SANTA LUCIA RIVER CROSSING

Quebrada Caracol, Chiriqui Panama

Lucia Associates

iDesign Final Report Fall 2015

Authors: Sophia Lopez
Jake Mathieu
Anna Romenesko
Joseph Schmitt, P.M.
Yusheng Zeng

Michigan Tech
Michigan Technological University

Advisors: Michael T. Drewyor, P.E., P.S.
David Watkins PhD., P.E.

LUCIA ASSOCIATES

Disclaimer:
This report, titled “Santa Lucia River Crossing”, represents the efforts of undergraduate students in the Civil and Environmental Engineering Department of Michigan Technological University. While the students worked under the supervision and guidance of associated faculty members, the contents of this report ***should not*** be considered professional engineering.

***DO NOT CONSTRUCT THIS FOOTBRIDGE UNLESS PLANS HAVE BEEN APPROVED BY A PROFESSIONAL ENGINEER.**

Table of Contents

List of Appendices

List of Figures

Executive Summary

The following report discusses the background, final design, technical drawings, construction schedule and cost estimate for a pedestrian bridge crossing over the Santa Lucia River in a rural community in Western Panama. The design team, Lucia Associates, traveled on a project assessment trip to Panama in August 2015.

Throughout the assessment trip, the team conducted interviews with community members to develop a better understanding of the background and needs of the community. The interviews were conducted with the help of a Peace Corps volunteer. Surveys and other site data were collected as well to determine the constructability and feasibility of the pedestrian bridge. It was determined that a suspension pedestrian bridge would be the most practical design for the community and the location. A brief overview of the design includes; a bridge span of 128 feet, 20 foot tall steel towers and high strength suspension cables. Locally available wood will be used as the material for the decking. Each main design component of the bridge is detailed in the end of this report.

The bridge was designed following various international building design guides, including Bridges to Prosperity's Design Guide, AASHTO Pedestrian Bridge Code and Load and Resistant Factor Design. Construction costs were estimated using approximate labor, equipment and material costs in the United States. Lucia Associates plans to submit the final design to the Peace Corps volunteer in Quebrada Caracol, to move forward with the design project.

1.0 Introduction

The team members of Lucia Associates are Civil Engineering undergraduate students at Michigan Technological University. Through the International Senior Design (iDesign) program at Michigan Technological University, students traveled on an assessment trip to collect data for a potential pedestrian bridge project. Lucia Associates has prepared the following report, which includes an analysis and design of a suspension footbridge across the Santa Lucia River for the community of Quebrada Caracol. This rural community in Western Panama is discussed in more detail in Section 2.0. The community members of Quebrada Caracol felt very strongly that a pedestrian footbridge would be very beneficial to the community.

The community has attempted to build bridges over the Santa Lucia River in the past, but the past bridges have not held up to the needs of the community. The first bridge was washed out during an intense flood, which caused a little girl to drown. This bridge was located about a hundred feet up the river from the current bridge location. After this tragic event occurred, the community came together and built a new bridge. This is the bridge currently being used. This bridge was built by twenty of the community members in a single day, and was designed as the bridge was constructed. Figure 1 on the next page shows the current bridge over the river. The current bridge has long bamboo poles which can become slick in the rain and tend to rot within 2-3 months. This has resulted in tremendous amounts of maintenance for the community members, since the decking has to be replaced often. The community is very concerned with the safety of the children on their way to school, since the current bridge is not a reliable way of crossing the river. Many community members have showed immense passion and interest in a pedestrian bridge project.

The Panamanian government has provided the community with a grant to construct a reliable footbridge. Within this grant, the community will have $50,000 to construct a graded road from the trailhead to the bridge site. This will allow easy access to the bridge site for the construction process. The community will then have a $36,000 grant to complete the construction of a footbridge. This project is planned to start within the next year. However the community members have also expressed a lack of faith in the local engineer since the engineer has not visited the community to collect data or survey. Therefore, Lucia Associates aims to work with the community to present a practical, economical and sustainable design which the community can implement and take ownership. The design will aim to ensure the safety of every one of its users, as well as take into careful consideration the finances, resources and values of the community.

Figure 1: Current Suspension Bridge

The team of Lucia Associates surveyed the area of the Santa Lucia River to aid in analysis of the potential river crossings. The survey methods are discussed in further detail in section 4.0, and the survey data collected while in Panama is compiled in Appendix A. Following the team's return to the United States, the data was analyzed. It was determined that a suspension bridge would be the best alternative to meet the needs of the community. The design procedures, calculations, technical drawings, cost estimate and construction schedule for the suspension footbridge are to follow in this report.

2.0 Community Background

Quebrada Caracol is located in the Comarca of Ngabe-Bugle, which is just outside of the Chiriquí province of Panama. A Comarca is a region where indigenous Panamanians reside. There is an active Peace Corps Volunteer, Leigh Miller, BEng, F.E., who has been living in the community since September 2014. She is the main contact between the design team and the community. The community has no road access and is about a two hour hike through rocky and muddy terrain. The closest neighboring community, Calabazal, is about a half hour hike down the mountain from Quebrada Caracol. The main mode of transportation throughout the community is on foot. A few families own horses which are rented out to other community members and used to bring in food and other necessary supplies. There is no electricity, very little running water and few latrines.

The majority of the houses are relatively spread out and surrounded by large fields and rough terrain.

The population of the Quebrada Caracol changes quite frequently due to the lack of economic opportunities within the community. Many community members, predominantly the male population, find work outside of the community. Many of these men work on temporary contracts, sometimes for months at a time, leaving the women of the family to tend to the house, land and kids. It is common for multigenerational families to live together in one household. The majority of the community actively participates in the local church in the community, which is Seventh-day Adventist. The church is the most active organization within the community.

There is no school within the community of Quebrada Caracol. The closest grade school is located in Calabazal, and the middle school is located about an hour hike further up the mountain from Quebrada Caracol. The closest high school is located in the small town of San Felix, which is about a two-hour hike out of the community and a thirty minute taxi ride into town. Due to the significant amount of travel time and other schooling costs, most of the children do not continue their education past middle school.

Leigh Miller has completed an initial assessment of the community and their goals, their main goal being to meet water and sanitation needs. However, there is also great community interest in a pedestrian bridge over the Santa Lucia River, which runs between Quebrada Caracol and Calabazal.

Recently, the community elected a bridge project committee to help plan and take ownership of the project. The communities of Quebrada Caracol and Calabazal have also been chosen to receive grants from the government to construct a road and a footbridge. The grants have been estimated at roughly $50,000 and $36,000 respectively. The road and footbridge project were scheduled to break ground in summer 2015, however, no further improvements on either project had been made as of now. Many of the community members express a lack of faith in the government representatives that promised to work on these projects. Lucia Associates plans to fulfill the community’s hopes of getting a safe and reliable footbridge for the children in the community. This assessment report for the footbridge will take into account the financial restrictions as well as community values and goals in order to ensure that the most efficient design is developed.

3.0 Project Location

The site for the pedestrian bridge design project is located over the Santa Lucia River, which divides Quebrada Caracol and Calabazal. Figure 2 shows a map of Quebrada Caracol. Currently, the majority of the children who attend school hop across various rocks to cross the river. During significant rainstorms, which are quite frequent in Western Panama, the children are forced to wade through dangerous water, cross a very unreliable bamboo bridge or stay home. The latter option is most common because many of the parents do not want their children to take the risks of crossing the river in such dangerous conditions.

Figure 2: Map of Quebrada Caracol

The water level of the Santa Lucia River varies depending on the season, but is highest in the wet season, which is roughly May through November. The water elevation of the river can change roughly 15-ft between the wet and dry seasons. During extreme rainfall events, the river will flood in multiple locations, flooding pastures and paths throughout the community.

The head of the bridge committee voiced that the community would like the new footbridge to be in relatively the same location as the bridge that is currently there. The team has placed the new footbridge approximately 30-ft north of the existing bridge to keep the bridge in the approximate location, but also keep the design practical and feasible for the community. The proposed location also reduces the required span. This decrease in span will be economically beneficial to this project, as well as provide a more practical and constructible design. Maps showing the location of Quebrada Caracol and GPS coordinate points of the bridge location can be found in Appendix A.

4.0 Methods and Procedures

Data collection included interviewing community members, a topographic survey, as well as soil and river data. All of this data was compiled and used to create the most feasible design for the area and the community.

5.1 Interview

The design team had the chance to interview the head of the bridge committee while in the community. The team was able to get a better idea of the design constraints for the bridge from this interview. One of the design requirements is that the community would like to have the bridge in the same location to avoid having to make new paths farther up or down the river. The individuals crossing the bridge will mainly be children traveling to school, but adults would use the bridge as well if the water level rises high enough to make other forms of crossing the river unsafe. The community members expressed desire for the new bridge to have thicker cables, steel towers and concrete foundations. Many of the community members have seen bridges in neighboring communities throughout the Comarca and want a bridge of similar design. Figure 3 below shows a typical bridge in a neighboring community.

Figure 3: Typical Suspension Bridge within the Comarca, Photo by: Leigh Miller

The head of the bridge committee also informed the team that the community has received a grant of $36,000 from the government for a pedestrian bridge. This grant gives Lucia Associates a target budget. The community has also received a $50,000 government grant to build a graded road leading up to the bridge. This would allow for materials and equipment to be brought to the site to construct the bridge. The bridge committee member also explained that the community was expecting a majority of the work would be contracted out. The community also expressed willingness to make an effort to raise money through various means, such as raffles and selling drinks, to help fund the project, if needed.

Another design constraint that the committee member explained is that there are laws that protect the significant trees along the riverbank. The community cannot cut them down without permission from the National Environmental Agency, or ANAM. If it were necessary to cut down some trees, the committee member stated that the community would most likely have to plant about ten new trees per the ANAM. Notes from the interview with the bridge committee member can be found in Appendix A.

5.2 Topographic Surveying

Surveying data was collected using a Nikon Rangefinder® and an improvised survey rod. This was constructed by using a folding carpenter’s ruler and a cardboard target duct taped to it. An original benchmark was set using the Garmin eTrex® GPS unit. Using this benchmark throughout the survey, with occasional elevation checks, allowed for consistent elevation measurements. Due to the accuracy error on the elevation of the GPS, it was decided that using this consistent elevation allowed for the greatest degree of accuracy on the topographic survey. A fixed target on the survey rod was also used, which allowed for another simplification of the data collection. Using the same fixed height on the rod eliminated an extra calculation. All of the shots taken using this method were recorded in the field notebook which can be found in the Appendix A.

Fortunately, the site of the existing bridge allowed for a very simple layout of the survey. The river through the site flows straight from north to south, and the bridge alignment spans intersects perpendicular to form a survey grid. An east/west line was set off of the existing bridge to conduct the survey. Using this line, survey shots were taken along this line every fifteen feet, out to a distance of 100 feet or longer from each bank of the river to allow for data collection to a location where the anchors of the bridge would be located. At each fifteen-foot station, shots were taken at a right/left or north/south offset at ten-foot increments out to a width of thirty feet from the east/west line. A site topographic map created in AutoCAD Civil3D® from these data points can be found in Appendix G, and the surveying data points recorded while in Panama can be found in Appendix A.

5.3 Soil Classification

Soil data was collected near the proposed bridge site. This data included a Unified Soil Classification System, or USCS visual classification of the soil. The existing soil is a poorly graded soil which had many fines that included clay. The results of the analysis resulted in a high plasticity clay with gravel, classified as a CH. Some assumptions were made due to the inability to take proper soil samples as well as not being able to run a sieve analysis. Using the visual classification method was the best choice due to lack of testing equipment and online database information. All soil classifications are very rough estimates. Figure 4 on the next page shows a cut on the river bank.

Figure 4: Observation of Soil on River Bank

5.4 River Flow Rate

Flow rate data of the river was collected, and cross sections were created at various locations of the river from north of the proposed bridge site to south of the existing bridge. Collecting the flow rate data was done by taping off a distance along the river. Using this distance, and various buoyant objects, a series of measurements were taken. These results were totaled and averaged to find the velocity of the water. Using the cross sections of the river, an area was approximated. This area was used with the velocity to find the flow rate of the river. The average observed flow rate of the river while the team was present in the community was calculated to be 75 cfs.

The team researched flood flow rates in various databases online as well as rainfall data for the Chiriquí province of Panama. Using this data, an approximate 100-year flood rates and water levels were estimated. No data was found specifically for the Santa Lucia River; therefore the design team had to make estimates using data from other sites in Panama in order to complete the required calculations. The calculations for the observed river flow rate, as well as river cross sections can be found in Appendix B.

5.0 Data Analysis and Design Alternatives

After all data was collected, it was then compiled and analyzed to determine the bridge design details and a final bridge design.

6.1 Site Topography

Using the surveying data collected as described in section 4.2, a topographic map was created using AutoCAD Civil3D®. Elevation points were input into the software to create a plan view of the proposed bridge location. The complete topographical survey can be found in Appendix B.

6.2 Site Hydrology

A hydrological analysis of the nearby rivers was completed using watershed, rainfall and flood data obtained from online sources and then scaled to estimate the flood flow rates and runoff values for the watershed of the community. Since Quebrada Caracol is a small community, there is no online data for the community in databases such as ETESA. Instead, the watershed from the Fonseca and Tabasara Rivers was analyzed and then scaled. This watershed covers the San Felix District, which includes Quebrada Caracol. Three different methods were performed in order to estimate the characteristics of a potential 100 year flood event in the area. The first method consisted of scaling flood flow events measured near David, Panama, which is also located in the Chiriquí province, to the Santa Lucia River watershed. The second method consisted of computing the area of the watershed and using the Creager formula, calculate flood flow rates. The final method consisted of computing the RCN value which estimates soil infiltration rates and then estimating water runoff in the watershed. All calculations and watershed maps can be found in Appendix C.

6.3 Design Constraints

Lucia Associates took into account all of the information provided by the head of the bridge committee and other community members, the design constraints were determined as follows: 1) the bridge had to remain in approximately the same location as the current bridge, 2) it had to be designed to accommodate children and adults on their way to school and work, 3) a minimal amount of trees and vegetation could be removed, and, 4) the bridge should be design to accommodate the 100-year flood event. There is also a design constraint of limited access to materials, equipment and labor.

6.4 Design Alternatives

There were a couple of different design alternatives that were considered. The first of these was the location for the bridge. The current location of the bridge is located at a topographical low point. This would require the span of the bridge to be much larger in order to avoid the risk of the abutments being located in the water. A larger span would lead to higher construction costs. Alternative locations for the bridge were analyzed and it was determined that a location about 30-ft north of the current bridge would be the most ideal location since the elevations are slightly higher. Another alternative considered was the loading on the bridge. The community members told the design team that only children and some adults could use the bridge. The team observed that community members would use horses to carry in various supplies from town. The team decided it would be worthwhile to analyze a bridge designed for equestrian loads, since the horses will have to cross the river to get from Quebrada Caracol into town.

6.0 Final Recommendation

7.1 Design Recommendations

The final bridge design details and calculations were performed following various bridge design manuals that have been cited. The design should be reviewed and approved by a professional engineer before implementation.

The calculations for the towers, cables, walkway, and suspender cables were performed following the *Bridges to Prosperity (B2P) Bridge Builder Manual, third edition, volume 4: Suspension Cable Bridge* [10]. B2P has completed bridges in various countries and in a wide range of environmental conditions; therefore, their design manual was assumed to be a reliable resource.

The foundations and main cable anchors were designed using the *Survey, Design, and Construction of Trail Suspension Bridges for Remote Areas [8]*. The foundations were designed based on the loadings from the towers. Since very basic soil data was observed while on site, conservative values for the strength of the soil were used in the foundation and anchor calculations. The anchor and foundation calculations checked the bearing capacity of the soil, the sliding force and the overturning force.

All design calculations for the towers, cables, decking, foundations and anchor blocks, have been performed in the MathCAD® software. The final bridge design as well as design detail drawings have been performed in AutoCAD® 2015. The towers were created using the software RAM Elements®.

The total span of the suspension bridge has been calculated to be 128 feet. This length ensures that the tower foundations will be located above the high water level, which was calculated in the hydrology section of this report and can be found in Appendix B. Designing the tower foundations above the high water line eliminates the need to design for scour around the foundations.

7.1.1 Loadings

The pedestrian suspension bridge has been designed using the Load and Resistance Factor Design (LRFD) method, following AASHTO load requirements. Various loads were analyzed using design loads from Bridges to Prosperity design manual, AASHTO Pedestrian Bridge design manual, as well as a Seismic Code Evaluation for Panama. The community did not express interest in allowing horses to cross the bridge, but Lucia

Associates decided to consider the possibly of an equestrian load due to horses in Quebrada Caracol that regular travel the path crossing the river. The loads analyzed included, pedestrian and equestrian live loads, a dead load, a seismic load and a wind uplift force. The total live load resultant force consists of 35.6-kips, which was an estimated value suggested by the AASHTO code requirements. The total dead load resultant force was calculated to be 12.5-kip, and was calculated based on the weight of all materials used to build the footbridge. The earthquake potential at the bridge site was evaluated and the team determined it would be necessary to include a seismic loading factor since Western Panama is located on a plate boundary. Based on the Seismic Evaluation code and the estimated soil classifications, the resultant seismic loading was determined to be 1.4-kip. A wind uplift force was also considered when determining the design loads for this footbridge. The AASTHTO Pedestrian Bridge Manual was used to estimate this uplift force, which was determined to be -0.8-kip. The design loads were then applied to the factored load combinations based on ASCE 7. The base shear was found to be ok after all the forces were added. A calculated total loading for the design has be determined to be 71.9-kip. All loading calculations can be found in Appendix D.

7.1.2 Cable design

A standard design for a suspension bridge was used with the assistance of *Bridges to Prosperity (B2P) Bridge Builder Manual, third edition volume 4: Suspension Cable Bridge* as a guideline for the layout and calculations. The general layout consists of several different parts that all work to support the specified loads on the bridge deck. The largest structural components are the towers on each end of the span supported by concrete foundations that resist all vertical and lateral applied loads. A set of main cables are suspended from tower to tower, and each end is anchored into large concrete blocks. These concrete blocks are located farther away from the river bank and provide resistance to the main cable tension. The vertical suspender cables are first fastened to the main cables on each side of the bridge and cut at specific lengths to allow for the bridge deck camber. The bridge deck is also connected to the suspender cables and the spanning cables, which will be discussed in further detail in Section 6.1.6 of this report. The vertical loads are applied to the decking surface and then transferred to the spanning cables and crossbeams which are supported by the suspenders. The suspenders then transfer the load to the main cables and finally into the anchor blocks.

The cable geometry and tension were also calculated using the text *Bridges to Prosperity (B2P) Bridge Builder Manual, third edition volume 4: Suspension Cable Bridge* for reference, which are found in Appendix D – Overall Bridge Design Calculations. The calculations are based on catenary cable equations to determine the cable sag and tensions in the main cables under various loading conditions. The bridge is designed to have a minimum of 5 ft of clearance under the center of the bridge when compared to the high water level. The overall bridge plan and profile can be seen in Drawing 2 of Appendix H. The bridge span is 128 ft from tower to tower with a 3 ft wide deck. The main cables consist of two 1-5/8 inch cables on each side of the bridge. Each cable is capable of handling over 250 kips of tension to resist against the maximum total main cable design tension of 95.9 kips (under full dead and live loads) with a factor of safety built in.

7.1.3 Tower Design

The towers support the main cables and provide enough height to allow the cables to sag under self-weight and loading conditions. The overall tower height is 20 ft from the top of the foundation to where the main cables are connected. The towers were designed in RAM Elements® based on the applied loading conditions from dead loads, live loads, wind loads and seismic loads transferred to the towers through the main cables as shown in Appendix E. The loads are primarily vertical under normal loading conditions because the main cables are allowed to slide freely over the top of the tower within a fabricated steel pipe section.

The towers themselves are composed of prefabricated steel box truss sections that will be fabricated offsite and assembled at the project site according to drawing 7 of Appendix H. There are two 20 ft box truss sections tied together by 2.5" x 2.5" x 3-1/4" A36 angle iron cross-bracing spaced 5 ft apart. These sections provide the towers with lateral stiffness and allow for clearance between them to accommodate the walkway. Each truss section is made of vertical 3" x 3" x 1/4" A36 angle iron sections that make up the corners of the box section. These are tied together by 3/4" A36 solid round steel bars in a truss-bracing pattern to stiffen the section. The solid bars are welded to the inside corners of the angles in a shop setting to ensure proper strength as opposed to facing the many challenges of field welding, especially in a rural setting. Each section will then be hoisted vertically, placed on top of the previous section, and bolted together with 1/2" A36 steel plates on all four sides with 1/2" A307 bolts.

The baseplate itself is made of a 2" thick A36 steel plate welded to the base of the tower. The tower is then anchored to the foundation by 1" B7 anchor rods that are pre-installed in the concrete foundation with an embedment of 12". Once the tower is assembled and anchored to the foundation, the main cables can be strung and the rest of the bridge construction process can continue.

7.1.4 Foundation Design

The tower foundations were designed based on the loads transferred from the towers. The foundations were calculated using the *Survey, Design, and Construction of Trail Suspension Bridges for Remote Areas*. The foundations were recommended to be without a foot in the soil. A foot is an extra L-shaped section of concrete on the footing. The foundation size was calculated to be 12 feet by 10 feet and 6 feet deep. Foundations on either side of the bridge have been designed to be the same dimensions. The foundations have been designed for a factor of safety of 2.5 for the bearing capacity. These calculations can be found in Appendix F. The towers will be attached to the foundation with threaded steel rods and a baseplate. Detailed design drawings of these connections can be found in Appendix H.

7.1.5 Anchor Design

The main cable anchor blocks were calculated using *Survey, Design, and Construction of Trail Suspension Bridges for Remote Areas*, using the same soil characteristics as the foundations. The anchor blocks designed for this pedestrian suspension bridge have been designed as one large reinforced concrete block, meaning each of the main cables on either side are connected to the same anchor block on their respective sides of the river crossing. The anchor blocks were calculated to be 12 feet by 16 feet and 8 feet deep, and have been designed to be the same on either side of the river. These dimensions ensure that the anchors can withstand the forces from the main cables as well as the bearing capacity. The bearing capacity calculations are shown in Appendix G. The anchors have been designed to include a reinforcing steel cage, to which the main cables will be secured around with a turnbuckle on each side to allow the main cables to be tightened during construction. The main cable anchors are located at backstay distances from the towers of about 45 ft on either side. The exact distances are shown in the final bridge design details in Appendix H. The anchor design details and calculations can be found in Appendix G.

7.1.6 Suspender and Walkway Design

The suspender cables have been designed to withstand the self-weight of the walkway as well as the pedestrian and equestrian loads, which have been calculated as described in the loading section above. The suspender cables have been calculated to be 1/4 inch diameter galvanized steel cables. The suspender cable calculations can be found in Appendix D. The suspenders have been sized to fit between the main cables and the bottom of the walkway supports. Detailed drawing 4, in Appendix H shows the suspender cables.

The walkway has been calculated and designed to have two steel angles, 2 L 3” x 3” x 1/2”, to support the walkway of the bridge. The entire width of the walkway has been calculated to be 4 feet, with only a 3ft walking path. A total of 31 beams will be used for the walkway, supported by two suspender cables per beam. The bridge has been designed using 2” x 8” x 4’ wooden beams. The suspender cables will be attached to steel plates, which will be used above the steel supports and below the wooden decking. The dimensions of the steel plates have been calculated to be PL 1/2" x 8” x 4’. Calculations for the walkway can be found in Appendix D. Detailed drawings of the suspender cables and walkway can be found in Appendix H.

7.2 Construction and Cost Estimation

Task durations were calculated based on the estimated quantities and production rates. These durations were then used to complete the project schedule. The final project is estimated to be completed within approximately 6 months of the start date. The construction time may fluctuate depending on the weather and the skill level of the workers used. The project is planned to begin the first of the year. Panama's dry season occurs between January and May. The construction will begin in the beginning of January to ensure the earth work and foundations will be completed before the rainy season begins. The construction schedule consists of preparing the site, gathering materials, constructing the foundations, anchor blocks, towers and decking assembly, install fencing on bridge, and create a pathway up to bridge. The full construction schedule can be seen in Appendix I.

A cost estimate was created using calculated costs of materials and labor. These costs include prices from Panama, as well as the United States. An attempt was made to find local prices, but ultimately to produce an actual cost estimate, mostly US prices were used. Since this is the case, the overall cost is higher than it likely would actually cost at current Panamanian prices for material and labor. This project will cost a total of approximately $84,000. The actual cost of the project will likely be lower due to differing labor and material cost. Any material that the community can get donated or offered at a discounted price will help to bring down the cost. An unskilled worker in the area makes approximately eight dollars per day; much lower than an unskilled worker at prices taken from our RS Means. A contracting company from outside of the community will be hired to erect the bridge to ensure adherence to the design as well as constructing the bridge in a safe manner. This estimate will allow a Peace Corps Volunteer and their community to get a good idea of how much this project will cost and how it will be constructed over a timeline. The full cost estimate document can be found in Appendix J.

7.3 Funding and Maintenance

The total cost of the project will be approximately $84,000. This estimated cost could be reduced by using the lower labor and material costs in the local area compared to the prices in the United States. These prices could be more easily calculated by someone in country. The project will be funded by multiple methods. The project will partly be funded by the $36,000 grant from the Panamanian government. A portion of the material cost can hopefully be donated, and the community can hold fundraisers to cover the rest of the total cost. It is common to receive used cables as a donation. If both of the main cable and suspender cables were donated, there will be a cost savings of approximately $13,700. It is also possible for other organizations to help cover the cost of the bridge. A few of these organizations may include; Bridges to Prosperity, the Peace Corps of Panama, and Engineers without Borders-Panama. The design completed by Lucia Associates will need to be reviewed by a professional engineer in order to ensure that all aspects of the project and design are adequate.

The bridge committee in the community will make sure proper maintenance of the bridge is completed when it is required to increase the lifespan of the footbridge. Common repairs may include painting the towers on a regular basis; checking the cables, bolts, and decking; and also checking for erosion around foundations. The knowledge of how to complete these repairs will be shared amongst the committee members to ensure the bridge will be maintained properly and remain safe for the children to cross. Lucia Associates suggests that the committee has the ability to either collect an annual fee from the members of the community who utilize the bridge or charge a toll for crossing the bridge. The fees or tolls collected will be used to cover the expenses of the needed maintenance.

7.0 Conclusion

Lucia Associates has outlined a pedestrian suspension bridge to be presented to Peace Corps volunteer, Leigh Miller, as well as the community of Quebrada Caracol. The bridge has been designed to ensure the safety of the children and other community members as they travel to school and work. This report has detailed the final design components and materials as well has an estimated, construction, schedule and cost for the bridge. The design components have taken into account the availability of different types of materials in the area. In order for the project to move forward, the community will need to find a resource to help fund the costs of the bridge since the grant from the government will not cover all of the costs. This could be accomplished by partnering with a non-governmental organization, such as Bridges to Prosperity. All designs presented in this report must also be reviewed and approved by a professional engineer before being implemented. Lucia Associates presents this bridge design with the hopes that the community will be able to implement and take ownership of the bridge.

8.0 Acknowledgements

International Senior Design Advisors:

Mr. Michael T. Drewyor, P.E., P.S.
Dr. David Watkins, PhD., P.E.

Peace Corps Volunteer:

Leigh Miller, Quebrada Caracol, Panama

Others:

Dr. Tess Ahlborn, PhD. – Michigan Tech Professor
Del Puente Engineering – International Senior Design Team Fall 2013

9.0 References

[1] *AASHTO LRFD Bridge Design Specifications*. 6th ed. Washington D.C.: American Association of State Highway and Transportation Officials, 2012. Print.

[2] ETESA: Empresa de Transmision Electirca, S.A. http://www.hidromet.com.pa/hidro_historicos.php

[3] LRFD Guide Specifications for Design of Pedestrian Bridges, American Association of State Highway and Transportation Officials, Washington, DC.

[4] Wurbs, Allen, James. Water Resources Engineering. Upper Saddle River, NJ: Prentice Hall, 2002.

[5] Edwards Wire Rope, http://www.edwardswirerope.com/wire-rope.html

[6] Metals Depot, http://www.metalsdepot.com/

[7] E-Rigging.com http://www.e-rigging.com/

[8] A. Grob, J. Krahenbuhl, A. Wagner. “Survey, Design and Construction of Trail Suspension Bridges for Remote Areas/Volume A, Design”. SKAT, Swiss Center for Appropriate Technology, 1983.

[9] Gutierrez, Jorge. “Seismic Code Evaluation Panama.” *Structural Design Code for the Republic of Panama.* Ch. 4, 2003

[10] Bridges to Prosperity. "Suspension Cable Bridge." *Bridge Builder Manual*. 3rd ed. Vol. 4, 2013.

10.0 Appendices

Appendix A:
Interview of Bridge Committee Head

Meeting with Roberto (Bridge Committee Prez.)
River Name: Santa Lucia
Community Name: Quabrada Caracol

- 2nd location - 3yr old girl drown at the first bridge location
- River rises 6” from base of bridge every year
- Made up design as they went, needed new one
- Made all by hand
- Children need to go to school - worried
- Community built it together as one work day
- Built in one day - 20 people
- $50,000 to build a road leading up to the bridge location
- $36,000 for the bridge
- Bridge use just for people/kids
- Replace existing bridge/same location
- Cable needs to be thicker
- Foundation - steel towers with concrete
- Do road first - so materials can be brought in by truck
- suspension bridge
- Metal plate for bridge decking
- Steel towers
- Engineer - project manager - and hire construction group
- All work to be contracted out
- Thinking it might still not happen
- Bridge committee was elected
- Raise money - raffle, sell drinks
- Bank on left is coming in, eroding
- Scale of 10yrs (in terms of major geological movement of the river)
- Boulders move in bigger flow
- Haven’t seen any more extreme water levels lately
- Don’t plan to cut trees along river bank
- Law that you can’t cut trees so close to the river
    - ANAM -environmental agency
    - “mi ambiente” new name
- Tole - engineer for all areas in comarca
- Construction - dry season - Jan. Feb. Mar.
- Don’t have to use the planned equipment

Appendix B:
Survey Point Data

Table 1: Survey Point Data

	Station	R (S) or L (N) Dist.	Height of Instrument	Measured Height	Elevation
WEST SIDE					
0+0	BM 1		331.0'		336.0'
	1	10' R		4.5'	335.5'
	2	20' R		4.0'	335.0'
	3	30' R		3.5'	334.5'
			335'		
	4	10' L		0'	335'
	5	20' L		0'	335'
	6	30' L		-1'	334'
0+15					
	7	10' L		-1.5'	333.5'
	8	20' L		-2.0'	333.0'
			337'		
	9	0'		-0.5'	336.5'
	10	10' R		-0.5'	336.5'
	11	20' R		-0.5'	336.5'
	12	30' R		-0.5'	336.5'
0+30	13	0'		-3.5'	333.5'
	14	10' R		-1.0'	336.0'
	15	20' R		0'	337.0'
	16	30' R		0'	337.0'
			337'		
	17	10' L		-3.5'	333.5'
	18	20' L		-4.0'	333.0'
	19	30' L		-4.5'	332.5'
0+45	20	0'		-4.5'	332.5'
	21	10' L		-5.0'	332.0'
	22	20' L		-5.0'	332.0'
	23	30' L		-5.0'	332.0'
			324.5'		
	24	10' R		6.5'	331.0'
	25	20' R	(Slope increases after this point)	8.5'	333.0'
0+60			322'		
	26	0'		7.5'	329.5'
	27	10' L		7.0'	329.0'

	28	20' L	(Flat)	6.5'	328.5'
	29	10' R		9.0'	331.0'
	30	20' R	(Slope increases after this point)	10'	332.0'
0+75	31	0'		5.0'	327.0'
	32	10' L		5.5'	327.5'
	33	20' L	322'	6.5'	328.5'
	34	30' L		5.5'	327.5'
	35	10' R		6.0'	328.0'
	36	20' R	(Slope increases after this point)	8'	330'
0+90			328.5'		
	37	0'		-4.5'	324.0'
	38	10' R		-4.5'	324.0'
	39	20' R	(Slope increases after this point)	-2.0'	326.5'
	40	20' L		-3.0'	325.5'
	41	35' L		-3.5'	325'
1+05	42	0'		-5.5'	323'
	43	10' R		-7.0'	321.5'
	44	20' R		-7.0'	321.5'
	45	30' R		-3.5'	325.0'
	46	10' L		-5.0'	323.5'
	47	30' L		-5.0'	323.5'
1+20	48	0'		-7.0'	321.5'
	49	10' R		-11'	317.5'
	50	20' R		-8.5'	320'
	51	30' R		-6.5'	322'
			325.0'		
	52	10' L		-3.5'	321.5'
	53	30' L		-3.0'	322'
			High water mark at bridge	1.0'	326'
EAST SIDE					
1+90		10' L	323.5'		316.5'
		0'	323.5'	-4.5'	319.0'
		10' R		-5.5'	318.0'
		20' L		-5.0'	318.5'
		30' L		-5.0'	318.5'
2+05		0'	323'	-4.0'	319.0'
		10' R		-3.0'	320.0'
		20' R		-2.5'	320.5'
		30' R		-2.5'	320.5'

		10' L		-2.5'	320.5'
		20' L		-2.0'	321.0'
		30' L		-1.5'	321.5'
2+20		0'		-2.0'	321.0'
		10' R		-2.5'	320.5'
		20' R		-2.0'	321.0'
		30' R		-2.0'	321.0'
		10' L		-1.0'	322.0'
		20' L		-0.5'	322.5'
		30' L	Slopes back down	-1.5'	324.5'
2+35		0'		-0.5'	322.5'
		10' R		-0.5'	322.5'
		20' R		-1.5'	321.5'
		30' R		-2.0'	321.0'
		10' L	Trail (Slopes down slightly)	0'	323.0'
		20' L		0.5'	323.5'
		30' L		0.5'	323.5'
2+50		0'		0'	323.0'
		10' R		0'	323.0'
		20' R		0'	323.0'
		30' R		-0.5'	322.5'
		10' L		0.5'	323.5'
		20' L		1.0'	324.0'
		30' L		2.0'	325.0'
2+65		0'	323'	1.5'	324.5'
		10' R	Inside fence/field	1.0'	324.0'
		20' R		1.0'	324.0'
		30' R		0.5'	323.5'
		10' L		2.5'	325.5'
		20' L		3.5'	326.5'
		30' L		4.0'	327.0'
2+80		0'	323.0'	2.0'	325.0'
		10' R		1.5'	324.5'
		20' R		1.0'	324.0'
		30' R		0.5'	323.5'
		10' L		2.5'	325.5'
		20' L		4.0'	327.0'
		30' L	Slope inceases	4.5'	327.5'
2+95		0'		2.0'	325.0'

		10' R		1.5'	324.5'
		20' R		1.0'	324.0'
		30' R		0.5'	323.5'
		10' L		2.5'	325.5'
		20' L		3.5'	326.5'
		30' L		4.0'	327.0'
3+10		0'		3.0'	326.0'
		10' R		2.0'	325.0'
		20' R		1.5'	324.5'
		30' R		1.0'	324.0'
		20' L		4.0'	327.0'
		30' L	Slope increses	4.5'	327.5'
3+25		0'		4.5'	327.5'
		10' R		3.0'	326.0'
		20' R		2.5'	325.5'
		30' R		0.5'	323.5'
		10' L		4.0'	327.0'
		30' L		5.5'	328.5'
3+40		0'	322.5'	6.5'	329.0'
3+55		0'		10.0'	332.5'
Proposed Bridge Sections (straight back from abt)					
EAST SIDE					
2+20					
		35' N	323.0'	2.0'	325.0'
ABT BM2	Towards River	W 10'	36' N of first line -Slopes up towards the N -Goes up steep incline after 100'	-1.5'	321.5'
		W 20'		-2.5'	320.5'
		E 10'		1.0'	324.0'
	Fence Line	20'		3.0'	326.0'
		30'		4.0'	327.0'
		40'		4.5'	327.5'
		50'		5.0'	328.0'
		60'		6.0'	329.0'
		70'		6.0'	329.0'
		80'		5.5'	328.5'
		90'		5.5'	328.5'
		100'		6.5'	329.5'
	Continued slope uphill = 0.1304				
WEST SIDE					

0+90					
		24' N	328.5'	-7.5'	325.5'
ABT BM3					
		W 0'	321.5'	4.0'	325.5'
		10'	24' N of first line	5.0'	3265'
		20'		5.5'	327.0'
		30'		6.5'	328.0'
		40'		8.0'	329.5'
		50'		8.5'	330.0'
		60'		9.5'	331.0'
		70'		10.5'	332.0'
		80'		12'	333.5'
		90'		13'	334.5'
		100'		14'	335.5'
	Slope = 0.05				
	Estimated Proposed Bridge Span: 126'8"				

Appendix C:

Hydrologic Analysis

San Felix Watershed:

The watershed analysis used the area in between the Fronseca and Tabasara rivers. This covers the San Felix District and the Tole district which encompasses Quebrada Caracol, where the Santa Lucia River is located. Figure 1 shows a map of all of the water basins in Panama. The water basin analyzed was number 112. Figure 2 shows a map of Panama from Rivers Fronseca and Tabasara. The principal river in the basin is the San Felix River.

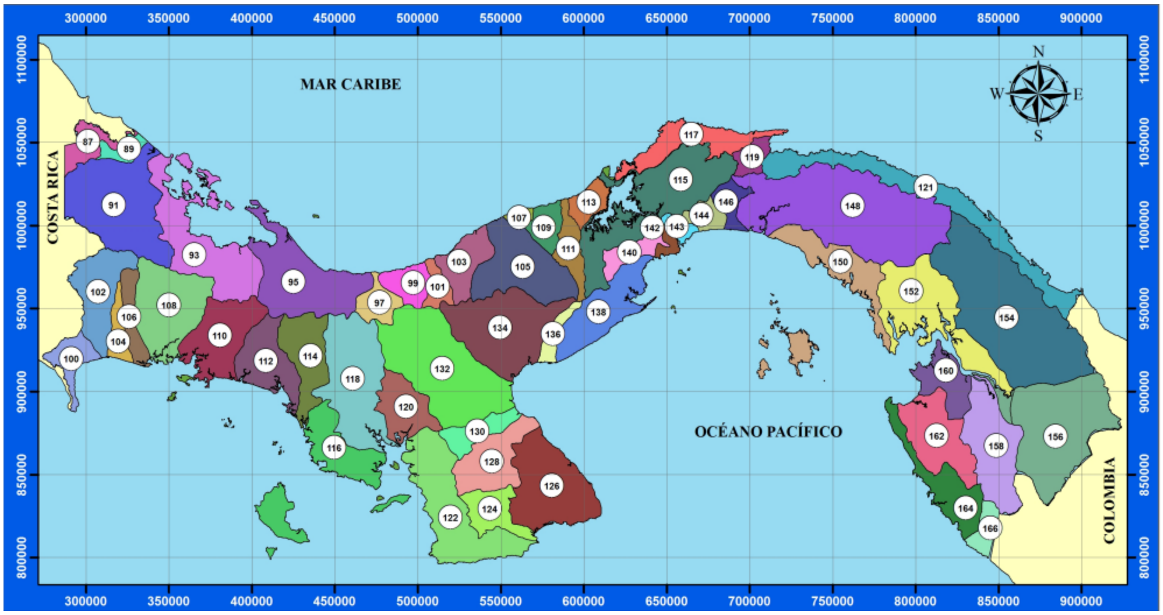


Figure 1: Panama Water Basins (Source: ETESA)

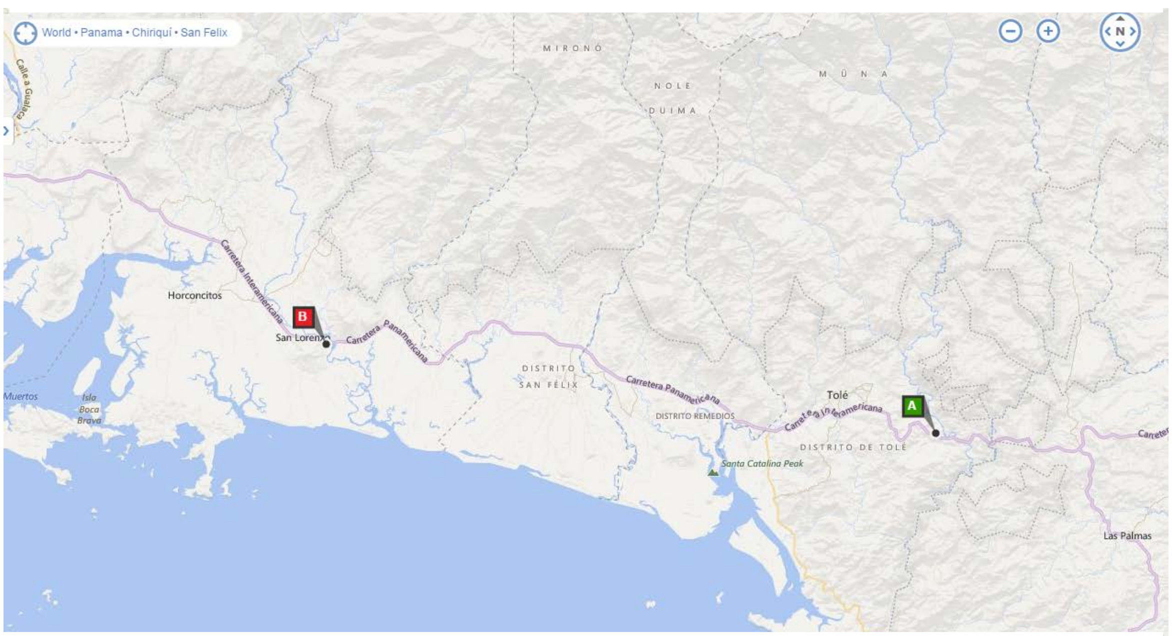


Figure 2: Map of Fronseca and Tabasara Locations. (Source: Bing Maps)

Method 1: Scaling Watershed:

Using the World Catalogue of Maximum Observed Floods from IAHS-AISH, data for David, Chiriqui, Panama was analyzed.

Table 1: Identification of Observation Sites and Characteristics of Basins

Observation Site						Characteristics of Basin							
				Coordinates									
Site Number	River Basin	Stream	Observ. Site	Lat.	Long.	Period	Area (km^2)	Slope	Soil	Cover	Regime	Mean Precip. (mm)	Dean Disc. (m^3/s)
1	Chiriquí	Chiriquí	David	N 08:25	W 82:21	1995 80	1200	F E	C D	A30 D70	0	4030	129
2	Santa Maria	Santa Maria	San Francisco	N 08:13	W 80:58	1955 80	1200	E D	C D	D	0	3290	87.5
3	Grande	Grande	Rio Grande	N 08:26	W 80:30	1955 80	471	E	C	D	0	2200	20.9

Table 2: Floods Characteristics

Flood Characteristics						
Site Number	Stream	Observ. Site	Year	Date of the Max	Max Discharge (m^3/s)	Climatic Origine
1	Chiriquí	David	1974	10-02	2980	1
			1970	04-09	2310	
2	Santa Maria	San Francisco	1955	11-13	3080	1
3	Grande	Rio Grande	1960	11-21	1900	1

A_1 = 1200 km^2 = 463.32 mi^2
Discharge = 2980 m^3s^-1 = 105,157 ft^3/s

By scaling the watershed of David to estimated watershed of the Santa Lucia, 7.8 mi^2

A_1/Discharge = A_2/Discharge
(463.32 mi^2)/(105157 ft^3/s) = (7.8 mi^2)/(Discharge)
Discharge = 1770 ft^3/s

Method 2: Creager Formula:

Using the Creager formula to calculate the flood discharge. This formula takes into account the watershed area.

$$\mathbf{Q = 46 * C * A^{0.894*A^{-0.48}}}$$

Where C is the flood year, in this case we are estimating the 100 year flood.
Therefore: C = 100 and A = 7.8 mi^2

Q = 24,289 ft^3/s

(Source: http://ponce.sdsu.edu/creager.php)

This estimate from the Creager formula shows that flood discharge is significantly higher than the value calculated above in method 1. This formula only takes into account the watershed area, which most likely over estimates the flow rate because it does not take into account the infiltration rate of the soils. In order to account for this, method 3 below calculates the flood flow rate using runoff curve numbers.

Method 3: Runoff Curve Number:

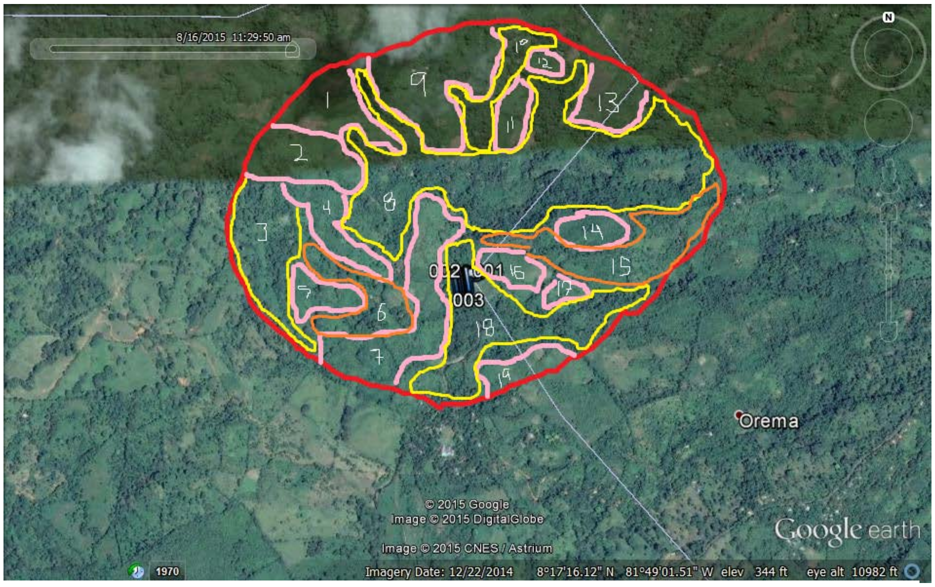


Figure 5: Estimated hydraulic soil groups on Google earth

Table 1: Runoff Curve Number Estimations					
Soil Cover Number from Image	Hydrologic Soil Group	Percent of Total Drainage Area	Land Use	RCN	Partial RCN
1	B	9%	Pasture, contoured, good	35	3.15
2	B	4%	Pasture, contoured, good	35	1.4
3	C	4%	Forest, good	70	2.8
4	C	3%	Meadow	71	2.13
5	C	3%	Pasture, contoured, good	35	1.05
6	C	3%	Woods, fair	73	2.19
7	B	10%	Pasture, contoured, good	35	3.5
8	C	15%	Forest, good	70	10.5
9	B	10%	Meadow	71	7.1
10	C	5%	Forest, good	70	3.5

11	B	3%	Pasture, contoured, fair	59	1.77
12	B	2%	Pasture, contoured, good	35	0.7
13	B	3%	Pasture, contoured, good	35	1.05
14	B	2%	Meadow	71	1.42
15	C	8%	Forest, good	70	5.6
16	B	2%	Pasture, contoured, good	35	0.7
17	B	2%	Pasture, contoured, good	35	0.7
18	C	9%	Forest, good	70	6.3
19	B	3%	pasture, contoured, good	35	1.05
		100%		Total RCN=	56.61

An estimation of the river flow rate when the channel is completely full, has been calculated below to check if the rate is higher or lower than the estimated rate above. The calculation uses the channel dimensions measured from the Santa Lucia River.

Using Manning's Equation:

$$Q = V * A = \frac{1.49}{n} * AR^{2/3}\sqrt{S}$$

$n = .05$ (estimated from Manning's tables)

$A_{Total} = 258.5\ ft\hat{}2$

(Calculated from channel dimensions, estimated as a trapezoid and assuming water is filling entire river basin as community member described)

$R = \frac{A}{P_w} = \frac{258.4ft^2}{65.8ft} = 3.93$ (R is hydraulic radius, Pw is wetted perimeter)

$S = .025$

$$Q = 3{,}033\frac{ft^3}{s}$$

By comparing the flood flow rates calculated above, the bridge will be designed to the high water level that the community member described. The analysis of the flow rate when the channel is completely full is greater than the flow rate calculated in method 1, which was estimated from historic flood flow data. Since the flow rate is higher when estimating a full channel, it is concluded that this is a conservative water level height to use since the record flood flow rates are not as high.

An estimate of high water levels in the community were provided by a community member recalling from years before. The design team surveyed the area and attempted to analyze high water marks on trees. However, not enough information was able to be collected to know if the flood event that the community member described was an 100 year event. It is possible, although unlikely, that it was a 500-year event or even an 1000-year event. A significant amount of data would need to be collected in order for this to be determined.

Appendix D:

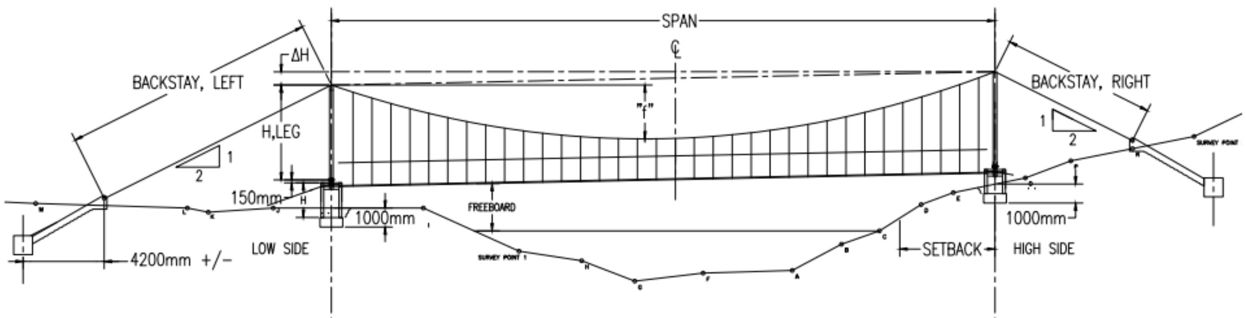
Overall Bridge Design Calculations

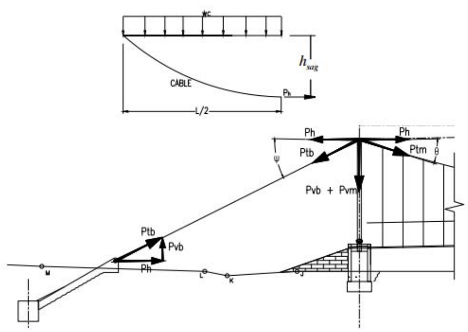
Overall Bridge Design Calculations:

The Bridges to Prosperity (B2P) Bridge Builder Manual for a Suspension Cable Bridge was used as a reference for all of the design calculation. Part 1: Bridge Design was used. The AASHTO Bridge Design Code and the AASHTO Pedestrian Bridge Design Code were also referenced when determining loading.

1. Design Criteria and Material Properties

<u>Bridge Layout</u>





Span Length: $L := 128\ ft$

Tower Height: $H_T := 20\ ft$

Design Sag: $S := 0.091 \cdot L = 11.648\ ft$

Camber: $c_d := 0.03 \cdot L = 3.84\ ft$

Deck Width: $w_d := 3\ ft$

Walkway Width: $w_w := 1.5\ m = 4.921\ ft$

Angle to Horizontal: $\theta := \operatorname{atan}\left(\frac{4 \cdot S}{L}\right) = 20\ °$

Bridge Materials:

Wood Deck:

Deck will be Zapatero (Hieronyma alchorneoides) Wood

$$\rho_w := 50 \frac{lbf}{ft^3}$$ (http://www.woodworkerssource.com/show_numerical.php?wood=Hieronyma%20alchorneoides)

$$t_D := 2\ in$$

$$P_{Deck} := \rho_w \cdot w_d \cdot t_D \cdot L = 3200\ lbf$$

Steel Supports:

Use 2L3x3x1/2 for the 31 support beams under the deck

$$w_s := 490 \frac{lbf}{ft^3}$$

$$A_g := 2 \cdot 2.76\ in^2 = 5.52\ in^2$$ (AISC Table 1-15)

$$V_b := 31 \cdot A_g \cdot 4\ ft = 8213.76\ in^3$$

$$P_b := w_s \cdot V_b = 2329.133\ lbf$$

Steel Plates:

Using 8"x1/2"x4' Plates

$$V_p := 3.44\ ft^3$$

$$P_p := V_p \cdot w_s = 1685.6\ lbf$$

Wood Beams:

Using 2"x8"x4'

$$V_w := 13.78\ ft^3$$

$$P_w := V_w \cdot \rho_w = 689\ lbf$$

Bolts:

$$P_{bo} := 29\ lbf$$

62

Miscellaneous Total:

$$P_m := P_p + P_w + P_{bo}$$

Main Cables:

1-5/8" Cable

$$w_c := 4.88 \frac{lbf}{ft}$$

$$L_c := 445.56\ ft$$

$$P_{mc} := w_c \cdot L_c = \left(2.174 \cdot 10^3\right)\ lbf$$

Stringer Cable:
1/4" Cable

$w_c := 0.105 \ \frac{lbf}{ft}$

$L_c := 639 \ ft$

$P_{sc} := w_c \cdot L_c = 67.095 \ lbf$

<u>Bridge Loading:</u>

Dead Load (Calculate based on our Materials):

$$DL := P_{Deck} + P_b + P_{mc} + P_{sc} + P_b + P_m = 12503.294 \ lbf$$

Distributed Load: $LL_D := 90 \ \frac{lbf}{ft^2}$

Point Load (for equestrian loading): $LL_P := 1000 \ lbf$

Total Live Load: $LL := LL_D \cdot L \cdot w_d + LL_P = 35560 \ lbf$

Earthquaking Loading: $E := 70.56 \ \frac{lbf}{ft} \cdot H_T = 1411.2 \ lbf$

(Siesmic Code Evaluations for Panama)

Uplift Wind Load: $W_{up} := -20 \ \frac{lbf}{ft^2} \cdot 2 \ ft \cdot H_T = -800 \ lbf$

(AASHTO Pedestrian Bridge 3.4)

Load Combinations (ASCE 7):

Case 1: $U_1 := 1.4 \ DL = 17504.612 \ lbf$

Case 2: $U_2 := 1.2 \ DL + 1.6 \ LL = 71899.953 \ lbf$

Case 3: $U_3 := 1.2 \ DL + 0.5 \ W_{up} = 14603.953 \ lbf$

Case 4: $U_4 := 1.2 \ DL + 1.0 \ W_{up} + 0.5 \ LL = 31983.953 \ lbf$

Case 5: $U_5 := 1.2 \ DL + 1.0 \ E + 0.5 \ LL = 34195.153 \ lbf$

Case 6: $U_6 := 0.9 \ DL + 1.0 \ W_{up} = 10452.965 \ lbf$

Case 7: $U_7 := 0.9 \ DL + 1.0 \ E = 12664.165 \ lbf$

$$P_u := \max\left(U_1, U_2, U_3, U_4, U_5, U_6, U_7\right) = 71899.953 \ lbf$$

Total Load Supported by Each Beam (Total of 31 Beams):

$$P_B := \frac{P_u}{31} = 2.319\ \boldsymbol{kip}$$

For Safety, Design for 2.5 kip: $P_B := 2.5\ \boldsymbol{kip}$

Total Load Supported by Each Stringer (2 Stringers per beam):

$$P_S := \frac{P_B}{2} = 1.25\ \boldsymbol{kip}$$

Horizontal Tension: $$P_h := \frac{P_u \cdot L}{8 \cdot S} = 98763.672\ \boldsymbol{lbf}$$

Total Tension in Cables: $$P_t := \frac{P_h}{\cos(\theta)} = 105103.11\ \boldsymbol{lbf}$$

Round up: $P_t := 106000\ \boldsymbol{lbf}$

Vertical Tension: $P_v := P_t \cdot \sin(\theta) = 36256.753\ \boldsymbol{lbf}$

Vertical Reaction at Towers: $F_y := 2\ P_v = 72513.506\ \boldsymbol{lbf}$

Number of Cables Needed: $FS := 3$ (Factor of Safety)

$BS := 132\ \boldsymbol{tonf}$ (Breaking Strength)

$$N := \frac{P_u \cdot FS}{BS} = 0.817$$

(Only one main cable is needed to support the load on each side)

Appendix E:

Tower Calculations

Tower Design Calculations:

1. Load determination-

Bridge Deck Area: $A := 128\ \mathbf{ft} \cdot 3\ \mathbf{ft} = 35.675\ \mathbf{m}^2$

Dead load: $q_d := 12523.769\ \mathbf{lbf}$

Live Load: $g_l := 35560\ \mathbf{lbf}$

Live load on each tower: $P_{LL} := \frac{g_l}{2} = 17.78\ \mathbf{kip}$

Dead load on each tower: $P_{DL} := \frac{q_d}{2} = 6.262\ \mathbf{kip}$

Length of main cable: $L_{tot} := 222.78\ \mathbf{ft}$

<u>Horizontal load on top of tower due to wind on span:</u>

Area of components: $A_{main} := 1.625\ \mathbf{in} \cdot L_{tot} = 30.168\ \mathbf{ft}^2$

$A_{suspend} := .75 \cdot \mathbf{in} \cdot 10\ \mathbf{ft} \cdot 88 = 55\ \mathbf{ft}^2$

$A_{deck} := A = 35.675\ \mathbf{m}^2$

Total area: $A_{total} := A_{main} + A_{suspend} + A_{deck} = 469.168\ \mathbf{ft}^2$

Resultant load on each tower: $W := \frac{A_{total} \cdot 20\ \mathbf{psf}}{2} = 4.692\ \mathbf{kip}$

Resultant load on each tower: $E := \frac{70.56\ \mathbf{plf} \cdot (128\ \mathbf{ft} + 20\ \mathbf{ft})}{2} = 5.221\ \mathbf{kip}$

- RAM Elements Was used to design and anylize the steel towers.
- The materials that were selected are as follows:

vertical members = L3x3x1/4"
webbing = 3/4" rounds
bracing = L2-1/2x2-1/2x3/16

2. Member Sizing Checks:

Webbing check:

Bottom 2 sections of webbing:

Max axial force bottom section: $P_u := 1200\ lbf$ Wind loading RAM Model

3/4" bar required

Input Variables: $E := 29000\ ksi$ $F_y := 36\ ksi$ $d_{bar} := 0.75\ in$ $L := 1.24\ ft$

$$A_{bar} := \frac{\pi}{4} \cdot d_{bar}^{\ 2} = 0.442\ in^2$$

radius of gyration: $r := \frac{d_{bar}}{4} = 0.188\ in$

$K := 1.0$ -> pinned-pinned connection

Elastic buckling stress: $F_e := \frac{\pi^2 \cdot E}{\left(\frac{K \cdot L}{r}\right)^2} = 45.446\ ksi$ E3-3

Critical stress: $\frac{K \cdot L}{r} = 79.36$

$4.71 \cdot \sqrt{\frac{E}{F_y}} = 133.681$ $79.36 \le 133.681$ -> Use Equation E3-2

$$F_{cr} := \left(0.658^{\frac{F_y}{F_e}}\right) \cdot F_y = 25.841\ ksi$$

$$\phi P_n := .9 \cdot F_{cr} \cdot A_{bar} = 10.275\ kip$$

$\phi P_n \ge P_u$ $10.275\ kip \ge 1.2\ kip$ -> OK

Use 3/4" A36 bar

Upper Angle Check:

Max axial force upper sections: $P_u := 5200\ lbf$ Wind loading RAM Model
L3x3x1/4"reqd'

Input Variables: $E := 29000\ ksi$ $F_y := 36\ ksi$ $L := 5\ ft$

$K := 1.0$ -> pinned-pinned connection

Effective length: $K \cdot L = 5\ ft$

$\phi P_n := 16.9\ kip$ Table 4-12

$\phi P_n \ge P_u$ $16.9\ kip \ge 5.2\ kip$ -> OK

Use L3x3x1/4" A36

Cross bracing Check:

Max axial force cross bracing: $P_u := 3500\ lbf$ Wind loading RAM Model
L2-1/2 x 2-1/2 x 3/16 reqd'

Input Variables: $E := 29000\ ksi$ $F_y := 36\ ksi$ $L := 5.83\ ft$

$K := 1.0$ -> pinned-pinned connection

Effective length: $K \cdot L = 5.83\ ft$ -> Round up to 6-ft

$\phi P_n := 6.61\ kip$ Table 4-12

$\phi P_n \ge P_u$ $6.61\ kip \ge 3.5\ kip$ -> OK

Use L2-1/2 x 2-1/2 x 3/16" A36

Base plate design:

$P_u := 67.2\ kip = 67.2\ kip$

Base plate dimemsions: $L := 12\ in$ $W := 12\ in$ $t := 2\ in$

$m := \frac{W}{2} = 6\ in$ $n := \frac{L}{2} = 6\ in$ AISC 14-5

$n' := \frac{\sqrt{2\ in \cdot 24\ in}}{4} = 1.732\ in$

$l := \max(m, n, n') = 6\ in$

min. plate thickness: $t_{min} := l \cdot \sqrt{\frac{2 \cdot P_u}{.9 \cdot F_y \cdot L \cdot W}} = 1.018\ in$ 14-7a

$\text{if}\ (t \geq t_{min}, \text{“OK”}, \text{“NG”}) = \text{“OK”}$

Concrete bearing: $\phi P_p := .65 \cdot .85 \cdot 2500\ psi \cdot L \cdot W = 198.9\ kip$

$\text{if}\ (\phi P_p \geq P_u, \text{“OK”}, \text{“NG”}) = \text{“OK”}$

Base plate OK

Appendix F:

Tower Foundation Design Calculations

Tower Foundation Design Calculations:

For square foundations:

$L := 12\ ft$

$W := 10\ ft$

$D := 6\ ft$ — Depth of foundation. Dependent on depth of possible excavation.

$V := L \cdot W \cdot D = 720\ ft^3$ — Volume of concrete needed

$Wt_{con.} := 150\ pcf$ — Standard unit weight of concrete.

$F_{con.} := Wt_{con.} \cdot V = 108\ kip$ — Force of concrete

$F_{tower} := 72.513\ kip$ — Force of tower calculated in the Final Calculation document

$F_{total} := F_{con.} + F_{tower} = 180.513\ kip$ — Total force acting down on the soil

Check Bearing Capacity:

$q := 4200\ psf$ — Estimated from ICC Presumptive load-bearing values. Taken as sedimentary and foliated rock. Coefficient of friction for laterial sliding: $\phi = .35$

$F_{soil} := q \cdot L \cdot W = 504\ kip$ — Force of soil on foundation

$FS := 2.5$ — Factor of safety

$$\frac{F_{soil}}{FS} = 201.6\ kip$$

$$\frac{F_{soil}}{FS} > F_{total}$$

Soil can support the load of the towers and the foundation

Check Overturning:

$V_{wind} := 7.6\ kip$ Shear force of tower due to wind

$M_{wind} := 76\ kip \cdot ft$ Moment force of tower due to wind

$M_{OT} := 2 \cdot M_{wind} + 2 \cdot D \cdot V_{wind} = 243.2\ kip \cdot ft$ Overturning moment

$M_{resist.} := F_{con.} \cdot \left(\frac{L}{2}\right) = 648\ kip \cdot ft$ Resisting moment is greater than

Appendix G:

Anchor Block Calculations

Anchor Block Calculations:

$F_{total} := 106000\ lb$ Tension in cable

$F := F_{total} = 53\ ton$

$F_T := F \cdot g = 106\ kip$

$B := 12\ ft$

$H := 8\ ft$

$L := 16\ ft$

$V := H \cdot B \cdot L = \left(1.536 \cdot 10^3\right)\ ft^3$

$Wt_{con.} := 150\ \frac{lb}{ft^3} \cdot V = \left(2.304 \cdot 10^5\right)\ lb$ Standard unit weight of concrete

$W_{con.} := 230.4\ kip$

$L_{steel1} := 4 \cdot L = 64\ ft$

$L_{steel2} := 130\ ft$

Length of reinforcing steel running perpendicular to cables

$L_{steel} := 130\ ft + L_{steel1} = 194\ ft$

$W_{no.7} := 0.376\ \frac{lb}{ft}$

Weight of steel is not very significant compared to concrete

$W_{steel} := L_{steel} \cdot W_{no.7} = 72.944\ lb$

$W_{steel} := 0.073\ kip$

$W := W_{con.} + W_{steel} = 230.473\ kip$

Resultant Forces:

$T_H := 98763.672\ lb$

$T_H = 49.382\ ton$

$T_H := T_H \cdot g = 98.764\ kip$

$\phi := 30\ °$

$T_V := 36256.753\ lb$

$T_V = 18.128\ ton$

$T_V := T_V \cdot g = 36.257\ kip$

Check Sliding:

$\mu := .50$ Friction factor

$F_{SL} := \mu \cdot \langle W - T_H \rangle = 65.855\ kip$ Force of sliding

$FS_{SL} := \frac{F_{SL}}{T_V} = 1.816$ > 1.5 Factor of safety for sliding

OK

Check Bearing Capacity and Shear Failure:

$Q_v := 4200\ psf$ Estimated, see foundation calcs for details.

$R_v := \frac{\langle W - T_V \rangle}{(B \cdot L)} = 0.007\ ksi$

$FS_{BC} := \frac{Q_v}{R_v} = 4.152$ > 2.0 Factor of safety for bearing capacity and shear failure

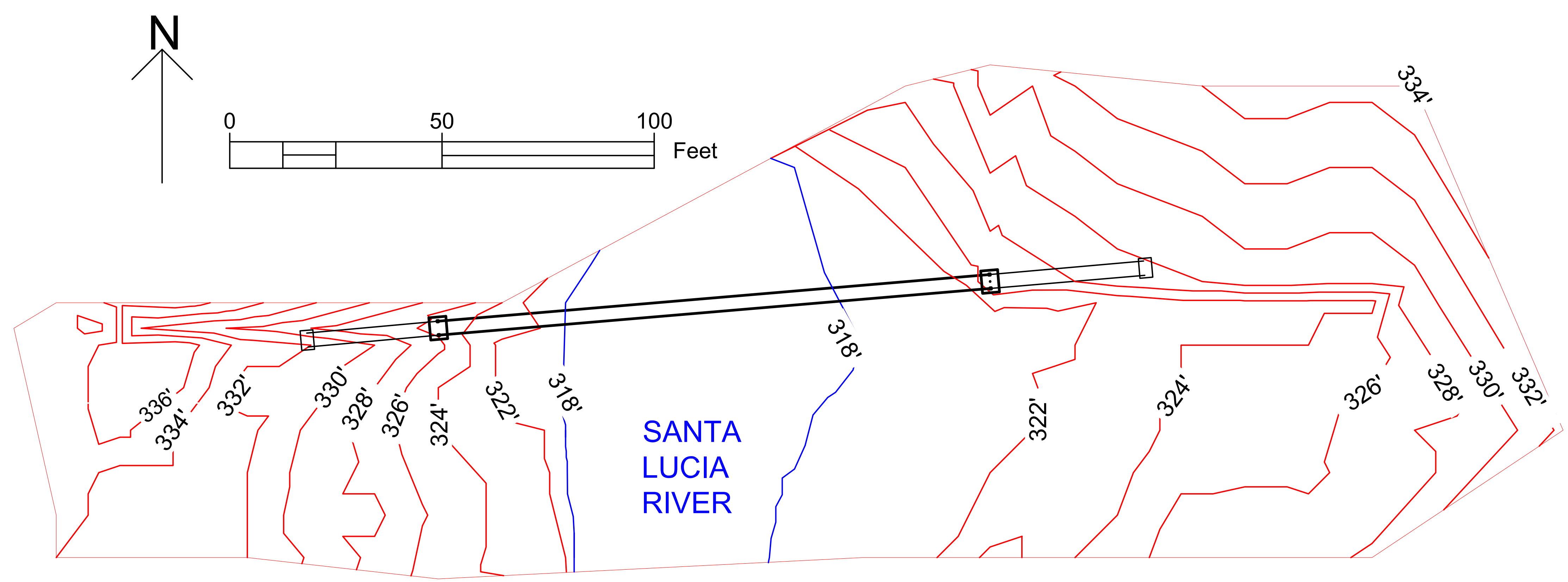
OK

Appendix H:
Design Drawings

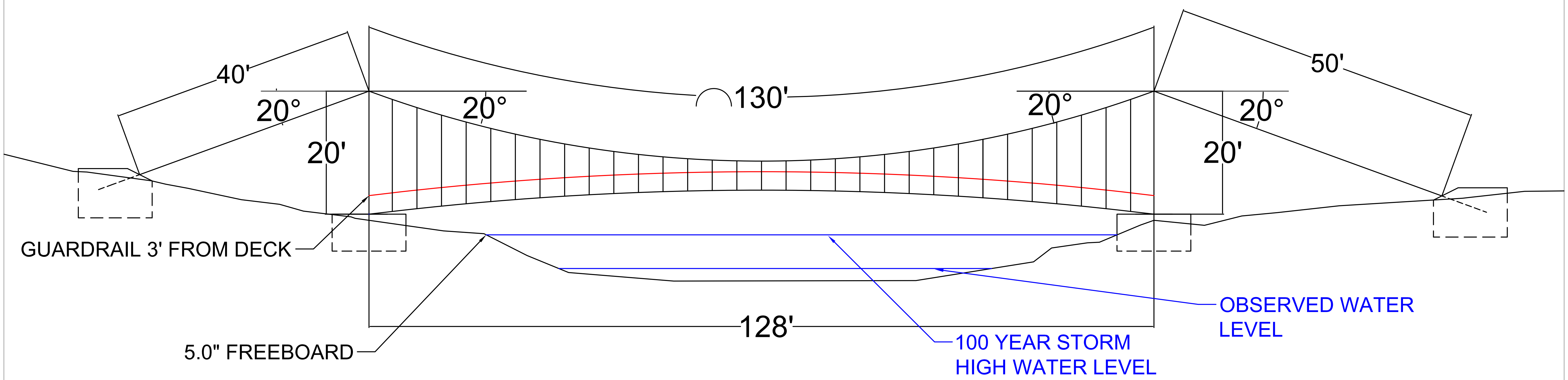
SANTA LUCIA RIVER CROSSING

QUEBRADA CARACOL
CHIRIQUI, PANAMA

INDEX OF SHEETS

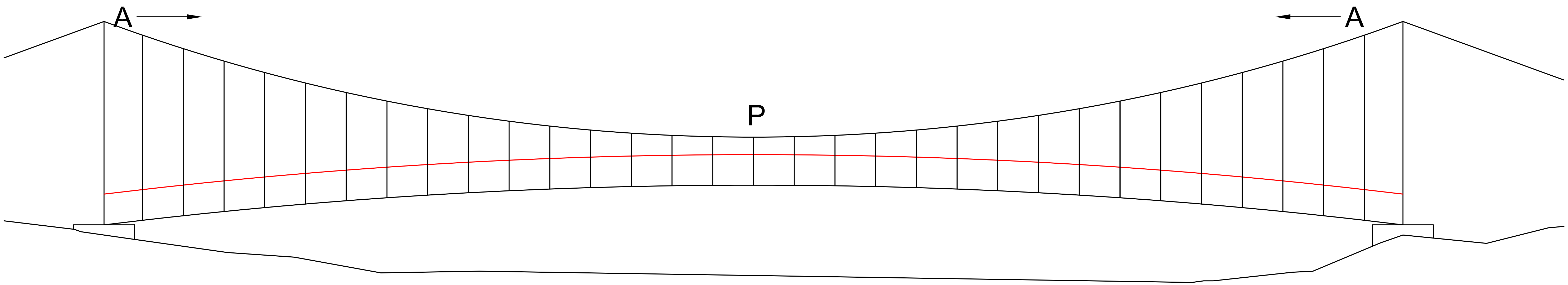


BRIDGE PLAN VIEW	QUEBRADA CARACOL RIO SANTA LUCIA SUSPENSION BRIDGE	SCALE: 1:16 CI: 2.0' DATE: 10/22/2015	BRIDGEDRAWINGPRELIM.DWG Pg. # 2 of 8

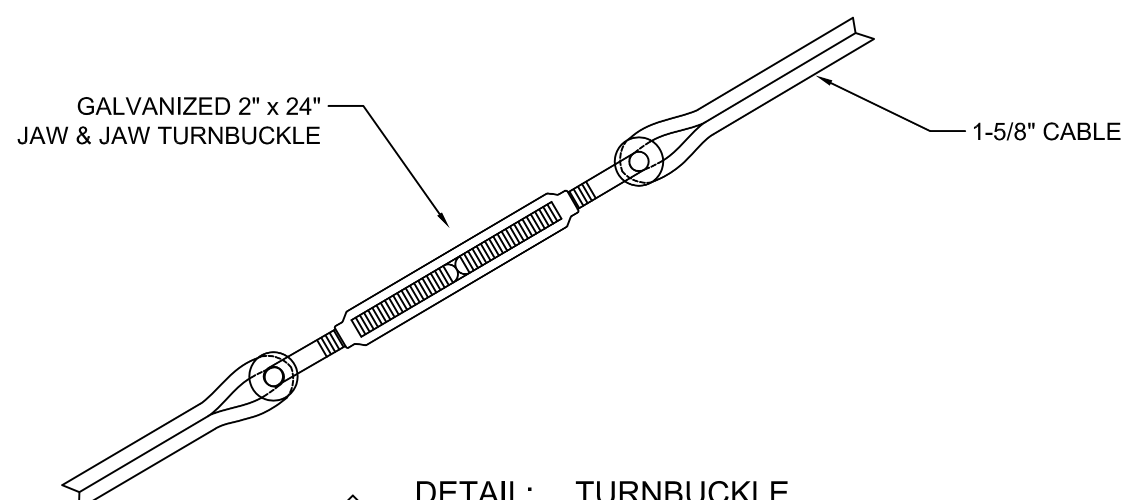


BRIDGE PROFILE	QUEBRADA CARACOL RIO SANTA LUCIA SUSPENSION BRIDGE	SCALE: 1:8	BRIDGE PROFILE.DWG
		DATE: 10/22/2015	Pg. # 3 OF 8

LUCIA ASSOCIATES



1 PROFILE: BRIDGE HANGER LAYOUT
SCALE: 1:5

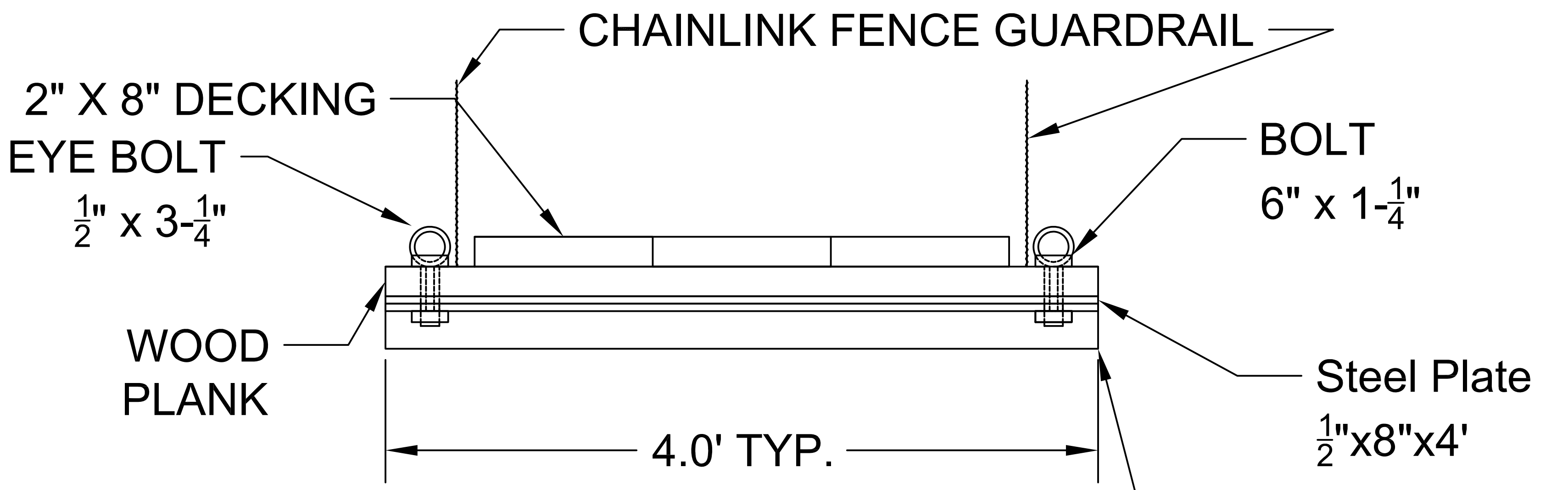


1 DETAIL: TURNBUCKLE
SCALE: 1:10

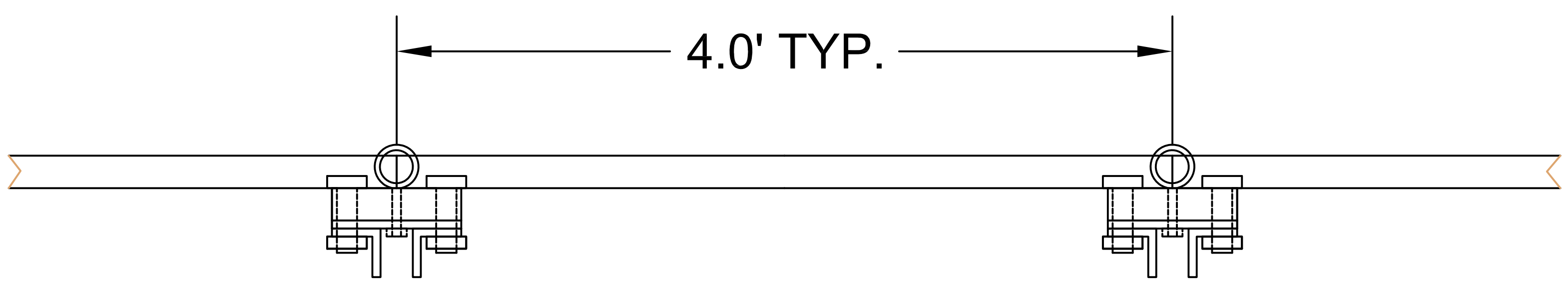
Hanger Cable Assembly Lengths

Location	Length (ft)	# Required
A	19.0300	4
B	17.2600	4
C	15.6200	4
D	14.1100	4
E	12.7300	4
F	11.4700	4
G	10.3400	4
H	9.3300	4
I	8.4400	4
J	7.6700	4
K	6.9900	4
L	6.4900	4
M	6.0500	4
N	5.7900	4
O	5.5900	4
P	5.5500	2
TOTAL LENGTH OF $\frac{1}{4}$" CABLE		639 Feet

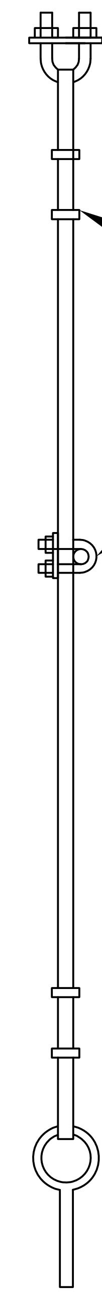
Suspender Cable Lengths	QUEBRADA CARACOL RIO SANTA LUCIA SUSPENSION BRIDGE	SCALE: AS SHOWN	SUSPENDER CABLES.DWG	LUCIA ASSOCIATES
		DATE: 10/20/2015	Pg. # 3 of 7	



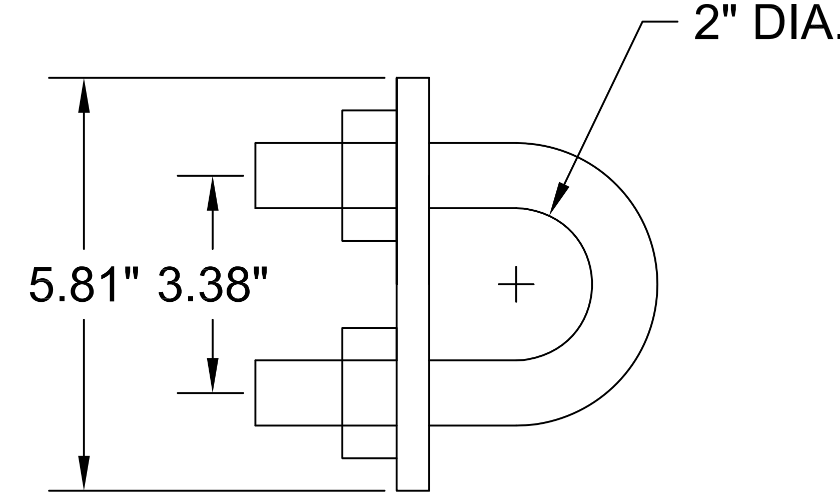
1 SECTION: BRIDGE DECKING
SCALE: 1" = 1'



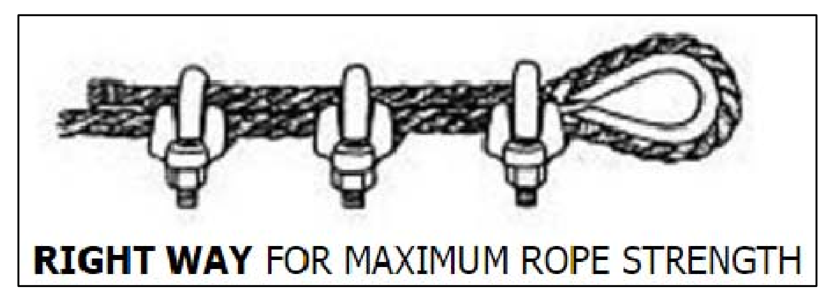
2 PROFILE: BRIDGE DECKING
SCALE: 1" = 1'



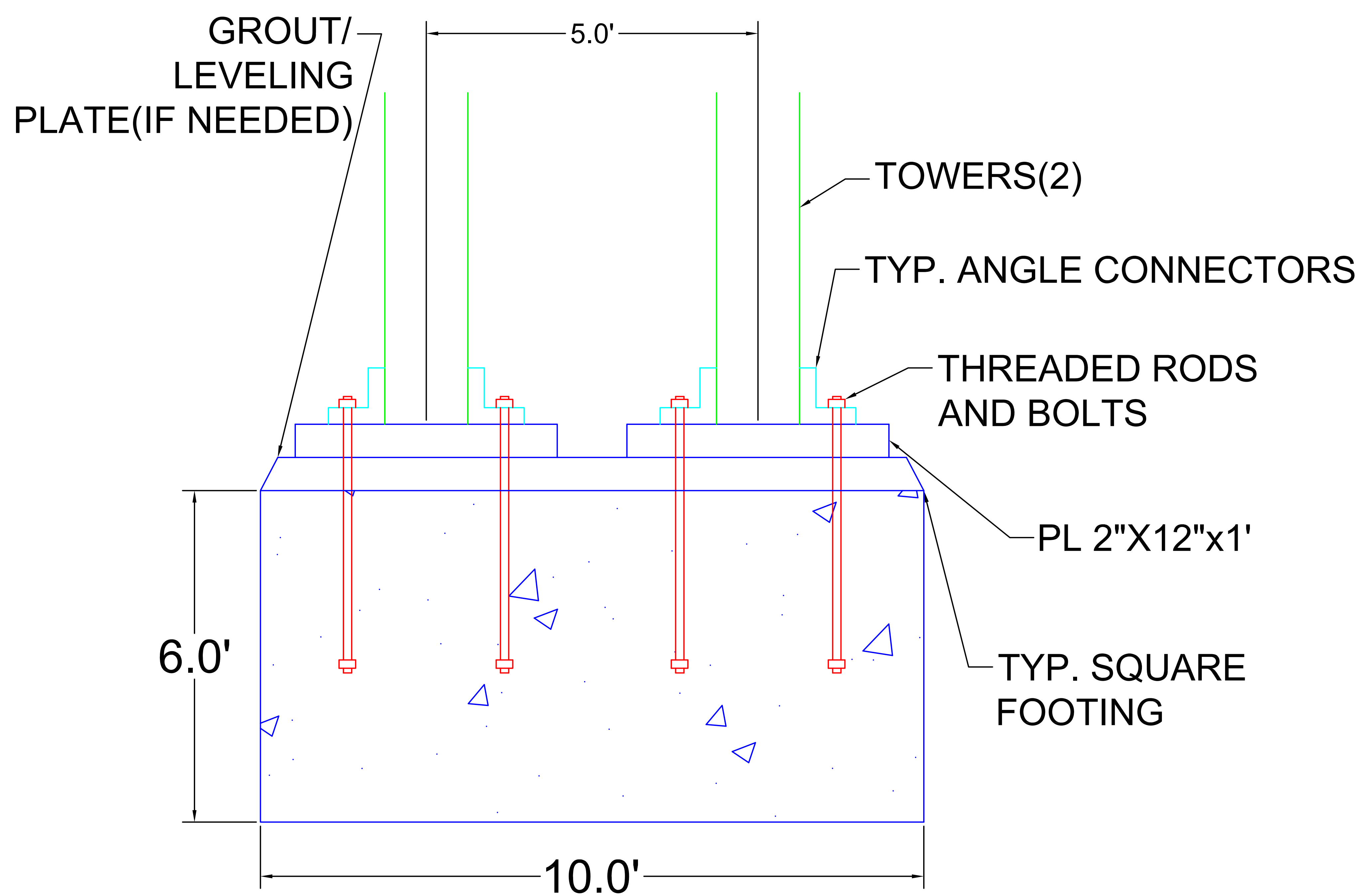
3 DETAIL: HANGER ASSEMBLY
SCALE: 1" = 1'



4 DETAIL: 2" WIRE CLIP
SCALE: 1" = 1'

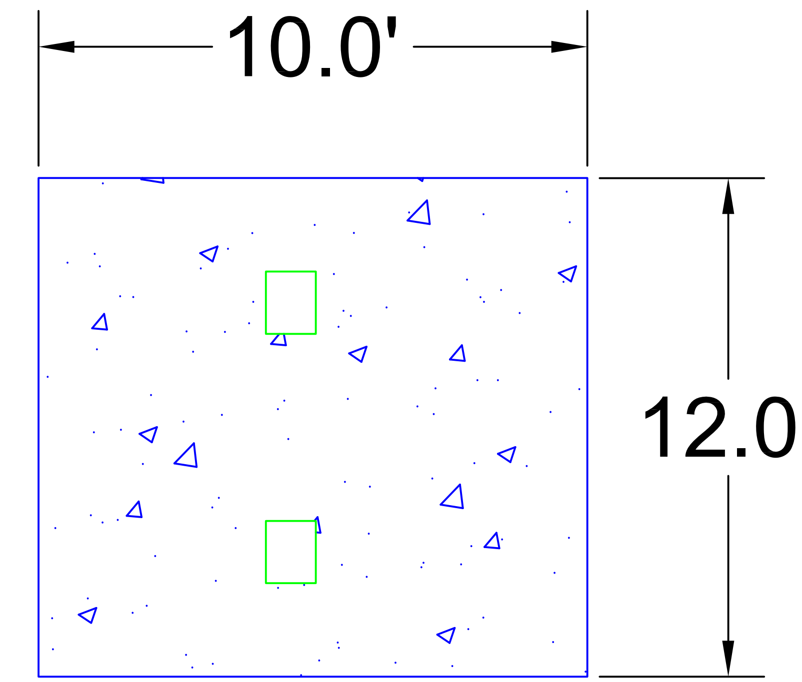


BRIDGE DECK DETAILS	QUEBRADA CARACOL RIO SANTA LUCIA SUSPENSION BRIDGE	SCALE: AS SHOWN	DECK DETAILS.DWG	LUCIA ASSOCIATES
		DATE: 10/20/2015	Pg. # 4 of 7	



1 PROFILE: FOUNDATION

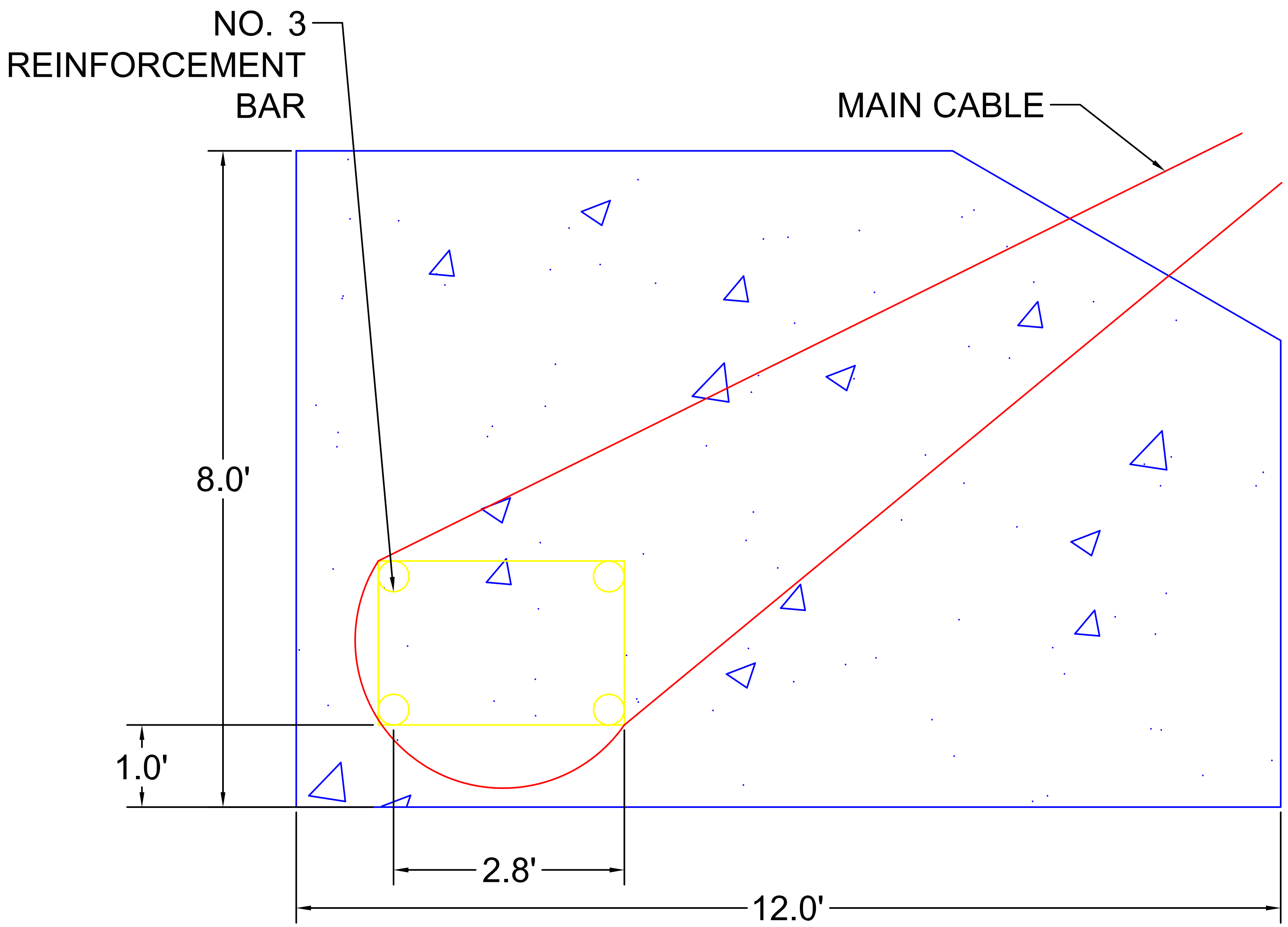
SCALE: 1:2



2 PLAN: FOUNDATION

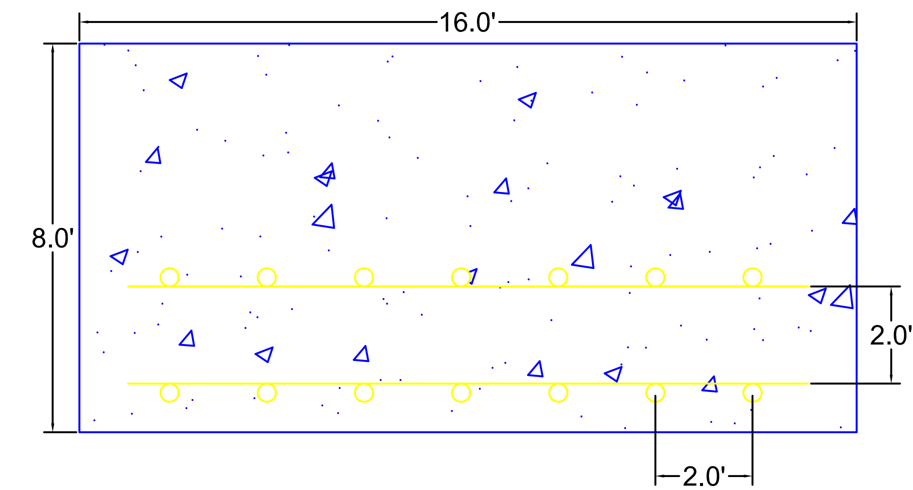
SCALE: 1:4

Foundation Detail	Quebrada Caracol Rio Santa Lucia Suspension Bridge	SCALE: As Shown	Foundation Detail.dwg
		DATE: 10/20/2015	Pg. # 5 of 7



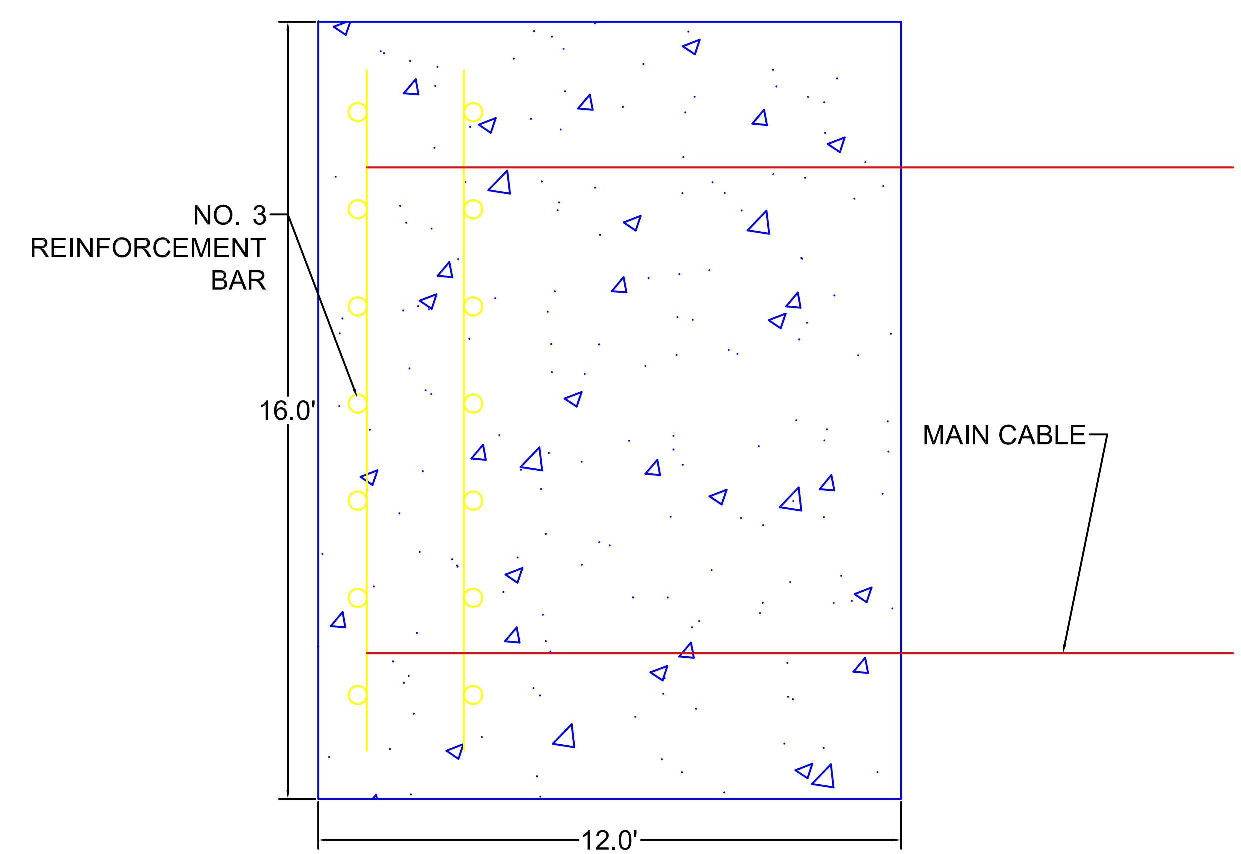
Section B-B: ANCHOR DETAIL

SCALE: 1:1



DETAIL: ANCHOR DETAIL

SCALE: 1:2

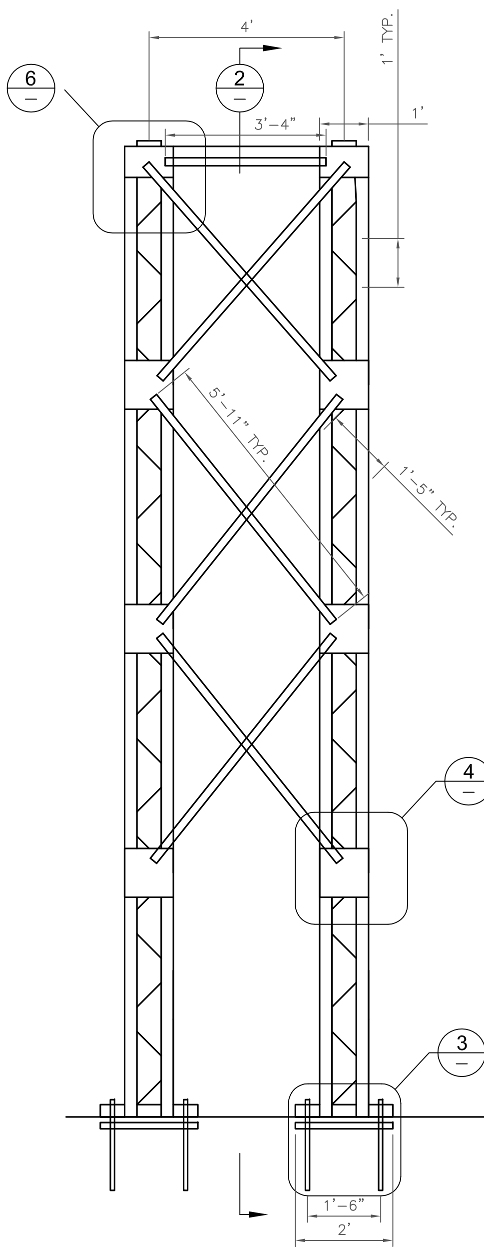


Plan View: TOWER FOUNDATION

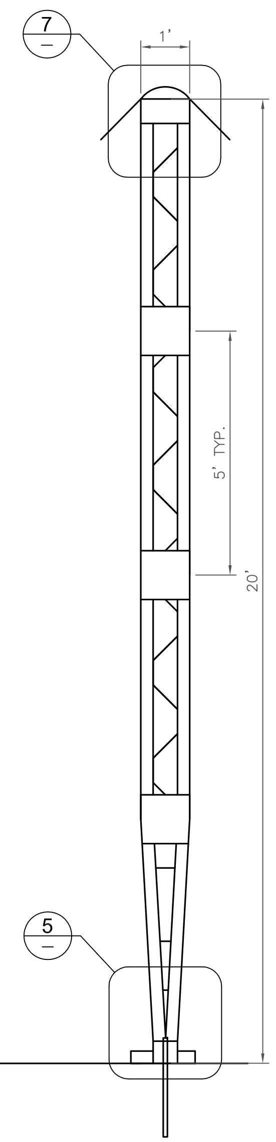
SCALE: 1:2

ANCHOR DETAIL	QUEBRADA CARACOL RIO SANTA LUCIA SUSPENSION BRIDGE	SCALE: AS SHOWN	ANCHOR DETAIL.DWG
		DATE: 10/20/2015	Pg. # 6 OF 7

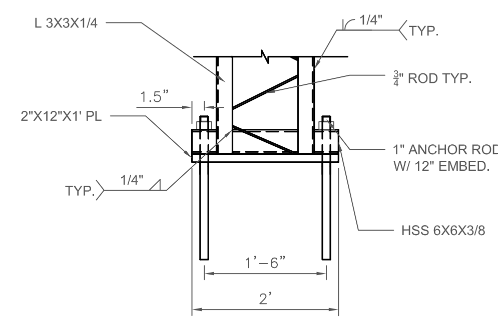
LUCIA ASSOCIATES



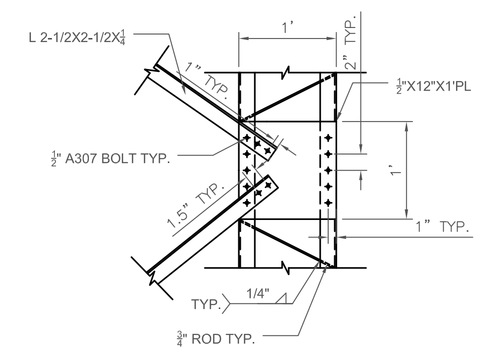
1 ELEVATION: TOWER
SCALE: 1/4" = 1'-0"



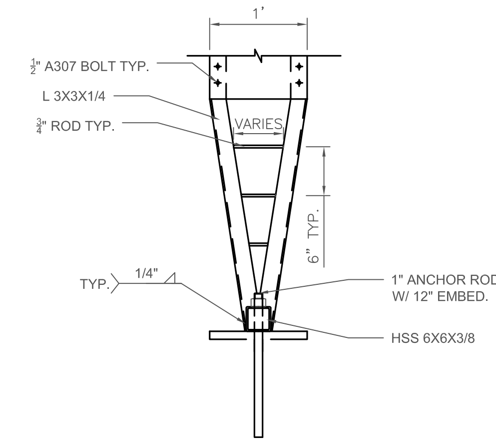
2 SECTION: TOWER
SCALE: 1/4" = 1'-0"



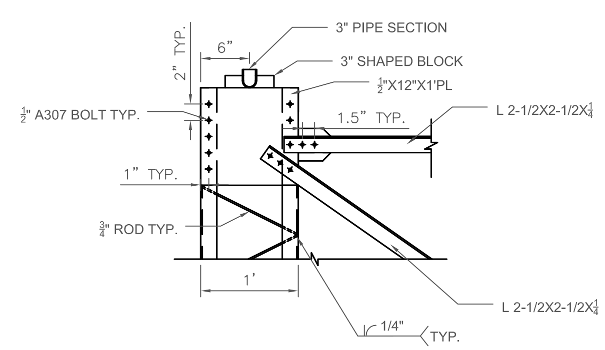
3 DETAIL: TOWER ANCHORAGE
SCALE: 1" = 1'-0"



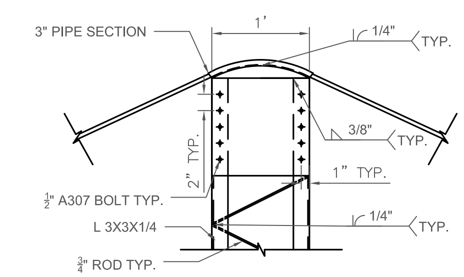
4 DETAIL: BRACING CONNECTION
SCALE: 1" = 1'-0"



5 DETAIL: TOWER ANCHORAGE
SCALE: 1" = 1'-0"



6 DETAIL: TOP CONNECTION/SADDLE
SCALE: 1" = 1'-0"



7 DETAIL: TOP CONNECTION/SADDLE
SCALE: 1" = 1'-0"

TOWER DETAILS	QUEBRADA CARACOL RIO SANTA LUCIA SUSPENSION BRIDGE	SCALE: AS SHOWN DATE: 10/22/2015	TOWER DETAILS.DWG Pg. # 7OF 7

LUCIA ASSOCIATES

Appendix I:
Construction Schedule

No.	Activity
1	Complete Road up to Bridge Site
2	Mobilization
3	Clearing and Grubbing at Site
4	Gather Materials for Foundations and Anchor Blocks
5	Construct Foundations
6	Construct Anchor Blocks
7	Gather Materials for Tower Assembly
8	Construct and Place Towers
9	Gather Materials for Decking Assembly and Fencing
10	Assemble and Place Decking
11	Adjust Main Cables to Level Bridge Deck
12	Install Fencing
13	Construct Pathway Up to Bridge
14	Demobilization
15	Bridge Opening Ceremony
16	Bridge Maintenance

Activities

1. Complete Road up to Bridge Site
    a. The existing pathway from the main road to the Santa Lucia River, at the bridge site shall be graded. This roadway will allow for equipment and trucks to access the bridge site for an easier construction process. There is $50,000 in funding to complete this project prior to the construction of the Santa Lucia Bridge Crossing.
2. Mobilization
    a. An Excavator shall be brought onto the site to assist in the completion of excavation requirements, as well as to assist with the lifting and placement of heavy members of the bridge.
3. Clearing and Grubbing at Site
    a. Clearing and grubbing tasks will be completed by the community members. The proposed location of the bridge was chosen to minimize the number of trees to be cut down. An Environmental Agency in the area discourages cutting down trees along the banks of the river, so there should not be extensive clearing and grubbing work to be completed.
4. Gather Materials for Foundations and Anchor Blocks
    a. Materials for the Foundations and Anchor Blocks include:
        i. Reinforcing Steel Rebar
        ii. Concrete, which will be brought to the site already mixed by truck
5. Construct Foundations
    a. The excavator will be used to create a cut section where the foundations will be placed.

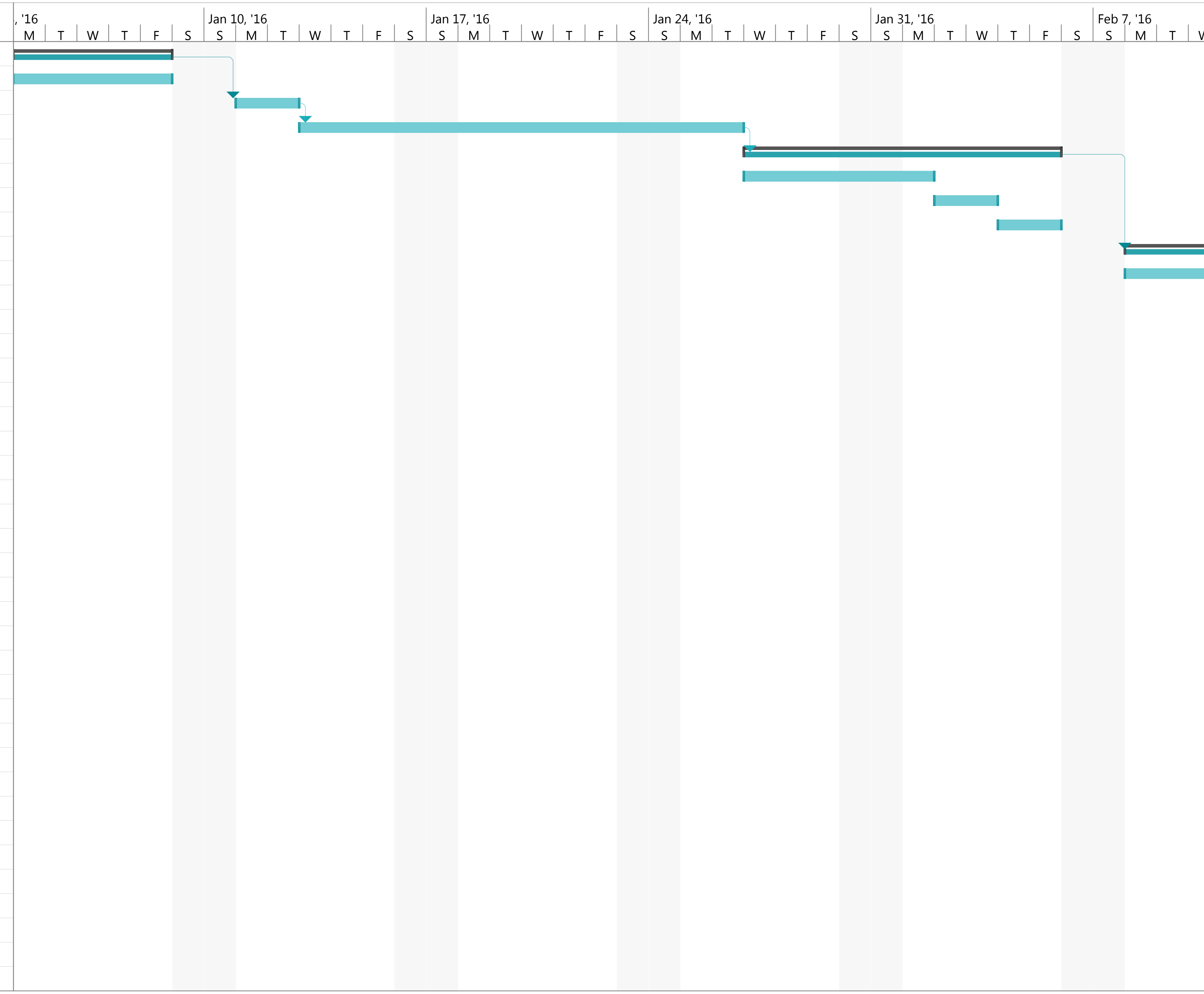
b. The reinforcing steel rebar will be tied and placed in the foundation according to the construction details.
c. Concrete will be brought in by trucks, poured in place over the tied rebar and finished.

6. Construct Anchor Blocks
   a. The excavator will be used to create a cut section where the Anchor Block will be placed.
   b. The reinforcing steel rebar will be tied and placed in the Anchor Block according to the construction details.
   c. Set the main suspension cable by wrapping the cable around the rebar cage. This will be completed according to the construction detail drawing.
   d. Concrete will be brought in by trucks, poured in place over the tied rebar and main suspension cable, and then it shall be finished.
7. Gather Materials for Tower Assembly
   a. Materials for the Towers include:
      i. Tower Assembly
      ii. Bolts
      iii. Base Plates
8. Construct and Place Towers
   a. The towers assembly will be built on site. This will only include bolting sections together.
   b. Place the Base Plates on the Foundation
   c. Attach Tower Assembly to the Base Plates. The excavator can be used to help erect the towers.
   d. Place the main suspension cables into place over the top of the tower assembly
9. Gather Materials for Decking Assembly and Fencing
   a. Materials of the Decking and Fencing include:
      i. Steel Angles
      ii. Steel Plates
      iii. Wood Beams
      iv. Wood Boards for Decking
      v. Stringer Cables
      vi. Bolts
      vii. Nails
      viii. Wire Clips
      ix. Fencing
10. Assemble and Place Decking
    a. Assemble the Cross Members of the Decking. This includes the steel angles, steel plate, wood beam, and bolts.
    b. Hang the stringers from the main suspension cable, using wire clips to attach. The length of the stringer cables should follow the lengths given in the table of the stringer cable construction detail.

c. Attach the assembled cross members to the stringers. The stringer cables will be threaded through the I-bolts on the cross member assembly and held in place by wire clips. Ensure the length of the stringer cables are following the given lengths in the construction details.
d. Attach wood decking boards with nails.

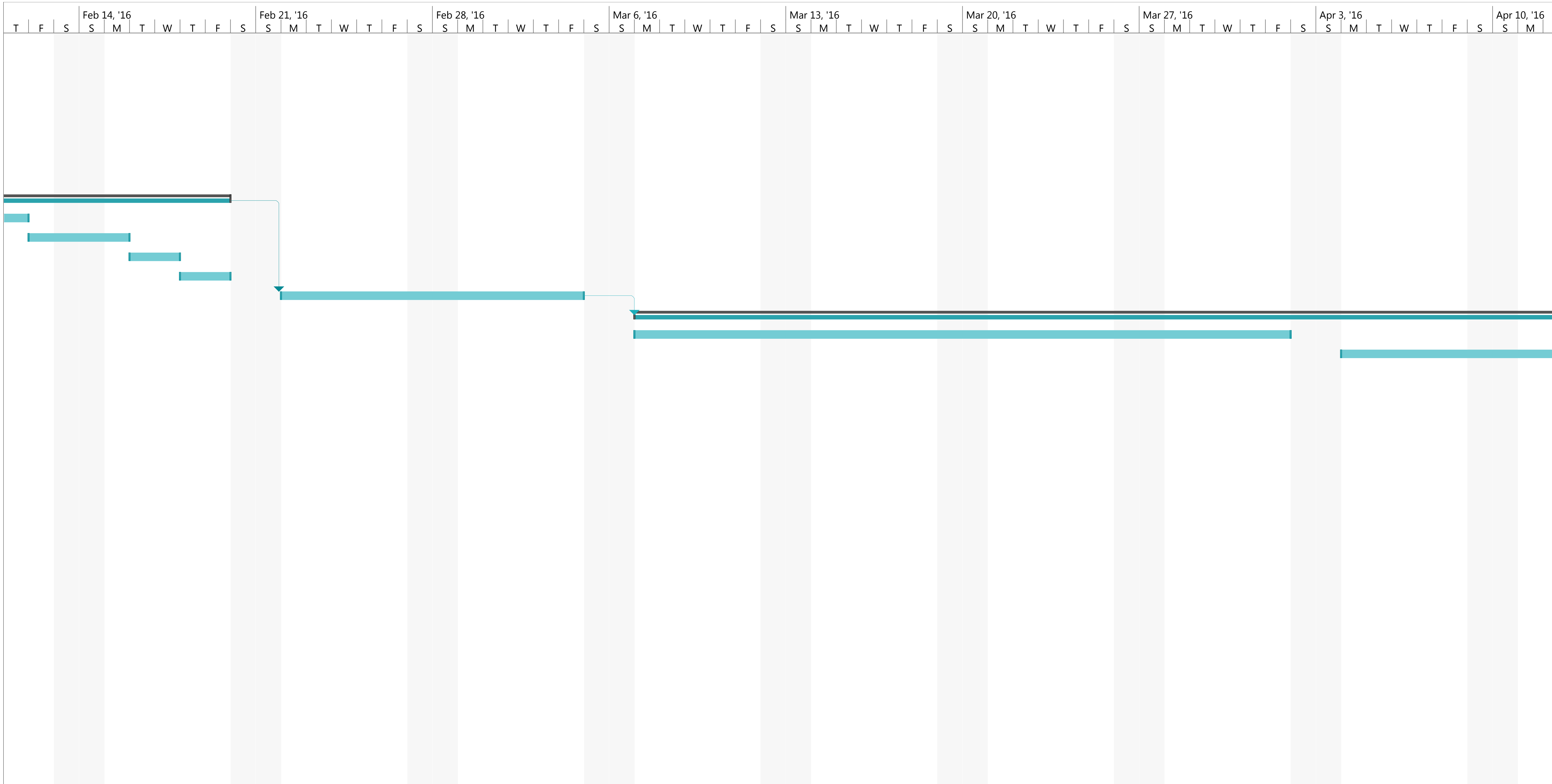
11. Adjust Main Cables to Level Bridge Deck
    a. The length of the main cable will be adjusted by the turnbuckle placed on one of the main suspension cables. The turnbuckle can be used to lengthen or shorten the main cable to level the bridge deck.
12. Install Fencing
    a. Chain link fencing will be used to ensure the bridge is safe for children to pass over by preventing the possibility of falling from the bridge deck. The fencing will be attached to the stringer cables using wire clamps.
13. Construct Pathway Up to Bridge
    a. The existing pathway shall be connected to the bridge approach. The pathway will be a compacted dirt path, and it will resemble the existing paths in the area.
14. Demobilization
    a. The excavator will be removed from the site.
15. Bridge Opening Ceremony
16. Bridge Maintenance
    a. Painting Towers on a regular basis to prevent rusting
    b. Check cables for stretching, any damaged or rusted sports
    c. Check and replace individual bolts if needed
    d. Check decking for rotten boards
    e. Check for erosion around foundations and make changes if necessary

ID	Task Mode	Task Name	Duration
1		**Mobilization**	**5 days**
2		Bring in Excavator	5 days
3		**Clearing and Grubbing at Site**	**2 days**
4		**Gather Material for Foundations and Anchor blocks**	**10 days**
5		**Foundations**	**8 days**
6		Excavation of Foundation Sites	4 days
7		Tie Rebar and Set in Place	2 days
8		Pour Concrete and Finish	2 days
9		**Anchor blocks**	**10 days**
10		Excavation of Anchor block Sites	4 days
11		Tie Rebar and Set in Place	2 days
12		Set Main Suspension Cable by wrapping around Rebar Cage	2 days
13		Pour Concrete and Finish	2 days
14		**Gather Materials for Tower Assembly**	**10 days**
15		**Towers**	**37 days**
16		Fabrication	20 days
17		Assembly Tower Parts	7 days
18		Place Baseplate on Foundation	2 days
19		Attach Tower to Foundation	4 days
20		Place Main Suspension Cable over Towers	4 days
21		**Gather Materials for Decking Assembly and Fencing**	**10 days**
22		**Decking**	**15 days**
23		Assemble Cross Members	5 days
24		Hang Stringers	3 days
25		Attach Cross Member Assemblies to Stringers	5 days
26		Screw down Wood Deck Boards	2 days
27		**Adjust Main Cables to level Bridge Deck**	**1 day**
28		**Fencing**	**2 days**
29		Place Fence and Attach to Stringer Cables	2 days
30		**Pathway**	**2 days**
31		Level Ground between existing trail and bridge approach	2 days
32		**Demobilization**	**2 days**
33		**Bridge Opening Ceremony**	**1 day**
34		**Bridge Maintenance**	
35		Paint Towers	
36		Check Cables	
37		Check Bolts	
38		Check Decking Boards	
39		Check for Erosion around Foundations	



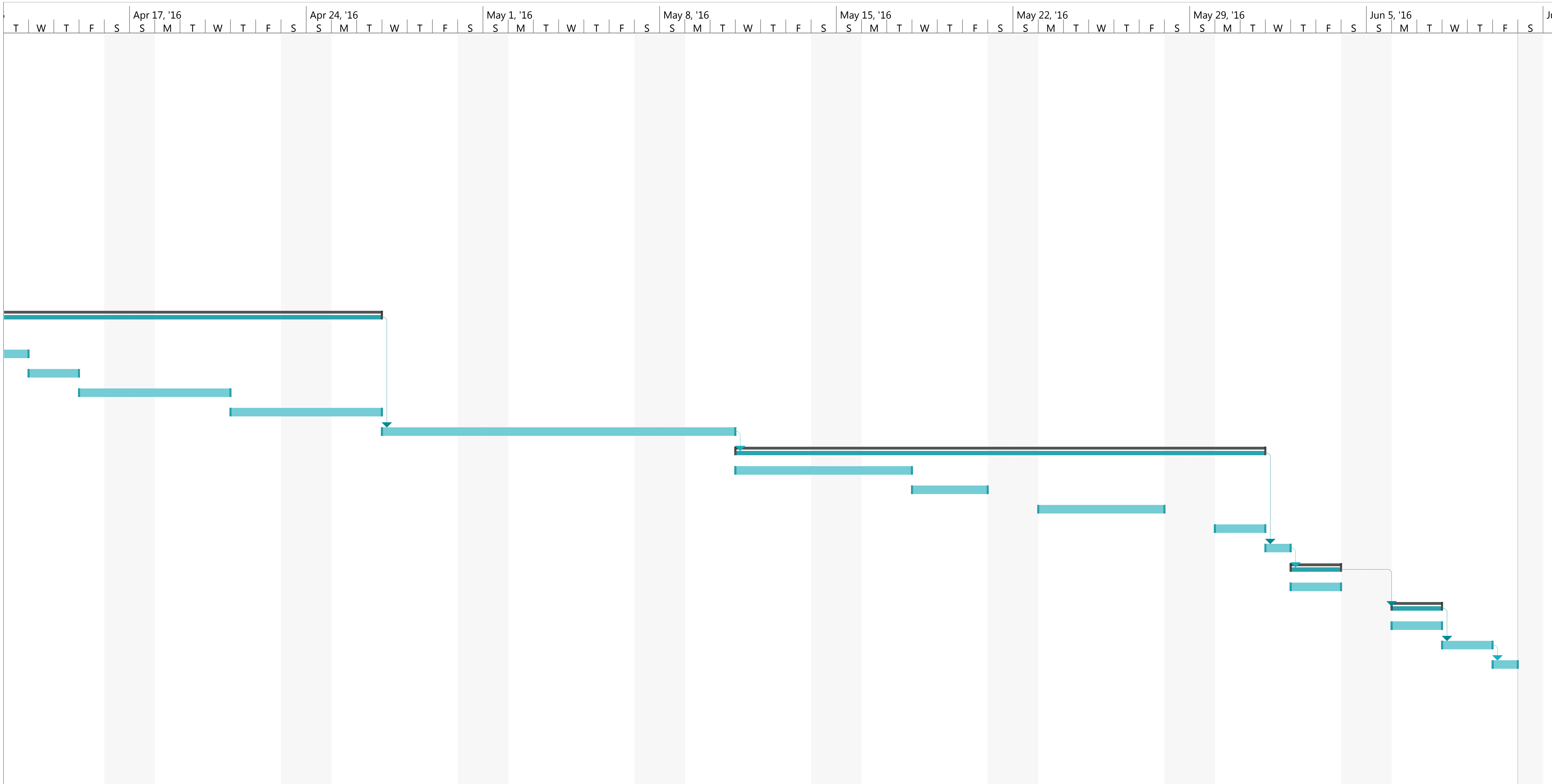
Project: CE4916_Construction_S
Date: Tue 11/17/15

Task		Project Summary		Manual Task		Start-only		Deadline	
Split		Inactive Task		Duration-only		Finish-only		Progress	
Milestone		Inactive Milestone		Manual Summary Rollup		External Tasks		Manual Progress	
Summary		Inactive Summary		Manual Summary		External Milestone			



Project: CE4916_Construction_S
Date: Tue 11/17/15

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	



Project: CE4916_Construction_S
Date: Tue 11/17/15

Task	Project Summary	Manual Task	Start-only	Deadline
Split	Inactive Task	Duration-only	Finish-only	Progress
Milestone	Inactive Milestone	Manual Summary Rollup	External Tasks	Manual Progress
Summary	Inactive Summary	Manual Summary	External Milestone	

Appendix J:

Cost Estimate

Item Number	Category	Item Description	Quantity	Units	Material Unit Rate	Equipment Unit Rate	Labor Unit Rate	Unit Cost	Unit Cost with Sm. Tools and delivery	Total Cost
001	Towers	L3x3x1/4" x 10'	320	LF	$ 8.56		$ -	$ 8.56	$ 9.42	$ 3,100
002	Towers	L2-1/2x2-1/2x3/16"x6'	143	LF	$ 8.56		$ -	$ 8.56	$ 9.42	$ 1,400
003	Towers	3/4" Round Bar	450	LF	$ 1.02		$ -	$ 1.02	$ 1.12	$ 600
004	Towers	5/16"x12"x12" Plate	40	EACH	$ 63.59		$ -	$ 63.59	$ 69.95	$ 2,800
005	Towers	1/2" A307 Bolts/Nuts	800	EACH	$ 0.38		$ -	$ 0.38	$ 0.42	$ 400
006	Towers	1-1/4" B7 Anchor Rods	8	EACH	$ 35.25		$ -	$ 35.25	$ 38.78	$ 400
007	Towers	2"x12"x1' Plate	4	EACH	$ 110.00		$ -	$ 110.00	$ 121.00	$ 500
008	Towers	Steel Erection	1	LS	$ -		$ 2,909.09	$ 2,909.09	$ 3,200.00	$ 3,200
009	Cables	1-5/8" Main - 223' ea.	446	LF	$ 25.36		$ -	$ 25.36	$ 27.90	$ 12,500
010	Cables	1/4" Rail - 128' ea	256	LF	$ 4.31			$ 4.31	$ 4.74	$ 1,300
011	Cables	1/4" Suspenders - vary	639	LF	$ 4.31			$ 4.31	$ 4.74	$ 3,100
012	Cables	2" Wire Rope Clips	80	EACH	$ 84.00			$ 84.00	$ 92.40	$ 7,400
013	Cables	1/4" Wire Rope Clips	0.69	EACH	$ 310.00			$ 310.00	$ 341.00	$ 300
014	Anchor Block	Turnbuckle - Crosby HG-228 Jaw & Jaw 2" x 24"	4	EACH	$ 600.00		$ 8.11	$ 608.11	$ 668.92	$ 2,700
015	Anchor Block	Concrete	115	CY	$ 149.00		$ 0.50	$ 149.50	$ 164.45	$ 19,000
016	Anchor Block	5/8" A36 Steel Round Bar	0.27118	TON	$ 702.38		$ 40.48	$ 742.86	$ 817.14	$ 300
017	Anchor Block	5/8" A36 Steel Ties	0.32542	TON	$ 702.38		$ 28.33	$ 730.71	$ 803.79	$ 300
018	Anchor Block	1" x 1" Square Bar Anchorage Hook	120	LF	$ 8.00		$ 0.67	$ 8.67	$ 9.53	$ 1,200
019	Anchor Block	Anchor Block Excavation	115	CY	$ -	$ 3.97	$ 4.15	$ 8.12	$ 8.93	$ 1,100
020	Tower Foundation	Concrete (Tower Foundation)	54	CY	$ 149.00		$ 0.50	$ 149.50	$ 164.45	$ 8,900
021	Tower Foundation	Anchorage Hooks	30	LF	$ 4.67			$ 4.67	$ 5.14	$ 200
022	Tower Foundation	No. 6 Rebar	0.58	TON	$ 700.00		$ 24.52	$ 724.52	$ 796.98	$ 500
023	Tower Foundation	Foundation Excavation	115	CY		$ 3.97	$ 4.15	$ 8.12	$ 8.93	$ 1,100
024	Walkway	2"x8"x8' Wood Deck Members	96	EACH	$ 10.00		$ 23.87	$ 33.87	$ 37.26	$ 3,600
025	Walkway	2L3"x3"x1/2" Steel Beams	62	LF	$ 24.32		$ 2.49	$ 26.81	$ 29.49	$ 1,900
026	Walkway	2"x8"x8' Wood Beams	31	EACH	$ 10.00		$ 24.23	$ 34.23	$ 37.65	$ 1,200
027	Walkway	Bolts/Nut 6" x 1-1/4" A307	124	EACH	$ 4.45			$ 4.45	$ 4.90	$ 700
028	Walkway	4" Decking Screws	600	EACH	$ 0.28		$ 0.12	$ 0.40	$ 0.44	$ 300
029	Walkway	8"x1/2"x4' Steel Plates	31	EACH	$ 85.70			$ 85.70	$ 94.27	$ 3,000
030	Walkway	Eye Bolts 1/2" x 3-1/4"	62	EACH	$ 12.62			$ 12.62	$ 13.88	$ 900
031	Walkway	Nut - 1/2" Dia.	340	EACH	$ 0.53			$ 0.53	$ 0.58	$ 200
032	Concrete	Concrete Trucks	19	EACH		$ 82.19		$ 82.19	$ 90.41	$ 1,800
					$ 66,717	$ 2,475	$ 7,365	$ 76,556	$ 84,212	$ 85,900