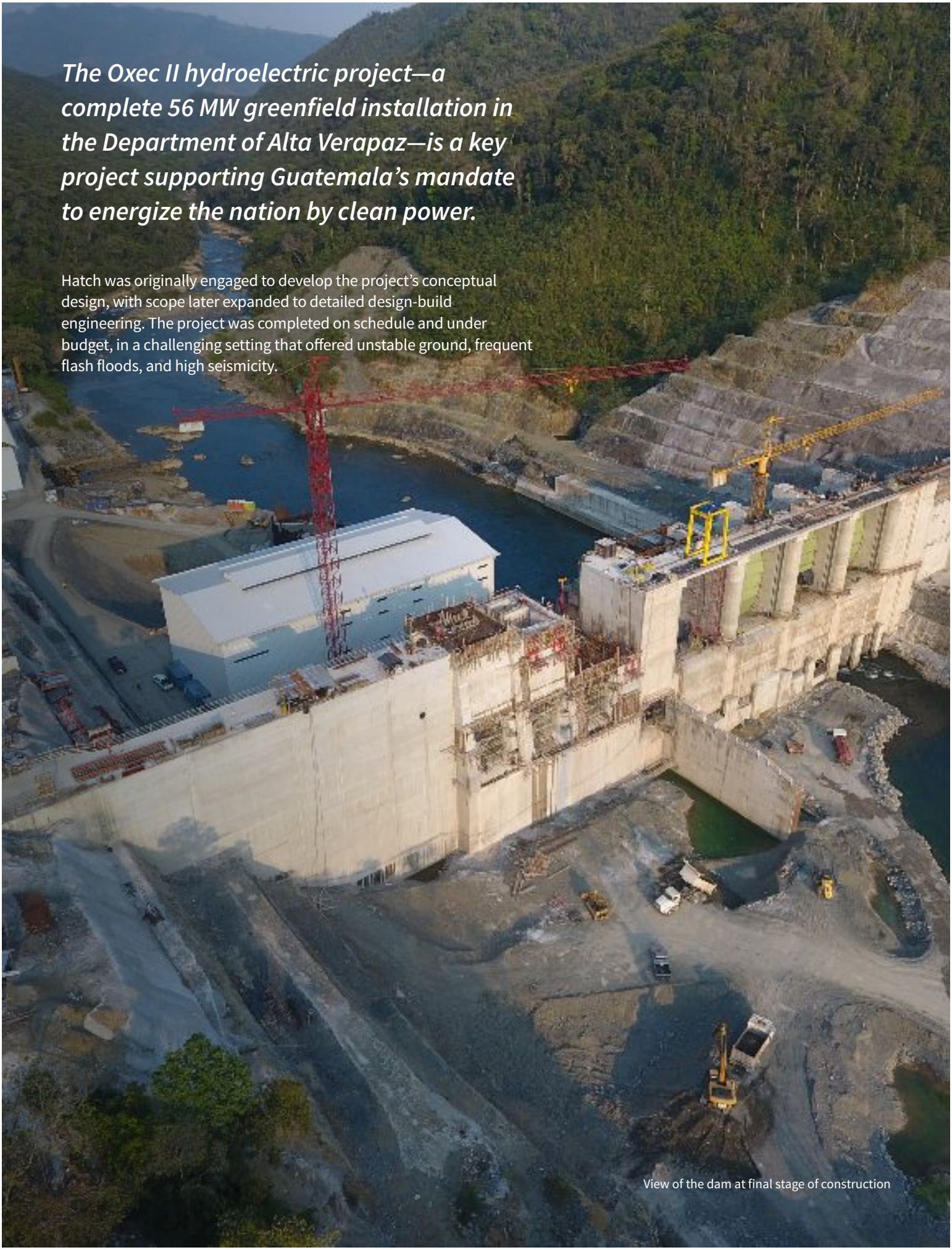
Oxec II Hydroelectric Project

2019 Canadian Consulting Engineering Awards

HATCH

The Oxec II hydroelectric project—a complete 56 MW greenfield installation in the Department of Alta Verapaz—is a key project supporting Guatemala's mandate to energize the nation by clean power.

Hatch was originally engaged to develop the project's conceptual design, with scope later expanded to detailed design-build engineering. The project was completed on schedule and under budget, in a challenging setting that offered unstable ground, frequent flash floods, and high seismicity.



View of the dam at final stage of construction

Project highlights

Innovation

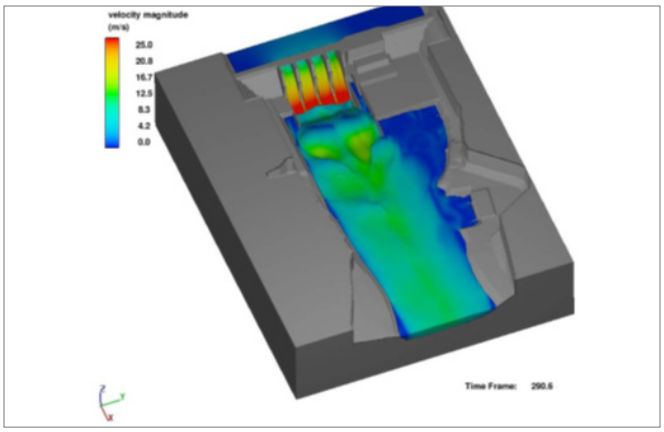
Oxec II is a relatively low head generating station with a concrete dam and spillway over 41-meters-high, with an overall crest length over 200 meters. The spillway is comprised of four bays, each equipped with a 12-meter by 17-meter radial gate. The powerhouse has three horizontal shaft S-type Kaplan units with a complete installed capacity of 56 MW.

The success of Oxec II hinged on the constructability and economy of the design. With that in mind, innovation was a necessity—every step of the way. Through Hatch's optimization efforts, an alternative layout was proposed to stakeholders with the purpose of reducing construction cost and improving design reliability. This approach was reflected in revising the diversion scheme, spillway design, intake block optimization, and overall construction methodology. Most notably:

- A two-stage diversion utilizing cellular cofferdams was proposed for temporary river diversion, this was in contrast of the original three-stage diversion using the embankment cofferdams outlined in basic design. Hatch's proposed plan addressed most of the concerns triggered by the limited footprint available for the temporary works where the revised diversion scheme offered improvements to the construction schedule, reliability of temporary diversion works, and onsite safety. The cofferdam (with 29 cells, measures nearly 300 meters in length and consists of 2,000 tons of steel and over 50,000 meters^3 of fill) was constructed in a period of less than four months. The cellular cofferdam, the first of its kind in Guatemala, exhibited high levels of reliability and safety during its installation and life in service, and offers a high level of control on release of sediment by providing an enclosed space isolated from the main river flow.

Stage 1 cellular cofferdam

- Innovation was also reflected in the design of the Spillway. The basic design included a stilling basin for energy dissipation, which was rather shallow and long with potential detrimental impact on the Oxec I powerhouse (immediately downstream of Oxec II). Hatch proposed a submerged roller bucket spillway for energy dissipation. This was a complex undertaking requiring 3D finite element analysis (FEA) to better determine the structural behaviour of the spillway subject to load, as well as additional hydrotechnical studies to determine the permissible depth for the roller bucket. The spillway's hydraulic performance under maximum design flood was also verified by a sophisticated CFD model, taking into account the three-dimensional features of the river bed and banks.



CFD model of the spillway

Spillway structure

In 2017, the innovative design of the cellular cofferdam was recognized by the Ontario Consulting Engineers, receiving an award of merit in the Industry, Energy, and Resources category.

Complexity

Faced with numerous obstacles, including unstable ground, frequent flash floods, and high seismicity, the Oxec II project presented challenges at every front. Additional risks associated with common high-magnitude flood conditions and in-water works were mitigated through the cellular cofferdam for river diversion.

Hatch provided several design details which improved the constructability of the permanent structures. The following are the highlighted examples:

- The radial gates at the Oxec II spillway are 12-meters-wide and 17-meters-tall. The hydrostatic load applied to each gate trunnion under normal operating conditions is equal to the thrust of a Falcon 9 rocket at take-off (~7.6 MN), making the trunnion anchorage one of the most critical components of the structure. Hatch adopted a design consisting of groupings of post-tensioned anchors which provide the necessary anchorage into the dam body, rather than the spillway piers.
- Part of Hatch's proposed diversion system included the very large conduits that were left in the main body of the spillway, set to be closed at the final step of the construction using concrete stoplogs. The closure planning had to consider the submerged weight of the stoplogs, the drag forces on the stoplogs, the capacity of the crane placing the final logs under fast flow conditions, and the frictional resistance of the logs against the guides. Detailed calculations and optimizations of the shape and aspect ratio of the concrete stoplogs led to a closure operation without incident.

Gate trunnion support structure and anchorage

Diversion conduit closure (left) and dam before impoundment (right)

Spillway and bottom outlet in operation during flood

Social and/or economic benefits

The Oxec II Generating Station will provide the country of Guatemala with 56 MW of renewable energy for the duration of its operating life. Furthermore, the facility will offer some measure of control during the rainy season, when the Cahabón River swells. The design includes a compensation flow pipe to provide for ecological river flow, even in dry conditions.

Local workforce in action

Guatemala is ripe for more hydroelectric facilities. Many of the features in the Oxec II project are unique in that region and have already set precedence for the future projects. This project further helped to strengthen the country's skills capacity, ensuring it is equipped for future ventures. Part of what made the project notable was that a cellular cofferdam had not been constructed before in Guatemala and the contractor's crew for the project had never worked on a project of this nature before. With zero experience, they built this magnificent structure in four months with no safety incidents. The owner was so thrilled with the result, that it is going to adapt a similar design for future developments, downstream.

The project represented a major source of employment for the local population. The contractor faithfully engaged local workers with every level of skillset and in various aspects of the project, including local roads and infrastructure maintenance throughout the project's construction. Construction of this scale provided a skill building opportunity for the workers, and a facility of this size will provide operations and maintenance jobs well into the future.

Environmental benefits

Hydropower by nature is green/renewable energy. Oxec II has supplied the region with 56 MW of green power reducing the nation's reliability on imported fossil fuels. The project design and adopted construction methodology included exceptional features with a view towards environmental protection.

Highlighted features include:

- In-water works generally involve significant release of fill and sediments into the river. Although special consideration is given to handling the earthworks in the water bodies, large quantities of fill can be released in the river particularly during the temporary works and cofferdam removal to the extent that it could change the river's regime. The cellular cofferdam designed by Hatch offered a high level of control on release of sediment by providing an enclosed space isolated from the main river flow. Additionally, the fill material was processed with a view towards removal methodology by limiting the maximum size of the aggregate to a certain size. Compared to similar projects in the region where significant sediment release occurs during cofferdam removals, this was considered a remarkable environmental achievement for the project and minimized the adverse impacts during construction.
- An uncontrolled environmental compensation flow pipe was designed to operate under varying headpond elevations and to maintain a minimum flow at all times.
- Concrete mixes for various structures were carefully designed and selected with view towards using less cement and more environmentally friendly blended cements, aiming to reduce the overall CO^2 footprint of the structure.

Meeting client's needs

Following the successful construction of the Oxec I hydroelectric project, Hatch was engaged to provide conceptual studies and engineering for the Oxec II hydroelectric project, which was later expanded to detailed design-build engineering.

Oxec II was delivered on schedule and under budget.

It should be noted that various features of the basic design, used for the EPC contract, were later assessed by Hatch as not economically viable. For example, the three-stage dewatering layout was estimated to extend the construction schedule by at least four months, adding a major step to the temporary dewatering works. Along with the large footprint of the embankment cofferdams and excessive bank excavation, this had the potential of terminating the project. Hatch's alternative—the cellular cofferdam—although initially received with skepticism (due to lack of precedence in the region) proved to be a major success.

Design optimization of the spillway structure and changing the stilling basin to a submerged roller bucket resulted in almost 40 percent savings in concrete volume of the spillway. Furthermore, the optimization of the intake block resulted in major cost savings—in material and simplified construction methodology.

Through value engineering clauses of the EPC contract, both project owner and contractor benefitted from the savings offered by Hatch's innovative designs. Hatch maintained its position as preferred engineer by both the owner and the contractor and continues to be engaged in the area by both—on existing and new projects.


Powerhouse interior view

HATCH