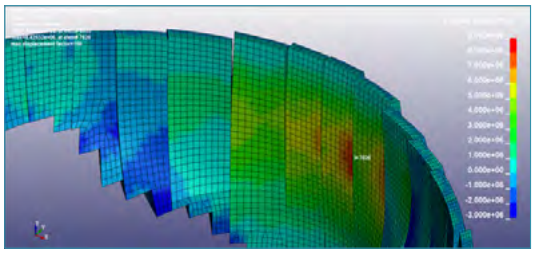
Initial simulations were done by another firm using more traditional state-of-the-practice simulation techniques, resulting in a more expensive seismic retrofit plan for the hoist tower. KCB performed similar simulations but used the latest state-of-the-art techniques and software for earthquake engineering of dams. KCB's simulations offered the client a cost-effective solution.

KCB also improved the original model by incorporating the construction sequence and concrete joint locations for more representative and reliable results. KCB used Civil 3D to model the dam in three dimensions. Once the model was completed, the structural engineering team was able to use it in their Finite Element simulations.

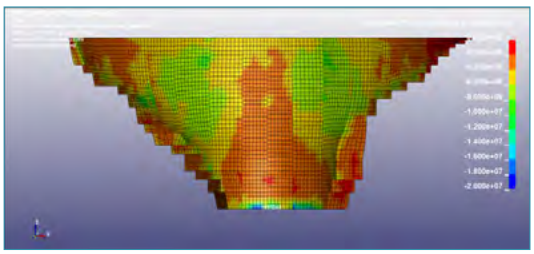
A thermal analysis was performed on the model of the arch dam to estimate the temperature distribution in the dam in summer and winter. This analysis was performed using the climatic data from the site.



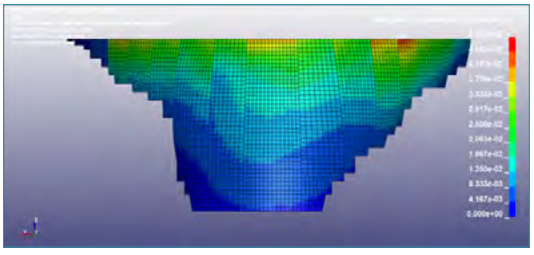
Envelope of tension in concrete,
Miyagi Oki Earthquake, maximum = 8.48 MPa



Maximum vertical stress and corresponding deflection
at time = 38.09 sec, Miyagi Oki Earthquake



Envelope of Compression in Concrete,
Maximum = 23.31 MPa, Miyagi Oki Earthquake



Envelope of Displacement in Concrete,
Maximum = 46 mm, Miyagi Oki Earthquake

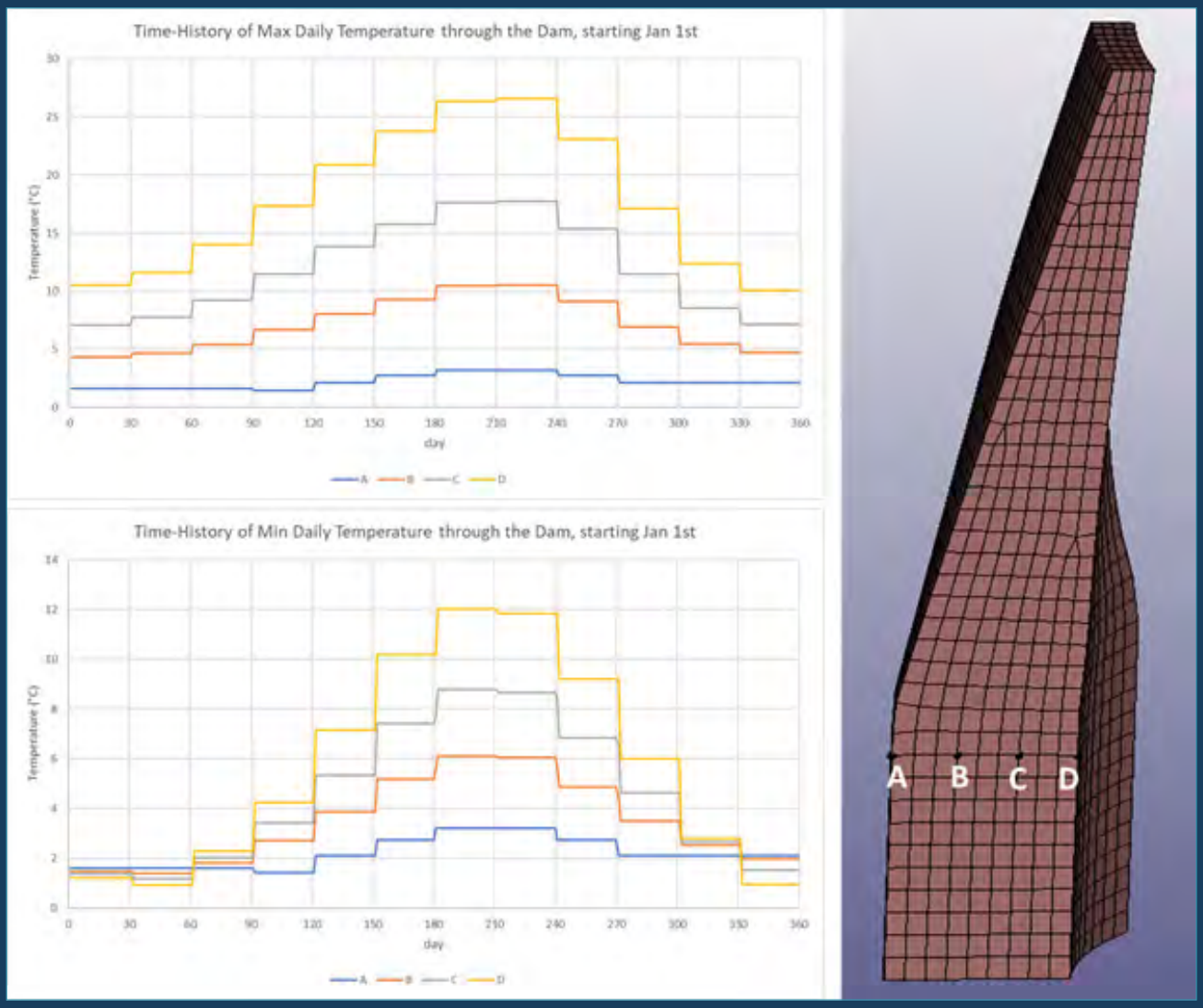
COMPLEXITY

Research and Development was required to overcome technical challenges in implementing the state-of-the-art solution using an advanced general-purpose simulation software. It was also challenging to model the complex, stepped interface between the concrete dam and rock abutments.

KCB had limited access to the surrounding rock foundations and therefore used historical information and engineering judgement to predict its physical properties. The historic drawings of the dam provided insufficient information. Therefore, site survey information and assumptions based on engineering judgement were also used to construct a representative model of the dam.

The rock foundation is shaped like a valley, which complicated the application of the earthquake records. In a unique solution, KCB back calculated the seismic waves at the depth of the foundation (deconvolution) and applied cyclic symmetry to the horizontal extents of the foundation.

Like many other complex simulation projects, this project had a slow and challenging start, especially regarding proper modelling of the foundation, dam, and spillway, and the R&D required to adapt a general-purpose simulation software for this specific type of simulation. However, good communication between KCB and Evolugen helped overcome initial challenges and the latter stages of the project proceeded smoothly.



Annual Variation of Nodal Temperatures through the Thickness of the Dam

Overview of the Lois Lake Dam facilities

SOCIAL AND/OR ECONOMIC BENEFITS

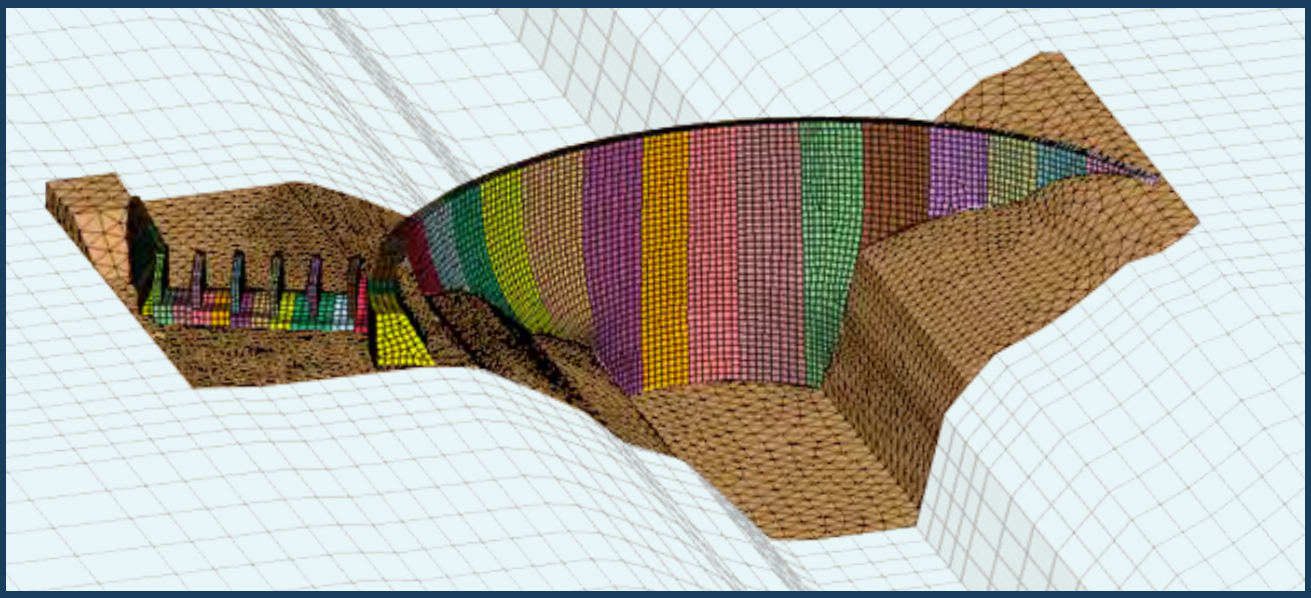
Lois Lake Dam's powerhouse provides clean electricity to a local mill that distributes its excess power to communities through the British Columbia grid. Maintenance and retrofit of the dam and its appurtenant structures increases the dam's lifespan and helps improve the local community's safety. Maintaining the dam and optimizing the retrofit effort has great economic benefits for both the dam's owner and the community.

The Lois Lake reservoir is close to the community of Powell River, B.C. Keeping the dam safe is key so that the 14 km-long reservoir of fresh water can continue to remain open to the public for recreational uses, including camping, fishing, boating, bird watching, bathing and sightseeing.

ENVIRONMENTAL BENEFITS

British Columbia's hydroelectric dams have contributed to reducing the impacts of a shifting climate for more than 100 years. Today, hydropower continues to be one of the best ways to meet society's demand for energy while also protecting the environment and reducing climate change.

Retrofitting the Lois Lake dam is a sustainable solution, because a new dam in a different location is not needed and the environment surrounding the existing dam is preserved. Evolugen also ensures that this dam remains safe and in compliance with safety regulations, and remains open to the public for recreational use.



Finite element model of Lois Lake Dam, spillway and foundation

MEETING CLIENT'S NEEDS

Evolugen had already obtained results of a sophisticated 3D simulation from other consultants. However, KCB proved throughout project execution that using the latest knowledge and simulation techniques produces more realistic and reliable results. This benefits the client significantly, because it optimizes the retrofit design and reduces costs.

Given KCB's engineering skillset and the company's renowned management, this state-of-the-art and highly complex simulation project was completed on time and within budget.

ASSOCIATION OF CONSULTING ENGINEERING COMPANIES | CANADA

ASSOCIATION DES FIRMES D'INGÉNIEURS-CONSEILS | CANADA

Klohn Crippen Berger

2020

AWARD SUBMISSION