# Radial 16 Canal and Road Between 5th Ring and 30th de Agosto Curichi


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Submitted To:
District 10 Santa Cruz, Bolivia

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## Disclaimer

This design report was completed by International Senior Design students at Michigan Technological University for a class project. This report must be checked and approved by a licensed Professional Engineer for accuracy before implementation.

# Acknowledgments

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## Executive Summary

Tip Third Engineering (T.T.E.) has developed a canal and roadway design to help alleviate flooding in District10, Santa Cruz, Bolivia. The project site is between 30th de Agosto Curichi (swamp) and the proposed Radial 16 roadway which are located in UVs 118 and 118A. The proposed design utilizes road pavement and concrete canals to transfer water from the 30th de Agosto Curichi to 5th Ring drainage system.

In August 2008, T.T.E. visited Santa Cruz Bolivia for two weeks. T.T.E. was given the job of designing a road and canal system which would reduce the flooding for local residents.  The visit consisted of collecting soil samples, a topographic survey, soil borings, and watershed delineation.

After returning to Michigan Technological University, T.T.E. designed the roadway and canal. T.T.E. designed to Bolivian standards while also making a safe, cost effective design. T.T.E. studied previous watersheds and watershed data from various sources, which is described further in the report. T.T.E. calculated the design capacity to effectively drain storm runoff from UVs 118 and 118A and reviewed the efficiency of different canal renovations design. Also, the health and safety benefits of the local residents, constructability, sustainability, construction, maintenance cost were considered.

The three design options for a canal were an earthen canal, a concrete lined trapezoidal canal, and a combination of covered and uncovered canal. The earthen canal was too large to fit in the road of the existing Right-of-Way. The combination of the covered and uncovered canal was too expensive to be implemented.

The three design options for a roadway were a gravel roadway, an asphalt roadway, and a non-reinforced concrete roadway. The earthen canal required continual maintenance and had a short life cycle. The asphalt roadway required more maintenance and cost more than a concrete roadway.

T.T.E. recommends that a concrete lined trapezoidal canal design be constructed on Radial 16 to alleviating the flooding between 30th de Agosto and 5th Ring. A non-reinforced concrete roadway should also be constructed on radial 16. The intersection at 5th Ring should have a box culvert built under the roadway to carry the water to an existing catch basin located on 5th Ring. The estimated cost of the design is 5,335,000 Bolivianos ($762,000 US). Construction of the design will improve the health and safety of the residents by removing stagnant water decreasing the amount of disease carrying mosquitoes.

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## 1.0 Introduction

In the summer of 2008, a group of students from Michigan Technological University traveled to Santa Cruz, Bolivia to gather data and propose engineering solutions for a canal and roadway near a wetland (curichi). This team of 4 students, called Tip Third Engineering (T.T.E.), is part of the 2008 International Senior Design class working on Senior Design projects in Santa Cruz. The students work on local infrastructure projects such as designing storm water transport systems, roadways, and solutions to wastewater problems at local schools and government buildings.

Tip Third Engineering is part of the August 2008 group. The city officials of District 10 of Santa Cruz, Bolivia gave T.T.E. a project to design a canal and roadway in District 10 in the southwest side of the city of Santa Cruz to remove storm water that floods in a wetland (curichi) during the rainy season. The flooded area creates standing water which becomes a breeding ground for disease carrying mosquitoes and creates transportation problems for the local residents. T.T.E. was asked by city officials to design a canal to remove the flood water and transport to a drainage system. T.T.E. surveyed the area, took soil borings, performed soil tests, and returned to Michigan Tech to develop an engineering report with a final recommendation and construction documents.

## 2.0 Background

### 2.1 Bolivia

Bolivia, the 28th largest country in the world, is a landlocked country in central South America. It has a total area (land and water) of 1,098,580 sq. kilometers (424,135 sq. miles). Bolivia shares borders with Brazil on the north and east, Chile and Peru on the west, and Argentina and Paraguay on the south. The climate varies with altitude from humid and tropical to cold and semiarid. The western part of the country is mainly highlands as opposed to the lowlands of the east. The highest point above sea level is at 6542m (21463 ft) and the lowest point is at 90m (295ft). Bolivia is divided in nine departments (provinces); Beni, Chuquisaca, Cochabamba, La Paz, Oruro, Pando, Potosi, Tarija, and Santa Cruz.

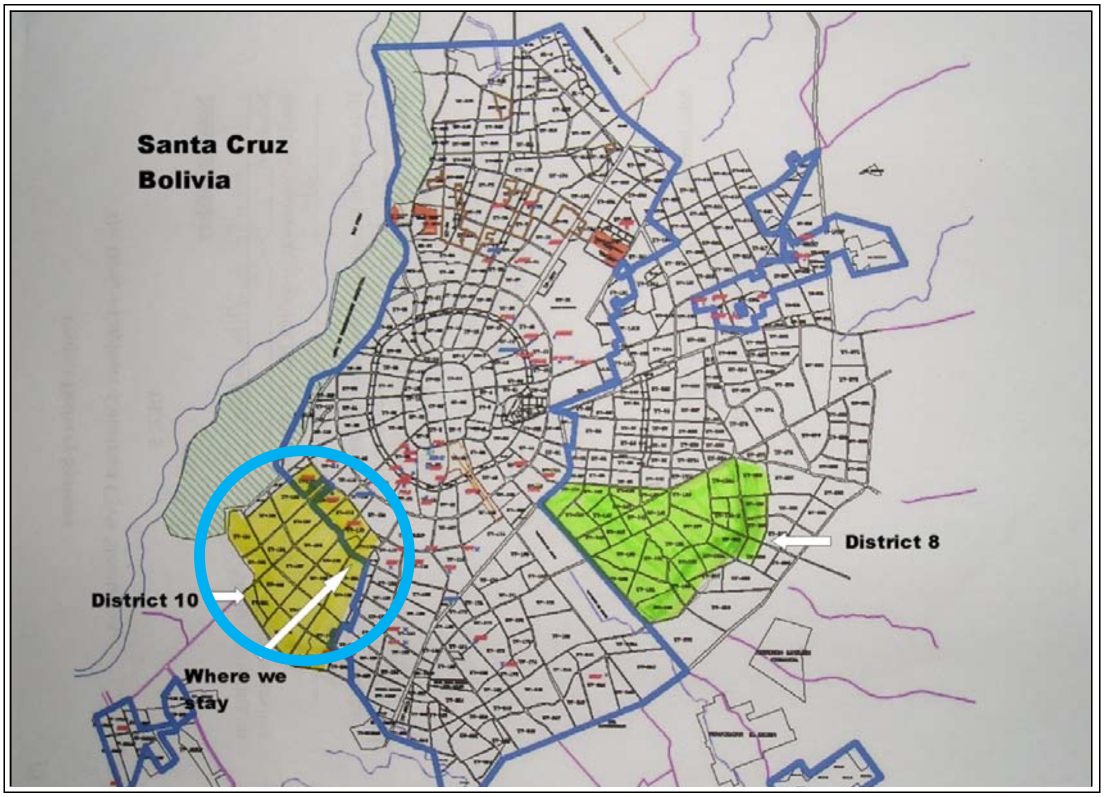

http://www.destination360.com/south-america/bolivia/bolivia-map.php http://www.bolivia-explorer.com/images/bolivia-map.gif

A B

**Figure 2.1:** Maps Showing Location of Project in Santa Cruz (A), Bolivia (B).

### 2.2 Santa Cruz

The design project is located in Santa Cruz, the largest department in Bolivia, which is in the eastern part of Bolivia and with a total area of 370,621 sq. kilometers (143098 sq. miles). Santa Cruz de la Sierra (Santa Cruz henceforth) is the capital city of the department of Santa Cruz. It has a population of approximately 2.4 million (2005 estimates). Santa Cruz is located at an elevation approximately 416m (1365 ft) above sea level and 17° South Latitude. The weather is semitropical with an annual average temperature of 21 degrees Celsius. January and February are the months where the highest amount of rainfall occurs.




Map given by District 10 Representatives

**Figure 2.2:** Map Showing District 10 in the City of Santa Cruz

### 2.3 Districts

Santa Cruz's street layout comprises a concentric ring model with the downtown located at the center. This project is located on the 5th ring of the city. The city of Santa Cruz is divided into districts, each with its own sub-mayor. This drainage and roadway design project is located in District 10, in the southwest region of the city. District 10 is unique because it is one of a few decentralized districts, meaning District 10 has its own professional staff, such as engineers, who work only on District 10 projects.

**2.4 UVs**

Within the districts, the neighborhoods are referred to as urbanization vecinals or "UVs". The design project is within UVs 118 and 118A. The UVs are further broken down into groups of neighborhood blocks or "barrios." The flooding problem in District 10 affects Barrio 30° de Agosto (30$^{th}$ of August).

**2.5 Flooding**

Bolivia has two seasons: rainy and dry. In certain areas of Santa Cruz, flooding occurs during the November through March rainy season due to the substantial rainfall and also because the terrain is flat. The local people described flooding in this area as "high as their knees" and the residents' health and travel are affected by this flooding.

**2.6 Curichi**

A curichi is a wetland or swamp area. The 30 de Agosto curichi was initially a smaller natural wetland. It was later enlarged by the removal of native clay soil for brick making. The large amount of clay removal resulted in a significant body of water about a square kilometer in size. The 30$^{th}$ de Agosto curichi has served as a retention basin for the local watershed, but its capacity is decreasing due to the city and residents using it as a landfill or disposal area for garbage. This practice aggravates the flooding problem and introduces chemicals and biological agents into the flood waters. A drainage canal will to help reduce the flooding of homes near the curichi, however water contamination remains a concern.

Photograph taken by T.T.E.

**Figure 2.3:** Picture Showing the Refuse Being put into the Northeastern Edge of Curichi

### 2.7 Proposal

The curichi is being filled with the local's garbage and this reduces curichi capacity and increases the flooding problem. Some District 10 residents have been working with the local government officials to prevent this persistent problem and District officials want the east end of the curichi filled so they can construct the $6^{th}$ Ring road. T.T.E. will design a drainage canal and roadway between $5^{th}$ Ring and $6^{th}$ Ring to alleviate the flooding while also providing a more feasible roadway.

**2.8 Health**

The flooding near the curichi can affect the local residents' health. Standing water creates a breeding area for mosquitoes which can carry diseases such as malaria, yellow fever, and dengue. Children swim and play in the standing water and suffer from skin rashes, infections, and other illnesses. Sanitary sewer piping is currently being installed in the area, but until residents connect to the new system, storm or curichi water could cause illness by mixing with wastewater from individual septic systems. If people consume contaminated water, they could suffer from illnesses such as diarrhea, cholera, hepatitis, or typhoid fever. A drainage canal and roadway should alleviate the standing flood water outside the curichi. The new canal, in addition to the new sanitary sewer system, should reduce some of these health issues.

The issue of the debris and refuse being placed in the curichi was not part of T.T.E.'s scope due to District 10 representatives' request. The reason is because a current PhD candidate and former ISD student at Michigan Technological University, Heather Wright Wendell, is researching environmental restoration of the curichi.

**2.9 Politics and Funding**

Engineering infrastructure projects are funded through the Bolivian Central government located in the capital city of La Paz. The money generated from each department goes to the central government in La Paz, who redistributes it to the departments and cities. The city council then decides which projects will receive funding. Funding for this drainage canal and roadway design will be subject to the decisions of the central government, the city of Santa Cruz, and District 10 priorities.

## 3.0 Methods and Procedures

The design for the Curichi Drainage project was done following a systematic series of steps. The design steps followed are as are outlined below:

### 3.1 Bolivia

1. T.T.E. had a meeting with Linda Phillips, P.E., P.M.P. (Professor of Practice, construction engineering at Michigan Technological University). At this meeting Professor Phillips introduced the new project to T.T.E. and outlined her expectations. T.T.E. had meeting with Heather Wright, an Environmental Engineering PhD Student at Michigan Technological University. Heather worked on the Curichi for her International Senior Design project in 2005. She is working with the City Council of Santa Cruz to improve the condition of the Curichi.
2. T.T.E. had a meeting with the District 10 Drainage and Road Engineer to define the scope of the problem and ask them questions about the Curichi and the District's expectations of the project. The meeting minutes can be found in *Appendix #.*
3. T.T.E. went on a site tour of the Curichi with the District 10 Representatives Ing. Waldo Varas and City Official Horacio Cardenas to familiarize the team with the project and the surrounding area.
4. T.T.E. photographed the site.
5. T.T.E. performed a preliminary topographic survey of the curichi.
6. Soil borings were performed to determine the makeup of the soil and determine the depth of the water table.
7. T.T.E. held a second meeting with the District 10 Engineers to discuss the Curichi project in further detail. The minutes from this meeting can be found in *Appendix #.*
8. T.T.E. also walked the project site to determine the watershed.

The detailed steps of the preliminary survey, the final topographic survey, and the soil borings will be discussed in detail in this section.

#### 3.1.1 1st Topographic Survey – 6th Ring

The tools and equipment utilized for the topographic survey were:

- Topcon GTS 225 total Station
- Tripod
- TDS Ranger data collector
- Prism
- Candy cane prism pole

- Metric tape measure
- Large nails
- Bright colored tape
- Bright colored spray paint
- Radio walkie-talkies
- Computer

T.T.E. performed a preliminary topographic survey of 6th Ring to determine the feasibility of option in draining the flood water from the curichi. The procedures used are as follows:

1. Found a control point which was benchmark 23
2. Set up tripod with Top Con total station on top
3. Connected the TDS data collector
4. Measured both the prism and total station height from ground then input into data collector
5. Established a starting point to determine elevation by performing a backshot of the benchmark
6. Took the relative sideshots such as right-of-ways, intersections, catch basins, etc.
7. Used radio walkie-talkies to communicate if sideshots were recorded
8. Traversed to next position and repeated steps 1 - 7.
9. Input data into computer

### 3.1.2 2nd Topographic Survey – Radial 16

The 2nd survey was done for Radial 16 and the same equipment, tools, and procedures used in 3.1.1 were applied.

### 3.1.3 Soil Borings

T.T.E. performed two soil borings to gather information on the soil stratification in the project area. One boring was taken near the school end (5th Ring) of the proposed roadway and the other was on opposite end near the curichi (Figure 3.1). The following procedure outlines how to perform soil borings.

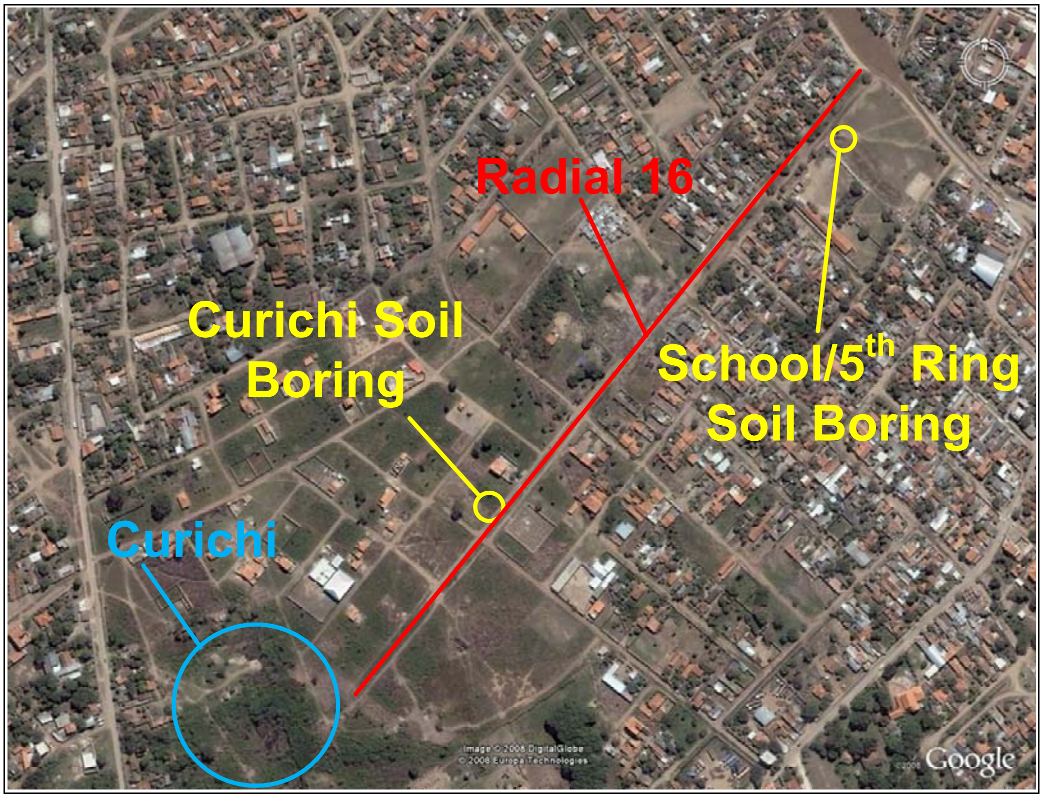



Image taken from Google Earth; edited by T.T.E.
**Figure 3.1:** An Aerial View of the Two Soil Boring Sites

1. Select and note location for boring
2. Use post digging tool to form hole in undisturbed soil until reservoir of tool is full.
3. Remove post digging tool from the hole, and empty the soil into a stockpile near the hole.
4. Note soil characteristics including color and dampness.
5. Repeat steps two through four until depth of hole is equal to one meter. At one meter down, remove the sample and place as much of the soil as possible into plastic bag labeled with location and depth.
6. Repeat steps two through five at one meter intervals until maximum reach of the tool is met or the water table is found.
7. Reserve the soil in the bags for classification and other soil tests. Return the soil in the stockpile to the hole.

The results of the soil borings can be found in Appendix B.

### 3.1.4 Soil Classification

T.T.E. performed soil classification to find out the makeup of the soil in the project area to determine whether they were sand and clay. The soil for this test was obtained during the soil borings on site. The following procedure outlines the soil classification.

1. Obtain soil sample from soil borings.
2. Follow the worksheet (Appendix B) to determine clay content.
3. Note color, texture, water content, and other physical characteristics.
4. Classify soil.
5. Repeat steps one through four for all the samples.

The results of the soil classifications can be found in Appendix B.

### 3.2 United States

### 3.2.1 Storm Runoff Calculations

The quantity of overland storm runoff was calculated for design of the drainage canal. To calculate the amount of overland storm runoff the rational method was utilized and can be seen in Equation 1.

$$Q = CIA \qquad (Equation\ -\ 1)$$

$$Q\ =\ Peak\ Storm\ Runoff\ \left(\frac{m^3}{s}\right)$$

$$C\ =\ Dimensionless\ Runoff\ \ Coefficient\ (0 \le C \le 1.0)$$

$$I\ =\ \text{Rainfall}\ Intensity\ \left(\frac{m}{s}\right)$$

$$A\ =\ Drainage\ Area\ (m^2)$$

An empirical rainfall intensity equation for the department of Santa Cruz, Equation 2, from the Norma Boliviana (NB) 688 and time of concentration equation obtained from a local engineer, Equation 3, were employed in computing rainfall intensity.

$$Santa\ Cruz\ (I) = \frac{393.70 * f^{0.3556}}{t^{0.7016}} \qquad (Equation\ -\ 2)$$

$$I = \text{Rainfall } Intensity \left(\frac{mm}{hr}\right)$$

$$f = \text{Rainfall } Frequency\ (years)$$

$$t = Time\ of\ Concentration\ (\text{min})$$

$$t_c = 0.06625 * \left(\frac{L^2}{S}\right)^{0.385} \qquad (Equation\ -\ 3)$$

$$L = Hydraulic\ Length\ (km)$$

$$S = Land\ Slope\ (decimal\ \%)$$

**Table 3.1:** Coefficients of Superficial Drainage as Assumed from Marin's Report

| Coefficients of Superficial Drainage | | |
|---|---|---|
| Description of Area | Runoff Coefficient | |
| | (a) | (b) |
| Commercial Area | 0.70 to 0.95 | |
| Commercial-Residential Area | 0.50 to 0.70 | 0.8 |
| | | |
| Single family homes | 0.30 to 0.50 | |
| Separated Multi-family dwellings | 0.40 to 0.60 | |
| Connected multi-family dwellings | 0.60 to 0.75 | |
| Suburban | 0.25 to 0.40 | |
| Inside of the 2nd or 3rd rings | | 0.5 |
| zone outside of the 3rd ring s/ pavement | | 0.35 |
| industrial zones | | |
| light | 0.50 to 0.80 | |
| heavy | 0.60 to 0.90 | |
| parks, cemeteries and hospitals | 0.10 to 0.25 | 0.2 |
| paved streets | 0.70 to 0.95 | |
| concrete streets | 0.80 to 0.95 | |
| (a) coefficients recommended according to different sources | | |
| (b) adopted for the stormwater drainage design for the city of Santa Cruz | | |

Runoff coefficients from Table 1 of Chapter 6 in NB 688, Table 3.1, were used to find a value for C, the dimensionless runoff coefficient.

A storm recurrence interval of 10 years and runoff coefficient c in Table 3.1 were assumed for the 30th de Agosto curichi site. The equipment and errors, assumptions, and considerations are covered below.

Equipment used:

a) Norma Boliviana (NB) 688
b) "*Water Resources Engineering*" Ralph A. Wurbs and Wesley P. James

Errors, Assumptions, and Considerations:

a) Runoff coefficient was based on development plans provided by the Sub Alcalde, Ing. Victor P. Escobar Díaz, and District 12 engineer, Ing. Javier Marín.

**3.2.2 Drainage Design**

Two different types of drainage structures were used in the preliminary design at the project site: box culverts, and open channels. To size these structures, Manning's equation for open channel flow was used, Equation 4; along with the overland storm runoff for a storm with a 10 year recurrence interval. Procedures, calculations, and supporting material can be found in the Appendix C.

$$Q_{full} = \frac{C_m}{n} * A * R^{\frac{2}{3}} * S^{\frac{1}{2}} \quad (Equation\ -\ 4)$$

$C_m = 1$ *for SI units, and* $1.49$ *for BG units* (*unitless coefficient*)

$n$ = *Manning's Roughness Coefficient* (*unitless coefficient*)

$A$ = *Cross Sectional Area of Structure* $\left(m^2\right)$

$R$ = *Wetted Perimeter*; $\frac{Area}{Perimeter}(m)$

$S$ = *Longitudinal Slope of Channel* (*Decimal* %)

Canal thickness was based on section drawings from Proyecto Canal Calama Distr. MPAL 10. These drawings were obtained by previous ISD students and were supplied to T.T.E. by Ing. Linda Phillips. The equipment and errors, assumptions, and considerations are covered below.

Equipment used:

a) Proyecto Canal Calama Distr. MPAL 10
b) "*Water Resources Engineering*" Ralph A. Wurbs and Wesley P. James

Errors, Assumptions, and Considerations:

a) Canal reinforcement was based off of previous projects completed in Santa Cruz. Reinforcement should be checked by a structural engineer for lateral earth and traffic loading pressures.

**3.2.3 Computer Aided Drafting (CAD)**

AutoCAD Civil 3D 2008 was utilized to display the survey data collected in Santa Cruz and used to model the proposed roadway and canal. AutoCAD drawings were also used to delineate the watershed and calculate canal and roadway parameters. The survey data was imported from the data collector and analyzed. The raw data was adjusted by adding a constant elevation of 325.649 m to the surveyed elevations. This transformed the raw data based on a benchmark at 100.732 meters above sea level to real data with a benchmark at 425.649 meters above sea level. After this adjustment was made, the points were rotated to the correct orientation.

The equipment and errors, assumptions, and considerations are covered below.

Equipment used:

a) AutoCAD Civil 3D 2008

Errors, Assumptions, and Considerations:

a) Rotation of misaligned points caused marginal error.

b) Existing road boundaries were identified from survey data, Google Earth images, and District 10 files.

AutoCAD Civil 3D 2008 Procedures:

1. Import survey data
2. Adjust elevations.
3. Rotate to correct alignment
4. Use Civil 3D tools to create a polyline centerline on existing roadway and canal and create a topographic map of the data
5. Use Civil 3D tools to create a surface from the survey information of the existing roadway and canal.
6. Use Civil 3D tools to create profile view of existing topographic conditions
7. Use Civil 3D tools to create cross section views of existing topographic conditions every 25 m
8. Draw proposed roadway profile into existing profile and use to calculated earthwork quantities (cut and fill)
9. Draw proposed canal cross section into existing cross sections.
10. Create details drawings of roadway and canal elements
11. Plot drawings

The survey points were imported into AutoCAD Civil 3D 2008 as a text file. Table 3.2 shows a portion of the survey data imported for the AutoCAD drawings. The complete survey information is included on the attached data CD.

**Table 3.2:** Sample AutoCAD Points from T.T.E.

| Point | Name | X | Y | Surveyed Elevation |
|---|---|---|---|---|
| 1 | start | 10000 | 10000 | 100 |
| 2 | bm23 | 10098.9 | 10000 | 100.732 |
| 3 | rd1 | 10052.96 | 9951.28 | 99.712 |
| 4 | rd2 | 10048.38 | 9944.387 | 99.684 |
| 5 | rd3 | 10045.7 | 9941.308 | 99.625 |
| 6 | rd4 | 10039.22 | 9931.091 | 99.604 |
| 7 | rd5 | 10035.44 | 9924.58 | 99.594 |
| 8 | cb1 | 10038.9 | 9928.031 | 99.712 |
| 9 | cb2 | 10040.09 | 9927.24 | 99.739 |
| 10 | cb3 | 10037.43 | 9923.021 | 99.745 |
| 11 | cb4 | 10034.72 | 9918.773 | 99.749 |
| 12 | cb5 | 10033.35 | 9919.669 | 99.744 |
| 13 | cb6 | 10036.77 | 9923.398 | 99.55 |
| 14 | cb7 | 10036.65 | 9923.165 | 98.47 |
| 15 | rd6 | 10029.47 | 9930.825 | 99.582 |

## 4.0 Existing Conditions

### 4.1 Site Tour

T.T.E. first visited the 30$^{th}$ de Agosto curichi with District 10 representatives Ing. Waldo Varas and Sr. Horacio Cardenas in August 2008. Figure4. 1 shows District 10 outlined in white. The main road between 5$^{th}$ Ring and 6$^{th}$ Ring is Radial 16 which can be seen in red on Figure 4.1. The location of T.T.E.'s project site is in the northeastern section of District 10 between 5$^{th}$ and 6$^{th}$ Ring roads. The 5$^{th}$ Ring road is a paved 2 lane road with heavy traffic. Currently the 6$^{th}$ Ring road is not continuous as it is interrupted by the 30$^{th}$ de Agosto curichi. The city however plans to fill this area of the curichi to complete the 6$^{th}$ Ring road.

The watershed is delineated by the larger white outline which is approximately 1.0 km$^2$. The area was determined using a combination of data received from Ing.

Cardenas and Ing. Varas, walking the site to find high points while in Santa Cruz, and using an AutoCAD drawing file with elevations obtained from District 10 officials.

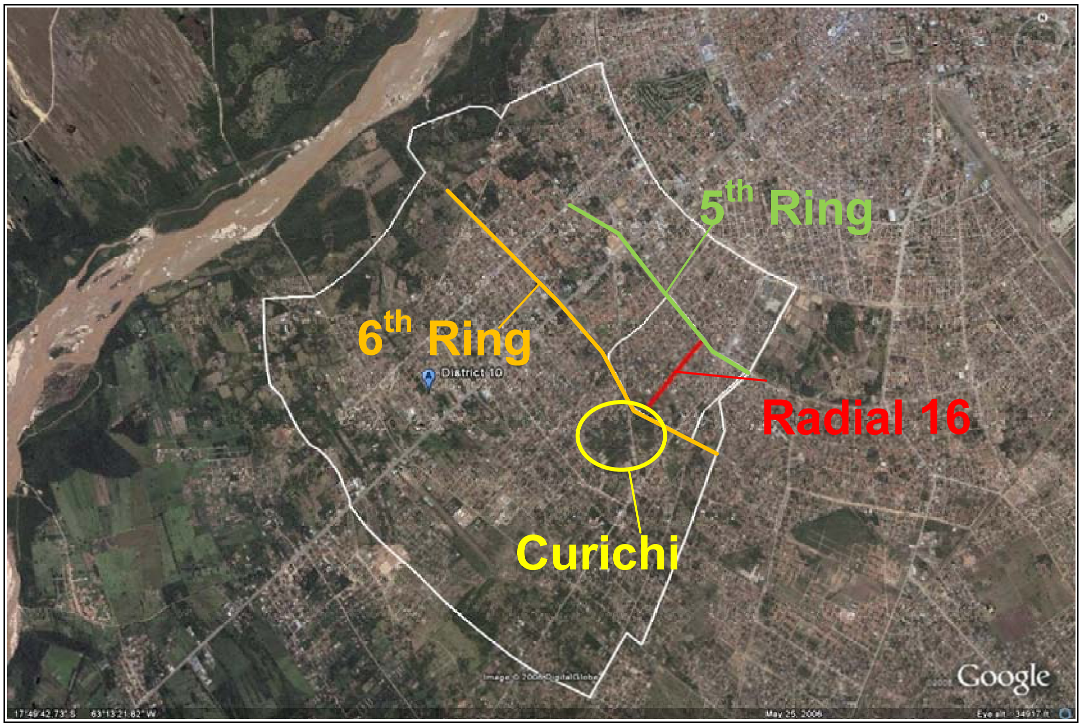



Image taken from Google Map; edited by T.T.E.
**Figure 4.1:** Map Showing District 10 and 30th de Agosto Curichi Site.

### 4.2 Curichi

The 30th de Agosto curichi is located in the southwestern portion of the project site (see Figure 4.2). As stated earlier, this curichi is a wetland/swamp area and was formed by the excavation of clay for brick making. When the clay was removed, a significant depression was left in the ground. Eventually, this depression filled with water. Now, the curichi acts as a retention basin for the watershed. During the rainy season, November to March, flooding occurs due to the large amount of rainwater that overwhelms the curichi, flooding the area northeast of the 6th Ring which can be seen in blue in Figure 4.2.

Currently, the city and locals are using the curichi as a landfill. The refuse not only contaminates the water, but is also decreases the physical size of the curichi, causing the flooding to worsen. While surveying the site, T.T.E. asked neighbors living along the project site how high the flood waters reach. Most residents replied "knee-level" which is approximately half a meter. Since the water is contaminated from the garbage, locals, especially children, are contracting sicknesses and skin rashes.

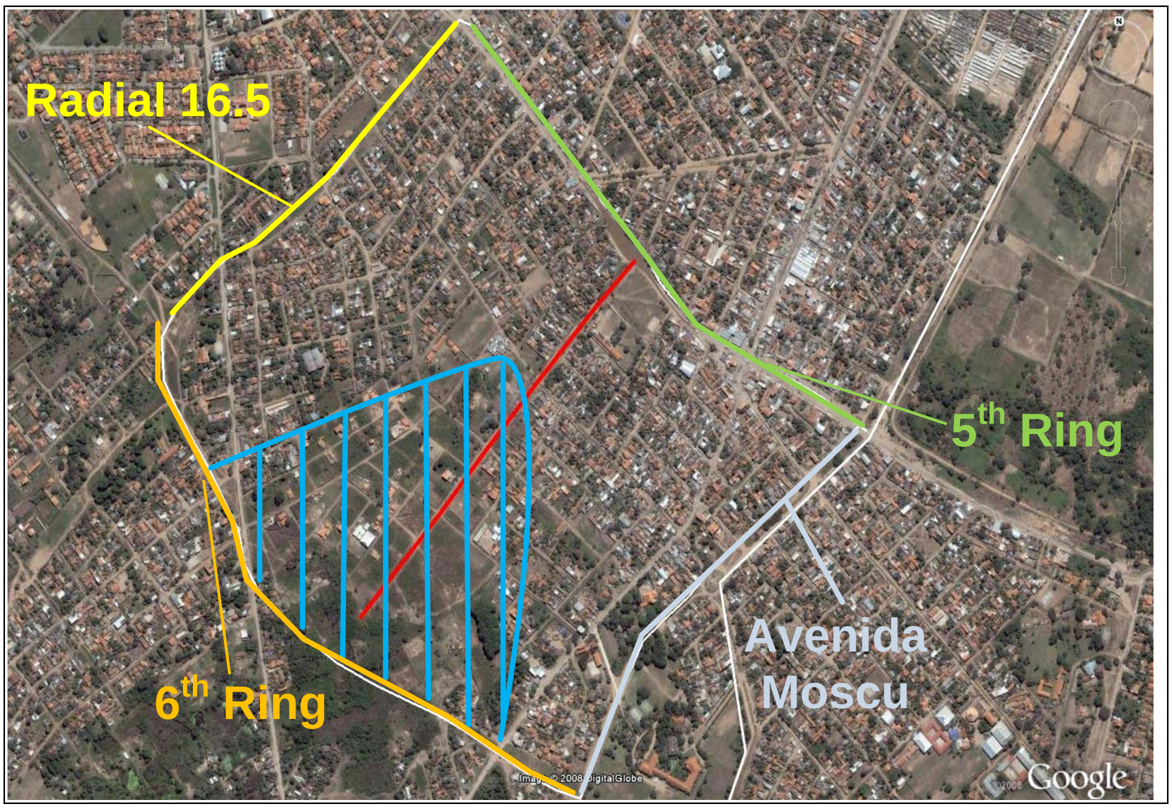



Image taken from Google Map; edited by T.T.E.

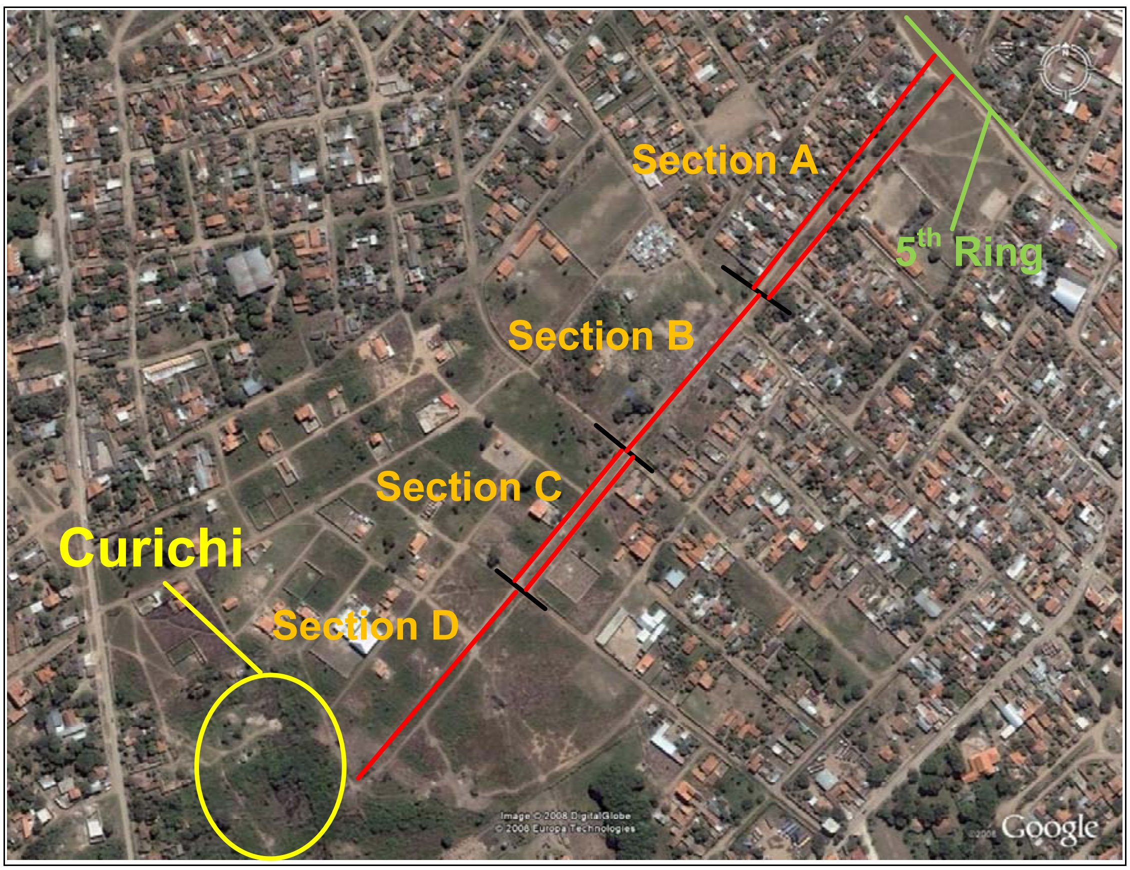
**Figure 4.2:** An Aerial View of the Curichi Site Showing the Flooded Area in Blue.

**4.3 Project Site**

A relatively flat ungraded dirt road bisects UV118 running northeast – southwest from 5th Ring to the curichi. This undeveloped road is Radial 16 which will serve as a major arterial connecting the 5th and 6th Rings. Radial 16 is midway between Avenida

Moscu to the south and Radial 16.5 to the north. The length of the Radial 16 is approximately 1.0 km, with three major intersections and several smaller intersections. Various types of traffic travel the road including taxis, buses and dump trucks carrying organic matter to fill the curichi for the 6th Ring road.

Starting from the 5th Ring and moving southwest for 300 m, Radial 16 is a two lane road divided by a median lined with trees [A] (Figure 4.3). Continuing southwest, the two lane road transitions into a one lane dirt road for about 100m [B], and then the one lane road transitions back to a two lane road divided by an earthen canal for 300 m (Figure 4.4) [C]. The southwest section of road is about 300m and is a one lane road with a soccer field on the southeast side [D].




Photograph taken from Google Earth; edited by T.T.E.
**Figure 4.3:** The Current Road System on Radial 16

Photographs taken by T.T.E.

**Figure 4.4:** Pictures of the Earthen Canal; Left – Facing Curichi, Right – Facing 5th Ring

Photograph taken by T.T.E.

**Figure 4.5:** 5th Ring and Radial 16 Intersection Looking Southwest Towards Curichi

### 4.4 Earthen Canal

The earthen canal running 500 meters from the northeastern side of the curichi towards 5$^{th}$ Ring was constructed in the 2007-8 rainy season by a recreational business located on the 6$^{th}$ Ring, per Ing. Waldo Varas. This emergency canal is approximately 1 meter wide and 1.5 meter deep and is located along portions of Sections [A], [B], and [C].

### 4.5 5$^{th}$ Ring Intersection

A large open soccer field exists at the intersection of Radial 16 and 5$^{th}$ Ring Road. The soccer field will be the site of a new school building. A catch basin and sedimentation trap are located on the northeast side of the road (see Figure 4.6). T.T.E. will design a canal to drain into this catch basin. This catch basin is covered by a large steel grate, part of which is broken.  The catch basin/sediment trap is made of concrete and is approximately 10 m in length by 1.5 m wide by 1.5 m deep.

Photograph taken by T.T.E.

**Figure 4.6:** Broken Grate on the Northeast Side of 5$^{th}$ Ring Intersection

A large amount of standing water accumulates at this intersection due to poor drainage (see Figure 4.7 B). The standing water spans approximately 40 meters long by 15 meters wide and approximately 0.2 meter deep. Heavy traffic, including taxis, buses, trucks, and large semi tractors transporting trailers use the 5th Ring Road. The standing water is so deep that smaller cars and taxis are not able to drive through it. Instead, traffic drives off the pavement on the left and southeastern shoulder of the 5th Ring to avoid the water (see Figure 4.7 A).

(A) (B)

Photograph taken by T.T.E.

**Figure 4.7:** 5th Ring Intersection (A – Looking into the Southwest; B – Looking Northeast)

### 4.6 Storm Water Flow

Currently storm water flows northeast from the 30th de Agosto along Radial 16 in the emergency canal to the 5th Ring catch basin/sediment trap. After passing through the sediment trap the water passes through underground box culverts installed in 2007, east along 5th Ring Road, to a newly constructed 16.5 Radial canal. Water proceeds north along the 16.5 canal to the 4th Ring canal which then takes the water north to the Rio Pirai (see Figure 4.8).

Photograph taken by T.T.E.

**Figure 4.8:** A Photograph of Rio Piraí During the Dry Season

### 4.7 Closing Problem Statement

Given the existing conditions, T.T.E. will design a canal to transport the flood waters from the 30th de Agosto curichi to the 5th Ring catch basin/sediment trap where it will flow through the existing drainage system to the Rio Piraí. T.T.E. will also design the Radial 16 roadway along both sides of the canal.

## 5.0 Design Options

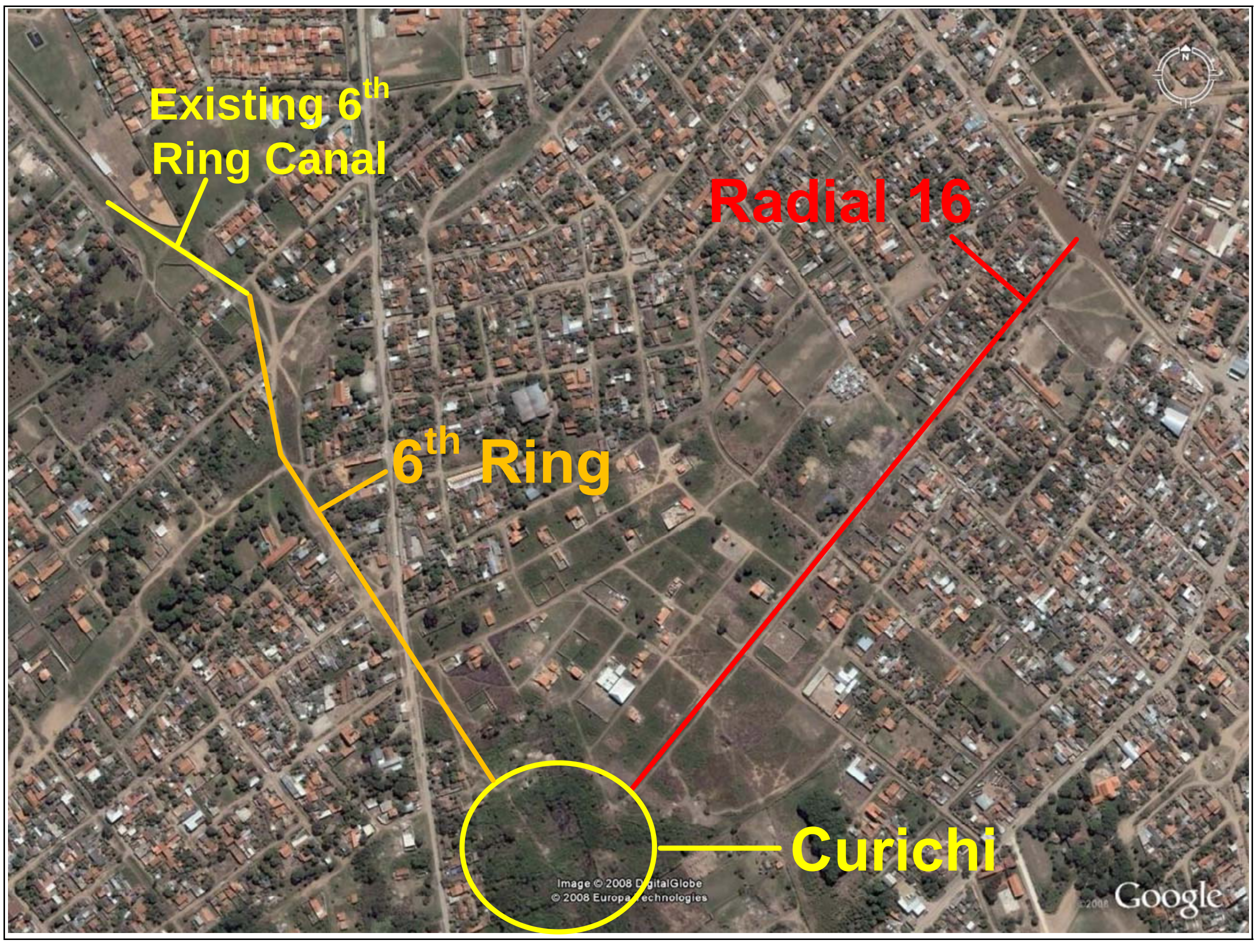
### 5.1 Location of Canal

Initially, the representatives from District 10 suggested T.T.E. consider two options for alleviating the flood water coming from the 30th de Agosto curichi:

1. The first option was to consider designing a canal that would run from the curichi to the intersection of 6th Ring and Radial 16.5 to an existing canal.

2. The second option was to consider a canal that would run from the curichi along Radial 16 to the catch basin at 5th Ring (see Figure 5.1).

T.T.E. first surveyed the 6th Ring Alternative but the survey data showed that the elevation change from the curichi to the existing drainage canal was going uphill, therefore, the 6th Ring alternative was not an option. Hence, the 5th Ring choice was the only feasible option for draining the flood water from the curichi.




Photograph taken from Google Earth; edited by T.T.E.
**Figure 5.1:** Map Showing Two Location Alternatives for Canal

### 5.2 Canal Design Options

T.T.E. chose three canal designs which are commonly used in Bolivia, and would be appropriate for this project site:

1. An earthen canal
2. A concrete lined canal
3. A combination of covered and uncovered concrete lined canal.

T.T.E. compared advantages and disadvantages for each, leading to a final recommendation.

#### 5.2.1 Earthen Canal Option

| Advantages: | Disadvantages: |
|---|---|
| - Low cost | - Too wide for existing Right-of-Way |
| | - Sediment and vegetation overgrowth |
| - Simple design | - High maintenance cost |

Other than low costs, the disadvantages outweigh the advantages. The canal width does not fit with road in existing Right-of-Way. In addition, District 10 Directives require a concrete lined canal be built. Therefore, earthen canals were ruled out, except to provide a design section size for a temporary flooding provision (see Figure 5.2). Should adequate funding for the recommended canal design not be available, a trapezoidal earthen canal should be excavated from the 30th de Agosto curichi to 5th Ring. The size of the canal was calculated to have a base width of 3 m, a top width of 8.9 m, a depth of 2.6 m, and a side slope of 2:1 (Figure 5.3). Note that this is a temporary solution and flooding at 5th Ring may be increased if the sediment trap and storm inlet are not maintained.

Photograph taken by T.T.E.
**Figure 5.2:** A Common Earthen Canal in Bolivia

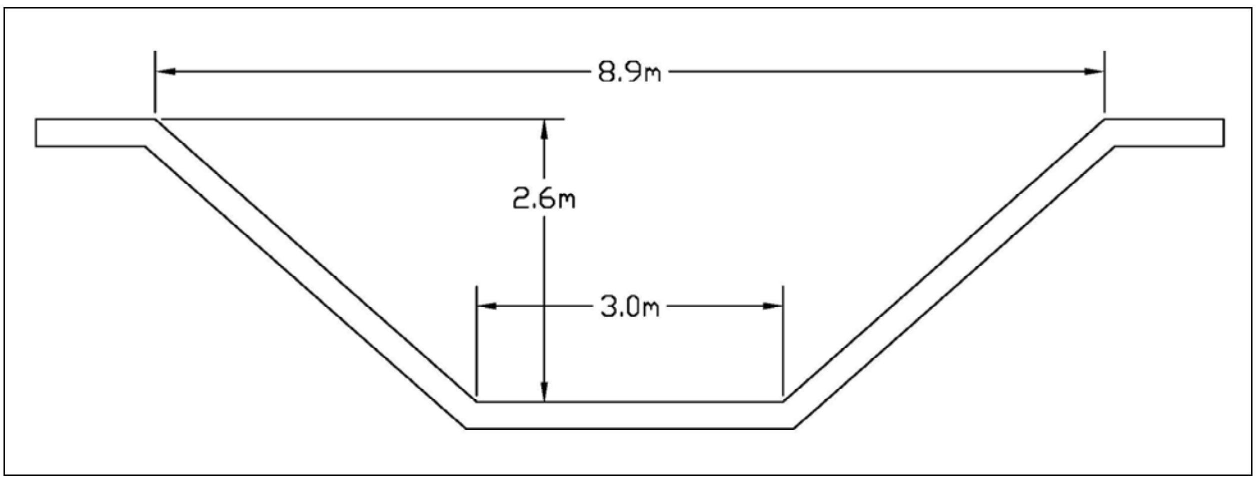



Image taken from AutoCAD Civil 3D; Designed by T.T.E.
**Figure 5.3:** Design of Earthen Canal

### 5.2.2 Concrete Lined Trapezoidal Canal Option

Concrete lined canals are common in Santa Cruz (Figure 5.4).

**Advantages:**

- Life cycle cost
- Durable
- Resists erosion
- Smaller cross section
- Hydraulically more efficient

**Disadvantages:**

- High initial cost

The first advantage of a concrete lined canal is the longevity of the canal life. Also since there is limited space the concrete lined canal can have a smaller cross section than the earthen canal and is hydraulically more efficient. The only disadvantage is the high initial cost but due to the request of the District 10 government, this option is preferred.

T.T.E. determined the dimensions of the canal to be 3.8 m base width, 5 m top width, 1.2 m depth, and a 2:1 side slope (Figure 5.5). The canal would also have weep hole drains on the side walls and bottom to relieve the water pressure due to the high water table. T.T.E. measured the water table to be 2.3 m deep during the dry season. This high water table could possibly create uplift pressure on the canal and damage the canal, without the proper weep hole drains in place. The drains will be placed 2 m apart throughout the entire canal. The canal would also have pedestrian crossings that will allow easy access for crossing the canal.

Photograph taken by T.T.E.

**Figure 5.4:** A Common Concrete Canal in Bolivia

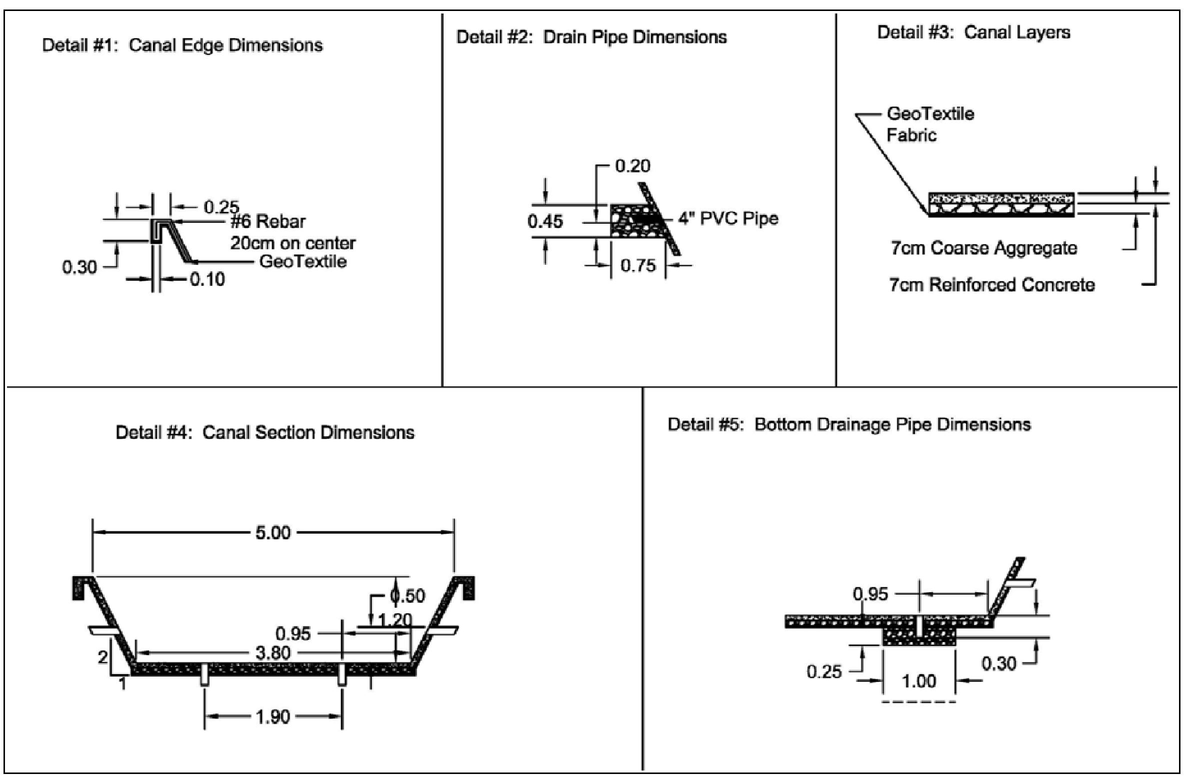



Image taken from AutoCAD Civil 3D; Design by T.T.E.

**Figure 5.5:** Trapezoidal Concrete Lined Canal Design

### 5.2.3 Combinations of Covered and Uncovered Concrete Lined Trapezoidal Canal

The canal must transition to a box culvert or pipes to cross under the 5th Ring, entering the catch basin, and 5th ring box culvert (Figure 5.6). To handle the necessary amount of flow the pipes would be larger than the canal itself, which wouldn't work because the flow would be constricted (Appendix C). A box culvert would allow for the necessary amount of flow while meeting 5th Ring road cover requirements and canal restraints. T.T.E. determined the box culvert to be 3 m wide by 1.2 meters high (Appendix C).

In addition, T.T.E. also considered covering a section of the concrete lined canal near the existing school and proposed new schools as a safety measure. An advantage of the covered portion of the canal is it prevents children at the school from entering the drainage canal and the contaminated water. Safety was a key component stressed by Ing. Varas and Sr. Cardenas for this project. The covered section would be 200 m in length starting from 5th Ring intersection and would consist of removable tops for cleaning.

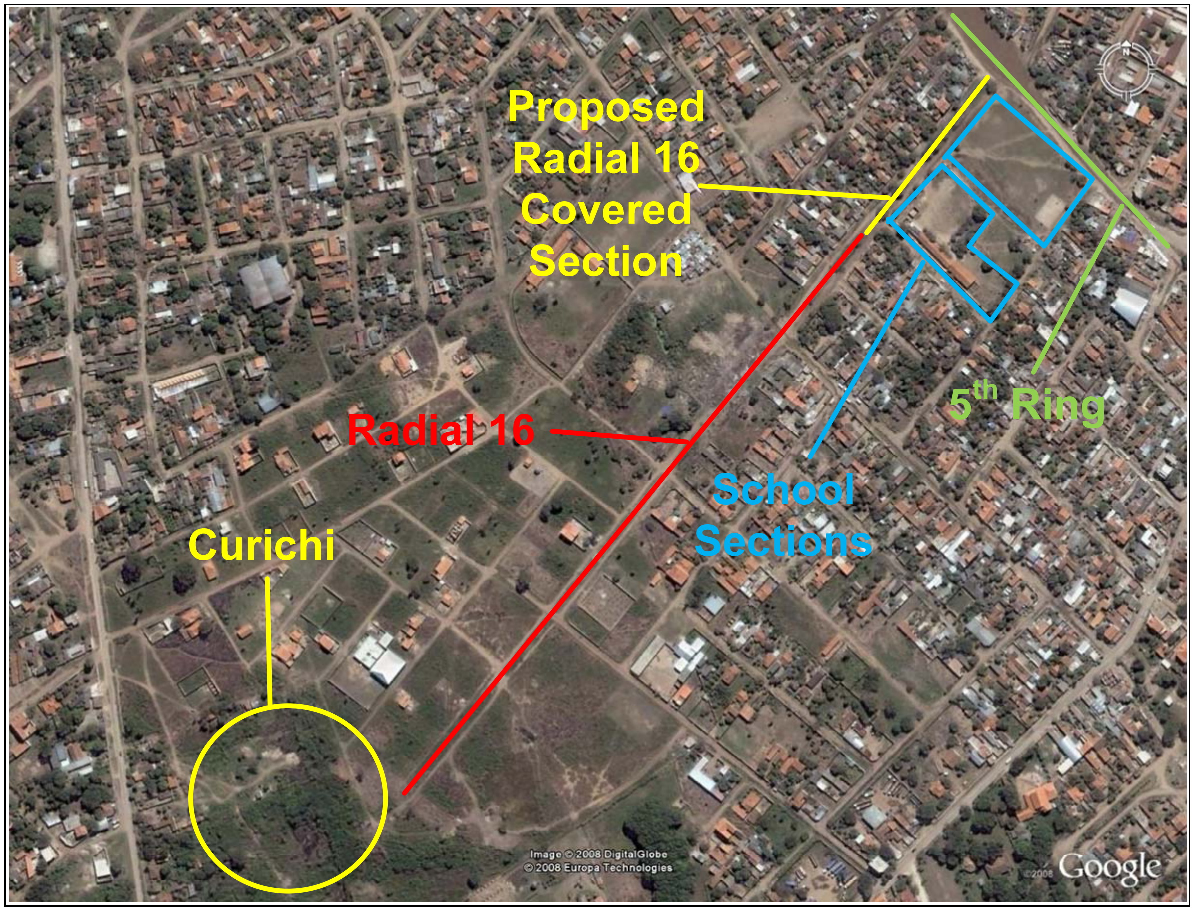
The combination canal is the most expensive option but is the safest of the three options for the students.

**Advantages:**

- Safety of school children
- Health of children playing in stagnate water

**Disadvantages:**

- Higher costs




Photograph taken from Google Earth; edited by T.T.E.
**Figure 5.6:** An Aerial View Showing the Proposed Covered Section

### 5.3 Radial 16 Roadway Design Options

The design options for the roadway were an Asphalt Pavement, Non-reinforced Portland cement concrete Pavement, and a Gravel Roadway which were evaluated based on cost/benefit analysis and advice from the District 10 Engineers.

Based upon the second group meeting (08/19/08) with the District 10 Engineers, it was clear that District 10 wanted T.T.E. to look into two options for the roadway design; a non-reinforced Concrete Pavement and a compacted gravel road. T.T.E. provides the Asphalt Pavement design as another option if they choose to not go with the recommendations of the District 10 engineers.

There are advantages and disadvantages related to the pavements types. As a result, a table of advantages and disadvantages of each of the options is considered.

**5.3.1 Gravel Roadway**

| Advantages: | Disadvantages: |
| --- | --- |
| - Low initial cost | - High maintenance requirements |
| - Simple construction | - Sediments entering canal |

The low cost and amount construction time are advantages but the roadway would require continuous maintenance after construction and permits sediment entry into the canal (Figure 5.7). The gravel is a good temporary option if initial funding is available to build only the canal. Since Radial 16 will connect to 6$^{th}$ Ring, eventually the non-reinforced concrete pavement will be necessary to handle the traffic loads. The gravel road would be built using crushed aggregate base at 15cm thickness. Therefore when building the non-reinforced concrete pavement, the crushed aggregate base can be refurbished and have the concrete surface built on top of it.

http://picasaweb.google.com/live2mogul/GMVLeslieWellPumpingRoads#5095340772888749314

**Figure 5.7:** A Poorly Graded Gravel Road

### 5.3.2 Non-Reinforced Concrete Roadway

| Advantages: | Disadvantages: |
|---|---|
| - Durability | - High initial cost |
| - Comfort of driving (less bumps) | - More runoff |
| - Low amount of maintenance | - Expensive to repair |
| - Reduces sediment entry into storm canal | |

A non-reinforced concrete roadway is advantageous due to the lack of maintenance required. The drawbacks of this option are the high initial cost and it increases the amount of runoff since the surface is impervious. Also, the maintenance for non-reinforced concrete is low and would also provide a smoother ride.

### 5.3.3 Asphalt Concrete Roadway

| Advantages: | Disadvantages: |
|---|---|
| - Less maintenance than gravel | - Expensive |
| - Easier to maintain than a concrete | - More maintenance than concrete |
| - Reduces sediment entry into canal | - Shorter design life than concrete |

Asphalt concrete is a common method of roadway design in Santa Cruz. T.T.E. considered this as a viable. The asphalt pavement has a shorter life than concrete and requires more maintenance.

### 5.3.4 Roadway Recommendation

The estimated prices obtained for each option are outlined below based on the dimension in Figure 5.8:

- **The estimated cost for Asphalt Pavement** = 1,650,000 Bolivianos ($236,000)
- **The estimated cost for a Non-reinforced concrete Pavement** = 1,110,000 Bolivianos ($159,000)
- **The estimated cost for a Gravel Road** = 181,000 Bolivianos ($26,000)

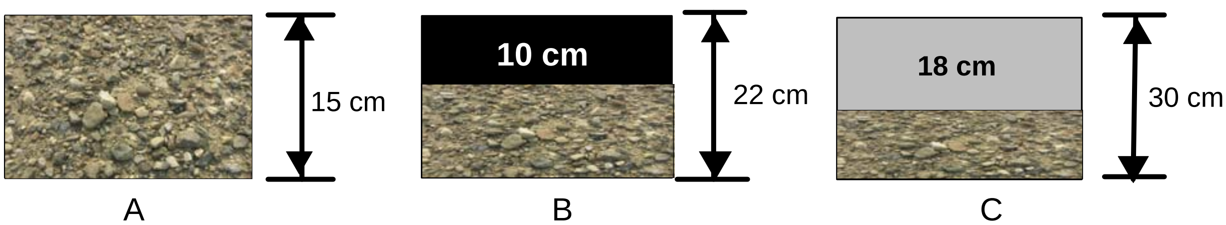



**Figure 5.8:** Dimensions of Roadway Options (A – Gravel, B –Asphalt, C- Non-reinforced concrete)

From an initial cost stand point, the gravel road is the least cost and asphalt concrete pavement is the most expensive. The gravel road cost does not include the cost for a curb while the cost of a curb was included for both the Asphalt and non-reinforced pavements.  T.T.E. recommends the non-reinforced concrete pavement for the design since it is less costly than asphalt, requires less maintenance, and a longer design life.

## 6.0 Final Recommendation

### 6.1 Considerations

The recommended design options were based on the following considerations:

1. **Cost:** The cost was a concern due to the lack of funding available so T.T.E. designed as economically feasible as possible.

2. **Maintenance:** The maintenance was important when selecting options because maintenance requires operational money, raising the cost. Also, without the proper maintenance, the catch basin could become blocked with refuse and sediment leading to stagnant water. Stagnant water promotes the reproduction of mosquitoes which leads to possible spread of malaria and dengue fever.

3. **Standard Practice:** When choosing design options a final recommendation the standard practices of Bolivia were considered. T.T.E. chose designs that can be constructed by the local labor force and local contractors.

4. **Health and Safety:** The residents' health and safety were main concerns when choosing the final design options. The most inexpensive design might not be the most appropriate when considering the safety and health of the residents and T.T.E. made this a priority as expressed by District 10 representatives.

### 6.2 Canal Recommendation

After considering the different design options, T.T.E. recommends the design option for a concrete lined trapezoidal canal. The canal is designed to carry storm water of a 10 year storm alleviating the 30th de Agosto curichi, Radial 16, and 5th Ring flooding problems. The covered section will consist of a box culvert 9 m in length for the 5th Ring road crossing to connect to the existing catch basin. This catch basin and sediment trap will be extended to meet the T.T.E. box culvert. T.T.E. also recommends that three vehicular bridges be designed by others to accommodate main intersections on Radial 16. **

The earthen canal was not recommended because the width was too large for right-of-way and roadway requirements and because the city now requires concrete lining for major discharge canals.

** Note: T.T.E. did not have enough time or direction from District 10 engineers to design these structures.

### 6.3 Roadway Recommendation

T.T.E. recommends a non-reinforced concrete roadway of 18 cm, a standard Bolivian design, because it has the lowest life cycle cost and lowest amount of maintenance compared to an asphalt road.

The gravel roadway is recommended only as a temporary solution until the paving funding is available. The gravel roadway requires on going maintenance and will allow sediment to enter the canal reducing water flow.

## 7.0 Cost – Benefit Analysis

The cost estimates were accomplished using a spreadsheet given to T.T.E. from the city of Santa Cruz. All calculated costs were rounded to the nearest thousand. All of the calculations and estimates can be seen in Appendix E.

### 7.1 Canal Cost Estimates

**Table 7.1:** Cost Estimate for Open Concrete Canal

| **Open Concrete Lined Canal** | |
|---|---|
| **Activity** | **Cost (Bs)** |
| Excavation with Machinery | 244,000 |
| Manual Slope Shaping | 14,000 |
| Reinforced Concrete Lining for Canal | 682,000 |
| Gravel Material | 250,000 |
| Drainage Pipes for Canal | 3,000 |
| Delivery and Placement of Box Culverts | 609,000 |
| Pedestrian Bridge by School | 20,000 |
| Roadway Crossings | 720,000 |
| **Total** | 2,542,000 |
| **Total USD** | 363,000 |

**Table 7.2:** Cost Estimate for Partially Covered Canal

| Combination of Covered and Uncovered Concrete Lined Canal | |
|---|---|
| **Activity** | **Cost (Bs)** |
| Excavation with Machinery | 244,000 |
| Manual Slope Shaping | 14,000 |
| Reinforced Concrete Lining for Canal | 682,000 |
| Gravel Material | 250,000 |
| Drainage Pipes for Canal | 3,000 |
| Delivery and Placement of Box Culverts | 15,841,000 |
| Pedestrian Bridge by School | 20,000 |
| Roadway Crossings | 720,000 |
| **Total** | 17,774,000 |
| **Total USD** | 2,539,000 |

### 7.2 Roadway Cost Estimates

**Table 7.3:** Cost Estimate for Gravel Roadway

| Gravel Roadway Design | |
|---|---|
| **Activity** | **Cost (Bs)** |
| Mobilization (Drainage) | 31,000 |
| Mobilization (Pavement) | 30,000 |
| Site Layout | 16,000 |
| Site Layout (Pavement) | 13,000 |
| Remove and Clear Rubble | 5,000 |
| Earth Work | 159,000 |
| Level and Compact Existing Ground | 100,000 |
| Provide and Place Crushed Base | 142,000 |
| Cut, Demolish, and Remove Concrete | 14,000 |
| General Cleaning | 16,000 |
| **Total** | 526,000 |
| **Total USD** | 75,000 |

**Table 7.4** Cost Estimate for Asphalt Roadway

| Asphalt Roadway Design | |
|---|---|
| **Activity** | **Cost (Bs)** |
| Mobilization (Drainage) | 31,000 |
| Mobilization (Pavement) | 30,000 |
| Site Layout | 16,000 |
| Site Layout (Pavement) | 13,000 |
| Remove and Clear Rubble | 5,000 |
| Earth Work | 159,000 |
| Level and Compact Existing Ground | 100,000 |
| Provide and Place Crushed Base | 113,000 |
| Deliver and Placement of Asphalt Concrete | 3,710,000 |
| Delivery and Placement of Curb | 139,000 |
| Cut, Demolish, and Remove Concrete Pavement | 14,000 |
| General Cleaning | 16,000 |
| **Total** | 4,346,000 |
| **Total USD** | 621,000 |

**Table 7.5:** Cost Estimate for Non-Reinforced Concrete Roadway

| Non-Reinforced Concrete Roadway Design | |
|---|---|
| **Activity** | **Cost (Bs)** |
| Mobilization (Drainage) | 31,000 |
| Mobilization (Pavement) | 30,000 |
| Site Layout | 16,000 |
| Site Layout (Pavement) | 13,000 |
| Remove and Clear Rubble | 5,000 |
| Earth Work | 159,000 |
| Level and Compact Existing Ground | 100,000 |
| Provide and Place Crushed Base | 113,000 |
| Concrete Slab Pavement | 2,157,000 |
| Delivery and Placement of Curb | 139,000 |
| Cut, Demolish, and Remove Concrete Pavement | 14,000 |
| General Cleaning | 16,000 |
| **Total** | 2,793,000 |
| **Total USD** | 399,000 |

### 7.3 Benefits and Implications

T.T.E.'s final recommendation cost analysis can be seen below in Table 7.6.

**Table 7.6:** Cost Estimation for Final Recommendation

| Final Recommendation | |
|---|---|
| **Design** | **Cost (Bs)** |
| Non-Reinforced Concrete Roadway | 2,793,000 |
| Combination of Covered and Uncovered Concrete Lined Canal | 2,542,000 |
| Total | 5,335,000 |
| Total USD | 762,000 |

One benefit includes less spread of disease from disease carrying mosquitoes because there will be less stagnant water in the area from flooding. The water from the curichi will not flood the local residents' homes of UVs 118A and 118 which will also lower disease rates.

There will also be an economic impact because without flooding occurring at Radial 16 and 5$^{th}$ Ring intersection the business can be open more days and less products lost or damaged from flood damage. Traffic will be able to proceed at a higher level of service (LOS) because flood water will be greatly reduced.

The final design was recommended because it is durable, has a long life cycle, and will require little maintenance other than periodic cleaning.

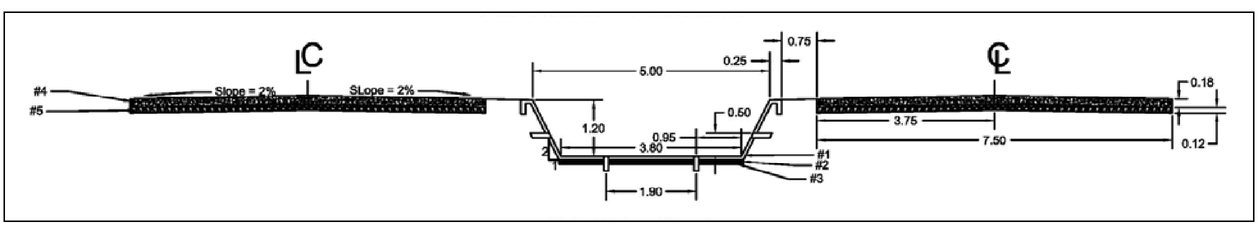



Image Taken in AutoCAD Civil 3D; Design by T.T.E.
**Figure 7.1:** Final Design Recommendation for Project Site

## 8.0 Conclusion

Tip Third Engineering made a trip to District 10 of Santa Cruz, Bolivia in August 2008 to gather data and recommend engineering solutions for a canal and roadway design. T.T.E. proposes a concrete lined canal with a non-reinforced roadway be implemented. With maintenance the design will alleviate flooding, increase transportation, and improve the economic activity of the residents.

## 9.0 References

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# Appendix A: Meeting Minutes

**Date:** August 12, 2008
**Time:** 10:00 am
**Location:** M.C.C. Santa Cruz, Bolivia
**Subject:** First Meeting with District 10 Engineers
**Attendees:** Ing. Linda Phillips, Ing. Javier Marin, Ing. Waldo Varas, and T.T.E.

Summary of Meeting:

The Problem

- The curichi cannot be filled in – must work as retention basin
  The roads are not big enough.

Watershed

- The project might encompass two watersheds (repeated again later during meeting). The canal should take all the water. Our canal should be bigger than the emergency canal based on flow calculations. We should walk the site to find high spots.

Design

- 6th Ring will be built through the curichi to connect to existing pavement.
- Are there alternative routes for the new canal?
- They would like to see two lanes with a canal in the middle.
- The route will likely be curichi to 5th Ring
- 6ht Ring will be built as connection to 16th Radial.
- This is a major artery/connector between rings. It is the only connection for the neighborhoods.
- The right of way for the new road should be 40 or 50 meters wide.
- Near the school, the new right of way should have the same dimensions as the existing road, only it will be paved.

Soil

- Take a meter of the soil out, because the top layer is clay.
- The sub-base (capabase) should be gravel and sand
- Use example reports from city for the cross sections.
- Information on permeability is in other report.
- Check design for 5th Ring catch basin and back calculate while sizing inlet.

Jurisdiction

- The central city government is in charge.

Maintenance

- The main city maintenance department is responsible for maintenance. The district has to ask for maintenance to be preformed.
- Once a week, they are lent a piece of equipment. Horatio decides where they need to use it.

- Every 2-3 months there is canal maintenance.
- Problems with maintenance occur when something is broken. For example, there was an accident and part of the curb was broken. They had to hire an outside firm to fix it.
- What usually happens in Bolivia is that the people who live on the street clean the sidewalks and street in front of their houses.
- Twice a year the sand is cleaned off the street.

Budget

- The main city sets overall budge in La Paz for the whole city of Santa Cruz.
- Whatever money they get, the city (Santa Cruz) decides priorities (what gets paid, etc).
- Canals are the most important.
- This project is projected for construction in 2009. They promise money for it.
- They will have to prioritize the project. The canal will go in and not the road. The road will still be dirt with the canal is in.
- Open canals have lower maintenance costs.
- Where the roads intersect, box culverts are needed.
- Maintenance money also comes from the center (routine maintenance).
- There is constant maintenance on all of the canals. It is year round in theory, or all the time. Approximately three times a year.
- Example of problems: A canal was built on the $8^{th}$ ring and they didn't clean it out for 7-8 years. This shows why routine maintenance is needed.
- They will hire outside firm to perform maintenance. They will renew their contract after 4 months or start a new contract.
- Having a maintenance program and schedule is a priority.

Materials

- Choice between asphalt and concrete (without reinforcement) roadway is based on cost. 15cm caja – 18cm principal road. This is the standard thickness without steel.
  12cm gravel and sand mixture.

The Area

- There is little industry in the area. There is a carpenter's shop outside, not in the neighborhood.
- There is a new school in the area. They might need a covered canal. Security is a big issue. We could put in bridges, but they thought it was better to have it covered.
- They'd like us to make a recommendation based on expense. At other schools, the canals are open.

Schedule

- They will build the canal in 2009. The road will follow. They will submit this project with their budge at POA on November 15.
- They'd like documents from us by end of October. Make Adobe PDF to email to Waldo. This should include report and drawings. This gives them time to look it over and put their budget together.

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**Date:** August 19, 2008
**Time:** 10:00 am
**Location:** M.C.C. Santa Cruz, Bolivia
**Subject:** Second Meeting with District 10 Engineers
**Attendees:** Ing. Linda Philips, Ing. Varas, Ing. Javier Marin, Morgan Davis, and Abdoulie Barry

Summary of Meeting:

- The city council intends to keep the Curichi as a retention basin for the flood waters or else the neighborhood of the Curichi will continue to flood. City Engineers do not want the Curichi to be filled.
- The Curichi project on Radial 16 has 50m right of way.
- The project would involve two lanes with an open canal in the middle.
- The city council has promised to provide the funding to build the canal in 2009 and the roads later. The canal has more priority to the city council than the roads and hence the decision to build the canal first.
- The District 10 engineers also suggested to design for an open canal since the maintenance cost is relatively cheaper. The City council provides the Districts with piece of equipment and the districts decide what roads or canals to maintain. All roads and canals are theoretically maintained 2-3 times a month. The maintenance of the roads and canals is done by contractors whose contracts are renewed every four months.
- The engineers pointed out that they would prefer a non-reinforced concrete pavement over asphalt pavements. The reason they gave for this is that the non-reinforced concrete pavements are much cheaper and the city government would be more willing to pay for a cheaper project than a more expensive one. The Curichi project will compete with other projects within Santa Cruz for funding. According to the District 10 Engineers, historically, the cheaper project gets the funding over the other more expensive ones.
- Projects are funded by the Bolivian Central government (La Paz). The central government provides funds to the City council of Santa Cruz who decide what projects from their city would get funding.
- According to the District 10 Engineers, the concrete pavement roads will normally have a 12cm of base material (sand & gravel) and 18cm of concrete pavement on top of the base material.

# Appendix B:
# Soil Field Data and Classification

Soil Boring
Boring Number/Description: 1 - In field where new school will be built

| | | | |
|---|---|---|---|
| Project No.: | | Elevation: | See Survey |
| Project Name: | Radial 16 Canal and Road Between 5th Ring and 30th de Agosto Curichi | X Coordinate: | |
| Project Location: | Radial 16 Between 5th Ring and 30th de Agosto Curichi in Santa Cruz, Bolivia | Y Coordinate: | |
| Client: | District 10 | Driller: | |
| A/E: | | Rig No.: | |
| Project Name: | | Classified By: | Morgan Davis |
| Total Depth: | 3 Meters | Checked By: | Scott Bauer/Branden Strayer |
| Date Started: | August 19, 2008 | Date Completed: | August 19, 2008 |

| Depth Range | Soil Description | USCS Symbol |
|---|---|---|
| Surface | Grass | |
| 10 cm | Dark Brown clay with Reddish Brown, Some Black Organics | |
| 40 cm | Dark Brown clay, some Reddish Tint | |
| 50 cm | Lighter Brown, Moist, Some Brownish Red | |
| 87 cm | Light Brown clay | |
| 1 m | Brown, Moist clay | |
| 1.25 m | Brown, Moist clay | |
| 1.5 m | Reddish, Brown clay | |
| 1.7 m | Drier, Crumbly, Some Sand | |
| 1.9 m | Sandy, Lighter in color | |
| 2 m | Sandy, Light Tan - Drier | |
| 2.3 m | Moist Tan Sand | |
| 2.75 | Moist Tan Sand (Wetter) | |
| 3 m | Wed Sand (Saturated) | |
| | End of Boring at 3m | |
| | | |
| | | |
| | | |

Notes: Depths are approximate.
Drill Method: Hand Auger
Boring Backfilled With: Existing Soil

Soil Classification

Boring Number/Description: 1 - In field where new school will be built
Sample Depth: 1 Meter

| Test Name | Test Procedure | Test Results | Analysis |
|---|---|---|---|
| Feel | Check the feel of a slightly wetted sample of soil. | Sticky and Greasy | Contains clay |
| | | Gritty | Contains sand |
| | | Powder, Residue | Contains Silt |
| Shine | Make a small cake of the sample and rub it with a finger nail or the flat side of a knife. | Surface shines | Contains clay |
| | | Surface remains dull | Contains silt and/or sand |
| Thread | Make a small lump (15mm diameter). Roll out the lump into a thinner thread of 3mm in diameter. If sample breaks before 3mm then add more water. If it can be rolled thinner than 3mm then re-lump it until it just breaks apart at 3mm. Reform ball of sample and apply pressure with fingers. | Ball deforms under large amount of pressure without cracking and crumbling | Contains clay |
| | | Ball deforms, cracks or crumbles under small amount of pressure | Contains little clay |
| | | Can not be made into ball | Too much sand and/or silt |
| Ribbon | Roll a sample thread 15mm in diameter and 10 cm long. The thread should be sticky but able to be rolled to 3 mm diameter without breaking. Place thread in the palm of one hand and hold the end between thumb and forefinger. Flatten and advance thread between thumb and forefinger. Form largest ribbon possible before breaking. | Long Ribbon: 20 -25 cm | Contains large amount of clay |
| | | Short Ribbon: 5 -10 cm | Contains medium to small amount of clay |
| | | No Ribbon | Contains little or no clay |

Soil Boring

Boring Number/Description: 2 - In field near curichi

| | | | |
|---|---|---|---|
| Project No.: | | Elevation: | See Survey |
| Project Name: | Radial 16 Canal and Road Between 5th Ring and 30th de Agosto Curichi | X Coordinate: | |
| Project Location: | Radial 16 Between 5th Ring and 30th de Agosto Curichi in Santa Cruz, Bolivia | Y Coordinate: | |
| Client: | District 10 | Driller: | |
| A/E: | | Rig No.: | |
| Project Name: | | Classified By: | Morgan Davis |
| Total Depth: | 2.3 Meters | Checked By: | Scott Bauer/Branden Strayer |
| Date Started: | August 19, 2008 | Date Completed: | August 19, 2008 |

| Depth Range | Soil Description | USCS Symbol |
|---|---|---|
| Surface | Grass | |
| 0 cm | Dark Brown clay | |
| 30 cm | Lighter Brown, Moist clay | |
| 60 cm | Lighter Brown, Moist clay | |
| 1 m | Drier, Brown/Red clay | |
| 1.2 m | Lighter Brown, Drier clay | |
| 1.4 m | Clay and sand | |
| 1.6 m | Lighter Brown, Drier sand | |
| 1.8 m | Light Brown, Dry sand | |
| 2.0 m | Wet sand with clay | |
| 2.1 m | Wetter sand with clay | |
| 2.2 m | Saturated sand | |
| 2.3 m | Water Table | |
| | End of Boring at 2.3 m | |
| | | |
| | | |
| | | |
| | | |

| | |
|---|---|
| Notes: | Depths are approximate. |
| Drill Method: | Hand Auger |
| Boring Backfilled With: | Existing Soil |

Soil Classification

Boring Number/Description: 1 - In field where new school will be built
Sample Depth: 3 Meters

| Test Name | Test Procedure | Test Results | Analysis |
|---|---|---|---|
| Feel | Check the feel of a slightly wetted sample of soil. | Sticky and Greasy | Contains clay |
| | | Gritty | Contains sand |
| | | Powder, Residue | Contains Silt |
| Shine | Make a small cake of the sample and rub it with a finger nail or the flat side of a knife. | Surface shines | Contains clay |
| | | Surface remains dull | Contains silt and/or sand |
| Thread | Make a small lump (15mm diameter). Roll out the lump into a thinner thread of 3mm in diameter. If sample breaks before 3mm then add more water. If it can be rolled thinner than 3mm then re-lump it until it just breaks apart at 3mm. Reform ball of sample and apply pressure with fingers. | Ball deforms under large amount of pressure without cracking and crumbling | Contains clay |
| | | Ball deforms, cracks or crumbles under small amount of pressure | Contains little clay |
| | | Can not be made into ball | Too much sand and/or silt |
| Ribbon | Roll a sample thread 15mm in diameter and 10 cm long. The thread should be sticky but able to be rolled to 3 mm diameter without breaking. Place thread in the palm of one hand and hold the end between thumb and forefinger. Flatten and advance thread between thumb and forefinger. Form largest ribbon possible before breaking. | Long Ribbon: 20 -25 cm | Contains large amount of clay |
| | | Short Ribbon: 5 -10 cm | Contains medium to small amount of clay |
| | | No Ribbon | Contains little or no clay |

Soil Classification

Boring Number/Description: 1 - In field where new school will be built
Sample Depth: 2 Meters

| Test Name | Test Procedure | Test Results | Analysis |
|---|---|---|---|
| Feel | Check the feel of a slightly wetted sample of soil. | Sticky and Greasy | Contains clay |
| | | Gritty | Contains sand |
| | | Powder, Residue | Contains Silt |
| Shine | Make a small cake of the sample and rub it with a finger nail or the flat side of a knife. | Surface shines | Contains clay |
| | | Surface remains dull | Contains silt and/or sand |
| Thread | Make a small lump (15mm diameter). Roll out the lump into a thinner thread of 3mm in diameter. If sample breaks before 3mm then add more water. If it can be rolled thinner than 3mm then re-lump it until it just breaks apart at 3mm. Reform ball of sample and apply pressure with fingers. | Ball deforms under large amount of pressure without cracking and crumbling | Contains clay |
| | | Ball deforms, cracks or crumbles under small amount of pressure | Contains little clay |
| | | Can not be made into ball | Too much sand and/or silt |
| Ribbon | Roll a sample thread 15mm in diameter and 10 cm long. The thread should be sticky but able to be rolled to 3 mm diameter without breaking. Place thread in the palm of one hand and hold the end between thumb and forefinger. Flatten and advance thread between thumb and forefinger. Form largest ribbon possible before breaking. | Long Ribbon: 20 -25 cm | Contains large amount of clay |
| | | Short Ribbon: 5 -10 cm | Contains medium to small amount of clay |
| | | No Ribbon | Contains little or no clay |

Soil Classification

Boring Number/Description: 2 - In field near curichi
Sample Depth: 2.35 Meters

| Test Name | Test Procedure | Test Results | Analysis |
|---|---|---|---|
| Feel | Check the feel of a slightly wetted sample of soil. | Sticky and Greasy | Contains clay |
| | | Gritty | Contains sand |
| | | Powder, Residue | Contains Silt |
| Shine | Make a small cake of the sample and rub it with a finger nail or the flat side of a knife. | Surface shines | Contains clay |
| | | Surface remains dull | Contains silt and/or sand |
| Thread | Make a small lump (15mm diameter). Roll out the lump into a thinner thread of 3mm in diameter. If sample breaks before 3mm then add more water. If it can be rolled thinner than 3mm then re-lump it until it just breaks apart at 3mm. Reform ball of sample and apply pressure with fingers. | Ball deforms under large amount of pressure without cracking and crumbling | Contains clay |
| | | Ball deforms, cracks or crumbles under small amount of pressure | Contains little clay |
| | | Can not be made into ball | Too much sand and/or silt |
| Ribbon | Roll a sample thread 15mm in diameter and 10 cm long. The thread should be sticky but able to be rolled to 3 mm diameter without breaking. Place thread in the palm of one hand and hold the end between thumb and forefinger. Flatten and advance thread between thumb and forefinger. Form largest ribbon possible before breaking. | Long Ribbon: 20 -25 cm | Contains large amount of clay |
| | | Short Ribbon: 5 -10 cm | Contains medium to small amount of clay |
| | | No Ribbon | Contains little or no clay |

Soil Classification

Boring Number/Description: 2 - In field near curichi
Sample Depth: 2.25 Meters

| Test Name | Test Procedure | Test Results | Analysis |
|---|---|---|---|
| Feel | Check the feel of a slightly wetted sample of soil. | Sticky and Greasy | Contains clay |
| | | Gritty | Contains sand |
| | | Powder, Residue | Contains Silt |
| Shine | Make a small cake of the sample and rub it with a finger nail or the flat side of a knife. | Surface shines | Contains clay |
| | | Surface remains dull | Contains silt and/or sand |
| Thread | Make a small lump (15mm diameter). Roll out the lump into a thinner thread of 3mm in diameter. If sample breaks before 3mm then add more water. If it can be rolled thinner than 3mm then re-lump it until it just breaks apart at 3mm. Reform ball of sample and apply pressure with fingers. | Ball deforms under large amount of pressure without cracking and crumbling | Contains clay |
| | | Ball deforms, cracks or crumbles under small amount of pressure | Contains little clay |
| | | Can not be made into ball | Too much sand and/or silt |
| Ribbon | Roll a sample thread 15mm in diameter and 10 cm long. The thread should be sticky but able to be rolled to 3 mm diameter without breaking. Place thread in the palm of one hand and hold the end between thumb and forefinger. Flatten and advance thread between thumb and forefinger. Form largest ribbon possible before breaking. | Long Ribbon: 20 -25 cm | Contains large amount of clay |
| | | Short Ribbon: 5 -10 cm | Contains medium to small amount of clay |
| | | No Ribbon | Contains little or no clay |

Soil Classification

Boring Number/Description: 2 - In field near curichi
Sample Depth: 2.35 Meters

| Test Name | Test Procedure | Test Results | Analysis |
|---|---|---|---|
| Feel | Check the feel of a slightly wetted sample of soil. | Sticky and Greasy | Contains clay |
| | | Gritty | Contains sanc |
| | | Powder, Residue | Contains Silt |
| Shine | Make a small cake of the sample and rub it with a finger nail or the flat side of a knife. | Surface shines | Contains clay |
| | | Surface remains dull | Contains silt and/or sand |
| Thread | Make a small lump (15mm diameter). Roll out the lump into a thinner thread of 3mm in diameter. If sample breaks before 3mm then add more water. If it can be rolled thinner than 3mm then re-lump it until it just breaks apart at 3mm. Reform ball of sample and apply pressure with fingers. | Ball deforms under large amount of pressure without cracking and crumbling | Contains clay |
| | | Ball deforms, cracks or crumbles under small amount of pressure | Contains little clay |
| | | Can not be made into ball | Too much sand and/or silt |
| Ribbon | Roll a sample thread 15mm in diameter and 10 cm long. The thread should be sticky but able to be rolled to 3 mm diameter without breaking. Place thread in the palm of one hand and hold the end between thumb and forefinger. Flatten and advance thread between thumb and forefinger. Form largest ribbon possible before breaking. | Long Ribbon: 20 -25 cm | Contains large amount of clay |
| | | Short Ribbon: 5 -10 cm | Contains medium to small amount of clay |
| | | No Ribbon | Contains little or no clay |

# Appendix C: Canal Design

**Watershed Area**

To complete the watershed calculations it was first necessary for T.T.E. to find the watershed area. This area was found using AutoCAD 2008. The total watershed area for the Curichi project site was found to be 958,725.23 $m^2$ or approximately 1 $km^2$ . Most of the watershed area is residential except for a small part around the Southwest Curichi end of the project site which is semi undeveloped. The complete watershed area will be treated as residential because future plans are to continually develop the site.

**Coefficient of Superficial Drainage (C)**

T.T.E. located a table containing Coefficients of Superficial Drainage which lists descriptions of the different types of terrain found in Bolivia and the associated ( C ) coefficient that accompanies them. This table is found in Ing. Marin's Drainage Report.

T.T.E. selected to use the zones outside of the $3^{rd}$/pavements option from the table because the Curichi project site is located between the $5^{th}$ and $6^{th}$ rings. A pre-developed Coefficient of Superficial drainage has been produced by the city of Santa Cruz drainage engineers. The coefficient that T.T.E. used for the watershed calculations was; C = 0.35.

**Table 1:** Coefficients of Superficial Drainage as assumed from Marin's report

| Coefficients of Superficial Drainage | | |
|---|---|---|
| Description of Area | Runoff Coefficient | |
| | (a) | (b) |
| Commercial Area | 0.70 to 0.95 | |
| Commercial-Residential Area | 0.50 to 0.70 | 0.8 |
| | | |
| Single family homes | 0.30 to 0.50 | |
| Separated Multi-family dwellings | 0.40 to 0.60 | |
| Connected multi-family dwellings | 0.60 to 0.75 | |
| Suburban | 0.25 to 0.40 | |
| Inside of the 2nd or 3rd rings | | 0.5 |
| zone outside of the 3rd ring s/ pavement | | 0.35 |
| industrial zones | | |
| light | 0.50 to 0.80 | |
| heavy | 0.60 to 0.90 | |
| parks, cemeteries and hospitals | 0.10 to 0.25 | 0.2 |
| paved streets | 0.70 to 0.95 | |
| concrete streets | 0.80 to 0.95 | |
| (a) coefficients recommended according to different sources | | |
| (b) adopted for the stormwater drainage design for the city of Santa Cruz | | |

**Rainfall Intensity (I)**

T.T.E. used Equation 1 below to find the rainfall intensity for the Curichi watershed. The Bolivian rainfall intensity equation was provided in NB 688, Chapter 6, Section 5.1.1.

$$I = \frac{393.7 * f^{.3556}}{(t*60)^{0.7016}} \quad (Equation - 1)$$

$I =$ Rainfall Intensity (mm/hr)

$f$ = Storm Frequency (years)

$t$ = Storm Duration (hours)

A storm frequency, f, of 10 years was selected and from the watershed being split into 7 different sections there were several different storm durations, t. The rainfall intensity for section 1 of the Curichi watershed was calculated using the sample calculation in Equation 2 located below.

$$I = \frac{393.7 * 10^{.3556}}{(.48429 * 60)^{.7016}} = 83.974(mm/hr) \quad (Equation - 2)$$

**Time of Concentration (t$_c$)**

T.T.E. was given a Bolivian equation called the Kirpich equation to find the time of concentration. This equation came from Ing. Marins report, it is shown below in Equation 3 below.

$$t_c = 0.06626 * (\frac{L^2}{S})^{0.385} \quad (Equation - 3)$$

$$t_c = \text{ time of concetration } (hours)$$

$$L = \text{hydraulic length } (km)$$

$$S = \text{ watershed slope } (\text{decimal percent in } m/m)$$

Using the length and slope from the furthest point on the edge of the watershed to theproposed channel it was possible to find slopes for each watershed section. After this slope was found it enabled T.T.E. to calculate the time of concentration, $t_c$ , for each section. Equation 4 below provides a sample calculation for the time of concentration, $t_c$, for section 1 of the Curichi Site.

$$t_c = 0.06626 * (\frac{.49214^2}{.00138})^{0.385} = .48429 \text{ hours} \quad (Equation - 4)$$

**Flow Rate (Q)**

Once the values for area, rainfall intensity, and C coefficient were found it was possible to solve for flow rate using the Rational Method, Equation 5. The design overland stormrunoff can be seen calculated in Equation 6.

$$Q = C * I * A \quad (Equation - 5)$$
$$Q = Overland\ Storm\ Runoff\ (m^3/s)$$
$$C = Coefficient\ of\ Superficial\ Drainage$$
$$I = RainFall\ Intensity (mm/hr)$$
$$A = Watershed\ Area (ha)$$

The values for coefficient of superficial drainage, C, rainfall intensity, I, and watershed area, A, have all been calculated which allowed for T.T.E. to calculate the flow for each section of the Curichi watershed. Equation 6 below shows a sample calculation for section 1 of the watershed area.

$$Q = \frac{(0.35*83.974*14.37)}{360} = 1.174 (m^3/s) \qquad (Equation - 6)$$

The final flow rate for the project site was then found by summing all 7 of the flow rates that were calculated for each watershed section. After this was completed T.T.E. found the total overland storm runoff, Q, to be 10.065 ($m^3$/s).

## Canal Sizing

### Creating Normal Depth, $Y_n$, Equation

Using Equations 7 and 8 below, it was possible to form an equation that relates the flow, Q, to the Velocity, V, and the Area, A, of the trapezoidal canal design. The two equations were combined and it provided T.T.E. with Equation 9 which is shown below. Equation 9 allows us to determine the normal flow depth for the trapezoidal canal by substituting Equations 10 and 11 in for the Area, A, and Wetted Perimeter, P, variables shown in Equation 9.

$$A = \frac{Q}{V} \quad (Equation - 7)$$

$$A = Canal\ Area\ (m^2)$$

$$Q = Canal\ Flow\ (\frac{m^3}{s})$$

$$V = Flow\ Velocity\ (\frac{m}{s})$$

$$V = \left(\frac{C_m}{n}\right) * \left(\frac{A}{P}\right)^{\frac{2}{3}} * S_o^{\frac{1}{2}} \quad (Equation - 8)$$

$C_m = 1.0$ *For International System (SI) units and* $1.49$ *for British Gravitational (BG) units.* $C_m$ *is a unitless coefficient*

$n =$ *Mannings Roughness Coefficient*

$P =$ *Wetted Perimeter* $(m)$

$S_o =$ *Slope of Canal* $(\frac{m}{m})$ *as a decimal %*

$$Q = \left[\left(\frac{1}{n}\right) * \left(\frac{A}{P}\right)^{\frac{2}{3}} * S_o^{\frac{1}{2}}\right] * A \quad (Equation - 9)$$

$A =$ *Area for Trapezoidal Canal*

$$A = (B + X * Y_n)Y_n \quad (Equation - 10)$$

$P =$ *Wetted Perimeter for Trapezoidal Canal*

$$P = B + 2 * Y_n * \sqrt{1 + X^2} \quad (Equation - 11)$$

$B =$ *Length of Base of Trapezoidal Canal* $(m)$

$X =$ *Side Slope of Canal Sides*

$Y_n =$ *Normal Depth* $(m)$

$Y_n$ *is also the variable being solved for in Equation - 9*

## Normal Flow Depth ($Y_n$)

The normal flow depth was solved using Equation 9 which is located above. The flow, Q, was found to be 10.065 ($m^3/s$) which was found in the watershed analysis section of this appendix. Manning's roughness coefficient, n, was chosen to be 0.015 for a concrete lined canal. This value was found in the table below which was taken from Water Resources Engineering by Ralph A. Wurbs and Wesley P. James.

**Table 2:** Manning Roughness Values

***Taken From Water Resources Engineering* by Ralph A. Wurbs and Wesley P. James.**

MANNING ROUGHNESS VALUES FOR OPEN CHANNELS

| | n |
|---|---|
| Natural Channels | |
| Clean, straight | 0.025-0.033 |
| Clean, irregular | 0.033-0.045 |
| Weedy, irregular | 0.045-0.080 |
| Brush, irregular | 0.07-0.16 |
| Floodplains | |
| Pasture, no brush | 0.030-0.050 |
| Brush, scattered | 0.035-0.070 |
| Brush, dense | 0.070-0.15 |
| Timber and brush | 0.10-0.20 |
| Excavated uniform earth channels | |
| Straight with short grass | 0.02-0.03 |
| Winding with short grass | 0.025-0.035 |
| Cobble, stony | 0.03-0.05 |
| Dense vegetation | 0.05-0.12 |
| Lined Channels | |
| Concrete, finished | 0.012-0.015 |
| Gravel | 0.02-0.03 |
| Asphalt | 0.015-0.02 |
| Closed conduits (partially full) | |
| Steel, welded | 0.010-0.015 |
| Cast iron | 0.011-0.016 |
| Concrete | 0.010-0.015 |
| Corrugated metal | 0.020-0.030 |

T.T.E. decided to use 3.8 m as a base width, B, for the canal, and a side slope, X, of 2H:1V. The canal slope was determined on AutoCAD 2008 from the survey data that was taken in Bolivia by T.T.E. The canal slope was also determined in AutoCAD 2008, and it was found to be .0016(m/m). Located below is Equation 12 for the Normal Depth, $Y_n$, of the trapezoidal canal.

$$10.065=\left[\left(\frac{1}{.015}\right)*\left(\frac{\left(\left(3.8+2y_n\right)y_n\right)}{\left(\left(3.8+2y\right)*\sqrt{\left(1+2^2\right)}\right)}\right)^{\frac{2}{3}}*.0016^{\frac{1}{2}}\right]*\left(\left(3.8+2y_n\right)y_n\right)\quad (Equation\ -\ 12)$$

$Y_n = 1.11\ m$

**Required Freeboard (FB)**

The canal at the Curichi site has no restrictions on depth, but a Required Freeboard calculation is still required. Freeboard calculations are required as a safety factor to prevent waves or current from overflowing in the canal. Located in Equation 13 below is the associated calculation for Required Freeboard, FB.

$$FB = C_{FB} * Y_n^{0.5} \quad (Equation\ -\ 13)$$

$FB = Freeboard\ (m)$

$C_{FB} = Coefficient\ of\ Freeboard$

$Y_n = Normal\ Flow\ Depth\ (m)$

$C_{FB}$ is a coefficient that varies from 0.6 for small canals to 0.9 for larger canals (Wurbs). T.T.E. chose a $C_{FB}$ of 0.6 due to the canal size for the Curichi site. A required freeboard height was calculated to be 0.6 meters as shown in Equation 14 below.

$$FB = 0.6*1.11^{0.5} = 0.63(m) \quad (Equation\ -\ 14)$$

**Top Width (T)**

In a trapezoidal canal, the most efficient design occurs when the base is the same size as the water depth. T.T.E. chose a larger base width of 3.8 meters. The normal flow depth, $Y_n$, was found to be 1.11 meters and the total depth of the designed canal was chosen to be 1.2 meters. Equation 15 below shows the calculation for the top width, T, of the canal.

$$T = B + (2 * SS * Y_n) \quad (Equation - 15)$$

$T$ = $Top\ Width\ (m)$

$B$ = $Base\ Width\ (m)$

$SS$ = $Side\ Slope$

$Y_n$ = $Calculated\ Normal\ Depth\ (m)$

A top width was calculated in Equation 16 below, and it was found that the top width should be 8.25 meters wide. Due to space requirements at the Curichi site T.T.E. was not able to select 8.25 meters as a top width for the canal. T.T.E. decided to use a top width of 5 meters to accommodate space requirements for the road design on each side of the canal at the Curichi site.

$$T = 3.8m + (2 * 2 * 1.11) = 8.25m \quad (Equation - 16)$$

**Flow Velocity (V)**

With all the dimensions selected and calculated for the trapezoidal canal it was possible to find the flow velocity, V, for the canal. Equation 17 below shows this calculation.

$$V = \left(\frac{1}{0.015}\right) * \left(\frac{((3 + 2 * 1.11)1.11)}{((3 + 2 * 1.11) * \sqrt{1 + 2^2})}\right)^{\frac{2}{3}} * .0016^{\frac{1}{2}} \quad (Equation - 17)$$

$$V = 3.00 \ \frac{m}{s}$$

**Froude Number (Fr)**

The Froude Number must be below 0.6 to avoid standing waves in the canal. Equation 18 below shows the required equation to calculate the Froude Number. Equation 19 shows the required calculation for the trapezoidal canal that T.T.E. is designing.

$$Fr = \frac{V}{(g * Y_n)^{0.5}} \quad (Equation\ -\ 18)$$

$V\ =\ Flow\ Velocity\ (m/s)$

$g = gravitational\ constant\ equal\ to\ 9.81\ m/s^2$

$Y_n\ =\ Normal\ Depth\ (m)$

$Trapezoidal\ Canal$

$$Fr = \frac{3.00}{(9.81 * 1.11)^{0.5}}\ =\ 0.651 \quad (Equation\ -\ 19)$$

Due to the Froude Number being greater than 0.6 as shown above in Equation 19, it was necessary to change the depth of the canal to accommodate for the Froude Number. T.T.E. selected to use 2 meters as a normal depth height for the canal and recalculated the Froude Number as shown below in Equation 20. This new normal depth brought the Froude Number below the required value of 0.6.

$$Fr = \frac{3.00}{(9.81 * 1.2)^{0.5}}\ =\ 0.57 \quad (Equation\ -\ 20)$$

**Transition Section Sizing**

T.T.E. was required to design a closed drainage section that transitions from the canal to the existing catch basin located at the 5th ring intersection. The section must be closed because it is necessary for the drainage to run underneath the existing 5th ring road to the existing catch basin. Two options have been discussed: the option of using pipes and the option of using a box culvert to connect into the existing catch basin. Due to the limiting size of the existing catch basin the diameter of the pipes or the height of the box culvert cannot be too large. The existing catch basin allow for a pipe diameter of 1.2 meters or a normal box culvert depth of 1.2 meters.

**Pipe Sizing**

The option of using pipes was considered to connect the canal to the existing catch basin. Equation 21 below shows the pipe sizing calculations.

$$D = [\frac{3.21 * \frac{Q}{\#\ of\ Pipes} * n}{C_m * S_0^{0.5}}]^{\frac{3}{8}} \quad (Equation\ -\ 21)$$

$D$ = Pipe Diameter $(m)$

$Q$ = Flow

$n$ = Mannings Coefficient

$C_m$ = 1 - Constant for SI units

Options of one, two, and three pipes were considered feasible, but Equations 22, 23, and 24 located below show that these dimensions are too large to connect to the existing catch basin with the dimension height of 1.2 meters. Based on these calculations it was determined that pipes will not work to connect to the existing catch basin.

$$D_1 = [\frac{3.21 * \frac{10.065}{1} * .015}{1 * .0016^{0.5}}]^{\frac{3}{8}} = 2.548m \quad (Equation\ -\ 22)$$

$$D_2 = [\frac{3.21 * \frac{10.065}{2} * .015}{1 * .0016^{0.5}}]^{\frac{3}{8}} = 1.96m \quad (Equation\ -\ 23)$$

$$D_3 = [\frac{3.21 * \frac{10.065}{3} * .015}{1 * .0016^{0.5}}]^{\frac{3}{8}} = 1.68m \quad (Equation\ -\ 24)$$

**Box Culvert Sizing**

Due to the option of the pipes not working T.T.E. explored the option of using a box culvert to connect the designed canal to the existing catch basin. Equation 25 below shows the equation used to find the normal depth ($Y_n$) of the rectangular box culvert.

$$Q = [(\frac{C_m}{n}) * (\frac{A}{P})^{\frac{2}{3}} * S^{\frac{1}{2}}] * A \qquad (Equation \ - \ 25)$$

$$Q \ = \ Flow \ (\frac{m^3}{s})$$

$$C_m \ = \ 1 \ for \ SI \ units$$

$$n \ = \ mannings \ coefficient$$

$$A \ = \ Area \ (m^2)$$

$$P \ = \ Wetted \ Perimeter \ (m)$$

$$S \ = \ Slope \ of \ Culvert \ (m / m)$$

$$\mathrm{A} = (3*\mathrm{Y}_n) \qquad \mathrm{P} = (3 + 2*\mathrm{Y}_n)$$

Equation 26 below shows the normal depth height of the designed box culvert with a base of 3 meters. A base of 3 meters was chosen to match the base of the canal for the maximum width of the box culvert. A normal height of 1.13 meters was found to be the adequate depth of the box culvert. T.T.E. has chosen a box culvert depth of 1.2 meters to provide the largest possible flow into the existing catch basin.

$$10.065 = [(\frac{1}{.015}) * (\frac{3*Y_n}{3+2*Y_n})^{\frac{2}{3}} * .0016^{\frac{1}{2}}] * (3*Y_n) \qquad (Equation \ - \ 26)$$

$$Y_n = 1.13 \ m$$

**Outlet and Inlet Flow**

Using Manning's equation for outlet controlled culverts, Equation 27, and inlet controlled culverts, Equation 28, it was possible to find the maximum flow through the culverts.

$$Q = N_C * A_C * C_C * \sqrt{2 * g * H_L} \quad (Equation\ -\ 27)$$

$N_P = Number\ of\ Culverts$

$A_P = Area\ of\ Culverts\ (m^2)$

$C_C = Loss\ Coefficient$

$H_L = Max\ Height\ of\ Head\ Loss\ from\ entrance\ to\ exit$

$$Q = N_C * A_C * C_O * \sqrt{2 * g * (H - \frac{D}{2})} \quad (Equation\ -\ 28)$$

$A_C = Area\ of\ Culvert\ Entrance\ (m^2)$

$O_C = Orfice\ Coefficient$

$\text{H} = \text{Head (m)}$

$C_C$ can be found using Equation 29 and Equation 30.

$$C_C = (K_e + K_f + 1)^{-0.5} \quad (Equation\ -\ 29)$$

$K_e = Entrance\ Coefficient$

$K_f = Friction\ Loss\ Coefficient$

$$K_f = \frac{L_C * n^2 * 2 * g}{R^{\frac{4}{3}} * C_m^{\ 2}} \quad (Equation\ -\ 30)$$

$L_C = Culvert\ Length\ (m)$

$R = Hydraulic\ Radius,\ \frac{A}{P}, (m)$

$K_e$ is 0.7 for parallel flat edged entrances, $C_O$ is 0.7 for sharp edged entrances, and the length of the culvert was found to be 11 m. This length of 11 meters was selected to run the box culvert from the end of the canal just the distance under the existing roadway at 5th ring. Using these variables T.T.E. was able to find the additional values for the required inputs, Equation 31 and Equation 32, and resulting outlet and inlet controlled flow rates, Equation 33 and Equation 34. The inlet controlled flow is not adequate to handle the flow from the canal of 10.065 $m^3$/s, but when the canal was designed it was designed to handle the slight back up that may occur due to the entrance controlled inlet of the box culvert.

$$K_f = \frac{11m * .0015^2 * 2 * 9.81\frac{m}{s^2}}{(\frac{3*1.2}{3+2*1.2})^{\frac{4}{3}} * 1.0^2} = .0008 \quad (Equation\ -\ 31)$$

$$C_C = (0.7 + .0008 + 1)^{-0.5} = .766 \quad (Equation\ -\ 32)$$

$$Q_{Outlet} = 1*(3.0*1.2)*.766*\sqrt{2*9.81\frac{m}{s^2}*1.2} = 13.38\frac{m^3}{s} \quad (Equation\ -\ 33)$$

$$Q_{Inlet} = 1*(3.0*1.2)*.7*\sqrt{2*9.81\frac{m}{s^2}*(1.2-\frac{1.2}{2})} = 9.46\frac{m^3}{s} \quad (Equation\ -\ 34)$$

The above calculations were repeated to accommodate for a box culvert section that will run from the existing catch basin up the 16th radial to where the school begins. The purpose of this is to keep children from playing in the canal. This service was requested by the District 10 engineers as a design option.

$$K_f = \frac{211m * .0015^2 * 2 * 9.81\frac{m}{s^2}}{(\frac{3*1.2}{3+2*1.2})^{\frac{4}{3}} * 1.0^2} = .016 \quad (Equation\ -\ 31)$$

$$C_C = (0.7 + .0038 + 1)^{-0.5} = .763 \quad (Equation\ -\ 32)$$

$$Q_{Outlet} = 1*(3.0*1.2)*.763*\sqrt{2*9.81\frac{m}{s^2}*1.2} = 13.32\frac{m^3}{s} \quad (Equation\ -\ 33)$$

$$Q_{Inlet} = 1*(3.0*1.2)*.7*\sqrt{2*9.81\frac{m}{s^2}*(1.2-\frac{1.2}{2})} = 9.46\frac{m^3}{s} \quad (Equation\ -\ 34)$$

# Appendix D: Pavement Design

The roadway chosen for the T.T.E project was a non-reinforced concrete pavement. In order to determine the thickness of the base and road surface, structural design and fatigue calculations were made.

The fatigue calculation was done using equation 6.1 from Concrete Pavement Design, Construction, and Performance, Norbert Delatte, Taylor and Francis:

$$SR = \frac{\sigma_t}{MOR} \qquad (Equation - 1)$$

$\sigma_t = load\ induced\ tensile\ stress\ in\ concrete$
$MOR = modulus\ of\ rupture\ or\ flexural\ strength\ of\ the\ concrete$

The pavement and the base for the Radial 16 would be similar to that of Radial 16 ½. The values used for the structural calculations where extracted from the Radial 16 ½ project. Therefore the adopted layer for the road is:

- 12 cm base granular layer with a minimum CBR of 60%
- 18 cm of rigid concrete pavement with no reinforcement
- The 28th day characteristic strength of concrete ($f'_c$) used for the concrete pavement is 230 kg/cm$^2$ (3271psi).

The values were extracted from Radial 16 ½ (5th Anillo –Av San Marten) provided by the Director of Works for the city of Santa Cruz.

The adopted weight for design for this project is 11000 kg/axle. A factor of safety of 1.2 would be used to account for any loads exceeding the design load.

The calculated load P, = 1.2*11tons = 13.2tons

The Resources used for performing the structural design and fatigue calculations are:

- Concrete Pavement Design, Construction and Performance, Norbert Delatte, Taylor & Francis
- Proyecto Radial 16 ½ (5th Anillo av. San Marten
- Traffic & Highway Engineering, Garber Hoel, 2nd Edition, PWS publishing

# Appendix E:
# Cost Estimate

# OPEN CANAL + GRAVEL ROAD

| CODE | ACTIVITY | QUANTITY | UNITS | COST | MATERIALS | | DIRECT LABOR | | EQUIPMENT | | TOTAL COST (Bs.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | UNIT | COST | UNIT | COST | UNIT | COST | |
| **MOBILIZATION AND SITE LAYOUT** | | | | | | | | | | | |
| **DRE001** | **MOBILIZATION (DRAINAGE)** | 1 | GBL | 4412.32 | | | | | | | 30,886 |
| INS001 | MOBILIZATION | 1 | GBL | | GBL | 3150 | | | | | |
| AL350 | MASON | 11 | HR | | | | HR | 8.2 | | | |
| AL355 | MASON HELPER | 25 | HR | | | | HR | 6.5 | | | |
| **PA0041** | **MOBILIZATION (Pavement)** | 1 | GBL | 4287.98 | | | | | | | 30,016 |
| MT001 | EXTRA MATERIALS | 1 | GBL | | GBL | 3000 | | | | | |
| AL351 | MASON | 15 | | | | | HR | 8.2 | | | |
| AL355 | MASON HELPER | 25 | | | | | HR | 6.5 | | | |
| **DRE002** | **SITE LAYOUT (SEWERS, CANALS, BRIDGES)** | 1024 | m | 15.18 | | | | | | | 15,542 |
| MA019 | WOOD STAKES 2"X2"X30cm | 124 | PZA | | PZA | 3 | | | | | |
| PT002 | PAINTING LATEX | 3 | GAL | | GAL | 72 | | | | | |
| HI001 | INDENTED IRON | 2.5 | KG | | KG | 12.72 | | | | | |
| **AL365** | TOPOGRAPHER | 10 | HR | | | | HR | 12 | | | |
| AL366 | RODMAN | 30 | HR | | | | HR | 6 | | | |
| MQ002 | SURVEY EQUIPMENT | 12 | HR | | | | | | HR | 40 | |
| | CHAIN SAW | 12 | HR | | | | | | HR | 35 | |
| **PA005** | **SITE LAYOUT (PAVEMENT)** | 1.024 | KM | 1821.05 | | | | | | | 12,747 |
| MA019 | WOOD WEDGES | 165 | PZA | | | | PZA | 60 | | | |
| PT007 | ALKYD BASE PAINT | 0.4 | L | | | | LITRES | 30.5 | | | |
| HI001 | NAILS | 1 | KG | | | | KG | 12.72 | | | |
| AL365 | TOPOGRAPHER | 10 | HR | | | | HR | 12 | | | |
| AL366 | RODMAN | 30 | HR | | | | HR | 6 | | | |
| MQ022 | SURVEY EQUIPMENT | 12 | HR | | | | HR | 60 | | | |
| **PA0071**** | **REMOVE & CLEAR RUBBLE** | | | | | | | | | | 5,415 |
| (AL381) | Dozer Operator | 10 | HR | | | | HR | 10 | | | |
| (MQ003) | Dozer | 10 | HR | | | | | | HR | 400 | |
| AL355 | ASSISTANT | 10 | HR | | | | HR | 6.5 | | | |

## PAVEMENT & SITE CURB

| CODE | ACTIVITY | QUANTITY | UNITS | COST | MATERIALS UNIT | MATERIALS COST | DIRECT LABOR UNIT | DIRECT LABOR COST | EQUIPMENT UNIT | EQUIPMENT COST | TOTAL COST (Bs.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **EXC002** | **EARTH WORK** | 11612 | m^3 | | | | | | | | 159,092 |
| AL355 | MASON ASSISTANT | 120 | HR | | HR | 6.5 | | | | | |
| AL361 | EXCAVATOR OPERATOR | 120 | HR | | HR | 6 | | | | | |
| MQ007 | EXCAVATOR | 120 | HR | | | | | | HR | 200 | |
| MQ009 | DUMP TRUCK | 120 | HR | | | | | | HR | 200 | |
| **ECX006** | **LEVEL AND COMPACT EXISTING GROUND** | 3484 | m^3 | | | | | | | | 100,261 |
| AL 360 | SOIL COMPACTOR OPERATOR | 40 | HR | | | | 2.10HR | 6 | | | |
| HO 902 | PLATE COMPACTOR | 40 | HR | | | | | | 0.1500HR | 25 | |
| **PA029** | **PROVIDE AND PLACE CRUSHED BASE (15 cm)** | 2283.75 | m^3 | 62.29 | | | | | | | 142,266 |
| AG015 | CAPA BASE | | m^3 | | 0.18HR | 230 | | | | | |
| AL385 | OPERATOR | | HR | | | | 0.03HR | 8.5 | | | |
| AL362 | ASSISTANT | | HR | | | | 0.02HR | 6.5 | | | |
| MQ001 | BULLDOZER 120G | | HR | | | | | | 0.0081HR | 284 | |
| MQ028 | VIBRATORY CONTRACTOR | | HR | | | | | | 0.0018HR | 284 | |
| MQ027 | PNEUMATIC COMPACTOR | | HR | | | | | | 0.0018HR | 284 | |
| MQ004 | WATER BEARER "AGUATERO" | | HR | | | | | | 0.0018HR | 130 | |
| **PA016** | **CUT, DEM. AND REMOVE CONC. PAVEMENT** | 198 | m^2 | 72 | | | | | | | 14,256 |
| AL385 | OPERATOR | | HR | | 0.400HR | 8.2 | | | | | |
| AL350 | LABORER | | HR | | 0.700HR | 6.5 | | | | | |
| AL355 | ASSISTANT | | HR | | 0.500HR | 8.5 | | | | | |
| MQ019 | PAVEMENT SAW | | HR | | | | | | 0.1800HR | 50 | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.1200HR | 200 | |
| MQ002 | FRONT ENTLOADER | | HR | | | | | | 0.2000HR | 310 | |
| PA047 | GENERAL CLEANING | 15360 | m^2 | 1.06 | | | | | | | 16,234 |
| AL355 | ASSISTANT | | HR | | 0.090HR | 6.5 | | | | | |

## CANAL

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **PA042** | **EX. W/ MACHINERY + TRANSPORTATION** | **7652.04** | **m^3** | **31.94** | | | | | | | **244,406** |
| AL361 | BACKHOE OPERATOR | | HR | | 0.050HR | 6 | | | | | |
| AL355 | ASSISTANT | | HR | | 0.050HR | 6.5 | | | | | |
| AL354 | FOREMAN | | HR | | 0.050HR | 9 | | | | | |
| MQ007 | EXCAVATOR | | HR | | | | | | 0.050HR | 200 | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.0720HR | 200 | |
| **DRE005** | **MANUAL SLOPE SHAPING (SIDE & BOT.)** | **2748** | **m^2** | **5.12** | | | | | | | **14,078** |
| AL350 | LABORER | | HR | | 0.180HR | 8.2 | | | | | |
| AL362 | ASSISTANT | | HR | | 0.190HR | 6.5 | | | | | |
| **DRE006** | **REIN. CONCR. LINING FOR CANAL: 20cm** | **5283.87** | **m^2** | **129.16** | | | | | | | **682,478** |
| AG901 | CEMENT | | KG | | | | 26.00KG | 0.94 | | | |
| AG002 | WASHED DEBRIS | | m^3 | | | | 0.062m^ | 140 | | | |
| AG001 | SAND | | m^3 | | | | 0.050m^ | 60 | | | |
| MA004 | CONSTRUCTION WOOD | | PIE2 | | | | 0.040PIE | 6.5 | | | |
| HI001 | NAIL | | KG | | | | 0.020KG | 12.72 | | | |
| AI004 | ANTISOL | | L | | | | 0.200L | 10.13 | | | |
| HI002 | REINFORCEMENT CORRUGATED REBAR | | KG | | | | 2.530KG | 11.55 | | | |
| HI003 | MOORING WIRE | | KG | | | | 0.080KG | 12.73 | | | |
| AI003 | GEOTEXTILE OP-20 (200 g/m^2) | | m^2 | | | | 0.300m^ | 8 | | | |
| AL363 | OPERATOR OF LIGHT FIELD EQUIPMENT | | HR | | 0.040HR | 6 | | | | | |
| AL350 | LABORER | | HR | | 0.950HR | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | 1.900HR | 6.5 | | | | | |
| HO901 | MIXER OF 350 LTS | | HR | | | | | | 0.040HR | 25 | |
| **DRE015** | **GRAVEL MATERIAL (STABILIZER)** | **1167.36** | **m^3** | **213.36** | | | | | | | **249,765** |
| AG002 | CLEAN GRAVEL | | m^3 | | | | 1.050m^ | 140 | | | |
| AL350 | LABORER | | HR | | 1.000HR | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | 1.200HR | 6.5 | | | | | |
| DRE020 | DRAINAGE PIPES FOR CANAL PVC 2" | 1024 | PZA | 2.52 | | | | | | | 2,578 |
| HI003 | REBAR TIE WIRE | | KG | | | | 0.200KG | | | | |
| HS138 | PVC PIPE | | m | | | | 0.0800m | | | | |
| AL350 | LABORER | | HR | | 0.0300HR | | | | | | |
| AL355 | ASSISTANT | | HR | | 0.0300HR | | | | | | |
| | **DEL. & PLAC. OF REIN. CONC. CULVERTS (4X3.70X2.30)** | **2** | **PZA** | **304631.3** | | | | | | | **609,263** |
| DRE002 | REPLANTEO DE CANALS PUENTES | 9.95 | ML | | | | | | | | |
| DRE003 | EXCAVATION WITH MACHINERY S/N.F | 59.69 | M^3 | | | | | | | | |
| DRE004 | EXCAVATION WITH MACHINERY B/N.F | 39.79 | M^3 | | | | | | | | |
| HOR0301 | CONCRETE STRENGTH = 110 kg/c2 | 93.15 | M^2 | | | | | | | | |
| HOR0355 | HoAo of Sewer booth fck=210 kg/cm2 | 58.43 | M^3 | | | | | | | | |
| HOR0353 | HoAo of Sidewalk and curb fck=210 kg/cm2 | 3.28 | M^3 | | | | | | | | |
| HOR0357 | HoAo compress of sewer fck=210 kg/cm2 | 5.44 | M^3 | | | | | | | | |
| DRE0031 | refill and compact with plate. S/prov of material | 24.05 | M^3 | | | | | | | | |
| HIE018 | Metallic Barandado F°G ° Ø 2 " | 25.9 | M | | | | | | | | |
| HOR0356 | HoAo Flagstone of approach fck=210 kg/cm2 | 4.05 | M^3 | | | | | | | | |
| HOR0358 | HoAo Losa de transicion fck=210 kg/cm2 | 8.33 | M^3 | | | | | | | | |
| **BRIDGES** | | | | | | | | | | | |
| | **PEDESTRIAN BRIDGE (L=11.8M) - By School** | **1** | **PZA** | **19,797** | | | | | | | **19,797** |
| DRE002 | REPLANTEO DE CANALS PUENTES | 11.8 | | | | | | | | | |
| DRE003 | EXCAVATION WITH MACHINERY S/N.F | 2.94 | M^3 | | | | | | | | |
| HOR0301 | refill and compact with plate. S/prov of material | 1.38 | | | | | | | | | |
| HOR001 | Zapatas de HoAo | 0.56 | M^3 | | | | | | | | |
| HOR002 | Concrete: Columns of HoAo | 0.17 | M^3 | | | | | | | | |
| HOR0361 | HoAo of Superstructure fck=210 kg/cm2 | 2.95 | M^3 | | | | | | | | |
| HOR0362 | HoAo of Diaphragm of stretch fck=210 kg/cm2 | 0.11 | M^3 | | | | | | | | |
| HOR0363 | HoAo of Diaphragm of support fck=210 kg/cm2 | 0.19 | M^3 | | | | | | | | |
| HOR0011 | Base of support bridge of HoAo | 0.29 | M^3 | | | | | | | | |
| HIE018 | Metallic Barandado F°G ° Ø 2 " | 23.6 | M^3 | | | | | | | | |
| DRE0031 | refill and compact with plate. S/prov of material | 2.38 | M^3 | | | | | | | | |
| HOR0356 | HoAo Flagstone of approach fck=210 kg/cm2 | 0.54 | M^3 | | | | | | | | |
| | ROADWAY CROSSING | 3 | PZA | 240000 | | | | | | | 720,000.00 |
| **TOTAL** | | | | | | | | | | | **3,069,080** |
| | | | | | | | | | | | **3,069,000** |

# OPEN CANAL + ASPHALT PAVEMENT

| CODE | ACTIVITY | QUANTITY | UNITS | COST | MATERIALS | | DIRECT LABOR | | EQUIPMENT | | TOTAL COST (Bs.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | UNIT | COST | UNIT | COST | UNIT | COST | |
| **MOBILIZATION AND SITE LAYOUT** | | | | | | | | | | | |
| DRE001 | MOBILIZATION (DRAINAGE) | 1 | GBL | 4412.32 | | | | | | | 30,886 |
| INS001 | MOBILIZATION | 1 | GBL | | GBL | 3150 | | | | | |
| AL350 | MASON | 11 | HR | | | | HR | 8.2 | | | |
| AL355 | MASON HELPER | 25 | HR | | | | HR | 6.5 | | | |
| **PA0041** | **MOBILIZATION (Pavement)** | **1** | **GBL** | **4287.98** | | | | | | | **30,016** |
| MT001 | EXTRA MATERIALS | 1 | GBL | | GBL | 3000 | | | | | |
| AL351 | MASON | 15 | | | | | HR | 8.2 | | | |
| AL355 | MASON HELPER | 25 | | | | | HR | 6.5 | | | |
| **DRE002** | **SITE LAYOUT (SEWERS, CANALS, BRIDGES)** | **1024** | **m** | **15.18** | | | | | | | **15,542** |
| MA019 | WOOD STAKES 2"X2"X30cm | 124 | PZA | | PZA | 3 | | | | | |
| PT002 | PAINTING LATEX | 3 | GAL | | GAL | 72 | | | | | |
| HI001 | INDENTED IRON | 2.5 | KG | | KG | 12.72 | | | | | |
| **AL365** | TOPOGRAPHER | 10 | HR | | | | HR | 12 | | | |
| AL366 | RODMAN | 30 | HR | | | | HR | 6 | | | |
| MQ002 | SURVEY EQUIPMENT | 12 | HR | | | | | | HR | 40 | |
| | CHAIN SAW | 12 | HR | | | | | | HR | 35 | |
| **PA005** | **SITE LAYOUT (PAVEMENT)** | **1.024** | **KM** | **1821.05** | | | | | | | **12,747** |
| MA019 | WOOD WEDGES | 165 | PZA | | | | PZA | 60 | | | |
| PT007 | ALKYD BASE PAINT | 0.4 | L | | | | LITRES | 30.5 | | | |
| HI001 | NAILS | 1 | KG | | | | KG | 12.72 | | | |
| AL365 | TOPOGRAPHER | 10 | HR | | | | HR | 12 | | | |
| AL366 | RODMAN | 30 | HR | | | | HR | 6 | | | |
| MQ022 | SURVEY EQUIPMENT | 12 | HR | | | | HR | 60 | | | |
| **PA0071**** | **REMOVE & CLEAR RUBBLE** | | | | | | | | | | **5,415** |
| (AL381) | Dozer Operator | 10 | HR | | | | HR | 10 | | | |
| (MQ003) | Dozer | 10 | HR | | | | | | HR | 400 | |
| AL355 | ASSISTANT | 10 | HR | | | | HR | 6.5 | | | |
| **PAVEMENT & SITE CURB** | | | | | | | | | | | |
| **EXC002** | **EARTH WORK** | **11612** | **m^3** | | | | | | | | **159,092** |
| AL355 | MASON ASSISTANT | 120 | HR | | HR | 6.5 | | | | | |
| AL361 | EXCAVATOR OPERATOR | 120 | HR | | HR | 6 | | | | | |
| MQ007 | EXCAVATOR | 120 | HR | | | | | | HR | 200 | |
| MQ009 | DUMP TRUCK | 120 | HR | | | | | | HR | 200 | |
| **ECX006** | **LEVEL AND COMPACT EXISTING GROUND** | **3484** | **m^3** | | | | | | | | **100,261** |
| AL 360 | SOIL COMPACTOR OPERATOR | 40 | HR | | | | 2.10HR | 6 | | | |
| HO 902 | PLATE COMPACTOR | 40 | HR | | | | | | 0.1500HR | 25 | |
| **PA029** | **PROVIDE AND PLACE CRUSHED BASE (15 cm)** | **1827** | **m^3** | **62.29** | | | | | | | **113,813** |
| AG015 | CAPA BASE | | m^3 | | 0.18HR | 230 | | | | | |
| AL385 | OPERATOR | | HR | | | | 0.03HR | 8.5 | | | |
| AL362 | ASSISTANT | | HR | | | | 0.02HR | 6.5 | | | |
| MQ001 | BULLDOZER 120G | | HR | | | | | | 0.0081HR | 284 | |
| MQ028 | VIBRATORY CONTRACTOR | | HR | | | | | | 0.0018HR | 284 | |
| MQ027 | PNEUMATIC COMPACTOR | | HR | | | | | | 0.0018HR | 284 | |
| MQ004 | WATER BEARER "AGUATERO" | | HR | | | | | | 0.0018HR | 130 | |
| **PA015** | **DELIVERY & PLACEMENT OF ASPHALT CONC.** | **1827** | **m^3** | **2030.75** | | | | | | | **3,710,174** |
| AG026 | CRUSHED SMALL AGGREGATE | | KG | | | | 1.320KG | 175 | | | |
| AG027 | FINE TN 4 | | m^3 | | | | 0.320m^3 | 68 | | | |
| AG912 | ASPHALT CEMENT | | m^3 | | | | 140.00m^3 | 9 | | | |
| AL354 | FOREMAN | | HR | | 0.120HR | 9 | | | | | |
| AL355 | ASSISTANT | | HR | | 0.850HR | 6.5 | | | | | |
| AL385 | OPERATOR | | HR | | 0.420HR | 6 | | | | | |
| MQ029 | ASPHALT PLANT | | HR | | | | | | 0.0560HR | 900 | |
| MQ030 | ASPHALT CEMENT DISTRIBUTOR TANK | | HR | | | | | | 0.0560HR | 300 | |
| MQ031 | GENERATOR | | HR | | | | | | 0.0550HR | 122 | |
| MQ002 | FRONT ENDLOADER | | HR | | | | | | 0.0560HR | 310 | |
| MQ032 | VIBRATORY PILE DRIVING | | HR | | | | | | 0.0350HR | 243 | |
| MQ032 | 5% MO | | HR | | | | | | 0.0350HR | 243 | |
| **PA011** | **DELIVERY & PLACEMENT OF CURB** | **2030** | **m** | **68.52** | | | | | | | **139,096** |
| AG901 | CEMENT | | KG | | | | 0.250KG | 0.9 | | | |
| AG001 | RIVER SAND | | m^3 | | | | 0.006m^3 | 60 | | | |
| AG916 | PREFABRICATED CORD | | m | | | | 1.000m | 42 | | | |
| AL354 | FOREMAN | | HR | | 0.080HR | 9 | | | | | |
| AL350 | LABORER | | HR | | 0.100HR | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | | 6.5 | | | | | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.010HR | 200 | |
| **PA016** | **CUT, DEMOLISH AND REMOVE CONC. PAVEMENT** | **198** | **m^2** | **72** | | | | | | | **14,256** |
| AL385 | OPERATOR | | HR | | 0.400HR | 8.2 | | | | | |
| AL350 | LABORER | | HR | | 0.700HR | 6.5 | | | | | |
| AL355 | ASSISTANT | | HR | | 0.500HR | 8.5 | | | | | |
| MQ019 | PAVEMENT SAW | | HR | | | | | | 0.1800HR | 50 | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.1200HR | 200 | |
| MQ002 | FRONT ENTLOADER | | HR | | | | | | 0.2000HR | 310 | |
| PA047 | GENERAL CLEANING | 1.554E+09 | m^2 | 1.06 | | | | | | | 16,234 |
| AL355 | ASSISTANT | | HR | | 0.090HR | 6.5 | | | | | |

## CANAL

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PA042 | EXCAVATION W/ MACHINERY + TRANSPORTATION | 7652.04 | m^3 | 31.94 | | | | | | | 244,406 |
| AL361 | BACKHOE OPERATOR | | HR | | 0.050HR | 6 | | | | | |
| AL355 | ASSISTANT | | HR | | 0.050HR | 6.5 | | | | | |
| AL354 | FOREMAN | | HR | | 0.050HR | 9 | | | | | |
| MQ007 | EXCAVATOR | | HR | | | | | | 0.050HR | 200 | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.0720HR | 200 | |
| DRE005 | MANUAL SLOPE SHAPING (SIDES & BOTTOM) | 2748 | m^2 | 5.12 | | | | | | | 14,078 |
| AL350 | LABORER | | HR | | 0.180HR | 8.2 | | | | | |
| AL362 | ASSISTANT | | HR | | 0.190HR | 6.5 | | | | | |
| DRE006 | REIN. CONCRETE LINING FOR CANAL: 20cm | 5283.87 | m^2 | 129.16 | | | | | | | 682,478 |
| AG901 | CEMENT | | KG | | | | 26.00KG | 0.94 | | | |
| AG002 | WASHED DEBRIS | | m^3 | | | | 0.062m^3 | 140 | | | |
| AG001 | SAND | | m^3 | | | | 0.050m^3 | 60 | | | |
| MA004 | CONSTRUCTION WOOD | | PIE2 | | | | 0.040PIE2 | 6.5 | | | |
| HI001 | NAIL | | KG | | | | 0.020KG | 12.72 | | | |
| AI004 | ANTISOL | | L | | | | 0.200L | 10.13 | | | |
| HI002 | REINFORCEMENT CORRUGATED REBAR | | KG | | | | 2.530KG | 11.55 | | | |
| HI003 | MOORING WIRE | | KG | | | | 0.080KG | 12.73 | | | |
| AI003 | GEOTEXTILE OP-20 (200 g/m^2) | | m^2 | | | | 0.300m^2 | 8 | | | |
| AL363 | OPERATOR OF LIGHT FIELD EQUIPMENT | | HR | | 0.040HR | 6 | | | | | |
| AL350 | LABORER | | HR | | 0.950HR | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | 1.900HR | 6.5 | | | | | |
| HO901 | MIXER OF 350 LTS | | HR | | | | | | 0.040HR | 25 | |
| DRE015 | GRAVEL MATERIAL (STABILIZER) | 1167.36 | m^3 | 213.36 | | | | | | | 249,765 |
| AG002 | CLEAN GRAVEL | | m^3 | | | | 1.050m^3 | 140 | | | |
| AL350 | LABORER | | HR | | 1.000HR | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | 1.200HR | 6.5 | | | | | |
| DRE020 | DRAINAGE PIPES FOR CANAL PVC 2" | 1024 | PZA | 2.52 | | | | | | | 2,578 |
| HI003 | REBAR TIE WIRE | | KG | | | | 0.200KG | | | | |
| HS138 | PVC PIPE | | m | | | | 0.0800m | | | | |
| AL350 | LABORER | | HR | | 0.0300HR | | | | | | |
| AL355 | ASSISTANT | | HR | | 0.0300HR | | | | | | |
| | DELIVERY & PLAC. OF REIN. CONC. BOX CULVERTS (4X3.70X2.30) | 2 | PZA | 304631.3 | | | | | | | 609,263 |
| DRE002 | REPLANTEO DE CANALS PUENTES | 9.95 | ML | | | | | | | | |
| DRE003 | EXCAVATION WITH MACHINERY S/N.F | 59.69 | M^3 | | | | | | | | |
| DRE004 | EXCAVATION WITH MACHINERY B/N.F | 39.79 | M^3 | | | | | | | | |
| HOR0301 | CONCRETE STRENGTH = 110 kg/c2 | 93.15 | M^2 | | | | | | | | |
| HOR0355 | HoAo of Sewer booth fck=210 kg/cm2 | 58.43 | M^3 | | | | | | | | |
| HOR0353 | HoAo of Sidewalk and curb fck=210 kg/cm2 | 3.28 | M^3 | | | | | | | | |
| HOR0357 | HoAo compress of sewer fck=210 kg/cm2 | 5.44 | M^3 | | | | | | | | |
| DRE0031 | refill and compact with plate. S/prov of material | 24.05 | M^3 | | | | | | | | |
| HIE018 | Metallic Barandado F°G ° Ø 2 " | 25.9 | M | | | | | | | | |
| HOR0356 | HoAo Flagstone of approach fck=210 kg/cm2 | 4.05 | M^3 | | | | | | | | |
| HOR0358 | HoAo Losa de transicion fck=210 kg/cm2 | 8.33 | M^3 | | | | | | | | |

## BRIDGES

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | PEDESTRIAN BRIDGE (L=11.8M) - By School | 1 | PZA | 19,797 | | | | | | | 19,797 |
| DRE002 | REPLANTEO DE CANALS PUENTES | 11.8 | | | | | | | | | |
| DRE003 | EXCAVATION WITH MACHINERY S/N.F | 2.94 | M^3 | | | | | | | | |
| HOR0301 | refill and compact with plate. S/prov of material | 1.38 | | | | | | | | | |
| HOR001 | Zapatas de HoAo | 0.56 | M^3 | | | | | | | | |
| HOR002 | Concrete: Columns of HoAo | 0.17 | M^3 | | | | | | | | |
| HOR0361 | HoAo of Superstructure fck=210 kg/cm2 | 2.95 | M^3 | | | | | | | | |
| HOR0362 | HoAo of Diaphragm of stretch fck=210 kg/cm2 | 0.11 | M^3 | | | | | | | | |
| HOR0363 | HoAo of Diaphragm of support fck=210 kg/cm2 | 0.19 | M^3 | | | | | | | | |
| HOR0011 | Base of support bridge of HoAo | 0.29 | M^3 | | | | | | | | |
| HIE018 | Metallic Barandado F°G ° Ø 2 " | 23.6 | M^3 | | | | | | | | |
| DRE0031 | refill and compact with plate. S/prov of material | 2.38 | M^3 | | | | | | | | |
| HOR0356 | HoAo Flagstone of approach fck=210 kg/cm2 | 0.54 | M^3 | | | | | | | | |
| | ROADWAY CROSSING | 3 | PZA | 240000 | | | | | | | 720,000.00 |
| **TOTAL** | | | | | | | | | | | **6,889,897** |
| | | | | | | | | | | | **6,890,000** |

# OPEN CANAL + NON-REINFORCED CONC. PAVEMENT

| CODE | ACTIVITY | Amount | UNITS | COST | MATERIALS | | DIRECT LABOR | | EQUIPMENT | | TOTAL COST (Bs.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | UNIT | COST | UNIT | COST | UNIT | COST | |
| **MOBILIZATION AND SITE LAYOUT** | | | | | | | | | | | |
| **DRE001** | **MOBILIZATION (DRAINAGE)** | **1** | **GBL** | **4412.32** | | | | | | | **30,886** |
| INS001 | MOBILIZATION | 1 | GBL | | GBL | 3150 | | | | | |
| AL350 | MASON | 11 | HR | | | | HR | 8.2 | | | |
| AL355 | MASON HELPER | 25 | HR | | | | HR | 6.5 | | | |
| **PA0041** | **MOBILIZATION (Pavement)** | **1** | **GBL** | **4287.98** | | | | | | | **30,016** |
| MT001 | EXTRA MATERIALS | 1 | GBL | | GBL | 3000 | | | | | |
| AL351 | MASON | 15 | | | | | HR | 8.2 | | | |
| AL355 | MASON HELPER | 25 | | | | | HR | 6.5 | | | |
| **DRE002** | **SITE LAYOUT (SEWERS, CANALS, BRIDGES)** | **1024** | **m** | **15.18** | | | | | | | **15,542** |
| MA019 | WOOD STAKES 2"X2"X30cm | 124 | PZA | | PZA | 3 | | | | | |
| PT002 | PAINTING LATEX | 3 | GAL | | GAL | 72 | | | | | |
| HI001 | INDENTED IRON | 2.5 | KG | | KG | 12.72 | | | | | |
| **AL365** | TOPOGRAPHER | 10 | HR | | | | HR | 12 | | | |
| AL366 | RODMAN | 30 | HR | | | | HR | 6 | | | |
| MQ002 | SURVEY EQUIPMENT | 12 | HR | | | | | | HR | 40 | |
| | CHAIN SAW | 12 | HR | | | | | | HR | 35 | |
| **PA005** | **SITE LAYOUT (PAVEMENT)** | **1.024** | **KM** | **1821.05** | | | | | | | **12,747** |
| MA019 | WOOD WEDGES | 165 | PZA | | | | PZA | 60 | | | |
| PT007 | ALKYD BASE PAINT | 0.4 | L | | | | LITRE | 30.5 | | | |
| HI001 | NAILS | 1 | KG | | | | KG | 12.72 | | | |
| AL365 | TOPOGRAPHER | 10 | HR | | | | HR | 12 | | | |
| AL366 | RODMAN | 30 | HR | | | | HR | 6 | | | |
| MQ022 | SURVEY EQUIPMENT | 12 | HR | | | | HR | 60 | | | |
| **PA0071**** | **REMOVE & CLEAR RUBBLE** | | | | | | | | | | **5,415** |
| (AL381) | Dozer Operator | 10 | HR | | | | HR | 10 | | | |
| (MQ003) | Dozer | 10 | HR | | | | | | HR | 400 | |
| AL355 | ASSISTANT | 10 | HR | | | | HR | 6.5 | | | |
| **PAVEMENT & SITE CURB** | | | | | | | | | | | |
| **EXC002** | **EARTH WORK** | **11612** | **m^3** | | | | | | | | **159,092** |
| AL355 | MASON ASSISTANT | 120 | HR | | HR | 6.5 | | | | | |
| AL361 | EXCAVATOR OPERATOR | 120 | HR | | HR | 6 | | | | | |
| MQ007 | EXCAVATOR | 120 | HR | | | | | | HR | 200 | |
| MQ009 | DUMP TRUCK | 120 | HR | | | | | | HR | 200 | |
| **ECX006** | **LEVEL AND COMPACT EXISTING GROUND** | **3484** | **m^3** | | | | | | | | **100,261** |
| AL 360 | SOIL COMPACTOR OPERATOR | 40 | HR | | | | 2.10H | 6 | | | |
| HO 902 | PLATE COMPACTOR | 40 | HR | | | | | | 0.1500HR | 25 | |
| **PA029** | **PROVIDE AND PLACE CRUSHED BASE (15 cm)** | | | | | | | | | | **113,813** |
| AG015 | CAPA BASE | | m^3 | | 0.18H | 230 | | | | | |
| AL385 | OPERATOR | | HR | | | | 0.03H | 8.5 | | | |
| AL362 | ASSISTANT | | HR | | | | 0.02H | 6.5 | | | |
| MQ001 | BULLDOZER 120G | | HR | | | | | | 0.0081HR | 284 | |
| MQ028 | VIBRATORY CONTRACTOR | | HR | | | | | | 0.0018HR | 284 | |
| MQ027 | PNEUMATIC COMPACTOR | | HR | | | | | | 0.0018HR | 284 | |
| MQ004 | WATER BEARER "AGUATERO" | | HR | | | | | | 0.0018HR | 130 | |
| **PA039** | **CONCRETE SLAB PAVEMENT (18cm)** | **15225** | **m^2** | **141.68** | | | | | | | **2,157,188** |
| AG 901 | CEMENT | | KG | | | | 55KG | 0.94 | | | |
| AG001 | RIVER SAND | | m^3 | | | | 0.090 | 60 | | | |
| AG002 | CLEAN GRAVEL | | m^3 | | | | 0.120 | 140 | | | |
| FP001 | PLASTIC FIBER | | KG | | | | 0.160 | 8.1 | | | |
| AL004 | ANTISOL | | L | | | | 0.120 | 10.13 | | | |
| AL001 | TAR | | KG | | | | 0.150 | 8.5 | | | |
| AG007 | WATER | | L | | | | 25L | 0.095 | | | |
| AL354 | FOREMAN | | HR | | 0.10H | 9 | | | | | |
| AL350 | LABORER | | HR | | 0.20H | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | 0.38H | 6.5 | | | | | |
| AL364 | DRIVER | | HR | | 0.19H | 6 | | | | | |
| MQ024 | CONCRETE BATCH PLANT | | HR | | | | | | 0.0060HR | 324 | |
| MQ025 | VIBRATOR | | HR | | | | | | 0.0100HR | 40.5 | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.0150HR | 200 | |
| **PA011** | **DELIVERY & PLACEMENT OF CURB** | **2030** | **m** | **68.52** | | | | | | | **139,096** |
| AG901 | CEMENT | | KG | | | | 0.250 | 0.9 | | | |
| AG001 | RIVER SAND | | m^3 | | | | 0.006 | 60 | | | |
| AG916 | PREFABRICATED CORD | | m | | | | 1.000 | 42 | | | |
| AL354 | FOREMAN | | HR | | 0.080 | 9 | | | | | |
| AL350 | LABORER | | HR | | 0.100 | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | | 6.5 | | | | | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.010HR | 200 | |
| | | | | | | | | | | | |
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|---|---|---|---|---|---|---|---|---|---|---|---|
| PA016 | CUT, DEMOLISH AND REMOVE CONCR. PAVEMENT | 198 | m^2 | 72 | | | | | | | 14,256 |
| AL385 | OPERATOR | | HR | | 0.400H | 8.2 | | | | | |
| AL350 | LABORER | | HR | | 0.700H | 6.5 | | | | | |
| AL355 | ASSISTANT | | HR | | 0.500H | 8.5 | | | | | |
| MQ019 | PAVEMENT SAW | | HR | | | | | | 0.1800HR | 50 | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.1200HR | 200 | |
| MQ002 | FRONT ENTLOADER | | HR | | | | | | 0.2000HR | 310 | |
| PA047 | GENERAL CLEANING | 15360 | m^2 | 1.06 | | | | | | | 16,234 |
| AL355 | ASSISTANT | | HR | | 0.090H | 6.5 | | | | | |
| CANAL | | | | | | | | | | | |
| PA042 | EXCA. W/ MACHINERY + TRANSPORTATION | 7652.04 | m^3 | 31.94 | | | | | | | 244,406 |
| AL361 | BACKHOE OPERATOR | | HR | | 0.050H | 6 | | | | | |
| AL355 | ASSISTANT | | HR | | 0.050H | 6.5 | | | | | |
| AL354 | FOREMAN | | HR | | 0.050H | 9 | | | | | |
| MQ007 | EXCAVATOR | | HR | | | | | | 0.050HR | 200 | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.0720HR | 200 | |
| DRE005 | MANUAL SLOPE SHAPING (SIDES & BOTTOM) | 2748 | m^2 | 5.12 | | | | | | | 14,078 |
| AL350 | LABORER | | HR | | 0.180H | 8.2 | | | | | |
| AL362 | ASSISTANT | | HR | | 0.190H | 6.5 | | | | | |
| DRE006 | REIN. CONCRETE LINING FOR CANAL: 20cm | 6639 | m^2 | 129.16 | | | | | | | 857,495 |
| AG901 | CEMENT | | KG | | | | 26.00I | 0.94 | | | |
| AG002 | WASHED DEBRIS | | m^3 | | | | 0.062I | 140 | | | |
| AG001 | SAND | | m^3 | | | | 0.050I | 60 | | | |
| MA004 | CONSTRUCTION WOOD | | PIE2 | | | | 0.040I | 6.5 | | | |
| HI001 | NAIL | | KG | | | | 0.020I | 12.72 | | | |
| AI004 | ANTISOL | | L | | | | 0.200I | 10.13 | | | |
| HI002 | REINFORCEMENT CORRUGATED REBAR | | KG | | | | 2.530I | 11.55 | | | |
| HI003 | MOORING WIRE | | KG | | | | 0.080I | 12.73 | | | |
| AI003 | GEOTEXTILE OP-20 (200 g/m^2) | | m^2 | | | | 0.300I | 8 | | | |
| AL363 | OPERATOR OF LIGHT FIELD EQUIPMENT | | HR | | 0.040H | 6 | | | | | |
| AL350 | LABORER | | HR | | 0.950H | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | 1.900H | 6.5 | | | | | |
| HO901 | MIXER OF 350 LTS | | HR | | | | | | 0.040HR | 25 | |
| DRE015 | GRAVEL MATERIAL (STABILIZER) | 1167.36 | m^3 | 213.36 | | | | | | | 249,765 |
| AG002 | CLEAN GRAVEL | | m^3 | | | | 1.050I | 140 | | | |
| AL350 | LABORER | | HR | | 1.000H | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | 1.200H | 6.5 | | | | | |
| DRE020 | DRAINAGE PIPES FOR CANAL PVC 2" | 1024 | PZA | 2.52 | | | | | | | 2,578 |
| HI003 | REBAR TIE WIRE | | KG | | | | 0.200KG | | | | |
| HS138 | PVC PIPE | | m | | | | 0.0800m | | | | |
| AL350 | LABORER | | HR | | 0.0300HR | | | | | | |
| AL355 | ASSISTANT | | HR | | 0.0300HR | | | | | | |
| | DEL. & PLAC. REIN. CONC. CULVERTS (4X3.70X2.30) | 2 | PZA | 304631.33 | | | | | | | 609,263 |
| DRE002 | REPLANTEO DE CANALS PUENTES | 9.95 | ML | | | | | | | | |
| DRE003 | EXCAVATION WITH MACHINERY S/N.F | 59.69 | M^3 | | | | | | | | |
| DRE004 | EXCAVATION WITH MACHINERY B/N.F | 39.79 | M^3 | | | | | | | | |
| HOR0301 | CONCRETE STRENGTH = 110 kg/c2 | 93.15 | M^2 | | | | | | | | |
| HOR0355 | HoAo of Sewer booth fck=210 kg/cm2 | 58.43 | M^3 | | | | | | | | |
| HOR0353 | HoAo of Sidewalk and curb fck=210 kg/cm2 | 3.28 | M^3 | | | | | | | | |
| HOR0357 | HoAo compress of sewer fck=210 kg/cm2 | 5.44 | M^3 | | | | | | | | |
| DRE0031 | refill and compact with plate. S/prov of material | 24.05 | M^3 | | | | | | | | |
| HIE018 | Metallic Barandado F°G ° Ø 2 " | 25.9 | M | | | | | | | | |
| HOR0356 | HoAo Flagstone of approach fck=210 kg/cm2 | 4.05 | M^3 | | | | | | | | |
| HOR0358 | HoAo Losa de transicion fck=210 kg/cm2 | 8.33 | M^3 | | | | | | | | |
| BRIDGES | | | | | | | | | | | |
| | PEDESTRIAN BRIDGE (L=11.8M) - By School | 1 | PZA | 19,797 | | | | | | | 19,797 |
| DRE002 | REPLANTEO DE CANALS PUENTES | 11.8 | | | | | | | | | |
| DRE003 | EXCAVATION WITH MACHINERY S/N.F | 2.94 | M^3 | | | | | | | | |
| HOR0301 | refill and compact with plate. S/prov of material | 1.38 | | | | | | | | | |
| HOR001 | Zapatas de HoAo | 0.56 | M^3 | | | | | | | | |
| HOR002 | Concrete: Columns of HoAo | 0.17 | M^3 | | | | | | | | |
| HOR0361 | HoAo of Superstructure fck=210 kg/cm2 | 2.95 | M^3 | | | | | | | | |
| HOR0362 | HoAo of Diaphragm of stretch fck=210 kg/cm2 | 0.11 | M^3 | | | | | | | | |
| HOR0363 | HoAo of Diaphragm of support fck=210 kg/cm2 | 0.19 | M^3 | | | | | | | | |
| HOR0011 | Base of support bridge of HoAo | 0.29 | M^3 | | | | | | | | |
| HIE018 | Metallic Barandado F°G ° Ø 2 " | 23.6 | M^3 | | | | | | | | |
| DRE0031 | refill and compact with plate. S/prov of material | 2.38 | M^3 | | | | | | | | |
| HOR0356 | HoAo Flagstone of approach fck=210 kg/cm2 | 0.54 | M^3 | | | | | | | | |
| | ROADWAY CROSSING | 3 | PZA | 240000 | | | | | | | 720,000.00 |
| TOTAL | | | | | | | | | | | 5,511,928 |
| | | | | | | | | | | | 5,512,000 |

# PARTIAL-COVERED CANAL + NON-REINFORCED CONCRETE PAVEMENT

| CODE | ACTIVITY | QUANTITY | UNITS | COST | MATERIALS | | DIRECT LABOR | | EQUIPMENT | | TOTAL COST (Bs.) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | UNIT | COST | UNIT | COST | UNIT | COST | |
| **MOBILIZATION AND SITE LAYOUT** | | | | | | | | | | | |
| **DRE001** | **MOBILIZATION (DRAINAGE)** | **1** | **GBL** | **4412.32** | | | | | | | **30,886** |
| INS001 | MOBILIZATION | 1 | GBL | | GBL | 3150 | | | | | |
| AL350 | MASON | 11 | HR | | | | HR | 8.2 | | | |
| AL355 | MASON HELPER | 25 | HR | | | | HR | 6.5 | | | |
| **PA0041** | **MOBILIZATION (Pavement)** | **1** | **GBL** | **4287.98** | | | | | | | **30,016** |
| MT001 | EXTRA MATERIALS | 1 | GBL | | GBL | 3000 | | | | | |
| AL351 | MASON | 15 | | | | | HR | 8.2 | | | |
| AL355 | MASON HELPER | 25 | | | | | HR | 6.5 | | | |
| **DRE002** | **SITE LAYOUT (SEWERS, CANALS, BRIDGES)** | **1024** | **m** | **15.18** | | | | | | | **15,542** |
| MA019 | WOOD STAKES 2"X2"X30cm | 124 | PZA | | PZA | 3 | | | | | |
| PT002 | PAINTING LATEX | 3 | GAL | | GAL | 72 | | | | | |
| HI001 | INDENTED IRON | 2.5 | KG | | KG | 12.72 | | | | | |
| **AL365** | TOPOGRAPHER | 10 | HR | | | | HR | 12 | | | |
| AL366 | RODMAN | 30 | HR | | | | HR | 6 | | | |
| MQ002 | SURVEY EQUIPMENT | 12 | HR | | | | | | HR | 40 | |
| | CHAIN SAW | 12 | HR | | | | | | HR | 35 | |
| **PA005** | **SITE LAYOUT (PAVEMENT)** | **1.024** | **KM** | **1821.05** | | | | | | | **12,747** |
| MA019 | WOOD WEDGES | 165 | PZA | | | | PZA | 60 | | | |
| PT007 | ALKYD BASE PAINT | 0.4 | L | | | | LITRES | 30.5 | | | |
| HI001 | NAILS | 1 | KG | | | | KG | 12.72 | | | |
| AL365 | TOPOGRAPHER | 10 | HR | | | | HR | 12 | | | |
| AL366 | RODMAN | 30 | HR | | | | HR | 6 | | | |
| MQ022 | SURVEY EQUIPMENT | 12 | HR | | | | HR | 60 | | | |
| **PA0071**** | **REMOVE & CLEAR RUBBLE** | | | | | | | | | | **5,415** |
| (AL381) | Dozer Operator | 10 | HR | | | | HR | 10 | | | |
| (MQ003) | Dozer | 10 | HR | | | | | | HR | 400 | |
| AL355 | ASSISTANT | 10 | HR | | | | HR | 6.5 | | | |
| **PAVEMENT & SITE CURB** | | | | | | | | | | | |
| **EXC002** | **EARTH WORK** | **11612** | **m^3** | | | | | | | | **159,092** |
| AL355 | MASON ASSISTANT | 120 | HR | | HR | 6.5 | | | | | |
| AL361 | EXCAVATOR OPERATOR | 120 | HR | | HR | 6 | | | | | |
| MQ007 | EXCAVATOR | 120 | HR | | | | | | HR | 200 | |
| MQ009 | DUMP TRUCK | 120 | HR | | | | | | HR | 200 | |
| **ECX006** | **LEVEL AND COMPACT EXISTING GROUND** | **3484** | **m^3** | | | | | | | | **100,261** |
| AL 360 | SOIL COMPACTOR OPERATOR | 40 | HR | | | | 2.10HR | 6 | | | |
| HO 902 | PLATE COMPACTOR | 40 | HR | | | | | | 0.150 | 25 | |
| **PA029** | **PROV. AND PLAC CRUSHED BASE (15 cm)** | | | | | | | | | | **113,813** |
| AG015 | CAPA BASE | | m^3 | | 0.18HR | 230 | | | | | |
| AL385 | OPERATOR | | HR | | | | 0.03HR | 8.5 | | | |
| AL362 | ASSISTANT | | HR | | | | 0.02HR | 6.5 | | | |
| MQ001 | BULLDOZER 120G | | HR | | | | | | 0.0081 | 284 | |
| MQ028 | VIBRATORY CONTRACTOR | | HR | | | | | | 0.0018 | 284 | |
| MQ027 | PNEUMATIC COMPACTOR | | HR | | | | | | 0.0018 | 284 | |
| MQ004 | WATER BEARER "AGUATERO" | | HR | | | | | | 0.0018 | 130 | |
| **PA039** | **CONCRETE SLAB PAVEMENT (18cm)** | **15225** | **m^2** | **141.68** | | | | | | | **2,157,188** |
| AG 901 | CEMENT | | KG | | | | 55KG | 0.94 | | | |
| AG001 | RIVER SAND | | m^3 | | | | 0.090m | 60 | | | |
| AG002 | CLEAN GRAVEL | | m^3 | | | | 0.120m | 140 | | | |
| FP001 | PLASTIC FIBER | | KG | | | | 0.160KG | 8.1 | | | |
| AL001 | TAR | | KG | | | | 0.150KG | 8.5 | | | |
| AG007 | WATER | | L | | | | 25L | 0.095 | | | |
| AL354 | FOREMAN | | HR | | 0.10HR | 9 | | | | | |
| AL350 | LABORER | | HR | | 0.20HR | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | 0.38HR | 6.5 | | | | | |
| AL364 | DRIVER | | HR | | 0.19HR | 6 | | | | | |
| MQ024 | CONCRETE BATCH PLANT | | HR | | | | | | 0.006 | 324 | |
| MQ025 | VIBRATOR | | HR | | | | | | 0.010 | 40.5 | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.015 | 200 | |
| **PA011** | **DELIVERY & PLACEMENT OF CURB** | **2030** | **m** | **68.52** | | | | | | | **139,096** |
| AG901 | CEMENT | | KG | | | | 0.250KG | 0.9 | | | |
| AG001 | RIVER SAND | | m^3 | | | | 0.006m | 60 | | | |
| AG916 | PREFABRICATED CORD | | m | | | | 1.000m | 42 | | | |
| AL354 | FOREMAN | | HR | | 0.080HR | 9 | | | | | |
| AL350 | LABORER | | HR | | 0.100HR | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | | 6.5 | | | | | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.010H | 200 | |
| **PA016** | **CUT, DEMO. AND REMOVE CONC. PAVEMENT** | **198** | **m^2** | **72** | | | | | | | **14,256** |
| AL385 | OPERATOR | | HR | | 0.400HR | 8.2 | | | | | |
| AL350 | LABORER | | HR | | 0.700HR | 6.5 | | | | | |
| AL355 | ASSISTANT | | HR | | 0.500HR | 8.5 | | | | | |
| MQ019 | PAVEMENT SAW | | HR | | | | | | 0.180 | 50 | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.120 | 200 | |
| MQ002 | FRONT ENTLOADER | | HR | | | | | | 0.200 | 310 | |
| PA047 | GENERAL CLEANING | 15360 | m^2 | 1.06 | | | | | | | **16,234** |
| AL355 | ASSISTANT | | HR | | 0.090HR | 6.5 | | | | | |

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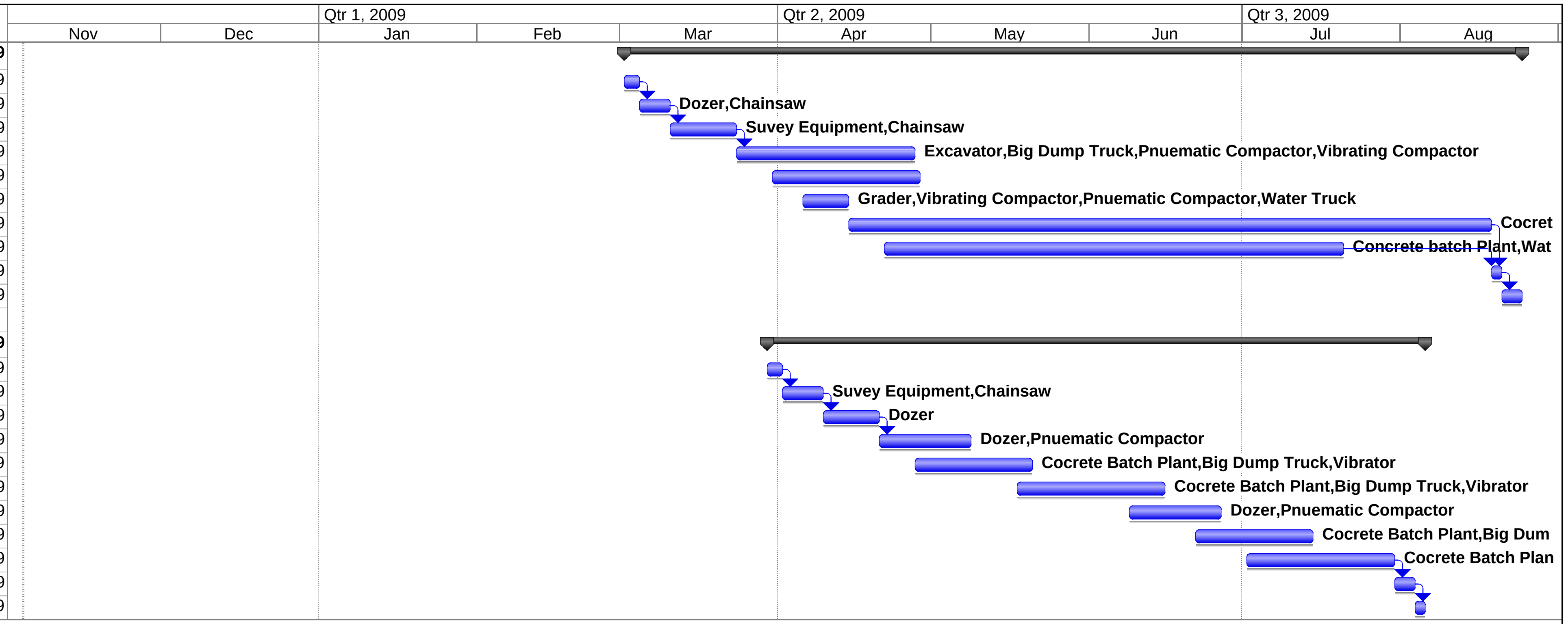
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **CANAL** | | | | | | |
| **PA042** | **EX. W/ MACHINERY + TRANSPORTATION** | **7652.04** | **m^3** | **31.94** | | | | | | | **244,406** |
| AL361 | BACKHOE OPERATOR | | HR | | 0.050HR | 6 | | | | | |
| AL355 | ASSISTANT | | HR | | 0.050HR | 6.5 | | | | | |
| AL354 | FOREMAN | | HR | | 0.050HR | 9 | | | | | |
| MQ007 | EXCAVATOR | | HR | | | | | | 0.050H | 200 | |
| MQ009 | BIGGER DUMP TRUCK | | HR | | | | | | 0.0720 | 200 | |
| **DRE005** | **MAN. SLOPE SHAPING (SIDE & BOT.)** | **2748** | **m^2** | **5.12** | | | | | | | **14,078** |
| AL350 | LABORER | | HR | | 0.180HR | 8.2 | | | | | |
| AL362 | ASSISTANT | | HR | | 0.190HR | 6.5 | | | | | |
| **DRE006** | **REIN. CONC. LINING FOR CANAL: 20cm** | **5283.87** | **m^2** | **129.16** | | | | | | | **682,478** |
| AG901 | CEMENT | | KG | | | | 26.00KG | 0.94 | | | |
| AG002 | WASHED DEBRIS | | m^3 | | | | 0.062m | 140 | | | |
| AG001 | SAND | | m^3 | | | | 0.050m | 60 | | | |
| MA004 | CONSTRUCTION WOOD | | PIE2 | | | | 0.040PI | 6.5 | | | |
| HI001 | NAIL | | KG | | | | 0.020KG | 12.72 | | | |
| AI004 | ANTISOL | | L | | | | 0.200L | 10.125 | | | |
| HI002 | REINFORCEMENT CORRUGATED REBAR | | KG | | | | 2.530KG | 11.55 | | | |
| HI003 | MOORING WIRE | | KG | | | | 0.080KG | 12.73 | | | |
| AI003 | GEOTEXTILE OP-20 (200 g/m^2) | | m^2 | | | | 0.300m | 8 | | | |
| AL363 | OPERATOR OF LIGHT FIELD EQUIPMENT | | HR | | 0.040HR | 6 | | | | | |
| AL350 | LABORER | | HR | | 0.950HR | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | 1.900HR | 6.5 | | | | | |
| HO901 | MIXER OF 350 LTS | | HR | | | | | | 0.040H | 25 | |
| **DRE015** | **GRAVEL MATERIAL (STABILIZER)** | **1167.36** | **m^3** | **213.36** | | | | | | | **249,765** |
| AG002 | CLEAN GRAVEL | | m^3 | | | | 1.050m | 140 | | | |
| AL350 | LABORER | | HR | | 1.000HR | 8.2 | | | | | |
| AL355 | ASSISTANT | | HR | | 1.200HR | 6.5 | | | | | |
| **DRE020** | **DRAINAGE PIPES FOR CANAL PVC 2"** | **1024** | **PZA** | **2.52** | | | | | | | **2,578** |
| HI003 | REBAR TIE WIRE | | KG | | | | 0.200KG | | | | |
| HS138 | PVC PIPE | | m | | | | 0.0800m | | | | |
| AL350 | LABORER | | HR | | 0.0300HR | | | | | | |
| AL355 | ASSISTANT | | HR | | 0.0300HR | | | | | | |
| | **DEL. & PLAC. REIN. CONC. CULVERTS (4X3.70X2.30)** | **52** | **PZA** | **304631.33** | | | | | | | **15,840,829** |
| DRE002 | REPLANTEO DE CANALS PUENTES | 9.95 | ML | | | | | | | | |
| DRE003 | EXCAVATION WITH MACHINERY S/N.F | 59.69 | M^3 | | | | | | | | |
| DRE004 | EXCAVATION WITH MACHINERY B/N.F | 39.79 | M^3 | | | | | | | | |
| HOR0301 | CONCRETE STRENGTH = 110 kg/c2 | 93.15 | M^2 | | | | | | | | |
| HOR0355 | HoAo of Sewer booth fck=210 kg/cm2 | 58.43 | M^3 | | | | | | | | |
| HOR0353 | HoAo of Sidewalk and curb fck=210 kg/cm2 | 3.28 | M^3 | | | | | | | | |
| HOR0357 | HoAo compress of sewer fck=210 kg/cm2 | 5.44 | M^3 | | | | | | | | |
| DRE0031 | refill and compact with plate. S/prov of material | 24.05 | M^3 | | | | | | | | |
| HIE018 | Metallic Barandado F°G ° Ø 2 " | 25.9 | M | | | | | | | | |
| HOR0356 | HoAo Flagstone of approach fck=210 kg/cm2 | 4.05 | M^3 | | | | | | | | |
| HOR0358 | HoAo Losa de transicion fck=210 kg/cm2 | 8.33 | M^3 | | | | | | | | |
| | | | | | BRIDGES | | | | | | |
| | **PEDESTRIAN BRIDGE (L=11.8M) - By School** | **1** | **PZA** | **19,797** | | | | | | | |
| DRE002 | REPLANTEO DE CANALS PUENTES | 11.8 | | | | | | | | | |
| DRE003 | EXCAVATION WITH MACHINERY S/N.F | 2.94 | M^3 | | | | | | | | |
| HOR0301 | refill and compact with plate. S/prov of material | 1.38 | | | | | | | | | |
| HOR001 | Zapatas de HoAo | 0.56 | M^3 | | | | | | | | |
| HOR002 | Concrete: Columns of HoAo | 0.17 | M^3 | | | | | | | | |
| HOR0361 | HoAo of Superstructure fck=210 kg/cm2 | 2.95 | M^3 | | | | | | | | |
| HOR0362 | HoAo of Diaphragm of stretch fck=210 kg/cm2 | 0.11 | M^3 | | | | | | | | |
| HOR0363 | HoAo of Diaphragm of support fck=210 kg/cm2 | 0.19 | M^3 | | | | | | | | |
| HOR0011 | Base of support bridge of HoAo | 0.29 | M^3 | | | | | | | | |
| HIE018 | Metallic Barandado F°G ° Ø 2 " | 23.6 | M^3 | | | | | | | | |
| DRE0031 | refill and compact with plate. S/prov of material | 2.38 | M^3 | | | | | | | | |
| HOR0356 | HoAo Flagstone of approach fck=210 kg/cm2 | 0.54 | M^3 | | | | | | | | |
| | ROADWAY CROSSING | 3 | PZA | 240000 | | | | | | | **720,000.00** |
| **TOTAL** | | | | | | | | | | | **20,548,680** |
| | | | | | | | | | | | **20,549,000** |

| ID | | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|
| 1 | | **Concrete Lined Canal** | **126 days** | **Mon 3/2/09** | **Mon 8/24/09** |
| 2 | | Mobilization | 3 days | Mon 3/2/09 | Wed 3/4/09 |
| 3 | | Site Clearing | 4 days | Thu 3/5/09 | Tue 3/10/09 |
| 4 | | Site Layout | 9 days | Wed 3/11/09 | Mon 3/23/09 |
| 5 | | Canal Excavation and Compaction of fill Section | 25 days | Tue 3/24/09 | Mon 4/27/09 |
| 6 | | Sloping Shaping | 21 days | Tue 3/31/09 | Tue 4/28/09 |
| 7 | | Placement of Gravel - Stabilizer | 7 days | Mon 4/6/09 | Tue 4/14/09 |
| 8 | | Placement of Reinforced Concrete lining | 90 days | Wed 4/15/09 | Tue 8/18/09 |
| 9 | | Pedestrian and Vehicle Bridges | 64 days | Wed 4/22/09 | Mon 7/20/09 |
| 10 | | Clean-up | 2 days | Wed 8/19/09 | Thu 8/20/09 |
| 11 | | Demobilization | 2 days | Fri 8/21/09 | Mon 8/24/09 |
| 12 | | | | | |
| 13 | | **PAVEMENT** | **93 days** | **Mon 3/30/09** | **Wed 8/5/09** |
| 14 | | Mobilization | 3 days | Mon 3/30/09 | Wed 4/1/09 |
| 15 | | Site Layout | 6 days | Thu 4/2/09 | Thu 4/9/09 |
| 16 | | Pavement Earthwork | 7 days | Fri 4/10/09 | Mon 4/20/09 |
| 17 | | Place and Compact Base - Roadway 1 | 14 days | Tue 4/21/09 | Fri 5/8/09 |
| 18 | | Placement of Curb - Roadway 1 | 17 days | Tue 4/28/09 | Wed 5/20/09 |
| 19 | | Placement of Concrete Pavement - Roadway 1 | 21 days | Mon 5/18/09 | Mon 6/15/09 |
| 20 | | Place and Compact Base - Roadway 2 | 14 days | Tue 6/9/09 | Fri 6/26/09 |
| 21 | | Placement of Curb - Roadway 2 | 17 days | Mon 6/22/09 | Tue 7/14/09 |
| 22 | | Placement of Concrete Pavement - Roadway 2 | 21 days | Thu 7/2/09 | Thu 7/30/09 |
| 23 | | Clean-up | 2 days | Fri 7/31/09 | Mon 8/3/09 |
| 24 | | Demobilization | 2 days | Tue 8/4/09 | Wed 8/5/09 |




| | | | | | | |
|---|---|---|---|---|---|---|
| Project: 30th de Agosto.mpp<br>Date: Tue 11/4/08 | Task | Milestone | Rolled Up Task | Rolled Up Progress | External Tasks | Group By Summary |
| | Progress | Summary | Rolled Up Milestone | Split | Project Summary | Deadline |