Design of Suspended Bridge for Guayabitos, Bolivia

A Technical Report submitted to the Department of Civil Engineering

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

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Spring, 2021

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature *Marlene McGraw* Date 05-08-2021
Marlene McGraw

Approved *jose gomez* Date 05/10/2021
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Table of Contents

Introduction

Our world has become exponentially more connected than it once was, and especially in America, most of us have enjoyed the privileges of having relatively easy access to food, healthcare, education, and amenities by car or bus. However, globally the lack of infrastructure, particularly bridges, has a profound impact on whether communities can access the services they need. Almost a billion people are prevented from accessing critical resources for some of the year because of an impassable river, which becomes a primary cause for poverty and can make treatable diseases fatal. Thus, designing and helping to construct these bridges can serve as a broad solution to several problems.

This thesis was a collaboration with the Engineers in Action (EIA) Bridge Program, a nonprofit organization focusing on building international bridge projects with communities that need it, and with industry mentors associated with Bridges to Prosperity (B2P), a professional counterpart to EIA's Bridge Program. This is the first year that this program has been run for a Capstone format, but the EIA team has been working with the various schools using this program this year to adjust their club format to accommodate the different circumstances of a capstone project. Because of this differing format, this report is structured in three parts, corresponding to the three review calls that are part of EIA's Bridge Program. The bridge development process follows a three-part structure, with the end of each part culminating in a review call with EIA personnel, B2P mentors, and university technical mentors present while the team explains the content they've developed over the course of the design. After each of these Review Calls, the capstone team was given the official Notice to Proceed, affirming their work as having been competently completed. Students also took leadership in running this project; Marlene McGraw was the team's Project Manager and handled the majority of the team's scheduling, correspondence with mentors, and general logistics. John McClorey was the team's Design Lead, managing the assignment of detailed design to different team members, providing guidance when needed, and collating finished drawings together. Robert Peacock managed many of the fundraising efforts the team worked on over the spring semester. While not included in the technical reports, the team did crowdfund around $2,000 for EIA in order to support the construction of the bridge they designed, even though the team will not be traveling this summer due to COVID-19.

Please note that some elements of this thesis are provided via links; this is in order to provide the best viewing experience. Because we had several AutoCAD drawings and complicated calculations which do not fit well into a letter format, it has been determined to be most convenient to provide links. Viewing access should be granted for each link, but if for any reason a link is not working, please feel free to contact the author at mbm8wd@virginia.edu.

Gratitude is extended to our contacts at EIA, Brenton Kreiger and Ethan Gingerich; our industry mentors, Leo Fernandez and Rupa Patel; and our technical advisor, Jose Gomez. Each of them provided valuable support and made this capstone a reality.

Please enjoy 😊

Concept Definition Report

1.0 Introduction

This Concept Definition Report will serve as a type, size, and location study for a pedestrian bridge crossing the Pojo River and linking the Guayabitos communities in Bolivia.

2.0 General Background

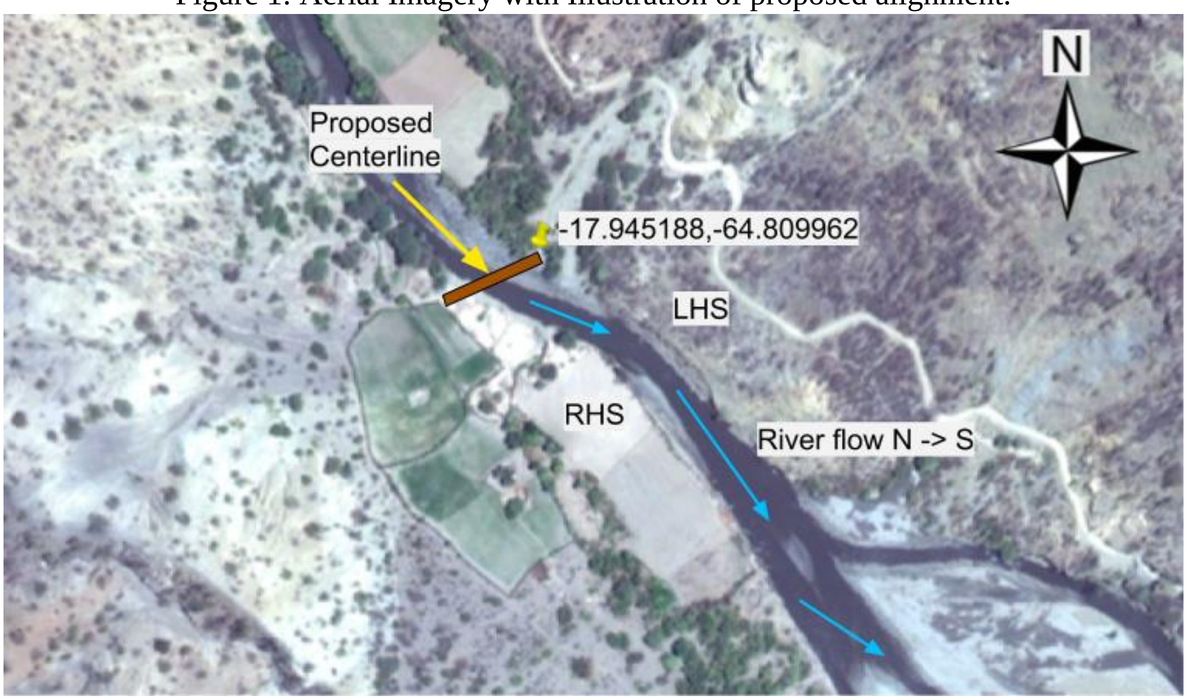
2.1 Project Development and Justification

This project is intended for the community of Guayabitos, which is located in the province of Pojo in Bolivia. This community's primary economic activity is agricultural, with a focus on the production of tomatoes, green beans, potatoes, beans, and a few other crops. The population is 30 people, and there is little in terms of local infrastructure, with most essential services being located tens of kilometers away. The river floods for about a week at a time and is prone to flooding during Bolivia's rainy season, which is from late October to early May. When the river is flooded, it blocks access to the secondary school and health center the community relies on, making this bridge integral to ensuring the community's wellness year-round.

2.2 Project Location

This project will be located in Guayabitos, Pojo, Cochabamba, Bolivia. The Pojo river runs through the center of Bolivia. From the bridge, the local school is 10.7 km away, the nearest health center is 20 km, the main market is 30 km, and Pojo, the nearest city, is 30.4 km away. The proposed alignment is shown below, in Figure 1, and spans from one of the clear banks on the left side to the edge of the fenced field on the right side. The area is mostly clear but has interspersed wooded patches. Note that the image resolution is unfortunately low due to the level of zoom on the aerial imagery.

Figure 1: Aerial Imagery with Illustration of proposed alignment.



2.3 Horizontal and Vertical Clearances

There is substantial tree cover that will be both a horizontal and vertical clearance issue, although there are no significant difficulties that removal will impose. Appendix 1.2a shows the area with the largest density of foliage that will need to be cleared. There are no other significant obstructions horizontally, as no major boulders fall within the area of the project and the road on the right bank has been cleared by the community to build over. There are no other vertical clearance issues to address for this site.

2.4 Restrictions and Utility Conflicts

Cell lines from Entel are in the area, but there is nothing in the technical report to suggest that they will interfere with the bridge construction. No information has been provided to suggest that water or sewer lines will need to be avoided. If any indication of utilities is received, the team will convene with their Bridge Corps mentors to ensure structural integrity of the design.

2.5 Material Acquisition

On site, both sand and stone have been listed as being readily available resources. In the financing sums document provided from EIA engineers in the area, in partnership with municipal and local governments, it is indicated that stone will be donated from on-site sources. A variety of materials, including concrete, steel, wood, wire, and paint will be purchased by the Pojo municipality, while EIA is set to purchase cables and forging clamps, among other materials. Materials will likely be brought to site via the roads that run alongside either bank of the river, both of which have good access during the dry season. The municipality will be responsible for the transportation of materials, which will be delivered in *volquetas,* dump trucks that range in size from 6 to 12 cubic meters. Local staff will coordinate to ensure materials arrive on time, but the team will need to keep track of the size of the *volquetas* delivering materials so that there is no confusion about how much of a product has been delivered. The team recommends that materials be brought to the right bank, due to the high amount of open space for organization and placement.

2.6 Environmental Impact and Land Usage

Construction of the bridge will require significant excavation and soil disturbance - given that this will occur quite close to the Pojo River, there is significant risk for sediment runoff to pollute the waters, and care will need to be taken to limit the amount of sediments that make it into the water. This will hopefully be mitigated by the fact that the team will build during the dry season. The clearing of trees by the bank in order to construct the bridge may also decrease bank stability, although this is not anticipated to be an immediate issue. Use of gasoline in construction equipment and machinery on site creates a risk of contaminated runoff, so plans will need to be made to ensure any gasoline being used is contained and any products interacting with the gasoline are not brought near the water source until the likelihood of contamination is low. Mixing concrete will also pose significant health and environmental safety hazards; proper protective equipment will need to be used when mixing concrete, and care should be taken to avoid wind carrying the concrete mix while it is dry. It is common practice to quickly wash out the containers in which the concrete was mixed to avoid it drying on the container, but this water will be highly caustic and care must be taken to avoid dumping this water into the river or close to farmland and plant life to avoid killing plants. The team will be further investigating practices for disposing of this wastewater that will minimize the impact on the local area, which will be included in our recommended safety practices. There were two land owners, one for each side of the bridge; Marcial Comacho Orozco had owned the right side, while Abal Gvagoda Aranibar had owned the left side; both have already ceded ownership of the land needed to build the bridge and have agreed to keep the bridge's access free to all. However, depending on how far the right side abutment needs to be to prevent it sitting on unstable soils, it's possible that the fenced field will be impacted, which could reduce farmable land. The orientation of these elements with respect to one another will be clearly evident in Section 4 detailing the structure of the bridge.

2.7 Community Engagement Plan

Given that this Capstone team has not yet completed the Cross-Cultural Competency training provided by EIA, we have decided to delay the creation of the Community Engagement Plan until after the module's completion and thus it is not attached to this report. The plan will be created, however, and sent for review to both Bridge Corps members and EIA to ensure the team is prepared for meaningful engagement with the community if travel is feasible.

3.0 Geotechnical Data and Hydraulic Conditions

3.1 Existing Soil Conditions

Given the information in the technical report provided to us (See Appendix 1.5), the left side's soil is characterized as sandy soil with small rocks, while the right side is classified at silty soil experiencing erosion. Figure 2 and 3 show both of these soils.

Figure 2: Left Side Soil Closeup

Figure 3: Right Side Soil Closeup

This is only half of the typical information needed to give an engineering classification of soils. As far as design is concerned, however, the team is referencing the EIA Manual to make conservative enough assumptions that specific engineering soil classifications will likely be unnecessary. However, apparent fissures on the right bank have raised concerns about the internal stability and the possibility of slope failure come the rainy season after construction. Conversations are ongoing, but a dye testing protocol is currently the most likely candidate if testing occurs to determine if slope failure is a significant concern. If testing determines that it is, abutment placement will need to be adjusted to prevent untimely failures.

3.2 Hydraulic Conditions and High Water Line

The river's flowline can be seen broadly from Figure 2, with the centerline outlined in brown and the flow direction of the river indicated with blue arrows. The site is located at a curve in the river, after which the river temporarily splits into several smaller tributaries.

Figure 2: 3D view of the Pojo River, looking downstream.

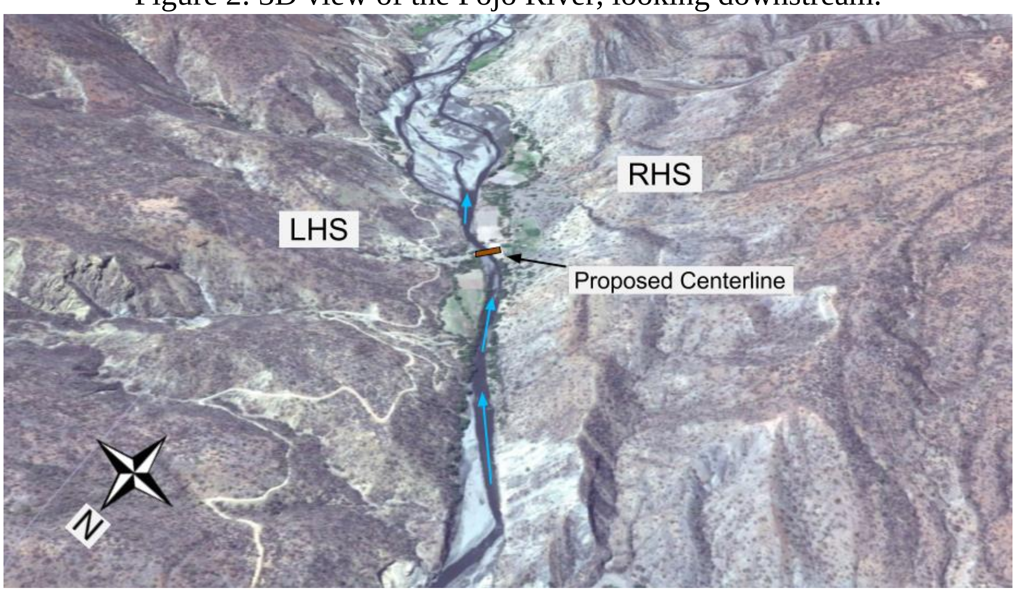


Figure 3 shows the expected channel shape, which is roughly trapezoidal; the high water line is 1.69m above the normal water line, and spills into the floodplain of the river, thus creating a more unusual shape. This site has characteristics of both a floodplain and a gorge; as Figure 3 illustrates, the left bank has very typical floodplain characteristics, with a gentle slope and lower ground that the water spills over onto during high water periods, while the right side has a more sharp rise and an eroded bank face. In conversations with EIA and our Bridge Corps members, it was decided that the team should work with the gorge's specifications for freeboard clearance, in order to create a conservative of a design and ensure the safety of the bridge. In addition to the cross section of the river, several trees upstream on the right bank sit on eroding soil and several of them, still relatively young, risk being downed by heavy storms. Figure 4 shows these trees, and Figure 5 shows a closer view of their root systems, which have been exposed by eroding soil. This further solidified the team's decision to use the more conservative 3m freeboard in their design.

Figure 3: Elevation view of site, from technical report provided by EIA.

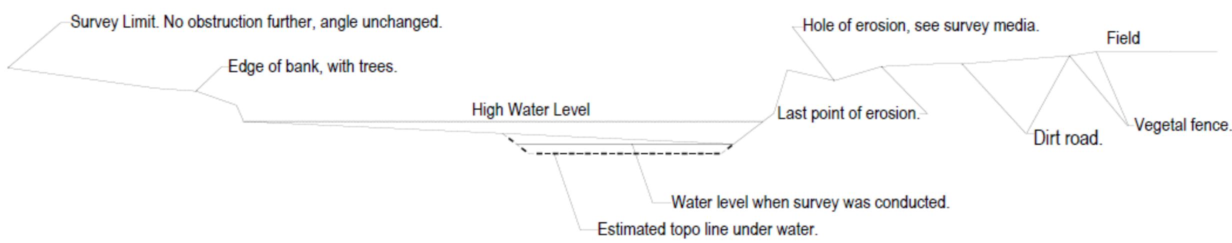


Figure 4: View of trees on eroding right bank, upstream

Figure 5: Closeup of exposed root systems in upstream trees

Historically, the river does not appear to have shifted significantly over the last 40 years - Figure 4 shows an overlay of the two available aerial images available from Google Earth Pro to characterize the site, and while the 1970 imagery's quality is lacking, it can still be seen that the river's path is fairly stable. In the winter months, it can be expected that water level will be higher, because of the rainy season.

Figure 4: Aerial Imagery from 2013 & 1970 respectively, overlaid in third shot.

2013 1970 Overlay

4.0 Structure

4.1 Design Standards

Site approval and bridge type selection will conform to the following design criteria: Bridges to Prosperity Bridge Builder Manual, 5th Edition.

4.2 Geometric Evaluation

EIA outlines a number of necessary design requirements to be taken into consideration when designing a suspended pedestrian bridge. These design requirements may be viewed in the table directly below:

Design Requirements
Foundation must be 3.0m from edge of bank in soil
Foundation must be 1.5m from edge of bank in rock
Foundation must be placed behind an angle of internal friction (35 degrees in soil, 60 degrees in rock)
The ground profile slope in soil must be less than 10 degrees
The height difference between cable saddles shall not exceed 4% of the span [Delta(H) <= L/25]
The minimum walkway cable saddle elevation above the ground is 1.4m and the maximum elevation is 3.4m
Freeboard in floodplains >= 2.0m, in gorge 3.0m
Keep foundation out of floodplains

Upon inspection and working with the "Guayabitos CL2 Auto Level Topo Line.dwg" file provided to us, it was determined that, on a very basic level, many geometric designs satisfied the aforementioned conditions for the site.

4.3 Anchor Type and Location

It was determined that a 2G-80B two tier gravity anchor and a 1G-80A one tier gravity anchor should be placed on the left and right sides of the river respectively. Each abutment is set back 3.0m from the edge-of-bank on either side. On either side, the foundations are placed behind an angle of internal friction considerably less than 35 degrees, and in each case, both ground profile slopes are less than 10 degrees. The table below conveys additional checks and pertinent calculations regarding height differences between the two towers and the amount of freeboard available.

2-Tier Left (LOW) / 1-Tier Right				
		Value	Units	Condition
Bridge Layout	Span, L	60.3	m	
	Deck Width	1.0	m	
	Terrain Type	Gorge		
	Left Foundation Elev.	93.4	m	
	Right Foundation Elev.	95.2	m	
	High Water Elev., HWL	91.9	m	
	No. Tiers Left	2.0		
	No. Tiers Right	1.0		
Check Height Difference	Max Height Difference	2.4	m	
	Height Difference (Delta(H))	0.8	m	Acceptable
Check Freeboard	Sag %, Bd	5.0	%	
	Height Difference	0.8	m	
	Dead Load Sag (h_SAG)	3.0	m	
	Distance to Lowest Point of Cable (f)	2.6	m	
	Elev Walkway Cable @ Lower Tower Saddle	96.8	m	
	Actual Freeboard (Fb)	4.1	m	Acceptable

As part of this preliminary design, a significant roadblock was encountered: a heavily eroded zone on the right bank of the river existing in front the right bridge foundation. Per EIA's guidance, a 3.0m setback from the eroded zone has been assumed at this moment, but going forward, this assumption may need to be adjusted for the final design. The setback from the eroded zone will likely have to be increased at some point in the future once soil testing yields a better understanding of the site on the right bank. Pertinent questions regarding the geotechnical mechanics of the soil include: What tests might we need to conduct in order to gain a more holistic understanding of the soil and stormwater flow of this particular project site? What is the most likely failure mode of the soil? What cost-effective actions might we take to prevent continued erosion in the future?

Moreover, a dirt road and vegetal fence exist behind the eroded zone on the right bank. Per EIA's guidance and the feedback from the community of Guayabitos, the bridge is able to fully extend into the dirt road, which is inevitable to ensure the correct setback from the eroded area. The extent to which the foundation encroaches beyond the vegetal fence and into the agricultural field beyond should be minimized, however. Thankfully, the one tier abutment on the right side only partially encroaches into the vegetal fence and not into the field with the existing design setback of 3.0m. If, going forward, it is deemed necessary to place the abutment tower further from the eroded zone, there would be an additional 0.6m of setback before the backside of the abutment began interfering past the vegetal fence and into the field.

4.4 Alternative Structure Type Comparison

Several alternate designs were considered before arriving at the design recommendations in this report. In addition to our design recommendation of 2G-80B LEFT / 1G-80A RIGHT, the following tier combinations satisfied the geometrical constraints (including the freeboard limit and difference between tower heights limit) outlined by EIA: 3G-80B LEFT / 3G-80A RIGHT, 3G-80B LEFT / 2G-80A RIGHT, 3G-80B LEFT / 1G-80A RIGHT, and 2G-80B LEFT / 2G-80A RIGHT. Calculatative justifications are available upon request for each of the cases listed. For clarity's sake, these calculations are excluded from this report.

4.5 Bridge Type Decision

From preliminary survey and design, this hybrid flood-plain/gorge river in Guayabitos, Bolivia merits a suspended bridge design. 2G-80B LEFT / 1G-80A RIGHT abutments are chosen because they satisfy all geometric conditions, provide ample amounts of freeboard, and are the most economical option in terms of limiting the sizes of each of the abutments. It was determined that five 1" diameter cables would be adequate to act as two handrail- and three walkway- cables for the bridge. Cable calculations are available upon request. Figures 5, 6, 7, and 8 are a few snapshots of the abutments from the AutoCAD design drawings. Formal AutoCAD drawings are likewise available upon request.

Figure 5: Elevation view of left abutment

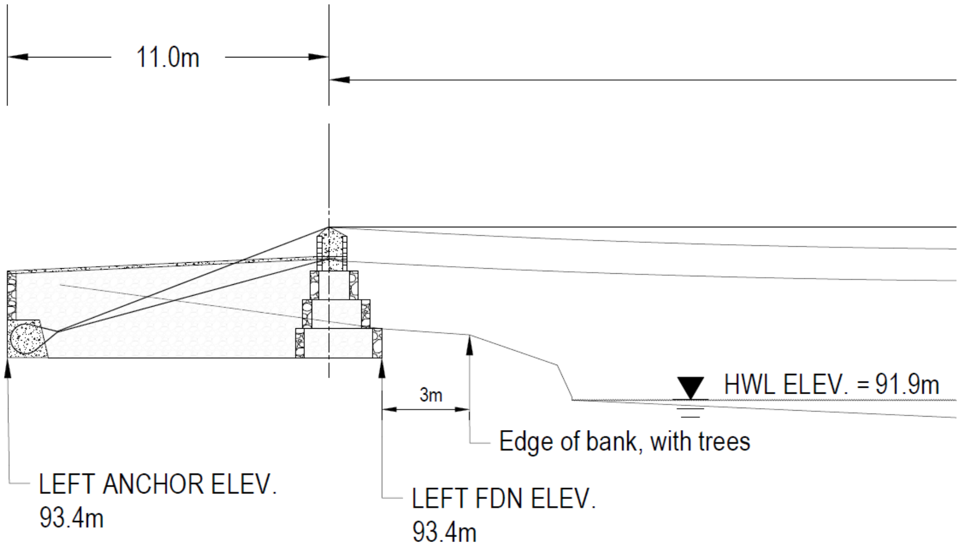


Figure 6: Elevation view of right abutment

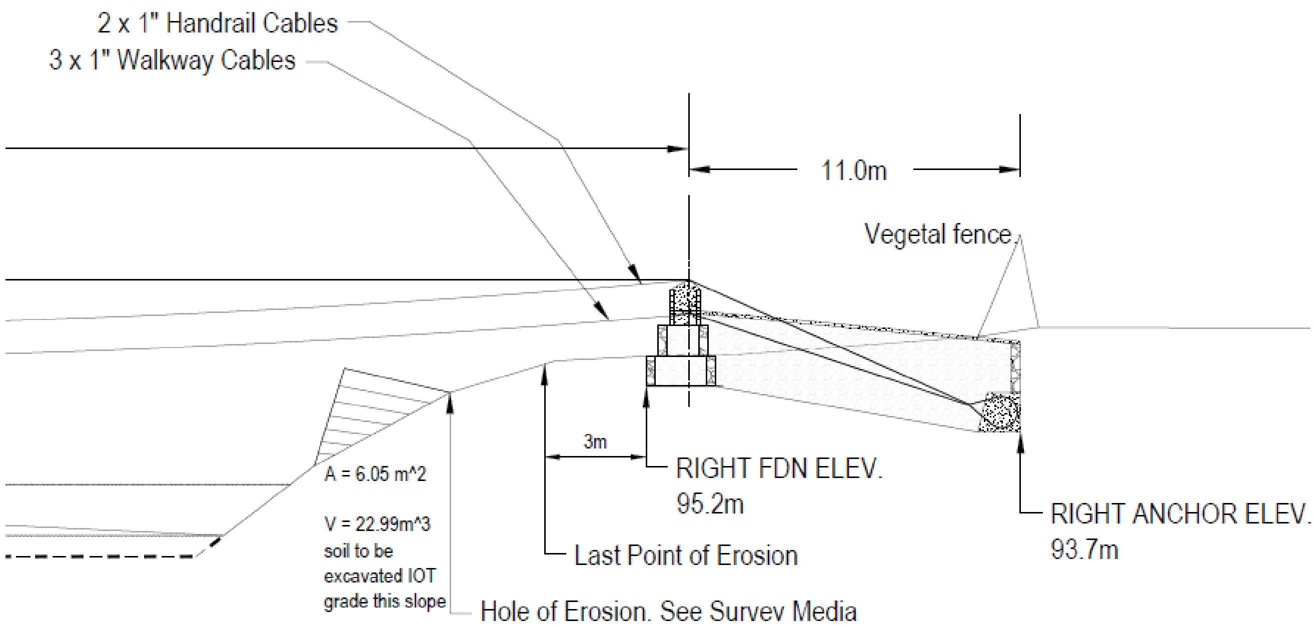


Figure 7: Plan view of left abutment

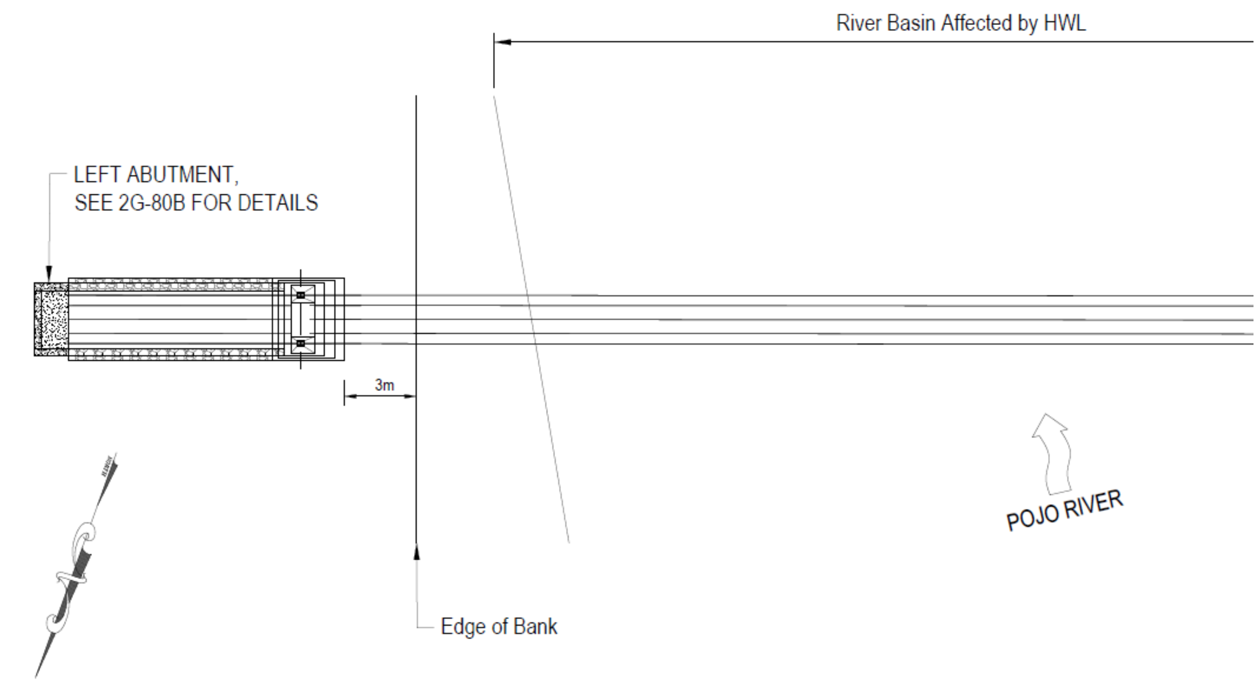
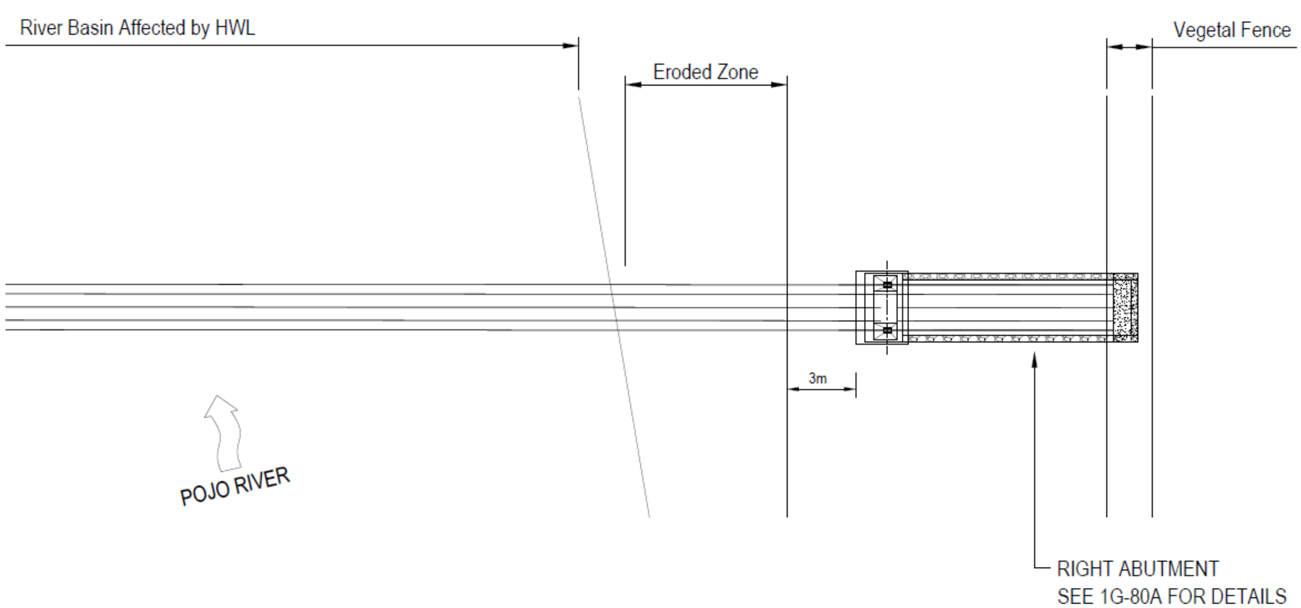


Figure 8: Plan view of left abutment



As illustrated in Figure 6, there exists an earthen area in front of the eroded zone on the right side of the river that juts out toward the walkway. Per discussion with EIA professionals, this zone will likely be fully excavated and pose no problem in terms of ground clearance underneath the walkway cables. It is estimated that 23 cubic meters of soil must be removed in order to grade this slope as necessary.

Again, the primary challenge with the Guayabitos bridge site is the existence of the eroded zone on the right bank of the river. This zone may call for a greater setback from the last point of erosion than was preliminarily designed. In order to accurately and efficiently estimate the correct amount of setback in excess of the minimum 3m, geotechnical testing of some sort must be conducted in order to determine the failure modes and plains of the existing soil. Once these factors have been defined, other possible structures for the site, namely structures that have an increased foundational setback of certain amount on the right bank of the river may be examined in more depth.

4.6 Future Work

At this point in the Guayabitos project, we have developed a viable bridge design that is approved by the head engineers at EIA. In order to continue with forming a plan for construction, there needs to be more on-site data collected. The possibility of a dye test has been presented to better analyze the capacity of the visually non-ideal soil on the right bank. Concern over the ability of this soil to resist erosion and provide a stable and long lasting base for the right abutment has been in question since the first survey data of the site was reviewed. A steep slope to the river, along with deep undercuts of erosion, is a feature already discussed at length that could make bridge construction much more expensive. With a dye tracing test, a bulk tracer would be distributed over the area of concern, then samples collected at a later time to be analyzed. More detailed information would need to be obtained from experts since these kinds of tests involve considerations of turbidity, flushing the site with hundreds of gallons of fresh water, and other considerations not yet known about Bolivian soil conditions.

As we draw closer to the beginning of construction, we need to start placing orders and organizing acquisition of the materials needed for the Municipal Government of Pojo to build the foundations for the abutments. A summary of costs has been provided to our team and translated, and is as follows:

NUMBER	**DESCRIPTION**	**UNIT**	**AMOUNT**	**UNIT PRICE**	**TOTAL PRICE (bolivianos)**
AUTONOMOUS MUNICIPAL GOVERNMENT OF POJO					**82,826.00**
1	Portland Cement (50 kg bag)	bag	389	57.00	22,173.00
2	*Profile/outline U 4x5, 4 lb/ft	bar	17	400.00	6,800.00
3	Corrugated steel 3/8" (10mmx12m)	bar	27	50.00	1,350.00
4	Corrugated steel 1/2" (12mmx12m)	bar	5	80.00	400.00
5	Corrugated steel 5/8" (16mmx12m)	bar	7	140.00	980.00

6	Corrugated steel 3/4" (20mmx12m)	bar	3	210.00	630.00
7	Berth wire	kg	8	15.00	120.00
8	Galvanized wire	kg	3	18.00	54.00
9	Nails 2 1/2"	kg	1	15.00	15.00
10	Wood fastener 3/8" x 2"	unit	293	1.10	322.30
11	Wood fastener 3/8" x 3 1/2"	unit	963	1.80	1,733.40
12	Staples for barbed wire	kg	2	13.00	26.00
13	Netting O. Galv. N° 10 (3,5x3,5 inches) Height 1.2m	m2	154	38.50	5,929.00
14	sandpaper for steel	m	4	9.00	36.00
15	Sand	m3	43	250.00	10,750.00
16	Netting to strain sand (fine 1/8")	m	4	100.00	400.00
17	Washed gravel	m3	14	270.00	3,780.00
18	Short staples 1"	kg	3	100.00	300.00
19	*Gambote Brick 18H 25x12x6cm	unit	1145	1.50	1,717.50
20	Hard wood (100x20x5cm)	unit	67	65.00	4,355.00
21	Hard wood (200x20x5cm)	unit	165	113.00	18,645.00
22	Synthetic paint de 0,9 L Color Red	unit	5	35.00	175.00
23	Synthetic paint de 0,9 L Color Yellow	unit	5	35.00	175.00
24	Synthetic paint de 0,9 L Color Green	unit	5	35.00	175.00
25	Synthetic paint 3,5 L Color Black	unit	2	180.00	360.00
26	Gasoline	L	20	3.74	74.80
27	Bucket 5 gal	unit	14	25.00	350.00
28	Fork lift	unit	4	250.00	1,000.00
ENGINEERS IN ACTION FOUNDATION					**104,898.60**
1	Cable 1.25"	m	404	200.00	80,800.00
2	Forging clamp 1.25"	unit	59	385.00	22,715.00
3	*Cable pulley (Hoop N° 14)	unit	4	75.00	300.00
4	Suction hose 3"	m	11	70.00	770.00
5	High density piping 2"	m	5	14.00	68.60
6	Spray red	unit	6	15.00	90.00
7	Construction markers for wood	unit	10	5.00	50.00
8	Brushes 4"	unit	3	20.00	60.00
9	Brushes 3"	unit	3	15.00	45.00
COMMUNITY OF GUAYABITOS					**19,900.00**
1	Uncut rock	m3	199	100.00	19900.00

SERVICES:

AUTONOMOUS MUNICIPAL GOVERNMENT OF POJO					**10,000.00**
1	Transportation for non-local materials	-	-	-	7,000.00
2	Transportation for local materials	-	-	-	3,000.00
ENGINEERS IN ACTION FOUNDATION					**91,016.00**
1	Services of foreign engineer	-	-	-	20,000.00
2	Services of domestic engineer	-	-	-	10,000.00
3	Skilled labor	-	-	-	30,204.00
4	Tools and equipment	-	-	-	2,972.00
5	Logistic expenses	-	-	-	27,840.00
COMMUNITY OF GUAYABITOS					**27,972.00**
1	Unskilled labor	-	-	-	25,000.00
2	Tools and equipment	-	-	-	2,972.00

TOTAL FINANCING SUMS:

ENTITY	**SUM IN BOLIVIANOS**	**%**
AUTONOMOUS MUNICIPAL GOVERNMENT OF POJO	92,826.00	28 %
ENGINEERS IN ACTION FOUNDATION	195,914.60	58 %
COMMUNITY OF GUAYABITOS	47,872.00	14 %
TOTAL	**336,612.60**	**100 %**

In U.S. dollars, the total estimated sum cost is $48,815.63 ($13,460 by Pojo Municipality, $28,410 by EIA, $6,940 by Community of Guayabitos). This summary is provided by the Pojo Municipality, and has some discrepancies with our current design. It does not take into account the excavation of the right bank to allow for adequate freeboard of the cable extending from the right abutment, and the movement of additional soil and equipment required for the work. It is also preliminary, and pricing of materials cannot be truly finalized until consensus is reached on a final bridge design. The differences vary largely on the materials needed for different abutment sizes, and no purchases should be made before EIA and our team is set on one viable plan. An example already exists, as we have 1" cables used in our design that satisfy load requirements and would save money as opposed to the 1.25" cables listed in the preliminary cost estimate. Other materials such as sand, gravel, and uncut rock could be acquired on-site during excavation and reused as a cost saving measure.

So far the extent of our contact with the Community of Guayabitos has been limited to receiving survey information and cost estimates. The Community Engagement Plan needs to be developed, in order to lay groundwork for successful communication with the community upon our arrival in Guayabitos. There is an EIA representative in the country at the moment who has been in contact with the community, and she will be able to manage any conversations about materials, cost, and construction scheduling if our estimates fall outside of the previously allotted range.

Design Report

1.0 Introduction

This report discusses the design that the UVA Capstone team has created for the Guayabitos Suspended Footbridge. Guayabitos is a community of 30 in the Pojo Province. The bridge will be a key connector for the community to access secondary school, healthcare centers, and the main market during the rainy season, when rains can flood the river and make travel dangerous at best and impossible at worst. There were no strong concerns about the site clearances, though uncertainty concerning the right side's soil conditions were a concern talked about at length.

1.1 Concept Definition Report Follow Up

Table 1.3.1 – Action Items from Review Call 1

	Action Item	Responsible Party	Status
1	Start on more detailed design of abutment and gravity anchor, focusing specifically on optimizing design for efficiency, integrating new cable sag & nonstandard design information from Brenton's document in Site Info, and balancing factors of safety and efficiency.	UVA Capstone Group	**Submitted Herein**

2.0 Design Objectives

What are the design objectives for the presented design? What standards does the design rely upon? Which are the focused objectives of the specific design presented in this report? Design objectives can be found in the current B2P design manual. If a nonstandard design is being presented, explain which design objectives this nonstandard design seeks to satisfy.

In preparing the presented design we were very conscious of the design objectives presented by EIA, and why it is of critical importance to keep these objectives in mind during design. These guidelines are presented in section 2.1 of the Bridge Builder Manual Volume 2a, and are ordered by relative importance. First, and most importantly, our duties as design engineers are to guarantee the safety of the bridge and those who use it. our design must maintain structural integrity, and incorporate features that are less directly unsafe but still critical to the safety of users, such as safety mesh to prevent falling through the cables. Second is durability, which is detailed for proper weatherproofing of the bridge materials to extend the structure's lifespan. Third is serviceability, which entails design features to reduce bridge sway and bounce, and ensure adequate approach ramp angles. Fourth is maintainability, ensuring that this project can be maintenanced at manageable rates for years to come so that the community can continue to reap the benefits from the safe crossing. Fifth is constructability, which directly applies to the design engineer as it is their job to use materials that are feasible to acquire, and prefabricate efficient measures for on-site work and interactions. Sixth is economy, which involves using local resources so that excessive funds are not needed for basic materials. Seventh and last is aesthetics. Although the appearance of the bridge is of minimal concern, we want the local community to be proud of its hard work paying off, and for their project to look as aesthetically pleasing as is feasible without compromising any of the earlier mentioned requirements.

Any considerations for non-standard design procedures will be taken into account and addressed when considering and planning for construction details and procedures. If the team is to choose a non-standard design going forward, it would be to address the abnormal fissure characteristics on the right bank as discussed in later sections. the changes would most likely be to alter the length and/or sag of the cables to ensure proper clearance and satisfy sliding checks.

3.0 Site Overview

Figure 1 shows a plan view of the bridge site (coordinates: -17.945188, -64.809962).

Figure 1. Plan View of Bridge Site

3.1 Topographic Survey

The topographic survey was completed by the EIA Bolivia Program Manager in December of 2019 with an auto level. The survey data was processed by the student chapter and provided to EIA for verification. Original survey data and the AutoCAD survey profile generated can be found in the Site Info folder on Google Drive.

3.2 Site Photos

In accordance with the site documentation requirements set forth in the Technical Survey Form, a series of site photos are provided in Appendix 1.2.

3.3 Site Specific Conditions

The right bank of the site exhibits abnormal, fissure-like characteristics throughout the soil along the bank (See Appendix 1.2, Right Bank Photos for details). These fissures pose a specific challenge for the design team as they are novel to EIA's experience and, if structural throughout the soil bank, could destabilize the slope and increase the likelihood of slope failure. The team consulted their geotechnical engineering and stormwater management professors, who both agreed that the situation was novel to them. While it was determined that more specific understanding of the soil would likely involve the use of a soil testing company, the team's geotechnical engineering professor advised that a dye test be carried out to determine the flow path of water entering fissures. If water emerged from the bank, that would be a clear indication that the slope likely has serious destabilization and that another site may need to be considered, or that the abutment would need to be built at a much greater distance from the bank. For the moment, economic uncertainty means that EIA may or may not be able to complete this soil testing, so to move forward the team has tried to be as conservative as possible in placement without encroaching too far on the fenced field the community needs for agriculture. The abutments will also interrupt two roads, but the Program Manager confirmed with us that the community had no conflict with that interruption, and so with their permission we have left the design as is.

4.0 Roles and Responsibilities

Roles and responsibilities shown below are in reference to Appendix 3.0.

EIA *roles and responsibilities include:*

- *Site Identification and Selection*
- *Technical survey form*
- *Local agreements*
- *Material procurement*
- *Site preparation*
- *Quality control point sign-offs*
- *Safety equipment and tools*
- *Transportation of cable and clamps to site*
- *Monitoring and evaluation of completed bridge project*
- *Bridge inspections*
- *Initial design of bridge*

University of Virginia Capstone Project *roles and responsibilities include:*

- *Safety equipment and tools*
- *Bridge design verification*
- *Construction and safety report*
- *Support training of local EIA staff*
- *Secure Bridge Corps members*

- *Spend minimum 3 weeks on site*
- *Financial commitment*

Bridge Corps *roles and responsibilities include:*

- *Design support*
- *Safety oversight*

5.0 Design Process

The design process first began with an evaluation of our site in accordance with EIA's design requirements. These design requirements may be viewed in the table directly below. Upon inspection and working with the "Guayabitos CL2 Auto Level Topo Line.dwg" file provided to us, it was determined that, on a very basic level, many geometric designs satisfied the aforementioned conditions for the site.

Design Requirements
Foundation must be 3.0m from edge of bank in soil
Foundation must be 1.5m from edge of bank in rock
Foundation must be placed behind an angle of internal friction (35 degrees in soil, 60 degrees in rock)
The ground profile slope in soil must be less than 10 degrees
The height difference between cable saddles shall not exceed 4% of the span [Delta(H) <= L/25]
The minimum walkway cable saddle elevation above the ground is 1.4m and the maximum elevation is 3.4m
Freeboard in floodplains >= 2.0m, in gorge 3.0m
Keep foundation out of floodplains

A number of standard abutment types were considered after ensuring all the aforementioned design requirements were satisfied. The results of this analysis are summarized in the following table.

Abutment Comparison		
Abutment Scheme	Freeboard Satisfied?	Delta(H) Satisfied?
3G-80B Left (LOW) / 3G-80A Right	Y	Y
3G-80B Left (LOW) / 2G-80A Right	Y	Y
3G-80B Left / 1G-80A Right (LOW)	N	Y
2G-80B Left (LOW) / 2G-80A Right	N	Y
2G-80B Left (LOW) / 1G-80A Right	N	Y
1G-80B Left (LOW) / 2G-80A Right	N	N
1G-80B Left (LOW) / 1G-80A Right	N	Y

From here, it was determined that a 3G-80B standard abutment should be used on the left bank of the river and a 2G-80A standard abutment should be used on the right bank of the river. This combination is the most economical option that satisfies the freeboard and Delta(H) limits, as indicated in the table directly below.

3G-80B Left (LOW) / 2G-80A Right				
		Value	Units	Condition
Bridge Layout				
	Span, L	61.1	m	
	Deck Width	1.0	m	
	Terrain Type	Gorge		
	Left Foundation Elev.	93.4	m	
	Right Foundation Elev.	95.2	m	
	High Water Elev., HWL	91.9	m	
	No. Tiers Left	3.0		
	No. Tiers Right	2.0		
Check Height Difference				
	Max Height Difference	2.4	m	
	Height Difference (Delta(H))	0.8	m	Acceptable
Check Freeboard				
	Sag %, Bd	5.0	%	
	Height Difference	0.8	m	
	Dead Load Sag (h_SAG)	3.1	m	
	Distance to Lowest Point of Cable (f)	2.7	m	
	Elev Walkway Cable @ Lower Tower Saddle	97.8	m	
	Actual Freeboard (Fb)	3.2	m	Acceptable

The geometric layout for the entire bridge in elevation and plan view may be referenced in the "GUAYABITOS SUSPENDED BRIDGE SUSPENDED BRIDGE LAYOUT" sheet of our design drawings set. Directly following, geometric details for the left abutment may be viewed in the "3G-80B LEFT ABUTMENT DETAILS SUSPENDED BRIDGE LAYOUT" page of the corresponding drawing set. Likewise, details for the right abutment may be viewed in the "2G-80A RIGHT ABUTMENT DETAILS SUSPENDED BRIDGE LAYOUT" page of the drawing set.

After solidifying our geometric design, the team entered into our design checks phase, the specifics of which are outlined in Section 5.4. These design checks included a general cable analysis, a sliding and shear check, a tower overturning check, a bearing pressure check, and an uplift check. The team referenced Bridges to Prosperity's (B2P) Bridge Builder Manual (Vol. 2a) for the completion of these design checks.

After confirming that the design checks were, indeed, satisfied, the team completed detailed design drawings for the gravity anchor, abutment towers, walkway timbers, and the steel crossbeam. These drawings are clearly indicated in the corresponding drawing set along with a title page and bridge layout.

5.1 Left Side Abutment Placement

On the left bank of the river, very few roadblocks were encountered. The 3G-80B abutment was placed 3.0m from the edge-of-bank at an angle of friction of 35 degrees its soil setting. On the left side, the 3.0m setback is the controlling factor.

5.2 Right Side Abutment Placement

Compared to the left bank of the river, the right bank has a considerable number of roadblocks, primarily, a heavily eroded zone existing in front the bridge foundation. Per EIA's guidance, a 3.0m setback from the eroded zone has been assumed at this moment, but following soil analysis, this assumption may need to be adjusted for the final design. Part of the eroded zone also extends upward vertically toward the walkway cables. After discussing with EIA SMEs, this roughly 23 m^3 volume of the eroded zone will be excavated in order to smooth out the profile of the right bank.

Moreover, a dirt road and vegetal fence exist behind the eroded zone on the right bank. Per EIA's guidance and the feedback from the community of Guayabitos, the bridge is able to fully extend into the dirt road, which is inevitable to ensure the correct setback from the eroded area. The extent to which the foundation encroaches beyond the vegetal fence and into the agricultural field beyond should be minimized, however. Thankfully, the 2G-80A abutment on the right bank only partially encroaches into the vegetal fence and not into the field with the existing design setback of 3.0m.

Overall, considering the eroded zone on the right bank, the placement of both abutments minimizes the span required for the suspended bridge.

5.3 Geometric Conformance

Primary geometric parameters are further summarized in the table below, all conforming to the geometric criteria described by EIA and B2P.

Geometric Conformance Summary

Parameter	**Value**	**Requirement**
Span length, L	61.1 m	< 120 m
Height Differential, ΔH	0.8 m	< 2.10 m
Freeboard	3.20 m	> 3 m
Left Abutment Offset	3.0 m	≥ 3 m
Right Abutment Offset	3.0 m	≥ 3 m

5.4 Design Checks

This section should detail the essential design checks performed in accordance with BEDU design courses, DEIC requirements, and advice from technical mentors and the technical committee. If additional nonstandard calculations are done or nonstandard sag values are used, the reason for this and the process should be explained and justified here. [Example]: To meet *the required FOS for uplift, ramp length was increased in order to decrease the vertical cable force.*

This section should also include:

1. *A table of every factor of safety (FOS) for each mode of failure, the FOS achieved, and the minimum FOS for that failure mode*
2. *Hoisting and design f values*
3. *An explanation of the cable size and quantity of clamps as it pertains to the design, including the breaking strength as provided by EIA*
4. *A reference to full calculations provided as an appendix to this report.*

Below is a summary of calculated factors of safety for each of the five design checks completed for this suspended bridge. Detailed calculations for each of the design checks may be referenced in the team's Suspended Bridge Conditions Sheet, which will act as a calculations Appendix to this report.

Factor of Safety Summary

Parameter	Value	Requirement
Cable Analysis (5 x 1 ¼")	3.2	≥ 3.0
Sliding/Shear Check	3.2 Left, 2.3 Right	≥ 1.5
Suspender Check	5	≥ 5.0
Tower Overturning Check	4.0 Left, 2.6 Right	≥ 1.5
Bearing Pressure Check	2 Left, 1 Right	≥ 2.0
Uplift Check	1.7 Left, 2.0 Right	≥1.5

Cable Analysis, Size, and Quantity - The cables for this bridge design were analyzed in accordance with Section 4.1 "Cable Analysis" of B2P's Bridge Builder Manual Vol. 2a. Eq. 4.1 & 4.2 dictate that the hoisting sag and the live load sag for the bridge cables are 4.6% and 6.1% of the bridge span, respectively. The hoisting sag, therefore, is 2.8m and the live load sag is 3.1m. These values, along with loading condition assumptions and freeboard / delta(H) calculations, were used to then describe the geometry and forces of the main span cables. Resultant geometry and force calculations include horizontal tension, vertical tensions on the high and low sides, angles to the horizontal on the high and low sides, total tension, total backstay tension, vertical backstay tension, total main span tension, vertical main span tension, and finally, the total vertical reaction at tower. Each of these engineering parameters' respective equations may be referenced in B2P's Bridge Builder Manual Vol. 2a Eq. 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 4.10, 4.11, 4.12, 4.13, & 4.14. The calculations for this analysis may be referenced in the "Cable Size and Quantity Sheet - Marlene/John" tab of the Suspended Bridge Conditions Sheet.

This preliminary analysis then enabled cable design, outlined directly following the aforementioned sections in Eq. 4.15 of B2P's Bridge Manual Vol. 2a. Cable design dictated a factor of safety of 3.0 between the maximum axial tension in the cable and the ultimate breaking strength of the cable. Determining the size/diameter of the cables and the number of cables to satisfy this requirement follow the general concept outlined in Section 8.4 “Select Cable Size and Quantity” of B2P’s Bridge Manual Vol. 2a. Again, the calculations for this analysis may be referenced in the “Cable Size and Quantity Sheet - Marlene/John” tab of the Suspended Bridge Conditions Sheet. It was determined that five 1 ¼” cables would need to be used in order to satisfy the design check under the given geometric and loading conditions. Five 1” cables would have also satisfied the design requirements, but EIA informed the team that only 1 ¼” cables would be available on-site in Bolivia for construction use.

Sliding/Shear Check - The sliding check ensures that the design choice for the anchor is sufficient to balance out the force of the tower of the bridge and thus prevents unequal compression of underlying earth, which could lead to the abutment as a whole sliding forward in the earth, compromising the safety and stability of the design. In order to properly calculate these forces, the geometry and material distribution of the abutment was obtained through analysis of previously created abutment drawings and known density quantities for different materials, alongside guidance from EIA’s Construction Management Course. The B2P Bridge Builder Manual Vol. 2a was used to calculate the majority of the force loads, using Eqns. 4.28-4.33, alongside guidance and some corrections from EIA’s Suspended Bridge Design Course, in the “Gravity Anchor” section. The calculations for this check may be referenced in the “Sliding/Shear Check - Marlene” tab of the Suspended Bridge Conditions Sheet.

Suspender Check - Suspenders are bridge elements that transfer load from walkway cables into the handrail cables. Since they are susceptible to fatigue and corrosion, a factor of safety of 5.0 is applied when calculating the acceptable amount of axial stress. The suspender check may be referenced in B2P’s Bridge Builder Manual Vol. 2a, Eq. 4.16 & 4.17. The calculations for this check may be referenced in the “Suspender Design Check - John” tab of the Suspended Bridge Conditions Sheet.

Tower Overturning Check - Tower overturning occurs when the total overturning moment, resulting from horizontal cable forces, exceeds the total restorative moment, resulting from the vertical self-weight forces of the towers and the vertical force from the cables on the tower saddle. Catastrophic bridge failure occurs when the overturning moment exceeds the restorative moment in this way. B2P recommends a factor of safety of 1.5 for this design check. The tower overturning check may be referenced in B2P’s Bridge Builder Manual Vol. 2a, Eq. 4.18, 4.19, 4.20, 4.21, 4.22, & 4.23. These equations define free-body moment summations and belt friction on the saddle, in addition to the design check itself. The calculations for this check may be referenced in the “Tower Overturning Check - John” tab of the Suspended Bridge Conditions Sheet.

Bearing Pressure Check - The load per unit area at which shear failure in soil occurs is called the ultimate bearing capacity. The allowable soil bearing capacity is the ultimate bearing capacity divided by a factor of safety. Specific values for the ultimate bearing capacity should be determined for the soil found at the bridge site. The bearing pressure check may be referenced in B2P’s Bridge Builder Manual Vol. 2a, Eq. 4.24, 4.25, 4.26, & 4.27. The calculations for this check may be referenced in the “Bearing Pressure Check - Rob” tab of the Suspended Bridge Conditions Sheet.

Uplift Check - The uplift check examines the forces acting on the anchor, determining if the weight of the abutment fill and self-weight is sufficient to secure the anchor and prevent it from moving when the bridge is loaded. It consists of calculating the vertical uplift and resisting forces and dividing the resisting force by the selected factor of safety (1.5). Failure of this type would not be immediately catastrophic, and would be indicated by excessive sag in the walkway cables as the anchors slide inwards towards the abutment tower. The uplift check can be found in the Bridge Builder Manual volume 2a, section 4.5 anchor analysis, equation 4.35. These calculations can be referenced in the "Uplift check - soil conditions - Dallas" tab of the Suspended Bridge Conditions Sheet.

5.4.1 Load Assumptions

Permanent Load:
Dead Load (DL): 106 kg/m

Transient Load:
Live Load (LL): 415 kg/m
Reduced Live Load (LL): 342 kg/m
Wind Load (WL): 0.5 kN/m

Primary Load Combination:
Distributed, Wc Primary (DL + LL): 448 kg/m

5.5 EIA Drawings Selection
With the geometric conformance satisfied, the appropriate EIA standard drawings were generated.

EIA Standard Drawings:
- 3G-80B abutment detail for left abutment
- 2G-80A abutment detail for right abutment
- A1 anchor detail
- T1 tower detail
- W2 decking detail

6.0 Bill of Quantities

Provided below is our current bill of quantities, along with the recommended on-site equipment needed. In comparison to the provisions list provided by the in-country team, Guayabitos community, and Pojo Municipality, we appear to satisfy the estimated needs.

Given in Manual
Calculated
From Design Sheet

Bill of Quantities	W/o contingency	W/ contingency		Materials
Clamps	56	58.8	pieces	Tie Wire
Cable	100.9632	100.9632	m (x4)	Cable Guides
Timber crossbeams	62.1	64.5632	pieces	Gasoline
Nailers	62.1	67.0464	pieces	Red spray paint
Decking	152.7	164.916	pieces	Paint
Length of Rebar (Walkway)	248.32	248.32	m	Asphalt paint
Cement	213.61	241.38	bags	Brushes
Bricks	912	930.24	pieces	Nails
Rocks	117.309901	123.1753961	m^3	Wood Markers
Sand	28.3227752	30.87182497	m^3	U-Nails
Gravel	9.221153708	9.682211393	m^3	Straining Mesh
Wheel Cable Saddle	4	4	pieces	Buckets
Roofing Tar	1	1	gallon	Wheelbarrows
75mm Flexible Plastic Tubing	1700	1870	cm	Galvanized Wire
50mm Flexible Plastic Tubing	660	726	cm	Barbed Wire Staples
Tie wire	10	10	kg	Steel Sandpaper
Lag screw (10mm x 7.5cm long)	763.5	954.375	pieces	Cable Chair Wheel
Fencing (1.2m tall)	146.64	153.972	m^2	Grease
Galvanized tie wire	5	5	kg	tarp
U-nails / Staples	6.11	6.11	kg	Shovel
Anchor Specific Materials				Pickaxe
A01 Bar	28.5	28.5	m	
A02 Bar	9	9	m	
A03 Bar	32.5	32.5	m	
Tower Specific Materials				
#3 Bar	24	24	m	
#5 Bar	24	24	m	

Construction and Safety Report

1.0 Introduction

Following Review Call 2, the team has now progressed on to preparing material for Review Call 3: Construction and Safety Logistics. A few design action items still remain, and may be viewed in Section 1.1 directly below. These action items will be completed in conjunction with Review Call 3 material and will affect some aspects of the construction of the bridge. Some sections throughout this report have been left empty, as they refer to details that the team would have to consider if traveling to Bolivia and aiding with the construction effort in-country. Since our team will not be traveling to Bolivia to construct this bridge, due to the COVID-19 pandemic and the beginning of post-undergraduate employment, the team has withheld from addressing these sections.

1.1 Design Report Follow Up

Table 1.1.1 – Action Items from Review Call 2

Action Item		Responsible Party	Status
1	Design optimization and subsequent adjustment of detailed design	Marlene, John	In Progress
2	Rectification of detailed design formatting	Rob, Dallas	In Progress
3	Fence detail	Dallas	In Progress

2.0 Team Organization

As the team will not be traveling for this project, this section is not required to be completed.

3.0 Local Logistics

3.1 Expectations for Community Involvement and Interaction

The community has many vital responsibilities outlined in the Financial Agreement for the Execution of the Project: “Construction of Guayabitos Pedestrian Bridge,” as obtained from EIA and translated by Sarah Kiscaden. They have already obtained the approval of both landowners to guarantee the availability of the land where the bridge is to be built (and to ensure that the bridge remains public property thereafter), but a majority of the rest of the tasks depend on a timeline for implementation, and so remain. The community will be responsible for collecting all locally available materials, as approved by the Coordinator of Construction for EIA and the Supervisors of Municipal Construction, as well as covering the cost of unskilled labor required for construction. They have agreed to supply 10 people every day to carry out unskilled labor, and supply basic manual tools and storage for materials. Expectations are also laid out to feed and house EIA personnel and ensure they’re treated respectfully. Finally, the community will assume responsibility for the bridge’s maintenance after its construction.

The team will not be traveling, which necessarily changes the plans that would normally be laid out for communication between the team and the community. However, the team recommends that the travel group that does eventually go to the site rely on the lessons their Cultural Relations Managers have been distributing about handling the unexpected and maintaining positive, supportive, and productive communication that is solutions-oriented, as opposed to blame-oriented. This document will lay out some risk management strategies that may be useful to a variety of situations that construction may create and will need to be handled, but as the unexpected can be difficult to plan for, the team should prepare to communicate with the community, municipality, Program Manager, DEIC, and each other to work through challenges that are encountered with no clear road map for management.

3.2 Expectations for Municipal Support

On the municipality's side, there are several responsibilities that have been agreed upon. They have strong involvement in the supply and equipment facets of the project, having assumed responsibility for the purchase of a variety of items laid out in the QOM agreement, the transportation of those materials, guaranteeing road access for construction purposes, and supplying machinery and heavy equipment. The municipality will also be responsible for designating a Supervisor of Municipal Construction to ensure that the construction process is up to proper standards and will process the purchase of materials to send back to the administration. It is also expected that the municipality will promote respectful interactions between the community and the volunteers and generally contribute to maintaining a healthy work environment.

The team will not be traveling, which necessarily changes the plans that would normally be laid out for communication between the team and the municipality. However, the team recommends that whatever travel group eventually goes to help construct the bridge do have some contact with the municipality, even if this is minimal - as the team is on the ground working on the project, they may be able to provide insights that could contribute to effective problem solving in combination with the Program Manager's expertise and awareness of other active projects.

3.3 Expectations for EIA Support

It is important to verify that EIA is willing and able to fulfill the expectations that will be provided in this section. EIA field staff will finalize the necessary agreements with local government and community beneficiaries. EIA field staff will facilitate communication between the university chapter, local government, and community, when necessary. EIA staff will ensure that a mason is available and on site for the implementation of this project. EIA will manage the supervision of local builders and local builders-in-training on this project. If travel occurs, EIA staff will prepare the site prior to the team's arrival based on the team's approved construction schedule. EIA will provide tools and safety equipment for the project. EIA is responsible for the maintenance of the bridge for any major structural damage or failure up to five years after the completion date.

The UVA chapter is supported by a Faculty Advisor, Jose Gomez, who offers organizational and technical guidance to the chapter. The Faculty Advisor will facilitate continuity and knowledge transfer from year to year and support fundraising efforts, specifically by helping to leverage university resources. The UVA chapter has identified Bridge Corps members Leo Fernandez and Rupa Patel to provide technical guidance, ensure professionalism in project correspondence, and check student design and construction reports prior to design review by EIA. The UVA chapter will complete online EIA University Training and prepare bridge design, construction and safety plans according to EIA standards. The UVA chapter will make a financial contribution to Engineers in Action in exchange for participating in a project

3.4 Food & Lodging

As the team will not be traveling for this project, this section is not required to be completed.

3.5 Transportation

As the team will not be traveling for this project, this section is not required to be completed.

3.6 In-country Finances

As the team will not be traveling for this project, this section is not required to be completed.

4.0 Construction Plan

Present a detailed plan for executing your design at your site. Step through the construction process and go into detail on your plans to perform each step. Also include a detailed construction schedule with each step of the process and the travel dates for each of your team members and Bridge Corps members.

How will you procure your materials on-time and of sufficient quantity and quality? What equipment/tools will you need for each step of the construction process? How will you identify and address quality issues? Who will be signing off on each QC point? Identify risks associated with the construction process and include them in your Risk Management plan (Section 6.0).

4.1 Site Overview

Figure 1 shows a plan view of the bridge site (coordinates: -17.945188, -64.809962).

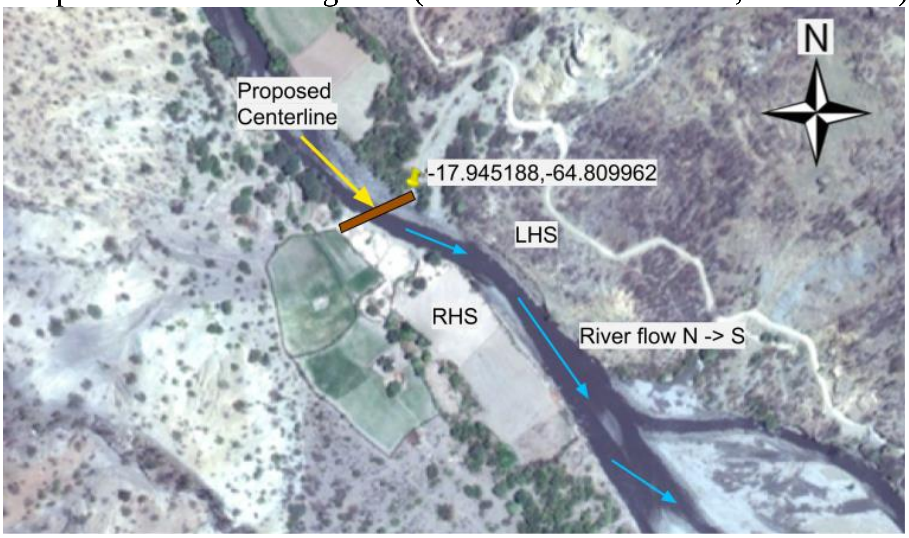


Figure 1. Plan View of Bridge Site

The site is located at the low of a valley, close to an area of arable land the community uses for farming. The site has a combination of characteristics from both valleys and gorges, but its most notable and challenging feature is the abnormal fissure-like characteristics of the right bank's soil. These fissures pose a specific challenge for the design team as they are novel to EIA's experience and, if structural throughout the soil bank, could destabilize the slope and increase the likelihood of slope failure. After consultation with relevant professors, it was determined that more specific understanding of the soil would likely involve the use of a soil testing company, and the team's geotechnical engineering professor advised that a dye test be carried out to determine the flow path of water entering fissures. For the moment, economic uncertainty means that EIA may or may not be able to complete this soil testing, so to move forward the team has tried to be as conservative as possible in placement without encroaching too far on the fenced field the community needs for agriculture. If testing is unable to occur, the soil will require monitoring as excavation and construction begins to occur, and if fissures prove significant the construction team will need to be prepared for relevant adjustments.

4.2 Design Overview

From Review Call #2, our team presented a standard bridge design consisting of a 3G-80B abutment on the left bank of the river, a 2G-80A abutment on the right bank of the river, and five 1 ¼" cables spanning just over 60 meters from saddle to saddle. Our standard design satisfied cable bearing capacity, sliding/shear, suspender, tower overturning, bearing pressure, and uplift checks across the board as seen in the table directly below.

Check	Side (if applicable)	Existing FoS	Threshold FoS	Condition
Cable Capacity		3.2	3.0	Acceptable
Sliding/Shear	Left	3.2	1.5	Acceptable
	Right	2.3	1.5	Acceptable
Suspenders		5.0	5.0	Acceptable
Tower Overturning	Left	4.7	1.5	Acceptable
	Right	3.0	1.5	Acceptable
Bearing Pressure (accounted for in ultimate bearing capacity)	Left	2.0	2.0	Acceptable
	Right	2.0	2.0	Acceptable
Uplift	Left	1.6	1.5	Acceptable
	Right	1.6	1.5	Acceptable

From this detailed design, the team made an addition of a fence detail to each of the abutment approach walkways, since each tower exceeds 6 feet in height. Due to freeboard limits, our towers were unable to be shortened. Despite our inability to decrease the height of the towers, however, partners at EIA advised the team to optimize the design by using a combination of shortening the approach ramp and raising the anchor. These modifications would then lower some factors of safety toward the indicated thresholds (in the table above), allowing for a more economical and constructable design.

Optimization primarily consisted of shortening the abutments on both the left and right banks of the river. The limiting factor when shortening the abutments was the slope of the concrete ramp cap on top of the abutment fill. As the abutment became shorter, the slope of the ramp sub the horizontal became larger. EIA subject matter experts informed the Team that an angle of 13 degrees was not to be exceeded. Therefore, once the 13 degree maximum had been met, the Team assessed the resultant factors of safety based on the new abutments. Below is a table outlining the new optimized factors of safety stemming from our design analysis (in contrast to the previous table from our standard design):

Check	Side (if applicable)	Existing FoS	Threshold FoS	Condition
Cable Capacity		3.0	3.0	Acceptable
Sliding/Shear	Left Right	2.9 2.3	1.5 1.5	Acceptable Acceptable
Suspenders		5.0	5.0	Acceptable
Tower Overturning	Left Right	3.3 2.5	1.5 1.5	Acceptable Acceptable
Bearing Pressure (accounted for in ultimate bearing capacity)	Left Right	2.0 2.0	2.0 2.0	Acceptable Acceptable
Uplift	Left Right	1.6 1.6	1.5 1.5	Acceptable Acceptable

4.3 Construction Preparation

As the team will not be traveling for this project, this section is not required to be completed.

4.4 Bridge Corps Support

As the team will not be traveling for this project, this section is not required to be completed.

4.5 Construction Schedule

Detailed construction schedule is completed in Microsoft Project. Site preparation is to be done in a timeframe of 3 weeks, preferably before student chapters arrive

Include a detailed construction schedule. Discuss construction considerations that are unique to your site. For example, discuss your plan for getting the cables across the river.

Additionally, discuss site preparation and its impact on the construction schedule. What do you expect to be done by the time your team arrives on site? Discuss agreement with the EIA Program Manager or approved in-country partner regarding excavation layout and site preparation. Has the community begun collecting rock and working on excavations?

4.6 Hazard Mitigation Plan

What are the major safety concerns/considerations associated with each step of construction? What steps will the team take to mitigate these risks? What plan is in place should one of these risks occur?

Safety critical stages

- Excavation safety (proper sloping/benching)
- Anchor construction
- Cable safety during sag set (winch safety, danger zone, clamp redundancy)
- Laying decking (fall protection above 6ft, equipment inspection)

The hazard mitigation plan will change on an almost daily basis due due the constant changing of the construction site. Each phase of construction will have its own style of hazard mitigation, with the major phases being excavation, anchor construction, cable installation and weighting, and laying decking. Every day a safety plan is composed and implemented by the team managing the site, including schedule, PPE, and the daily hazard mitigation procedures. It is very important that these procedures are thought out and developed before the phases of construction begin, since many of them include details integrated into the shaping of the earthwork and other major project components while they are being carried out.

Excavation

While removing soil and rock from the bridge site, the equipment operator must follow instructions to effectively slope or bench the soil to prevent collapse on future workers in the vicinity. When digging deeper than 1.5 meters, the soil must be sloped to a minimum angle of 45 degrees, or benched at 1.0 meter deep by 1.0 meter wide. Proper drainage must also be considered when excavation is carried out by taking into account the surrounding slopes and features that could cause a pooling or flooding incident. An excavation perimeter must be established around a pit to prevent anyone falling in. A safe path must also be laid out for workers to exit the pit, and for materials to be easily ferried in and out. These safety measures extend and apply to the foundation construction phase as well.

Anchors

The concerns surrounding anchor construction are primarily weight related. While during foundation construction heavy stones can be rolled into place in the pit, the anchor cage is attentively built away from the pit and must be carefully lowered into position. This can be challenging given the immense weight of the steel structure, and overexertion is a very real risk if this task is not given the manpower it needs to be carried out safely. Hazard mitigation will be composed of detailed team communication and day-specific planning on-site to prevent injury. This stage also requires mindfulness of large cables being laid out across the worksite, creating tripping hazards, and knowledgeable operation of cable clamps. Tight coordination and a well thought out daily plan is necessary for safety during anchor construction.

Cable Hoisting

Cable Hoisting hazard mitigation can be divided into two parts: winch and cable safety.

Winch safety: Preventing cable slip is the primary matter of importance concerning usage of the winch. Only trained team/community members can be allowed to operate this equipment, since a loose cable can cause severe injury to any in its vicinity. Before use, the winch must undergo an inspection of its condition and reliability. Clamps and latches used to secure the winch must also be in good condition, with no cracks, rust, or other signs of damage. Clear the site around the winch when using it, and set safety and danger zones during use.

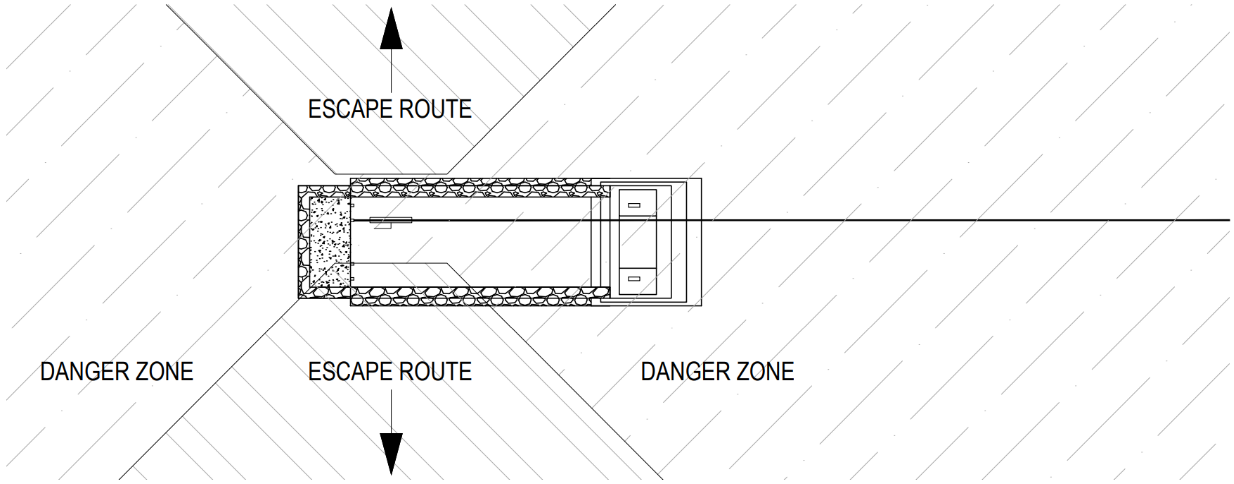


Figure 2: Illustration of winch safety and danger zones.

Cable safety: Cable safety involves preventing cable loosening and cable whip by securing the cable ends properly. Clamping at the cable end is required before transitioning weight to another point on the cable. When attaching clamps the operator must ensure that the clamps are torqued to the required amount.

Walkway Construction
When constructing the walkway and laying decking there is an additional safety factor to consider. Height is now an issue for workers on the bridge, since they could be over a dozen meters in the air above a river or gorge. This means that safety harnesses are required for anyone traversing the walkway before its completion. These harnesses will be linked by carabiner to secure cables to prevent falling. Any other community or team members must not walk beneath the walkway during its construction since there will likely be objects falling from or being dropped during work on the decking.

4.7 Emergency Rescue Plan

4.7.1 If Fall Occurs During Decking Installation

Ask your Ambassador to help you collect recommendations from what other teams have done for their Emergency Rescue Plans.

A previously assembled fall prevention and safety plan, with emergency response procedures: https://docs.google.com/document/d/1A0scCDZKYDJjKnupq6EuMz9HjuWkgjPIABapKUEDrtM/edit

4.7.2 In Case of Snake Bite

Ask your Ambassador to help you collect recommendations from what other teams have done for their Emergency Rescue Plans. The EIA snake safety information can be found here.

If bitten:

1. Get away from the snake. If you can clearly identify it, tell someone and/or write it down, or take a picture.
2. Draw a small circle around the bite with a marker and write the time —> repeat this every 15 min with the intention of capturing the notable effects (e.g. swelling, redness, etc.) within the circle you draw. That way the doctor can identify the venom type by observing how the symptoms have progressed with respect to time.
3. Call the Anti-venom Association to report the bite and inform them as to which hospital you will be going to so they can bring the anti-venom. They may also direct you otherwise.
4. Get to the selected medical facility as fast as you can safely. Bring at least one person with you with knowledge about snake bites to advocate for your treatment and help with local language, if applicable. <u>Surgery is not the correct treatment for snake bites - it is antivenom.</u>

4.8 Quality Control Sign Offs

Some Quality Control points can be signed by the student QC manager on-site. Others require someone more experienced (that's usually a Bridge Corps mentor, master mason, or EIA staff). The major QC concerns include damaged and low-quality materials, supplier and vendor failures, subcontractor mishandling, failure to document changes and practices, last-minute changes, scope creep, miscommunications between teams, and ignored audits and testing. The plan for identifying/mitigating concerns is described below, under the risk management plan. If there are issues with the quality of work proceeding, it is important to address to the appropriate party that work is not up to expectations, and then communicate ways to correct the change and get the work within acceptable quality limits. The student QC manager is responsible for ensuring all QC forms are filled out. If there is not a student QC manager on site, EIA staff will do it or delegate it to someone else with proper experience. It's up to the student Project Manager to delegate who works on which parts of the Post-Travel report. It is advised through Ethan Gingerich that we skip the O&M sheet since this is a capstone.

4.9 Material Estimate and Procurement

The procurement and cost for the materials estimated in RC #2 is listed below. Note that estimation guidelines were not available for all materials listed in the official agreement, and so any missing here should be assumed to be identical to the agreement between the municipality, community, and EIA. The team's full estimate can be found on the next page.

Materials procured by the community are expected to be on site upon arrival, and the municipality is in charge of procuring a majority of the remaining materials. Key components of early construction, like sand and cement, are also expected to be on site upon arrival in order to expedite the construction process. Specific materials have their arrival scheduled in the Microsoft Projects file generated with the construction schedule. Payment for materials has already been assigned to different stakeholders in the process. Materials will be driven to the site with the municipality's *volquetas*, or dump trucks. These trucks can be between and 12 cubic meters in carrying size, so the team should communicate with the Program Manager and municipality to ensure that the correct amounts of material are delivered to the site. For the most part, it can be expected that materials will either be dumped onto the ground (i.e. sand, gravel, etc) or can be conveyed down by hand (bricks, wooden planks, etc), so no tools are anticipated.

Given that construction will take place during the dry season, materials may be driven through the river if the water level is low; if the river is impassable, plans should be made either to ferry materials on separate *volquetas* or for one to travel around to the other side by the roads.

Bill of Quantities	W/ contingency		Cost (USD)
Clamps	58.8	pieces	$3,169.32
Cable	100.9632	m (x4)	$11,307.88
Timber crossbeams	64.5632	pieces	$587.53
Nailers	67.0464	pieces	$19.71
Decking	164.916	pieces	$2,608.97
Length of Rebar (Walkway)	0	m	$0.00
Cement	444.24	bags	$3,545.03
Bricks	930.24	pieces	$195.35
Rocks	156.3776813	m^3	$2,189.29
Sand	35.73777332	m^3	$1,250.82
Gravel	25.80219149	m^3	$975.32
Wheel Cable Saddle	4	pieces	$42.00
Roofing Tar	1	gallon	$0.00
75mm Flexible Plastic Tubing	1870	cm	$18.33
50mm Flexible Plastic Tubing	726	cm	$7.11
Tie wire	10	kg	$21.00
Lag screw (10mm x 7.5cm long)	954.375	pieces	$280.59
Fencing (1.2m tall)	153.972	m^2	$829.91
Galvanized tie wire	5	kg	$12.60
U-nails / Staples	6.11	kg	$85.54
Anchor Specific Materials			
A01 Bar	28.5	m	$88.20
A02 Bar	9	m	$19.60
A03 Bar	32.5	m	$33.60
Tower Specific Materials			
#3 Bar	24	m	$14.00
#5 Bar	24	m	$39.20

4.10 Equipment & Tools

What equipment and tools will you need for each step of the construction process? How will you acquire these tools? Do you own these tools already, or have you made agreements to borrow from the EIA Program Manager? What tools or equipment do you expect the community to supply?

In the original summary of costs and materials provided by the Pojo Municipality, EIA is listed as providing cables, forging clamps, cable pulley, suction hose, high density piping, red spray paint, construction markers for wood, and 4 and 3 inch brushes. The community and local government will provide the rest of the materials for bridge construction. However, tools will need to be acquired from EIA, other university chapters, and the local community. Along with the PPE covered later in this document, the tools suggested in the Bridge Builder Manual are:

LIST OF SUGGESTED TOOLS

- Automatic level, Philly rod, and tripod
- Buckets
- Construction square
- Duct tape
- Drills
- Drill bits
- Excavation bars
- Excavation picks
- 4-foot level
- Hacksaw
- Hammer (5 pound)
- Impact driver
- Ladder
- Linesman pliers
- Machete
- Masonry tools
- Markers
- Measuring tapes
- Plumb bob
- Pipe
- Rated rope
- Rebar bender
- Saw
- Saw blades
- Shovels
- Spray paint
- Stakes
- String line
- Sockets
- Socket wrench
- Tamping rod
- Torque wrench
- Wire cutters
- Wood saw
- Winch

Figure 4: List of Suggested Tools.

4.11 Challenging Design and Constructability Elements

During the team's preliminary design, a significant roadblock was encountered: a heavily eroded zone on the right bank of the river existing in front the right bridge foundation. Per EIA's guidance, a 3.0m setback from the eroded zone has been assumed at this moment, but going forward, this assumption may need to be adjusted for constructability purposes. Moreover, a roughly 23 cubic meter mass of soil in front of the right abutment must be excavated in order to provide enough clearance between the walkway cable and the ground. Excavator machinery may be necessary in order to accomplish this objective, and there may be concerns with the feasibility of actually transporting this machinery to site.

Any large rocks encountered during excavation may also merit large excavation efforts and machinery. Hydraulic excavators may be necessary to scoop and remove large boulders from the site, and jackhammer machinery may be necessary in order to section these boulders into more manageable pieces for ease of handling and transport.

Constructability elements that may prove difficult relate primarily to logistics, such as whether there are enough workers available to accomplish a given task over the course of a day, couple of days, or weeks. Or perhaps whether shipments of component bridge items are backordered until a later date than expected. Otherwise, as long as the construction team follows standard construction design and safety protocols, these other difficulties should be able to be avoided.

5.0 Safety Protocol

Go into detail on how you will enforce safety at each step in the construction process. Include safety considerations that may be step-specific and site-specific. How will you create a culture of safety on your work site? How will you identify and address safety concerns? What is your plan for health emergencies? Who on your team is trained in Wilderness First Aid and who will be making decisions during emergencies? Identify risks in regard to both personal and construction safety and include them in your Risk Management Plan (Section 6.0).

5.1 Plans for Implementation with Team and Community

Since our team is not traveling, the information provided here will more broadly address the traveling group of volunteers who eventually arrive at the Guayabitos site and lays out the plans and recommendations of the UVA Capstone group. It's recommended that the traveling group select a team member that does not have another fundamental role (cultural relations manager, design lead, etc) to lead the safety effort, and that this member be intimately familiar with the content taught in the various design courses about safety and to be comfortable with all of the safety plans included in this guide, such that they can provide guidance to other team members rapidly and are prepared for rapid or unexpected changes to construction plans or incidents and near-misses. This team member should also plan on having consistent interaction with a community-based safety lead, so that the construction group as a whole can have cohesive and multicultural communication of safety expectations. The team should plan to discuss the safety concerns with the community at minimum twice a day: once in the morning, to establish expectations and provide a place for education and discussion around any new safety procedure that may be implemented for the day, and once at the end of the workday, when the team and community should debrief the day, talk about anything that the group may want to adjust for the next day and remind the group of any specific activities planned for the next day that may require specific equipment or preparation. These meetings should be discussions, with primary information distributed equally by the team and community safety leads and plenty of time and space afforded for volunteers to ask questions, make suggestions, or raise concerns about any of the plans laid out. Ensuring that these meetings are not rushed, and that proper time is taken to greet all volunteers, welcome everyone to the site, answer questions, and speak about safety plans will be crucial to helping both team and community members feel involved in the process and making the meetings a space where everyone is empowered to contribute to the conversation and will help safety feel like a unified goal, instead of an imposed standard. In the instance that safety protocols are not agreed upon equally by the team and the community, take time to listen to the community's concerns or disagreements and focus on resolving any miscommunications or communicating where the team's perspective on safety comes from. Remember that the team's role is not to command, but to cooperate, and that successful communication avoids blame-based messaging. Your cultural relations manager may have thoughts on how to more indirectly address issues as they arise, but for team meetings a good rule of thumb is to avoid singling out anyone and instead focus on the safety of the group.

5.2 PPE

What PPE do you need on site? What will you bring with you and what will you purchase in-country? What PPE will you provide for the community volunteers and what do you expect them to already have?

PPE (Personal Protective Equipment) is an essential component of the construction process. We want our team and other EIA engineers to be safe, and also ensure that the local community is trained and provided with the necessary supplies for their safety as well. Because of the variety of manual labor undertaken by all on-site persons, we will divide the use of PPE into two categories - general sitework and specific tasks (which will have its own subcategories).

General Sitework

This category will detail equipment worn by all on-site personnel at all times, as well as when doing general work/labor, site tours, site management, etc. These items cover the minimum safety requirements for everyday interaction with a construction project, and help with minimizing risk and injury from the most common and preventable mishaps.

- Hard hat
- Long pants, belt
- Steel toed shoes/boots
- Safety glasses/sunglasses
- Protective gloves
- High-visibility safety vest
- Recommended: long sleeve shirt (varies with weather conditions)

Specific Tasks

This category will cover the equipment needed beyond the everyday needs of working on a bridge construction site. Some tasks require additional PPE to ensure the safety of the worker, and it is important for us to consider the variety of specialized equipment needed for the various tasks during construction. The stages of construction that would require this equipment include concrete mixing, soil testing and dyeing, traversing bridge cables before decking is built, using power tools, etc.

- Respirator
- Hazmat/full body protective suit
- Harness connected to safety lines
- Hearing protection
- Face shield

5.3 Personal Safety Plan

The personal safety plan of team members begins first with the individual taking responsibility for him- or herself- and his or her safety. On a basic level, the individual must at all times wear proper safety equipment, including hard-hats, eye protection, and fall protection when applicable. All team members should have international cellular data plans in the case of an emergency. This way all members of the team are equipped to handle unforeseen emergency events. All members of the team must possess copies of important documents, including identification and international travel passports. The team should also have the contact information for not only EIA and community officials, but also for local POCs including law enforcement. Before departing, every team must have registered with the State Department and have undergone the proper avenues within their respective university systems for international service and travel. Finally, once on site, the individual must also take responsibility for personal health, which factors into personal safety, by remembering to apply sunscreen and hydrate on particularly sunny, hot days, executing proper dental and bodily hygiene, and nursing any injuries that arise from physical labor.

(As the team will not be traveling for this project, this section is not applicable.)

5.4 Incident Plan

This section is written as an intended aid for the traveling group that makes its way to Guayabitos, and thus there may be some elements that that team will need to complete to meet their own personal news and situations. However, this plan lays out a structure within which that team can work.

Wilderness First Aid Training Plan

The traveling team should plan on having a minimum of two people who have trained in wilderness first aid (WFA), so that if one person is engaged helping an injured person for an extended period of time, or is injured themselves, the site will still have someone on site to handle any additional incidents that may arise. However, the more students who have exposure and experience to this training, the better! It is also highly recommended that students who do complete this training brief their teammates on a general overview of the content that they've learned so that others have exposure to these concepts and may be more able to administer basic aid in small incidents.

Plan for Minor Injuries and Illness

It is likely that over the course of construction, a few people on the site will experience minor injuries or suffer from illness. The team is advised to bring a basic first aid kit with the materials that may be important to manage these small injuries, especially in rural areas which may have less access to sterile tools, water, or other health services. In the case of minor injury, have the person who has been injured looked at by one of your WFA trained members in order to assess the injury and make any recommendations, or apply any aid if the person is unable to apply it themselves. The injured party and one of your WFA trained members can talk together to decide if they are okay to return to work on the project as they were before, in a modified format, or if it would be best for them to cease work for the day. Make sure that minor injuries are followed up on to prevent infections, which have the potential to create more serious health issues if not prevented. If team members are experiencing mild illness (flu, stomach bug, etc), the team should plan to excuse them from work for the day in order to allow them to rest and recover. Symptoms should be checked against symptoms of more serious illness, and if they seem to be more serious plans should be made to transport them to a medical facility to be checked.

Location, Contact for, and Transportation to Health Centers and Hospitals

The nearest health clinic is located 1 hour away in Challhuani, Bolivia. No phone number was provided by EIA field staff, but the following hours were provided:

Weekdays:
- Mornings: 08:00AM-12:00PM
- Afternoons: 02:00PM-06:00PM

Saturdays:
- 08:00AM-12:00PM
- 02:00PM-05:00PM

Sundays:

08:00AM-12:00PM
02:00PM-04:00PM

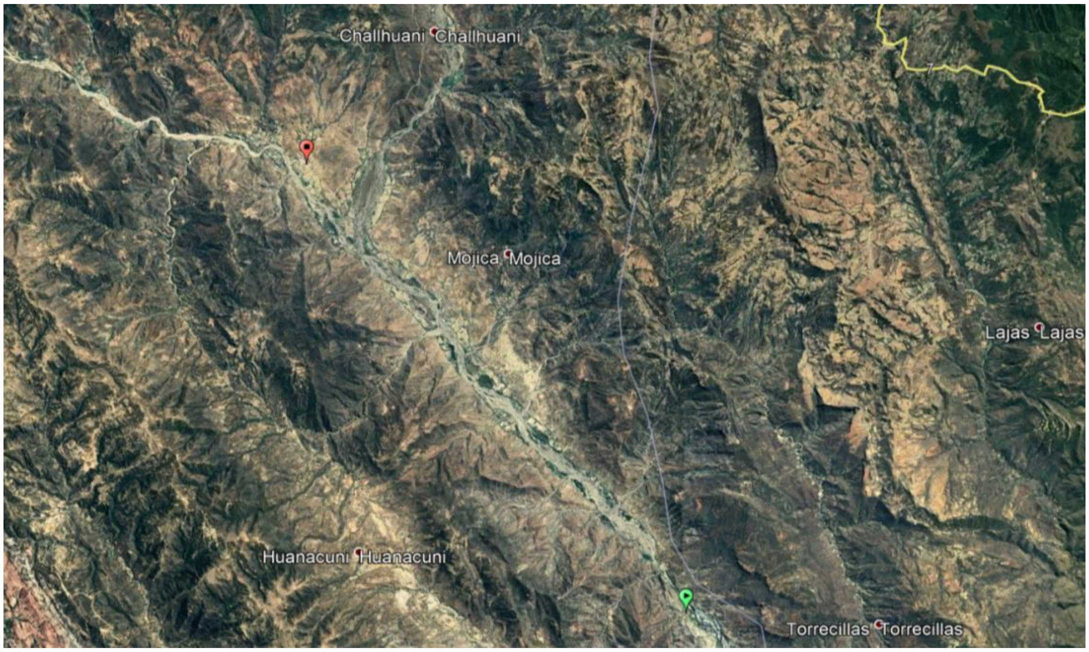


Figure 3: Illustration of Location of Challhuani (Red) in relation to Guayabitos (Green).

If more serious medical attention is needed, the closest hospital is located in Pojo, which is 2 hours away. No phone number was provided by EIA staff, so the team should plan on acquiring this information prior to travel and ensuring all members have these numbers saved to their own phones and written down physically in a paper that remains with the WFA trained members, alongside team information. Transportation will need to be arranged, either through EIA, the community, or the municipality.

Plan for Significant Injuries

Ahead of any significant injuries, plan on a few preparatory steps:

1. Have your WFA trained members, alongside those with significant medical experience, brief the group at large about general things that everyone should know about managing an incident immediately after it occurs in order to streamline the management process and reduce the risk of chaos as people figure out what to do.
2. Ensure that your WFA trained members, alongside your traveling adult volunteer, have physical copies of all volunteer insurance information on their person at all times, so that any trips are not delayed by needing to find necessary papers.

In the instance of a significant injury, several steps should be taken immediately:

1. All work occurring near/around the injured person should be ceased, and the area should be cleared.

2. A WFA team member, alongside anyone else with significant medical experience, should analyze the injury. If it is safe to move the injured person, they should be moved from the construction site for more detailed inspection.
    a. If the person has suffered a head injury or a possible spine injury, they should not be moved immediately. If it is possible to call emergency services to reach you, this should be done, and the person's head should be supported until they arrive, as is shown here. However, given the rural nature of Guayabitos, this may not be a possibility. In this situation, a flat surface long enough for the person's entire body should be procured, and multiple people should carefully roll the person such that their spine is neutralized onto the board so that they can be removed from the site and preparations can be made for their transport to a medical facility. One person should be supporting their head and neck during the entirety of this process. To get a sense of how this should be done, watch this video.
    b. In instances of broken bones, the affected limb should be immobilized and pressure applied with the aid of towels or other padding - if the bone is protruding from the skin, apply pressure around it, not over it. If ice or a cooling pack is available, apply it to the area to prevent swelling.
    c. Serious instances of bleeding should be managed in a similar fashion to broken bones, with general pressure applied to reduce and stop bleeding, and iced if possible to reduce swelling.
    d. Your WFA will be able to brief on the various management strategies for a variety of other serious injuries - this should not be taken as a complete list.
3. Plans for transporting the injured member to the hospital should be arranged at the same time as emergency first aid is being administered - plan on your most Spanish-proficient student speaker directing people and efforts, while one of your student leads makes necessary phone calls (numbers are listed below).
    a. Contact the EIA Program Manager first. If you cannot reach the PM, contact:
        i. Ethan Gingerich, Bridge Program Director – 319-530-8210 – ethan.gingerich@engineersinaction.org
        ii. Julie Allen, Executive Director – 402-770-1499 – julie.allen@engineersinaction.org
    b. Contact Faculty Advisor (or designated university/state-side contact) to notify the university and the student's emergency contact

Sexual Assault

It is crucial, before leaving for the project, that your team build strong and healthy relationships with each other, demonstrating respect and support for each other and learning about each other before you travel. Telling someone else about a sexual assault is an experience that can be accompanied by intense anxiety about how someone else's perception of the victim may change, whether they will be believed, and whether they will be supported. If your team has not previously built the relationships and trust in each other to provide this care, it is unlikely that an assault will be reported, and this may lead to a team member struggling to remain physically and mentally well or present in the project. More resources will be included to provide additional information and answer more questions, but here are some key takeaways that will be crucial to keep in mind:

1. It has likely taken a lot of courage for the survivor to open up to you and tell you what happened, and their personal well being might be in poor condition. Believe them. Be compassionate for this situation and try to avoid overwhelming this person with questions, to-dos, or solutions. Listening and supporting are your primary roles right now. This is not information to share with others unless they tell you that you can.
2. It is vital that the survivor retains agency over the steps that occur after the assault has happened. It is worth encouraging the person to report this action up through the organization, but don't push them if they don't want to. It's most important to support them in the ways that they need you to at this moment. Continuing to gently encourage them to report this situation may help them obtain support, but remember that this is about what they want to do and how they want to recover.
3. In a rural setting like Guayabitos, it is unlikely that the survivor will be able to avoid their assaulter. If the assaulter is within the community, it may be difficult to remove them from the project without offending the community, although if this person desires this action to be taken and is comfortable bringing the issue to a higher level this is an option that should be discussed with adult mentors and the community leader. If the assaulter is within the team, it will likely be impossible to avoid them. Recognize that having to work with one's assaulter can be a triggering and exhausting experience, and this will likely strain this person's ability to be as present in the project. Be ready to provide additional support to them in ways that you both agree on.

Resources that may be relevant to those in Charlottesville or UVA:
https://eocr.virginia.edu/chart-confidential-resources

American National Sexual Assault Hotline: 1-800-656-4673

Political Emergencies

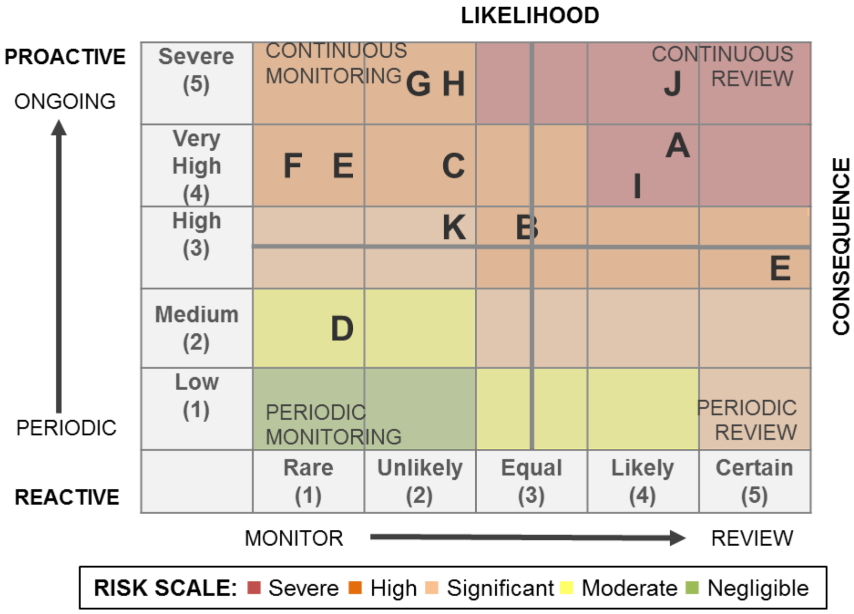
The best way to avoid encountering significant challenges associated with political emergencies is to keep awareness of their potential. The team should acquaint themselves with news of the political environment of Bolivia ahead of travel - if it looks like significant unrest is imminent, then it may be best to delay the trip. If the situation looks less clear, talk with the Program Manager and other EIA staff to determine the best course of action to balance the team's safety and the community's project. In the scenario that unrest occurs suddenly in the country, the team may have a buffer period because of the remoteness of the location, but may also have less opportunity to receive updates. They should plan on contacting the Program Manager and ensuring their safety, as well as making a plan to move forward. The team may also wish to call the US Embassy, whose information is listed below, for information on possible emergency evacuations or other guidance on keeping safe. The team may either need to attempt to arrange transport out of the country, which may be able to be done commercially or may require working with the embassy, or will need to request an extended stay with the community until it is safe to leave. Keep an eye on local broadcasts for possible information from the embassy and find ways to support the community if you do need to stay longer. Do your best to stay in contact with the Program Manager, and if you are able to try to get word back to your home university, employer, or others who may be able to assist in your extraction from the country if the embassy is not able to assist you. Use social media to keep in touch with friends and family members and provide updates.

US Embassy in Bolivia:
Avenida Arce 2780
Casilla 425
La Paz, Bolivia
Phone: (591) 2-216-8000

5.5 Travel in-Country

As the team will not be traveling for this project, this section is not required to be completed.

6.0 Risk Management Plan



A: Municipality fails to supply construction materials
B: Late arriving materials
C: Rock encountered in excavation
D: River flooded
E: Saturated soil conditions
F: Lack of community participation
G: Injury/loss of teammate
H: Injury to community worker
I: Municipality fails to supply transportation
J: Insufficient rock quantities
K: Weather issues

Risk		Monitoring Frequency	Scenario	Remedial Action	Responsible Party
E	Saturated soil conditions	Daily	Grade 1: Standing water in excavation pits only following major rain event	No action needed; bridge design accounts for saturated condition once or twice per rainy season per B2P Manual	Bridge Engineer
			Grade 2: Standing water always in excavation pits, indicating high water table	Verify design capacity accounting for buoyant force. Consider installing drainage or possible redesign.	
F	Lack of community participation	Daily	Grade 1: Fewer workers than expected at job site	Convene Bridge Committee, adjust schedule	Construction Manager
			Grade 2: Insufficient workers during critical points in construction	Engage EIA mason or Project Manager for full evaluation of community's willingness and ability to contribute; Recruit workers from nearby towns; Suspend project	
G	Injury/loss of teammate	Continuous	Grade 1: Injury that cannot be treated on-site with first aid	Transport teammate to hospital in Diramba (see Table 8); Reorganization of team roles & responsibilities	Safety and Operations Manager
			Grade 2: Teammate can no longer work on project/returns home	Permanent reorganization of team roles & responsibilities	

H	Injury to community worker	Continuous	Injury that cannot be treated on-site with first aid	Transport community member to hospital in Diramba (see Table 8)	Safety and Operations Manager
I	Municipality fails to provide transportation for rocks	Weekly	Rocks are collected but municipality does not provide truck	Use community members with trucks (one identified over fall break); Depending on time-sensitivity, consider hiring Marvin or Fruto's truck	Safety and Operations Manager
J	Insufficient quantities of rock collected	Weekly	Grade 1: Sufficient quantities of river rock for structural work, insufficient quantities of rock for fill	Expand scope of collection zone; Contact local quarries to collect rock fragments and debris	Safety and Operations Manager
			Grade 2: Insufficient quantities of river rock for structural work, insufficient quantities of rock for fill	Expand scope of collection zone; If inadequate, purchase rock from regional supplier	
K	Severe weather	Continuous	Grade 1: Intermittent inclement weather	Cover excavated areas and curing concrete during heavy rains; inspect integrity of excavations	Construction Manager
			Grade 2: Ongoing or consistent inclement weather	For afternoon storms, adjust workday start; Optimize critical tasks for predicted breaks in weather; Inspect integrity of excavations – suspend work and shore if needed	

Appendix

1.1 Maps

Community: Guayabitos Region: Carrasco Province GPS Coordinates: *N/S -17°94'51.88"*
District: Cochabamba Country: Bolivia *W/E -64°80'99.62"*

1.2 Media

Note: Compare site photos to the topographic survey and note visual confirmation of the survey or possible discrepancies.

1.2a Downstream

1.2b Upstream

1.2c Left Bank, Towards River

1.2d Left Bank, Away

1.2e Right Bank, Towards River

1.2f Right Bank, Away

1.3 Proposed Profile

Figure 9: Full elevation profile

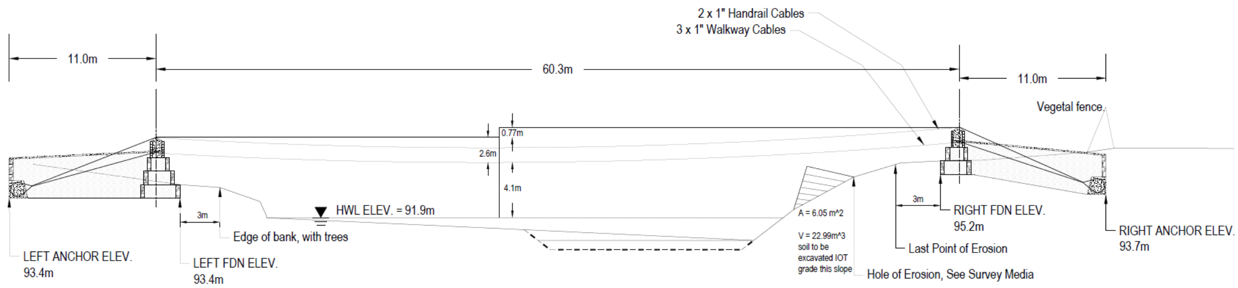
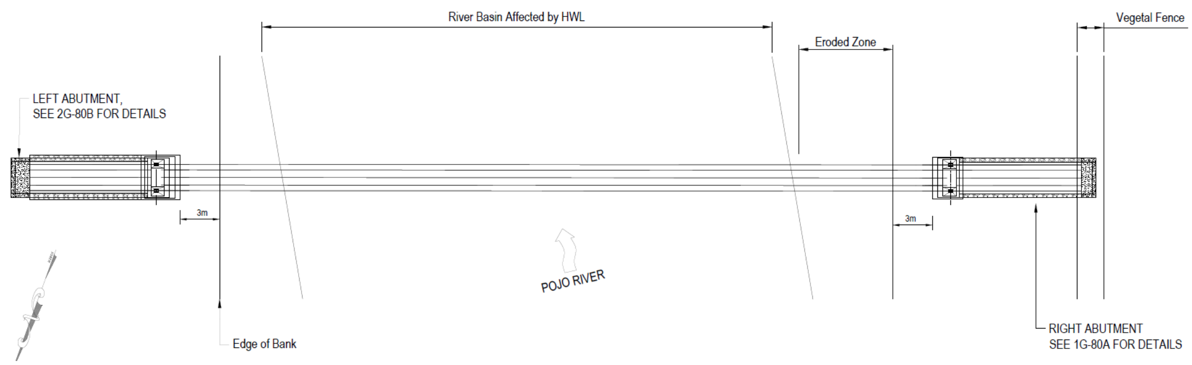


Figure 10: Full plan profile



1.4 Project Assessment

FIEA **Evaluación de Proyecto**

Asesor: EC (Nombre Completo) Fecha: 13 /sept

Información sobre el Lugar

Nombre del puente propuesto: Guayabitos

Nombre(s) de la comunidad o comunidades: Salto la Viña
(todas las comunidades que son beneficiarias directas)

Nombre de la alcaldía o del municipio: Pojo

Nombre de la provincia o del departamento: Carrasco

Ubicación del puente propuesto (coordenadas GPS): Nombre del río: Pojo

Latitud: __________

Longitud: __________

Información General y Accesibilidad del Sitio

¿Cuándo es el sitio accesible por un vehículo con tracción 4x4?

☐ Nunca ☐ A veces ☒ Todo el año

Nombre de la carretera pavimentada o adoquinada más cercana: Camino a Pojo

Nombre del municipio o pueblo más cercano: Pojo

Tiempo de viaje desde el puente hacia el municipio o pueblo más cercano: 1 hr

Calidad de servicio celular: ☐ No existente ☐ En algunos lugares ☒ Bueno solo Entel

Fundacion Ingenieros en Accion Evaluación de Página 1 de 6

Compañías de servicios celulares: Entel

Describa el acceso de entrega de materiales en los lados derecho e izquierdo del río:

Lado izq. bien acceso

¿Qué materiales locales hay en el río, la comunidad, o en comunidades cercanas (como piedra bolón, arena fina, madera fina, madera para formaletas)? Piedra, arena

Información general del sitio y accesibilidad: Tiene buen acceso al lado izquierdo, el lado derecho no tiene acceso en época de lluvia

Información Social

Número de beneficiarios directos del puente: 12
(personas para quienes el acceso está consistentemente bloqueado)

Opcional: Número de niños y niñas que se beneficiarían directamente: 6

Opcional: Número de mujeres en edad reproductiva que serían beneficiarias: 4
(15 – 49 años)

Población de todas las comunidades beneficiarias directas e indirectas: 30
(población total de todas las comunidades que potencialmente utilizarían el puente, incluidas las directamente servidas)

Actividades económicas primarias y secundarias: Agricultura

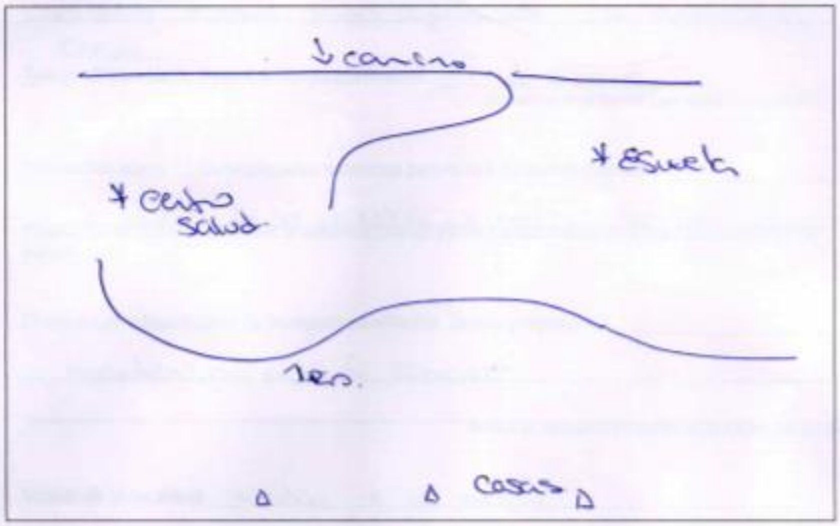
Cultivos primarios: tomate, pimentón, vainita, papa, haba, camote

Cuáles son los meses cuando voluntarios de la comunidad tienen cosechas u otro trabajo temporal, y tal vez les sería difícil trabajar en la construcción del puente:

☒ Enero	☒ Febrero	☐ Marzo	☐ Abril	☐ Mayo	☐ Junio
☐ Julio	☐ Agosto	☐ Septiembre	☐ Octubre	☐ Noviembre	☒ Diciembre

otas sobre la población: Todos los comunitarios sufren accidentes en época de lluvia

Mapa de la comunidad (incluya características como la ubicación de la comunidad o los centros principales de la población, la ubicación del puente propuesto, las carreteras principales y caminos, escuelas, centros de salud, mercados, iglesias, paradas de autobús y edificios o casas comunales):



Descripción de servicios importantes, oportunidades o destinos bloqueados por el río: Debes cruzar el río y caminar 10 km hasta la escuela más cercana

(Esto puede incluir escuelas primarias o secundarias, clínicas u hospitales, granjas o mercados, servicios gubernamentales, iglesias o cualquier otro destino importante para la comunidad. Por favor sea tan detallado como sea posible e incluya los tipos de escuelas o centros de salud y cuántas personas sirven, el tamaño de los mercados y la frecuencia con que ocurren, y otros detalles que ayudarán a contextualizar y particularizar las necesidades de la comunidad y, entre ellas, la necesidad de un puente.)

Número de lastimados causado por el cruce de río en los últimos tres años: 12

Número de muertes causado por el cruce de río en los últimos tres años: 2

Opcional: Descripciones de lastimados o muertes por el cruce del río: se cayeron al río y nadie pudo ayudarlos, hay demasiada agua.

Tiempo de inundación durante la temporada lluviosa: 1 semana
(Cuando el río se inunda, ¿por cuánto tiempo dura?)

Información acerca de las propiedades o terrenos para el sitio del puente propuesto:
1 dueño lado derecho, lado izq. no tiene dueño
(Quiénes son los dueños de los terrenos en ambos lados del río, y si han expresado interés en apoyar o preocupación por un puente)

Proyectos de infraestructura de transporte planificados, locales y regionales:
mantenimiento de caminos
(Incluye la descripción y cualquier lugar o fecha conocida)

Método de cruce actual: Nadan, o se mojan
(Nadar, puente de madera, etc.)

Punto de cruce más cercano: En época seca los autos cruzan por el punto de estudio para el puente.

Fundacion Ingenieros en Accion Evaluación de

Página 4 de 6

ombres, títulos e información de contacto de los principales interesados (líderes comunitarios, representantes gubernamentales, etc.):

1: Nombre y apellido : Abel Corcapeta Título: Dirigente

Teléfono: 68501347 Correo electrónico: ____________________

2: Nombre y apellido : Marcial Corredor Título: Comunario

Teléfono: 74312893 Correo electrónico: ____________________

3 Nombre y apellido : ____________________ Título: ____________________

Teléfono: ____________________ Correo electrónico: ____________________

Índice de Aislamiento

Número de días al año que el río es difícil o imposible de cruzar: 1 semana

Distancia de viaje desde el sitio del puente propuesto al centro de la ciudad más cercana (kilómetros):

33,4 km hasta Poto

Distancia de viaje desde el centro de la comunidad beneficiaria al sitio del puente propuesto (kilómetros): Variado

Distancia de viaje desde el sitio del puente propuesto al mercado principal (kilómetros): 30

Tiempo de viaje desde el sitio del puente propuesto al mercado principal (a pie, en minutos): 20

Distancia del sitio del puente al centro de salud más cercano (kilómetros): ,20

Distancia del sitio del puente propuesto a la escuela secundaria (kilómetros): 10,7 km (hasta La Viña)

Fundacion Ingenieros en Accion Evaluación de

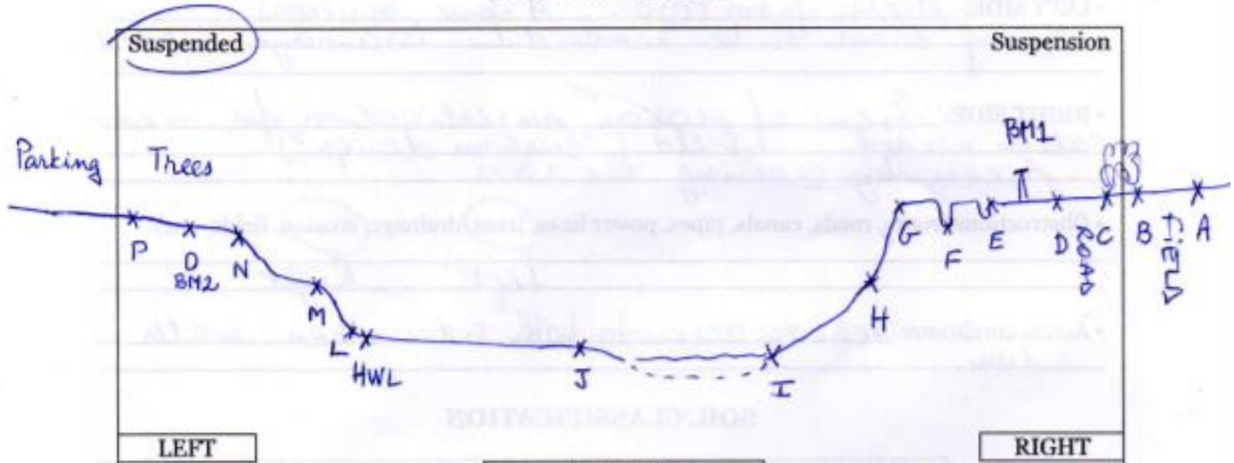
Página 5 de 6

1.5 Technical Survey Form

TECHNICAL SURVEY

Project Name: Guayabitos CL2 Surveyor: Kacie | Pierre
Date: 12 dec 2019 GPS: -17,945188 | -64,802962

PROFILE SKETCH



LOOKING DOWNSTREAM

BM1	Height of inst.	1,420 m		
BM2	Height of inst.	1,635 m	Reference point	O
BM3	Height of inst.		Reference point	
BM4	Height of inst.		Reference point	

POINT	REFERENCE	DESCRIPTION	AHEAD (+) BACK (-)	LOW	MID	HIGH	NOTES
A	BM1	Survey Limit	-	——	0,540	0,645	
B	BM1	Field	-	——	0,520	0,580	
C	BM1	Fence	-	0,775	0,825	0,875	
D	BM1	Road	-	2 meters from BM1			
E	BM1	Erosion	+	1,600	1,620	1,640	
F	BM1	Erosion	+	2,635	2,6725	2,710	
G	BM1	Edge of bank	+	1,820	1,875	1,930	
H	BM2	Slope	-	3,270	3,500	3,730	
I	BM2	Water	- 43,0		5,8		Range Finder
J	BM2	Riverbed	- 25,8		5,0		Range Finder
L	BM2	Toe of bank	—	3,960	3,9925	——	
M	BM1	Slope	+	4,240	4,500	4,760	
N	BM1	Edge of bank	+	3,180	3,455	3,730	
O	BM1	BM2	+	2,950	3,240	3,530	
P	BM1	Survey Limit	+	1,380	1,725	——	
* HWL1	BM2	High water level	—	4,0725	4,105	4,1375	
HWL2							

ENGINEERS IN ACTION

SITE DESCRIPTION

- Width of river from bank to bank (in meters): 44 m
- Height differential in banks (in meters): 1,5 m
- LEFT SIDE: Access from Pojo. A few boulders. Many trees to be removed! Drainage needed
- RIGHT SIDE: Signs of erosion, investigation for medication needed. Field (custom design?) Access by crossing the river
- Obstructions (rocks, roads, canals, pipes, power lines, trees, drainage, erosion, fields, etc.): trees – Left; erosion – Right
- Access conditions: Vehicle access to both sides when water is low.

SOIL CLASSIFICATION

	Course grained	Fine grained	Rock
Left side	□ Gravelly soil	□ Silty soil	□ Hard rock (fractured: Y/N)
	☑ Sandy soil + small rocks	□ Clayey soil	□ Soft rock (fractured: Y/N)
Right side	□ Gravelly soil	☑ Silty soil + EROSION	□ Hard rock (fractured: Y/N)
	□ Sandy soil	□ Clayey soil	□ Soft rock (fractured: Y/N)

PHOTOS AND VIDEOS

☑ Left survey limit	☑ Left top of bank
☑ Right survey limit	☑ Right top of bank
☑ Riverbed	☑ High water line
□ Soil, left side	☑ Soil, right side
☑ Existing crossing method	☑ Marked points
☑ Access to the site	☑ Site description
□ Community	□ Place for the team

NOTES

Start when rainy season is over

2.0 Matrix of Responsibilities

Task	Responsibility			
	EIA	**UVACP**	**Bridge Corps**	**Completed**
Site Identification & Selection				
Technical Survey Form				
Project Assessment				
Local Agreements				
Material Procurement				
Site Preparation				
Quality Control Point Sign-offs				
Safety Equipment and Tools		*Will contribute*		
Transportation of Cable and Clamps to Site				
Monitoring and Evaluation of Completed Bridge Project				
Bridge Inspections				
Initial Design of Bridge				
Bridge Design Verification				
Construction and Safety Report				
Support Training of Local EIA Staff				
Secure Bridge Corps Members				
Spend minimum 3 weeks on site				
Financial Commitment				
Design Support				
Safety Oversight				

3.0 Design Calculations

Design calculations may be found here:

Appendix 4.0: Suspended Bridge Conditions Sheet

4.0 Drawing Set

Drawing Set can be found here:

Final Detailed Design Drawings

5.0 Emergency Resource Information

As the team will not be traveling for this project, this section is not required to be completed.

6.0 Sample Emergency Protocol

As the team will not be traveling for this project, this section is not required to be completed; however, emergency contacts as provided for Bolivia have been retained below.

Contact list (in order of priority) - Bolivia
This is the order of contact in case of an incident. Note that you should begin contacting people only once the scene has been deemed safe and appropriate measures have been taken to ensure the safety of affected individuals. Remember - the project you're conducting takes place in a resource constrained context. It is likely that local emergency services will be unreliable or even unavailable. So long as the incident that has occurred will not be made worse by moving the affected individuals (e.g. in case of suspected spinal injury), you should take immediate action to transport the individuals to the nearest sufficient medical facility, using local vehicle contacts and all the resources which you have access to. *It is important to spend the time ensuring that the info in the following chart is up to date and relevant to your site.)*

1. Emergency Vehicle Contact (see below)
2. Bolivian Emergency Numbers - delegate to a nearby community or team member
    a. Police: 110
    b. Fire: 119
    c. Ambulance: 165
    d. Emergency: 165
3. EIA Field Staff
    a. Kacie Wolverton: +591 631 31 444 (calls and WhatsApp)
    b. Pierre Ledys: +591 71 99 80 36 (calls and WhatsApp)
    c. Field phone: +591 68 50 19 55 (calls and WhatsApp)
        i. If EIA Field Staff is nearby, use vehicle for transport
4. Insurance Providers for every student with phone numbers (RC3 appendix)
    a. International SOS:
    b. Geoblue:
5. Medical Clinic (see below)
6. School Emergency Contacts
    a. Faculty Advisor:
    b. International Department:
    c. Police Department:
    d. Other:
7. Personal Emergency Contacts (RC3 appendix)

8. Ethan Gingerich[1]: +1 (319) 530 8210
    a. If not available contact Julie Allen: +1 (402) 770-1499

Emergency Vehicle Contacts
Students should find three community members with access to vehicles in case of emergency.

Emergency Vehicle Contacts

Name	**Phone Number** (WhatsApp?)	**Who is this?**	**Vehicle Type**	**Availability**	**Location**	**English?**
Vehicle 1						
Vehicle 2						
Vehicle 3						

Medical Clinics
It is important to spend the time ensuring that the info in the following chart is up to date and relevant to your site. You should save the GPS locations for each medical facility offline in Maps.me or Google Maps Offline.

Medical Clinics

Name	**Phone Number**	**Address**	**GPS Coordinates**
Bolivian Clinics			

[1] Note: Only contact the Bridge Program Director once you have contacted the Country Program Manager. If the Country Program Manager is unavailable, leave a message summarizing the situation and the steps being taken.

7.0 Sample Hazard Mitigation Plan

HAZARD MITIGATION PLAN					
Task Details			**Safety Details**		
Task	#	Description	Required PPE	Safety Concerns	Safety Precautions
Stone Collecting	1	To be collected and used for tiers & approach ramp walls and loose fill within the approach ramp and tiers	1. Work Gloves 2. Safety Glasses 3. Work Boots 4. Long sleeve shirt and long pants	1. Getting lost 2. Animal and bug bites 3. Dropping stone on feet 4. Sprained ankles 5. Blistering feet 6. Dehydration 7. Heat Exhaustion	1. Buddy system and walkie talkies 2. Bug spray. first-aid kit, wear required PPE 3. Wear required PPE 4. Wear required PPE 5. Bring extra pairs of socks 6. Bring water 7. Breaks in shade
Foundations | Cement Pad	2	Mix and pour cement into the pit dug for the foundation	1.Work Gloves 2. Safety Glasses 3. Work Boots 4. Long sleeve shirt and long pants	1. Cement burns	1. Wear required PPE and wash off 2. Immediately if cement gets on your skin
Foundations and Tiers | Exterior Walls	3	Set Stones around the edge of the pit with mortar in the spaces around the stone	1. Work Gloves 2. Safety Glasses 3. Work Boots 4. Long sleeve shirt and long pants	1. Cement burns 2. Stones falling	1. Wear required PPE and wash off 2. Immediately if cement gets on your skin 3. Wear required PPE
Foundations and Tiers| Loose Fill	4	Pile stone aggregate in the interior of the built stone walls	1. Work Gloves 2. Safety Glasses 3. Work Boots	1. Stones falling on people	1. Wear required PPE
Foundations and Tiers | Cement (5cm)	5	Place a level 5cm thick layer of cement on top of the loose fill to encapsulate it.	1. Work Gloves 2. Safety Glasses 3. Work Boots	1. Rolling ankle on loose fill. 2. Concrete burns	1. Wear required PPE 2. Wash off cement
Towers | Exterior Walls	6	Place stones or CMUs, joining them with mortar, to build the walls to the appropriate height	1. Work boots 2. Safety Glasses 3. Gloves	1. Getting concrete burn from the mortar.	1. Wear gloves.
Towers | Rebar & Cement	7	Place rebar in the towers, making sure the spacing is accurate. Hold steady while pouring cement into the towers until they are filled	1. Work boots 2. Safety Glasses 3. Gloves	1. Concrete burns	2. Wear gloves.

Anchors | Excavation	8	Dig pit to contain the anchor	1. Work Gloves 2. Safety Glasses 3. Work Boots	1. Shovel hitting feet/others 2. Animal and bug Bites 3. Dehydration 4. Heat Exhaustion 5. Pit Collapse 6. Dirt Thrown into other people	1. Wear required PPE 2. Bring Water 3. First aid kit 4. Be alert to people working

Task Details			Safety Details		
Task	#	Description	Required PPE	Safety Concerns	Safety Precautions
Anchors | Steel Cage	9	The cage holds the cables in place in the anchor. It's made of rebar bent into squares.	1. Work Gloves 2. Safety Glasses 3. Work Boots	If by chance the cable comes loose, then tension in the cable can be lethal when released	1. Be alert
Anchors | Tubing	10	Place conduit around the steel cage with both ends sticking out of where the concrete will be. Have 1 conduit for each cable.	1. Gloves	1. Small cut on rebar or conduit	1. Perform basic first aid.
Anchors | Concrete	11	Fill the excavation with concrete, making sure the steel cage is completely covered and that no concrete enters the conduit.	1. Work Gloves 2. Safety Glasses 3. Work Boots	1. Concrete burns	1. Wear PPE.
Cables | Handrail | Feed through Anchor	12	Take the end of the cable and push it through the conduit and out the other end.	1. Work Gloves	1. Small cut from the wire or conduit	1. Wear PPE
Cables | Handrail | Clamp	13	To be used to hold the cables together after going around the cable	1. Work Gloves 2. Safety Glasses 3. Harness	1. Cable Swinging Out 2. Pulling a muscle	1. Make sure partner stands on cable at all times 2. Don't strain too hard. Get help
Cables | Handrail | Over Gap	14	Carry the cable across the chasm so that it stretches across the gap and stretches the distance of the proposed bridge	1. Work Gloves 2. Safety Glasses	1. Falling while carrying cable/falling into the pit	1. Wear required PPE
Cables | Handrail | Second Anchor	15	Feed cable through conduit and clamp loosely to hold in place	1. Work Gloves 2. Safety Glasses 3. Work Boots	1. Falling while carrying cable/falling into the pit cable slips	1. Wear required PPE safety clamps

Cables | Handrail | Clamp	16	To be used to hold the cables together after going around the cable	1. Work Gloves 2. Safety Glasses 3. Harness	1. Cable Swinging Out 2. Pulling a muscle	1. Make sure partner stands on cable at all times 2. Don't strain too hard. Get help
Cables | Handrail | Tension - Sag-Setting	17	Set the appropriate amount of sag (the vertical drop that the cable will dip below a line drawn between each towers) in the cables before clamping them in place	1. Work Gloves 2. Safety Glasses 3. Work Boots	1. Cable swinging Out 2. Pulling a muscle 3. Cable pulls out	1. Safety clamps
Rebar & Suspender Preparation	18	Cut and bend the rebar into the appropriate length and shape	1. Work Gloves 2. Safety Glasses	1. Cutting yourself on the rebar	2. Wear PPE

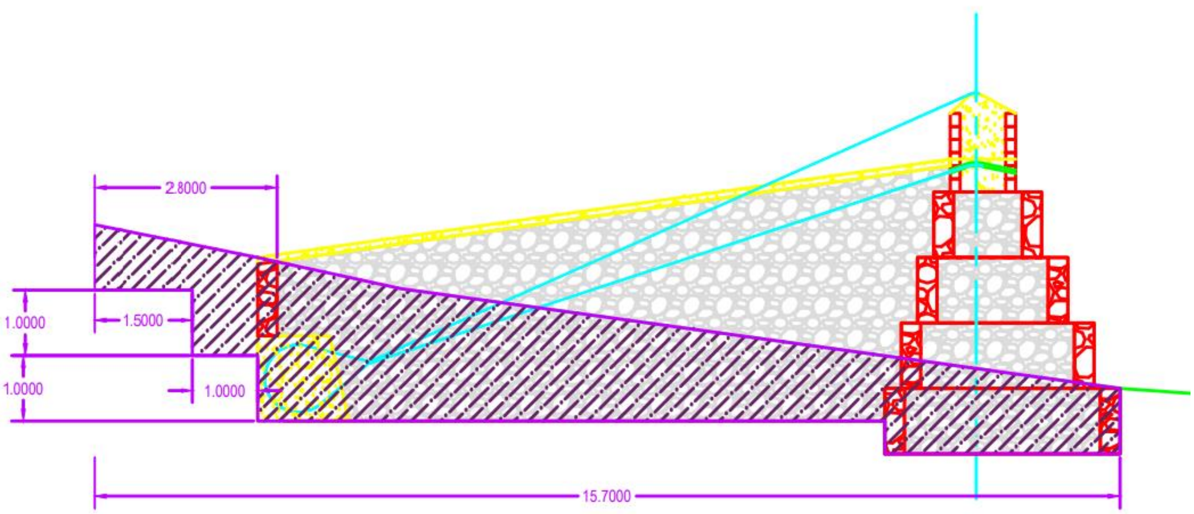
Task Details			**Safety Details**		
Task	#	Description	Required PPE	Safety Concerns	Safety Precautions
Crossbeam Preparation	19	Cut the crossbeams to the appropriate length and drill the 4 holes in each for the rebar to be placed through later.	1. Work Gloves 2. Safety Glasses	1. Cutting yourself on the wood, splinter	1. Wear PPE
Nailer Preparation	20	Cut the nailer to the appropriate length.	1. Work Gloves 2. Safety Glasses	1. Cutting yourself on the wood, splinter	1. Wear PPE
Decking Preparation	21	Cut the decking to the appropriate length.	1. Work Gloves 2. Safety Glasses	1. Splinters cutting yourself with saw	1. Wear PPE
Connect Nailer to Crossbeam	22	Place the nailer on top of the crossbeam and firmly nail it into place. Nails should be spaced evenly, around a foot apart.	1. Work Gloves 2. Safety Glasses	1. Hitting hand with hammer, Splinters	1. Wear PPE
Suspender & Crossbeam installation	23	Place the crossbeam on the three bottom cables. Hold it steady while the suspenders are put in place. Bend the end of the suspender once it is in the drilled hole to lock it in place.	1. Work Gloves 2. Safety Glasses 3. Harness	1. Falling	1. Wear PPE
Decking Installation	24	Once the crossbeams are in place, place the decking over it and nail it into	1. Work Gloves 2. Safety Glasses 3. Harness	1. Falling	1. Wear PPE

		place. They should be 5 boards wide.			
Fencing Preparation	25	Cut the fencing into the desired lengths	1. Work Gloves 2. Safety Glasses	1. Cutting oneself with the wire cutters	1. Wear PPE
Fencing Installation	26	Unroll the fence along the suspenders and tie it in place with metal ties. Fold the extra over the top hand cable and tie the excess down to itself.	1. Work Gloves 2. Safety Glasses 3. Harness	1. Falling	1. Wear PPE

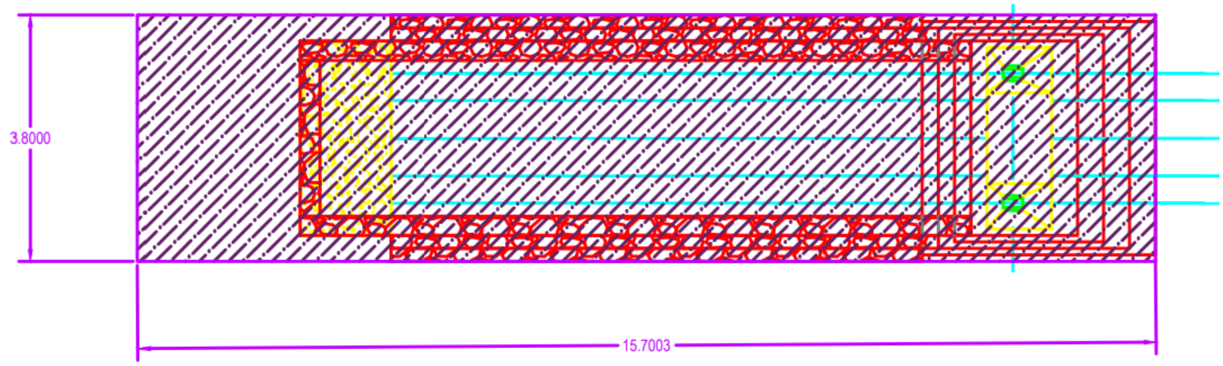
8.0 Construction Schedule

9.0 Sample Excavation Drawings

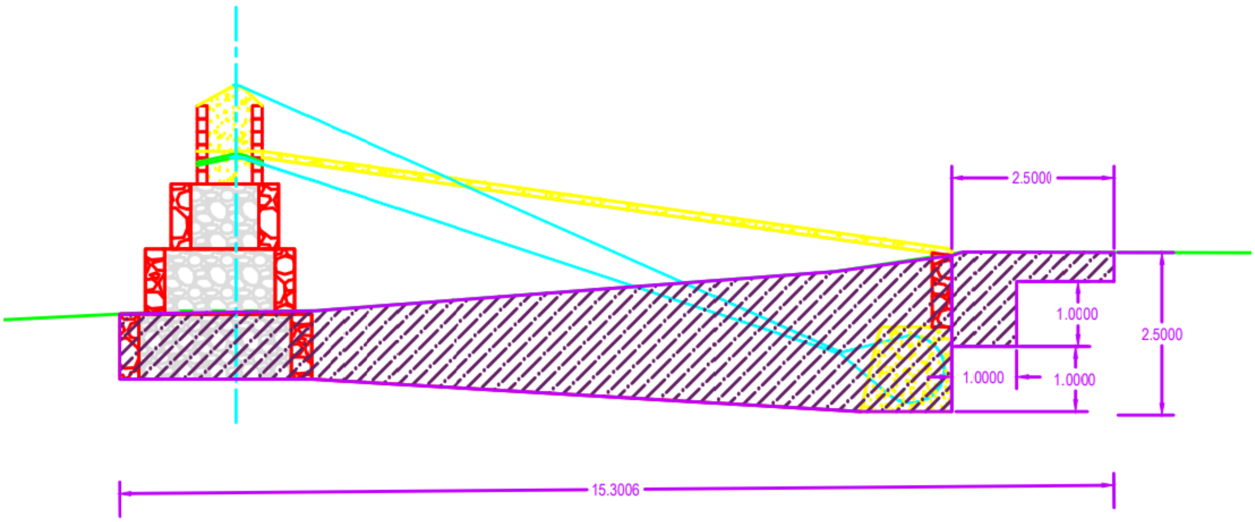
Guidance for excavation drawings is coming soon to BEDU. Note that excavation drawings must be saved separately from the Construction and Safety Report document in the University Projects Drive folder but should be linked in this report.



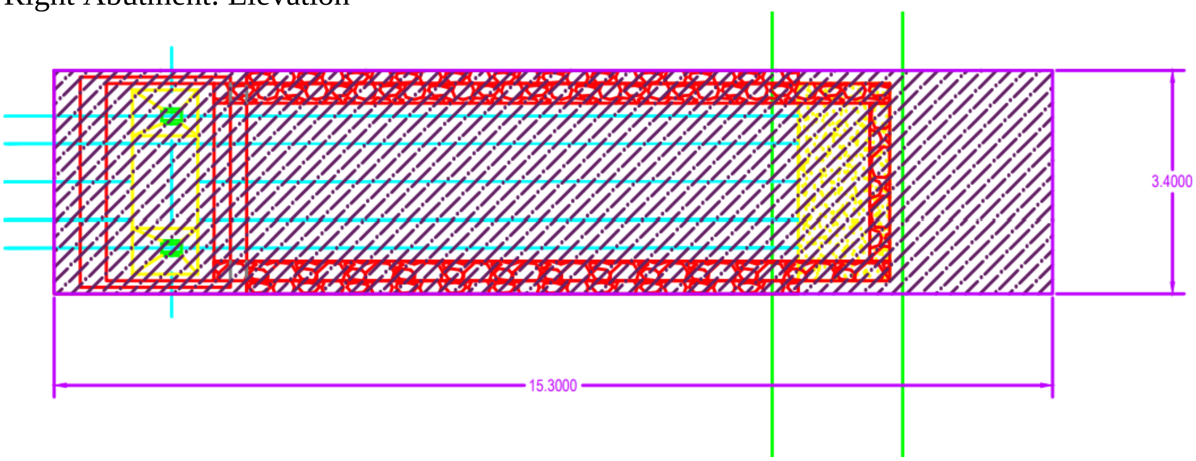
Left Abutment: Elevation



Left Abutment: Plan



Right Abutment: Elevation



Right Abutment: Plan