

MIT International Development Initiative : Grant Report

Project: Bridge Building in Lesotho
Student: Todd Radford



From Jan 7 to Jan 26, 2007, Todd Radford traveled to a rural area of Lesotho to investigate the potential for a trail bridge building program that could involve MIT undergraduates.

The major objectives of this information-gathering trip were:

- To assess the need and desire for trail bridges
- To assess the capacity and potential to build bridges
- To assess the potential as a destination for an MIT undergraduate project

To achieve these objectives, a variety of tasks were performed.

Task: General Survey of the Area

Lesotho is a country with a population of about 2 million people, a land area on a par with Belgium, and one major paved highway which runs through the lowlands of the country. Needless to say, much of the population is underserved in terms of transport. Rural transport largely takes place on poorly maintained dirt roads, which are relatively dangerous and/or slow. Or people wait in lines to take small aluminum ferries across rivers, as shown in the photo above. There is a general need for improved rural transport, to provide better access to more remote regions for people and supplies. This would improve the lives of much of the rural population, and help to combat migration to the lowland corridor and more urban areas.

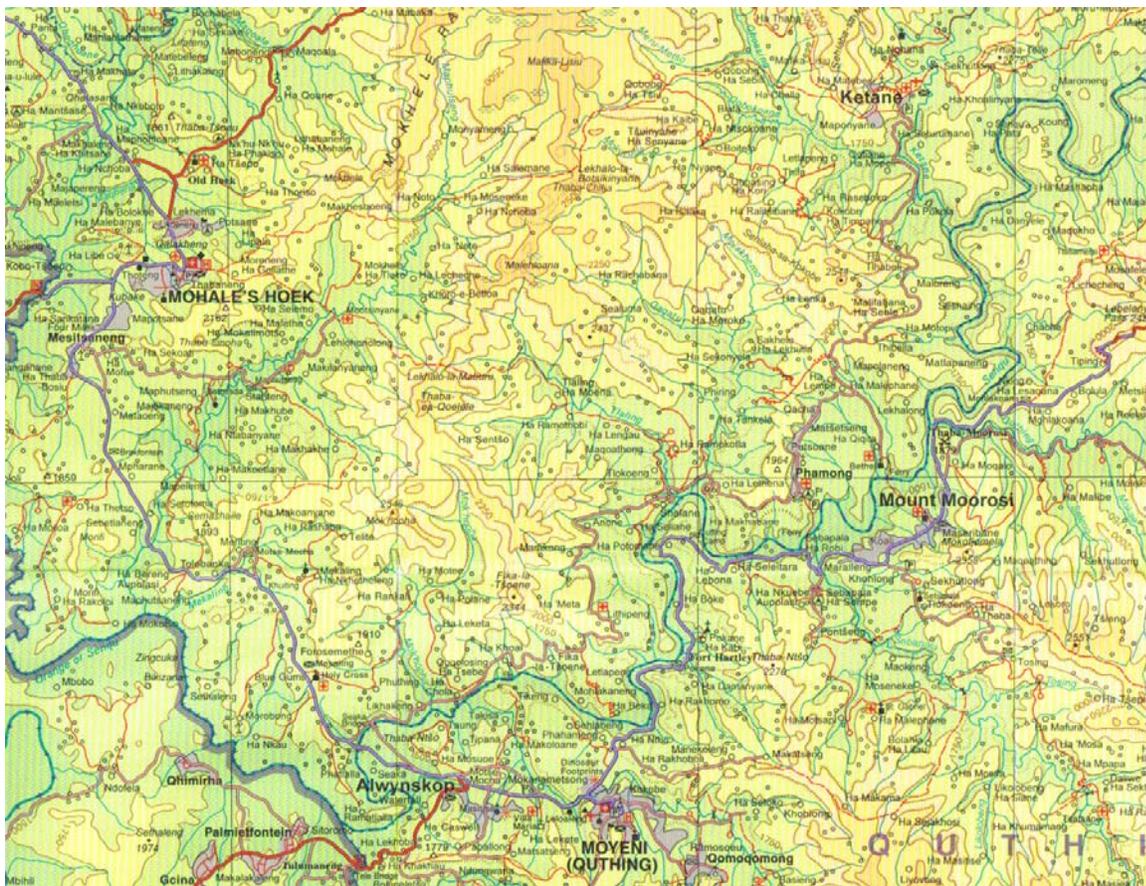
There are a number of ways that rural transport could be improved and there could be much discussion on their relative merits. One method of improving transport is to provide reliable pedestrian crossings of the many rivers and dongas. That will be the primary focus of this project. Another method would be to improve the road network, including road bridges, which would definitely benefit the population. However, that is seen to be less immediately feasible, so a focus on the pedestrian network is warranted. It is important in the planning, to try to insure that improving the pedestrian network will not have an adverse effect on progress in improving the road network.

While there is a general need in the country for improved transport, this project will first focus on a specific area that is underserved. Phamong is an area within the Mohale's Hoek District of Lesotho (shown in the southwest part of the country in the map below). Mohale's Hoek district is separated from the Quthing district by the Senqu River. This river also serves as a barrier between much of the rural population of the district and the one paved highway, which provides significantly improved access to supplies and services. The Phamong area is located in the Mohale's Hoek district, just across the river from Mount Moorosi on the map below.



The map below shows a larger view of the western part of the Maseru's Hoek District. The paved road, shown in purple, runs from Maseru to the northwest, through Mohale's Hoek to Outhing, crossing the Senqu River at Seaka. From Outhing, the road runs northeast along the south side of the Senqu River to Mount Moorosi. From there, the road continues east to Qacha's Nek and the border with South Africa. It takes about two hours to drive from Maseru to Mohale's Hoek and about another hour to get to Mount Moorosi on the paved road.

To get to the Phamong area, which is just across the river from Mount Moorosi, one must leave the paved road before it crosses the Senqu and travel on a dirt road along the north side of the river, shown in pink on the map. It takes about three hours to travel from Mount Moorosi to Bethel along the dirt road, as opposed to the hour it would take to travel the same distance on the paved road. In addition, this road is labeled as a "fair-weather road" implying that it is not usable during, and perhaps for a time after, a large storm.



Mount Moorosi is the major source of supplies and services for the Phamong area, including food and postal services. To get access, people who live in the Phamong area must cross the river at one of several free government funded ferry crossings. Ferries consist of inconsistently maintained aluminum rowboats operated by teenagers. Ferries run only between 7am and 4pm. If you arrive after 4pm, it may be possible to cross, though the operators will often charge for this service.

During the operating hours, service is inconsistent. Waits can be up to several hours long when the boat is operating properly and longer if there is any sort of problem. Additionally, the order of priority for the ferry is supplies (such as beer) first, followed by men, followed by women and children.



There are currently three ferry crossing points in the area that would be good possible bridge crossing points, Ha Teboho, Phamong, and Shelane, indicated roughly by circles on the map above.

Task: Meet with Department of Rural Roads

On Thursday Jan 25, 2007, a meeting was held with the Lesotho Department of Rural Roads. Present at the meeting were the Chief Engineer of DRR as well as a number of senior regional engineers.

The purpose of the meeting was to begin a dialogue with the Department of Rural Roads as they would be the major builder of trail bridges for the country, and would generally be responsible for any trail bridges built through other programs. Thus, DRR is interested in acquiring the in-house ability to design and construct wire-rope bridges, and being included in the planning and decision-making for any other projects that they might ultimately inherit.

Some major points that came out of the meeting:

- DRR is interested in acquiring in-house ability, but cannot lose any of their limited number of engineers for a significant period of time. Thus a remote residence course is less than ideal
- Due to the limited number of engineers, the design and construction phases will likely be clearly divide between engineers and technicians. Thus, it may make sense to structure a course accordingly
- DRR has a strong interest in labour-based construction, which should be considered in the development of bridge designs and any training
- There is a preference, if teaching a course on suspensions bridge design, to not limit the scope to just trail bridges, but also include road bridges. It was thought that this would be only a small addition of material to teach while being more generally useful and marketable
- DRR has a training facility near Maseru that could be used if the timing of a course worked out. The facility has accommodations in addition to teaching facilities
- There is interest in trying to include engineers and technicians outside of just the government. To do this, logistical information needs to be nailed down in a timely manner so that advertising can take place
- It is suggested that the course should not be free to participants and that they should have to contribute some fee to show serious intentions. Irish aid funding could still be used to subsidize this cost, but should not be used exclusively
- May/June would be good timing as that corresponds to low water levels

Relevant contact information:

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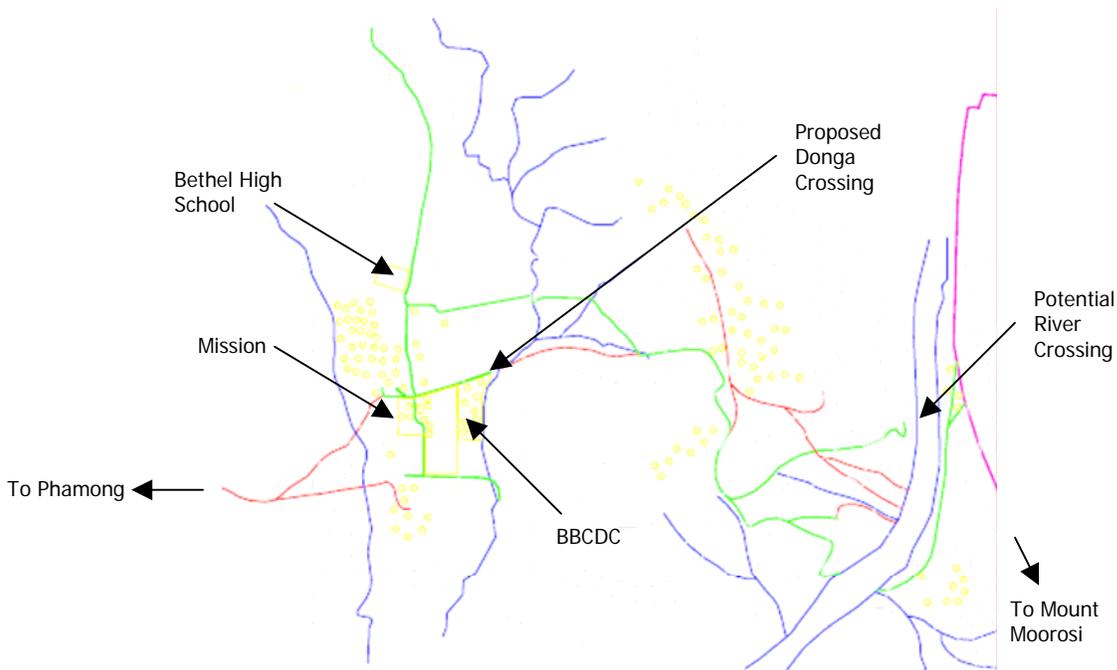
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Task: Begin Development Prototype Bridge Project

To assess the possibility of building the bridges a single prototype bridge design was begun. This prototype bridge would cross the donga next to the Bethel Business and Community Development Center, a likely base of operations for the project.

As part of this planning, and as part of the potential planning for the first Senqu River crossing, a more detailed survey of the area around the BBCDC was conducted to assess facilities and general pedestrian flow. A map of the surrounding area is shown below.



Roads are shown in green; trails are shown in red; water is shown in blue; structures are shown in yellow.

The community on the left of the map is Ha Qiqita, commonly referred to as Bethel, which is the name of the RC mission and the high school originally built by the mission. The community on the right is Ha Teboho. Pedestrians travel from Ha Qiqita, Ha Teboho, and other villages to the north and west by foot on the roads and trails to cross the Senqu River by ferry at the location marked as a potential river crossing to get to Mount Moorosi. Typically, people will travel to and return from Mount Moorosi in a single day, provided they can catch the ferry on the return trip. Though it is only a 3km journey from the BBCDC to Mount Moorosi, a round-trip journey is typically a full day affair.

A crossing of the Senqu River would have a span on the order of 100m, which is an ambitious project. To assess the capabilities to accomplish such a project, it was proposed to design and construct a shorter crossing first. Such a bridge would demonstrate capacity to build bridges, allowing for more credible requests for funding and budgeting. Also, the design and construction of the bridges could be used as a means of teaching and transferring knowledge to people in Lesotho.

The proposed site for a prototype bridge is a crossing of the Nokana ea Liboti donga located between Ha Qiqita and Ha Teboho, just to the east of the BBCDC. The donga has a relatively extensive watershed, catching huge amounts of water off of the surroundings ridges whenever there is precipitation and carrying it down to the Senqu River. This crossing is indicated in the map above.

About Dongas

Erosion is a serious problem in Lesotho. A combination of a lack of vegetation, severe topography, and large rainfall events results in large amounts of soil erosion. In many locations, these high levels of erosion result in sudden deep erosion gulleys, locally called dongas. These dongas tend to have very large changes in flow, varying from a trickle to a raging torrent. In the best of times, they offer a hardship in terms of travel. In the worst of times, they can completely isolate sections of the population. When in full flow, the dongas are extremely dangerous, and they can switch from no flow to full flow in a matter of minutes during extreme rainfall events.

The extreme nature of the dongas is relatively unique and seems to be based on the combination of the water flow characteristics and the properties of the soil. A high amount of fine sediment and clay creates a cohesion that allows the dongas to have vertical walls for many meters of depth. The dongas also start suddenly, going from nothing to a sudden deep wide gulley. A variety of photos of different dongas are shown below.





In many cases, donga crossings are not a priority because they are not necessary most of the time. Trails have been made that travel in and out of the dongas, so they are passable, albeit not easily. When they do flood, they can cut off traffic, however the water levels typically only form a barrier for a maximum of a day or two, and usually only for a number of hours. They do, however, pose a hardship for the people who must cross them every day. Some of the dongas can be very deep and need to be crossed daily by students heading to school. While not a priority, providing donga crossings would have a positive impact on many people's lives.

To work with dongas, a better understanding of the mechanics of their formation and erosion is necessary, as well as an analysis of their stability. Geotechnical engineering professors in the civil engineering department will be consulted.

Bethel Donga Crossing



From North



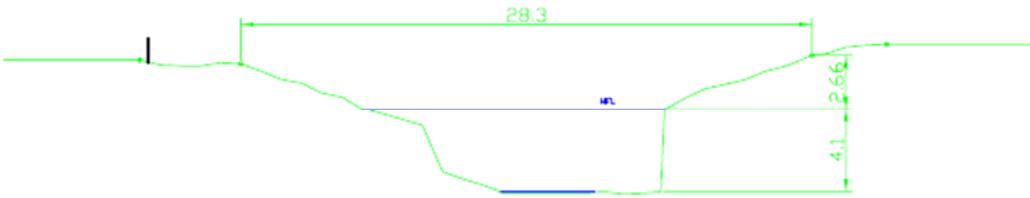
From West



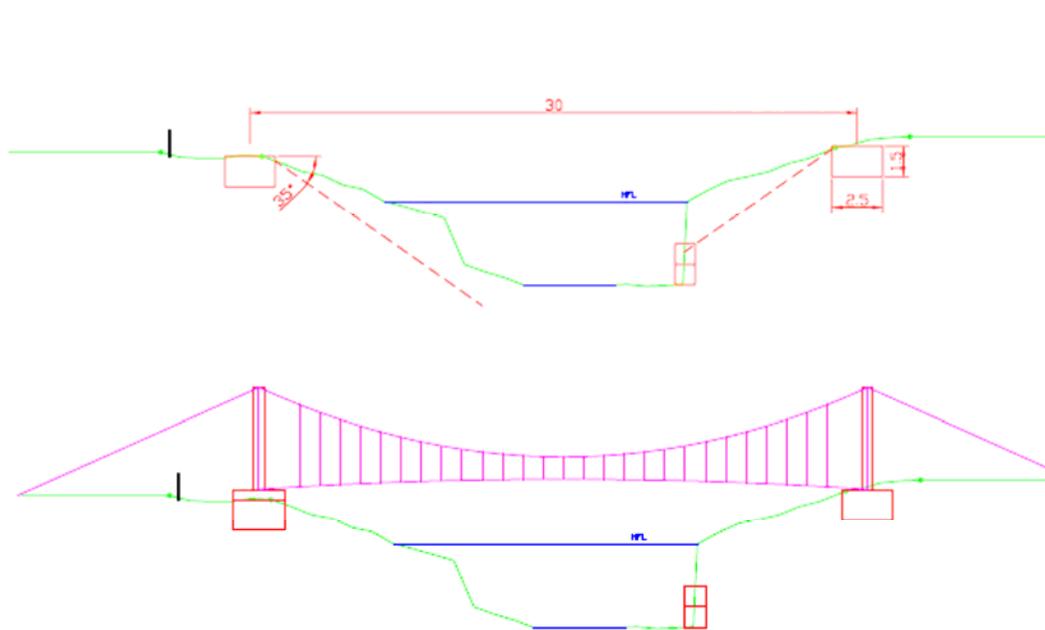
From East



From South



A rough preliminary design for a crossing was performed. Photos of the proposed location taken from rough cardinal directions are shown above, along with the surveyed profile at the crossing point. Using some slope reinforcement for the east wall of the donga, a possible span of 30m seems to be a reasonable. A potential bridge layout is shown below.



The exact details of the bridge are still to be designed. To accomplish this, availability of materials and prices were surveyed.

There are a number of possible suppliers, at a variety of locations, which will be considered for acquiring bridge materials. They will be contacted for more detailed information and pricing once decisions have been made. For the moment, some idea of cost is necessary to perform preliminary design. A list of potential suppliers as well as preliminary quotes from several suppliers are provided below.

Jandrell's Hardware, Mophale's Hoek, Lesotho
Contact Yvan for more detailed contact info

Lesotho Steel, Maseru, Lesotho
Contact Yvan for contact info

MacSteel, Bloemfontein, South Africa
Ph +27 51 403 9400

Kevcor (wire rope), Bloemfontein, South Africa
Ph +27 51 447 9423 / +27 51 447 9459

Note: Only carry up to 13mm but can order from Johannesburg

Rope Constructions (wire rope), 8 Prop St, Johannesburg, South Africa
Ph +27 11 493 7956/9 ropecons@ropecon.co.za www.ropecon.co.za

KevCor
 Bloemfontein
 South Africa
 +27 51 447 9423
 +27 51 447 9459
 Date: 25/01/07

Approx \$

13mm Steel Wire Rope Galvanized (6x19) (1560kg) Fibre Core (\$/m)	R 16.40	\$ 2.34
13mm Rope Clamp Comm Bulldog	R 4.72	\$ 0.67
13mm Rope Clamp SABS-813	R 16.10	\$ 2.30
16mm Turnbuckle E&E	R 22.27	\$ 3.18
13mm Shackle Bow 15x16 2 ton	R 13.01	\$ 1.86

Jandrell's
 P.O. Box 4
 Mophale's Hoek
 Lesotho
 Date: 25/01/07

Approx \$

Angle Iron 40x40x3mm x 6m	R 167.94	\$ 23.99
Angle Iron 50x50x6mm x 6m	R 224.12	\$ 32.02
Angle Iron 80x80x6mm x 6m	R 394.95	\$ 56.42
Flat Bar 25mm x 5mm x 6m	R 52.98	\$ 7.57
Flat Bar 50mm x 5mm x 6m	R 85.97	\$ 12.28
Mesh Diamond 1.2m x 75mm x 2mm	R 165.95	\$ 23.71
Rebar 10mm x 6m	R 26.10	\$ 3.73
Rebar 12mm x 6m	R 33.51	\$ 4.79
Rebar 16mm x 6m	R 68.33	\$ 9.76
Rebar 6mm x 6m	R 11.10	\$ 1.59
Rebar 8mm x 6m	R 20.92	\$ 2.99
Rebar Y12 x 6m	R 36.97	\$ 5.28
Rect Tubing 32x25mm x 6.4m	R 75.92	\$ 10.85
Round Tube 25mm x 1.6mm x 6.4m	R 65.97	\$ 9.42
Round Tube 50mm x 2mm x 6.4m	R 134.96	\$ 19.28
Round Tube 76mm x 2mm x 6.4m	R 240.35	\$ 34.34
Square Tube 25mm x 1.6mm x 6.4m	R 74.65	\$ 10.66
Square Tube 50mm x 2mm x 6.4m	R 156.93	\$ 22.42
Square Tube 76mm x 1.6mm x 6m	R 277.24	\$ 39.61

Task: Learn About the BBCDC

The Bethel Business and Community Development Center was the base of operations for the trip and would likely be the base of operations for both the prototype bridge and future bridges over the Senqu River.

The BBCDC is a post-secondary school with a focus on rural skills. They teach courses in carpentry, solar energy, permaculture, business, metalworking, and hospitality, among others. The school is very progressive for the area and is in many ways a study in sustainable living. The campus has a dozen buildings or so, including workshop, classrooms, office, dormitories, conference center, support facilities, and personal homes for the teachers at the school.

Electricity

There is a solar mini-grid that covers five of the campus buildings (workshop, kitchen, office, dormitory, conference center) from a single large solar array mounted on the workshop. In addition, most of the other buildings have their own individual solar power systems. The grid is also set up to be run off of a petrol or diesel generator during times of high use so as not to drain the batteries of the solar system. Heavy use tools such as the mill and lathe must be run off a generator.

The mini-grid tends to be close to capacity when students are in residence and especially when there are conferences being held. However, there is enough capacity most nights, such that there is lighting and consistent refrigeration.

Water

Clean water is provided to the BBCDC, the mission, Bethel High School, and the village of Ha Qiqita from a natural spring located below the mission to the west. A continuously operating ram pump creates a reliable and consistent supply. The water is potable, though someone not used to it may have an adverse reaction at first.

Hot Water

Hot water is provided in all living accommodations by solar water heaters mounted on the roofs of the buildings.

Cooking

LPG tanks and stoves are available for cooking. In addition there are a number of solar cookers and solar dryers which can be used.

Workshop

The workshop is well stocked with hand and power tools. Notable power tools include:

- lathe
- mill
- band saw
- cut-off saw
- drill press
- abrasive chop saw
- power drills

Other useful things owned by the BBCDC include

- gas-powered arc welder
- 2 gas-powered cement mixers
- 3-ton truck
- tractor with front-end loader

Cost

Accommodations at the BBCDC were free during this past trip, though that might not be the case if there were more people. Communal food was possible for about R150/week (~\$22/week.)

Conclusions

Objective: To assess the need and desire for pedestrian bridges

There is definitely a need for some number and type of fixed crossings of the Senqu River to serve the relatively large population that live on the north side of the river. Ideally, this would be a road bridge. However, as the resources are not present and are not likely to be available in the foreseeable future, it makes sense to look into other solutions. Pedestrian bridges offer a viable alternative, and wire-rope supported bridges are likely to be the most appropriate solution for the spans in question.

There is interest from the Department of Rural Roads in learning how to design and build wire-rope suspension bridges, to be able to serve the needs of the Phamong area as well as other underserved areas of Lesotho. The department has a current trail bridge building program, however this program focuses on the use of angle iron trusses, which have a limited span. Transferring knowledge on how to build bridges with longer spans could create opportunities within these areas.

There is interest from the Phamong District Council and from the local chiefs to have bridges built in the area. Early in 2006, the Phamong District Council was approached by the BBCDC and asked for support in an effort to improve infrastructure for the crossing of the Senqu River in this region. Another meeting was convened at the BBCDC on December 1, 2006, during which this information gathering trip and possibilities for follow-up work were discussed. It is unclear what such support would consist of.

Conclusion: There is a definite need and desire for pedestrian bridges. It is unclear, however, exactly what level of support will be provided by the various stakeholders. It is worth pursuing the project, however an effort needs to be made early to determine the future of bridge-building in Lesotho.

Objective: To assess the capacity and potential for realizing the bridges

There seems to be strong interest in a course in how to design and construct wire-rope suspension bridges. As part of this course, a prototype bridge across the Nokana ea Liboti donga could definitely be built. Irish Aid has donated money towards such a course, and, while

a budget needs to be determined, it seems at this preliminary stage that this funding combined with some small amount of tuition for the course, should provide enough resources to build the prototype bridge.

Materials to use in the bridges are definitely accessible, from suppliers in South Africa if not in Lesotho. The supply network in Lesotho could be used to set up access to pretty much any materials that would be needed. Getting materials to the site is not quite so straightforward, though definitely still possible.

The proposed river crossings seem to be feasible spans for the technology proposed and the materials available. It is unclear where funding for these bridges will come from, but this is something that can be pursued in communication with the BBCDC and DRR.

The BBCDC has many resources that greatly facilitate the construction of these bridges (front-end loader for excavation, cement mixers, portable arc-welder, metal-working shop.) Labour, and especially skilled labour, is somewhat of a concern. It is hoped that the support of the local chiefs and the Phamong District Council will facilitate unskilled workers. It is also hoped that skilled workers can be supplied by DRR in the form of technicians who are learning how to construct this type of bridge.

Conclusion: There is definite capacity to implement the donga crossing in the near future, and potential for the realization of Senqu River crossings farther in the future. As part of the prototype design and construction, work towards establishing funds and support for the Senqu River crossings should continue.

Objective: To assess the potential as a destination for an MIT undergraduate project

In many ways, this is an excellent destination for an initial undergraduate development project. The BBCDC as a base of operations is well setup with electricity, clean water, and good technical capacity. And the country itself, while definitely a developing nation suffering from poverty and AIDS, does not have many of the other problems that make countries difficult to work in such as malaria and other tropical diseases or political instability. The people are in general very friendly and supportive, and many, especially in important positions, speak English, greatly facilitating communication.

Conclusion: Lesotho, and the BBCDC in specific, would make a good destination for an MIT undergraduate development project.

Proposed Direction for the Project

With the information gathered on the trip, the project seems feasible and should go forward. The proposed next step is to establish a bridge building group within the Department of Civil and Environmental Engineering.

There are currently 9 undergraduate students in CEE that have expressed interest in this project and being part of a group. The next step is to write up a formal proposal to the Civil and Environmental Engineering Department to determine and establish the status of the group and the possibility of funding.

Once established, the goal of the group would be to amass knowledge on appropriate bridge technology and assemble it in one location, possibly in the form of a bridge building guide. This knowledge could then be made available to populations throughout the developing world through future bridge building projects.

In the short term, this amassing of knowledge would happen through a variety of tasks related to the bridge project in Lesotho, including:

- Design the prototype bridge
- Develop a course on design and construction of suspension bridges to be taught in Lesotho
- Travel to Lesotho to help build the prototype bridge
- Develop the Senqu River crossings (surveying, funding, design, etc...)

There is also the possibility of trying to link some of these tasks into the curriculum of the CEE department, through courses, UROPS, and internships.