# EWB Junior Clinic Report:

# The Gambia

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## Executive Summary

In late August 2008 Rowan University's chapter of Engineers Without Borders received a project to repair a four kilometer stretch of the Kuntaur Road in The Gambia, which is difficult to traverse due to flooding and rutting. The original information about the project was submitted by a Peace Corps volunteer in the region. Through contact with people in the area it was determined that the road can be divided into three main sections based upon the conditions of the road which include: rutting, muddy road surface, and standing water ranging from six inches to three feet deep. Initial research led to a number of possible solutions to these problems, including: raising the road, rerouting the road, diverting the water utilizing drainage systems, and repairing or replacing the road surface.

An assessment trip was carried out in January 2009. During this assessment trip data was collected to inform the design and planning in preparation for implementation of a solution. The data indicate that the road does have three major problems comprised of standing water, muddy sections of road, and rutting, as suspected prior to the trip. The data about the conditions of the road, the elevation of the road, water level, and available materials led to the selection of raising the road as the primary solution of those considered prior to the assessment trip. The land survey data was used to calculate the amount of soil and materials needed to raise the road and establish cost and time estimates. This data was used to consider implementation alternatives varying from completely mechanized to fully manual labor. Combining mechanization and manual labor was considered for two conditions, the type of labor being done, such as hauling or excavating, and the section and condition of the road being improved, such as standing water or rutting.

An analysis was done of the current conditions of the road and in order to raise the road to an appropriate level approximately 11,990 $yd^3$ of fill is required. From this, the preliminary cost estimate of the fully mechanized method was determined to be \$67,569 (~£46,306) and 49 days. The direct cost for the fully hand labor method would be minimal, requiring the purchase of some hand tools and would require170 days with a crew of eight. The mixed method would incorporate mechanized methods for excavating and hauling and hand labor for compacting and grading, making the cost estimate approximately \$61,359 (~£40,812) and the number of days at 48. The recommendation is that a mixed method be used because this will minimize cost and

the extensive labor of excavating and hauling will be mechanized while allowing the community to be involved and gain the skills required for compacting and grading.

## Introduction

Figure 1 is a map of the region of The Gambia with the road shown as a line from Kuntaur to Kundang. Portions of the road are severely flooded during and following the six month rainy season. A total of eight villages depend on this road to reach Kuntaur in order to obtain health care, education, and food. This road also provides access to the rice fields that are tended daily by the women of the villages. There are many health hazards associated with the road in its flooded state. Standing water on the road is a breeding ground for mosquitoes, which can increase outbreaks of malaria. There are also parasites that reside in the standing water. Schistosomiasis is an example of a parasitic disease in this region that spreads through standing water. This is a chronic illness known to damage internal organs and impair growth. Physical injuries occur often due to the condition of the road. Villagers trip over the unseen ruts and rocks underwater. Carts and vehicles have also been known to fall into ruts, occasionally throwing passengers to the ground.

There is also an economic impact of the road being flooded. The amount of goods that can be transported is limited due to the current state of the road. Being able to bring fresh produce back from Kuntaur would allow the villagers to enhance their diets, improving their overall health. The economic well being of the communities also depends on year round access to the road. The women in the villages need to access their rice fields, which lie at the end of the road. Cultivation of the rice is a primary source of food and revenue for the communities. They also need to get to the markets of Kuntaur not just to buy food, but to sell their crops.

The need for the Kuntaur Road project was identified by Kellee Davis, a Peace Corps health volunteer who lived in one of the villages, Sambel Kunda, located along the Kuntaur Road (Point G on the Google map in Appendix A). Kellee submitted the proposal to EWB-USA in December 2007. Rowan University EWB applied for and received the project in August 2008. Entailed in the following report are the results of the assessment trip including health and land surveys. Also included in the report are the details of the preliminary design alternatives, including estimates of fill volume, compaction lifts, and cost; along with a study of the available resources needed for the construction of the road.

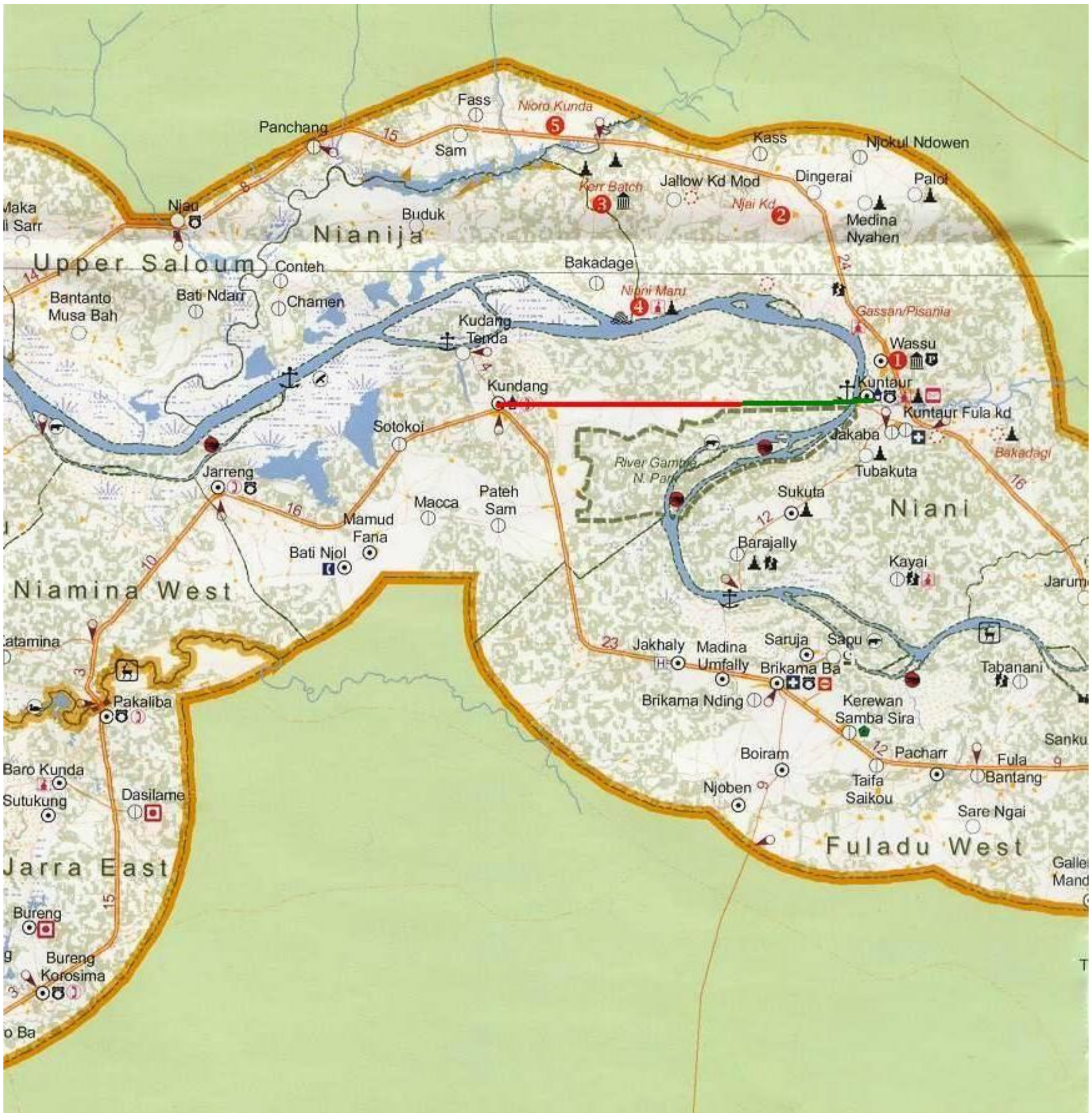


**Figure 1: Kuntaur Region with Road Outlined**

## Overview of Assessment Trip

A travel team of three students (Katie Booth, Brian Fischer, and LaDonne Harris) and one professor (Dr. Jess Everett) made the trip to The Gambia from January 8-17, 2009. The travel was from JFK airport in New York City to Banjul, The Gambia with a stop in London Gatwick airport. The team met the Peace Corps volunteer, Kellee Davis at the airport. For the duration of the trip she served as guide, translator, and collaborator. Heather Armstrong and Horse and Donkey Trust employees made all of the travel and lodging arrangements while in The Gambia. It took one day each way to travel from the capitol, Banjul, to the region where the road is located near Kuntaur. Both Banjul and Sambel Kunda where the road is are located on the south side of the river. However, due to the poor condition of the South Bank Road, a ferry was taken in Banjul to cross to the North Bank Road, which was then traveled approximately 200 kilometers to Kuntaur where a small boat was used to cross back to the south side of the river. Trucks were taken from the Kuntaur crossing to Sambel Kunda. Due to the lengthy travel, the team was only in the Kuntaur region for three days. A detailed itinerary appears in Appendix B.

During our first day in Kuntaur we were able to do a preliminary walk of the road and had a group meeting with the village political and religious leaders (i.e. alkalos and imams). Other villagers who were interested in the road and our presence in the region also attended the meeting. During that meeting we obtained some history of the road and the input of the leaders on what equipment and resources are available in the region. On the second and third days we split into two groups. One group conducted a land survey of the road to obtain technical data about the topography of the land. The other group met with the leader of each of the eight villages individually to learn about the road, assess their ideas and commitment to improving the road and to learn of other issues that our group might be able to address during our five year commitment to the region.

After leaving the Kuntaur region and traveling back to the capitol we met with the National Road Building Authority and received their input, suggestions, and cooperation on the project. Because they have no specific budget and this road is in their lowest priority road classification they did not have resources or any data to benefit the project specifically. However, they did supply us with some of their cost estimates for materials and equipment.

### *Community Attributes*

The most useful contacts located in-country for this project were established prior to the trip. These contacts include the Horse and Donkey Trust (HDT), a local NGO that is headquartered in

Sambel Kunda and works in the surrounding villages educating people to take care of their animals and Kellee Davis, the Peace Corps (PC) health volunteer living in Sambel Kunda through May 2009. HDT provided our housing and food in Banjul and in the village and made all of our transportation arrangements. We also worked very closely with Kellee, who submitted the original project proposal. We also made contacts in Banjul with the National Road Building Authority (NRA). During the previously mentioned meeting we met a number of NRA staff. Figure 2 shows those in attendance at this meeting. Additional affiliation and contact information is available in Appendix C.

**Figure 2: Meeting at National Road Authority**

The community will play a large role in this project. Local villagers will assist by researching available materials, meeting with regional government leaders to make them aware of the project, providing background information about the road, approving a final design, providing manual labor to build the road, and establishing a maintenance committee. The villagers do not have specific road building skills, but during meetings with each village leader we received an oral commitment to provide labor to move soil and support to implement the final project and provide continued maintenance. We also received a commitment from two local people, Mr. Bah and the alkalo of Yida to help with translation after Kellee leaves the area. The community has also expressed a willingness to house and provide food for any volunteers. However, the HDT house is available so we will continue to use that resource for food and housing.

The communities will need to create a specific committee to oversee the construction and maintenance of the road. Each alkalo indicated their willingness to organize members of their community to both work on and maintain the road; however, a formal committee of volunteers has not been established yet. Another meeting of all of the village leaders will be necessary. The communities have various capacity to raise funds for maintenance based on the level of organization of the village development association. For example, Misera has a very organized and active village development association that collects funds from the villagers to improve the village. Other villages however were not as organized. This is an issue that will have to be very clearly established to avoid any contention or disparity in financing and maintaining the road. Even with good organization and leadership of the construction and maintenance committee, the cost will need to be minimal as the villages have very few financial resources.

As a design is chosen a formal Memorandum of Understanding will need to be created because currently there is only verbal commitment by the village leaders to cooperate in the project.

### *Brief Health Assessment Summary*

Due to time constraints the travel team was not able to conduct the questionnaire that appears in Appendix D. Kellee committed to conduct this survey in each compound in every village after we left the country. However, because she returned to the United States earlier than anticipated, she was not able to conduct the survey. Currently Dr. Banutu-Gomez, a Gambian native who is a management professor at Rowan University is being consulted to determine another avenue for getting the survey administered. However, while in The Gambia, a portion of the travel team met with the leader of each village. These meetings were intended to add to the regional meeting that each leader attended earlier in the week. The meetings were translated in Pular by Kellee and when necessary, in Mandinka by her host brother, Ousman. The objective of these meetings was to make contact with each village leader and to learn about the big picture of the needs and desires of each village to inform our efforts, not just to repair the road, but also other potential projects over the five year commitment to the region. The results of these meetings are summarized below

#### *Karantaba*

The alkalo of Karantaba serves as the political and spiritual leader of Karantaba. He committed himself and his villagers to work to repair the road. He then explained that the greatest challenge his village endures is obtaining a clean, reliable sources of water. The villagers have one pump well and two open wells, but they travel to the next village, Kunuku to get good water because the water in their open wells is contaminated and the water from the closed well is hard. The hard water tastes bad and is bad for washing. The only closed well in the village is 14 years old and was dug by hand by someone from Basa. The pump in every well in the eight villages is an International Procurement Agency Mark-II, Model F-100, No. RS-89-191 Cylinder R6 63225/98 well obtained from Senegal, but originating in the Netherlands. The pump breaks every three months and the man who repairs them, Ali Unjy lives in Jafy (West of Kundang). It is very expensive to have the pumps repaired, about one year ago they paid 9500 Delasi to have the pump repaired, however it broken soon thereafter and so the village opened the well and now uses buckets to retrieve water. The cut in the well can be seen in Figure 3.

**Figure 3: Karantaba closed well**

The two open wells were dug 31 and five years ago, respectively. They do not use the older well, but dug the newer one in hopes of getting soft water. However, it gets dirty when it rains and does not taste good so they do not use if for drinking. This well appears in Figure 4.

**Figure 4: Karantaba open well**

Each compound has pit latrines. When a latrine is full they cover it with dirt and dig a new one. They have one generator in the alkalo's compound that is used to play movies occasionally. They also have an issue with their livestock dying during the rainy season. Many animals get an infection on their hooves, mouth, and ears.

*Kunuku*

The alkalo of Kunuku was not at home when we visited so we met with his uncle and a few other men in the village as seen in Figure 5. The men indicated that there are many problems facing the villagers. These include, the well pump breaking, having to cook on an open fire where lots of the heat escapes into the air, and the women having to work very hard. They expressed a desire to have equipment to alleviate farming, cultivating, and processing their food by hand. The men only know how to farm and do not have a trade to occupy them during the dry season. They sell enough food to get money to buy clothes, pots, necessities, and pay taxes. The uncle's compound pays 550 Delasi each year to the area council and they also pay 15 Delasi for each cow they own. They do not see any benefits from paying the taxes, but are legally required to do so. They explained that they have complained to the area council, but have received little response. The protocol for doing so is to have the alkalo report to the chief in Kararuntua, who is the head of the region, who then takes issues to the area council for the Central River Region in Janjangbureh.

They have never tried irrigating, but think that would help provide fresh food in the dry season and would allow the men to work all year long. They harvest corn, peanuts, millet, which does not spoil during the dry season, but the pumpkin, watermelon, and items grown in the women's gardens do spoil.


**Figure 5: Meeting in Kunuku**

*Touba*

The alkalo of Touba and his brother met with us to discuss the issues facing their village. They explained that the Department of Agriculture started a bank for villages to put money to save for large projects and problems. However, they have been unable to save enough money to fund large projects because other issues such as taxes arise that need to be paid. They expressed similar concerns as the previous two villages, emphasizing the lack of good health care, the need for grain crushers to ease the work of the women returning from the rice fields and the need for machinery to help in farming. Some compounds do not even own a wooden hoe or three-prong spade. They must borrow from each other to do their work. Having irrigation, even just for a garden would be helpful so they could eat well year round, not just during the few months after harvesting. They also have issues with their wells. They have one pump well and two open wells in the village. When the pump breaks it takes 2-3 months to raise enough money to have it repaired. During the rainy season they do not drink out of their wells because the water is not good. They go to Kunuku, Sambel Kunda, or the open well in the community garden about 1 kilometer away.

The alkalo gave a history of the road as he knows it, explaining that about six years ago a bulldozer worked on the rice fields and it took less than one week to repair the rice fields and road to how they are now. They got the bulldozer from Sapu. The area council paid and arranged for the repairs. They just piled the soil up from the side of the road and did not add any gravel or boulders that he knows of. He indicated that another road was built to go to the small fishing village that did have gravel added and that road is still in good repair. Rice fields used to be located along this road. He said that the concrete culvers are about fifty years old. The government has only come twice in fifty years to maintain and repair the road. At one time there was a ferry at Kuntaur that took cars and people across. Many people would come from Northern Senegal to cross into Southern Senegal using this ferry. The Kuntaur ferry was moved to Barajally. He anticipates that if the road was repaired sufficiently cars and trucks would use the road and the area councils would meet to try to return the ferry to Kuntaur. He agrees that he, Kellee, and the alkalo of Sambel Kunda should go to the chief to have him petition the government for help on this road project.

*Wellingara*

Anjabara, the alkalo of Wellingara agreed that his village would help repair the road. He said that the road is a major issue for his village because the standing water makes the road difficult to cross so when there is an emergency, like someone falling ill it is very difficult to get them to Kuntaur for medical attention. He also mentioned that some of the women have difficulty breast feeding their babies and is concerned about this. He recognized this might not be something we can work on, but wanted to mention it. He said that ideally they would like the road repaired all the way to Kudang. He also said having a ferry at the river to cross to Kuntaur would be very helpful because it can be difficult to find a boat to get across. He then discussed that their water is supplied by open wells and the taste is good. The people use a piece of cloth to filter the water and remove any debris that has fallen into the well. The people have been living in the village for 19 years and built a well when they moved there. The new well was supposed to have a pump, but money ran out and they left it uncovered. One of the major issues facing his village is the need for a place to store their grain and have a way to crush grain and relieve the work of the women. Currently the grain is stored in a house within each compound. However, they fear that if there was a fire in a house, everything would be destroyed. They would prefer to have one building to store the entire village's grain. They used to have a place like this in Sambel Kunda, but the building collapsed during the rainy season.

*Misera*

The meeting in Misera was held with the alkalo and his son, whom appear in Figure 6. The alkalo of Misera, Cabajabe said that the road is their first priority. Traveling is very difficult and makes their lives very difficult. They go to a hill with rocks that could be used for the road and it costs them 200 Delasi to hire Ynkuba Jobateh in Kundang to drive a truck to haul the rocks. He said that grain storage is their second priority because the people are afraid of fires ruining their entire food supply and that rats get into the food when it is kept in their houses. They are in the process of raising money to build a storage building for the entire village's food supply. They have priced and quantified everything needed for the building and these values are given below:

Costs:

- 275 Dalasi for one bag of cement
- A packet of corrugated roofing is 1600 Dalasi (25 pieces)
- 8mm rebar is 75 Dalasi for 12 m
- A kilo of nails is 50 Dalasi
- Tractor to haul sand – 300 Dalasi
- Hire a mason – 10,000 Dalasi (It would take a week)

Supply amounts:

- 300 bags of cement
- 8 roof packets
- 20 kilos of 4 in nails
- 30 kilos of 3 in nails
- 20 lengths of rebar
- 200 beams

The community just purchased a coos crusher and rice mill. They bought it from Sutura Import & Export Company in Banjul. The coos mill cost 120,000 Delasi and the rice mill 130,000 Delasi. They have chosen two people to run the machines for the entire village and have a generator to run the machines. They raised the money for this and are raising the money for the storage building through a communal fund kept in Trust Bank in Touba or Basse. Each compound has to pay a certain amount to the fund each month. They estimate it will take two years to raise enough to build the grain storage and are also saving for another milling machine for a different type of grain. They currently have one closed well and like their water. Through the help and funding of the Horse and Donkey Trust they are in the process of installing a tank and six taps throughout the village. The village was the most efficient and organized village visited and they are motivated to work and improve their lives.

**Figure 6: Meeting in Misera**

*Bani*

The alkalo of Bani said that although they are the closest village to Kuntaur it still takes a long time to travel through the standing water and they need a better way to reach their rice fields. They have a closed well and do not like the taste of the water because it is hard water. They indicated that after being in the village for a short time the water "changes their stomachs" so that they do not get sick from it. However, because they do not like the taste of the water they often bring water from Misera. They share the well with Yida and there are too many people and disputes arise over the pump. They would like a place to store their food to protect it from fires and animals. One of their main concerns is having adequate farming tools. Currently all farming and grain crushing is done by hand and they would like machines to help make these processes less difficult. Bani appeared in worse condition when compared to the other villages visited.

*Yida*

Nafean Yave, the alkalo of Yida spoke to us in English. He works at the chimpanzee refuge. Yida is very small with only seven compounds. Nafean explained that his grandfather worked on the initial road in the early 1950's and that the road was built by hand by taking stones and rocks and placing them on the road and then using pickaxes to smooth the road. He said that he would be willing to help with translation and securing supplies and as well that he and his people would work on the road. He suggested working with the Agricultural Department in Sapu because they have equipment to use on the road. It is important to them to fix the road because it is difficult for them to transport crops during the rainy season and it is dangerous, especially for women and children to travel through the water on the road. He believes that if the road is wide enough cars and trucks will use it because it is their main road.

Mr. Yave said that they share water with Bani because the well and pump put in by Action-Aid at the beginning of 2008 broke in September 2008 and that they do not have the money or person to fix it because they suspect the man in Soma is trying to have them buy another bad pump and that they would prefer to get their pump from Wassu from a man named Opa. He also said that they need help with sanitation because the toilets are very bad. He also would like a place for his village to store their food to keep it from fires and animals.

*Sambel Kunda*

The alkalo of Sambel Kunda, Ismilo Barry, along with Kebba Barry and Mamajan Barry explained the needs of Sambel. At the end of the meeting Chairn Bubakar Ba, the imam of Sambel stopped to say hello. They would mostly like the road repaired because it is currently very difficult to cross the river for funerals, births, and schooling which are located in Kuntaur. They have family that will be much easier to see if the road is passable. They also have additional concerns. They would like water taps because the pumps are always breaking and it would be nice to be able to have a garden that they could water year round so that they would have fresh fruits and vegetables. They used to have a garden but the fencing was moved to the health clinic so they stopped using it. They would also like tools to farm the land. They are currently working to improve their rice fields which are near the National Park, but they would like to expand them. However, they cannot encroach on the park so they are meeting to discuss building on the side of the river that is not part of the park. The fields near the park get invaded by hippos and hogs and they cannot do anything because the animals are protected by the park.

Because the Rowan EWB chapter has made a five year commitment to the area, once the road is address the other issues faced by the villages will be considered. A summary of these issues and concerns appear in Table 1.

**Table 1: Summary of Village Issues**

| Village | Water Supply Issues | Farming Equipment/ Irrigation | Grain Crushing | Grain Storage | Health | Transportation/ Road |
|---|---|---|---|---|---|---|
| **Karantaba** | X | | | | X | X |
| **Kunuku** | X | X | X | | X | X |
| **Touba** | X | X | X | | X | X |
| **Wellingara** | X | | X | X | X | X |
| **Misera** | | | X | X | | X |
| **Bani** | X | X | X | X | X | X |
| **Yida** | X | | | X | X | X |
| **Sambel Kunda** | | | | | | X |

## Design Discussion

### *Current Conditions*

While a significant portion of the road is flooded for six months, there are different problems associated with various sections of the road. According to Kellee and Bill the flooding is a result of rain water runoff; it is not from the river. The road is typically used for foot traffic, bicycles and horse and donkey carts. During the dry season some cars and motorcycles travel the road. Rutting occurs when vehicles and carts attempt to use the road during the wet season or shortly after; ruts are a hazard when the water levels rise as they cannot be seen.

Before the assessment trip the team, with the help of Kellee Davis, used a satellite photo of the road to locate the problem areas of the road. Using the picture, the team was able to locate where the standing water was located. During the trip, it had been almost four months since the rainy season and there was some standing water remaining on the road. On the assessment trip, the team was able to examine the condition of each part of the road while surveying the elevation. Figure 7 is the surveyed road elevation with labeled control points.

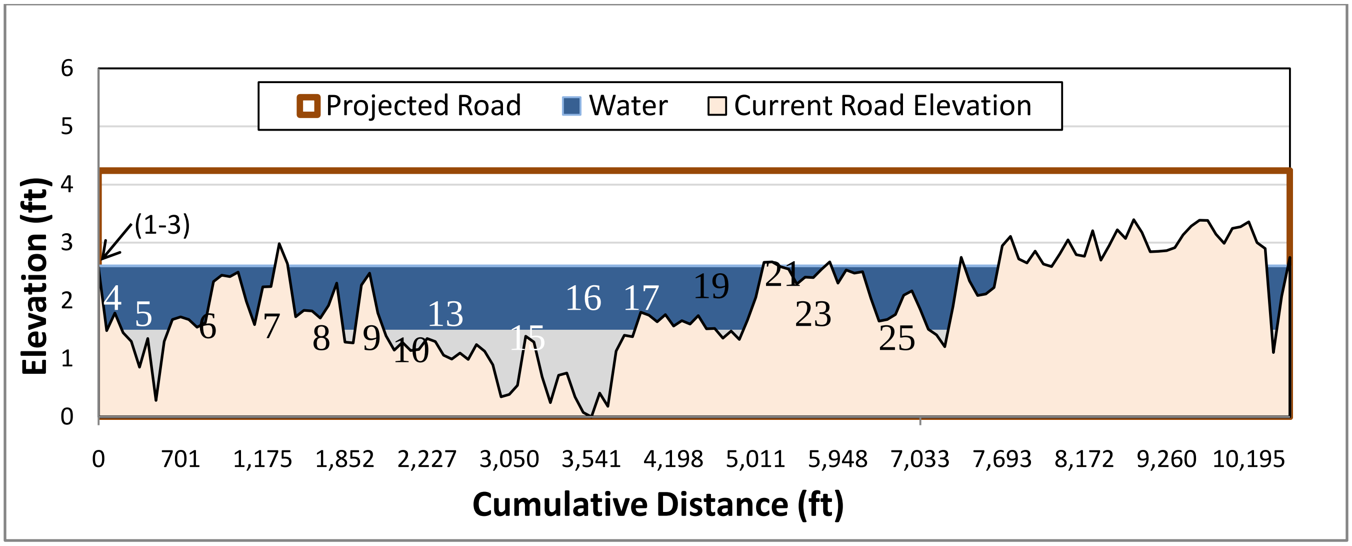



**Figure 7 Elevation of road with control points**

The first control point (CP) used for surveying was set up at the first culvert towards the villages. We were told that when the water level is at its highest point it doesn't go over that culvert. The road in that area was dry and mostly flat with few spots of rutting. There was a large area of standing water just south of that point. CP 2 was shot west of CP 1 in order to set an orientation on the total station. Between CPs 1 and 4, the road continued to stay mostly dry with some rutting. There was another culvert in the area. There were several culverts along the road, but many were hidden by overgrown grass on either side.

Around CP 5, heavy rutting began to occur with some standing water along either side of the road. On some sections of the road during the assessment trip, there was standing water collected on the side of the road, but the road was flooded only at certain points. The flooding on the road begins at CP 6. The area on either side of the flooded road is flooded as well, but the water does not flow from either side. There are small slightly elevated sections along either side of the road that separate the road with the ponds of water. On the 405 ft of road between CPs 6 and 7, there is a culvert that stands about 1.5 feet above the level of the road. The culvert separates two large puddles of standing water on the road.

CP 7 marks a muddy, heavily rutted 'dry' spot between areas of flooding on the road. Shortly after the dry spot, the largest area of deep flooding occurs. The road is very wide where it is flooded and has standing water on both sides of the road some distance away. The section where the flooding is the worst is 300 ft long, while the entire length of road that was flooded spanned 675 ft.

After the end of the flooding at CP 8, the road is mostly flat and dry. The road continues with the same conditions for most of the road. Between CP 12 and 13 marks the intersection of the road with a smaller trail some people take during the dry season. After CP 13, the vegetation along the side of the road becomes thicker. There were large trees closer to the road. At CP 14, the road continued to be dry and flat but the width of the road increases until CP 15.

At CP 15, the road is flat and dry. The land on either side of the road seemed to be slightly higher than the road. According to the surveying data, this is the point where the road is at its lowest elevation despite it being dry and in good condition at this point. The road conditions remained consistently dry and flat until CP 19 where some rutting occurred.

Between CPs 19 and 21, there was heavily wooded land on either side of the road. Heavy rutting also occurred just before CP 21. CP 23 marks the beginning of the rice fields. The land along the road at the fields is dug out several feet below the road. On the elevation graph, there are points where the road is below the projected water level at the rice fields but the lowered fields along the road provide for drainage at that section.

On the section of the road through the rice fields, the main issue is rutting. The most severe rutting occurs around CP 26. Some ruts were up to a foot deep at places. At the end of the road towards the river, there was a small stream crossing the road only a few inches deep and no more than two feet wide. According to the villagers, the stream is not a problem for them even during the rainy season, although this may be a good spot for a smaller culvert.

**Figure 8: Ruts in the** Road **(**HDT)

**Figure 9: Muddy Tracks in the Road (Davis 2007)**

**Figure 10: Water is 1 Foot Deep (Davis 2007)**

**Figure 11: Water is 3 Feet Deep (Davis 2007)**

Based upon plastic limit testing and capillary rise testing, the in situ soil is sandy silty clay with American Association of State Highway and Transportation Officials classification of A-6 and Unified Soil Classification System classification of CL-ML. Both of these classifications indicate a high porosity and relatively low strength of the soil and susceptibility to settling. Materials such as lime may be added to stabilize the road and improve the strength. Also, obtaining larger aggregates to add to the sub base of the road will improve the gradation and strength of the soil due to increased interlock and load transfer between various size aggregates.

The meeting with the NRA indicated that there are "quarries" located near Kuntaur that can be used to obtain laterite gravel. Because the regional NRA employee was unavailable to show the travel team the quarries during the trip, additional information is currently being sought about the nature of the soil to determine if any specifications are available and how the soil has been used in other project. However the NRA did mention that laterite is the material used for road construction in all of Gambia. In compliance with the specifications received from the NRA, the material will be excavated from the side of the road or from preapproved quarries. Communication is still taking place with the NRA to determine the location and nature of the available/approved borrow pits. The specification document received from the NRA indicates that all material used in the road shall be tested based upon its use. The required test for each portion of the road is indicated in Table 2. Table 3 shows the minimal criteria for each test. Because of the light use of the road and its location and remoteness from materials, a request has been submitted to find out if these tests are required for the Kuntaur Road and if so, what agency may be able to complete the testing. The results of these inquiries will influence how much fill will be obtained from the side of the road and how much will be brought in from local quarries, as well as what type of machinery is most appropriate for compacting this type of soil.

**Table 2: NRA Soil Testing Requirements**

| | Sub-base | Base | SD Aggregates |
|---|---|---|---|
| **Grading** | X | X | X |
| **Atterberg Limits** | X | X | |
| **CBR** | X | X | |
| **MDD** | X | X | |
| **LA Abrasion** | | X | X |
| **Flakiness Index** | | | X |
| **10%Fines Value** | | | X |
| **Wet/Dry Ratio** | | | X |

**Table 3: Soil Criteria**

| | Formation | Sub-base | Base | SD |
|---|---|---|---|---|
| **Grading** | - | 4000 t | 2000 t | 300 t |
| **Atterberg Limits** | - | 4000 t | 2000 t | - |
| **CBR** | - | 8000 t | 4000 t | - |
| **MDD** | - | 4000 t | 2000 t | - |
| **LA Abrasion** | - | 8000 t | 4000 t | 300 t |
| **Field Densities** | 100 m | 40 m | 20 m | - |
| **AggregateSpread Rate** | - | - | - | daily |
| **Bitumen Spray Rate** | - | - | - | daily |

### *Pre-Assessment Alternate Designs*

During the pre-assessment design, the team considered many ideas for improving the road. Having several designs in mind helped during the assessment trip in order to know what type of information should be collected. The design ideas included ways to raise the road, divert the water, and resurface the road. After the assessment trip the list of solutions was narrowed.

Some of the initial alternatives that were found to be inappropriate include road resurfacing, rerouting the road, and draining the water away from the road. The road surfaces considered in the preliminary possibilities were a product called Zycosoil and a simple technique of surfacing a road with trees and logs called a corduroy road. The team learned about Zycosoil at an EWB conference workshop from a team that used the product on their project. It is a chemical compound that is sprayed onto the surface of a dirt road. The spray would bond with the top layer of dirt and prevent water from permeating into the soil below it. It would also prevent erosion on the road. This idea was found to be not feasible for a few reasons. The product itself would be hard to obtain and to bring to the site. It also would only stop water from seeping into the road if the water had somewhere to drain. During the assessment trip, months after the rainy season, the road was still flooded with deep standing water in a few locations. During the rainy season, the road is flooded over a significant distance. There is too much standing water and very little drainage, making this product ineffective. Constructing a corduroy road was considered as a possible solution but was found to be infeasible. The design requires the use of mostly straight tree trunks laid across the width of the road. There are not enough trees in the area that would work for this particular design.

Another idea considered prior to the assessment trip was diverting the water that covered the road. This idea largely depended on the water moving rather than just pooling, and would necessitate a low-lying area for the water to flow into. On the assessment trip the people of the community informed the travel team that the water that flooded the road did not flow. The land on either side of the road was found to be at the same elevation of the road. Not enough data was collected about the far-reaching area to determine a feasible low-lying, drainage point so diverting the water was found to not be feasible.

On the map of the region shown in Appendix A, there appeared to be small trails around the road used as alternate routes. One design plan was to divert the road to one of the smaller trails. The travel team asked several people in the community about the alternate routes because some people were seen traveling on them. The locals informed the team that they use them during the dry season because they are a little less rutted, but by the rainy season they are much worse than the main road.

With these alternatives ruled out, the data indicated that the most feasible alternative would be to raise the road above the flood level. Interviews with villages indicate that a significant portion of the road was raised in the past, but has since subsided from flooding and use. Raising the road will involve using large amounts of fill and culverts. On the assessment trip, four to five existing culverts were found in the road. The culverts are made of concrete boxes that extend to the road surface. They stand as much as three feet above the current road surface, indicating that the road was higher when it was originally constructed. The existing culverts are estimated to be about fifty years old and still in good condition. Additional culverts may be added in order to equalize standing water on either side of the road and assist in raising the road. The NRA has indicated that box culverts similar to those currently there are most practical, however inquiries have been made to the NRA about forms for cylindrical concrete culverts.

Prior to the assessment trip, erosion was identified as a potential problem. The use of local vegetation along the embankment of the road was considered to reduce erosion. The roots would hold the soil in place and prevent erosion. This possibility is still being considered as part of the design to raise the road.

### *Raising the Road*

Hindson (1983) recommends widening a road a little at a time every year for four years. This is recommended for raising a narrow road that is eroded in the tracks. Repeating the same process every year will provide a well cambered road with side drains. If the road is raised in a series of operations, it will yield better results. Holes can be compacted by traffic and filled again the next time the road is resurfaced, which makes the whole road surface equally hard at the end of the four years of operations. Hindson warns that if the road is raised in one operation, traffic passing over the road will create holes that will hold water indefinitely. If raised in stages, the road can be improved every time. This procedure should be followed whether erosion has occurred just as rutting or across the entire road. If there are deep ruts, it is not recommended to just fill them with rock, stones, or gravel as it may get washed away or a new rut would form next to the old. It is recommended to remove the excess flow of water along the road before filling in ruts with soil as it is a cheaper building material than stone.

Because raising the road was determined the most feasible solution, the assessment trip data was analyzed to determine what would be involved in this solution. First, the data was used to determine the amount of soil and type of lifts and grade that would be used on the road. Then three alternatives were considered using this information to determine the cost and feasibility of each. These three alternatives include (1) fully mechanizing the process with available equipment, (2) using only resources currently available in the villages and (3) a combination of these two alternatives.

*Data Analysis*

To create a design for raising the road, estimates of the volume of fill necessary are required. Graphs were created using the survey data to illustrate the trends of the road. The existing ground elevations were graphed with cumulative distance along the road as shown in Figure 7. In terms of distance, zero was taken at a survey point towards the villages and the end of the road is at the river.

From this figure some of the original perceptions were confirmed. The most severe flooding occurs in the beginning and middle regions of the road. Also it should be noted that the rice fields towards the end of the road are largely above the water level.

A spreadsheet model was created to estimate the volume of fill needed to raise the Kuntaur road. The spreadsheet model uses survey data acquired during the assessment trip. Since the elevations varied from point to point, the model was designed to calculate the volume between each pair of consecutive survey points. The total fill volume is a summation of all the individual volumes. A schematic representing the overall model used for the volume calculation between two successive points is shown in Figure 12.

The point $(x_i,y_i,z_i)$ represents the easting, northing, and elevations of the current road measured during the land survey using the Total Station. The lowest elevation of the road was assigned a value of zero.  A road This model was derived as a function of road surface width (W), maximum elevation of water ($H_W$), height of the projected road above the elevation of water ($H_R$), and side slope (S).  The length ($L_i$) between the two points $(x_i,y_i,z_i)$ and $(x_{i+1},y_{i+1},z_{i+1})$ was calculated using the distance formula shown as Equation 1.

$$L_i = \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2} \tag{1}$$

To determine the current elevation ($H_Z$) of the ground, an arithmetic average was taken between two consecutive points.  $H_W$, $H_R$, and $H_Z$ (shown below) are measured relative to the lowest point on the road.  Along the surveyed span of the road the elevations varied 3.4 ft.  The constructed road should be built according to the maximum water height.  Since the survey was performed during the dry season, the actual maximum height of the water could not be precisely measured and was estimated from a discussion with locals.  For that reason the maximum water elevation ($H_W$) was left as a variable, to be entered upon a more accurate measurement.  It should be noted that depending on the maximum water level used in the spreadsheet model, the average elevation of the current road between two consecutive points may be higher than the water level.  In that case the volume of fill was set to zero.

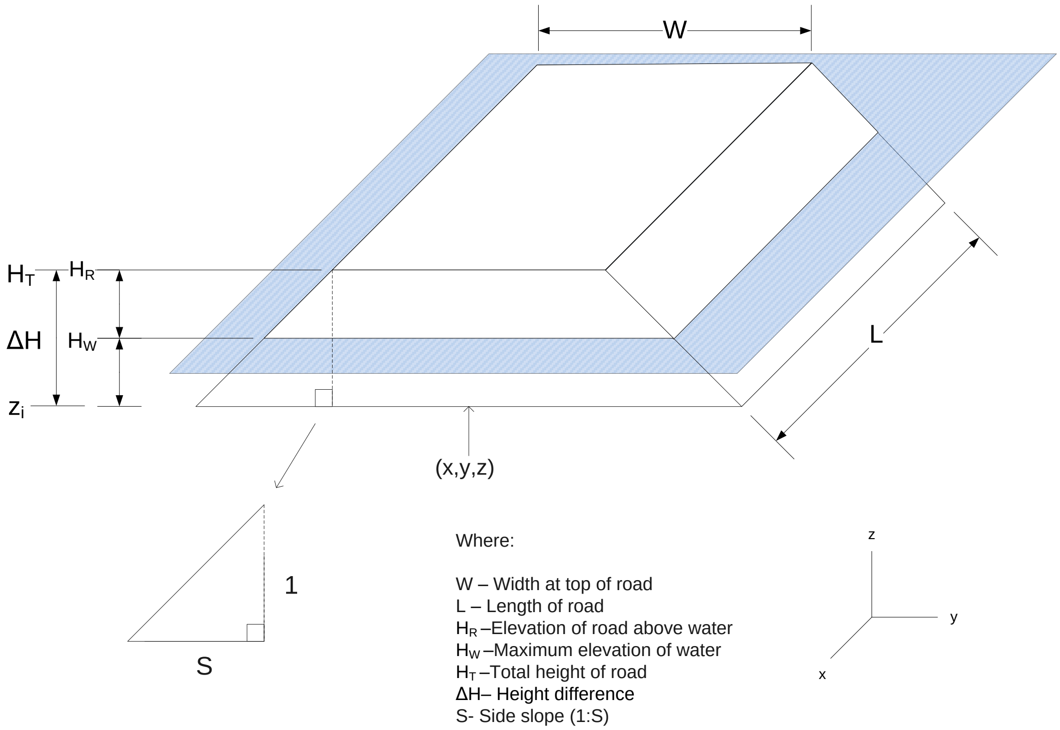



**Figure 12: Schematic of model used to determine road fill volume**

The maximum height of the water ($H_W$) and the height of the projected road surface above the water ($H_R$) are assumed to be constant throughout the extent of the road. At present, $H_R$ is set to be 1.64 ft. Therefore the elevation of the projected road surface height ($H_T$) is also a constant throughout the span of the road and determined using Equation 2.

$$H_T = H_R + H_W \tag{2}$$

As previously mentioned, if the measured elevation of the ground ($z_i$) was higher than the total road height ($H_T$), the corresponding volume was set as zero (using an if/else statement). The cross sectional area of the road segment is represented by the shaded area in Figure 13:


**Figure 13: View of cross sectional area of road segment**

where $W_s$ is the width of the outer sides of the road. $W_s$ is dependent on the desired side slope as shown in Figure 14. $W_s$, by definition of side slope, is a function of the height of the segment ($\Delta H$). While the actual elevation of the projected road is the same height ($H_T$) across the whole span of the road (i.e., 1.64 ft above the maximum water height), the height difference at each segment ($\Delta H$) is dependent on the existing ground elevation measured for each segment. The shape of the cross sectional area was rearranged to form a rectangle as shown in Figure 14 to simplify the calculations.

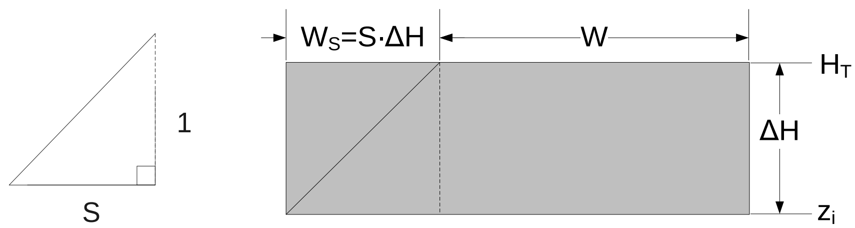



**Figure 14: (*Left*) Side slope (*Right)*Rearranged cross section of road segment**

The area of the rectangle was calculated using Equation 3.

$$A_{C,i} = (H_T - z_i)[W + S(H_T - z_i)] \tag{3}$$

where $(H_T - z_i)$ represents the height of the road segment ($\Delta H$). The volume was then calculated for each segment using Equation 4.

$$V_i = A_{c,i} L_i \tag{4}$$

The total volume was then computed by summing the volumes of the individual line segments. There was a total of 151 survey data points; since two points were needed for each segment the summation was from 1 to 150.

$$\text{Total Volume} = \sum_{i=1}^{n} V_i \tag{4}$$

When considering the actual construction of roads, the volume is not filled all at once. Instead, it is completed in a series of smaller fills called lifts. In between these fills the road material is compacted in order to make a more durable final road. Another variable was introduced; the fill height, which represents the height of the individual fill. Common values for fill height range from 6 in - 1 ft. The model was modified to calculate the number of fills, for each road segment, depending on the height of the road segment ($\Delta H$). Using the number of fills necessary, the fill area was computed. This value is an important variable in road construction. Values for road surface width, side slope, lift height water height, and road height above water level are entered and the model determines the total volume and lift area. Model inputs and outputs are given in

Table 4. These values were used for preliminary cost estimates.

**Table 4: Inputs and Results of Model**

| Inputs | | |
|---|---|---|
| **Width (top** | W | 9 ft |
| **Side slope (1:S)** | S | 2.75 |
| **Road Above Water** | $H_R$ | 1.64 ft |
| **Lift Height** | $H_L$ | 1 ft |
| **Water Height** | $H_W$ | 2.6 ft |
| **Road Elevation** | $H_T$ | 4.24 ft |

| Results | |
|---|---|
| **Total Length** | 10550 ft<br>3.2 km |
| **Total Lift Area** | 214377 $ft^2$ |
| **Total Lifts** | 254 |
| **Total Volume** | 23820 $yd^2$<br>11990 $yd^3$ |

*Culverts*

After speaking with Mike Paddock (2009), one of the members of the TAC, the team has decided to add culverts into the design of the road. There are what we believe to be about five or six culverts in the currents road. The suggestion from Mike was to have a culvert every 200 meters along the road. He also suggested using molds to make concrete pipes used for culverts. He mentioned that many governments in developing countries have these molds available for road construction. After contacting the National Road Authority, the team was informed that these molds are not available in the area.

Another design for culverts is the use of box culverts. Instead of molding large concrete tubes, either three or four slabs of concrete or a pre-cast solid box, as seen in Figure 15, would be used to allow water to run under the road.

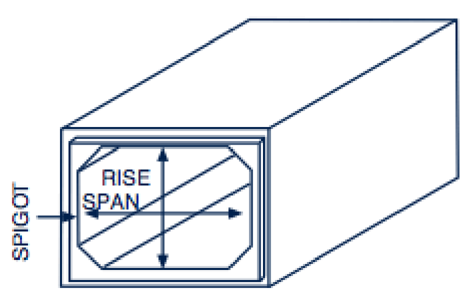



**Figure 15: Precast Solid Box Culvert (Shaw Pipe 2009)**

The design of the culverts is currently ongoing with the help of Rowan University civil engineering professor Dr. Mehta and considerations from Rowan civil engineering students. It has been decided to use modular slabs of concrete to build box culverts. The slabs of concrete would be about six inches in width. The width of the reconstructed road is going to be about 15 feet across, so each culvert may need to be built in two parts seven feet long and set next to each other across the road.

There are several options for culvert construction and installation. One way to accomplish this is to mold the two walls of the culvert in place on the road, then mold the top elsewhere and fit it into place. The top slab may also be molded into place. Molding each piece separately then positioning each slab into place is also an option. If there is not a horizontal fourth piece of the culvert on the bottom, the two sides of the culvert would have to be dug into the soil to prevent the force of the soil from pushing the walls in. Another consideration that must be dealt with is how to fit the slabs of concrete into one another. If the top slab is simply laid across the top of the two walls, there is a greater risk of the culvert collapsing due to outside forces on the walls. One solution is to cut keyways into the top slab, the sides or both shown in

Figure 16 This would allow the pieces to fit into one another and reduce the risk of failure due to forces from the soil on the walls. Steel rebar may be used in this design if the materials are available. The rebar may be used to reinforce the slabs or be run diagonally through the top slab and the wall on either side.

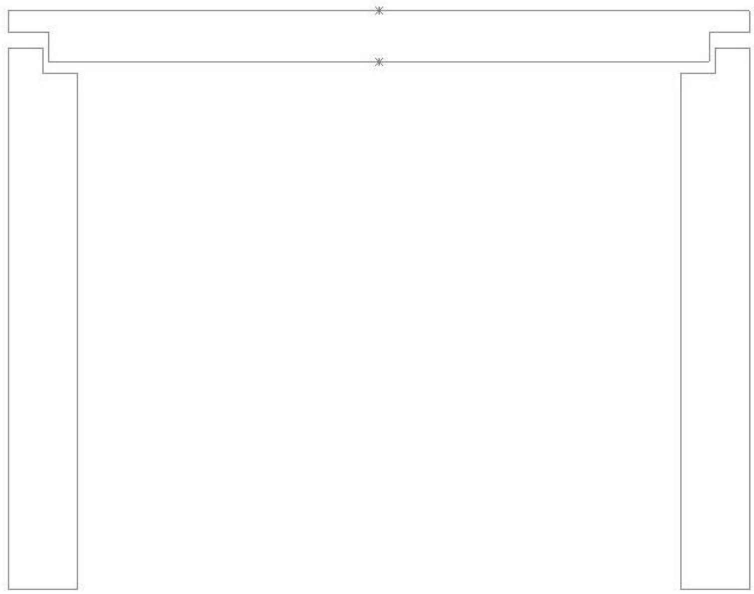


**Figure 16: Culvert with Keyways**

## Alternatives for Raising the Road

Using the volume results previously discussed, raising the road was further investigated and several alternatives were created. The first two represent extremes: one is comprised of a completely mechanized method while the other uses only the local resources of the villagers. The implemented solution will most likely be a combination of both of these extremes. The availability and cost of material and labor will be used to determine the final solution. Regardless of which method is used, the road construction will be separated into phases. The first phase would be to fill in all the lowest regions, currently in standing water during the rainy season. The second phase would be to level the entire road well above the water level, repairing the muddy sections of road. This will allow for ease of travel to finish the last phase of construction, which will fill the ruts in the road at the rice fields.

### *Alternative 1: Fully Mechanized Method*

There are four basic activities involved in raising the road. They are listed below with the general type of equipment needed to accomplish each.

1. Excavating - collecting gravel and soil from a specified source;
    - Bulldozer
    - Excavator
2. Hauling - transporting the gravel and soil the from source to the road;
    - Front Loader/Back hoe
    - Dump Truck
3. Compacting - compacting the gravel and soil to create a firm, strong surface on the road which is done in 1-ft lifts until the road is at the desired height;
    - Sheepsfoot or smooth wheeled roller
4. Grading - putting a crown on and leveling and smoothing the surface of the road so that water will run off and not pool.
    - Grader

Table 5 was provided at the meeting with the NRA during the assessment trip. It lists the equipment available to the NRA. The rates quoted in Table 5 are average daily rates based upon historical data for contractors who have worked in The Gambia. The values include the cost of diesel and wages for an operator, but do not include the cost of transporting the equipment to the worksite. The NRA will investigate the cost of transporting the equipment from Kombo to the worksite; an initial estimate of 25,000 Delasi each way was provided. The NRA will also be responsible for negotiating favorable rates prior to awarding the actual contract. This will be done to possibly lower the rate per day if, for example, the equipment is rented for an unusually long period of time (Meyers 2009). For the purposes of the cost model presented in this report, the values in Table 5 were used.

Table 5: Equipment accessible to the NRA in Kombo

| Machine Type | Machine Description | Capacity | Rate per Day (Delasi) (8 hours) |
|---|---|---|---|
| D7 | Bulldozer | | 20,000 |
| 140G | Grader | | 18,000 |
| 966 | Wheel Loader | | 20,000 |
| | Pneumatic roller | 9 tons | 10,000 |
| | Water Bowser | 10,000 litres | 5,000 |
| Dynapac | Drum Compactor | 18 tons | 32,400 |
| | Truck | 10-15 $m^3$ | 15,000 |
| CAT 219 | Excavator | 1.0 $m^3$ | 25,000 |

It is not imperative to utilize the specific models described in Table 5 to implement the final design. The purpose of the pictures and information given below is to explain the general purpose of the equipment and how it will be used in The Gambia. Certain Gambian agricultural projects have some construction equipment, including a grader. The NRA will contact these projects to determine the type and capacity of equipment that may be available for this project, along with all related costs. Using equipment from these projects would be more cost effective as these projects are located closer to Kuntaur than the equipment listed in Table 5.

*Excavating*

**Figure 17: CAT bulldozer D7E**


**Figure 18: CAT 219 excavator**

**Figure 19: CAT966D wheel loader**

Figure 17 is the CAT bulldozer D7E. This exact bulldozer model is available in Kombo although any type of bulldozer could be used. Figure 18 is the CAT 219 excavator which is also available. It would be used to excavate all of the soil needed to repair the road. In general, any type of excavator or backhoe would be needed. Figure 19 is the CAT 966D wheel loader, the exact model available to the NRA. It is primarily used to load material onto a dump truck to be transported. Any type of wheel loader could be used.

*Hauling*

A dump truck would also be needed to transport the soil. There is a truck available in Kombo that has a capacity of 10-15 $m^3$, which indicates that this piece of equipment is considered to be a large dump truck.

*Compaction*

Figure 20 is a CAT sheepsfoot roller. This specific type of roller is best for clay material because the protruding feet knead the clay and help to compact it. It was determined that the soil at Kuntaur Road is a type of clay; therefore any type of sheepsfoot roller would suffice, however no equipment of this type has been identified as available within the country. The plough on the front is not necessary to compact the soil, but it could be useful to have both tools in one piece of equipment, in order to move the soil and then compact it. Also pictured is a smooth wheeled roller which is used for compaction. The pieces of equipment shown in Figure 21 are not as good in clayey soil, but a smooth wheeled roller may be an option if the sheepsfoot roller is not available.


Figure 20: CAT sheepsfoot roller

Figure 21: smooth wheeled roller

*Grading*
Figure 22 is the CAT 140G grader that is available in Kombo.  This will create a precise flat surface or finish grade after the rough grading is done by the bulldozer.


Figure 22: CAT 140G grader

The volume and lift area calculations were used with the rates in Table 5 to create a cost estimate using all of the machines necessary to complete each phase of the design.  This estimate utilized the RSMeans Guide (2007) as a resource for the amount of time required to complete each phase and the costs from Table 3.  The total cost of $67,568 (~£47,116) does not include transportation of the equipment to Kuntaur and does not include oversight costs for a foreman or other overseer of the project.  Furthermore, contingency costs are not included.  The summarized results of the cost and time estimates for the fully mechanized method are shown in Table 6.

**Table 6: All Mechanized Time & Cost Estimate**

| Process | Crew Size | Crew Days | Cost |
|---|---|---|---|
| Excavation | B-10B | 20 | $16,118 |
| | B-12A | 20 | $19,980 |
| Hauling | B-34D | 36.9 | $22,131 |
| Compaction | B-10Y | 3.4 | $4,439 |
| Grading | B11L | 6.8 | $4,900 |
| **Totals** | **-** | **87.1** | **$67,568** |

The total projected cost is $67,568. The total number of crew days required to complete the project if no work was completed simultaneously is 87. However, some of the work can occur simultaneously. Assuming that after excavating for one day the excavation, loading and hauling would occur simultaneously, the total number of days to complete this work is reduced to 38. While some compaction could occur during hauling, it will take time to spread the soil in the lifts and grading will not begin until after compaction, so the number of crew days remained 3.4 and 6.8 respectively for these activities. Thus, the total number of days to complete the project would be approximately 49 days. The detailed calculations and estimates used to generate this total cost are outlined in Appendix E.

### *Alternative 2: All Hand-Labor Method*

The hand calculations were broken up into four operations: excavation, hauling, compaction, and grading.

1. Excavating - collecting the best gravel and soil mixture from a source next to or close to the current roadway;
    - People with hoes, picks, spades and shovels
2. Hauling - transporting the gravel and soil the from source to the road;
    - Donkey carts and handlers
3. Compacting - compacting the gravel and soil to create a firm, strong surface on the road which is done in 1-ft lifts until the road is at the desired height;
    - Compaction will happen with use of the road (i.e. driving donkey carts, and tractors over the road)

4. Grading - putting a crown on and leveling and smoothing the surface of the road so that water will run off and not pool.
   - Soil will be leveled by hand for each lift
   - A jig will be made to help mold the crown

The time estimations for some of these processes were done two ways. The first used the Means Guide Standards. This estimation was completed using information for work that closely resembled the work to be carried out in The Gambia. For example, the excavation and fill section used to estimate digging and emptying of the donkey carts was labeled in the Means Guide as a 3 foot deep trench, width not given (Means Cost Guide 2007). The second set of calculations was comprised of rough estimates taken from Turtle Creek Software (2009) and a survey of numerous people with some experience with hand labor and/or conditions in The Gambia. For this estimate, many of the functions were left as variables in the Excel spreadsheet used for estimating purposes, for example: time it takes to dig a 1 $m^3$ hole (Watts, Raymond, McCarson 2009) velocity of the donkey carts (LaDonne, Fischer 2009) etc. This approximation also gives an idea of how long it will take given limited resources, such as the number of donkey carts available. The results of the time estimates are summarized in Table 7.

**Table 7: Local Resources Time Estimate**

| Process | Excavation Load/Unload carts | Hauling[1] | Grading |
|---|---|---|---|
| Time per person-volume of fill (hr/person-$yd^3$) | 1 | 1.784 | .034 |
| Days (8hr work) | 4000 | 2673.77 | 50 |
| Crew size | 9 digging | 8 carts | 1 |
| **Total Days** | **170** | **170** | **50** |

1. Assumed donkey cart capacity 1 $yd^3$/cart, speed of 1.3 mph and haul distance of 1 mile

By defining our most limited resource at 8 donkey carts, a completion time of 170 8-hour work days is predicted. It should be noted that these labor estimations do not include logistics such as a foreman or tools including shovels (wheel barrels etc). These calculations do not include compacting because the smallest versions of compacters found were vibrating plate compacters. Since the material in the region is classified as clay, a vibrating plate will not suffice

(Contractors Depot). Also, information could not be found on tamping the ground by hand. It may be possible to rely on the donkey carts loaded with dirt and other vehicles to compact the road.

To complete the entire road using hand labor and the resources around the community, a source of fill must be found close to the road. The fill will be transported to the road, at a rate which the labor can unload and grade, to allow the road to be constructed with less difficulty. Involving the communities with the construction of the road will heighten their technical understanding of the process.

*Excavation and Unloading*

Locating adequate excavation sites will be important for the completion of the road; these sites should be marked on the map. Alternative uses of the excavation sites will be taken into consideration. For example, rather than just creating a large hole in the ground a fish pond or rice fields could be constructed (Lebo J. and Schelling D 2001).

*Hauling*

According to the estimates, transporting fill a long distance using a small number of donkey carts is the most time consuming portion of the process. Getting fill from areas closer to the road would result in a large time reduction. Assuming that donkey carts are a fixed resource in the area, reducing the distance between the excavations site and the construction site will increases the amount of dirt that can be hauled per time. Therefore, reducing the distance between the cut and fill site allows the ability to complete more hauls, and ultimately incorporate more people in to the process to move the extra soil. Thus further reducing the time it would take to construct the road. This would also allow a quicker transfer of labor between sites.

*Compaction & Grading*

The design will include plans of the road with detailed drawings of any small bridges or culverts and a way of coordinating any drawing or plans to the locating on the road. Road construction will be overseen by a foreman to insure that there is proper compaction before starting the next lift. The final road surface will be crowed using a jig that will be left in town to be used to repair the road.

*Supplies*
For the all local resources method, labor cost could include money for food and water. Showing gratitude for the workers with water and food giving people an incentive to come back every day and help build a better future, as well as create a good image for the project. Sufficient tools will need to be available on site for the first day of the implementation trip. Some of the obvious tools that are needed are listed in Appendix F, along with safety materials. The supply list contains items such as shovels, pick and levels. Safety materials for the construction of the road, such as stakes and rope to put on the site during the rainy session, should be available. Having materials on hand will help start the project swiftly. A local supply system with expense account will help keep the project going.

*Supervisor*
The supervisor will be a crucial key in the development of the road. The foreman will also be our eyes, ears, and hands onsite. She could also make sure things are being completed with satisfaction. Someone also needs to lead the workforce; this could be the foreman for the technical side of things but a local leader may also work well. However, to keep the locals involved they can pick the lowest levels of the road to fill in first.

### *Alternative 3: Mixed Method*
A combination of mechanized and hand labor may allow the project to be completed at a reasonable cost in a reasonable amount of time, transfer important skills to the local population, and enhance the commitment of the local villages to maintain the road.

*Excavating*
The large amount of fill soil required lends itself to a mechanized excavation. However, the primary determinant in a mixed design will be where the soil is excavated from. If a high quality fill source is located in a quarry some distance from the road, excavating equipment will be necessary because excavating consolidated material by hand will be too time and labor intensive and the increased strength of gravel would make machinery advantageous. However, if the fill soil on the sides of the current road is deemed as desirable it would be possible to use a locally

available backhoe rather than transporting one from the capitol. However, to be conservative, the cost estimate given assumes a quarry will be used.

*Hauling*

Hauling thousands of cubic yards of soil from a distant quarry is not feasible on a horse or donkey cart due to the constraint of having enough carts and the time it will take the carts to haul the soil. If a distant quarry is used as a fill source, a dump truck will be necessary. However, if the soil used is from the side of the roads and thus only needs to be hauled a short distance, it would be feasible to use the available horse or donkey carts and perhaps any small trucks that could be obtained. Because the location of the soil is still unknown and efforts to determine its location are thus far unsuccessful, the conservative assumption being made is that the hauling will be done by machinery.

*Compacting*

A mechanized compactor would create the most uniform and desirable compaction. If the soil at the side of the road is used a push compactor with a vibrating plate will not work because the soil has too high of a clay content. If consolidated laterite is brought in from a quarry a vibrating plate compactor would become feasible. However, compaction is an operation that can be completed without machines. This is can be achieved by utilizing any local vehicles, horse and donkey carts and other traffic that traverses the road. This type of compaction will provide a less uniform compaction, and will necessitate building the lifts of the road in slower stages to allow time for each lift to be compacted. This type of compaction could be achieved if dump trucks are used for hauling and can remain on site long enough to drive over the road a few times per lift.

*Grading*

Grading is the area most feasibly done completely by hand. According to Lebo and Schelling (2001) machinery is not typically required for the lowest-volume roads. Labor equipped with hand tools can achieve adequate results for low-speed basic access. Tools such as a wooden frame will need to be created to ensure a proper crown is achieved, but an acceptable road surface can be achieved with picks, shovels, and rakes.

If it is assumed that machinery will be required for the excavation and hauling and that compaction and grading occur using the dump trucks to compact and hand labor to grade, the cost of $9339 will be saved, but an additional $3000 will be required for the additional five days added to the dump truck rental for compaction. This is an estimate of the additional time it will take the place to drive across each lift evenly. This places the total cost at $61,359. The total days for excavation and hauling will remain close to the mechanized method for these tasks. The cost for the grading for the hand labor method is minimal and the number of crew days to complete this task is approximately 5 days for a crew of 10 people, making the total time for this method 48 days, 21 for excavating, 17 additional days for hauling, 5 for compaction, and 5 for grading. These results are summarized in Table 8. These costs do not include a supervisor, transportation cost from the capital, or contingency cost.

**Table 8: Mixed Method Time & Cost Estimate**

| Process | Crew Size | Crew Days | Cost |
|---|---|---|---|
| Excavation | B-10B | 21 | $16,118 |
| | B-12A | 20 | $19,980 |
| Hauling | B-34D | 37 | $22,131 |
| Compaction | B-34D | 5 | $3,000 |
| Grading | 20 | 5 | $130 |
| **Totals** | **-** | **89** | **$61,359** |

### *Alternatives: Comparison & Selection*

Each construction plan was put into the matrix shown in Table 9 and ranked according to several design criteria. The criteria for the design are total cost of the road, community involvement in construction, sustainability, time needed to construct, and overall durability. Each plan was ranked as low, medium, or high, with low indicating the least desirable of the three and high indicating the most desirable alternative for that particular category. The rankings of each criterion were analyzed for the three designs. The combination using both machinery and hand labor received the best overall rating making it the most favorable design according to the criteria.

**Table 9: Alternative Comparison Matrix**

| Method | Cost ($) | Community Involvement | Sustainability | Construction Time (days) | Durability of Road |
|---|---|---|---|---|---|
| All Mechanized | 67,568 | Low | Low | 49 | High |
| All Local Resources | 468 | High | High | 170 | Medium |
| Combination | 59,429 | Medium | High | 48 | Medium |

Cost was considered in choosing a design. Using the cost estimates generated for each design, the alternatives were ranked. The cost of using all mechanized power had the highest cost because of the high price to rent machinery. Using all local resources had the lowest cost. The combination was almost as expensive as the all mechanized alternative because many of the tasks are infeasible without machinery.

Community involvement is an important aspect to the project. Dr. Banutu- Gomez (2009), an expert on development in the Gambia, stresses the importance of involvement from the communities. According to Dr. Banutu- Gomez, the more the community is involved in a project, the higher the chance for success. With alternatives 2 and 3, the community will have a greater sense of pride in the road and will have more motivation to maintain the road. Hiring equipment to do all of the work (alternative 1)would involve the community the least, while alternatives 2 and 3 would necessitate their commitment to the road's repair and hopefully ensure a personal commitment for its endured success.

Sustainability was picked as a design criterion. Each design was ranked on a prediction of road maintenance. Alternative 2 and 3 were ranked highest because the people in the community would be highly involved in the construction and would learn the basic skills needed to maintain the road. This may also result in a better constructed road.

Construction time is an important consideration because the time restraint due to the length of the dry season. The road would not be able to be worked on during the rainy season and the beginning part of the dry season because of the remaining standing water on the road. Machines have the ability to excavate, haul, and compact dirt faster and more efficiently than using hand labor. Using a combination of hand labor and machines, jobs that would take the longest to do by hand or that would require the much person power would be chosen to be done by machine.

Durability of the road would be difficult to calculate accurately, but can be predicted using collected data and estimations from experts. Using all mechanized power, the road's strength would be greater than if it were done all by hand. Compaction is an important component in constructing a durable road. Compacting by hand would not be feasible due to the time constraints and the limiting nature of using a push-compactor in clay soil.

Each construction plan was assessed based on cost, community involvement, sustainability, construction time and durability of road. Using a combination of local resources and heavy machinery is considered the best alternative. The implementation plan will be based on this alternative.

## Implementation Plan

The proposed construction of this project can be broken up in two ways. The first method is to raise the whole span of the road in lifts starting at the lowest point. The second is to section the road into zones that reflect the current conditions and raise the road in the worst zones first. This will be further investigated and finalized according to incoming information regarding availability of resources and the opinions of villagers.

The first method involves creating the road one lift at a time starting at the lowest point. This method would resolve the worst sections along the span of the road first. It would also make for a level road to ease travel for further construction. From there the whole road will slowly be raised, lift by lift, to a final height above the water level.

For the second possible method the road would be sectioned into zones. Zone 1 would be the middle, severely flooded, section. It would be raised first by a series of lifts, above the water height; complete with a crowned top surface. This lower section will most likely contain culverts and ramps at each end leading back down to the original road height. After that, raising the road would continue according to the severity of flooding experienced for a given zone. Working on the road in zones has some advantages, including learning how the improved road will withstand erosion and use. The ramp may help show the community how standing water damages a dirt road. The first completed phase can be used to show how to crown the surface to help keep the high road free of ruts and water. This will also be an example of how their new road will look and work for them. The details of how this section of the road will be built are still being debated. Because shipping the heavy equipment is expensive, shipping it back and forth for every phase would be a big expense, however compaction is most crucial in this section because there are many lifts.

## Future Work

Before implementing the final design, a comprehensive materials list must be created. As part of this, specific locations of the quarries and a determination of the quality of the soil available from each quarry need to be determined. Contact has been made with the NRA to obtain this information, however as of yet no response has been received. Also, establishing the availability and cost of machinery closer to the site needs to be determined. The NRA committed to do this at the March 18, 2009 meeting, but no information has been received thus far. A request has been submitted to the HDT to find a local contact to investigate the soil and machinery locally available and follow-up will be needed. It also needs to be determined how to obtain or construct culverts and how frequently they should be placed along the road.

Finalizing the culvert design will be a task for future work. Besides locating all the materials needed for the culvert, the construction plan must be established. The current design plan is to use a three sided box culvert made from concrete. There are two main ways to accomplish the design. One would be to have three modular slabs that would be set into place after the concrete sets. The other option is to mold the entire culvert in place. Designing the dimensions of the culvert including total width of the culvert and the width of each slab will also have to be finalized. Additions including rebar reinforcements should be considered into the final design if the materials are found to be available.

Safety considerations need to be added to the final design and the design needs to be accessible to the local community. Also, identifying a local foreman/committee to oversee the arrangements and implementation for any equipment and a spokesperson for laborers will be necessary. This committee should also be involved in approving the final design. In the project proposal the idea of a maintenance committee was mentioned and the implementation and maintenance committee could be the same or a new committee could be formed to ensure maintenance. A sustainable maintenance plan that is clearly outlined and understandable must be implemented with the input of this of the locals as represented by this committee.

The construction plan for the road will be further elaborated. After building the road a clearly defined maintenance plan should be made preferably in the form book with many pictures. This will ensure the condition of the road well into the future.

Obtaining funds for travel, equipment, materials, food, and supplies for laborers any other items will need to done. This is primarily being handled by HDT through fundraisers in the United Kingdom, but communication about the cost estimate and fundraising progress is ongoing and needs to continue in the future.

## References


ASCE (2005) "American Society of Engineers", www.asce.org, accessed April 24, 2005.

Auroville Earth Institute “Earth as a Raw Material”, http://www.earth-auroville.com/index.php?nav=menu&pg=rawmaterial&id1=3, accessed April 1, 2009.

Contractors Depot “Soil Compaction Handbook”, http://www.concrete-catalog.com/soil_compaction.html, April 2, 2009.

Everett (2005) “Environmental Engineering II”, users.rowan.edu/%7Eeverett/courses/EEII/EEII.htm, accessed April 24, 2005.

Everett, Jess (2005) Personal communication, Rowan University, Department of Civil and Environmental Engineering, April 24, 2005.

Hindson, Jack (1983) Earth Roads: Their Construction and Maintenance, ITDG Publishing, Bourton-on-Dunsmore, Warwickshire, UK.

Lebo J. and Schelling D. (2001) “Design and Appraisal of Rural Transport Infrastructure: Ensuring Basic Access for Rural Communities”, World Bank, Washington D.C.

Lowe’s online Store (2009) http://www.lowes.com/lowes/lkn?action=productList&Ne=4294967294&category=Shovels&N=4294922151, accessed April 30, 2009.

Lowe’s online Store (2009) http://www.lowes.com/lowes/lkn?action=productDetail&productId=28167-302-1912800&lpage=none, accessed May 4, 2009.

Lowe’s online Store (2009) http://www.lowes.com/lowes/lkn?action=productDetail&productId=249095-302-RP6SLW25&lpage=none, accessed May 4, 2009.

McCarson, Nate (2009) Personal communication, student, February 5, 2009.

Meyers, Bill (2009) Personal communication, Peace Corps, Gambia Technical Training Institute, March 23, 2009.

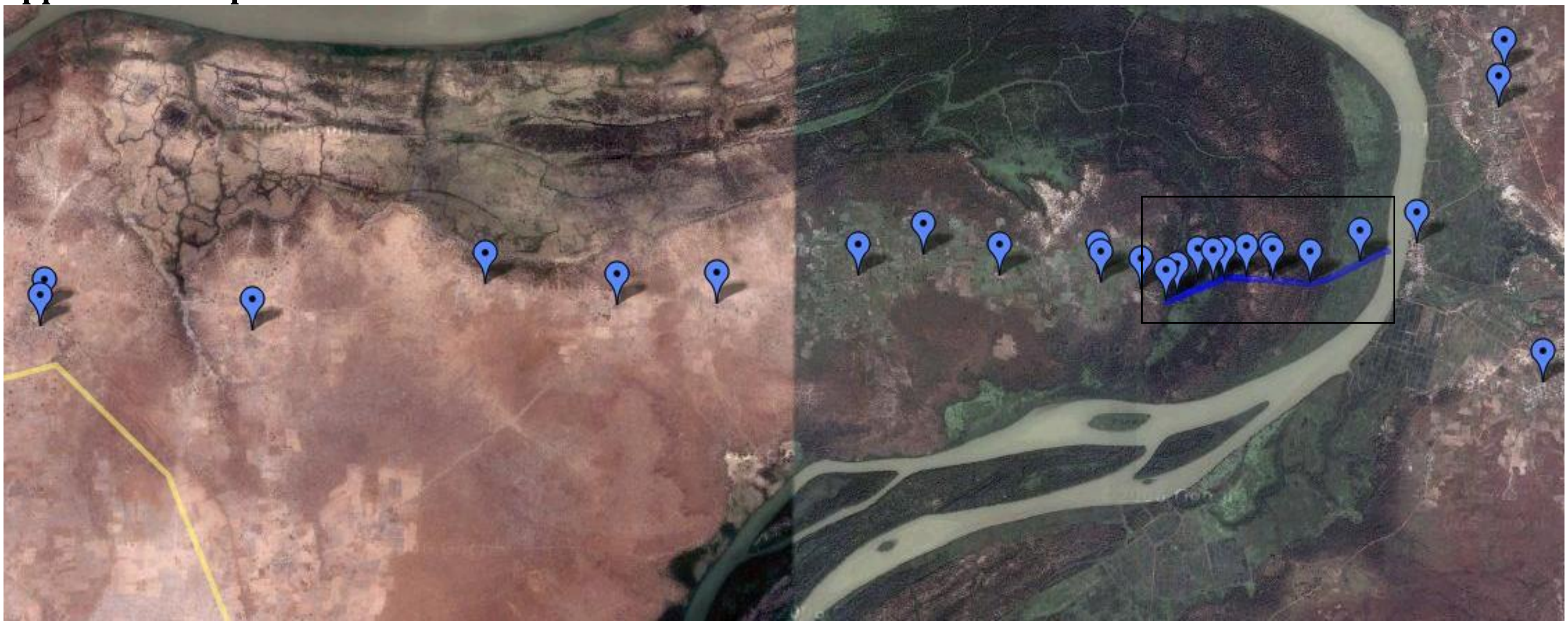
Raymond, Mike (2009) Personal communication, student, February 5, 2009.

RSMeans (2007) Building Construction Cost Data, RSMeans, Kingston, MA.

Turtle Creek Software (2009) “Turtle Creek Software”, http://www.turtlesoft.com/construction-costs/Excavation/excavation.htm, February, 5, 2009.

Watts, Christopher (2009) Personal communication, construction, February 5, 2009.

**Appendix A-Map of Kuntaur Road**




Last Revised 5/8/2009

Index of Reference Points

A. Kudang, a medium sized town on the South Bank Road. There is a hospital and an Upper Basic (middle) school here, as well as an Army Base.

B. The South Bank Road. Going East on the South Bank Road takes you to Brikama Ba, Janjangbureh (Georgetown), Bansang, and Basse. Going west takes you to Jarreng, Soma, and (eventually) Banjul. The road between Soma and Brikama Ba is full of potholes and is in generally bad condition.

C. Kerewan Demba, a Fula community of about 30-35 compounds.

D. Karantaba, a Fula community of about 6-7 compounds.

E. Kununku, a community of about 15 compounds, mainly Mandinka, but with some Fula families.

F. Touba Demba Sama, a community of about 20 compounds, both Mandinka and Fula.

G. Sambel Kunda, a Fula community of about 30 compounds. Kellee lives here and this is also the site of the Horse and Donkey Trust.

H. Welingara, a Fula community of about 8 compounds.

I. Misera, mainly Mandinka with some Fulas.

J. Bani, both Mandinka and Fula with about 10-12 compounds.

K. Yida, both Mandinka and Fula with 6 or 7 compounds.

L. The water does not extend past here. There is a slight incline going towards the villages of Bani and Yida, so water cannot collect there.

M. This is where the mud ends (you can see the 2 drier paths going up towards the villages).

N. A second "bridge" is in this general area.

O. This is a stream, but it only flows in the rainy season. In the dry season it is a dry bed. The surrounding vegetation is mature forest, mainly baobab trees.

P. There is a lot of standing water here that extends almost to the point of the first village.

Q. There is a broken concrete slab here that people built as a "bridge" at one time. This is barely visible above the water when it is at its deepest.

R. This is where the water starts to get really bad, up to 3 feet deep in some areas. People have put rocks there because they thought they might be able to walk on top of them, but they actually make it more dangerous to walk because you never know what you're going to hit your foot on. This is much worse for animals pulling heavy loads. I've seen horses fall down while pulling carts through this area.

S. People end up making new paths when they search for ways around muddy areas, but the whole area is pretty muddy and there is no completely dry path in this section before the end of November.

T. This section does tend to be drier. It isn't at a higher elevation than the surrounding area. It still gets muddy and carts get stuck, but it doesn't have the deep ruts like the parts ahead of it that collect water and take a long time to dry out.

U. There are various muddy parts all through this area, but not as much standing water.

V. These are the rice fields. They belong to the women of Misera, Bani, Yida, and Kuntaur. People throughout the country farm rice along the river, depending on how close their villages are to it, but it is not one continuous line along the whole length of the river. The road here is elevated above the fields but is heavily rutted and muddy, making it dangerous for horse/donkey carts and the people riding on them.

W. Kuntaur. The health center is near where the marker is. There is an Upper Basic (middle) school (in Fula Kunda), and this is the seat of the Niani Area Council, the regional governing body for the Niani district. The road goes to Wassu on the North Bank Road.

X. The North Bank Road. East takes you to Janjanbureh (Georgetown); West takes you to Farrafenni, Kerewan, and Barra, where there is a ferry to cross to Banjul. It has been recently paved and only takes about 4-5 hours to get to Barra.

Y. Wassu, a medium-sized town on the North Bank Road. It holds a large lumo (weekly market) on Mondays, which many people in Niamina use the Kuntaur Road to travel to. It also has an Upper Basic (middle) school, a Senior Secondary (high) school, and a car park on the main road that has cars going every day to and from the capital.

Z. Fula Kunda and Jakaba, suburbs of Kuntaur. Kuntaur's Upper Basic School is located here.

## Appendix B-Assessment Trip Itinerary

**Thursday, January 8th**

- Packed up vans/ cars to leave for airport at 12pm
- Departed from Rowan University to JFK at 12:30 pm
- Departed JFK to London Gatwick Airport on British Airways at 6pm

**Friday, January 9th**

- Arrived in London Gatwick at 6:05 am
- Departed Gatwick to Banjul on Gambia airline at 9:15 am
- Arrived in Banjul at 4:30 pm
- Collected baggage, loaded car, exchanged money
- Traveled to HDT house at Cape Point

**Saturday, January 10th**

- Walked to beach
- Traveled to Banjul at 9:30am to queue for ferry. Kellee and Dr. Everett went to grocery store and Africell. Original plan was to have the car cross the night before, but this did not happen.
- Boarded ferry at 2pm
- Ate lunch in Barra
- Arrived in Kuntaur at 6:30pm
- Crossed river and took HDT trucks to house. Arrived at house at 7:30pm.
- Ate dinner and went to sleep.

**Sunday, January 11th**

- Walked the road in the morning.
- Held regional meeting from 3-6pm
- Ate dinner and went to sleep

**Monday, January 12th**

- Dr. Everett, Bill, Brian and Hassan started land survey
- Kellee, Katie, LaDonne, and Ousman Barry met with the alkalos of Karantaba, Kunuku, and Touba

**Tuesday, January 13th**

- Dr. Everett, Bill, Brian, and Hassan finish land survey
- Kellee, Katie, LaDonne, and Ousman Barry met with the alkalos of Welingara, Misera, Bani, and Yida
- Had Attaya and Le at Kellee's husband's shop with local young men.

**Wednesday, January 14th**

- Kellee, Katie, and LaDonne met with the alkalo of Sambel Kunda.
- Brian and Dr. Everett did soil testing
- At 11am loaded car and crossed river
- Ate lunch in Farafenni
- Arrived at HDT house at 6pm
- Ate dinner at Italian restaurant and then went to sleep

**Thursday, January 15th**

- 10am met with the National Road Authority
- Ate lunch

- Toured GTTI and showed students how to use total station
- Went to Serrekunda market to buy souvenirs
- Played games and went to sleep

**Friday, January 16th**

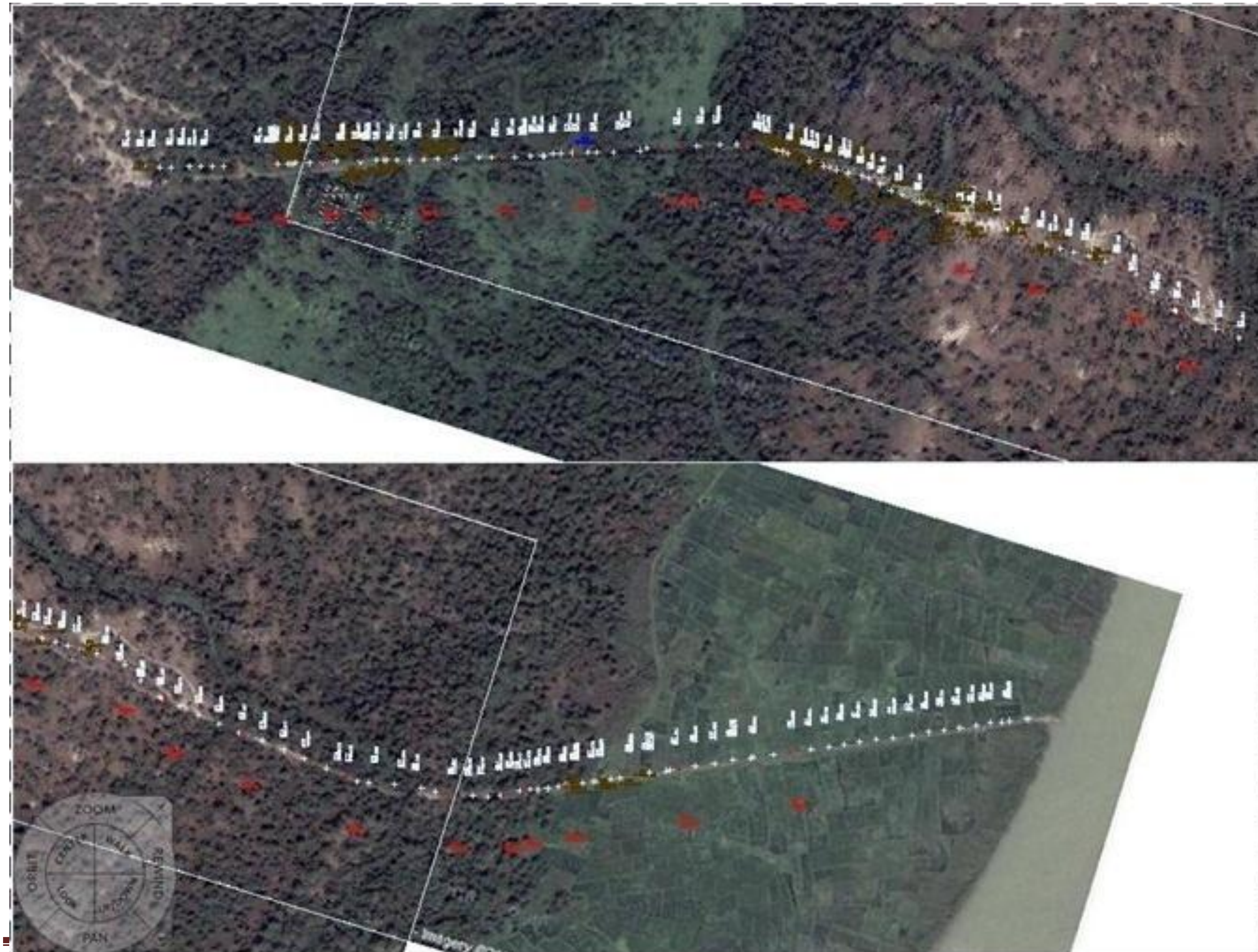
- Went to Bakau market to buy souvenirs
- Traveled to Banjul airport at 1pm
- Left Banjul at 4:55 pm
- Arrived in London 10:40 pm
- Collected bags and took taxi to Gatwick Airport Holiday Inn

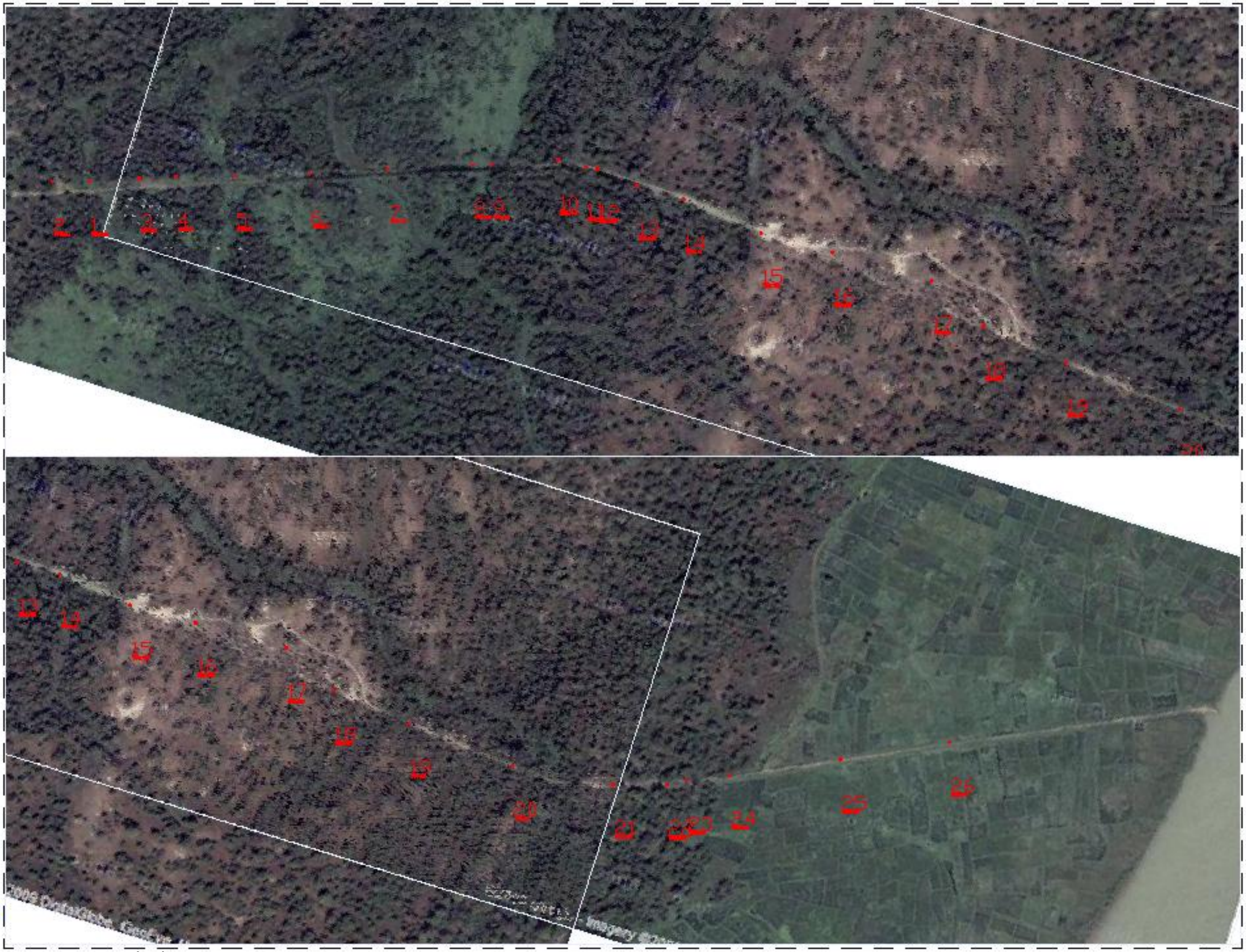
**Saturday, January 17th**

- Met Heather for breakfast at 7am in the hotel
- Left hotel at 8:30am and stopped at ATM to get pounds to pay taxi driver
- Departed London Gatwick at 11:15 am
- Arrived at JFK at 2:15 pm

## Appendix C-NRA Meeting Contact List

| NAME | DESIGNATION | TELEPHONE | EMAIL ADDRESS |
|---|---|---|---|
| **Momodou Senghore** | NRA Operations & Safety Manager | 9995056 | modou_@hotmail.com |
| **Kebba Fye** | NRA Planning & Design Manager | 9989204 | kebab.fye@gmail.com |
| **Frances Coker-Singhateh** | NRA Feeder Roads Manager | 9956876<br>7734655 | iyamide3@hotmail.com |
| **Eliman Secka** | Gambia Horse & Donkey | 9985151 | |
| **Lang Baba Sisay** | Gambia Horse & Donkey | 9702004<br>7008882 | |
| **Salifu A.H. Bah** | Sambel Kunda Teacher | 7577532 | Salifubah--@yahoo.com |
| **Kellee Davis** | Peace Corps volunteer Sambel Kunda | 7669834 | ngomachica@gmail.com |
| **Bill Meyers** | Peace Corps volunteer GTTI | 7307515 | billglobaltrip@yahoo.com |
| **Jess Everett** | EWB Rowan Professor | 8562565326 | everett@rowan.edu |
| **Katie Booth** | EWB Rowan Student | 6094257854 | boothc71@students.rowan.edu |
| **Brian Fischer** | EWB Rowan Student | 7326740250 | fische50@students.rowan.edu |
| **Ladonne Harris** | EWB Rowan Student | 8562875378 | ladonneh@hotmail.com |


ZOOM
ORBIT
PAN
REWIND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## Appendix D-Health & Transportation Survey

Village________________________

Date ____________________

**General Information**

Name of Compound ______________________________________

Number of Households________

Head of Household (s) _________________________________________

Name of Respondent ________________________________________

Age of Respondent __________

# Persons by Sex and Age

| | 0-4 | 5-14 | 15-45 | 45+ | Totals |
|---|---|---|---|---|---|
| Males | | | | | |
| Females | | | | | |
| Totals | | | | | |

Names (0-4) ______________________________________________________________

________________________________________________________________________

Names (5-14) _____________________________________________________________

________________________________________________________________________

Names (15-45) ____________________________________________________________

________________________________________________________________________

Names (45+) _____________________________________________________________

________________________________________________________________________

**Health**

How many times have you or members of your household been to the hospital in the last year, and for what reasons?

| Patient | Where? | Who? | When? | For What? |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

How many times have you or members of your household been to the traditional healer in the last year, and for what reasons?

| Patient | Where? | Who? | When? | For What? |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

How many times have people in your household had malaria in the past year? _________

How many times have people in your household had severe diarrhea or stomach upset in the past year? _________

How many people in your household died in the past year? __________
Cause, if known ________________________________________________________________
________________________________________________________________________________

How many births were there in your compound in the past year? ________

What water sources are available near you and what do you use them for?

| Water Sources | # functional | # broken | Used for? | Distance | How often? |
|---|---|---|---|---|---|
| Well-open | | | | | |
| Well - covered | | | | | |
| Pump | | | | | |
| River | | | | | |

How much water do you use daily?

| | ~ # liters | # times filled | Subtotal |
|---|---|---|---|
| Buckets | | | |
| Bidongs | | | |
| Headpans | | | |
| Other | | | |
| Subtotal | | | |
| Total | | | liters/day |

Does your compound have a pit latrine/latrines?

| Available? | # | For # people | Distance | Clean? | Full? | Cover? |
|---|---|---|---|---|---|---|
| | | | | | | |

If you don't have a pit latrine, what do you do? _____________________________________
________________________________________________________________________________

Who in your household is or has been to school of any kind?

| Name | Type of | Present or Final | Where? |
|---|---|---|---|

| | School | Level | |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**Transportation**
How often do people in your compound use the road to Kuntaur:

In the rainy season?

| | Daily | Weekly | Monthly | Once A Season | Never |
|---|---|---|---|---|---|
| Lumo | | | | | |
| Rice Fields | | | | | |
| School | | | | | |
| Visiting | | | | | |
| Other | | | | | |

If other, please describe ____________________________________________________
_____________________________________________________________________________

In the dry season?

| | Daily | Weekly | Monthly | Once A Season | Never |
|---|---|---|---|---|---|
| Lumo | | | | | |
| Rice Fields | | | | | |
| School | | | | | |
| Visiting | | | | | |
| Other | | | | | |

If other, please describe ____________________________________________________
_____________________________________________________________________________

What form of transportation do you tend to use and how long does it take to reach the river?

| | Rainy Season | Time | Dry Season | Time |
|---|---|---|---|---|
| Walking | | | | |
| Bicycle | | | | |
| Motorcycle | | | | |
| Horse cart | | | | |
| Car | | | | |

Does the flooding on the road affect your income? Please describe how. ______________
_____________________________________________________________________________

______________________________________________________________________________

What are your concerns about the road? ___________________________________________
______________________________________________________________________________
______________________________________________________________________________

How do you think the problem should be solved? __________________________________
_______________________________________________________________________________
_______________________________________________________________________________

Does the improvement of the road help you, your family and the community?

a) yes
b) no

Would you or members of your family be willing to:

a) pay to use an improved road _____________
b) be willing to contribute time and labor to work on the road _____________

What skills do you have that would help improve the road? _______________________
_____________________________________________________________________________
_____________________________________________________________________________

# Appendix E Mechanized Cost Estimate

| Excavation | |
|---|---|
| Equipment | |
| Description | 200 HP 150' haul, sand & gravel |
| Crew | B-10B |
| Units | B.C.Y. |
| Daily Output | 595 |
| Crew Days | **20.15** |
| Labor Hours | 0.02 |
| Total Hours | **239.76** |
| Total Days (Assuming 8hr Day) | **29.97** |
| Daily Cost (Delasi) | 20000 |
| Total Cost (USD Assuming 25Delasi=1USD) | **$16,118** |
| | |
| Equipment | CAT 219 Excavator $1m^3 = 1.09\ yd^3$ |
| Description | Backhoe, hydraulic, crawler mtd. 1 C.Y. cap=75 C.Y./hr. |
| Crew | B-12A |
| Units | B.C.Y. |
| Daily Output | 600 |
| Crew Days | **20** |
| Labor Hours | 0.027 |
| Total Hours | **323.67** |
| Total Days (Assuming 8hr Day) | **40.46** |
| Daily Cost (Delasi) | 25000 |
| Total Cost (USD Assuming 25Delasi=1USD) | **$19,980** |

| Hauling | |
|---|---|
| Equipment | Truck $10\ m^3 = 13.1yd^3$ |
| Description | 20 C.Y. dump trailer, 1 mile round trip, 2.5 loads/hr |
| Crew | B-34D |
| Units | L.C.Y. |
| Daily Output | 325 |
| Crew Days | **36.89** |
| Labor Hours | 0.025 |
| Total Hours | **300** |
| Total Days (Assuming 8hr Day) | **37.5** |
| Daily Cost (Delasi) | 15000 |
| Total Cost (USD Assuming 25Delasi=1USD) | **$22,131** |

| Compaction | |
|---|---|
| Equipment | Dynapac Drum Compactor |
| Description | Riding, vibrating roller, 12" lifts, 3 passes |
| Crew | B-10Y |
| Units | E.C.Y. |
| Daily Output | 3500 |
| Crew Days | **3.43** |
| Labor Hours | 0.003 |
| Total Hours | **35.96** |
| Total Days (Assuming 8hr Day) | **4.50** |
| Daily Cost (Delasi) | 32400 |
| Total Cost (USD Assuming 25Delasi=1USD) | **$4,439** |

| Grading | |
|---|---|
| Equipment | CAT 140G Grader |
| Description | Grade subgrade for base course, roadways |
| Crew | B-11L |
| Units | S.Y. |
| Daily Output | 3500 |
| Crew Days | **6.81** |
| Labor Hours | 0.005 |
| Total Hours | **59.94** |
| Total Days (Assuming 8hr Day) | **7.5** |
| Daily Cost (Delasi) | 18000 |
| Total Cost (USD Assuming 25Delasi=1USD) | **$4,900** |

| Totals | |
|---|---|
| Total Cost (USD) | **$67,568** |
| Total Cost (GBP) | **£47,116** |
| Total Crew Days | 87.24 |
| Total 8-Hour Days | 119.88 |

## Appendix F Supplies for Hand Labor Method

**Supply list:**

- shovels
- picks
- parts to convert carts for hauling fill
- spikes
- rope
- string
- food
- water

**Safety**

- rope
- markers that the rope can be led through

## Appendix G Cost Estimate

| | | | |
|---|---|---|---|
| Total Volume of Soil | 11,990 | $yd^3$ | 61222 |
| Total Tamp Area | 23820 | $yd^2$ | 109130 |
| Excavation and fill (Trench) | | | |
| | | qty. | cost |
| Equipment | shovels | 14 | $ 25.00 |
| Description | excavation by pick and shovel light soil | | |
| Crew | 1 COMMON BUILDING LABORERS | | |
| Units | bank Cubic Yards | | |
| Daily Output | 8 | | |
| Crew Days | **1498.75** | | |
| Labor Hours | 1 | | |
| Total Hours | **11990** | | |
| Total Days (Assuming 8hr Day) | **1498.75** | | |
| Daily Cost (Delasi) | 0 | | |
| Total Cost (USD Assuming 25Delasi=1USD) | **$338** | | |
| | | | |
| Estimations w/ workforce | | | |
| Estimated average number of laborers working | 9 | Common Builders | |
| Estimated total hours | 1332.222222 | hours | |
| Estimated total 8 hr days | 166.5277778 | days | |
| | | | |
| Hauling | | | |
| | | | |
| Equipment | Hauling Cart & Donkey | | |
| | Volume | 1 | $yd^3$/cart |
| | Velocity | 1.3 | mph |
| | Haul Dist | 0.5 | mile |
| Crew | a donkey handler | | |
| | Excavator | 1 | person |
| Units | cubic yards | | |
| Daily Output | **4.48** | | |
| | Wait time | 1.034 | hr |
| | Haul Time | 1.784 | hr/ $yd^3$ |
| | | | |
| Total Hours | **21390.16** | | |
| Total Days (Assuming 8hr Day) | **2673.77** | | |
| Estimations w/ workforce | | | |
| Estimated average number of carts working | 8 | carts | |

| | | | |
|---|---|---|---|
| Estimated total hours | 1341.547778 | hours | |
| Estimated total 8 hr days | 167.6934722 | days | |
| Compaction | | | |
| I have found no calculations on compacting anything by hand. The smallest compacter I've found is a gas powered compacter that is hand held. | | | |
| Grading | | | |
| | | qty. | cost |
| Equipment | shovels | 2 | $ 25.00 |
| Description | hand Grading | | |
| Crew | b18 | | |
| Units | S.Y. | | |
| Daily Output | 700 | | |
| Crew Days | **34.03** | | |
| Labor Hours | 0.034 | | |
| Total Hours | **407.66** | | |
| Total Days (Assuming 8hr Day) | **50.96** | | |
| Daily Cost (Delasi) | 0 | | |
| Total Cost (USD Assuming 25Delasi=1USD) | **$38** | | |
| estimations w/ workforce | | | |
| estimated average number of carts working | 1 | carts | |
| estimated total hours | 407.66 | hours | |
| estimated total 8 hr days | 50.9575 | days | |
| | | | |
| Totals | | | |
| Total Cost (USD) | **$64** | | |
| Total Cost (GBP) | **£44** | | |
| total hours | **33788** | | |
| total labor days | **1717** | | |