**Flood Control Channel Design for a River in Northwest Haiti**

**Abstract**

All engineering students at our university are required to complete a year-long, industrially-sponsored senior design project prior to graduation. Last year, a team of four students worked under the supervision of three liaison engineers from a local civil engineering firm and a faculty advisor to design a flood control channel for a river in northwest Haiti. During fall quarter, the students prepared a written proposal outlining the project purpose, a scope and plan of work, a set of project deliverables, a schedule, and a budget. Design work was done in winter and spring quarters and culminated in a report describing hydrologic and hydraulic modeling, engineering design of the channel and its inlet and outlet structures, and construction-ready drawings and calculations. The team made oral presentations to the sponsoring company at the end of fall, outlining the project scope, and in spring quarter, describing their final design, and also met regularly with the liaison engineers over the course of the year. The attached paper describes the project, the student experience and the benefits of the university-industry partnership.

The project addresses flooding along Riviére des Moustiques, a river in northwest Haiti where recent flooding has adversely affected the agricultural productivity of the region, hurting the livelihood of the community. Prior to our involvement, a European non-governmental organization partnered with a US engineering company to develop a comprehensive floodplain management plan outlining a series of engineering projects needing further design development. The plan included a preliminary design for a diversion channel to route floodwater away from farmland into an uninhabited salt flat.

The company requested the team to finalize the design of the diversion channel. In response, the team updated the existing hydrologic and hydraulic models to determine an appropriate design discharge, designed the geometry, lining, and inlet/outlet structures for the channel, and created a set of construction drawings. Erosion and sediment control played a major role in the design. The inlet structure was designed with an erodible berm overlying concrete-lined gabion baskets to maintain low flow in the existing channel while allowing larger discharges competent for transporting sediment to freely enter the diversion channel. The channel was designed to safely convey the 200 $m^3/s$ design flow with a minimum footprint. A set of energy dissipation structures was included near the outlet to prevent erosion at the mouth of the channel. The channel lining consisted of Reno mattress and gabion baskets with concrete lining in the stilling pool.

During the year, the student team met with the faculty advisor weekly and with the liaison engineer every second or third week. The team also regularly consulted with a liaison engineer in Haiti regarding the feasibility of design options and the collection of input data (e.g. topographic surveys) necessary for the design. Team members served sequentially as project manager, running team meetings, setting agendas, assigning tasks and following up on action items. The project strengthened the team's ability to apply their technical knowledge, to work as a team, to communicate effectively, and to practice project management and leadership skills. The project also provided a unique perspective on engineering in the context of international development work.

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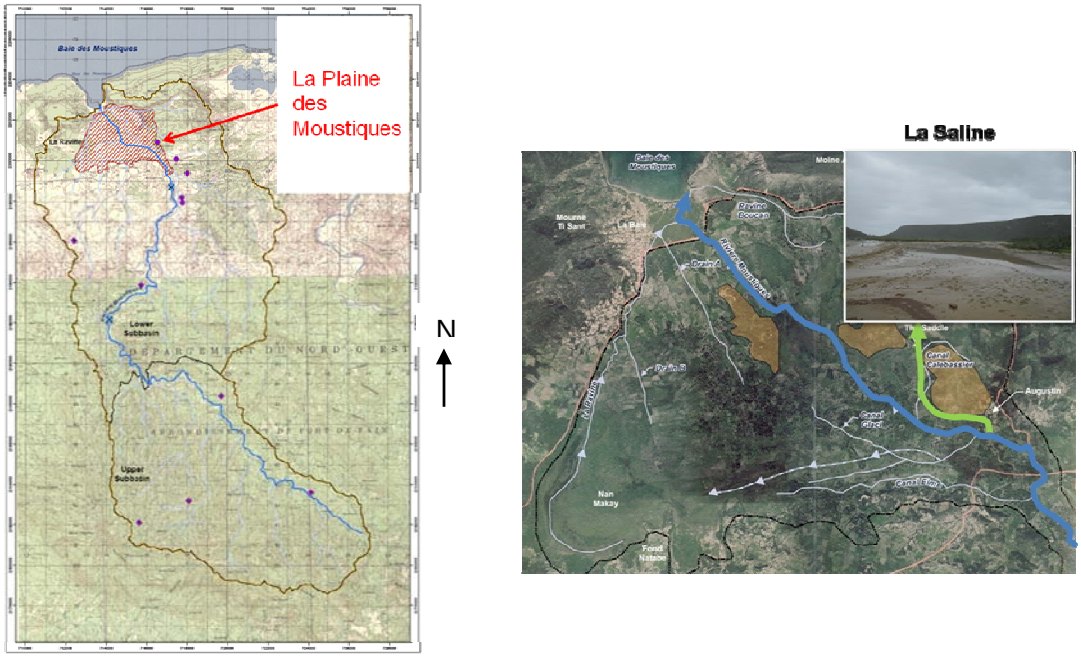
## I. Project Description

### Introduction

A farming community along Riviére des Moustique, a river in northwest Haiti, is adversely affected by flooding. In 2007 a European non-governmental organization partnered with a US civil engineering company located close to our university to develop a comprehensive flood control plan for the region. In 2010, a student team brought one portion of the program through full engineering design as part of their year-long senior capstone project. The student team worked under the supervision of three engineers from the civil engineering firm, a representative of a non-governmental international development agency in Haiti, and a faculty advisor.

### Background

The Riviére des Moustiques river basin has a semi-arid climate and covers approximately 222 square kilometers. The Riviére des Moustiques drains the slopes of the Massif du Nord mountain range, supplying water and sediment to a low-elevation alluvial fan known as Plaine des Moustiques. Figure 1a shows the project site.




(a) (b)

Figure 1. Maps of Project Site a) Watershed, b) Main River (in blue) and Diversion Channel (in green). The diversion channel ends in a salt flat known as La Saline.

The Plaine des Moustiques is used for agriculture and was quite productive historically. However, the most productive land (cross-hatched in Figure 1a) is prone to flooding when hurricanes or tropical storms encounter the steep topography of the watershed. The problem is exacerbated by long term sediment accumulation within the channel, a process that is characteristic of alluvial fans. River bed aggradation increases the probability that

the river will abandon its existing course in favor of a low-lying but agriculturally important part of the floodplain in a process known as an avulsion. The channel bed aggradation, the incipient avulsion, and poor drainage in the lower parts of the floodplain have led to excessive flooding and have adversely affected agricultural productivity, posing a complicated water resource management problem for the local community.

To alleviate the situation, in 2007, a European based non-governmental organization (NGO) partnered with a US-based civil engineering company (hereafter referred to as the 'company') and a US-sponsored Haitian development organization to create a comprehensive flood management plan for the region. Phase I included a diversion channel that is intended to prevent flood water from entering the agriculturally productive area and redirect it to a large uninhabited salt flat named La Saline. The company came up with a preliminary alignment for the diversion channel, as shown in Figure 1b.

In the summer of 2009, the company requested the senior design team to use the information the NGO and the company had collected over the previous two years to finalize the design of the diversion channel.

The team was specifically asked to complete the following tasks:

- Update the existing hydraulic and hydrologic models
- Perform a sediment transport analysis
- Design the inlet and outlet structures
- Design the channel alignment and geometry
- Develop construction ready design drawings
- Carry out a cost estimate

**Work Accomplished**

The students used new rainfall data collected by the liaison in Haiti to develop a design discharge for the project. The ensuing design included the final alignment and cross section, the lining, and the locations and geometry of inlet and outlet structures and an energy dissipation structure, as shown in Figure 2. The students developed design details for each component of the channel and took care to ensure that the plans were consistent with the phased construction recommended in the NGO's flood master plan. All elements of the channel were designed to be compatible with the sediment loads it would be required to convey.

**Hydraulic/Hydrologic Modeling**

Because flood discharge was previously unavailable, the sponsoring company had installed rain gages throughout the watershed in 2007, capturing precipitation for two major storm events, Hurricanes Hannah and Ike. Using these data and rainfall data obtained from a geographically similar area in Puerto Rico, the team updated rudimentary hydrologic and hydraulic models developed by the company. All modeling was performed using the U.S. Army Corps of Engineers HEC-HMS and HEC-RAS computer programs. Results showed that the diversion channel should accommodate a discharge of 200 $m^3/s$. Once the channel design was complete, its hydraulic performance was tested using a separate HEC-RAS model developed by the team.

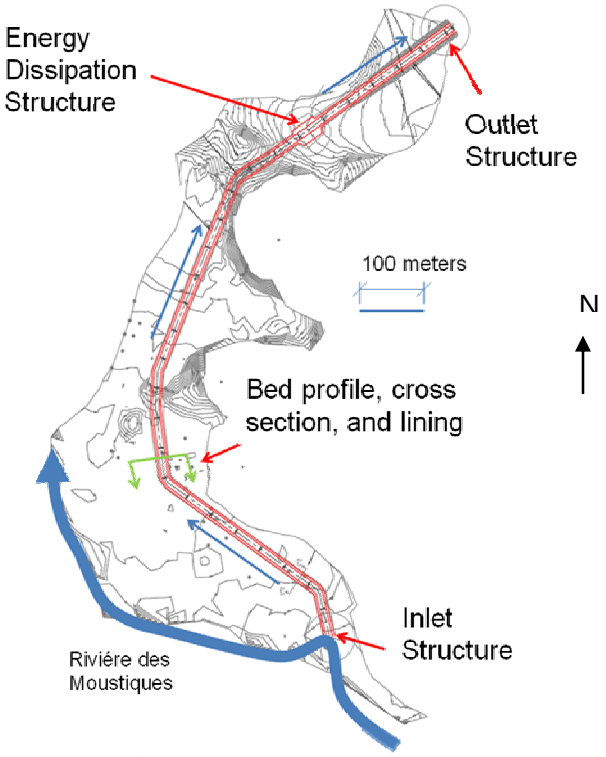


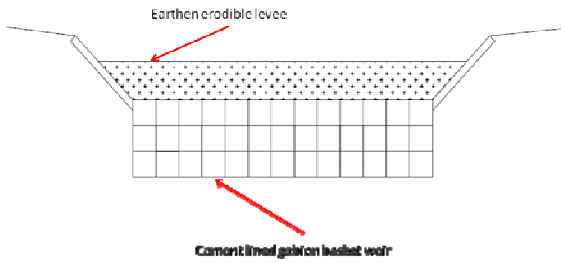

Figure 2. Plan View of Diversion Channel

**Sediment Transport Analysis**

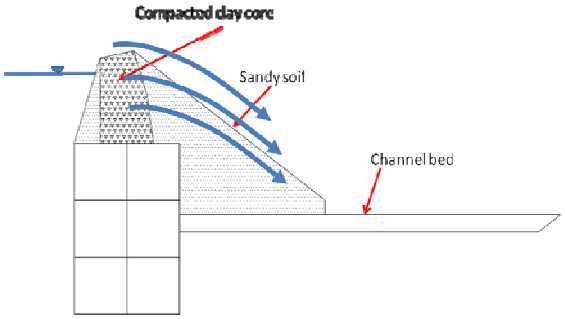
Because one of the root causes of the flooding was sedimentation, the team carried out a sediment transport analysis using methods available in literature. The team concluded that the high design flow of 200 $m^3/s$ and the steep slope at the inlet to the diversion channel will prevent sedimentation from occurring within the diversion channel itself. However, large quantities of sediment could be deposited in La Saline below the mouth of the diversion channel. Furthermore, the potential upstream phase of the project discussed in the management plan would be at greater risk for sedimentation. The team provided design recommendations regarding sediment management for such a channel.

**Design of the Inlet Structure**

The goal of the inlet structure is to divert flood water from the river to the diversion channel while reducing the chance that low velocities at low stages would lead to sedimentation problems either in the channel or in Riviére des Moustiques below the diversion. To achieve this goal, the team designed an erodible levee at the point of diversion. The core of the levee is composed of compacted clay to provide stability and prevent water seepage. The rest of the levee is made of easily eroded sand and gravel. The foundation of the levee is a concrete line gabion basket wall that will operate as a weir once a sufficiently large flood overtops the levee and washes it away. Figure 3 shows the front and side views of the inlet structure.




(a) Cross Sectional View




(b) Side View

Figure 3. Cross Section and Side Views of the Inlet Structure

**Design of the Diversion Channel**

The diversion channel has a trapezoidal cross section with 1:1 side slopes as shown in Figure 4. The channel is lined with Reno mattresses along the bed and has smooth side walls, with gabion baskets along bank tops at locations where lateral inflow is anticipated. The diversion channel has a longitudinal slope of 1% and is aligned such that there are no major obstructions along the channel. The current alignment allows for future channel extensions upstream of the current inlet structure.

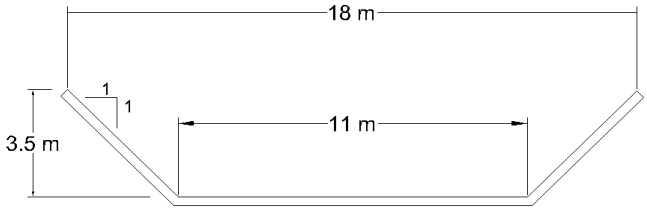



Figure 4 Cross Sectional Views of the Diversion Channel

As shown in Figure 2, an energy dissipation structure is incorporated about 200 m upstream of the mouth of the channel to reduce velocity near the outlet. The energy dissipater was designed to incorporate a free hydraulic jump using methods outlined in the Federal Highway Administration Hydraulic Engineering Circular 14 and consists of concrete lined gabion baskets and Reno mattresses. These are underlain by two layers of

gabion baskets to prevent settling and damage to the concrete energy dissipater. Figure 5 shows the cross sections of the diversion channel and the energy dissipater.

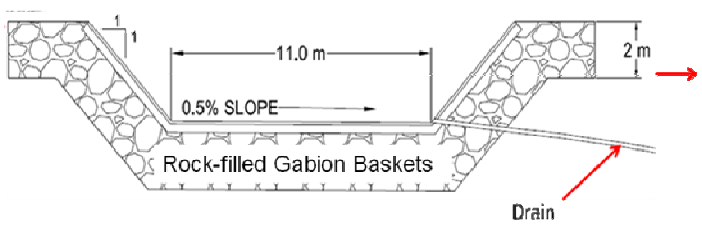



Figure 5. Cross Sectional View of the Diversion Channel
at the Energy Dissipation Structure

**II. Collaboration of Faculty, Students and Licensed Professional Engineers**

All engineering students are required to successfully complete a team-based, industrially sponsored, year-long capstone project. The team for the above project consisted of four students (two women and two men) and was supervised by three practicing civil engineers of which one was a licensed professional engineer. A civil engineering faculty member who was also a licensed professional engineer served as a faculty advisor.

The students met with their faculty advisor weekly and with their company liaisons every two or three weeks. The company liaisons provided technical assistance when needed and provided feedback on the proposals and reports. The faculty advisor provided technical assistance throughout the project, provided feedback to several drafts of the proposal in fall quarter and the final report in spring quarter.

**III. Benefit to Public Health, Safety and Welfare**

Haiti is the only country in the Americas that is listed on the United Nations list of Least Developed Countries. Historically, political corruption has made the distribution of international aid money difficult. The 2010 magnitude 7.0 earthquake has worsened the plight of Haitians and placed an additional burden on already limited resources. While earthquake-related reconstruction is certainly a priority of many aid organizations, there is still a need to address other long-standing problems. Since the funds from the NGO are dedicated to working for the welfare of the farming community, the students were aware that their work would directly benefit the farmers. There is hope that the diversion of sufficient sediment into the existing salt flat could eventually create new arable land.

The diversion channel is about 10 feet deep, posing safety concerns to local residents and livestock, especially when the channel flows full. The students discussed safety precautions appropriate for the project such as a fence at the top of the levees and bridges across the channel and recommended that the client in Haiti perform additional analysis in areas where student expertise was insufficient.

## IV. Multidiscipline or Allied Professional Participation

The project was supported on the ground in Haiti by a US-based international development organization focused on Haitian development. The students regularly communicated with the Haiti-based representative from the organization who, while originally trained in the US as an engineer, has focused on development projects for most of his 30-year career. This person provided invaluable advice regarding appropriate construction methods for the area.

Closer to home, our department has an active advisory board consisting of about ten local civil engineering practitioners. The board meets once a quarter to provide feedback on curriculum, future growth and other industry-academic issues. The student team made an oral presentation to the board in fall describing their project scope and plan of action. In spring quarter the team presented their final design and recommendations.

Two licensed civil engineers from the region reviewed the proposal and report and provided feedback to the teams a week prior to the final submission. The team spent the last week of both fall and spring quarters addressing the practitioners' comments before finalizing the proposal and the report, respectively.

It is mandatory for all capstone teams to participate in an annual ASCE local section presentation competition. These presentations were judged by a panel of four licensed civil engineering practitioners. The format for this competition is a 15 minute oral presentation followed by questions and answers.

## V. Skills Gained

Students developed the following skills through this project: technical skills, oral and written communication skills, project management and leadership skills, ability to work in a team setting and to interact with clients. They were also exposed to international development and developed skills coordinating work in an international environment.

### a) Technical skills

The students learned how to take a preliminary flood control project to a final design stage ready for construction. Along the process they became proficient in the following:

- Design and Analysis Software: US Army Corps of Engineers Hydraulic Engineering Center's River Analysis System (HEC-RAS) and Hydrologic Modeling System (HEC-HMS); HEC-GeoRAS
- Design Manuals: Federal Highway Administration Hydraulic Engineering Circular 14 (FHWA HEC-14)
- Mapping and Computer aided drafting (ArcGIS, AutoCAD 2007)
- Research: researching the suppliers for various channel lining materials, locally available construction materials, cultural practices of Haiti, researching regional rainfall data, sediment transport analysis.

**b) Communication skills**
The students submitted a written proposal to the sponsor at the end of fall quarter, outlining their understanding of the project, scope of work, plan of implementation, and schedule. At the end of spring quarter, they submitted a final report describing the work done, engineering calculations, drawings and other deliverables requested by the sponsor.

The students were required to make oral presentations to their peers twice a quarter. Each student had to make at least one presentation each quarter. In addition, students presented their proposed work to the company at the end of fall quarter and their final design at the end of spring quarter. The academic year concluded with projects day, a conference style event, where the team presented its work to the entire university community, sponsors of all the senior capstone projects, prospective sponsors, friends, family and alumni.

Project reports were passed along to the liaison in Haiti, who provided comments, suggestions, and data regarding design. Much of the survey data provided by the liaison was in French, which required that the team proactively ask questions to clarify the meaning of the data.

**c) Project Management and Leadership skills**
Each team member served as the project manager for part of the academic year. The project manager was responsible for setting up the team meetings, developing the meeting agenda, conducting the meetings, assigning tasks to the team members and following up on action items. He/She was also responsible for contacting the company liaison and the faculty advisor in between team meetings, when needed.

**d) Global Awareness and Issues in Engineering**
Students learned how design constraints were different in Haiti than in the US. They considered the limitation of equipment and construction materials, inexpensive labor force, language and cultural differences in their design.

**Summary**
A team of four civil engineering seniors designed a flood control channel for a river in northwest Haiti under the supervision of three liaison engineers from the sponsoring company and a faculty advisor. The diversion channel will provide relief and economic stability to a farming community devastated by recent storm events. Through the project, the students were exposed to various design software, design manuals and oral presentations tools. They developed project management skills, leadership and communication skills, an understanding of consultant-client relationships, and an appreciation for global issues.