INTRODUCTION

Paul C. Rizzo Associates, Inc. is currently working with the Madagascar Ministry of Energy and Mines to complete the planning and conceptual design for the Volobe Amont Project in Madagascar.

The Volobe Amont (Upstream Volobe) Hydroelectric Project is currently conceptualized as a 60 MW run-of-river project owned and operated by the Government of Madagascar.

Paul C. Rizzo Associates helped to develop the concept for the Project, and is undertaking a Feasibility Study that is being partially-funded by the United States Trade & Development Agency, and also cost-shared between the Madagascar Ministry of Energy and Mines and Paul C. Rizzo Associates.

In cooperation with the project owner, three Malagasy engineers worked in the RIZZO offices in Pittsburgh, Pennsylvania to assist in the completion of the required studies and analysis, and to benefit from technology transfer and training while in the United States for four months.

The unique aspects of the project and the development process will be summarized in the paper, as well as a report on the experience of the Malagasy engineers working in the USA.

PROJECT DESCRIPTION

The Volobe Amont (Upstream Volobe) Hydroelectric Project site is located 30 kilometers west-northwest of Toamasina, the second largest city in Madagascar, and the largest shipping port on the Island.
The Project is currently conceptualized as a 60 MW run-of-river project owned and operated by the Government of Madagascar. Located on the Ivondro River, this project has the potential to increase the installed hydropower capacity in the country by more than 50 percent. Paul C. Rizzo Associates helped to develop the concept for the Project, and is undertaking a Feasibility Study that is being partially-funded by the United States Trade & Development Agency, and also cost-shared between the Madagascar Ministry of Energy and Mines and Paul C. Rizzo Associates.

1 The Energy Information Administration’s International Energy Tables indicate that Madagascar had 105 megawatts of installed capacity in 2004.
The current conception of the Project is to capture the Ivondro’s flow at a location approximately 11 kilometers upstream of the proposed powerhouse. A small dike, less than 10 meters in height, will be constructed across the river to allow adequate water depth for intake during seasons of low flow. This dike will not serve to create a reservoir, as it will be overtopped by the River’s flow during most times of the year. The water collected at the intake will be transported through a large-diameter tunnel, constructed by drill and blast methods, through rock strata between the intake and powerhouse sites.

The primary initial load for the hydropower development will be a proposed privately developed processing facility for the products of local mining operations. The processing facility will have a peak power demand of approximately 81 megawatts, currently planned to be provided by fossil fuel fired power plants. The Volobe Amont hydropower plant will offset a significant portion of the need for additional fossil capacity with clean, economical hydro-generated energy. In addition to the processing facilities, the Volobe plant will serve the increasing electrical loads of Toamasina, as well as some local rural electrification needs.
**UNIQUE INTERAGENCY COOPERATION**

As the project team sought funding on behalf of the Madagascar Ministry of Energy and Mines for a Feasibility Study of their 60-megawatt Volobe Amont Hydroelectric Project, some creative and innovative means were employed. The U.S. Trade and Development Agency (USTDA) agreed to fund most of the Study if the remaining costs were shared between the Ministry and RIZZO. Since the Ministry could not afford a significant monetary contribution, the project team suggested that they send three engineers to work in the Paul C. Rizzo Associates’ Monroeville, Pennsylvania headquarters for a period of four months. From the USTDA perspective, this proposed “knowledge transfer” presented an unprecedented and intriguing approach to solving a common problem. All parties agreed to this unique cost-sharing idea, and the appropriate agreements were reached.

In late October of 2005, a team from Paul C. Rizzo Associates traveled to Madagascar to begin the Feasibility Study for the Volobe Amont Hydroelectric Project. The team met with the Ministry of Energy and Mines and various other agencies in Antananarivo, then spent several days at the project site, located in a remote region of jungle, about 30 kilometers inland from Toamasina. The site visit included exploration of all relevant project features, GPS data collection, geologic interpretation, and hydrologic assessment. This initial reconnaissance indicated that Volobe Amont is a very attractive construction site from a geologic perspective.

After the initial field reconnaissance, the three nominated engineers from the Ministry of Energy and Mines were scheduled to spend four months working on the Project in Pittsburgh, PA, at the headquarters of Rizzo Associates. Vololonirina Ratsiranto is a hydraulic/civil engineer who consulted on several international hydroelectric projects. Augustin Randrianarivony is an environmental engineer, and Chief of the Environmental Unit of the Ministry of Energy and Mines. Francois-Xavier Rakotozafy is an electrical engineer who is the Chief of Transmission and Distribution of JIRAMA, the state-run utility in Madagascar. These three engineers brought important knowledge to the Feasibility Study team.

Vololona, Augustin, and Xavier arrived at the Pittsburgh International Airport on January 5, 2006. Their stay in Pittsburgh proved to be even more valuable to us than anticipated. Xavier evaluated several schemes for interconnection with the existing electrical grid, and provided a conceptual design for his recommended system. Augustin spent his time in the U.S. defining all the potential environmental and social impacts of the Project. Vololona brought an incredible knowledge of local engineering practices, making her the most important critical reviewer during conceptual design of the civil works.

This arrangement was also a success from their perspective. The Malagasy engineers had never been exposed to such a “structured” engineering environment, where research publications and computing power were so readily available. They had also typically focused on intense technical details, rather than on the “big picture” when approaching
engineering challenges, which proved to be the biggest difference between the two engineering cultures. In addition, since it was their first time in the United States, they were able to visit Washington, D.C.; Niagara Falls; the Saluda Dam in Columbia, SC; Gettysburg; the Chesapeake Bay Bridge-Tunnel; as well as everything that Pittsburgh had to offer, including a Steelers Super Bowl championship!

It would have been difficult to bridge the information gap that exists between the United States and a remote region in Madagascar, in order to conduct a relevant and accurate Feasibility Study. But by sharing thoughts and ideas with three talented local engineers, both sides were able to gain a much better understanding of the subtleties that will contribute to the overall success of the project.

CIVIL PROJECT LAYOUT AND ENGINEERING CONCEPT

Several alternative intake locations were investigated as a result of the site visit. The advantages and disadvantages were discussed at length with the project team, and the project concept will be based on an overflow spillway structure to be located upstream of the previously envisioned intake sites.

The intake structure will include an ogee-type spillway, with its length designed as such to sufficiently pass a 6,000 m³/s flood flow without prohibitive backwater effects.

The intake system will also consist of a gated tunnel entrance to be located upstream of the spillway. The ecological flow (3 m³/s) will be released through a gate in the spillway, at an elevation such that the water is adequately oxygenated.

This intake design was the most technically challenging aspect of the Project. Our three consultants indicated that debris and sedimentation are a major design challenge in their region. The Volobe Hydro Power Station, which exists downstream of the proposed site, requires hydromachinery rehabilitation every five years due to erosion.

With this in mind, debris and sedimentation became a significant issue. After deliberation, our project team determined that floating debris will be handled by diversion over the spillway. Settled debris will be flushed through a sluice gate to be located through the bottom of the spillway. Suspended solids will be given adequate time to settle, likely in sedimentation basins to be located between the river and the tunnel intake.

From the gated intake, a tunnel will extend approximately 4,900 meters to the powerhouse site. Significant groundcover for this tunnel alignment will allow the tunnel to extend directly to the powerhouse, reducing hydraulic losses associated with any bends. An Economic Diameter Analysis indicates that the horseshoe-shaped tunnel will be 6.4 meters in height and 3.4 meters in width.

A surge tank will also be necessary. It is envisioned to be located approximately 450 meters from the discharge site. A shaft will be drilled into rock, and a surge chamber,
approximately 18.5 meters deep and 18.5 meters wide, will be placed atop a local mountain peak above the tunnel.

It has been determined that the axis of our hydroelectric turbines must be located 4.5 meters below the minimum elevation of discharge in order to prevent cavitation problems. The powerhouse will house two Francis-type turbines, in addition to the generating and electrical equipment. The powerhouse will be contained mostly below-ground, and will be designed with hatch-type entrances on the top of the building only, so that it can be submerged under water during flooding.

**Power Generation Capacity**

Analysis of flow data taken at the nearby Ringaringa gauging station indicates a flow duration curve as seen on *Figure 1*.

![Flow at Volobe Amont Proposed Intake](image)

**FIGURE 1**

*FLOW DURATION CURVE FOR PROPOSED INTAKE*

Generation optimization analyses indicate that the Project should contain two (2) 30-megawatt Francis turbines. These 2 x 30MW units will provide average annual generation of 452 gigawatt-hours.
TRANSMISSION INTERCONNECTION / RURAL ELECTRIFICATION

In addition to evaluating several alternatives for transmission line routing, as well as implementing the interconnections to the various substations that are concerned, Mr. Rakotozafy has recommended a rural electrification component for the Project. The recommended scheme, shown on Figure 2, envisions 250KWA electrical power that will serve more than twenty villages and 5,000 people.

FIGURE 2
RECOMMENDED RURAL ELECTRIFICATION SCHEME

PRELIMINARY ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT

Mr. Randrianarivony completed a Project Idea Note (PIN) and the Clean Development Mechanism (CDM) memo, for issuance to the Ministry of Environment, as stipulated by the Project’s Terms of Reference.

Mr. Randrianarivony addressed many aspects of potential environmental impacts, including ongoing use of the Ivondro River, the impact of backing up a part of the River by constructing a spillway, excavation and tunneling considerations, emissions, various impacts to the populations, and many other items. Also, an environmental flow release was calculated (3 m³/s) and used to size the discharge gate through the spillway.
COST ESTIMATE AND FINANCIAL ANALYSIS

The cost estimate and financial analysis are currently being completed. Much input was provided by the three consultants related to the unit costs of certain construction activities. Additionally, the project team visited a large international hydropower machinery manufacturer, based in Pennsylvania. The input from this supplier will be used for estimating the machinery.

The financial analysis is being completed by members of the project team, who have also met with officials from the Inter-American Development Bank in Washington, DC, to discuss the Project and endeavor to establish the economic parameters and boundary conditions.

CONCLUSIONS

In conclusion, Volobe Amont appears to be a technically feasible and attractive project. Our Feasibility Study was met with several challenges, most notably the debris and sedimentation issues at the intake, and the natural difficulties that would arise in working in a remote, underdeveloped region of the world.

A unique approach was adopted to bridge the information and cultural gaps between our engineering consulting firm located in the United States, and the project owner located nearly 15,000 kilometers away in Madagascar. When the Ministry of Energy and Mines provided us with three highly-qualified Malagasy engineers who were dedicated to the success of the project, we were able to share knowledge and experience with each other. This transfer proved to be a significant benefit for two main reasons: first, it allowed for a much more efficient Study, where ideas and concerns were voiced between client and consultant in real-time; and second, we formed good relationships with each other that will be of great importance as we work together for the duration of this Project.

Author Profiles

**Mike Edwards** is a Project Engineer with Paul C. Rizzo Associates, Inc. in Monroeville Pennsylvania, USA. Mr. Edwards received a B.S. degree from Carnegie Mellon University in Civil Engineering in 2002. Mr. Edwards works primarily on hydropower projects and dams worldwide, with specialized expertise in the development of pumped-storage schemes. Mr. Edwards served as the Project Manager for the Volobe Amont Study.

**Melvin Koleber, P.E.** is a Project Manager and Director of Sales and Marketing for Paul C. Rizzo Associates, Inc. Mr. Koleber received a B.S. degree in Civil Engineering from the University of Colorado in 1980. Mr. Koleber has extensive experience with hydropower development, primarily in North and South America, including planning and design of new hydropower plants and dams, and rehabilitation of existing plants.