

Hydro-Agricultural Engineering in Rwanda



2012 CANADIAN CONSULTING ENGINEERING AWARDS

International

MUVUMBA PERIMETER 8 IRRIGATION SCHEME DEVELOPMENT (4 DAMS, 1 CANAL) ON 1,500 HA



ASSOCIATION OF CONSULTING ENGINEERING COMPANIES CANADA ASSOCIATION DES FIRMES D'INGÉNIEURS-CONSEILS CANADA



As part of its policy and its fight against poverty, the government of Rwanda instructed the Ministry of Agriculture and Animal Resources (MINAGRI) to launch a comprehensive rural development program for the sustainable development of wetlands. This proposed development of the irrigation schemes of the marsh and Muvumba River aims to increase agricultural production in rural communities, allowing them to achieve food self-sufficiency.

The development of the Muvumba perimeter is also designed to allow a double cropping of rice in an area of 1,500 ha. This crop will be secured by the construction of a diversion dam at the head, and by three dams with distributing reservoirs fed by a 27 kilometer canal, allowing distribution of water into the rice fields.

When CIMA+ International was mandated to conduct the preliminary design studies, the final design studies and the environmental impact assessment, at that point, no engineering study or pre-feasibility study had yet been conducted on the Muvumba perimeter.

CIMA+ International first conducted the data collection, identified and located the various hydraulic structures (dams, main canals, etc.) and arable land to be irrigated. It was necessary to prepare the plans and profiles of the hydraulic structures, of the canal and perimeter, and assess the costs of the options under consideration. CIMA+ International also conducted the hydraulic, geotechnical, environmental and soil studies, and the required topographic surveys.

In the absence of hydrological data and flood discharge values for the Muvumba River, to the right of the site where the diversion dam is located, CIMA+ International had to use reference stations and flood marks on the trunks of trees on which we conducted topographic surveys.

CIMA+ International then conducted an analysis of key inputs and studied several variants of the project. The engineers had to find the best solution to mobilize the waters of the Muvumba River and ensure the irrigation of the rice fields, using a canal and compensating reservoir-dams. The storage dam sites had to be defined to irrigate all the arable land along the 27 km perimeter. The engineers also had to design culverts that would allow the population living on the hills, overlooking the perimeter, to cross the canal.

In six months, CIMA+ International prepared the plans, the specifications and estimates for the development works, including a diversion dam, three compensating reservoir-dams and a 27 km long canal for water transfer and distribution, with nine road crossing culverts.

Given the importance of the flows and seasonal flooding of the Muvumba River and to ensure a safe diversion dam, our engineers developed a combined structure consisting of a central concrete spillway and two earth dikes on the left and right banks. The total length of the diversion dam is 215 m; its central concrete spillway includes a Creager shaped threshold of 30.70 m long and 4.45 m wide to evacuate the projected flood (95 m³/s). At the foot of the spillway is an energy stilling basin of the discharged waters measuring 10.65 m long and 33.50 m. The spillway has a bridge measuring 1.80 m wide and 39.20 m long with a base made of 0.15 m thick reinforced concrete slabs, resting on the side and intermediate walls which divide the lots. The bridge is equipped with two rows of guard rails measuring 1 m high, made of poles and steel pipes. CIMA+ International designed the entire project to minimize contingencies during construction. We coordinated and conducted field studies (topography, geotechnics, pedology).

With its experience in Rwanda and upon the client's request, CIMA+ International optimized the studies and implemented a design for the structures that promotes the execution of the works by local workforce using the labor-intensive method. In all the studies conducted in this project, CIMA+ International always had in mind to optimize both the direct costs of construction and maintenance costs expected after the commissioning. In this case, the optimization effort resulted in the selection of simple solutions for the operation of the structures (gates, cofferdam, etc.).

The need to design mobilization and water transfer structures in a swampy bush forest was the greatest challenge in this project. From a geotechnical standpoint (bankseats and foundations), the construction of a reinforced concrete gravity dam and earth dikes in wetlands was indeed very complex.

To render the project technically feasible and economically viable, the design of the structures and the choice of materials were carefully studied in the plans and specifications. The environmental impact proved to be important for a sustainable development whose goal is rice production, a non-traditional crop in Rwanda, over two seasons per year and enable the sustainability of cattle breeding in the area.

Having prepared the plans enabled CIMA+ International to master all the technical issues and complete the project on time. The verification of the foundations of the compensating diversion dams was conducted from the onset of the excavations; just as was done for quality control and quantity control of the construction materials. At the start of construction, the geotechnical engineer had to be on site almost full-time.

In November 2011, a month ahead of schedule, the completion of the central spillway of the dam on the left bank made it possible to successfully divert the Muvumba towards the dam. Thus began the water transfer into the main canal and the filling of the reservoirs of the compensating dams.

The Muvumba project became the "pathfinder project" of Rwanda in the field of sustainable rural development. The President of the Republic of Rwanda gave great importance to this project and visited the site in person. The President was kept regularly informed on the progress through the MINAGRI.

Designing and building structures in wetlands allows CIMA+ International to showcase its experience and expertise, having successfully managed to create a set of hydraulic structures well adapted to site conditions and use materials available on site to minimize construction costs.

Overall, this project has facilitated the transfer of knowledge between designers and the people working on the site. Finally, it is the contractor and the RSSP/MINAGRI together who have benefited from CIMA+ International's experience in carrying out major sustainable rural development projects. We can say that the image of Canadian consulting engineering in Rwanda is thereby improved once again, and this further strengthens our commitment to develop excellence in executing our mandates both here and abroad.

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1. ENGINEERING CONSULTANT'S APPROACH

1.1 SELECTION PROCESS

As part of its policy and its fight against poverty, the government of Rwanda instructed the Ministry of Agriculture and Animal Resources (MINAGRI) to launch a comprehensive rural development program for the sustainable development of wetlands.

This proposed development of the irrigation schemes of the marsh and Muvumba River aims to increase agricultural production in rural communities, allowing them to achieve food self-sufficiency. The Rural Sector Support Project (RSSP) is a body of the MINAGRI, responsible for managing this project. The development of the Muvumba perimeter is designed to allow a double cropping of rice in an area of 1,500 ha. This culture will be secured by the construction of a diversion dam at the head and by three dams with distributing reservoirs fed by a 27 kilometer canal, allowing distribution of water into the rice fields of the irrigated perimeter of Muvumba.

As a result of an international request for expressions of interest and its strong technical expertise in sustainable rural development in Africa, CIMA+ International was mandated to conduct the engineering study for the execution of the hydro-agricultural works on the perimeter of the Muvumba valley, in the District of Nyagatare, in Rwanda.

The studies and invitation to tender documents prepared in 2008 by CIMA+ International enabled the MINAGRI to launch

two international consultations for the construction of the Muvumba irrigation schemes. In July 2010, CIMA+ International was entrusted with supervising the works for a period of 19 months. CIMA+ International was chosen from five consulting engineering firms: SHER (Belgium), SCET (Tunisia), STUDI Int. (Tunisia), SNC-LAVALIN Int. Inc. (Canada), and LOTTI & ASSOCIATI (Italy). The works, planned over 18 months, were entrusted to the Indian firm SPENCON.

1.2 PARTICIPATION IN PROJECT IDENTIFICATION

The Muvumba marshes, located in wetlands, are not being used to their full potential in terms of agriculture, as is the case with all of the Eastern Province. Given its grass cover, the marshes are used as pasture.

When CIMA+ International was mandated to conduct the preliminary design studies, the final design studies and the environmental impact assessment, there had been no engineering study or pre-feasibility study conducted on the Muvumba perimeter.

CIMA+ International first conducted the data collection, identified and located the various hydraulic structures (dams, main canals, etc.) and arable land to be irrigated. It was necessary to prepare the plans and profiles of the hydraulic structures, of the canal and perimeter, and assess the costs of the options under consideration. CIMA+ International also conducted the hydraulic, geotechnical, environmental and soil studies, and the required topographic surveys.



In the absence of available hydrological data and flood discharge values for the Muvumba River, which runs to the right of the site where the diversion dam is located, we had to make use of reference stations and flood marks on the trunks of trees, on which we conducted topographic surveys.

CIMA+ International then conducted an analysis of key inputs and studied several variants of the project. The engineers had to find the best solution to mobilize the waters of the Muvumba River and ensure the irrigation of the rice fields using a canal and compensating reservoir-dams. The storage dam sites must be defined to irrigate all the arable land along the 27 km perimeter. The engineers also had to design culverts that would allow the population living on the hills overlooking the perimeter to cross the canal. In six months, CIMA+ International prepared the plans, the specifications and estimates for the development works, including a diversion dam, three compensating reservoir-dams and a 27 km long canal for water transfer and distribution, with nine road crossing culverts.

Participation in the preparation of the project was crucial to ensure that the future irrigation schemes of the Muvumba were designed with sustainable rural development in the region and the fight against poverty in mind.



1.3 PARTICIPATION IN PROJECT DEFINITION

The development of the perimeter was to be designed to allow rice crops over two seasons, secured by the design of mobilizing and storage structures and a water transfer and distribution system over the entire perimeter (27 km).

Starting from only the national development plan and a delineation of the development area, CIMA+ International has truly defined the project. The engineers designed structures adapted to the topographical and geotechnical elements and the characteristics of this marshland in Muvumba, all this within the deadline.

Given the importance of the flows and seasonal flooding of the Muvumba River and

to ensure a safe diversion dam, our engineers developed a combined structure consisting of a central concrete spillway and two earth dikes on the left and right banks. The solution proposed by CIMA+ International to place a weir in the central axis of the dam would make it possible to bypass a structure on the left bank, which would have interfered greatly with water transfer in the canal, and plan for a long concrete chute on the right bank to link to the Muvumba River.

The total length of the diversion dam is 215 m; its central concrete spillway includes a Creager shaped threshold of 30.70 m long and 4.45 m wide to evacuate the projected flood (95 m³/s). An energy stilling basin of the discharged waters measuring 10.65 m long and 33.50 m wide sits at the foot of the spillway. The spillway has a bridge measuring 1.80 m wide and 39.20 m long with a base made of 0.15 m thick reinforced

concrete slabs, resting on the side and intermediate walls which divide the lots. The bridge is equipped with two rows of guard rails measuring 1 m high, made of poles and steel pipes.

As for the embankments of the diversion dam, they are located on either side of the sidewalls of the spillway crest, where they

> extend all the way to the hills on which they are rooted; they measure 68 m long on the right bank and 98 m long on the left bank. These homogeneous dikes, made of clay soils, are 4.51 m high and 4 m wide at the crest. The crest is covered with a layer of 20 cm of laterite upstream. The upstream and downstream slopes of the dikes have slopes of 2/1. The upstream slope protection against erosion is provided by a dry riprap of 0.10 m to 0.20 m in diameter, placed by hand on a gravelly sand

filter, while the grass cover of herbaceous species very common in marshes and resistant to drought protects the downstream slope.

The diversion dam, located between the spillway crest of the dam and the embankment of the dam on the left bank, will function as a regulator and run-of-river. It will be equipped with a guard and two gates.

The main canal, located on the hillside, is 27 kilometers long and dominates the water expanses of the three storage dams and intakes of the distribution channels in the perimeter. The canal crosses the valley, where it is located in an area of soil fill measuring 262 m and is covered with a stone masonry. The remainder of the canal, on a length of 26.7 km is made entirely of non-surfaced excavated material.



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area, CIMA+

The canal has a trapezoidal cross section, decreasing from one section to the other based on the water flow to be transferred to irrigate the remaining area; its two slopes are streamlined to have a slope of 1/1.

The main canal is equipped with all the necessary structures (desilting structure, cofferdams, drop structures, culverts, safety and spillway structures, and canals to distribute water to the perimeter).

The trapezoidal desilting basin measuring 7 m wide and 27 km long, acts as a decanter for the sediments. Timber-plank cofferdams are placed across the canal 1 m immediately downstream of the secondary intake canals.

Nine (9) culverts, each made up of a 9 meters long, 5 meters wide and 35 centimeters thick concrete slab, cross over the main canal at the crossing points, close to the nearby towns.

There are three irrigation flow compensating reservoir-dams on the axis of the main canal. Each consists of a homogeneous dike made of laterite clay. The slopes are 2.5/1 for the upstream slope and 2.0/1 for the downstream slope. The crest of the dikes, measuring 4 m wide, will be protected by 20 cm of laterite. Protection against erosion of the slope upstream of the dikes is ensured by a dry riprap of 0.10 to 0.20 m in diameter, placed by hand on a gravelly sand filter meanwhile, the downstream slope is protected by a cover crop. The existing materials in the basins of the reservoirs provide full sealing.

These storage dams are equipped with a spillway, a water intake from the main canal to the reservoir, and an intake providing water to the perimeter. Flood flows are discharged from 2.21 m³/s for dam No. 1, from 4.13 m³/s for dam No. 2 and 2.69 m³/s for dam No. 3. Control of the filling of the reservoirs will be done using a water intake on entry.

The 1,500 ha perimeter of the marsh to be irrigated is divided into three (3) areas that extend over 27 km along the Muvumba River and on a width varying from 200 m to 800 m. Each area is sub-divided into irrigation sectors and worked on based on the land to be irrigated by a small number of operators.







1.4 PARTICIPATION IN THE EXECUTION AND IMPLEMENTATION PHASES

CIMA+ International designed the entire project to minimize contingencies during construction. To do this, the firm coordinated and conducted field studies (topography, geotechnics, pedology). With its experience in Rwanda and upon the client's request, CIMA+ International optimized the studies and implemented a design for the structures that promotes the execution of the works by local workforce using the labor-intensive method. In all the studies conducted in this

project, CIMA+ International always had in mind to optimize both the direct costs of construction and maintenance costs expected after the commissioning. In this case, the optimization effort resulted in the selection of simple solutions for the operation of the structures (gates, cofferdam, etc.).

While executing the mandate, the professional competence of CIMA+ International, its experience in agricultural engineering, and the previous successful completion of five similar projects for the RSSP/MINAGRI were governing factors in its designation as the project owner and have made this firm a partner of choice.

For either engineering purposes or to reduce cost, CIMA+ International had to adapt the plans to the new field data revealed during excavations on the dams. To ensure that the contractor would deliver safe and high quality structures on time, consistent with its project design, CIMA+ International recommended dividing the construction into five separate lots: Lot 1: Diversion dam and its spillways and water intake

Lots 2, 3 and 4: Three dams and their appurtenances

Lot 5: Main canal and its nine culverts

With regards to the work schedule for each lot, CIMA+ International insisted on publishing the commissioning and correction of deficiencies phases.

With a highly qualified resident team, led by an experienced Engineer/Head of Mission, and supported by a Project Manager

at headquarters specializing in dams, mandated with monitoring the strict quality standards, deadlines and project costs, CIMA+ International participated proactively in the execution of each step of the project and provided full supervision of the irrigation schemes, despite their spatial spread (27 km). All customer expectations were met, and the work was done according to CIMA+ International's strict quality standards.

In its final design, CIMA+ International came up with a design promoting the use of the laborintensive method for the construction phase.

CIMA+ International spared no effort to provide ongoing and efficient support to the requests made by the contractor to implement this method.

The close collaboration between the Control Mission team and the technicians and officials from the RSSP/ MINAGRI on the one hand, and with the technicians from the contractor on the other, we were able to build quality infrastructures on time and on budget.



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2. HUMAN RESOURCES MANAGEMENT

2.1 CHOIX DES RESSOURCES

The challenges of the irrigation schemes of the Muvumba River perimeter required the implementation of a team of experienced engineers, both for the studies and the site supervision.

CIMA+ International put together an experienced team, responsible for preparing the plans and specifications, under the supervision of Dr. Hamidou Mamadou Abdou, Engineer/Dir ector and Dr. Nacer-Eddine Zerrouk, Engineer/Project Manager at our headquarters in Canada. This team has a comprehensive knowledge of Rwanda and extensive experience in irrigation

scheme studies. On site, the team was led by Mr. Harouna Boukari, Chief Engineer for this mandate. The team of engineers (geotechnical engineers, agronomists, environmentalists and topographers) delivered a design well suited to the harsh conditions of these wet and swampy areas.

For the supervision phase, CIMA+ International assigned the same geotechnical engineer who took part in the studies; a professor and head of the geotechnical laboratory at the National University of Rwanda (NUR). CIMA+

International understood that the integration of resources from Rwanda and/or from the region would have a positive effect on team motivation and synergy.

In all its projects, and this one in particular, CIMA+ International enables its technicians to use all their supervision and monitoring skills and provides, where appropriate, assistance to the contractor. However, the technicians had to be vigilant to carry out the work in accordance with the drawings approved by the Control Mission. The Head of Mission held a weekly meeting with the team to discuss the difficulties of the site and give the necessary instructions; he visited each work station daily in order to supervise the technicians and get their feedback.

The challenges of the site were often examined in a tripartite committee which was attended by the Head of Mission from CIMA+ International, the Technical Assistant and Project Coordinator from the RSSP/MINAGRI as well as the works supervisor and the director representing the contractor. The cohabitation of team members with a wide range of experiences enabled greater knowledge transfer between the client's representatives and our staff.

The Head of Mission's experience with earth dikes and concrete structures was particularly useful during the construction of the diversion dam (joint structure), where the placement of the earth when coming into contact with the concrete required a careful compaction to avoid infiltrations between the ground and the concrete.

2.2 MOBILIZATION

The implementation of a permanent team and external experts from CIMA+ International alone could not guarantee a sense of belonging to the project. At CIMA+ International we wish to promote synergy among all our team members thus, the mobilization of team members is at the core of the creative momentum required for the project's success.

To ensure consistent understanding of client expectations, to enable the client to keep an eye on the progress with the project and to fully mobilize the resources, CIMA+ International planned weekly meetings on site between the Head of Mission, the geotechnical engineer, the works supervisor and the contractor's director, the **RSSP/MINAGRI Project Coordinator and Technical** Assistant. To promote a sense of belonging to the project, CIMA+ International made sure to maintain a climate of greater cooperation between the site supervision team and the contractor. At the very beginning, after mobilizing

the Head of Mission, CIMA+ International held a kick-off meeting with the RRSP/MINAGRI during which the team members were introduced.



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CIMA+ International

2.3 MOTIVATION

The best way to meet the engineering and construction challenges of the project was not only to create a sense of belonging, but also to preserve the utmost interest and motivation from everyone involved.

From the beginning of the mission, a great complicity was created between all team members. All members of the supervision team resided in the town of Nyagatare, 10 km from the site, which facilitated meetings and daily interaction.

The meetings became indispensable; they were held over the weekend around a team dinner where various topics were discussed, such as the success of the project, the team goals and personal expectations. These meetings also helped mark the end of various stages of the project (end of the digging of the canal, diversion of water from the Muvumba River, etc.).



Organized Site Visit

Guided tours were organized by the Head of Mission in conjunction with the client to explain the purpose of the proposed Muvumba project to future beneficiaries of the agricultural cooperatives. At the request of the MINAGRI, the project was presented to college and university students from across the country, led by the Head of Mission and his supervisors. These visits were a source of great pride for our team. These visits provided greater visibility for CIMA+ International and allowed the firm to show its expertise in sustainable development projects; this in itself was very motivating for the team.

The Project Manager visited the site on numerous occasions, especially during the critical stages to ensure that the team was working well and also to ensure that they were in good spirits. As for the Director, he also visited the site to ensure that the project was running smoothly. The visits of these officials from CIMA+ International always included meetings with the Project Coordinator (RSSP/MINAGRI) and the contractor's director. These visits greatly motivated team members, who felt supported and valued.



3. CHARACTERISTICS OF THE PROJECT

3.1 COMPLEXITY

The need to design mobilization and water transfer structures in a swampy bush forest was the greatest challenge in this project. From a geotechnical standpoint (bankseats and foundations), the construction of a reinforced concrete gravity dam and earth dikes in wetlands was indeed very complex.

The construction of irrigation schemes in the Muvumba River perimeter was also complicated because they are spread over 27 km. The project involved building a diversion dam to divert water from the Muvumba River and, using a canal, to irrigate a 1,500 ha perimeter and fill three compensating storage dams. The supervision of such a complex project was a challenge in itself for the team.

To render the project technically feasible and economically viable, the design of the structures and the choice of materials

were carefully studied in the plans and specifications. The construction work and the foundations of the structures had to be executed with precision. Indeed, for the diversion dam, the works were performed using the underpinning method, which required great care as to the execution and planning within the whole project. The big challenge was to complete the work on the foundations in the bedrock during the dry season, hence the need to meet a very demanding work schedule.

The environmental impact proved to be important for a sustainable development whose goal is rice production, a non-traditional crop in Rwanda, over two seasons per year and enable the sustainability of cattle breeding in the area. The environmental impact of the proposed irrigation schemes in the Muvumba region was to bring the necessary reassurance to farmers in the region that the project was consistent with their needs and fit into a rural development and fight against poverty project.

During the execution of the works, the construction of the canal caused serious challenges. Indeed, farmers who are part of the overall project were to remain on their land and continue to bring their herds to drink from the Muvumba River. As the digging of the canal would isolate them from the river, CIMA+ International had to find a solution to this sensitive issue. Moreover, once the canal was dug, the risk of accidental falls would raise other concerns.

The big challenge was to complete the work on the foundations in the bedrock during the dry season, hence the need to meet a very demanding work schedule.

The operation, maintenance and supervision of the dams and the canal itself required the installation of a dirt road on the right bank, along the canal.

One major constraint was the importance of completing the irrigation schemes at the end of 2011 and to divert water from the Muvumba River to fill the storage dams to allow a first rice crop in January 2012 and provide a double cropping for that year.

3.2 ORIGINAL SOLUTIONS

Having prepared the plans enabled CIMA+ International to master all the technical issues and complete the project on time. The verification of the foundations of the compensating diversion dams was conducted from the onset of the excavations; just as was done for quality control and quantity control of the construction materials. At the start of construction, the geotechnical engineer had to be on site almost full-time.

> To complete the work on time, it was necessary to closely monitor the contract schedule. When the work began, the Control Mission insisted that all construction equipment be operational and that the mechanics be on site permanently, ready to intervene in case of breakdowns (excavators, bulldozers, rollers, etc.).

> To meet the work schedule, CIMA+ International had to ensure that the reinforced concrete central spillway of the diversion dam, located to the right of the low-flow channel of the Muvumba River, would be completed before the onset of the rainy

season. It was necessary to isolate the central structure of the Muvumba River to work on its foundations.

The excavation of the diversion dam in the underpinning and on a site near the Muvumba River was quite a challenge. Given that the level of the foundation was below the natural ground level and that the works on the foundations of the concrete structures were executed in the bedrock, it was necessary to address the problem of water infiltration. A permanent pumping was needed to dry the foundation until the undesirable matter (silty sand and other alluvial deposits) were brought to the top. Many precautions were taken to ensure that the contractor would not face any safety issues while performing these manual works in the underpinning.



Besides the complexity of the work to be performed at the top of the irrigation scheme, the contractor had to build three parallel storage dams and dig the main canal; this required careful planning of the work and human resources, adjusted based on the progress with the work. The work on the diversion dam, the "heart" of the project, could not in any way jeopardize the work on other structures.

The excavation on the central spillway could not disrupt the foundations and the embankment adjacent to the earth dikes on the left and right banks of the diversion dam.

CIMA+ International convinced the contractor to build the central concrete spillway before the earth dikes on the left and right banks. This solution was used to isolate the left bank from the Muvumba River and begin the excavation on dry grounds and build the bedrock structures before the rainy season began. The embankments of the dam on the left bank began when the side walls on both sides of the spillway were completed.

This construction method is accompanied by a delicate installation of the earth embankments

in the area of contact with the concrete side walls, where it was necessary to use small double-cylinder manual compactors and jumping jacks.

To make rapid progress on the canal and meet the deadlines, construction was executed in three steps. The first step was to widen the canal using a mechanical shovel, as close as possible to the final section, the second was to instruct a first team to conduct the rough sloping manually and as progress was being made to mechanize the process and the last step was to perform the finishing slope with the help of a second team using simple hoes.

To facilitate the construction of the canal in the embankment area, CIMA+ International recommended to the client and the contractor to modify the layout of the canal near the intake structure by moving from the areas of fill; this helped reduce costs as the excavated areas do not require riprap slope protection, unlike the embankment. The crossing of goods and people over the canal had to be ensured through the construction of nine culverts. The culverts were built using reinforced concrete rather than eucalyptus trunks (commonly used in the region). These culverts will be more durable and allow the passage of heavy vehicles and construction equipment to populated areas in the hills.

To prevent people and animals from accidentally falling into the canal, barbed wire fences were installed but, they were removed by the population for their own needs. We then came up with an economical, efficient and environmental solution

that involved planting shrubs that grow easily in this area, all along the canal, and thus create a natural protection.

The heavily polluted waters of the Muvumba River would pose short-term issues with sediment deposits in the main and secondary canals. To mitigate this phenomenon, a 7 meters wide and 27 kilometers long trapezoidal sand trap was designed and built, to be used as a sediment decanter. The mean velocity during sediment deposit is of 0.2 m/s, and during discharges is of 3 m/s. These discharges are

performed by three manual discharge valves, located at the top of the collector.

The rate of flow in the three dams was done through inlet openings and closings from the reservoir. To allow better regulation of water coming into and out of the reservoir and canal, it was necessary to adjust the layout of the reservoir by building a bypass upstream of each reservoir.

The layout of the perimeter had to meet the following requirements: easy access for the construction, operation and maintenance, while taking into account topographic and soil conditions. The land use plan suggested 39 secondary canals, for a total length of 35, 166 m, meeting with the tertiary canals (sprinklers) to irrigate the hydraulic units. The internal roads in the perimeter are located along the secondary drains and the collector. The crossing structures of the drains and collectors are made of eucalyptus.

CIMA+ International convinced the contractor to build the central concrete spillway before the earth dikes on the left and right banks.

3.3 FUNCTIONALITY

The excavations and concreting of the central part of the diversion dam were carried out without difficulties to reach the natural terrain and the Muvumba River. Besides the construction of a dike (stop log), the monitoring team had to monitor the level of the river during wet weather, because the catchment of the river could be affected by storms that can cause overflows and flooding in the foundations located in the bedrock.

In November 2011, a month ahead of schedule, the completion of the central spillway of the dam on the left bank made it possible to successfully divert the Muvumba towards the dam. Thus began the water transfer into the main canal and the filling of the reservoirs of the compensating dams.

When closing the bottom sluice gate valves, the spillway worked perfectly, and the surplus water not transferred to the canal flowed through the threshold to reach the

Muvumba River. The Control Mission team, the contractor, the client and visitors (from the World Bank) could not hide their satisfaction. Congratulations to the CIMA+ International Control Mission team were coming from all sides for having diverted the water one month before the scheduled date of December 2011.

This diversion of the river has accelerated the construction work on the right bank of the diversion dam. All that was in the plans and specifications were completed successfully.

Bypassing the canal using the reservoirs upstream made it possible to ensure water management in the three dams without disrupting their feed. By closing and opening the gates, the reservoirs can provide an independent distribution of water to the plots to be irrigated.

The idea was to divert the axis of the canal in the fill area towards an excavation area, this had nothing but positive impacts both on costs and simplicity of execution.

To facilitate water management within the perimeter, a simple organization of the sprinkling was adopted. The flow transported by the headrace is split inside the perimeter to simultaneously serve several numerous secondary canals in the same area.

In November 2011, a month ahead of schedule, the completion of the central spillway of the dam on the left bank made it possible to successfully divert the Muvumba towards the dam.

3.4 BUDGET

Being on budget is undoubtedly one of the outstanding successes of the project. Meeting this objective required close and proactive monitoring with the client and the contractor in order to anticipate any overrun.

CIMA+ International, together with the RSSP/MINAGRI, had to stay within the budget allocated by IDA, for which the World Bank ensured the monitoring through regular visits throughout

the construction and through the monitoring of the monthly and background reports the Control Mission provided to the client.

Moreover, no additional fees were requested. The payment for the services was subject to the submission of the preliminary, final design and environmental assessment reports. The procurement time frame of six months was met.

On the supervision and control of the work, the Control Mission began on July 31, 2010. At the end of construction, the supervisors

were demobilized but the Head of Mission was maintained so that he could take part, with the client, in the provisional acceptance.

The contract for the works on the irrigation schemes was awarded to the Indian company SPENCON, and the turnaround time was 18 months. On March 1, 2010, the contractor was ordered to begin the work, and deadlines were met despite the delays due to bad weather. Necessary changes were made to the execution of the project and a cost estimate was done by the contractor. These costs were approved by the Control Mission and the Client. These changes made it possible to improve the safety and durability of the structures and make significant gains in turnaround times related to the work without incurring additional costs, as they were offset by savings on other works.

3.5 SCHEDULE

Based on the programming by the MINAGRI, the development of the Muvumba perimeter was to be operational beginning January 2012 to ensure from that year two rice cropping seasons. Therefore, the works on all the hydraulic structures had to be completed by the end of 2011. The planning for the

construction of the structures in groups, as suggested by CIMA+ International, helped in meeting these deadlines.

CIMA+ International designated a site supervisor for each reservoir dam, while for the canal, two supervisors monitored the work. For the diversion dam, a supervisor was responsible for supervising the work on the concrete structures, while a second was responsible for the earth dikes.

Gradually, as work progressed, the lack of availability of construction equipment (excavators, bulldozers, graders, rollers and sheepsfoot, etc.) became apparent, due to the breakdowns attributable to the difficult terrain. The Mission Control had to be vigilant to ensure that the breakdowns were kept to a minimum in order to meet the deadlines.

To avoid shortage of building materials, the Control Mission had to ensure that procurement was done regularly and that there was no inventory shortage.

CIMA+ International designated a site supervisor for each reservoir dam, while for the canal, two supervisors monitored the work.

Early in the project, difficulty in accessing borrow pits were common, as the owners were opposed to any intervention on their land if their benefits were not paid. Red tape was cumbersome and required that the Head of Mission and the Project Manager intervene with officials from the RSSP/MINAGRI to raise awareness about the dangers of delays

in carrying out the work. In response to our interventions, several meetings with local authorities and land owners took place to break the deadlock and settle disputes.

The "skipped areas" were completed in December after the drinking bowls were built in the foothills of the hills; without causing any delay with the completion of the canal.

One of the important objectives was the completion of the diversion dam at the head of the canal. On November 23, 2011, when the

central spillway was completed and the Muvumba River was closed to divert its waters towards the diversion dam, CIMA+ International had successful completed the project on time. The remaining works on the earth dikes on the right bank of the diversion bank could then be completed quickly as there were no obstacles. The nine culverts were completed on December 1, 2011, ten days ahead of schedule.



4. SUSTAINABLE DEVELOPMENT

4.1 INTEGRATION OF SUSTAINABLE DEVELOPMENT

The project's main objective was to increase agricultural production, communication and, above all, to fight against poverty. The irrigation schemes in this perimeter as part of the sustainable rural development programme of the Rwandan government included in its strategic plan for 2020.

The development of the Muvumba perimeter is one of actions undertaken for the development of the marshes which aims to establish effective mechanisms to: facilitate the adoption by farmers of efficient and sustainable techniques and practices for a profitable management of crops in the marshes and encourage and develop the intervention skills of private operators in the construction and maintenance of hydroagricultural infrastructures.

The Nyagatare District sustainable development plan aims to build 3,000 small dams in the hills for irrigation, comparable to the irrigation schemes of Muvumba.

Economic

In the final design, CIMA+ International planned to use material located near the sites and available in large quantities, making it possible to minimize transportation costs. The clay and laterite were chosen for the body of earth dikes of the three storage dams and banks of the diversion dam. The use of this material, which is easy to compact, reduced the number of impervious and homogeneous dikes without using a sealing ring and, thus, make substantial savings. Moreover, all the cuttings from the main canal were deposited on its right bank and, once leveled, formed the basis for the access road yet to be covered with a layer of laterite.

The diversion dam and reservoir dams were designed for a lifespan of at least 50 years with minimal maintenance, except that of the hydraulic gates and the curettage of the main canal when necessary. To reduce siltation of the canal, due to water filled with sediment during floods; a sand trap was planned downstream from the water diversion outlet to the canal.

The project's profitability is based on the development costs, based on the operation of an irrigated perimeter, and on the economic profitability of rice crops in the irrigated area. The estimated revenue for rice crop are: export surplus of rice, 450,291 tons in 2011 and 427,063 tons in 2016 and in export value, \$ 180 116 000 USD in 2011 and \$ 170 825 000 USD in 2016.



Social

In 2012, the population of Nyagatare will reach 327 000 inhabitants, of which 51% are women. Nine out of ten poor people live in rural areas. The project is of great importance for riparian communities as it will result on a socio-economic growth which will play an important role in achieving gender equality and equity in all aspects of daily life.

New opportunities will become available for women and young people, which in turn will contribute to poverty reduction, improvement of the quality of life in rural areas, within the context of sustainable rural development.

The first result of the project was job creation locally as the labor-intensive method was used during construction. During construction, the contractor hired 350 laborers, thirty or so employees (masons, setters, guards, etc.), and 30 construction equipment drivers and mechanics. When conducting land leveling and construction work on the tertiary canals of the perimeter, local businesses recruited 3,000 to 5,000 laborers, depending on the construction phases.

At the end of the construction work, the implementation of a cooperative of farmers from the local population is planned to highlight part of the irrigated scheme.

As part of the social initiatives in this project, CIMA+ International supported the contractor's plan to provide lunch to all the employees. This enabled everyone to have a balanced meal (which was often their only meal of the day).

Environmental

CIMA+ International conducted an environmental impact assessment (EIA) for this project. With regards to the works, the team was therefore well placed to meet the recommendations on environmental protection in a very sensitive area.

During the study, CIMA+ International delineated the Muvumba perimeter while taking into account environmental, soil and topography constraints. To comply with environmental policies, the gallery forest along the Muvumba was delineated and excluded from the area to be developed. The foothills of the hills which are unfit for rice cultivation could, after summary development, be used for forage crop and tree crops.

The contractor had to comply with the recommendations from our environmental study at each stage of completion of the work and maximize the use of all excavated material for the construction of the structures.

Furthermore, the risk of accidental spills of petroleum products, as well as oil spills, oils or grease from the construction equipment could also be sources of soil and water pollution. CIMA+ International ensure that the contractor was aware of environmental protection measures. During the project, no discharge of any pollutant of any kind was noted. The Control Mission made sure that the contractor cleaned the site as the work progressed.

Following the advice of the Control Mission, the contractor organized the work according to specific tasks, and often planned the work after the passage of heavy equipment.

Welfare and Safety of Users and Public

The project required a lot of construction in the bedrock in the excavations of the dams and the canal, which represented a safety risk for workers; given the amount of work to be performed by hand, the number of people working at the same time and often near the excavation and compaction equipment.

Following the advice of the Control Mission, the contractor organized the work according to specific tasks, and often planned the work after the passage of heavy equipment.

To save time, the contractor had sought to dig the canal at night. The Control Mission was opposed to this idea because of security concerns. Indeed, because of the lack of electricity in rural areas, the work would have had to be executed in the dark with only the light from the equipment. Also, the presence

of venomous reptiles prohibited any night work. By implementing three teams working during the day, one for mechanical excavations and two for manual bank sloping, the work in the canal proceeded without any delays.

When building the foundations of the spillway, the formwork and concreting were done in the bedrock and required particular attention from the contractor so that the slopes could be built safely to avoid any soil landslide. The groundwater also required close monitoring as the Muvumba River was also closely monitored, particularly during storms.





5. IMPACT ON THE PROFESSION

5.1 IMPACT ON THE IMAGE AND PRACTICE OF THE PROFESSION

The Muvumba project became the "pathfinder project" of Rwanda in the field of sustainable rural development. The President of the Republic of Rwanda gave great importance to this project and visited the site in person. The President was kept regularly informed on the progress through the MINAGRI.

The Prime Minister of Rwanda and the Minister of the MINAGRI visited the site several times, and at different stages of the project. Several MPs visited the site during construction. As a future beneficiary of the project, the Governor of the Eastern Province also took part in these visits. The World Bank, which funded the project, also sent its experts on site; they witnessed the progress of the work and the efficient supervision and monitoring provided by CIMA+ International. All these dignitaries and officials were pleased with the work done by the Control Mission, and the fact that the project was on time, and above all, of executed to the highest standards.

Designing and building structures in wetlands allows CIMA+ International to showcase its experience and expertise, having successfully managed to create a set of hydraulic structures well adapted to site conditions and use materials available on site to minimize construction costs. Muvumba perimeter were performed without any major changes to the design recommended by CIMA+ International, which proves the firms knowledge of the area and its expertise in agricultural engineering. The CIMA+ International team received congratulations, from members of the World Bank who visited the site on November 30, 2011, during the diversion of the Muvumba River and the opening of the dam, for having respected the schedule and costs, as well as for the quality of the work.

The construction works for the irrigation schemes for the

We can say that the image of Canadian consulting engineering in Rwanda is thereby improved once again, and this further strengthens our commitment to develop excellence in executing our mandates both here and abroad. The contractor SPENCON, executing its first project in Rwanda, was able to rely on the cooperation and expertise of the CIMA+ International team; the team helped the contractor in its activities to carry out the work. All this was possible because of CIMA+ International's constant desire to foster open communication with the contractor.

Overall, this project has facilitated the transfer of knowledge between designers and the people working on the site. Finally, it is the contractor and the RSSP/MINAGRI together who have benefited from CIMA+ International's experience of in carrying out

major sustainable rural development projects. We can say that the image of Canadian consulting engineering in Rwanda is thereby improved once again, and this further strengthens our commitment to develop excellence in executing our mandates both here and abroad.











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