Document 525
PRE-IMPLEMENTATION REPORT

CHAPTER: Duke University
COUNTRY: Bolivia
COMMUNITY: Obrajes
PROJECT: Bridge in Obrajes, Bolivia
TRAVEL DATES: May 18 – July 14, 2009

PREPARED BY
Brianne Connolly, Ben Gagne, Maria Gibbs,
Russell Glorioso, Catherine Joseph,
Magdalena Kelleher, Devin McDaniel,
Laila Sharafi, Patrick Ye

April 19th, 2009

ENGINEERS WITHOUT BORDERS-USA
www.ewb-usa.org
Pre-Implementation Report Part 1 – Administrative Information

1.0 Contact Information

<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
<th>Phone</th>
<th>Chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Lead</td>
<td>Patrick Ye</td>
<td><a href="mailto:patrick.ye@duke.edu">patrick.ye@duke.edu</a></td>
<td>(630) 857-8863</td>
</tr>
<tr>
<td>President</td>
<td>Stephanie Chang</td>
<td><a href="mailto:stephanie.h.chang@duke.edu">stephanie.h.chang@duke.edu</a></td>
<td>(309) 360-9866</td>
</tr>
<tr>
<td>Mentor #1</td>
<td>Dwayne Lee</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mentor #2</td>
<td>Christine Beaule</td>
<td><a href="mailto:cbeaule@duke.edu">cbeaule@duke.edu</a></td>
<td>(808) 953-0853</td>
</tr>
<tr>
<td>Faculty Advisor</td>
<td>David Schaad</td>
<td><a href="mailto:david.schaad@duke.edu">david.schaad@duke.edu</a></td>
<td>(919) 660-5174</td>
</tr>
<tr>
<td>Health Point Person #1</td>
<td>Laila Sharafi</td>
<td><a href="mailto:laila.sharafi@duke.edu">laila.sharafi@duke.edu</a></td>
<td>(202)-294-3512</td>
</tr>
<tr>
<td>Health Point Person #2</td>
<td>Trisha Lowe</td>
<td><a href="mailto:trisha.lowe@duke.edu">trisha.lowe@duke.edu</a></td>
<td>(305) 849-1527</td>
</tr>
<tr>
<td>NGO/Community Contact</td>
<td>Alan Carvajal</td>
<td><a href="mailto:carvajal_alan@yahoo.es">carvajal_alan@yahoo.es</a></td>
<td></td>
</tr>
</tbody>
</table>

2.0 Travel History

<table>
<thead>
<tr>
<th>Dates of Travel</th>
<th>Assessment or Implementation</th>
<th>Description of Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 12-June 1, 2008</td>
<td>Site Assessment</td>
<td>First Trip to Bolivia</td>
</tr>
<tr>
<td>May 18- July 14, 2009</td>
<td>Implementation</td>
<td>Building the Bridge</td>
</tr>
</tbody>
</table>

3.0 Travel Team

<table>
<thead>
<tr>
<th>Name</th>
<th>E-mail</th>
<th>Phone</th>
<th>Chapter</th>
<th>Student or Professional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwayne Lee</td>
<td></td>
<td></td>
<td></td>
<td>Professional</td>
</tr>
<tr>
<td>Christine Beaule</td>
<td><a href="mailto:cbeaule@duke.edu">cbeaule@duke.edu</a></td>
<td>(808) 953-0853</td>
<td>Duke</td>
<td>Professor</td>
</tr>
<tr>
<td>Philip Danser</td>
<td><a href="mailto:philip.danser@duke.edu">philip.danser@duke.edu</a></td>
<td>(405) 816-9523</td>
<td>Duke</td>
<td>Student</td>
</tr>
<tr>
<td>Ben Gagne</td>
<td><a href="mailto:ben.gagne@duke.edu">ben.gagne@duke.edu</a></td>
<td>(802) 338-7754</td>
<td>Duke</td>
<td>Student</td>
</tr>
<tr>
<td>Maria Gibbs</td>
<td><a href="mailto:maria.gibbs@duke.edu">maria.gibbs@duke.edu</a></td>
<td>(828) 685-3555</td>
<td>Duke</td>
<td>Student</td>
</tr>
<tr>
<td>Russell Glorioso</td>
<td><a href="mailto:russell.glorioso@duke.edu">russell.glorioso@duke.edu</a></td>
<td>(703) 242-8162</td>
<td>Duke</td>
<td>Student</td>
</tr>
<tr>
<td>Andrew Harris</td>
<td><a href="mailto:andrew.harris@duke.edu">andrew.harris@duke.edu</a></td>
<td>(540) 580 2217</td>
<td>Duke</td>
<td>Student</td>
</tr>
</tbody>
</table>
4.0 Safety

4.1 State Department Warning
There is a warning from the State Department alerting U.S. citizens to the unstable social and security situation in Bolivia. They suggest that U.S. citizens remain vigilant and not pass through or around roadblocks. It is also suggested that citizens stay out of the departments of Santa Cruz, Beni, Pando, Chuquisaca, and Tarija due to violence from pro-government and opposition forces. We will be traveling to the department of La Paz and Oruro, where there are no specific travel warnings.

4.2 Point to point travel detail

<table>
<thead>
<tr>
<th>Start Date</th>
<th>End Date</th>
<th>Location/Destination</th>
<th>Accommodations</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009-5-18</td>
<td>2009-5-19</td>
<td>La Paz, Bolivia</td>
<td>Hotel El Dorado</td>
<td>Flights into La Paz</td>
</tr>
<tr>
<td>2009-5-19</td>
<td>2009-5-21</td>
<td>La Paz</td>
<td>Hotel El Dorado</td>
<td>Orientation Week. Acclimate to altitude. Limited activities due to lower oxygen at higher altitude. Also we will stay in La Paz so that anybody with severe altitude sickness can be returned to lower altitudes immediately. Accustom to local language by practicing Spanish. Physical conditions allowing, visit nearby Valle de la Luna national park.</td>
</tr>
<tr>
<td>2009-5-22</td>
<td>2009-5-24</td>
<td>Oruro</td>
<td>Hotel Repostero</td>
<td>Take 3-hr bus ride to Oruro, the largest city nearest to the site. Purchase supplies for construction, groceries, and other house supplies. Meet with Oruro Prefecture if possible.</td>
</tr>
</tbody>
</table>

2009-5-26 | 2009-7-9 | Obrajes | Rented House | Unpack belongings and settle in. Begin project. Trips to Oruro for Internet access, groceries, calling home, purchasing supplies, communicating with Oruro Prefecture as necessary.

2009-7-10 | 2009-7-10 | Oruro | Hotel Repostero | Last day in Obrajes. Depart for Oruro. Final meeting with Oruro Prefecture.

2009-7-11 | 2009-7-11 | La Paz | Hotel El Dorado | Return to La Paz on 3-hr bus ride.

2009-7-11 | 2009-7-14 | La Paz, Lake Titicaca, Tiwanaku ruins | Hotel El Dorado | Relax in La Paz. Purchase souveniers. Potential day trip to visit Lake Titicaca and/or Tiwanaku ruins. Listen to Dr. Beaule's expert opinion as an archaeologist about the Tiwanaku civilization.

2009-7-14 | 2009-7-14 | United States | Home sweet home | Flight back to US

### 4.3 Safety Plan

Our primary means of dealing with an emergency will be to call phone numbers on our emergency contact list. This list includes phone numbers for each participant’s family as well as the contact numbers for the American Embassy in La Paz, the closest hospital, Duke emergency response, and International SOS. The project site has reasonably good cell phone coverage. In the case of emergency, International SOS (an insurance policy purchased by Duke on our behalf) provides services such as telephone advice and referrals to full-scale evacuation by private air ambulance. We are in the process of obtaining an emergency plan from the American Embassy in Bolivia.

### 4.4 Contacts

#### 4.4.1 On-the-ground phone number and email for travel team

See numbers and emails from group list, Bolivian cell phone to be purchased on arrival
4.4.2 Nearest US Consulate Contact Information
Consular Section in La Paz
American Citizen Services
Tel: +591-2-216-8297
Fax: +591-2-216-8808
After Hours Emergency Number: +591-2-216-8500
E-mail: USCit.Services.Bolivia@gmail.com, consularlapaz@state.com
Internet: http://Bolivia.usembassy.gov

4.4.3 Nearest Hospital Contact Information
Hospital Metodista
Avenida 14 de Septiembre #5809 – Esquina Calle 12, Obrajes, Zona Sur. Tel. 278-3509 or Tel. 278-3372

5.0 Budget

5.1 Cost

<table>
<thead>
<tr>
<th>Expense</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airfare</td>
<td>$7700</td>
</tr>
<tr>
<td>On Ground</td>
<td>$4920</td>
</tr>
<tr>
<td>Materials</td>
<td>$17380</td>
</tr>
<tr>
<td>Other</td>
<td>$200</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$30200</strong></td>
</tr>
</tbody>
</table>

5.2 Hours

<table>
<thead>
<tr>
<th>Names</th>
<th># of Weeks</th>
<th>Hours/Week</th>
<th>Total Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project lead:</strong> Patrick Ye</td>
<td>50</td>
<td>5</td>
<td>250</td>
</tr>
<tr>
<td>Mentor: Christine Beaule</td>
<td>50</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td><strong>CE 142 Design Teams:</strong> Edmund Finley, Nick Menchel, Trisha Lowe, Anna Sleeter, Brianne Connolly, Ben Gagne</td>
<td>16</td>
<td>5</td>
<td>960</td>
</tr>
</tbody>
</table>
5.3 Donors and Funding

<table>
<thead>
<tr>
<th>Donor Name</th>
<th>Type (company, foundation, private, in-kind)</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duke University Public Policy Grant</td>
<td>Research</td>
<td>$2500</td>
</tr>
<tr>
<td>Duke University Center for Latin American and Caribbean Studies</td>
<td>Research</td>
<td>$1500</td>
</tr>
<tr>
<td>Duke University Stay In Focus</td>
<td>Student</td>
<td>$1000</td>
</tr>
<tr>
<td>Iovino Family Foundation</td>
<td>Foundation</td>
<td>$8690</td>
</tr>
<tr>
<td>Thorton Tomasetti Foundation</td>
<td>Foundation</td>
<td>$8000</td>
</tr>
<tr>
<td>Duke University Engineering Alumni Council</td>
<td>Private</td>
<td>$2000</td>
</tr>
<tr>
<td>Mulch Fundraiser</td>
<td>Fundraising</td>
<td>$1014.82</td>
</tr>
<tr>
<td>Lord Foundation</td>
<td>Foundation</td>
<td>$7500</td>
</tr>
<tr>
<td><strong>Total Amount Raised:</strong></td>
<td></td>
<td><strong>$32204.82</strong></td>
</tr>
</tbody>
</table>
6.0  Project Location
Longitude: 66°59’30.79”W
Latitude: 17°49’23.39”S

7.0  Project Impact
Persons directly affected:
The communities of Obrajes, Iruma, Jachuma, and Condor Chinoka will be directly affected. With this bridge, they can transport their livestock and crops during the rainy season, thus increasing their productivity. Also, they will be able to reach health care facilities and schools.

Persons indirectly affected:
None significantly.

8.0  Mentor Resume
Pre–Implementation Report Part 2
Technical Information

Brianne Connolly
Ben Gagne
Catherine Joseph
Magdalena Kelleher
Devin McDaniel
1.0 INTRODUCTION
The Bolivian communities of Condor Chinoka, Iruma, Jachuma, and Obrajes are split up by a channel of water (Rio Iruma) which during the rainy becomes an impassable river, thus hindering agricultural productivity and transportation. This project proposes to build a bridge with support from the Engineers Without Borders–Duke Chapter, which will connect the two sides of the Rio Iruma, thus allowing safe, accessible transportation for these communities during the rainy seasons.

The project will bring students into Obrajes where they will undertake in building the bridge with the use of local materials and the aid of local skilled laborers. The goal of the project is to eventually give the bridge to the community. The bridge should be finished by the time students leave Obrajes, but if it is not, a local engineer will be given the plans and oversee the completion of the project. In the long run, the community will own it and be responsible for its upkeep. This bridge will benefit the community by providing a safe passage during the rainy season for agricultural transportation (livestock and crops) and for local access to schools and health clinics.

This report documents the EWB–Duke implementation trip to Bolivia. It will include three possible bridge designs, a proposed timeline and budget, and details about the community.

2.0 PROGRAM BACKGROUND
As a freshman, Patrick Ye had Dr. Christine Beaule as his Writing 20 professor. Dr. Beaule, an archeologist who does research in the Altiplano of Bolivia, had heard from her workers about their community’s need for a bridge. When she mentioned this to the class, Patrick thought it could become an EWB project. The project began November 1, 2007.

During the summer of 2008, EWB–Duke members visited the Obrajes Valley to explore the possibility of building a bridge to help the communities in the valley. The team took surveying and cone penetrometer measurements data at five river crossing, checked the availability and prices of local construction material and tools, and interviewed community members of the five communities (Obrajes, Iruma, Jachuma, Condor Chinoka, and Tontoco) in the valley. Upon their return, members of EWB–Duke started designing a bridge for the community in weekly meetings. In the Spring 2009, students formed three design teams for a civil engineering class that were each charged to design the bridge. This report will detail the designs which came out of this class.
3.0

FACILITY DESIGN

3.1

DESCRIPTION OF PROPOSED FACILITIES

Our facility will be a \(~28\) m spanning concrete roadway over two meter in diameter culverts that will be dug one meter into the existing riverbed. The culverts will be covered with soil and gravel up to the bottom of the concrete roadway. The walls of the bridge will be concrete.

3.2

JUSTIFICATION FOR SPECIFIC DIMENSIONS

Culvert size:
We chose to use eight 2-meter diameter culverts to achieve more than adequate flow. The culverts will each be 4.556 meters long. This will allow for a 3.048 meter roadway as well as a retaining wall with a 45° angle top, while still allowing 0.5 meter of culvert extending beyond the wall.

Width of the Roadway:
Our roadway is 3.048 meters (10 ft) wide; an appropriate width for the level of traffic of the site. Making the bridge too wide would create unnecessary costs, however a bridge that is too narrow would not meet the purpose of the bridge. We concluded that 10 feet would be a suitable width for the bridge.

Angle of ends of the bridge:
The roadway’s beginning and end are both sloped at 15° angle since the roadway is built at a level higher than the embankment. This will allow for a smooth transition onto the roadway for cars and pedestrians at not too steep of an incline.
FLOW RATE CALCULATIONS

To calculate the volumetric flow rate of the river we used Manning’s formula,

\[ V = \left( \frac{k}{n} \right) R_h^{2/3} S^{1/2} \]

where \( k \) is equal to 1.0 because we’re using SI units, \( n \) is the manning coefficient of roughness, \( R_h \) is the hydraulic radius, and \( S \) is the slope of the riverbed. We conservatively used the manning coefficient of 0.025 for a gravelly earth channel. The hydraulic radius is equal to \( A/P \), where \( A \) is the cross sectional area and \( P \) is the wetted perimeter. We calculated the river’s cross sectional area with AutoCAD, which yielded an area of 18.9554 m², as well as the wetted perimeter, which was 56.9150 m. The slope \( S \) was determined by using a point on the cross section and a point prior to it. This equaled 0.0455 m/m.

By plugging in these numbers into Manning’s formula, we found the velocity of the river to be 4.06 m/s. We then took this velocity and plugged it into the continuity equation: \( Q = AV \), where \( Q \) is flow rate, \( A \) is the cross sectional area, and \( V \) is the velocity. The final flow rate came out to be 76.96 m³/s.

Once we determined the max flow rate of the river, we looked into figuring out the flow rate going through one culvert to determine how many culverts we needed to keep the river from damming. To do this, we manipulated the D’Arcy Weisbach equation for head loss into the form

\[ \Delta h = f \left( \frac{4Q}{\pi(1/2)dh * nu}, \frac{\epsilon}{(1/2)dh} \right) \left( \frac{8Q^2l}{\pi^2g((1/2)dh)^5} \right) \]

With \( h \) being the head equal to the length of the culvert multiplied by the slope of the riverbed, \( f \) being the D’Arcy Weisbach friction coefficient, \( Q \) being the volumetric flow rate through the culvert, \( dh \) being the hydraulic diameter of the culvert equal to four times the area divided by the wetted perimeter, \( nu \) being the kinematic viscosity of water equal to 1.004 mm²/s, \( \epsilon \) being the roughness constant used in the D’Arcy Weisbach equation equal to 45 mm for corrugated metal, \( l \) being the length of the culvert equal to 4556 mm, \( g \) being the acceleration of gravity equal to 9810 mm/s².

This yielded an expression for \( Q \) equal to

\[ myQ = \frac{P^2g((1/2)dh)^4h}{8f \left[ \frac{4Q}{\pi nu * (1/2)dh, (1/2)dh} \right] l} \]

\[ \left( \frac{\epsilon}{(1/2)dh} \right)^{1/2} \]
A one-foot layer of stone and rock put on the bottom of the culverts will affect the hydraulic radius. With a hydraulic radius equal to 0.926 m, this yielded a flow rate of 15.14 m³/s for every 2-meter in diameter culvert. With an original volumetric flow rate of 76.96 m³/s, we determined that 5.08 culverts would be needed to achieve the requisite flow. Therefore, our ultimate design has eight culverts, allowing for more rocks to be added to the layer inside the culverts if need be with still a significant factor of safety.
VERTICAL FORCE/BENDING CONSIDERATION

Ensuring the maximum bending moment exerted by the bridge on the culvert is within the tolerance of the culverts is impossible without the exact specifications of the culvert we are using. However, the standard 72 inch (~2 meter) in diameter, 12 gauge, 3x1 inch arch culvert used in the United States is regularly used in highway construction where the loading would be presumably be much greater than for our design. Under this assumption, the bending moment should not cause the bridge to fail.
FORCE CALCULATIONS: FLOW FORCE

\[
V = \left(\frac{k}{n}\right) R_s^{2/3} S^{1/2} = 4.06 \text{ m/s}
\]

\[Q = AV = 76.96 \text{ m}^3/\text{s}\]

\[F = \rho QV = (1000 \text{ kg/m}^3)(76.96 \text{ m}^3/\text{s})(4.06 \text{ m/s}) = 312,458 \text{ N}\]

\[p = \frac{F}{A} = \frac{312,458 \text{ N}}{37.5 \text{ m}^2} = 8332.2 \text{ Pa}\]

FORCE CALCULATIONS: HYDROSTATIC FORCE

\[p = \gamma x = \rho g x = (1000 \text{ kg/m}^3)(9.81 \text{ m/s}^2)(x) = 9810x \text{ Pa}\]
FORCE CALCULATIONS: TOTAL FORCE

\[ p_{\text{tot}} = (16,483.8 + 9810 \times x) \text{Pa} \]

The potential for the force on the inside of the culvert from flowing water to loosen the culvert from underneath retaining wall and the soil was taken into consideration. However, according to Woody Kloesel, a representative from the EWB–Asheville Professionals Chapter, this is more of a long term operation and maintenance issue than a design issue. The weight of the stone layer and the friction between the soil and the culverts will be enough to keep the culverts from washing away on any one storm. It will take reinforcing the soil regularly and is therefore more of an operation and maintenance issue.

**Concrete Roadway Design**

The roadway of the culvert bridge will be a plain concrete pavement design. Because of the low traffic and low loading bearing capabilities needed, it was deemed adequate to have a 0.10 meter depth set on a 0.10 meter crushed stone base. No steel reinforcement will be used on the center section of the bridge. Based on the knowledge of quick and drastic changes in temperature in the region the bridge will be built in, the plain concrete pavement will be scored at the time of pouring to provide a control area for cracks that may form.

The center section of the bridge (set at 0 degrees from the horizontal) will be 23.73 meters long, 2.76 meters wide, and 0.10 meters deep (see drawing). The concrete will be set on a 0.10 meter base of crushed stone. It will be set as one section of road. The concrete will be scored transversely every 2.74 meters. The score mark will be 0.06 meters deep from the top surface of the concrete. These measurements are based on
the standards for road design, specifically set by the Washington State Department of Transportation, for thin concrete slabs.

The approach sections of the bridges roadway will be 2.21 meters long on either side and will be 2.76 meters wide. The sections will be set 15° from the horizontal. The depth of this section nearest to the bridge will be at a depth of 0.57 meters and the section will then taper down to be level with the elevation of the banks. Because the approach section of the bridge will be set on soil that has not been specifically compacted, it may be subject to significant settling. To prevent damage to the bridge due to settling, #3 reinforcing steel will be used to strengthen the bridge roadway approaches. Only transverse reinforcements will be used. In the thicker sections, the reinforcing steel will be set in two layers. These measurements are also based on standards set by Washington State Department of Transportation. However, due to time constraints, we have not been able to access the resources necessary to design for the spacing of the reinforcement. This detail will be worked out in the upcoming week (by April 24th) and we will notify the EWB-USA of our completed design.
Retention Wall Design
Design Retaining wall

Concrete road on top

Find: Retaining wall dimensions & design of rebar

Given:
- Fe' = 2500 psi
- fy = 36000 psi
- Soil bearing pressure = 1000 psf
- Active pressure = 45 psf/ft
- Passive pressure = 350 psf/ft
- Coef of friction of undisturbed soil = 0.45
- Concrete density = 150pcf
- Soil density = 142pcf
Guess Dimensions (from excel file)

Check bearing

See excel file

Used

\[ \sigma = \frac{P}{A} + \left( 1 + \frac{6e}{b\omega} \right) \]
Check sliding

\[ w_1 = \text{weight of retaining wall} = 150((6' - 0.66') + 1'(3.33')) \]
\[ = 1100 \text{ lbs} \]

weight of soil above heel

\[ (1.646')(6')(142 \text{pcf}) = 1420 \text{ lbs} \]

Weight of concrete road = \((1'(1.6')) = 2.6'(.774')(150)\)
\[ = 270.8 \text{ lbs} \]

Total weight = 2790.8

Resisting \( S = 0.45(2790.8) = 1256 \text{ lbs} \)

Applied \( S = \frac{45 \text{ psf}}{12}(6')(6') = 810 \text{ lbs} \)

\[
\frac{RS}{AS} = 1.55 > 1.5 \quad \checkmark
\]
Checking overturning \( \Sigma H_a \)

Stabilizing Moment

\[(1420 \text{lbs})(2.83') + (600 \text{lbs})(1.5' = 4384 \text{ lbs-ft})\]

Resisting Moment

\[(810 \text{lbs})(2') = 1620 \text{ lbs-ft}\]

\[
\frac{SM}{RM} = \frac{4384 \text{ lbs-ft}}{1620 \text{ lbs-ft}} = 2.706 \checkmark
\]
Check Shear

On heel

\[ V_c = 1.4 \times (1419.99) = 1988 \text{ lbs} \]

Find \( V_c \)

\[ \phi V_n = \frac{\phi V_c}{\phi Z} \cdot \frac{f_{c'} b w d}{2} = 7.5 (2.5 - 500 \cdot (12'')(8'')) \]

\[ = 7200 \text{ lbs} \]

or 7.2 kips

\[ \phi V_n = 7200 \text{ lbs} > V_u = 1988 \text{ lbs} \]

On stem

\[ V_0 = 1.4 \times (810 \text{ lbs}) = 1134 \text{ lbs} \]

\[ \phi V_c = \frac{.75 (2 \cdot 2500 \cdot 12 \cdot 8'')}{2} \]

\[ \phi V_c = 3600 \]

\[ \phi V_c > V_0 \checkmark \]

toe \[ \checkmark \]
Design for bending moment

Assuming uniform load under the retaining wall.

See excel file

\[ M_n = M_u \]

\[ P = \frac{1}{m} \left[ 1 - \sqrt{1 - 2 \frac{R_n}{f_y}} \right] \quad \text{where} \quad R_n = \frac{M_n}{bd^2} \]

\[ \varepsilon = \frac{f_y}{5500} \]

\[ A_s = \frac{Pbd}{m} \]

Design shrinkage & temp steel

Used \( A_s = 0.0020 \text{ in.} \)

OE PROJECT #: ______________________

PAGE: ____ of ____

DESIGNED BY: ______________________ DATE: _______ CHECKED BY: ______________________

SUBJECT: ______________________

(date)
3.3

DRAWINGS
ALL UNITS IN METERS

SOIL HEIGHT

American standard #4 bar spaced every 0.38 meters

American standard #4 bar spaced every 0.38 meters

4 x American standard #5 bars spaced every 0.25 meters

RETRAINING WALL DESIGN  EWB Bolivia Project
ALL UNITS IN METERS

CROSS SECTION OF ROADWAY

EWB Bolivia Project
## 5.1

**CONSTRUCTION TIMELINE**

<table>
<thead>
<tr>
<th>Task</th>
<th>Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Obtain materials and equipment</td>
<td>1</td>
</tr>
<tr>
<td>2. Excavate riverbed for culverts</td>
<td>2–12</td>
</tr>
<tr>
<td>3. Lay forms for base of retaining walls</td>
<td>13–14</td>
</tr>
<tr>
<td>4. Pour partial base of retaining walls</td>
<td>15–16</td>
</tr>
<tr>
<td>5. Place steel rebar in concrete and pour rest of base</td>
<td></td>
</tr>
<tr>
<td>6. Pour concrete retaining walls. Insert rebar appropriately with progress.</td>
<td>18–26</td>
</tr>
<tr>
<td>7. Fill space between retaining wall with compacted soil</td>
<td>26–34</td>
</tr>
<tr>
<td>8. Lay forms for angled wall/curb</td>
<td>35</td>
</tr>
<tr>
<td>9. Place concrete for angled wall/curb</td>
<td>36–37</td>
</tr>
<tr>
<td>10. Place crushed stone on top of soil as base for roadway</td>
<td>38</td>
</tr>
<tr>
<td>11. Procedure to lay concrete roadway</td>
<td></td>
</tr>
<tr>
<td>a. Lay forms for horizontal section of roadway</td>
<td>33</td>
</tr>
<tr>
<td>a. Pour horizontal section of roadway</td>
<td>34–36</td>
</tr>
<tr>
<td>b. As concrete is set, score the transverse joints for cracking control</td>
<td>34–36</td>
</tr>
<tr>
<td>c. Lay forms for approach sections of roadway</td>
<td>37–44</td>
</tr>
<tr>
<td>d. Pour partial concrete for sections</td>
<td>38–45</td>
</tr>
<tr>
<td>e. Place steel rebar in concrete and pour rest of section</td>
<td>38–45</td>
</tr>
</tbody>
</table>
5.2 SAFETY CONSIDERATIONS

Before construction begins, we will hold a safety orientation, conducted in Spanish, for community members that will be working on the bridge. Workers must wear closed-toed, preferably steel-toed, footwear while working. Hard hats, safety glasses, back braces, and gloves will be worn as necessary.

Two team members have been certified in First Aid and CPR so emergency care can be provided on-site.
6.0

OPERATION AND MAINTENANCE

Safety factors:
We have added safety factors in various aspects of our design. We must also consider other failure modes for culverts and prepare for these failures in the chance that they occur. The most common failure modes for culverts are insufficient capacity, plugging, and embankment erosion.

Our design allows for the following measures to be taken in the event of bridge failure:

Preventative Measures

For the Insufficient capacity failure mode:
- Install armoring and wing-walls at the entrance and outlet of the culvert to increase pressure of the flow through culverts.
- Install a relief culvert.

For the Plugging failure mode:
- Install a sediment catch basin upstream.
- Install a relief culvert.

For the Embankment Erosion failure mode:
- Place riprap to reduce embankment erosion.
- Shape culvert entrance to match embankment slope.
- Construct flared end section to direct flow.

How Often:
Maintenance of the bridge will require periodic bridge inspections. At the time of completions, an initial inspection will occur. The purpose of this inspection is to reevaluate site conditions and identify deficiencies that may not have been identified during construction. This includes reevaluation of erosion, debris guards, and grades of banks.

Routine inspections will be regularly scheduled, occurring every two years during the dry season. Inspection of equipment of bridge evaluation tools will occur first (cleaning tools, visual aid tools, measuring equipment, safety equipment, etc.). The bridge inspector will inspect the bridge for fractures, structural deficiencies, failures in the metal culverts, and will identify changing conditions.

Interim inspections will occur every six months to identify any quickly changing conditions with the bridge. These inspections may be performed by local (or district) trained inspectors. During these inspections, the inspector should also remove any debris from the debris guards to allow for maximum flow through the culverts.
Damage inspections will be performed as needed, generally as a result of environmental damages, fires, collisions, or severe floods. Underwater inspections may be performed as needed during low water seasons. Wading techniques may be used for this inspection. In-depth inspections may also be performed to investigate deficiencies found during routine inspections.

It will also be useful to develop in information database containing all data gathered during bridge inspections. This will help in monitoring load-bearing capacities of the bridge.

**Operation Costs:**
Cost to operate the bridge will be composed of pay for a bridge inspector and funds for future bridge repairs. This will be proportional to the average pay rate for bridge inspectors in Bolivia and the cost of materials for the future repairs necessary. There will be no daily operation cost for the bridge.
PROJECT OWNERSHIP & SUSTAINABILITY

Upon completion of the project, ownership of the bridge will belong to the local communities in the Obrajes valley. We plan to hand legal ownership and responsibility to the Oruro Prefecture, as that is how infrastructure projects work in the area. However, maintenance will ultimately be the responsibility of the communities. With the help of Dr. Christine Beaule, an archeologist who is extensively involved in the local communities and will be with us during our stay, we will secure the transfer of ownership. We have prepared a memorandum of understanding that is to be signed by the mayors of all the surrounding villages. This document will place the responsibility of the bridge’s maintenance on the shoulders of the communities which it benefits, not EWB. The following are two parts of this memorandum. The first is a legal memorandum which will be signed by the local prefectural engineering office in Oruro. The second is the document that will be presented to the mayors of the local communities of Iruma, Jachuma, Condor Chinoka, and Obrajes. These documents follow this page.
MEMORANDUM OF UNDERSTANDING
BETWEEN
THE ORURO PREFECTURE OF THE REPUBLIC OF BOLIVIA
and
THE DUKE UNIVERSITY CHAPTER OF ENGINEERS WITHOUT BORDERS-USA

The Duke Chapter of Engineers without Borders agrees to contribute specific resources for the creation of a bridge in the Republic of Bolivia at 17° 49’ 22"S | 66° 59’ 31"W (approximately 100 meters south of the railroad bridge in the City of Obajes). The stated goal of this project is to ease the transportation and mobility problems due to river flooding during the rainy season (November to April) for the Bolivian communities of Condor Chinoka, Iruma, Jachuma, and Obajes. The local communities are separated from their pasture, fields, schools, and health clinics on the opposite bank. Most damaging, however, is the fact that villagers are also isolated from the City of Oruro, the market center where they buy or sell crops, thereby limiting the level of welfare that they can attain. Since these communities are primarily supported by farming economies, crossing the river during the rainy season is crucial. Harvested crops decrease in value for each day that farmers are unable to cross the river and get to market. Some attempt to take a detour and cross at a point that is still unsafe for their livestock, for their equipment, and for themselves. Trucks full of produce often tip over when attempting to cross the river, washing away the primary income of the local farmers. Also, without a crossing, people in the village cannot reach their crops and grazing fields that lie on the other side. Since the livestock are confined to one bank, they exhaust the land and thus villagers are unable to properly feed their livestock. The bridge project will remedy the aforementioned problems by creating means for pedestrians and vehicles to cross the river when the crossing would otherwise be impassable.

The Duke University Chapter of Engineers Without Borders (Duke EWB), the Prefecture of Oruro (the Prefecture), and the communities of Obajes, Condor Chinoka, Iruma, and Jachuma will collaborate in the construction of a one-lane bridge for Obajes and the surrounding communities of Condor Chinoka, Iruma, and Jachuma. Construction will begin during in late May or early June of 2009.

Duke EWB, with the aid of a licensed Professional Engineer, will produce a bridge design for the river crossing in Obajes. Both Duke EWB and a licensed Professional Engineer will (1) travel to Bolivia, (2) supervise the project, and (3) supervise the volunteer laborers (coming from from the surrounding communities) during the seven to eight weeks that we are in the country of Bolivia. Duke EWB will provide funding for all materials that are required to construct the bridge.

The Duke EWB team will consist of between eight and twelve students, Dr. Christine Beaule, and a Professional Engineer. Excluding extreme circumstances that would make it unsafe for the group to stay, the group will remain until the stated date of termination. The stated date of termination is July 16, 2009. No single individual is required to remain for the entire time.

Dr. Beaule will act as a liaison between Duke EWB and the communities. She will communicate on our behalf with the communities. Duke EWB members are students, not professionals, and therefore the design will have been evaluated and approved by licensed professional engineers in the United States before we travel to Bolivia. We plan to have a professional engineer travel with us to Bolivia and oversee the beginning phases, if not the entire duration, of the construction.
Per the guidelines set forth in the agreements made with each village, laborers will assist with the bridge construction every day, Monday through Friday, until the project is complete. The laborers will not receive any monetary compensation, bearing in mind that the bridge will directly aid them and their communities. Volunteers should be able to reproduce some construction techniques so that they may continue construction on the bridge if the project is not complete when the Duke EWB team leaves in July. Members of the communities near Obrajes must realize that just because the site will be near the Obrajes community, all communities that will be using or indirectly benefiting from the bridge must contribute to the construction effort.

The prefecture of Oruro will possess any and all legal ownership of the bridge and is encouraged to collaborate with Duke EWB and the community as much as it sees fit. Though the national Engineers without Borders Technical Advisory Committee will approve the design and all construction processes, because the prefecture will take legal responsibility for the bridge they will approve the bridge design and ensure that the design complies with all Bolivian construction code and safety requirements.

The Prefecture is encouraged to disclose information and documentation pertaining to the design and construction of the bridge with an eye toward future projects in the region. Any knowledge or techniques the community members or the Prefecture learn with regards to the bridge from the Duke EWB team is transmitted in the hope that the communities and the prefecture can collaborate on future river-crossing related projects independent of external aid. Duke EWB agrees to donate to any requesting party all design and construction documentation pertaining to the bridge.

The communities of Condor Chinoka, Iruma, Jachuma, and Obrajes agree to perform regular maintenance on the bridge. Duke EWB will educate the community members on upkeep of the bridge for the years following its construction. The communities and the Prefecture know that in the event that the bridge sustain damages, Duke EWB may advise on the best course of action to take toward repairing the damages but may not immediately have the resources to return to Bolivia and work on the bridge ourselves. The prefecture will not incur any financial costs other than the man hours required to approve the bridge design and inspect the structure while it is under construction. Throughout the construction, we will educate community members about the construction and sustainable maintenance of the bridge. In the event that the bridge is not completed before our departure, we will not be able to inspect the bridge for possible failures. Throughout construction we will advise local community members, as best as we are able, on some major issues that may arise and cause the bridge to fail. Duke EWB asks that the Prefecture make regular inspections to ensure that the bridge does not fail catastrophically.

Duke EWB agrees to maintain a five year relationship with the local communities that are beneficiaries of this bridge. We agree to provide technical assistance for any questions that the community may have regarding operation and maintenance. In the event of a partial or complete failure of the bridge, we agree to provide technical assistance for the required repairs. If absolutely necessary, we will make a good faith effort to return to the community to assist with reconstruction.

Duke EWB is not liable for any injury sustained by any person as a result of their involvement in constructing the bridge.
Duke EWB will provide funds to purchase raw materials for construction, as well as provide a majority of the laborers' hand tools. In the event that the bridge is not completed before the Duke EWB team leaves, the necessary amount of remaining construction materials will be purchased by Duke EWB and left with an in country representative that will be appointed by Duke EWB. An in country representative will also be appointed to supervise continuing construction. Duke EWB may fund skilled laborers that are employed during our stay there, but only at the discretion of the Duke EWB team.

Laborers are asked to carpool or walk to the construction site. We will not be providing transportation for them to the site; it is up to them to show up, on time, to work on their bridge. We will be arranging for transportation of materials from Oruro to the job site.

If the bridge is not complete, Duke EWB will appoint a foreman to oversee the remainder of the bridge construction.
CONSIDERING THAT the community of Obrajes (CO), Bolivia wishes to obtain the help of Engineers Without Borders with the construction of a vehicular bridge 100 meters south of the train bridge in Obrajes; and
CONSIDERING THAT, EWB wishes to assist the community of Obrajes (CO) with the construction of the vehicular bridge,
THEREFORE, the community of Obrajes (CO) and Engineers Without Borders agree to the following stipulations.

EWB will design and help with the construction of a vehicular bridge.
EWB will buy the cement, wood, culverts, and tools necessary for the construction of the bridge according to the design.
EWB will bring students from Duke University to the site of the project to participate in the construction of the bridge and a professional engineer to supervise the construction, at least until the community can finish the project.
EWB will finish working on July 16, 2009. If construction is not completed by this date, EWB will provide a supervisor that will stay on site until the bridge is complete.
EWB will maintain a relationship with CO for a minimum of 5 years and be available to help with any problems that arise.
EWB will teach CO how to perform tasks of operation and maintenance.

CO will provide 10 men to help with the construction of the bridge from 8 am to 5pm. The men will be volunteering their labor and will not receive monetary compensation for their work. Each man is responsible for bringing his own food for lunch and finding transportation to and from the site during the period of construction.
CO will bring shovels to help with the construction of the bridge.
CO will gather the required amount of dirt according to the design.
CO will build a shed that is big enough to protect bags of cement, tools and other materials.
CO will be in charge of maintaining the bridge once it is completed.
CO will establish a committee to manage operations and maintenance of the bridge and secure funds to implement these tasks.

If any of the stipulations made in this agreement are not upheld, EWB reserves the right to terminate the project.
Solicitud

CONSIDERANDO QUE, la comunidad de Obrajes (CO), Bolivia desea obtener la ayuda de Ingenieros Sin Fronteras (EWB), para la construcción de un Puente vehicular 100 metros al sur del puente del tren en Obrajes; y
CONSIDERANDO QUE, EWB desea asistir a la comunidad de Obrajes (CO) para construir el puente vehicular,
POR LO TANTO, la comunidad de Obrajes (CO) y los Ingenieros Sin Fronteras (EWB) se comprometen a las siguientes estipulaciones:

EWB diseñará y asistirá a construir un puente vehicular.
EWB comprará el cemento, madera, alcantarillas y herramientas necesarias para construir el puente vehicular según sea el diseñado.
EWB traerá estudiantes de Duke University al lugar del proyecto para participar en la construcción del puente y un ingeniero profesional que supervise la construcción; por lo menos hasta que la comunidad pueda terminar la estructura.
EWB terminará con sus tareas el 16 de Julio. Si la construcción no ha terminado para entonces, EWB proporcionará un supervisor que quedará en el lugar de construcción hasta que el puente sea completado.
EWB mantendrá relaciones con CO por un mínimo de 5 años y estará disponible para ayudar con problemas de mantenimiento que se presenten.
EWB enseñará a CO como hacer tareas de operación y mantenimiento.

CO proveerá _____ hombres para ayudar con la construcción del puente desde _____ hasta _______. Los hombres trabajarán voluntariamente y no recibirán pago monetario por su trabajo. Cada uno será responsable de traer su propia comida y buscar su propio medio de transporte al sitio durante el periodo de la construcción.
CO traerá palas para ayudar con la construcción del puente.
CO recogerá _________ tierra del lugar o cerca del local de excavación.
CO construirá una galera suficientemente grande para proteger los sacos de cemento, otros materiales y las herramientas.
CO se encargará del mantenimiento del puente una vez que el puente sea completado.
CO establecerá un comité que pueda manejar las operaciones y mantenimiento del puente y asegurarse de fondos para implementar estas funciones.

Si alguno de las estipulaciones hechas en esta solicitud no son cumplidas, EWB reserva el derecho de concluir el proyecto.
## COST ESTIMATE

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
<th>Total Cost</th>
<th>Acquired from:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000mm metal pipe culverts</td>
<td>8</td>
<td>$11,481.12</td>
<td>Oruro</td>
</tr>
<tr>
<td>Portland Cement</td>
<td>2.51m³</td>
<td>$480</td>
<td>Oruro</td>
</tr>
<tr>
<td>Gravel – 8.092 m³ for sub-base</td>
<td>17.432 m³</td>
<td>$740</td>
<td>Oruro</td>
</tr>
<tr>
<td>– 9.34 m³ for concrete mixture</td>
<td>14 truckloads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand (fine aggregate)</td>
<td>5.92 m³</td>
<td>$160</td>
<td>Oruro</td>
</tr>
<tr>
<td>Soil</td>
<td>106 m³ total</td>
<td>--</td>
<td>Riverbed excavation and surrounding area</td>
</tr>
<tr>
<td>Wood – concrete forms</td>
<td>--</td>
<td>--</td>
<td>Local Scrap Wood</td>
</tr>
<tr>
<td>#3 steel rebar</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>#4 steel rebar</td>
<td>28 bars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#5 steel rebar</td>
<td>28 bars</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Equipment Needed**

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
<th>Total Cost</th>
<th>Acquired from:</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 L Gas Concrete mixer</td>
<td>1</td>
<td>$1000</td>
<td>Oruro</td>
</tr>
<tr>
<td>Level (18”)</td>
<td>2</td>
<td>$5</td>
<td>Oruro</td>
</tr>
<tr>
<td>Shovels (flathead)</td>
<td>20–30</td>
<td>$245–$365</td>
<td>Oruro</td>
</tr>
<tr>
<td>Wheelbarrows</td>
<td>5</td>
<td>$430</td>
<td>Oruro</td>
</tr>
</tbody>
</table>

Total Costs were converted from "bs" to "."

Assumptions for culverts:
- I assumed the price was in $$."
- I guessed that a 2m diameter pipe would cost 1.5 more that a 1m diameter pipe
- I assumed the cost was per meter.
- Does not include cost of delivery.
- Cement, sand, and gravel (as aggregate) measurements based on Portland Cement Association standards