2006-2646: WATER RESOURCES EVALUATION FOLLOWING NATURAL DISASTER IN HAITI

Bruce Berdanier, Ohio Northern University
Dr. Bruce Berdanier is currently an Associate Professor of Civil Engineering in the TJ Smull College of Engineering at Ohio Northern University. In this position, Dr. Berdanier is responsible for teaching all of the courses in Environmental Science, Water and Wastewater Treatment, Solid and Hazardous Waste, Surface Water Quality and Project Management that are included in the Civil Engineering curriculum. Additionally, Dr. Berdanier directs all teaching and research activities in the Environmental Engineering laboratory. Dr. Berdanier also conducts research in surface water quality and wastewater treatment and is involved in outreach and support to K-12 teachers in the use of watersheds as tools in science education while maintaining an ongoing involvement in policy and research in the fields of Environment and Water Resources in the Middle East and Haiti.

WATER RESOURCES EVALUATION FOLLOWING NATURAL DISASTER IN HAITI

Abstract

This paper will present a case study of the impacts of a hurricane and the resultant flooding during June 2005 in Deschapelles, Haiti on spring box collection systems and gravity feed water systems which serve Hospital Albert Schweitzer (HAS) and the surrounding Deschapelles community. The paper will explore long and short term options for replacement or rehabilitation of existing systems and discuss the field evaluation performed and recommendations made by the author in cooperation with the directors of the Grant Foundation. HAS is a private hospital which was founded in 1954 by Dr. Larimer and Mrs. Gwen Grant Mellon. Currently HAS is funded and administered through the Grant Foundation in Pittsburg and provides medical services, community development, and community health services to the Artibonite Valley in Haiti in service to well over 300,000 people. The paper presents the culmination of the project which has evolved over the past five years involving the professor project leader, two graduate students, and one senior level BSCE in developing field survey data, technical feasibility studies and preliminary cost estimates.

Introduction

What characteristics define educational pursuits that interest the American Society for Engineering Education (ASEE)? The Environmental Engineering Division of ASEE is interested in the application of service learning in developing communities especially in the topical areas of providing safe water and sanitation. Case studies presented regarding the experiences of members in developing countries that develop educational opportunities for members, students and indigenous populations should be of interest. Additionally, ASEE members need to realize that their technically specialized education and American experiences do not provide the context to guide them in developing countries. To actually be an effective leader/engineer for students and for the indigenous population in an international service learning situation, the professional engineer/educator needs to invest time in learning about and understanding how the specific culture, social and economic realities, and project environment will integrate to impact the proposed design. Not only must any proposed solution be cost effective, but also robust and simple to operate and maintain, and congruent with the indigenous population. The subject project has been used successfully to present specific examples of international environmental design topics and project management topics to junior and senior level undergraduates in Civil Engineering at both Ohio Northern University and the South Dakota School of Mines and Technology. The paper is presented here as a case study of a specific project for the professional development of engineering faculty.

It is suggested that a definition of Liberation Engineering for the governance of international service work be considered in guiding the efforts of our society members in their international service pursuits: "Liberation Engineering is the study and implementation of practices and designs to meet the "life needs" of localized human populations taking into account their unique cultural history and socio-economic interactions with nature and their environment while subverting, contesting, and reforming the current engineering practices that transform the earth through an overarching focus on development[1]."

Background for Haiti

> "Each society carries what we refer to as an "environmental imaginary," a way of imagining nature, including visions of those forms of social and individual practice which are ethically proper and morally right with regard to nature[2]."

Haiti, which is the western one third of Hispaniola Island (Figure 1), is generally recognized as the poorest country in the Western Hemisphere with approximately 80% of the population living in abject poverty. McGeehin [3] has indicated that such descriptions hinder open discourse by separating people into philosophical households based on their wealth or lack thereof.

> "What does the phrase "poorest country in the western hemisphere" mean? The phrase objectifies the situation of Haiti and its people into a discursive materialist formation. The Haitian people live in the 'poverty sector.' The phrase is ripe with semiotic density. Haitians are poor, because they do not have a high standard of living. Haiti is a member of the Western Hemisphere and has a long history of independence, but it lacks the cultural, political, and economic organization inherent in the USA."[3]

McGeehin's thesis is that there is a relation between the poverty in Haiti and the public discourse in the US and that today's overwhelming environmental problems in Haiti have been caused by the historical application of various governments' economic development plans over the past two hundred years:

> "……. no singular solutions to the root causes of poverty identified by academics can come from the general discourse, without being related to the *problem*. This point is stated best by Paul Farmer [4]:"But depicting Haiti as divorced from "the outside world" turns out to be a feat of Herculean oversight, given that Haiti is the creation of expansionist European empires - a quintessentially Western entity. "

Although the CIA World Factbook[5] currently lists annual per capita purchasing power as $1500, it is closer to the truth that the average Haiti earns on the order of $300-$500 annually and may be able to find day-labor approximately every third day. Two-thirds of all Haitians are believed to be without any kind of regular employment and depend on small-scale subsistence farming to survive. Due to the geographic location of the island natural disasters frequently sweep the nation especially during the annual season for tropical storms and hurricanes.

Haiti's population growth rate is currently reported as 2.25% with a median age of 18 years and life expectancy of 53 years[5]. The current population of approximately 8 million people lives in a land area slightly smaller than the state of Maryland with approximately 2 million people living in the capital city of Port Au Prince. Following legislative elections in May 2000, which were judged inconsistent by the US government, international donors - including the US and EU -

suspended almost all aid to Haiti and the economy has averaged over 1% shrinkage each of the last five years. Haiti also suffers from rampant inflation averaging over 20% per year, a lack of investment by the international community, and a severe trade deficit. Civil strife escalated in 2004 when President Aristide was forced to leave the presidency, and the country has been administered by an interim government and United Nations troops since that time.

Extensive flooding due to tropical storm occurred throughout 2004, and additional storm damage which occurred in the spring and summer of 2005 caused severe flooding in local watersheds in the Artibonite Valley and completely destroyed the two main water conveyance systems for Hospital Albert Schweitzer (HAS) and surrounding areas of the Deschapelles community.

Figure 1. Haiti, the Western one third of Hispaniola Island [6]

Background for HAS

HAS was established in 1954 by Dr. Larimer Mellon and his wife Gwen Grant Mellon. Mrs. Mellon found the site for the hospital in the Artibonite valley of Haiti and negotiated the long term lease with the Haitian government while Dr. Mellon was completing medical school. Dr. Mellon had the hospital designed as a state-of-the-art tropical hospital with approximately 125 beds. The hospital has been expanded and reorganized several times over the past 50 years and now provides surgical, pharmaceutical, and clinical services to an area of approximately 300 square miles in the Artibonite valley region.

The hospital systems have deteriorated over the past fifty years, and there has been a concerted planning and funding effort by the Grant Foundation (which now funds the hospital operations) and the hospital staff over the past ten years to evaluate and upgrade the mechanical systems including water treatment and distribution and wastewater treatment and collection.

A large portion of Dr. Mellon's work also included outreach to the surrounding communities for family health and community development. Dr. Mellon planned and constructed several spring box collection systems for the hospital and surrounding communities and multiple open channel irrigation systems during his over 30 years of work in the valley. This paper specifically focuses on the evaluation and proposed upgrade of one of the spring box collection and pressurized distribution systems that Dr. Mellon built in the mid 1950s which was completely destroyed by flooding in 2005.

Current Status of the Ca Charles Water System

> The concept of marginality and how political, economic and ecological marginality can be self-reinforcing: "land degradation" as they say "is both a cause and result of social marginalization" [7].
>
> Environmental degradation is created……by the rational response of the poor households to changes in the physical, economic and social circumstances in which they define their survival strategies[8].

Ca Charles is a small valley area that is contributory to the Les Forges valley which drains naturally toward the HAS campus. Both valleys are characterized by high steep walls with highly erosive soils and rock outcrops that show nearly vertical and narrowly spaced faulting. The spring box systems were constructed near the top end of the valleys to cap springs or hill side seeps.

For the past ten years the maintenance staff has had to invest increasing amounts of labor and material to maintain the water supply piping on an ongoing basis especially during spring rains due to large rock and soil deposition damaging the system. It has been increasingly more difficult to maintain and protect the spring box systems in the both the Cas Charles and Les Forges valleys from the yearly damage. Large projects have been constructed using local labor to build stone cut off walls and gabions around the spring boxes in an attempt to limit the amount of silt coming into the spring box collection from up watershed runoff in the valley. This area, as is generally true throughout the country, (Haiti is 98% deforested) suffers from severe erosion and loss of topsoil due to the extensive deforestation. Available woody materials are constantly harvested by the local population to be used in the production of charcoal for cooking fuel and for sale for income. In the summer of 2004, the author and a senior level BSCE student provided a complete field survey of the Les Forges and Ca Charles spring box systems and made recommendations for repair and stabilization of the pipes, boxes, and valley walls.

The Cas Charles water delivery system consists of the spring box collection system, two parallel three inch diameter steel water lines which originally fed two reservoirs in the Cite above HAS (one belonging to HAS and one to the Cite), various feeder lines throughout the Cite, and down gradient to HAS and additional housing and commercial area known as the Corridor. Due to extensive housing development and "freeses" or illegal tap connections to the main Cas Charles line up gradient of the reservoirs, the line from the reservoirs to HAS and Corridor no longer flows, and the HAS reservoir has been abandoned due to dilapidation.

There have been ongoing discussions with the Cite over the past five years concerning how best to improve the service capacity of the Cas Charles system. Additionally, residences in the Cite and Corridor have installed freeses into the HAS distribution system's perimeter piping due to lack of water from the Cas Charles system. This makes maintenance and planning for water distribution very difficult for the HAS system operators. Additionally, HAS treats their water by chlorination, and much of the cost of this benefit is lost as some of the local freeses are used for irrigation.

Approximately five years ago, HAS conducted field investigations with the assistance of the author and two graduate students to find and eliminate all open illegal connections from their system to try to limit the loss of chlorinated water. Additionally, HAS rebuilt their entire distribution system to secure the system and to remove all freeses. Most of the gains from this intensive effort have been gradually lost over the past five years as the local residents have reinstituted their connections to the perimeter system.

The country of Haiti suffers from ongoing dire lack of clean water for approximately 80% of its population. However, this situation is severely compounded in the dry season. The strain on the population of the Cite and the Corridor and on HAS during the dry season is crippling to human life and hospital operations. This situation was further complicated in the summer of 2005 when the entire spring box collection system and waterline from Cas Charles was destroyed by massive flooding. The watershed finally succumbed to the decades of deforestation and loss of soil and yielded all of its remaining trees along with most of its near surface rocks. The narrow rolling valley was carved flat from side to side and almost all vegetation and soil were removed. The upper end of the valley was also extended further up gradient from the spring box location. Along with the reshaping of the valley bottom, the spring boxes and waterlines and all of the engineered protection were removed by the floods.

Summer 2005 Feasibility Study

A field damage assessment was conducted by the author and by Mr. Andrew Stern of ATS Chester Engineers in early August 2005. Damage to the spring box and water line system in Cas Charles was devastating and complete. There was insufficient material remaining in the watershed for repairing the line to restart water flow to the Cite. As a side note the Les Forges spring box and water line system which currently provides 1/3 to ½ of the HAS daily water supply was also completely destroyed. The destruction of both systems put a large additional strain on the HAS treated water distribution system as a larger population base in the Cite and Corridor were using the campus water on a daily basis. The Les Forges system is approximately twice the system size of the Cas Charles system and would represent a much larger, more difficult project and commitment of funds to undertake for reconstruction. The field assessment took several days to complete as members of the water committee in the Cite and Corridor participated in guiding us to see major points of the system which were destroyed. Unfortunately, the spring box collection system had been under reconstruction at the time major flooding hit and all construction work which the Cite and HAS had been cooperating on was also destroyed.

Upon completion of the damage assessment, we were to provide HAS staff with a recommendation for the type of system and design that should be built to replace the spring box collection and gravity water pipeline system. Additionally, the Grant Foundation and HAS staff requested a cost estimate for the material and labor to complete the proposed new system. While the remainder of this paper focuses on the proposed solution for the Cas Charles system, we were actually evaluating short term, mid term, and long term options for the Les Forges system, HAS campus, and surrounding communities. Further discussions and evaluations looked at treating the systems as separate controlled entities in comparison with joint systems to serve communities and HAS. The extent of all of these discussions is beyond the scope of this paper.

The system originally designed by Dr. Mellon capped a hillside seep or spring and fed by gravity down through the small valley before starting gradually upslope over a “knob” into the Cite and feeding the reservoir. Water then distributed by gravity throughout the Cite from the reservoir. This system had sufficient energy head to supply the three inch line to the reservoir and to feed the Cite down gradient of the reservoir. However, over the past fifty years, additional homes were built further up gradient from the reservoir in the Cite. Distribution lines for these homes were tapped into the Cas Charles water line feeding the reservoir up gradient of the reservoir until there wasn’t sufficient flow and head to supply the reservoir. Some of the Cite residents told us that they had to sometimes bring a pump to prime the line to get the water from the spring box over the knob so it would feed the reservoir.

In the United States, we would have obviously made a decision to complete a design which would have included installation of a pump station near the spring box along with improvements to the Cas Charles supply line and properly sized distribution lines to the Cite sufficient to meet the needs of the entire population with pressurized water at or near their individual homes. However, we have to be aware that such a pumping and properly valved system could not survive in this environment. It could not be properly maintained and secured. Also, the addition of a pumping station would have encouraged more residential and agricultural development which would have quickly depleted the water source creating need for additional ground water or surface water source development. There are small and inconsistent ground water sources available in the area, but the lithology does not generally support large yielding wells within several hundred feet of the surface, and much of the drilling is through rock. Just deciding how electricity would have been made consistently available to the pump station and who would pay for it would have been major hurdles to such a construction.

The system originally designed and installed by Dr. Mellon in 1954 recognized the limitations of the water source. It was a simple, robust system that functioned with little maintenance or cost for over 50 years. It was only through over development of the residential areas by people who didn't understand the hydraulics of the system followed by the destructive forces of the environment due to deforestation and flooding that the system had failed. Therefore our recommendation to the Cite and to HAS was that the system should be replaced to function much as Dr. Mellon had originally conceived it with alterations in the spring box design and the water line alignment to take into consideration the changes that had occurred in the valley due to environmental damage. This proposal does not allow for the continued residential development of this area with pressurized water at each home which would be a US model, and could not be sustained in this environment. In fact much of the damage to Dr. Mellon's original system was caused by overdevelopment of the system and trying to mimic a "modern" US design with pressurized water delivered to all locations. Water can be delivered by the system to the reservoir in the village and by water line distribution to down gradient areas if desired. Up gradient tapping of the system must be discontinued. This will not be easy for the local water board to accomplish due to social/political impacts within the community, and historically HAS and Cite have failed to be able to prevent the freeses in their systems.

Developing a Cost Estimate

Developing an accurate cost estimate for material and labor for construction projects is a very important component of the project development process. This estimating can be difficult even for simple projects in the United States during times of material and labor cost volatility such as was experienced in 2005 for various environmental and world economic reasons. The situation predicting the cost and availability of materials is much more difficult and volatile in Haiti. The availability of materials is controlled by many and various political factors outside of the country, and it is very expensive to request a certain size and material of pipe be delivered to Port Au Prince for your waterline project in Haiti. Many of the construction supply businesses have left the country the past two years due to political and economic instability. Additionally, construction companies with operating equipment such as back hoes and dump trucks are almost non existent in remote regions such as Deschapelles, and therefore most of the labor is done by hand for small utility line projects.

How would engineers from the US estimate the material and labor for such a project? It is necessary to develop an estimate within perhaps 25% accuracy in order to obtain funding from various foundations and for developing support of the community to share in providing labor. Many of our engineering estimates in the US are based and certified on our past experience of prices for similar construction in the area of the state or country that our firm is working. If you could estimate the complete manual labor needed for installation of a waterline, do you understand enough about the culture and their work habits to fairly estimate their productivity? Do you understand about their need to be provided a lunch and water to drink during each construction day? Perhaps the meal that they will receive is more important to them than the opportunity to work if they are offering their labor as a cost share in the project. How will that affect productivity? What if other members of the community want to come and eat also?

Andy Stern from ATS Chester developed the prototype spreadsheet model (Figure 2) that was used to develop the funding cost estimate for building the first phase of the Cas Charles system from the spring box to the Cite reservoir. The spread sheet is heavily dependent on needed materials, an estimate of how many joints of pipe can be laid per day, and how many unskilled and skilled workers will be needed to complete the work. The spread sheet provides a flexible tool for the local project managers to change estimates of material needed and daily production of laborers, along with material and labor cost while giving them a good estimate of the funding that will be needed for the material and labor.

HAS-HAITI WATER SUPPLY PROJECT
CA CHARLES SUPPLY LINE
ESTIMATED COSTS
OCT 26 - A.H. STERN

NOTE: **BLUE** VALUES - INDEPENDENT VARIABLES
NOTE: **RED** VALUES - CALC'D INDEPENDENT

ASSUMPTIONS

ALL LINE PIPING AND FITTINGS ON-HAND AND NOT INCLUDEI

LINE LENGTH	1.6	KM
PIPE SEGMENTS	20	FT
PYLONS PER SEGMENT	1	EA
THRUST BLOCKS	10%	PERCENT OF JOB
HIGH INCLINE ANCHORAGES	10%	PERCENT OF JOB
SKILLED C	10	JOINTS PER DAY
UNSKILLE	6	PER DAY
UNSKILLE	3	PER DAY
UNSKILLE	5	PER DAY

UNIT COSTS (USD)

DRAINAGE	3.50	/FT
PORTLAN	9.00	/#94 SACK
REBAR	0.62	/FT (#6)
ANCHORA	30.00	EA - EST

CALCULATED

LINE LENGTH	5250	FT
NO. OF JOINTS	262	EA
NO. PYLONS NEEDED	262	EA
NO. THRUST BLKS NEEDED	26	EA
ICLINE ANCHORAGES NEEDED	26	EA

PYLONS

PYLONS FOUNDATION EXCAVATED 1 FOOT
REBAR IN FOOTER ONLY AND DRIVEN TO KEY
CONSTRUCTED AS MASONRY UNITS FROM COBBLES
USE LOCAL AGGREGATE AND SAND FOR FOOTERS
USE LOCAL SAND FOR MORTAR

1	BAG PORTLAND
20	FT RBAR (#6)

THRUST BLOCKING

FOUNDATION EXCAVATED 1 FOOT
REBAR IN FOOTER ONLY AND DRIVEN TO KEY
ABOVE GROUND CAST IN PLACE AND BUTTRESSED MASONRY
1 CUBIC YARD EQUIVALENT - EA
NO ENCASEMENT OF PIPE

3	BAG PORTLAND
40	FT RBAR (#6)

ANCHORAGES

STAR DRILLED ROCK ANCHORS
ATTACHMENT SADDLE CLAMP

2	ROCK ANCHORS
1	SADDLE FITTINGS

FOR CONSERVATIVE ESTIMATION PURPOSES, NO DEDUCTION OF PYLONS FOR THRUST BLOCKS OR PIPE ANCHORAGES
NO TRAVEL ISSUES CONSIDERED FOR TECHNICAL OVERSIGHT FROM USA PARTICIPANTS
ASSUMED A CONCRETE MIXER WILL BE AVAILABLE - NO HAND POWER TOOLS - ALL HAND LABOR
LABOR COSTS - VALUES ESTIMATED FOR BUDGET PURPOSES

PROJECT STAF	PM	FIELD ENGINEER	ENG. ASSIST (1)	ENG. ASSIST (2)	CONST FOREMAN	SKILLED CREW	UNSKILLED CREW
RATE/DAY (U	25.00	15.00	9.00	7.50	6.00	4.50	3.00
NUMBER OF CL/	1	1	1	1	1	4	4
TASKS (ESTIMATED IN DAYS)							
I ENGINEERING / SURVEY RTE	1.0	3.0	3.0	3.0			
/QC CALCS - OPTIMIZE DESIGN		2.0					
FIELD LAYOUT / MARK ROUTE	1.0	2.0	2.0	2.0	2.0		
PROJECT MOB AND MEETINGS	3.0	2.0	2.0				
ENT FEEDERS TO SPRING BOX	1.0	1.0	1.0		1.0		5.0
REHABILITATE SPRING BOX	1.0	1.0			10.0		10.0
IOVE / REHAB EXIST. 400' LINE					5.0	5.0	
STRING AND INSTALL LINE	4.4	1.0			43.7	43.7	
INSTALL PYLONS	4.4	5.0			43.7		43.7
INSTALL THRUST BLOCKS	0.9				8.7		8.7
ISTALL INCLINE ANCHORAGES	0.5				5.2	5.2	
CONNECT TO RESERVOIR	0.2				2.0	2.0	2.0
TEST - COMMISSION - DEMOB	2.0				2.0	2.0	2.0
EGORY - DAYS DIRECT LABOR	19.3	17.0	8.0	5.0	123.2	57.9	71.3
ORY - COST OF DIRECT LABOR	483	255	72	37.5	739.2	1041.6	856

S/TOTAL DIRECT LABOR		3484.3
LABOR CONTINGENCY	10%	348
TOTAL DIRECT LABOR		**3833**

MATERIALS

AUGMENT INTAKE T	100	FT PIPE	3.50	USD/FT	350
CONCRETE FOR PYL	262	BAGS	9.00	USD EA	2358
REBAR FOR PYLONS	5240	FT RBAR	0.62	USD/FT	3249
CONCRETE FOR THI	78	BAGS	9.00	USD EA	702
REBAR FOR THRUST	1040	FT RBAR	0.62	USD/FT	645
HIGH INCLINE ANCH	26	ASSBLY	30.00	USD EA	780
HAND TOOLS AND EXPENDABLES ***			1500.00	LOT	1500

TOTAL MATERIALS		9584
HAITIAN MAT'LS MULTIPLIER	1.80	
S/TOTAL MATERIALS		17250
MAT'LS CONTINGENCY	10%	1725
TOTAL DIRECT LABOR		**18976**

***** MISC TOOLS**
WHEEL BARROWS
STAR DRILLS, DRILLING BARS, HAMMERS
HAND TOOLS (TROWELS, SHOVELS PICKS, MATTOCKS)
SURVEY SUPPLIES
FUEL

TOTAL PROJECT **22808**

Figure 2. Material and Labor Spreadsheet

Conclusion

There is much work to be done in the developing world that requires the kinds of thinking, planning, and designing that US engineers have traditionally been educated in. However, much of our engineering in the US is driven by regulations and our free market development economy. We are taught to think of the growth and economic development of all of the areas that we are working in and to plan for future needs with the assumption that all future people will want the same level of service or more than the current people and to a great extent that the raw resources and monies will be there to meet those needs. We are starting to feel the limitations of water resources in the US now and additional considerations need to be given to what we are designing. But still we design as if the development will never cease, and we legislate where the future water will come from.

In countries like Haiti, we must step back from our US engineering design paradigm, and perhaps even design engineering to limit future growth, future economic development, and future luxuries. Yes, we must in some cases subvert the engineering designs that have already been planned or put in place based on current engineering practices. Rural Haiti generally cannot support the type of pressurized water supply and distribution systems that we have become accustomed to. In many areas where systems have been developed they may need to be removed and proper feasible systems engineered that will fit the needs of the people integrated with an environment where no further development can occur as none can be sustained.

If we wish to prepare students in our American engineering programs for a more active international role in developing countries in their careers, we have to be able to at least introduce them to a context that is very different from the US engineering scene. Although some factors such as funding may be more constraining, the typical legislated constraints that control much of engineering design in the US may be nonexistent. It will be necessary for the faculty to invest the time working in developing countries and sharing case studies with each other to be able to convey these nuances to their students.

References

1. Berdanier, B.W., (2005), "Liberation Engineering Defined," personal communication, December 27, 2005.
2. Peet, R. and Watts, M., (1996), Liberation Ecologies, Routledge, London, p. 263.
3. McGeehin, M., (2002), "Haiti's Environmental Problem: An Alternative Discourse," http://www.clubs.psu.edu/up/phaiti/mcgeehin.htm.
4. Farmer, P., (1994), The Uses of Haiti, Common Courage Press. Maine.
5. The World Fact Book, US Central Intelligence Agency, (2005), http://www.cia.gov/cia/publications/factbook/geos/ha.html.
6. The Wednesday Report, Canada's Aerospace and Defense Weekly, www.thewednesdayreport.com .
7. Blaike, P., and Brookfield, H., (1987), Land Degradation and Society, London, Methuen, p.23.
8. de Janvry, A., and Garcia, R., (1988), "Rural Poverty and Environmental Degradation in Latin America," IFAD Conference on Smallholders and Sustainable Development, Rome.