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The 98.5 MW Huanza hydropower project in the central Andean region of Peru, where a 2.7-km long steel penstock was constructed. Photo courtesy: Stantec

Conveying Water in Steep Heights:

Solutions for a Hydropower Project in the Andes Mountains

BY JOSE ALVOEIRO AND CARLOS CALDERARO

To increase the reliability of electric power supply for its mining operations, Peruvian mining company Buenaventura elected to develop a hydroelectric project in the Pallca River basin of the Andes Mountains in Peru, approximately 130 kilometers east of the capital city Lima. Water conveyance for hydropower in the high mountains of the Andes is often a technical challenge and, in many cases, can result in significant construction costs.

The Andes' steep terrain, unfavorable geological conditions, and restricted access conditions presented further challenges for a hydroelectric project in this area. This article describes the project's challenges, solutions and how learnings can be applied to similar situations that can benefit power companies, developers, and the engineering community in general.

What was the main driver or need for the project? And, why was a hydropower project needed in this part of the Andes?

In 2007, there was wide concern in Peru that the rate of growth of newly installed electric generation capacity was insufficient to meet the projected demand of energy. In addition, the country was experiencing sustained GDP growth of more than 5 to 6 percent per year. This was particularly relevant to the mining sector, which is among the largest consumers of energy in Peru as mining projects are developed. Therefore, Buenaventura implemented a plan to secure its own power supply for its growing mining operations of precious metals.

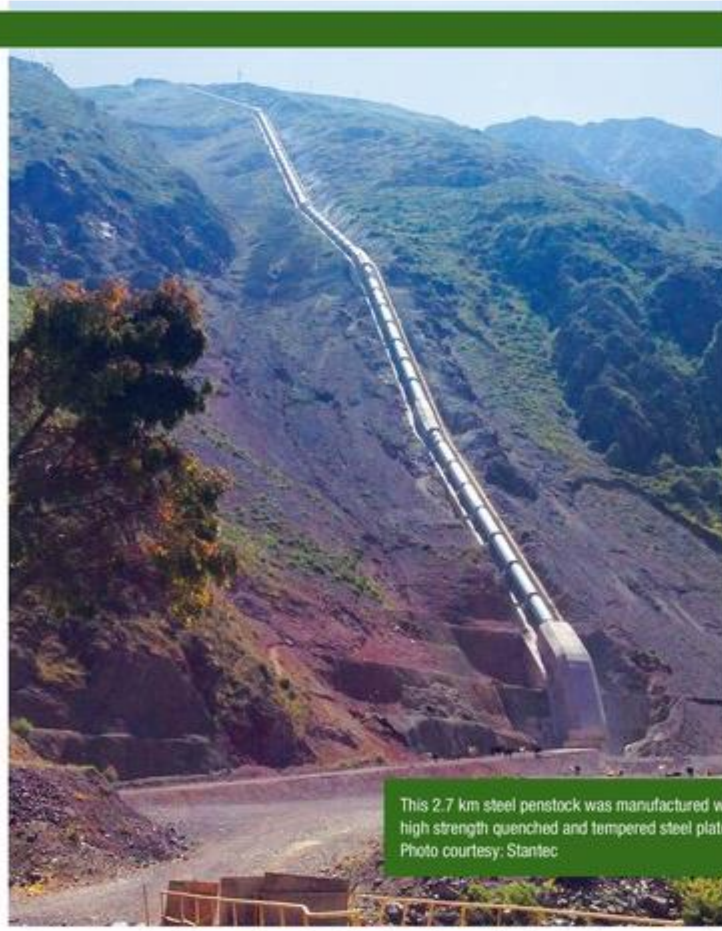
Hydropower was the best solution for the project due to its low environmental impacts and ability to generate clean and renewable electric energy. The project also needed to fully integrate into the Peruvian national power grid to supply power to Buenaventura operations scattered in other parts of the country. Buenaventura turned to Stantec, whose role on the project was to design a 40-meter high concrete gravity dam on the Pallca River and to develop a conveyance system for moving water 712 meters below to a powerhouse with two identical generating units. The Huanza Hydroelectric Project began in 2007 and commercial operation started in early 2014.

What design or construction challenges did the team face?

The Huanza Hydroelectric Project is set at a very high elevation varying from 4,100 meters at the water intake to about 3,350 meters at the powerhouse in a distance of about 12 kilometers. Although the high altitude was a challenge, the very high head combined with steep terrain and restricted access proved to be the biggest challenge of the project, and particularly for the steel penstock design. A detailed logistic plan needed to be laid out for concrete and steel parts, including the can sections of the penstock. With the first section of the water conveyance structure a tunnel, several access tunnels or construction adits were excavated by drill and blast to facilitate construction, hence material removed from the excavations was also considered in the plan.

The location for the powerhouse on the banks of the Pallca River was only accessible through a narrow and winding road that climbed the Andes up to an elevation of 4,100 meters. This elevation presented challenges of a higher altitude, steeper terrain and unfavorable ground conditions. As a result of these factors, optimizing the design of the water conveyance structure in the steep mountainous terrain was critical for the Huanza Hydroelectric Project's economic and construction viability.

In addition, safety was a top priority for the Stantec team. Living conditions were known to be quite difficult due to a high altitude and lower oxygen levels. Each employee assigned to work at the site would have a medical examination before ascending to the project site as a preventive measure and to look for any existing health conditions. In addition, only designated trained drivers were assigned to transport working staff to the site with clear communication protocols. Cell phone service was not available on site, so a dedicated radio frequency was utilized to coordinate vehicle traffic, especially when heavy trucks or off-road vehicles were operating on the access road.



This 2.7 km steel penstock was manufactured with high strength quenched and tempered steel plates. Photo courtesy: Stantec

How did the team overcome these challenges? Can you describe the design elements of the project?

After conducting the necessary surveys, geotechnical and materials investigations, hydrology and flood assessment and hydraulics and seismicity studies, the team needed to design a conveyance system from the Pallca reservoir to the powerhouse in variable ground conditions and changing elements. Stantec engineers designed a water conveyance system consisting of a low-pressure tunnel leading into a steel penstock.

As with most projects, unforeseen factors occurred during the construction phase, like navigating around existing archeological sites and limited access points. This resulted in an increase in the total length of the penstock. Despite the increased penstock length, Stantec engineers negotiated for a reduced product cost by working directly with the supplier of the steel plates for the penstock manufacturer – cutting back on costs that would otherwise have significantly increased the project budget.

The penstock was manufactured with very high strength quenched and tempered steel plates, using a specially designed gas-fired oven for stress relief. In the initial 700 meters, the penstock was exposed and installed in very steep terrain, and then it was buried in a trench excavated in soil along the winding access road.

In spite of the more difficult welding process and post-weld heat treatment, the material selection helped the project cost as the can sections weighed less, which better facilitated transportation and handling by cranes.

Stantec engineers optimized the design of the buried section to reduce the number of anchor blocks and to rely on the soil strength to withstand the forces resulting from changes in pipe bends, so as to reduce the amount of concrete and steel required.

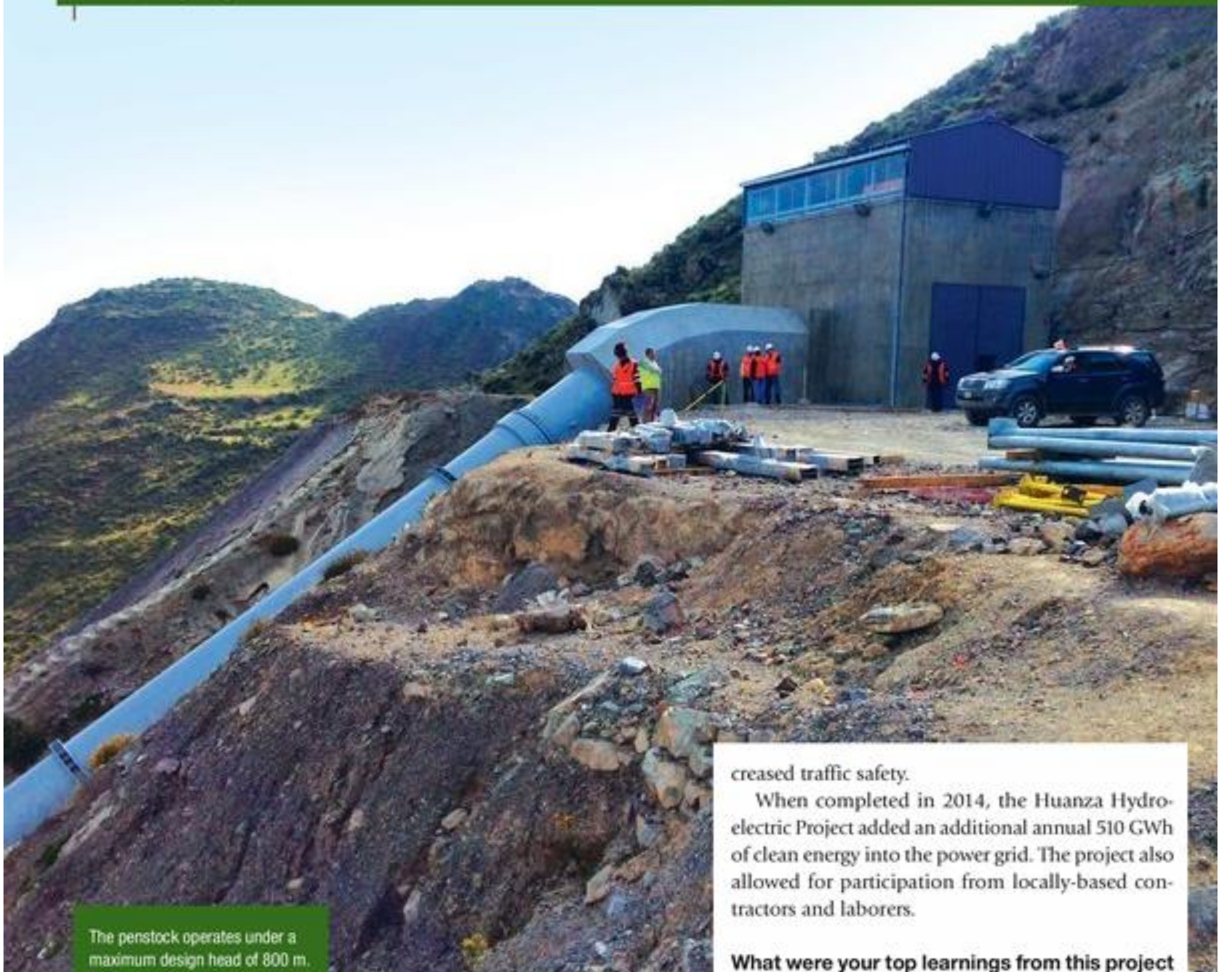
Did this approach lead to any other benefits for the project?

An optimized penstock design resulted in lower head losses for the project and was key in an increased project output reaching 100 MW capacity after final commissioning tests.

Can you describe the design process for the dam and powerhouse?

The team was responsible for designing a 40-meter-high conventional concrete gravity dam with a 205-meter-long crest, which accounts for a daily peaking reservoir storage volume of 543,000 m³ at the normal supply level of 4,063 meters. The dam also incorporated a 12-meter-wide free overflow spillway with a sky jump terminal structure and a low-level outlet structure.

The powerhouse was a concrete



The penstock operates under a maximum design head of 800 m. Photo courtesy: Stantec

structure with a steel roof and metal cladding containing two vertical shaft generating units with a total installed capacity of 55 MVA at the generator terminals.

How did the Huanza Hydroelectric Project benefit the nearby community?

The local community was involved with the project for more than 15 years and was very enthusiastic about improvement of the access roads, the hiring of local personnel during project construction, and the establishment of an annual fund for community improvements once the project started. Some of the community improvements included access road paving, improvements of bridges crossing creeks along the roads, road widening to accommodate larger vehicles, and increased traffic safety.

When completed in 2014, the Huanza Hydroelectric Project added an additional annual 510 GWh of clean energy into the power grid. The project also allowed for participation from locally-based contractors and laborers.

What were your top learnings from this project that could benefit other communities/power-generating companies facing a similar situation?

Early assessment of project sites can help teams discover an alternative penstock trace, like it did with the Huanza Hydroelectric Project. This is especially helpful in cases where there could be an environmental or archeological barrier.

In addition, specific design elements can help with project costs, like reducing the amount of concrete and steel by optimizing the penstock anchors in number and size; and reducing the weight of the steel cans by selecting a high strength material, which reduces the capacity and size of the lifting equipment.

Lastly, it's important to work in close collaboration with the project contractor. This ensures the project design is fully optimized and helps determine whether or not the team is able to use available local materials versus ordering materials that might have longer lead times and higher costs. pe