Rio K'allu Mayu Suspended Footbridge

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

Jessica Brown

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technical project collaborators:
Sacha Choubah
Ronald Orellana
Calvin Reeves
Gabriel Witter

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.

Technical advisor: Jose Gomez, Department of Civil Engineering

Introduction and Background

This report will describe the type, size, and location study performed by the UVA Capstone team for a pedestrian footbridge in Bolivia that crosses the Río K'ellu Mayu and links the Pocona Municipality to vital resources in the region (Figure 1).

The pedestrian bridge design consists of a suspension footbridge over the Río K'ellu Mayu and will serve the Pocona Municipality in Bolivia. Residents of the municipality requested this bridge because they cannot cross the river 150 days of the year due to flooding. The river's flooding is exacerbated during the rainy season that takes place from November to March[1]. The lack of a suitable river crossing restricts their access to schools, health clinics, markets, and other services. Children must cross the river daily to attend primary and secondary schools. These schools are located 18 kilometers (about 11.18 mi) away from the site. The nearest medical clinic is across the river and is also 18 kilometers away from the site. The community currently uses makeshift crossings over the Río K'ellu Mayu, and they are not safe, reliable, or durable for use as permanent crossings. There have been no reported river crossing deaths to date, but residents risk their lives when crossing the river during the high-water months and will continue to do so as it is their only connection to vital resources.

The K'ellu Mayu community's economy is centered around agriculture and animal tending. Cultivated crops include potatoes, corn, wheat, peas, beans, barley, peaches, and apples. Animal husbandry includes cows and sheep.

The bridge will be designed to safely support pedestrians traveling across the river on foot, as well as those with bicycles, motorcycles, wheelbarrows, and livestock. Constructing this bridge will directly aid the 190 residents of the community, 10 of whom are children. In addition, about 220 people in neighboring communities will use the bridge for year-round market access. Providing access to markets, health centers, and schools will together improve economic conditions and attract additional residents to the municipality.

The bridge is located in the Cochabamba region of Bolivia (Figure 1). According to the Project Social Evaluation report provided by the organization Engineers in Action (EIA) and prepared by Mr. Richar Galvez on May 7, 2022 (Appendix 5.4), the nearest pedestrian bridge is the Yana Gaga pedestrian bridge located 8 kilometers downstream of the site. Additionally, the site is 2 kilometers away from their nearest beneficiary community. The nearest town, Lopez Mendoza, is about 16 kilometers (about 9.94 mi) away to the west of the site, and the closest market, hospital, and school are 18 kilometers away to the east (Figure 1). In addition, the closest paved road to the site is Old Cochabamba Road Santa Cruz (Route 7).

[1] "When to visit Bolivia". Exoticca. Accessed December 5, 2023

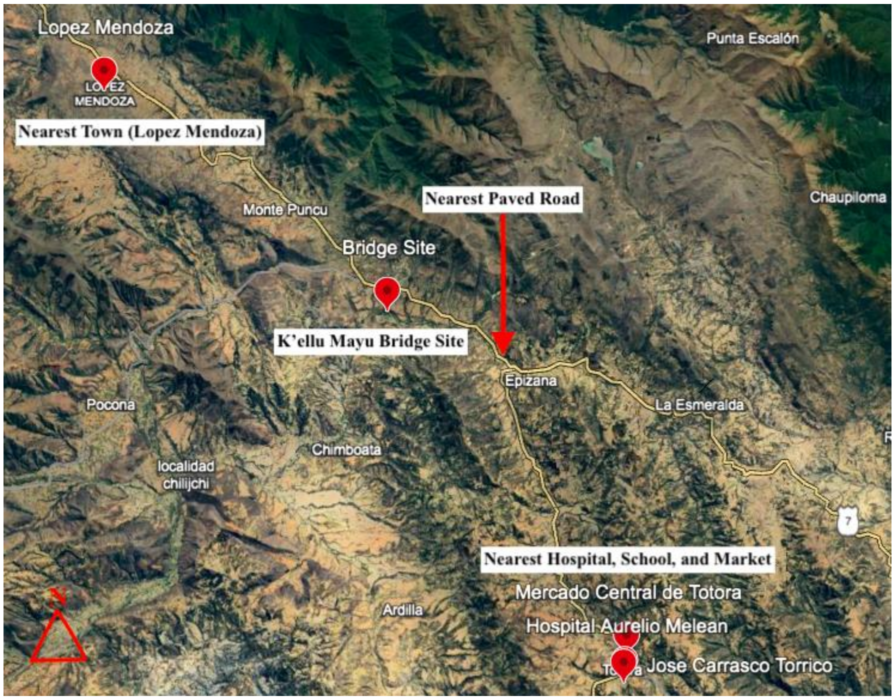

Figure 1. Bridge site location relative to other local resources

The bridge's proposed alignment is illustrated in Figure 2. According to EIA conventions, one should be facing in the direction of the river's downstream flow when determining which is the "left" and "right" abutment. The K'ellu Mayu river flows westward, meaning the left abutment faces the agricultural land and the right abutment faces unpaved vehicular road (Figure 2). This unpaved vehicular road is a different road than the paved Old Cochabamba Road and is located closer to the site.

Figure 2. Aerial view of bridge site

The Social Evaluation (Appendix C) provided by Engineers in Action describes the bridge site, allowing us to determine its vertical and horizontal clearances. In this description, they state that there are houses and agricultural land adjacent to the left riverbank, neither of which will affect or be affected by the bridge construction. The land on this side of the river is also described to be flat in both the longitudinal and transverse directions. There is little vegetation, including Sewenka plants and two Alder trees. On the river's right side, the land is sloped longitudinally and flat in the transverse direction. The vegetation on this side of the river is mainly native Kewinas trees. According to the Technical Evaluation provided by EIA (Appendix C), there are no obstructions such as adjacent structures, buried pipes, electrical lines, or drainage that need to be mitigated prior to the bridge construction.

Regarding material acquisition, Bridges to Prosperity developed a Bridge Builder Manual which dives into the organization's principles and strategies regarding pedestrian bridge projects (Appendix C). Importantly, the manual outlines the typical roles and responsibilities of key stakeholders in a bridge project (Table 1). EIA follows the same format as Bridges to Prosperity. Our project's material acquisition process will follow what is outlined in the table. The Municipal Government of Pocona, our site's local government, is responsible for heavy machinery work and the transportation of materials. The K'ellu Mayu community and Bridge Committee are responsible for building and maintaining the bridge. Lastly, EIA is responsible for acquiring materials that are not available in Bolivia.

Table 1. Key stakeholders' roles, responsibilities, and contributions table

Local Government		
Role	Responsibilities	Contribution
Lead project and support community	• Purchase of materials not available for collection • Transportation of materials • Heavy machinery work • Legal support	• Skilled labor • Purchased sand • Purchased gravel • Purchased stone • Purchased timber • Cement • Reinforcing steel • Fencing
Community and Bridge Committee		
Role	Responsibilities	Contribution
Build and maintain bridge	• Organization of work groups • Resolution of communiy related issues • Organize community contributions • Collection of local materials • Site Prep • Material Storage • Accomodation & food for any B2P staff on site	• Unskilled labor • Collected sand • Collected gravel • Collected stone • Collected timber
B2P or Other Qualified Partner		
Role	Responsibilities	Contribution
Facilitate and supervise project	• Engineering services/bridge design • Construction supervision • Acquisition of materials not available in country	• Construction drawings • Experienced construction supervisors • Cables and clamps • Steel towers (if applicable) • Steel crossbeams (if applicable)
Partner Organization		
Role	Responsibilities	Contribution
Support community in implementation of bridge project	Any of the responsibilities of the other three key stakeholders as agreed upon by all key stakeholders and based on organization's experience and strengths	Any of the contributions from other three key stakeholders dependent upon the agreed responsibilities

With regards to the K'ellu Mayu Bridge, components other than the cables will be constructed using locally sourced materials. According to the List of Materials, Services, and Project Financing Amounts that was provided by EIA (Appendix 5.10), the project's three material suppliers are Engineers in Action, the Municipal Government of Pocona, and the K'ellu Mayu Community. This material's list was stamped for approval by the Pocona Municipal Government as seen on the document (Appendix C). Per the list, EIA will supply galvanized steel cables, and other components such as galvanized clamps, tubes, and hooks. The Municipal Government of Pocona will be responsible for providing nearly all other materials, including Portland cement, tie wire, nails, screws, washed gravel, paint, and sand. Lastly, as stated in the project's Social Evaluation (Appendix C), the primary material that exists in the K'ellu Mayu river, community, and nearby communities is stone. Therefore, the K'ellu Mayu Community will supply stone for the bridge abutments. They will also provide the manpower to support the physical labor of constructing the bridge.

The Municipal Government of Pocona is transporting non-local and local materials to the site, which is accessible year-round by vehicle. On the right side of the river, there is no direct access to where the abutment will be placed. However, the community and the municipality will create an access route approximately 150 meters from the vehicular road. There is also direct access to the proposed left abutment location. According to the municipality, access to the left abutment will require cleaning of vegetation and other natural obstructions 100 meters from the vehicular road.

During bridge construction, vegetation and soil on both sides of the river will require removal. The construction team must be cautious when removing the existing vegetation and soil to reduce the risk of the river water being polluted by the removed materials. Also, the soil removed if not relocated properly could become suspended solids and pollute the air. Lastly, there will be environmental impacts such as water and air pollution during the mixing and pouring of concrete. The construction will have to be cautious during this process to prevent the concrete harming the surrounding land. The land on the right side of the river is owned by Mr. Sebastian Parra, who has agreed to the build. According to the social evaluation conducted by the community, Mr. Parra was present during the site survey. Based on the same evaluation, the owner is not listed, but the project will not disturb other private buildings. EIA has provided the signed confirmation documents from the K'ellu Mayu Board of Directors for the bridge to be constructed.

The goal of this project is to meet the K'ellu Mayu community's needs. To accomplish this goal, the team's approach to international development involves being empathic learners throughout this process. The team recognizes that this is an opportunity for the Pocona community to get safe access over the river throughout the year and for the capstone group to learn from Bolivian culture. We are grateful to be a part of the community building this necessary footbridge.

Geotechnical and Hydraulic Conditions

Before beginning the bridge's design, an overview of the site's geotechnical and hydraulic conditions was developed using materials that EIA provided. Figure 3 shows an aerial view of the Río K'ellu Mayu bridge site (coordinates -17.620584, -65.271513). Using EIA's naming conventions, the left riverbank is facing the agricultural land, and the right bank is facing the road.

Figure 3. Site overview

A topographic survey was completed by Mr. Richar Galvez on May 7, 2022. Mr. Galvez also conducted the site's Technical Evaluation (Appendix C). He provided a topographic profile of the site on AutoCAD, as well as site videos and photos. The original survey data and the AutoCAD survey profile generated were provided by EIA.

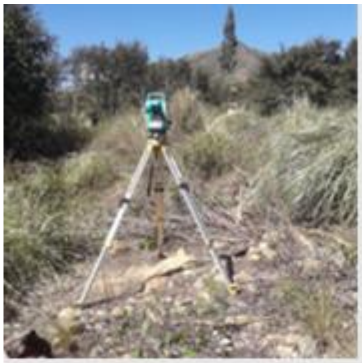

Figure 4. Total station survey

Figure 5. Dual grad prism pole

Figure 6. Survey marker **3.3**

Both sides of the river at the site are inaccessible by vehicles. Based on the Social Evaluation (Appendix A.4), the owner of the land on the left side of the river is not listed. To access the right side of the bridge, the community and municipality will build a 150-meter-long provisional road. This land is owned by Mr. Sebastian Parra. The left and right sides of the site will need vegetation cleared. The left side has little vegetation, while the right side has significantly more trees present. This is explained in greater detail in section 2.3. There are no known utility conflicts on our site.

Regarding existing soil conditions, the soil classification on the river's left side is sandy loam according to the Technical Evaluation (Appendix C). Per EIA's Bridge Program- Volume 2, the soil bearing capacity is 143 kPa or 20.7 psi[4]. According to EIA's Advanced Suspended Bridge Design Module, the soil has a safety factor of 2. The right-side soil is clay. The assumed soil bearing capacity on the right side is 95.3 kPa or 13.2 psi, and the factor of safety is 3.

The high-water line is the line at the riverbank where the water reaches during high water events (Figure 7). Per the Social Evaluation completed by Richar Galvez on May 07, 2022 (Appendix C), the river floods for approximately one day a year during the rainy season. The High-Water Line (HWL) was established by local elders from storm events they experienced in their lifetime. The HWL is 2732' above sea level. According to EIA's Bridge Program- Volume 2, all suspended bridge sites should be considered a gorge and will have a 3.0 meter freeboard[5]. Gorge flow only goes downstream quickly and rises. Freeboard is the minimum required height of the footbridge relative to the high-water line.

Figure 7. High-water line marking

Design

Standard Design

Figure 8 below illustrates an elevation view of the bridge's standard design. This shows the span and the abutments. A standard 3G60A abutment was chosen for the left riverbank. 3G60A consists of 3 tiers (3G60A) for a 40–60 meter span (3G60A) and a ground slope between 0 and 5 degrees (3G60A). A 1G60B abutment is designated for the right riverbank. A 1G60B abutment has 1 tier (1G60B) for a 40–60-meter span (1G60A) with a ground slope angle between 5 and 10 degrees (1G60B). A standard A4 anchor was used (Appendix A.9c). A standard T4 tower is used due to the 4-cable design (Appendix D.2). According to EIA's Bridge Program- Volume 2, "Empirical data has proven that bridges of up to 120-meters in span show no significant dynamic effects due to wind load. Therefore, no lateral stabilizing measures are considered in this suspended bridge design guide." Because our span is 44.50 meters this design did not consider wind loads.

A constraint of the location is the elevation difference of the lower left side to the right. A difference of 2.18 meters was measured.

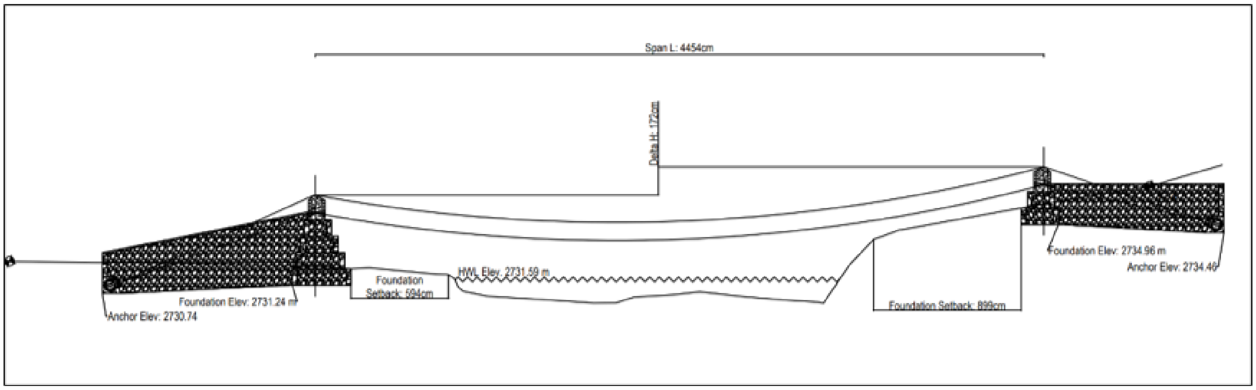

Figure 8. A dimensioned drawing of standard design bridge showing span and abutments

EIA Bridge Program- Volume 2, the footbridge is required to meet the below listed geometric evaluation criteria[7]:

- The maximum span shall not exceed 120 meters to avoid lateral stabilizing measures. The proposed footbridge spans approximately 44.50 meters (see figure 8).
- The foundation set-back from the edge of the riverbank to the top of the foundation must be at least 3 meters on either side due to soil conditions. 3 meters is the requirement under soil conditions, rock requires a different measurement. The setback reduces issues from erosion. The left side foundation setback is 5.94 meters, and the right-side setback is 8.99 meters. Start of the bank was assumed to be where the grade began sloping uniformly.t
- The foundation setback requires a maximum angle of friction of 35 degrees on each riverbank to reduce potential erosion issues. The proposed bridge has an internal angle of friction of 11.33 and 25.76 degrees on the left and right riverbanks respectively.
- The angle of the ground slope shall be 0 to 10 degrees. The ground slope is the uniform slope of the terrain past the bank. The proposed footbridge has an angle of 4 degrees on the left side and 10 degrees on the right. The slope angle approximates the ground slope. The difference in the height between the two towers is a serviceability design constraint to avoid a steep walkway. The height between the saddles shall not exceed 4% of the span. Under the standard design, the proposed footbridge The standard design has an elevation difference between the two sides of 3.86%.

Table 2. Proposed design geometric requirements summary

Variable	Value	Limit	Units	Checks
Left foundation setback	5.94	3.0	meters	OK
Right foundation setback	8.99	3.0	meters	OK
Left foundation behind angle of friction	11.33	35.0	degrees	OK
Right foundation behind angle of friction	25.76	35.0	degrees	OK
Span Length	44.54	120.0	meters	OK
Δ (delta) H	1.72	1.782	meters	OK
Left side ground profile slope β (Beta)	4.0	10.0	degrees	OK
Right side ground profile slope β (Beta)	10.0	10.0	degrees	OK
Left side number of tiers	3	3	tiers	OK
Right side number of tiers	1	3	tiers	OK
Freeboard	2.39	3.0	meters	NG

The required freeboard is 3 meters (river classified as gorge). The cable sag results in a freeboard of 2.39 meters. The proposed standard footbridge did not meet the freeboard requirement. This is discussed further in depth in Section 4.4 below.

Custom cable design sag values were provided by EIA as mentioned in the EIA Bridge Binder. Engineers in Action provided a hoisting sag value (h_2) of 4.08%, a dead load sag value (h_3) of 4.51%, and a live load sag value (h_4) of 5.51%. The live load sag value (2.39 meters) considers the theoretical maximum load case of dead load and live load and is 0.61 meters below the required minimum freeboard of 3 meters. The geometric requirement was not met.

The final geometric requirement is cable clearance. The dead load sag requires a 1.0-meter clearance from the bottom walkway cable to the top of the ground. If this requirement is not met, the live load sag is then considered with a requirement of 0.5-meter ground clearance. The proposed standard bridge does not meet the dead load sag ground clearance but meets the live load sag ground clearance of 0.5 meters.

The left and right anchors are EIA standard design anchors for bridges with span length, L, between 20 and 60 meters. The above ground soil angle beyond the anchor, β, is approximated to be zero as the existing ground slope beyond each anchor is less than 10 degrees. The height, H, of the active soil is the overall height of the ramp at the anchor. Less anchor sliding occurs due to no additional soil height about the top of the anchor.

This standard design outlined above does meet the geometric constraints outlined in the EIA Bridge Program Volume 2 – Design textbook. Therefore, the sag clearance requires a custom design. Increasing the height of the left foundation allows for this clearance. Proposing a 0.5-meter height increase of the foundation on the left foundation per Section 5.8 of EIA's

Bridge Program Volume 2 moves the cable sag closer to the required clearance. The manual states the following:

> "Consider raising the anchor 0.5-1.5 meters while maintaining minimum embedment for the abutment components. Note that an extra access ramp will be necessary to get from ground level onto the approach ramp if this is high above the ground."

An extra ramp at the end of the left abutment is required due to this adjustment. We are limited in increasing the foundation's height to avoid needing a long extra ramp. EIA defines a long extra ramp that exceeds 4 meters. An extra ramp Additional analysis will be performed for Review Call #2 regarding the custom design.

Table 3. Summary of factors of safety

Design Check	FS Required	High Side FS	Low side FS
Cable Design	3	3.567	
SuspenderDesign	5	17.551	
Tower Overturning	1.5	6.417	6.268
Bearing Pressure	2 (right), 3 (left)	13.791	3.436
Anchor Sliding	1.5	2.339	3.959
Anchor Uplift	1.5	1.489	1.403

Per each component:

1. Abutment
    a. 3G60A: Selected as the bridge is between 40 to 60 meters. Due to the lower elevation on the left side, 3 tiers would reduce the total elevation difference between the two tower saddles. Placed under a ground slope of less than 5 degrees (Appendix A.9a).
    b. 1G60B: Selected as the bridge is between 40 to 60 meters. Due to the lower elevation on the left side, 1 tier was placed on the right to not raise the elevation difference between the two abutments (Appendix A.9b).
2. Anchor
    a. A4 anchors were chosen as a result of the span length being between 20 to 60 meters (Appendix A.9c).
3. Tower
    a. Cable calculations resulted in a requirement of 4 cables, 2 walkway and 2 handrail cables. Therefore, the T4 tower choice was made (Appendix A.9d).
4. Walkway Details

a. Cable selection was provided by EIA; 6x19 Galvanized steel cable with a diameter of 1-⅜”, which will require a 10% reduction in future calculations

Because of the standard design calculations, as well as the geometric sag issue, the anchor uplift check did not pass all factor of safety checks. Therefore, the team proposed alternative custom footbridge design will be used for the Rio K’ellu Mayu’s footbridge.

Custom Design

The custom design was derived from the freeboard requirement and anchor sliding failing. In the standard design, the bridge did not meet the required freeboard of 3 meters. The standard design did not meet the anchor uplift factor of safety requirement. To resolve the low sag cable, the team decided to decrease the span length as it is directly proportional to increased sag values. The site location and geometric conformance restricted potential adjustments to the design. The custom element involved increasing the tower height elevation of the left abutment. This was achieved by adding 0.5 meters to the foundation to raise the bottom of the cable to meet the freeboard. The backstay cables, ramp, and fill were adjusted to meet the new height of the tower. The increased foundation height was also intended to address issues with the anchor uplift. Figure 9 below illustrates the bridge’s custom design.

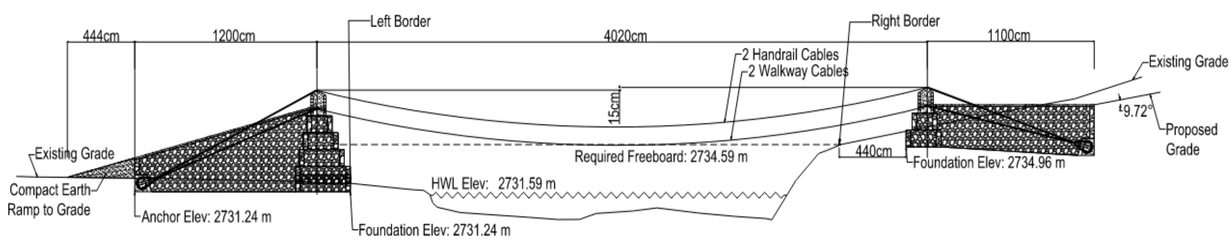

Figure 9. A dimensioned drawing of custom design bridge showing span and abutments

The changes outlined above allowed the design to provide the sufficient requirements needed to pass all but two design checks. Due to a combination of calculation errors and calculation checks late in the design process, it was discovered that the left anchor uplift and tower overturning checks did not meet the required factors of safety with the increased tower height and resulting backstay cable angles of the custom design. The shorter span of 40.2 meters (see Figure 9) decreased the sag values. Construction, hoisting, and dead load sag all rest above the required 3 meters of freeboard. The live load sag, which represents the worst-case scenario of all loads, falls slightly under by less than 10cm but within tolerance. The change in elevation from one end of the tower to the other is 0.65 meters, reducing steepness when walking across the footbridge. This change will improve serviceability for the Pocona community. The additional 0.5 meters in the foundation resulted in a custom 3G-60B abutment (see Appendix D.2). The increased height of the left abutment required an extra approach ramp to be able to access the approach ramp on the left side. The standard right abutment remained unchanged.

As outlined in the Bridge Binder Volume 2 Design Section 2.1, the primary objective of the footbridge is to provide public safety. Secondary aspects include durability, serviceability, maintainability, constructability, and economy.

1. Safety:
   Refers to the priority of structural integrity and user safety. There is little tolerance for failing to meet the minimum safety requirements.

2. Durability:
   Material selection and design should be selected to preserve the footbridge's usage over a long time. Design selections should protect the structure from weathering and frequent usage.

3. Serviceability:
   Deformations within the structure must be reduced to provide user comfort when crossing the bridge. Examples include reduced swaying and minimal slope across the span of the footbridge.

4. Maintainability:
   The lifespan of the structure should be designed with accessible maintenance points and economical solutions when replacement is needed.

5. Constructability:
   The design must also provide a safe means to erect the structure. Any structure is most vulnerable under construction and safety measures must be accounted for when designing the footbridge.

6. Economy:
   Engineers in Action believe in locally sourcing most materials to drive down the overall cost of the project. Materials include stone, and sand, but not the steel cables. Providing an economical solution will ensure that the community can have a footbridge.

7. Aesthetics:
   After the completion of the footbridge, the community is encouraged to decorate the bridge providing an opportunity to illustrate their culture so long as it does not interfere with the integrity of the bridge.

The original standard design failed to meet safety and serviceability requirements. Meeting the required freeboard provides a buffer from the highest water line to avoid the bridge sagging too close to the water. This buffer aims to prevent damage caused by the flowing water. The slope across the footbridge was also close to the maximum allowable slope, providing users with an uncomfortable trek across the bridge. The custom design created a large elevation difference from the ground to the approach ramp thus requiring an extra approach ramp.

The left anchor is standard. The design included extra anchor uplift capacity. Masonry sidewalls and backwall provided an increased overturning moment. That said, the anchor uplift factor of safety of 1.5 is still not satisfied.

The left abutment is a custom design and is illustrated in Figure 10. The left side of the site layout provided options for the abutment's design as the ground slope did not surpass the maximum 10 degrees.

The span had to remain shorter to reduce the sag values. The left abutment is placed 8.99 meters from the left riverbank. The customization added 0.5 to the foundation added 0.5 meters to the overall height of the abutment (see Appendix D.2 and Figure 10). This was done to raise the overall cable sag to meet the 3-meter freeboard requirement. Increasing the height of the foundation past 0.5 meters would require far more materials on the left abutment, a steep approach ramp, and a much longer extra approach ramp. To provide a more conservative approach, the abutment was modified to 3G-60B as the ground slope angle exceeded 5 degrees in multiple places on the left side.

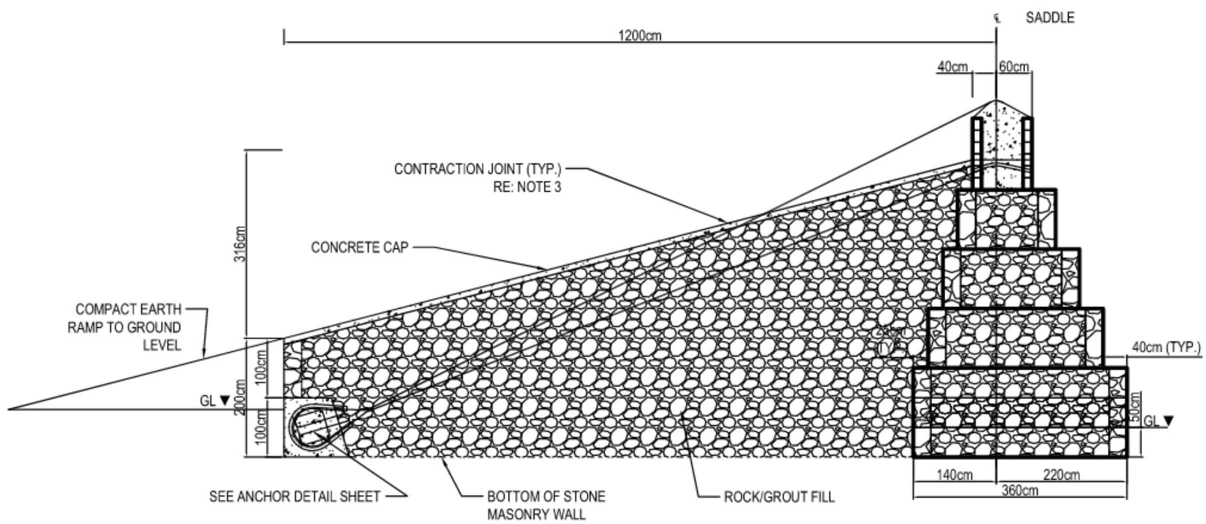

Figure 10. A dimensioned and labeled drawing of the custom left abutment.

The right anchor is standard. The design included extra anchor uplift capacity. Masonry sidewalls and backwall provided overturning moment. The anchor uplift factor of safety of 1.5 is satisfied.

The right bank has a steeper ground slope. The location of the abutment was determined by the ground slope angle. For a standard design, the ground slope required an angle of 0 to 10 degrees. The smallest angle was approximately 10 degrees and was found 5.94 meters away from the right bank. The right abutment is a standard 1G-60B abutment (see Appendix D.1). Due to the sloped nature of the layout, the right side will require heavy excavation. The sloped terrain will also require drainage to avoid settling on the abutment.

The standard design geometry of the Rio K'ellu Mayu footbridge provides an optimal layout for the site. Thus, the layout was not changed from the standard to the custom.

Table 5: Geometric Conformance Summary

Parameter	Value	Requirement
Span length, L	40.2 m	< 120 m
Height Differential, ΔH	0.65 m	< 1.61 m
Freeboard	2.94 m	> 3 m
Left Abutment Offset	5.94 m	≥ 3 m
Right Abutment Offset	8.99 m	≥ 3 m

The team considered alternative customizations to satisfy the freeboard. The right abutment was increased to a 2-tier system. Increasing the tower height raised the lowest point on the live load sag curve. This adjustment to the right abutment meant a large elevation change that did not meet the serviceability check. The walkway would have been far too steep. EIA suggested that the foundation be increased from 1 meter to 1.5 meters. Another consideration was increasing the foundation past 0.5 meters. The increased elevation change would result in a larger extra approach ramp and even higher backstay angles. The design already requires significant approach ramp volume. Another possibility the team considered was a longer span. The longer span would provide a larger factor of safety for the serviceability check but again would increase the sag value, which was already failing to meet the required freeboard.

The Rio K'ellu Mayu followed the Engineers in Action Bridge Binder procedure for the calculations. As stated by the EIA Bridge Binder, any Bolivia project will receive custom sag values. EIA provided the team with custom sag values (see Table 7 and Figure 11). To meet the required factor of safety for anchor uplift, the team decided to recalculate the forces of the abutment by completing the Tier 2 checks. The Tier 1 checked underestimated the total fill of the abutment thus decreasing the total vertical forces acting on the ground. The construction analysis for anchor sliding and uplift provides a design check for the footbridge while under construction. The anchor sliding check under construction can provide a recommendation of when to hoist the cables. The left abutment can hoist the cables with 10% of the ramp walls constructed and no backwalls. The right abutment can hoist the cables with 80% of the ramp walls constructed and no backwalls to provide the proper forces so that the footbridge can be safely erected.

Table 6: Factors of Safety (FS) of Custom Design

Failure Type	**Minimum FS**	**FS Achieved Left Side**	**FS Achieved Right Side**
Cable Design	3.0	5.66	
Suspender Design	5.0	26.33	
Bearing Pressure	3.0 (left), 3.0 (right)	3.04	13.52
Tower Overturning	1.5	1.28	1.59
Anchor Uplift	1.5	1.01	2.23
Anchor Sliding	1.5	4.36	4.17
Construction FS			
Erection Hook	3.0	4.12	4.03
Anchor Sliding Construction	1.5	1.88*	1.54**
Anchor Uplift Construction	1.5	7.48	11.35

* *The design check accounts for 10% of the ramp walls to be completed under construction and no backwalls. All other components are accounted for.*

** *The design check accounts for 80% of the ramp walls to be completed under construction and no backwalls. All other components are accounted for.*

Table 7: Custom Sag Values Summary

Sag Type	**Sag Value (meters)**	**Design f Values (meters)**
Construction (h1) 3.00%	1.21	0.90
Hoisting (h2) 4.08%	1.64	1.33
Dead Load (h3) 4.55%	1.83	1.52
Live Load (h4) 5.51%	2.22	1.90

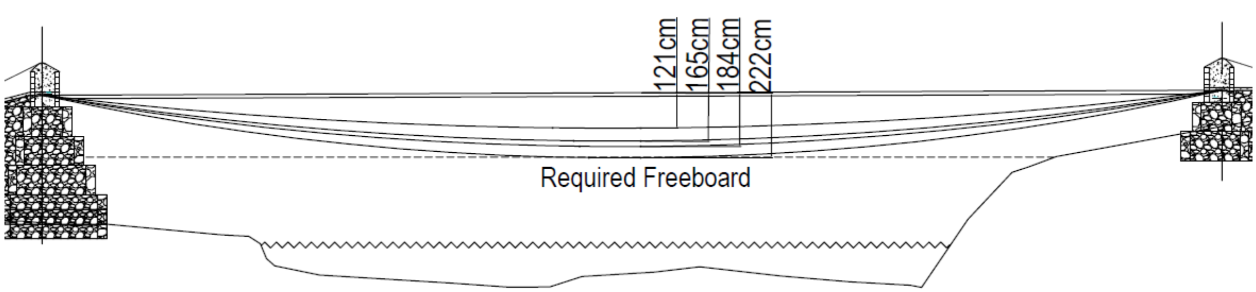

Figure 11. Illustration of the four sag values in profile view

Uplift

Initially, the anchor uplift did not meet the standard design factor of safety. The Tier 1 calculations conservatively estimated the total weight of the abutment thus reducing capacity. Tier 2 aimed to provide a more accurate abutment volume using the masonry weight. This change in calculation coupled with increased total fill volume that resulted from the increased foundation height was expected to cause the left side to pass, but the increased backstay angle caused a greater upward vertical force on the anchor and caused it to fail. The right side was also failing in the standard design. With Tier 2 calculations, the anchor sliding on the right achieved the factor of safety required.

Construction

The construction sag was the final check. This calculation provides a check for when hoisting the cable. An erection hook is connected to the anchor. The hook is connected to a chain winch that is attached to the cable when hoisted. When hoisting the cables under construction, the winch and erection hook bear the self-weight of the cable and are settled at the desire sag. In the construction analysis, the maximum capacity of the erection hook is 29.4 kN. The maximum force in the cables due to self-weight only as it is in construction, cannot exceed the capacity of the erection hook. This will ensure that the anchor will not slide or cause an uplift. The cables do not exceed and therefore 4 cables can be safely utilized under construction. The construction analysis also provides a recommendation for when to hoist the cables. The construction anchor uplift and sliding analysis can determine how much fill can be placed to safely hoist the cables. On the left side, 10% ramp wall fill and no backwall will be sufficient. On the right side, 80% ramp wall fill and no backwall will be sufficient (See Appendix C, Construction Sag). This recommendation will be accommodated in our construction schedule.

See Appendix C for an in-depth look at the design calculations.

Load Assumptions:

Permanent Load:
Dead Load (DL): 1.05 kN/m

Transient Load:
Live Load (LL): 4.07 kN/m
Reduced Live Load (LL): 3.89 kN/m

Primary Load Combination:
Distributed, Wc Primary (DL + LL): 4.93 kN/m

Future Design Considerations

The current custom design did not meet the tower overturning and anchor uplift factors of safety on the left abutment (see Table 6). After the second review call with Engineers in Action, discrepancies between EIA's calculations and the UVA team's calculations were brought to light, revealing a need for design changes due to the following reasons. Regarding anchor uplift, the backstay angles of the cable attached to the anchor were designed to be too steep. The steepness resulted in greater vertical component of the combined forces of the cables which in turn would cause the anchor to uplift. The steep backstay angle also resulted in tower overturning to not meet its required factor of safety. To address these issues in a new design iteration, the team would consider raising the left anchor or extending the length of the abutment. The raised anchor would decrease the backstay angle, decreasing the vertical force acting on the tower from the cables, and increasing the nominal capacity. Potential issues with raising the anchor would include decreasing the total volume of the fill for the abutment, decreasing the total downward force acting on soil, and would present issues with the bearing pressure capacity. Extending the abutment length would also decrease the backstay angle and solve the issue similarly to how raising the anchor would. The concern with extending the abutment length would be the required volume of materials would increase, driving the cost of the project higher. A possible solution would include a combination of raising the anchor and increasing the abutment length.

Construction

<u>Bridge Construction</u>

Table 8 below outlines the estimated Bill of Quantities (BOQ) for all the variable materials in our custom design. The list of materials and their corresponding quantity estimates were developed based on the following recourses provided by EIA: the EIA Bridge Program: Volume 2 Design Manual[7], the BP- 301 Construction Management course on Bridge EDU, as well as a sample BOQ for Bolivia found in the EIA Bridge Program: Volume 2 Design Manual[8]. Because these were the references given for developing the BOQ, the UVA team decided to use the same contingency factors as what was used in these references.

Table 8: Bill of Quantities (Variable Materials)

Bill of Quantities (Variable Materials)									
Description	Units	Left Abutment	Left Tower	Walkway	Right Abutment	Right Tower	Total Needed	Contingency Factor	Total
CABLE 1-3/8" Cable 1-3/8"	m			321			321	1.00	321
CLAMP 1-3/8" Abrazadera Forjado 1-3/8"	unit			56			56	1.05	59
TIMBER Madera Dura (200x20x5cm)	unit			101			101	1.08	109
TIMBER NAILER Madera Dura (100x20x5cm)	unit			41			41	1.08	45
CROSSBEAM Perfil U 4x5, 4 lb/ft	6m bar			41			41	1.04	43
SCREW (timber) Tirafondo 3/8" x 3 1/2"	unit			503			503	1.25	628
SCREW (timber nailer) Tirafondo 3/8" x 2"	unit			165			165	1.18	194
FENCING Malla O. Galv. N° 10 Alt 1.2m	m²			96			96	1.05	101
ROCK Piedra Bolón	m³	141			46		186	1.05	196
TUBING Manguera de Succion de 3"	m	6			6		12	1.10	13
CEMENT Cemento Portland (50 kg bolsa)	50kg bag	180	7		86	7	280	1.13	317
SAND Arena	m³	18	3		8	3	32	1.09	35
GRAVEL Grava Lavada	m³	4	3		4	3	14	1.05	15
REBAR (#4) Acero Corrugado 1/2" (12mmx12m)	12m bar	3			3		7	1.05	7
REBAR (#5) Acero Corrugado 5/8" (16mmx12m)	12m bar	1	2			2	4	1.05	4
REBAR (#6) Acero Corrugado 3/4" (16mmx12m)	12m bar	2			2		5	1.05	5
REBAR (#3) Acero Corrugado 3/8" (10mmx12m)	12m bar		1	13		1	16	1.05	17
PLASTIC HOSE Tuberia de Alta Densidad de 2"	m		4			4	8	1.10	9
BRICK Ladrillo Gambote 18H 25x12x6cm	unit		545			545	1090	1.02	1112

After calculating the BOQ, the UVA team compared the UVA estimate to the materials estimate provided by our in-country manager (found in Appendix 8.1) to determine if there are any major discrepancies. The comparison is illustrated in the table below (Table 9). Materials with a higher UVA estimate are highlighted in red, and materials with a higher EIA estimate are highlighted in yellow.

Table 9: Comparison of UVA Team's Estimate to In-Country Manager Estimate

Bill of Quantities (Variable Materials)					
Description	Units	UVA Estimate	In Country Manager Estimate	Difference (UVA - Manager Estimate)	Percent Difference
CABLE 1-3/8" Cable 1-3/8"	m	321	302	19	6
CLAMP 1-3/8" Abrazadera Forjado 1-3/8"	unit	59	44	15	25
TIMBER Madera Dura (200x20x5cm)	unit	109	115	-6	-6
TIMBER NAILER Madera Dura (100x20x5cm)	unit	45	48	-3	-8
CROSSBEAM Perfil U 4x5, 4 lb/ft	6m bar	43	12	31	72
SCREW (timber) Tirafondo 3/8" x 3 1/2"	unit	628	629	-1	0
SCREW (timber nailer) Tirafondo 3/8" x 2"	unit	194	200	-6	-3
FENCING Malla O. Galv. N° 10 Alt 1.2m	m²	101	114	-13	-13
ROCK Piedra Bolón	m³	196	220	-24	-12
TUBING Manguera de Succion de 3"	m	13	20	-7	-52
CEMENT Cemento Portland (50 kg bolsa)	50kg bag	317	320	-3	-1
SAND Arena	m³	35	80	-45	-129
GRAVEL Grava Lavada	m³	15	12	3	19
REBAR (#4) Acero Corrugado 1/2" (12mmx12m)	12m bar	7	4	3	42
REBAR (#5) Acero Corrugado 5/8" (16mmx12m)	12m bar	5	4	1	23
REBAR (#6) Acero Corrugado 3/4" (16mmx12m)	12m bar	5	2	3	62
REBAR (#3) Acero Corrugado 3/8" (10mmx12m)	12m bar	17	19	-2	-14
PLASTIC HOSE Tuberia de Alta Densidad de 2"	m	9	4	4	50
BRICK Ladrillo Gambote 18H 25x12x6cm	unit	1112	920	192	17

Upon comparing the two quantity estimates, the following differences were noted. The UVA team recognizes that there are some major discrepancies, however this is mainly because our design is quite different than the initial design assumed upon conducting the project's Technical Survey Form (Appendix A.5).

1. Number of Crossbeams
    a. The UVA estimate of 42.85 6m crossbeam bars is higher than EIA's estimate of 12 6m crossbeam bars (about a 72% difference). While this is a large discrepancy, it is likely because the initial estimate for the bridge's span was 20-100m as stated on page three of the Technical Survey Form (Appendix A.5). The lower limit of this estimate is much smaller than the actual bridge span of 40.204, which could have led to an underestimate of the number of cross beams needed.

2. Quantities of Rock and Sand
    a. The UVA estimate for the volume of rocks is 50.8% lower than the EIA estimate.
    b. The UVA estimate for the volume of sand is 142.77% less than the EIA estimate. Despite both the rock and sand quantities not aligning with the in-country manager's estimate, it should not cause any material acquisition or economic problems as we are below and not above the estimate provided by the in-country manager. In addition, the in-country manager's estimate likely provided a larger estimate as it is better to have more rocks and sand than not enough. A suggestion could be to meet halfway between the UVA and EIA estimates. This allows us to meet our requirements and reach contingency factors in case more material is needed.

3. Rebar Quantities
    a. The UVA estimates for the total quantities of #4 and #6 rebars are higher than the EIA estimate. The UVA's BOQ calls for 6.87 12m bars of #4 rebar while the in-country manager's estimate calls for four 12m bars. In addition, UVA's BOQ calls for 5.20 12m bars of #4 rebar while the in-country manager's estimate calls for two 12m bars. This difference can likely be because the initial estimate for the bridge's span was 20-100m as stated on page three of the Technical Survey Form (Appendix A.5).

Table 10 outlines a comprehensive list of equipment and tools necessary for the bridge's construction.

Table 10: List of Equipment and Tools

Tool Name	Construction Layout	Excavation	Foundation & Tiers	Towers	Anchor & Cables	Approach Ramp	Cable Hoisting	Walkway
Shovels		x	x	x	x	x		x
100-meter measuring tape	x	x		x	x	x	x	x
Level	x	x	x	x	x	x	x	
String Line	x	x	x	x	x	x	x	
Plumb Bob	x	x	x	x	x	x		
Spray Paint	x	x	x	x	x		x	
Stakes	x	x	x					
Machete	x							
Hammer	x	x				x		x
Auto level, tripod, and survey rod	x	x						
Tamping rod			x			x		
Excavation bars		x						
Picksaxe		x			x	x		
Wire cutters					x			x
Mallet					x			
Carpentry Nails		x						
Buckets		x		x	x	x		x
Water tube		x						
Masonry tools				x	x	x		x
Construction square				x	x	x		
Grinder				x				
Saw				x				x
Saw blades				x				
Hacksaw				x				
Angle grinder				x				
Angle grinder discs				x				
Generator				x				
Cement Mixer					x	x		x
Winch							x	
Torque wrenching							x	x
Sockets							x	x
Automatic level and tripod							x	
Duct tape							x	
Drill								x

The detailed excavation drawings are attached in Appendix E.1. The construction process for the abutment includes excavation for the foundation, ramp walls and gravity anchor. These plans provide dimensions for both Phase 1: Foundations and Phase 2: Approach Wall and Anchor. Each set of drawings covers elevation and plan views for both the left and right abutments.
Benching instructions are outlined in the OSHA handbook, (1926 Subpart P). The soil on the site is described in Appendix A.5, Technical Survey Form, the soil on the left and right side were classified as clay. By OSHA 1926 Subpart P, the maximum horizontal to vertical slope is ¾:1. Per EIA guidelines, benching is required for required if the excavation depth exceeds 1.5m. Spoil piles resulting from excavation must be at least 1 meter away from the edge of the excavation.

The detailed construction schedule is attached in Appendix B. The construction schedule includes the tasks, professional personal, and student roles needed for the week. Additionally, the schedule includes the materials needed for each week. The construction schedule was created from the template provided by EIA. Our schedule considers the accessibility to both sides of the river and decided that it would be best for larger tasks to be completed in full before it is started on the other side to reduce excessive movement of materials from being transported side to side.

Quality control will be the key to successfully constructing the K'ellu Mayu Bridge. Quality control processes are to be performed by the designer or the construction team to ensure that each construction phase is performed according to EIA Bridge Program: Volume 3 Field Operations[9], and that the bridge meets all design requirements.

Each part of the construction sequencing has its own specific quality control form that must be completed by the construction manager, and each quality control point must be signed by the Construction Manager and by the Technical Supervisor. Quality control activities listed in these forms include construction procedures, checking dimensions, sampling and testing, and material handling. All quality control forms can be found in Appendix E of this report. In addition, concrete quality control must be performed by the Quality Control Manager, who should oversee the mixing and proportioning of the concrete. Included in these forms are quality control photos, which must be taken during designated steps of the construction process. The quality control photos are all outlined in a checklist (Appendix E.3k). If the Quality Control Manager cannot be present, the Construction Manager is responsible for overseeing quality control operations.

Lastly, it is important to recognize that some quality control activities might be completed before the volunteer team arrives at the site. However, it is still necessary for all quality control points and photos to still be checked again upon the team's arrival.

The following table compiles all the major quality control concerns at each stage of construction using the information listed in Volume 3 of the bridge builder binder and the quality control forms.

Table 11: Major Quality Control Concerns

Construction Stage	**Major Quality Control Concerns**
Construction Layout	• Establish centerline • Establish foundation locations with respect to survey markers • Verify span length • Verify heigh difference between abutments • Confirm all dimensions with respect to design drawings and correct any discrepancies
Excavation	• Record bottom of excavation elevations for left and right foundations • Record bottom excavation elevations for left and right anchors • Record soil types for left and right anchors • Confirm all dimensions with respect to design drawings and correct any discrepancies • Provide drainage is water seeps into excavation

	• Record critical as-built dimensions
Foundation and Tier	• Ensure excavation is clear of debris • Check for water seepage and provide drainage if needed • Check all foundation and tier dimensions against drawings with emphasis on orientation relative to bridge centerline • Stone masonry perimeter wall must be constructed plumb and within an hour of mixing mortar • Use range of stone sizes when filling foundation and reach fill density noted in design • Fill must not exceed three lifts per day and must not include soil • Record all as-built elevations and dimensions
Tower	• Minimum concrete dimensions must be met • Steel reinforcing cage must be placed centered in the column and proper clearances must be kept on all sides • Handrail cable saddle must be properly aligned with bridge centerline • Verify vertical distance between handrail cable and walkway cable support points • Verify span length and elevation difference at top of tiers • Check all dimensions against design drawings and with emphasis on orientation relative to bridge centerline • Level cable support points across the walkway hump and between towers • Record as-built dimensions and distances
Anchor and Cable Preparation	• Concrete must be placed within an hour of mixing • Wet concrete surface if too much time elapses • Prevent debonding between layers if construction joint is required • Verify excavation dimensions and elevations before anchor construction • Check for water seepage • Verify anchor dimensions with design drawings with an emphasis on orientation relative to bridge centerline • Record as-built length, width, and height of each anchor beam • Record as-built number of clamps per cable and spacing of clamps at fixed anchor • Check tolerance limits for as-built dimensions
Approach Ramp Stage 1	• Verify excavation is free of debris and water • Verify wall thickness and outside-to-outside ramp width at base of walls • Verify that each stone masonry wall is constructed plumb • Ensure mortar is used within one hour of mixing • Verify all ramp wall dimensions against design drawings to ensure within tolerance • Record as-built dimensions of ramp walls

Cable Hoisting	• Recalculate and record f values using as-built elevation difference and as-built span • Ensure survey equipment is calibrated • Verify cable positions at least 24 hours after initial hosting • Verify cable positions again 24 hours after sag is set before decking • Ensure all cable positions are within tolerance • Ensure proper size and number of clamps are installed at the appropriate spacing • Coat cables inside approach ramp with tar or mastic to prevent corrosion • Record as-built number of clamps per cable and spacing between clamps, and all other critical as-built dimensions
Approach Ramp Stage 2	• Verify ramp wall thickness • Ensure interior fill only constructed with stone and gravel and no soil • Ensure voids are filled and cover fill with layer of concrete slurry • Ensure no more than 3 lifts per day of fill • Ensure design fill density is achieved • Ensure cables aren't damaged when filling approach ramp • Ensure cables and clamps are left fully exposed • Record as-built dimensions of approach ramp and ramp walls
Walkway	• Verify crossbeam, nailer, decking board, and suspender dimensions • Ensure each component of walkway, crossbeams, nailers, decking boards, suspenders, and fencing are installed per drawing set • Confirm crossbeam spacing and decking board dimensions • Confirm fencing is fixed to edge of decking boards • Measure level of deck at midspan, and adjust level of deck if tilted • Record as-built dimensions for crossbeams, nailers, decking boards, and locations of pre-drilled holes • Confirm as-built dimensions with tolerance limits
Approach Ramp Stage 3 and Completion	• Record as-built dead load sag of bridge • Mark handrail cables at the centerline of saddle to monitor cable movement in the future • Ensure area is free from all hazardous material after bridge completion • Grade surrounding area so bridge is easily accessible • Ensure water will not drain toward the structure • Revegetate area as much as possible to reduce erosion around abutment • Conduct final check of as-built drawing dimensions and survey the bridge's design sag post-decking

To identify and mitigate quality control concerns, it is necessary to perform all quality control activities and complete all quality control forms. These checks will bring to light any errors in a timely manner to make sure that if problems arise, they can be corrected without causing significant delays or costs. In the case that there are issues with the quality of work, it is the Quality Control Manager, technical supervisor, and construction manager's responsibility to identify such issues and make correctional changes. Between the quality control forms, a photo inventory that documents each phase of construction, and as-built dimensions marked on the design drawings, these records will confirm that the bridge was built within accepted construction tolerances and are necessary for future inspection of the bridge.

Conclusion and Discussion

Upon completing our design and developing a construction plan, it is important to note the following design and constructability elements that are expected to be challenging during the K'ellu Mayu Bridge's construction.

Material costs

One change made in the bridge's custom design was to increase the number of walkway cables from two to four. While this change was made to ensure that the bridge remains upright while under construction, it ultimately increases the project's total cost. This poses a challenge with material acquisition and funding as we will need to purchase, deliver, and store more steel for our design. It is important to recognize this design element as a challenge as steel is the most expensive material needed for the bridge's construction and is the only material not locally sourced.

Extra Approach Ramp

To make the bridge's approach ramp accessible to all members of the community, such as young children and the elderly, the design calls for an approach ramp with a gradual slope as opposed to a steep ramp. To achieve the gradual slope, however, the ramp must be 4.5 meters long. The longer ramp will require more materials as well as a longer construction time. The ramp will maintain the original slope of the existing approach ramp on the abutment. According to Bridge EDU Advanced Suspended Bridge Design course, in Bolivia "project materials account for everything through the back of the anchor and DO NOT include an extra access ramp behind the anchors". Therefore, it is suggested that this access ramp be built using compacted dirt and that the ramp's maintenance be designated as the community's responsibility.

Site access

As discussed in sections 2.6 and 3.3 of this report, both sides of the river of the bridge site are accessible by vehicle, but the right abutment's location is not directly accessible. In response, the community will need to build a provisional road. In addition, it is important to note that the owner of the left side of the river is not listed, and that clearing vegetation will be necessary to access the where the left abutment will be built. Enacting these measures will be challenging but necessary, as without them accessibility to the site and bringing materials to the site will be impossible. In addition, because moving back and forth between the right and left abutments is inconvenient, it is important to minimize the movement of people and materials as much as possible to save time. This practice is illustrated in the way construction activities are ordered in our schedule.

Excavation Drainage

A unique feature of our site's topography is that the elevation of the left riverbank is significantly lower than that of the right riverbank. During construction, the likelihood of hitting the water table will be higher when excavating the left abutment. Therefore, groundwater seepage might result in the need for drainage measures such pumping out water might be necessary.

Appendix A
Updated Gantt Chart schedule

Appendix B
See page 7 for changes from the standard design to fit location restraints.

Appendix C
Bridges to Prosperity Bridge Builder Manual
Engineers in Action Bridge Manual Volume 2
Engineers in Action Site Documents

- Social Evaluation of the Project pg. 10 - 15
- Technical Evaluation pg. 16 - 18

The custom design for the Rio K'ellu Mayu bridge satisfies the EIA Bridge Program Vol. 2 - Design requirements. The team's design process was guided by this document and by EIA Education modules (Suspended Bridge Design – EIA 201, Advanced Suspended Bridge Design – BP211). Custom design of the left abutment with the standard right abutment, walkway, crossbeam, and tower details meets the following design requirements set forth by EIA:

1. Cable design
2. Suspender design
3. Tower Overturning
4. Bearing pressure
5. Anchor Sliding
6. Anchor Uplift

The calculation package supports the design's requirement checklist.
The design considers geometric restraints EIA Bridge Program Vol. 2 – Design and the results of the onsite survey. Factors include:

1. Foundation setback
2. Angle of friction
3. Span
4. Change in height between abutments
5. Profile slope
6. Number of tiers
7. Freeboard

These design restraints are discussed further in the Design Section of the report.

FUNDACIÓN INGENIEROS EN ACCIÓN

Social Evaluation of the Project

Advisor: Richar Galvez. Date: May 7, 2022
(Full name)

1. Location information

-Name of proposed bridge: K'ellu Mayu River Pedestrian Bridge.
(Must be a unique name for this crossing, not just the name of the river or community)

-Name of the community or communities that are direct beneficiaries: K'ellu Mayu.

- Name of the municipality: Pocona.
- Department Name: Cochabamba.
- River name: Río K'ellu Mayu.
- Latitude Longitude: -17.620584°. -65.271513°.

2. Information about the site

- When is the site accessible in a light vehicle with 4x4 drive?

☐ Never ☑ All year round ☐ Sometimes: After the rainy season

-Name of the nearest paved or cobbled road:
Old Cochabamba - Santa Cruz road.

- Name of the nearest town: Lope Mendoza.
- Travel time from the site to the nearest town: 15 minutes by light vehicle.
- Quality of cellular service: ☐ Not existing ☑ In some places ☐ Good
- Cellular service companies: Entel.
- Describe the accesses for the transfer of materials to the right side and the left side of the river: eitherLeft: There is no access to the place where the abutment will be located, but materials can be reached by vehicle to the place where the abutment is located. You will only need to do a clearing approximately 100 meters from the vehicular path.

  eitherRight: There is no access to the place where the abutment will be located, but the community and the municipality are going to enable a provisional road approximately 150 meters from the vehicular path.

-What local materials exist in the river, in the community, or in nearby communities?

☑ Stone ☐ Sand ☐ Fine wood
☐ Wood for formwork ☐ Record ☐ Others: ____________

-Are there trees, structures or property that would be affected by the construction of the bridge? ______________________________

-General site information and accessibility: On the left there is agricultural land, but the land will not be affected; The climate in this place varies, in summer it is hot and in winter it is cold; The road is passable for single trucks and lightweight vehicles.

3. Social Information

-Number of direct beneficiaries of the bridge: 190 inhabitants.
(People for whom access is consistently blocked)

- Number of boys and girls who would benefit directly: 10.

- Number of women of reproductive age (15 – 49) who would be beneficiaries: __________

-Population of all direct and indirect beneficiary communities: 220 inhabitants.
(Total population of all communities that would potentially use the bridge, including those directly served)

-Primary and secondary economic activities: Agriculture and animal husbandry.

- Main crops: Potatoes, corn, wheat, peas, broad beans, barley, peaches, and apples.

- Animal husbandry: Cow and sheep.

- What are the months of planting, harvesting and other activities in the field of agriculture or other temporary jobs where people dedicate all their time, which would make it impossible for them to fully participate in the construction of the bridge?

☑ January ☑ February ☑ March ☑ April ☑ May ☑ June
☑ July ☑ August ☑ September ☑ October ☑ November ☑ December

-Notes on population: The families in this population are dedicated to agriculture and raising domestic animals; The families live in different sectors of the community, the houses built of adobe with tile and corrugated iron roofs.

-How often and where do the community(s) meet?*(Weekly, monthly, specific date)*
People meet every first Sunday of the month at their union headquaters.

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4. Community map

Include characteristics such as the location of the community or major centers of the population, the location of the proposed bridge, main roads and paths, schools, health centers, markets, churches, bus stops and buildings or communal houses.

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5. Information about the river

-Description of important services, opportunities or destinations that the river isolates:

U. E. K'ellu Mayu, U. E. Monte Punko, Monte Punko Health Center, agriculture, transportation, social and cultural events.

(This may include primary or secondary schools, clinics or hospitals, farms or markets, government services, churches or any other important destination for the community. Be as detailed as possible and include the types of schools or health centers and how many people serve, the size of the markets and the frequency with which they occur, and other details that will help contextualize and particularize the needs of the community and, among them, that of a bridge)

- Number of people injured while crossing the river in the last three years: ___________
- Number of people killed while crossing the river in the last three years: ____________

-Description of the accident or death of the people when crossing the river, with dates: _____

(Include the number of injury or death accidents. For example, if there was a major flood and three people were injured during this single event trying to cross, clarify it. It should be clear how many injuries or deaths were one-time events)

-Flood time during rainy season: 1 day.
(When the river floods, how long does it last?)

-Current crossing method: Yana Gaga Pedestrian Bridge.
(Swimming, wooden bridge, etc.)

-Nearest crossing point: 8 km downstream of the located site.

- Information about properties or land on both sides of the bridge site proposed*(Who are the owners of the land, and if they have expressed interest in supporting or concern about a bridge)*:

  eitherLeft side: They have no owner.

  eitherRight side: Sebastián Parra (Agreed, he was present on the day of the site visit).

- Planned local and regional transportation infrastructure projects*(Include description and any known places or dates)*: ________________________

6. Isolation

- Number of days per year that the river is difficult or impossible to cross: 150 days.
- Distance from the proposed bridge site to the center of the nearest town*(km)*: 18.
- Distance from the center of the beneficiary community to the site of the proposed bridge*(km)*: 2.
- Distance from proposed bridge site to main market*(km)*: 18.
- Distance from the bridge site to the nearest health center*(km)*: 18.
- Distance from proposed bridge site to high school*(km)*: 18.

-Travel time from proposed bridge site to main market*(On foot, in minutes)*: ______

7. Contacts, municipality and community

1. Name and surname: Feliciano Coscio.

Post: Leader of K'ellu Mayu.

Tel.: 67517633. CI: ______

Email: ______

2. First and last name: Mario Rocha.

Post: Strio. of Aciendas of K'ellu Mayu.

Tel.: 67461220. CI: ______

Email: ______

3. Name and surname: Justino Coronado.

Post: Community member K'ellu Mayu.

Tel.: 72210715. CI: ______

Email: ______

4. First and last name: ______________________________

Post: ______________________________

Tel.: ____________________ CI: ______________

Email: ______________________________

5. Name and surname: ______________________________

Post: ______________________________

Tel.: ____________________ CI: ______________

Email: ______________________________

8. Bolivia addendum

- Does the Municipality have PTDI (Comprehensive Territorial Development Plan), census or any other support with data information for each community?

The municipality has the PTDI.

9. Rotary addendum

- What other types of projects are needed?

☐School/Classroom(s) ☐Health post ☐Bathrooms) ☐Irrigation ☐Drinking water
☐Other: Boarding School environments.

- Does the community/municipality already have final designs for some of these projects? If so, which ones?

10. Notes

ENGINEERS IN ACTION

TECHNICAL EVALUATION

Project name: Const. K'ellu Mayu River Pedestrian Bridge. Location: Pocona Municipality.
Advisor: Richard Galvez GPS: Latitud: -17.620584° y Longitud: -65.271513°.
Date: May 7, 2022.

PROFILE DRAWING

Suspended | Suspension

View AutoCAD file in Drive: Río Kellu Mayu_31AGO2022 Perfil de Terreno.

LEFT | WITH THE CURRENT | RIGHT

BM1	inst height			
BM2	inst height		Reference point	
BM3	inst height		Reference point	
BM4	inst height		Reference point	

SPOT	REF.	DESCRIPTION *	ADEL.(+) BACK(-)	LOW	HALF	HIGH	NOTES or ANGLE
E-1		STAKE 1					
E-2		STAKE 2					
E-3		STAKE 3					
E-4		STAKE 4					
E-5		STAKE 5					
HWL1							
HWL2							

ENGINEERS IN ACTION

SITE DESCRIPTION

▪ LEFT SIDE: On this side the terrain is flat longitudinally and transversely; On this side there is little vegetation, there are only sewenka plants and in between there are only two alder trees.

▪ RIGHT SIDE: On this side the land is flat longitudinally and transversely . On this side there is vegetation, most of are native trees of the place that are the kewinas, there are also smaller trees that are the tholas, and then you can also see grasslands on this side.

▪ Obstructions (stones, roads, canals, pipes, electricity lines, trees, drainage, erosion, crops, etc.):

▪ Access condition: There is no access on either side of the river. To reach the left side with materials it is only necessary to clean approximately 100 meters from the vehicular road, and to reach the right side with materials the community and the municipality are going to enable a temporary road for almost 150 meters. .

SOIL CLASSIFICATION

	Coarse-grained	Fine-grained	Rock
Side	☐ Gravel floor	☐ Silt soil	☐ Signature rock (fractured: Y/N)
Left	☐ Sand soil	☑ Clay soil	☐ Soft rock (fractured: Y/N)
Side	☐ Gravel floor	☐ Silt soil	☐ Signature rock (fractured: Y/N)
Right	☐ Sand soil	☑ Clay soil	☐ Soft rock (fractured: Y/N)

PHOTOS AND VIDEOS

☑ Left lifting limit	☑ Top of the left ravine
☑ Right lifting limit	☑ Top of the right ravine
☑ River bed	☑ Maximum water level
☐ Floor, left side	☐ Floor, right side
☐ Current crossing location	☑ Marked points
☐ Access to the site	☑ Site description
☐ Community	☐ Place for the brigade

GRADES

ENGINEERS IN ACTION

TECHNICAL STUDY CHECKLIST

☐ Walk 200 meters upstream and downstream from the proposed site or from the crossing point

☐ Measure 2 or 3 lines on the first visit

☐ Bridge length estimate: 20 m to 120 m

☐ Estimation of the "freeboard" (floodplain 2 m, gorge 3 m) with descent = 5%. Height difference between the lowest side and the maximum water level must be greater than L/20.

☐ Estimation of the height difference. Maximum 4% of the length, ± 2 meters with levels

☐ Space of 25 meters from the ravines on both sides, width of 5 meters

☐ Access to site for both sides, especially during construction season?

☐ Ask about land ownership! Make sure the owners agree!

☐ Ask at least two people for the HWL! Measure 2 points, one on each side if possible.

☐ Avoid utilities! Power lines, canals, light poles, roads, pipes, etc.

☐ Avoid confluences and curves (hydrological consideration)

☐ Signs of erosion? Banks and surroundings

☐ Soil classification, dig 1 meter if suspicious

☐ Draw the line in aerial view if necessary

☐ Suggest FFL and FFR in profile drawing

☐ Side slopes, steep?

☐ Don't forget the height of the instrument!

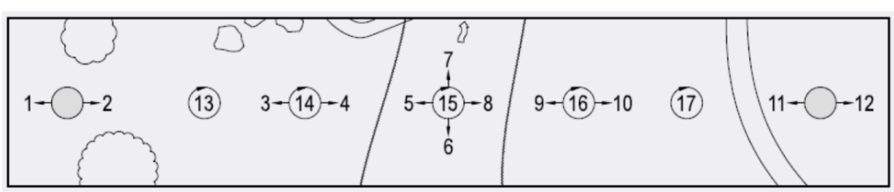
☐ Don't forget the HWL (2 points if possible) and the river bottom (right and left)!

☐ Leave stakes in the line, 4 if possible, or colored rocks

☐ Ask people in the community to remember and maintain the points marked with stakes/rocks

☐ Something or someone for proportion/perspective in photos and videos + comments

☐ The following figure shows where to take photos and videos



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Appendix D

1. Calculation Book
2. Drawing Pack

Appendix E: Project Schedule