Avenida Fatima I Design Report

Submitted to:

Distrito 12
Santa Cruz de la Sierra
Bolivia
Sub Alcalde: Ing. Victor P. Escobar Díaz

Submitted by:

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DISCLAIMER

The following project was completed by students at Michigan Technological University in Houghton, MI – USA as part of a class assignment. Students are not licensed Professional Engineers and therefore any information used from this report must be checked by a licensed Professional Engineer to ensure accuracy and applicability.

Executive Summary

The Design-Build firm of Cinco Cero Engineering (C.C.E.) was developed in participation with the International Senior Design program at Michigan Technological University (MTU). Over the summer of 2008, C.C.E. was given the task of designing a road and storm drainage structure for Avenida Fatima I in District 12 of Santa Cruz, Bolivia. The project was petitioned for by the local community and the project scope was improved road quality and flooding.

In May of 2008, C.C.E. spent two weeks in Bolivia researching the project site, typical construction practices, and culture. Procedures completed included a topographic survey, watershed delineation, single soil bore, soil laboratory tests, and multiple interviews with project sponsors and clients. Several procedures that were unable to be performed by C.C.E., but were thought vital to the project, included a traffic count, additional soil bores, and stream velocity calculation of the nearby curichi. In the end, three possible design options were developed using the data obtained, all three utilizing a Portland Cement concrete pavement.

In order for the design to be cost-efficient and perform as expected, C.C.E. decided that the recommended design should conform to two different limitations.

1. **Follow the existing topography**: To reduce the amount of cut and fill, the design should rely on the existing topography, as much as possible.

2. **Drainage structure depth less than 1.3 m**: Due to the first limitation, the canal depth should not exceed 1.3 m below the existing ground, to achieve a slope of 0.1%. Any slope smaller than 0.1% was not considered feasible for the design.

The three designs that were developed included: underground storm sewer pipes, precast box culverts, and an open rectangular canal. The first design was found to be unacceptable due to the required pipe sizes not conforming to the depth limitations of the drainage structure. The second design was found to be feasible, however more costly than the third design, an open rectangular canal.

Ultimately, C.C.E. believes that an open rectangular canal would be the best option for Avenida Fatima I. This option was chosen based on:

1. **Cost**: An open rectangular canal is less costly than precast box culverts.

2. **Standard Practice**: An open canal design was observed in both the canal to the north and south of Avenida Fatima I.

3. **Maintenance**: An open canal is easier to access by maintenance crews.

The recommended design would consist of two, one-way standard Bolivian Portland Cement concrete pavements, split by a rectangular canal of 1.3 m in depth and 4.1 m in width. The canal would have a 0.5 m barrier wall on either side for the safety of vehicles and pedestrians along Avenida Fatima I. In the last 250 m of the southwest section of road, the available cross-section width reduces to around 8.0 m. Underground storm sewer pipes and smaller lane widths of 3.75 m will be utilized in this area. In total, this design option will cost around **$5,023,000 Bs** or **$708,500 USD**.

Additional concerns related to this design included implementation of vehicle and pedestrian bridges for the convenience of users and the completion of the supplementary procedures mentioned above, which C.C.E. was not able to complete. Professional Engineers should also verify any calculations made and should be employed in the design of the bridges, storm sewer pipe, and drive-over grates. Finally, areas of further development were noticed within the watershed area and it is suggested that if additional road and storm drainage structures are expected, designs should occur simultaneously with Avenida Fatima I. This will reduce redundancy and costs for all projects.

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Giancarlo Calbimonte – ISD May Mentor

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1.0 Introduction

In April of 2008 the Design-Build firm of Cinco Cero Engineering (C.C.E) was formed, comprised of three undergraduate civil engineering students from Michigan Technological University (MTU): Dylan Gerhart, Kari Klaboe, and Travis Velasco seen in Figure 1.1. The team was formed in participation of the International Senior Design (ISD) class at MTU, which is one of the capstone senior design courses that conclude the baccalaureate engineering programs at MTU. ISD has been in existence since 2000 and provides students of all backgrounds with an opportunity to participate in service learning and engineering design. The program is under the direction of Ing. Linda Phillips, Ing. Dennis Magolan, and Ing. Mike Drewyor, who are also the project principals and class instructors.

(a) **(b)**

Figure 1.1: (a) Cinco Cero Engineering Design-Build Firm; from left Dylan Gerhart, Travis Velasco, and Kari Klaboe (b) May ISD Class With Friends and Mentors.

In the same month of its conception, C.C.E. was given the task of designing a road and storm drainage system for a community in Santa Cruz, Bolivia. The team traveled with a group of seven other MTU students, Figure 1.1, to Santa Cruz in May of 2008. The main objective was to gather pertinent data; while also becoming familiar with the site, local construction practices, and culture of Bolivia; which are all vital aspects of the design process.

The project was proposed by the district's Sub Alcalde (sub-mayor), Ing. Victor P. Escobar Díaz, after being petitioned by the local community. The project site, which is called

Avenida Fatima I, is located in District 12 of the department of Santa Cruz and currently consists of a dirt road with some earthen ditches constructed to help direct storm water. The road is also impassible in some areas during the wet and dry seasons. Improved road quality and storm drainage are the two main goals presented by the community and will be the scope of the following report.

2.0 Background

In order to meet the needs of the community of Avenida Fatima I, C.C.E. researched the geography, climate, government, economics, and health of Bolivia, the city of Santa Cruz, and surrounding area of Avenida Fatima I. In addition, field data was collected, as well as a topographic survey to be used in the project design.

2.1 Geography

Bolivia is located in central South America and can be seen in Figure 2.1 bordered in black. The country is a landlocked nation bordered by Brazil to the north and east, Paraguay and Argentina to the southeast, Chile to the southwest, and Peru to the northwest.

Figure 2.1: South America and Bolivia (13).

There are three distinct regions within the country: the mountains and Altiplano which edge Bolivia's west, the temperate valleys of the northeast, and the lowlands or Oriente in the north and east; seen in Figure 2.2 (7).

Figure 2.2 Geography of Bolivia (12).

The Oriente can also be divided into three distinct regions: the north, eastern-central, and southeast. Tropical rain forests and savannas are dominate in the eastern-central region, which encompasses the city of Santa Cruz (7).

2.2 Climate

The entire country of Bolivia is situated in the tropical latitudes; with day time high temperatures above 30˚C (86˚F) and high humidity and rainfall prevailing in most parts (7). In the eastern-central lowlands a tropical wet and dry climate is experienced, with the wet season occurring from October through April and the dry season occurring from May through September. Annual precipitation for Santa Cruz is around 1200 mm, with the historic average for the month of January alone ranging between 100 to 200 mm (1). Additional precipitation data for Santa Cruz can be found in Appendix A.

2.3 Government

The government of Bolivia has a well-defined structure, which has lately been the scrutiny of many of its 9.5 million inhabitants (10). Presently, the structure of government is a Republic, with the executive and legislative bodies headquartered in the administrative capital of La Paz. These two bodies hold control over fiscal spending and development within Bolivia, which, per C.C.E.'s understanding, is the main source of discourse. Below the current structure of government and the current events that are changing and shaping the future structure of government are described in detail.

2.3.1 Current Structure

Bolivia is home to two separate capitals, Sucre, the constitutional capital and La Paz, the administrative capital. Beyond the national government, Bolivia is divided into nine departments: Beni, Chuquisaca, Cochabamba, La Paz, Oruro, Pando, Potosi, Santa Cruz, and Tarija, which can be seen in Figure 2.3.

Figure 2.3: Departments of Bolivia (14).

The nine departments are further separated into provinces, municipalities, and then districts. Avenida Fatima I is located in District 12 of the municipality of Santa Cruz de la Sierra in the province of Andrés Ibáñez. Figure 2.4 shows the location of District 12 and its orientation in the city of Santa Cruz.

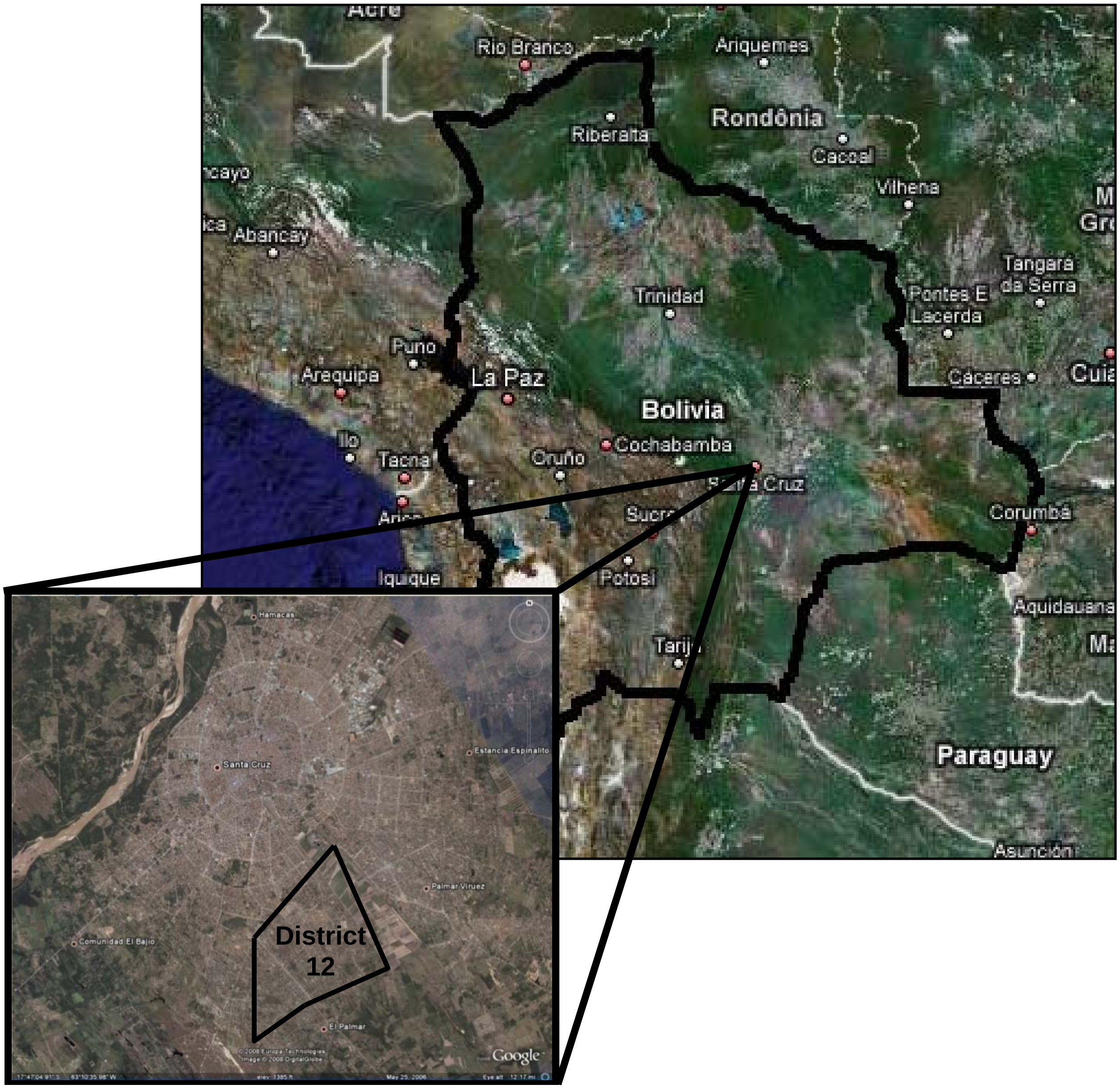


Figure 2.4: City of Santa Cruz, Bolivia (13).

Each district is divided into unidades vecinales (UVs) or neighborhood groups, with each UV being composed of barrios or individual neighborhoods. To direct the activities of the districts, a Sub Alcalde or sub-mayor is appointed for each and is responsible for the welfare of the district. UVs also have a leader called a UV president and all of the UV presidents report to a single community member called the President Junta Vecinal. District 12 is represented by Sub Alcalde Ing. Victor P. Escobar Díaz and Presidenta Junta Vecinal Loreto Moreno.

2.3.2 Current Events

In December of 2005, current President, Evo Morales, was elected by a 53.7% majority vote (2). Since then, he has been enacting and influencing many changes within the country; one of which being the referendum for regional autonomy (4).

Regional autonomy within Bolivia would allow each department the right to control their own resources, and would afford resource rich departments, like Santa Cruz, Beni, and Pando, to keep a larger portion of their income. This would provide more funds for public projects in these departments. If the departments are allowed regional autonomy, public projects would only need approval of the departmental government, rather than the national government. For the department of Santa Cruz, these changes could possibly allow for more projects to be approved either by an increase in fiscal spending or an increase in authorization of developmental projects.

Initially, a national vote for regional autonomy failed. However, strong supporters are continuing their petitions for the referendum, even to the dismay of President Morales. The departments of Santa Cruz, Beni, Pando, and Tarija have even held secondary elections, which were deemed illegal by the national government, Figure 2.5, (8). These secondary elections have validated the desire for autonomy with over 80% approval in Santa Cruz, Beni, and Pando and around 80% approval in Tarija (3,5).

Figure 2.5: Bolivia's Secessionist Regions (11).

2.4 Economics

Bolivia is one of the poorest countries in South America, with almost 59% of the population classified as poor (9). Yet the country is rich in many minerals, as well as holding the second-largest reserves of natural gas in South America (6). In the department of Santa Cruz, only about 38% of the two million people are classified as poor, which is the lowest percentage within the departments of Bolivia (9).

Within the city of Santa Cruz, the disparity between the upper/middle class and lower class can be observed by walking from the city center outwards. The city itself is composed of nine co-centric rings, with radials extending from the center. As you move from the city core outwards, the average family income decreases. Avenida Fatima I is located between the 6th and 7th rings.

2.5 Health

Due to its tropical climate, the residents of Bolivia are susceptible to diseases like malaria, dengue, and yellow fever. All three of these diseases can be fatal and originate from mosquitoes that breed in standing water. In the department of Santa Cruz alone, there were

3,033 cases of malaria and 189 cases of dengue reported in 2002, with 94% of the population at risk of malaria (9). These numbers, with respect to malaria, are only equaled by the departments of Beni and Pando which also lie in the lowlands of Bolivia. With regards to dengue, the Department of Santa Cruz out-numbers all other departments, making up around 69% of the total number of dengue cases reported in 2002 for Bolivia. Additional statistics on health for the Department of Santa Cruz can be seen in Appendix B.

3.0 Methods and Procedures

In the following section, the techniques used by C.C.E. are detailed as they relate to experiences in Bolivia and the United States (US).

3.1 Bolivia

While in Bolivia, C.C.E. collected survey, soil, watershed, and background data for use in the design process. Meetings were also held with local officials, engineers, and mentors to review project information, scope, planning, and design alternatives.

3.1.1 Topographic Survey

A topographic survey was completed to determine watershed boundaries, horizontal and vertical road alignment, and required cut and fill amounts; with standard topographic survey procedures being utilized, see Figure 3.1. See Appendix C for survey procedure, benchmarks, and notes.

(a) **(b)**

Figure 3.1: (a) Travis Velasco Surveying the Southwest End of Avenida Fatima I (b) Dylan Gerhart Exhibiting the Tripod Technique for Rod Holding.

The method used during surveying involved setting up a control point and establishing a permanent benchmark. After the necessary sideshots were taken, a traverse point was set-up and, if available, another benchmark. This process was repeated down the length of the road in distances ranging from 60-100 m. At the southwest end of the road, an existing benchmark was located and corresponding data for the benchmark was obtained. The equipment and errors, assumptions, and considerations are covered below.

Equipment used:

a) Topcon GTS225 total station
b) TDS Ranger data recorder
c) Tripod
d) Prism and prism pole
e) Radio communication
f) Metric tape measure
g) Large nails and bright colored tape
h) Personal computer with Foresight program

Errors, Assumptions, and Considerations for C.C.E. Survey:

a) Prism may not have been held perfectly level.

b) Current road was dirt and alignment was unclear.

c) Watershed was too vast for a complete topographic survey within C.C.E.'s time limits; therefore, the watershed along the northwest and southeast boundaries was walked and visually inspected.

d) Points 1-414, except traverse points, were mislabeled and had to be corrected by individual inspection by C.C.E.

e) Traverse Point 6 was removed by residents; therefore, points 532 through the end of survey were rotated. Rotation accuracy is within +/- 8cm from the true location. Method for correction of this error is included in section 3.2.1 Computer Aided Drafting (CAD).

f) Traverse points were temporary and may not exist at time of construction.

g) Survey data at the North and South ends of the avenue was accurate as of May 15-24 of 2008. Construction projects in progress in these areas may have altered terrains.

h) Multiple setups cause compounding errors.

3.1.2 Soil Bores

A single soil bore was performed to determine the general water table location and composition of sub-surface soil. The bore was located at the intersection of the Curichi and Avenida Fatima I and was performed by a local water well driller, Sr. Teodardo Gandarillas, and ISD students, Figure 3.2. During the soil bore, a description of sub-surface soil was recorded by C.C.E. with the aid of Ing. Carlin Fitzgerald who was an ISD mentor to the May class and previous ISD student.

(a) (b)

Figure 3.2: Soil Bore on Avenida Fatima I (a) Travis Velasco Assisting Sr. Gandarillas (b) Dylan Gerhart Assisting Sr. Gandarillas.

The method used during the soil bore involved hand turning a soil auger to a depth ranging from 0.10 to 0.15 m. The soil layer was removed, deposited next to the bore hole, and the bore depth was measured. A description of the soil layer was taken which included: soil type, grain size, color, moisture, and additional comments. After the description was taken, a sample of the soil layer was bagged and sealed. The bagged samples were later re-checked and identified using the Unified Soil Classification System (USCS). Field soil bore and USCS classification results can be found in Appendix D, along with supporting documents that were referenced or utilized. The equipment and errors, assumptions, and considerations are covered below.

Equipment used:

a) Soil auger-manual
b) Metric tape measure

Errors, Assumptions, and Considerations:

a) Only one soil bore was taken and results may not be consistent in the watershed or road areas.

b) Additional bores were referenced with respect to water table level and soil type, and are listed in Appendix D.

c) Soil was placed on ground without cover during record of soil description. Sun exposure may have affected moisture descriptions.

d) Soil description was made with the discretion of a single tester and judgment may vary from person to person.

3.1.3 Soil Tests

The Standard Proctor Test and AASHTO Soil Classification were performed on soil taken from three different locations along the road. The three samples were mixed uniformly and one sample of the mix was tested. Tests were performed to determine the level of compaction that could be achieved and to obtain a general soil identification that was of laboratory quality.

ASTM D 1557/AASHTO T-180 were used to complete the Standard Procter Test, while AASHTO M-145-66 was used for soil identification. Soil test results can be found in Appendix E.

3.1.4 Watershed Delineation

Watershed delineation was performed to obtain the watershed area for surface runoff calculations. The watershed area was delineated using two different methods: topographic survey and visual identification. Data from the topographic survey was used to find flow paths and gradients. Methods and procedures for the topographic survey are listed in Section 3.1.1 and Appendix C.

3.1.4.1 Visual Identification

Visual identification was performed by C.C.E. with the help of Giancarlo Calbimonte, ISD mentor to the May class and previous ISD student. Ridges and high points along the boundaries of Avenida Fatima I were noted and compared to aerial photographs, Figure 3.3. Identification of flow barriers (i.e. walls) and land usage were also observed and recorded.

(a) (b)

Figure 3.3: (a) Travis Velasco Obtaining a Better View of the Watershed (b) Giancarlo Calbimonte, Travis Velasco, and Kari Klaboe Investigating a Ridge to the West of Avenida Fatima I.

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

Equipment used:

a) Aerial maps

Errors, Assumptions, and Considerations:

a) Additional low or high points were not identified beyond the ridges found.

b) Visual identification is prone to human error and judgment.

3.1.5 Project Meetings

While in Bolivia, C.C.E. attended meetings with city officials, local and US engineers, and community members. Meeting topics ranged from engineering design to culture, and encompassed all aspects of the project. To set-up a meeting, C.C.E. or Ing. Linda Phillips contacted the person or group to find a time and place that was convenient for both parties. C.C.E. then prepared by developing a list of questions ranging from typical Bolivian practices to information that could be acquired, Figure 3.4. Meeting notes and any pertinent information were collected during the meeting. The following is a list of the information gathered while in Bolivia and meeting minutes can be found in Appendix F.

(a) (b)

Figure 3.4: (a) C.C.E. Meeting with Ing. Javier Marín (center) and Sub Alcalde Ing. Victor P. Escobar Díaz (far right) (b) C.C.E. Meeting with Ing. Humberto Calbimonte from Cochabamba, Bolivia.

Information Gathered:

a) 2008 plot report for Santa Cruz city development

b) Canal plans for Nuevo Camino al Palmar and Antiguo Canals

c) Community needs and problem areas

d) Cost estimation data

e) Storm run-off calculations

f) Typical canal plans, design, and construction procedures

g) Typical road plans and design

3.2 United States

Upon arrival to the US, data was analyzed in the form of AutoCAD drawings, storm runoff calculations, pavement design, and canal design. Additional meetings were also held with project principals and mentors to discuss design options and methods.

3.2.1 Computer Aided Drafting (CAD)

AutoCAD Civil 3D 2008 was used to create an accurate model of the existing conditions along Avenida Fatima I, which was used in the watershed delineation and pavement and canal designs and calculations. First the completed survey data was imported into AutoCAD as a text file and analyzed. The data had two errors. One of which was the mislabeling of points, and the other being the alignment from traverse point 7, TR-7, and on. The mislabeling of points was fixed by individually inspecting the points and determining the correct label. The alignment inaccuracy was fixed, while in Bolivia, by re-surveying known points and overlaying the correct path onto the incorrect data. From that, the points were rotated to the correct position within 8 cm of true location. The team has determined this error marginal for the project. A description of the procedure used can be found in Appendix G. The equipment and errors, assumptions, and considerations are covered below.

Equipment used:

a) AutoCAD Civil 3D 2008

b) Personal computer with Foresight program

Errors, Assumptions, and Considerations:

a) Rotation of misaligned points caused marginal error.

b) Existing road boundaries were undefined.

c) No points were able to be taken in undeveloped portion of the watershed.

d) Points 1-414, except traverse points, were mislabeled and had to be corrected.

3.2.2 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.

$$Q = CIA \quad (Equation\ 1)$$

Q = Peak storm runoff (m^3/s)
C = Dimensionless runoff coefficient ($0 \leq C \leq 1.0$)
I = Rainfall intensity (m/s)
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 (20).

$$Santa\ Cruz\ I = \frac{393.70\, f^{0.3556}}{t^{0.7016}} \quad (Equation\ 2)$$

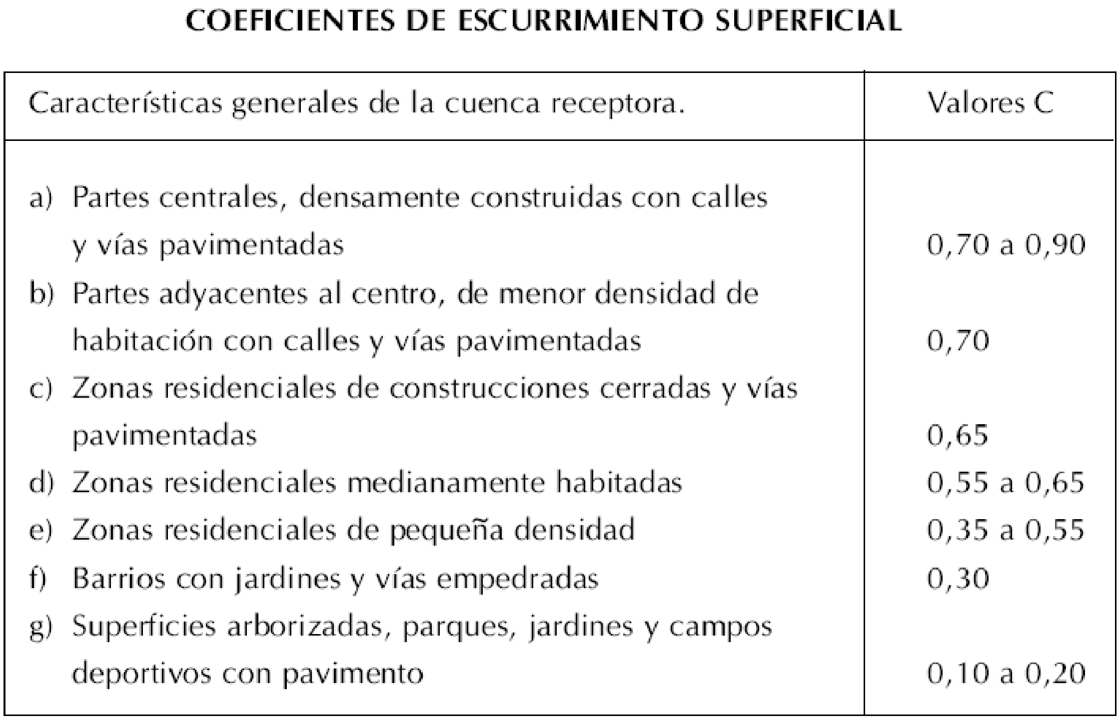
I = Rainfall intensity (mm/h)
f = Rainfall frequency (years)
t = Time of concentration (min)

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

L = Hydraulic length (km)
S = Land slope (decimal percent)

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 (20).

Table 3.1: Runoff Coefficients from Table 1 of Chapter 6 in NB 688 (20).



COEFICIENTES DE ESCURRIMIENTO SUPERFICIAL

Características generales de la cuenca receptora.	Valores C
a) Partes centrales, densamente construidas con calles y vías pavimentadas	0,70 a 0,90
b) Partes adyacentes al centro, de menor densidad de habitación con calles y vías pavimentadas	0,70
c) Zonas residenciales de construcciones cerradas y vías pavimentadas	0,65
d) Zonas residenciales medianamente habitadas	0,55 a 0,65
e) Zonas residenciales de pequeña densidad	0,35 a 0,55
f) Barrios con jardines y vías empedradas	0,30
g) Superficies arborizadas, parques, jardines y campos deportivos con pavimento	0,10 a 0,20

A storm recurrence interval of 10 years and runoff coefficient c in Table 3.1 were assumed for Avenida Fatima I. 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. Development plans showed future expansion of District 12, with the entire watershed of Avenida Fatima I being urban neighborhoods.

3.2.3 Pavement Design

A typical Bolivian Portland Cement concrete pavement section was used in the pavement design for Avenida Fatima I, Figure 3.5. The pavement section was based off of a Bolivian project manual obtained by previous ISD students and was supplied to C.C.E. by Ing. Linda Phillips.

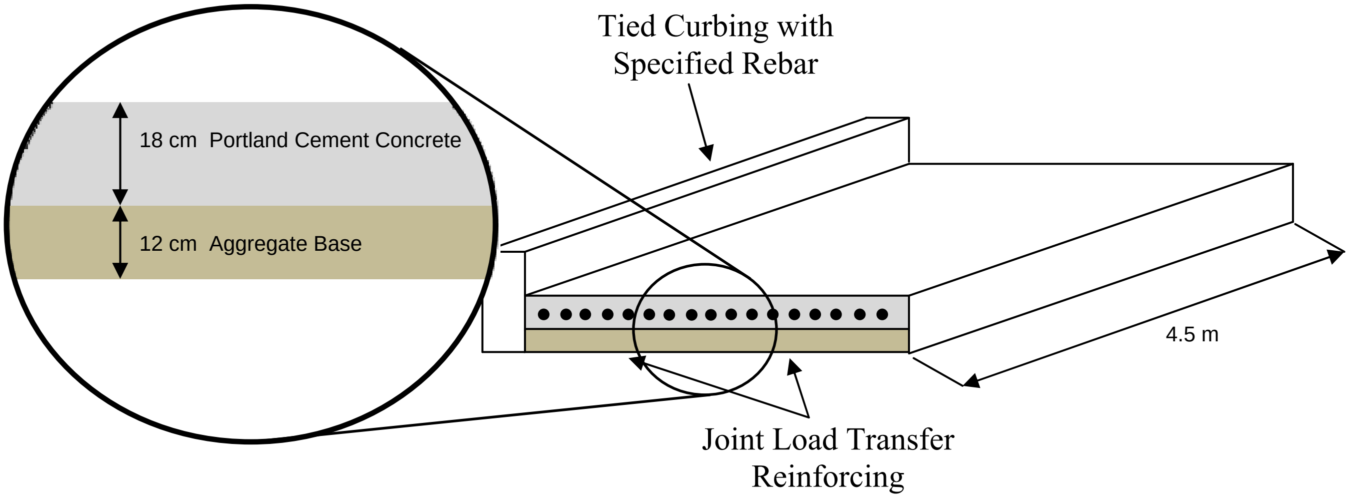


Figure 3.5: Typical Bolivian Pavement Section.

The maximum standard design load for major Bolivian roads is 11,000 kg/axel with a 28 day compressive strength (f'_c) of 230kg/cm^2. The section used for these major roads, with a factor of safety of 20%, is 18cm of Portland Cement Concrete and 12cm of aggregate base. Supporting material used in the design and a summary of the procedure used can be found in Appendix H. The equipment and errors, assumptions, and considerations are covered below.

Equipment used:

a) Proyecto Radial 16 ½ Desde 5 to Anillo hasta Av. San Martin

b) "*Pavement Design and Materials*" A. T. Papagiannakis and E. A. Masad

Errors, Assumptions, and Considerations:

a) Pavement section was taken from a project completed in Santa Cruz for a road connecting two main roads. However, this does not mean that conditions are similar for the two locations.

b) A traffic count was not obtained by C.C.E. while in Bolivia, due to current road conditions. However, a traffic count should be completed to estimate the amount of traffic and type of traffic loads to be expected along Avenida Fatima I.

   - If such a traffic count is not possible, traffic counts from Avenida Nuevo Palmar or Avenida Antiguo may helpful in assuming the amount of traffic and type of traffic loads.

3.2.4 Drainage Design

Three different types of drainage structures were used in the preliminary design of Avenida Fatima I: pipe culverts, 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 Appendix I.

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

C_m = 1.0 for International System (SI) units and 1.49 for British Gravitational (BG) units (unit less)
n = Manning's roughness coefficient (unit less)
A = Cross sectional area of pipe (m^2)
R = Wetted perimeter; $\frac{Area}{Perimeter}\ (m)$
S = Longitudinal slope of channel (decimal percent)

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 C.C.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 along Avenida Fatima I.

3.2.5 Project Meetings

While in the US, C.C.E. attended meetings with project mentors and engineers. Meeting topics ranged from engineering design to cultural acceptance. To set-up a meeting, C.C.E. contacted the person or group to find a time and place that was convenient for both parties. C.C.E. then prepared by developing a list of questions focused on the data or information required. Meeting notes and any pertinent information were collected during the meeting. Below is a list of the information gathered while in the US and meeting minutes can be found in Appendix F.

Information Gathered:

a. Canal design options

b. Pavement design options

c. Soil characterization

4.0 Existing Conditions

Existing conditions were observed and investigated using techniques and methods listed in Section 3.0 Methods and Procedures.

4.1 District 12

District 12 is the newest district within the municipality of Santa Cruz emerging from an adjacent district, District 9, on May 14, 1999. There are 42 UVs and 76 barrios within District 12 with 170,000 residents. Currently residents face a number of infrastructure issues such as inadequate water drainage, Figure 4.1, and sewer systems, partially due to a flat topography and high water table, around 1.2 m below ground level.

(a) **(b)**

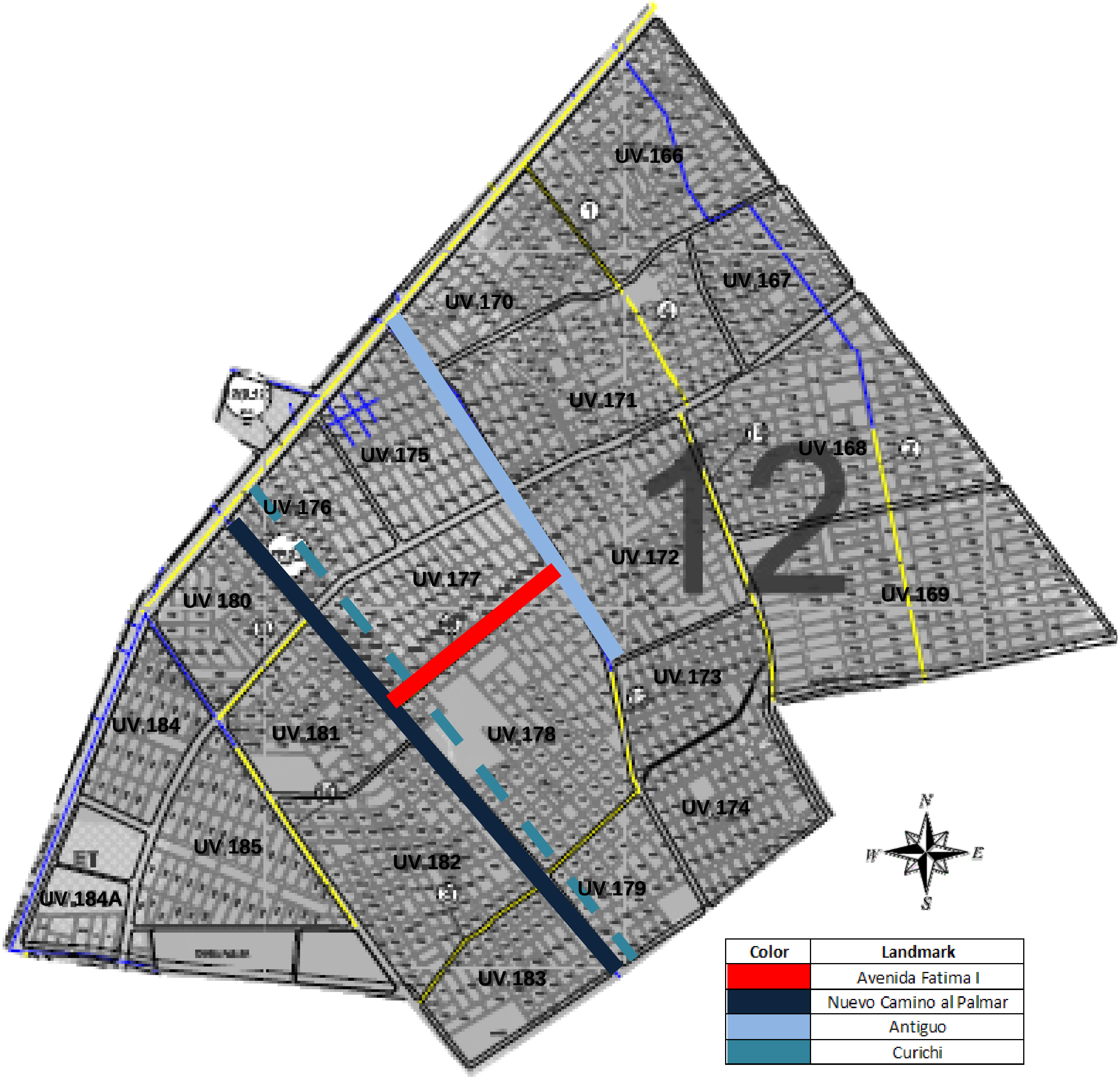
Figure 4.1: (a) - (b) Photographs Taken Near the Policia National in November of 2007 by Ing. Linda Phillips.

The district is addressing the inadequate water drainage by constructing two major drainage canals, the Nuevo Camino al Palmar and Antiguo, Figure 4.2.

(a) **(b)**

Figure 4.2: (a) - (b) Canal Construction of Nuevo Camino al Palmar Taken in May of 2008 by C.C.E.

These canals were designed with a capacity to handle 40% of the flooding in the district. Both canals, along with Avenida Fatima I are shown in Figure 4.3.



Color	Landmark
🟥	Avenida Fatima I
⬛	Nuevo Camino al Palmar
🟦	Antiguo
🟦	Curichi

Figure 4.3: District 12

The full effects these two canals will have on the area drainage is still unknown, since they are under construction. However, construction of the canals alone will not fully address the flooding without properly draining the surrounding areas to the canals. The community of Avenida Fatima I was just one of several communities that need to divert excess storm water to the new canals due to flooding and standing water, Figure 4.4.

(a) **(b)**

Figure 4.4: (a) - (b) Flooding Along Avenida Fatima I: Photographs Taken November 24, 2007 by Ing. Linda Phillips.

4.2 Avenida Fatima I

Existing conditions of the two main concerns for Avenida Fatima I, storm drainage and road quality, are described below.

4.2.1 Storm Drainage

Avenida Fatima I is an area prone to standing water throughout both the wet and dry seasons. Standing storm water is a serious problem because it supports the reproduction of mosquitoes that promote dengue, yellow fever, and malaria. Standing water is not the only issue; a curichi or natural stream also runs through UVs 176, 177, and 178, which contributes to the flooding during the wet season. The curichi originates from a quebrada or wetland to the west of the UVs, Figure 4.3, and shows minimal flow during the non-rainy season, also noticed from field observation.

The watershed of Avenida Fatima I is around one square kilometer and can be seen bordered in black in Figure 4.5 below. To the northeast and southwest the watershed is delineated by the Antiguo and Nuevo Camino al Palmar canals. A ridge to the northwest and Avenida Fatima I provide the remaining two boundaries.

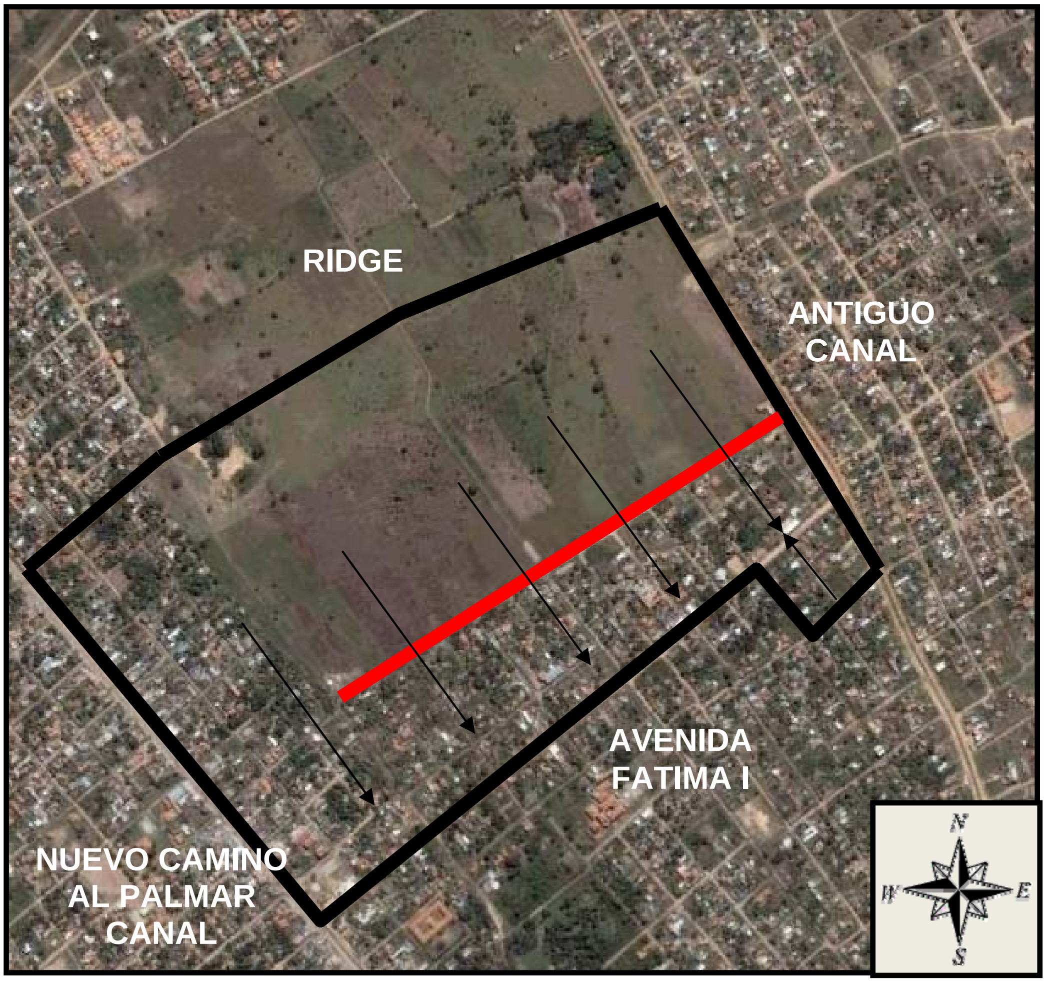


Figure 4.5: Avenida Fatima I Watershed

Land slope is from the northwest to the southeast, except for a small portion of land in the northeast corner, which is included in the watershed area. Land usage is a mix between undeveloped grasslands to urban residential areas. However, development plans for District 12 show the entire area eventually being urban residential. From the soil bore conducted by C.C.E., it was discovered that a clay layer exists about one meter below the existing ground level. This impedes infiltration to the ground water around 1.2 m below the existing ground level.

Current drainage structures along Avenida Fatima I include earthen ditches located on each side of Avenida Fatima I and a temporary earthen emergency ditch highlighted in red in Figure 4.5. During inspection of the drainage structures in and around Avenida Fatima I, it was noticed by C.C.E. that sediment, organic material, and trash accumulate within the structures, Figure 4.6. This poses a barrier to water flow, which decreases the structures effectiveness.

(a) (b)

Figure 4.6: (a) - (b) Debris Accumulation in Drainage Structures: Photographs Taken in May of 2008 by C.C.E.

4.2.2 Road Quality

Avenida Fatima I is a graded dirt road composed of soils ranging from silty sands to sandy clays. Traffic is moderate, where attainable, and consists mainly of taxis and city buses; which is the favored transportation of most of the community members. The road has a 0.1% slope towards the Antiguo canal and has a cross section ranging from 3.5 to 6 m, with around 16.8 m of total usable width within the right of way. In the southwest end, the road is constricted by the Policia Nacional and existing electric poles. The cross section width of the road is limited to around 8.0 m of total usable width.

During field observation, C.C.E. noticed that the northern portion of Avenida Fatima I was inaccessible by motor vehicles due to what was stated to be previous efforts to construct a paved road and drainage canal, Figure 4.7.

(a) **(b)**

Figure 4.7 (a) - (b) Northeast End of Avneida Fatima I Facing South: Photographs Taken in May of 2008 by C.C.E.

The Sub Alcalde Ing. Victor P. Escobar Díaz and the engineer for District 12, Ing. Javier Marín, informed C.C.E. that construction had been previously initiated along Avenida Fatima I. However, construction was halted once it became apparent an improved storm drainage design was needed. Earthwork remnants from the construction not only make some areas of the road impassable, but also reduce road quality due to the rough grade and standing water. The problem needs to be addressed since it is also blocking storm water flow into the canals.

Although not mentioned by community members or the Sub Alcalde, C.C.E. observed dust clouds produced by winds during the dry season which appeared to be uncomfortable for anyone outdoors, Figure 4.8. This occurs because some of the area consists of exposed sandy soil. Ultimately it is expected that construction of a paved road will reduce dust clouds and improve visibility and comfort for residents along Avenida Fatima I.

(b) **(b)**

Figure 4.8: (a) - (b) Discomfort Due to Dust Clouds.

5.0 Design Options

C.C.E. developed three basic pavement and storm drainage design options for Avenida Fatima I, with all three options designed for a storm with a 10 year recurrence interval.

- **Design Option 1**: Continuous grade PC concrete pavement utilizing underground storm sewer pipes for storm water drainage.
- **Design Option 2**: Continuous grade PC concrete pavement utilizing PC concrete box culverts for storm water drainage.
- **Design Option 3**: Continuous grade PC concrete pavement utilizing a PC concrete lined open rectangular canal for storm water drainage.

Alternative construction materials are also available for the three design options; however, a preference towards concrete has been observed by C.C.E. All three options utilize a diversion canal to the northwest of Avenida Fatima I, which directs the curichi towards the Nuevo Camino al Palmar canal. The diversion, design options, and alternative construction materials are discussed.

5.1 Diversion

Several concerns were raised after inspection of the curichi that runs perpendicular to Avenida Fatima I, Figure 4.3. During inspection C.C.E. observed that during the dry season the curichi experienced minimal flow, Figure 5.1. However, flooding and standing water occurred throughout the year and poses a hazard and nuisance to the residents in UV 177.

(c) **(b)**

Figure 5.1: (a) Curichi Flow During Dry Season: Photograph Taken in May of 2008 by C.C.E. (b) Curichi Flow During the Wet Season: Photograph Taken November 24, 2007 by Ing. Linda Phillips.

After meeting with Sub Alcalde Ing. Victor P. Escobar Díaz and District 12 engineer, Ing. Javier Marín, it was decided that the curichi would be temporarily diverted to the Nuevo Camino al Palmar canal. In the future, a road will be developed (International Road) shown in orange in Figure 5.2 to the northwest of Avenida Fatima I. The temporary diversion will be incorporated into the overall drainage plan of that road.

5.1.1 Diversion Options

While in Bolivia, C.C.E. investigated and surveyed two locations for diversion of the curichi, Figure 5.2. Location A is 7.5 blocks to the northwest of Avenida Fatima I and currently consists of a dirt paved road. Location B is 9 blocks to the northwest of Avenida Fatima I and currently consists of an ungraded grass path.

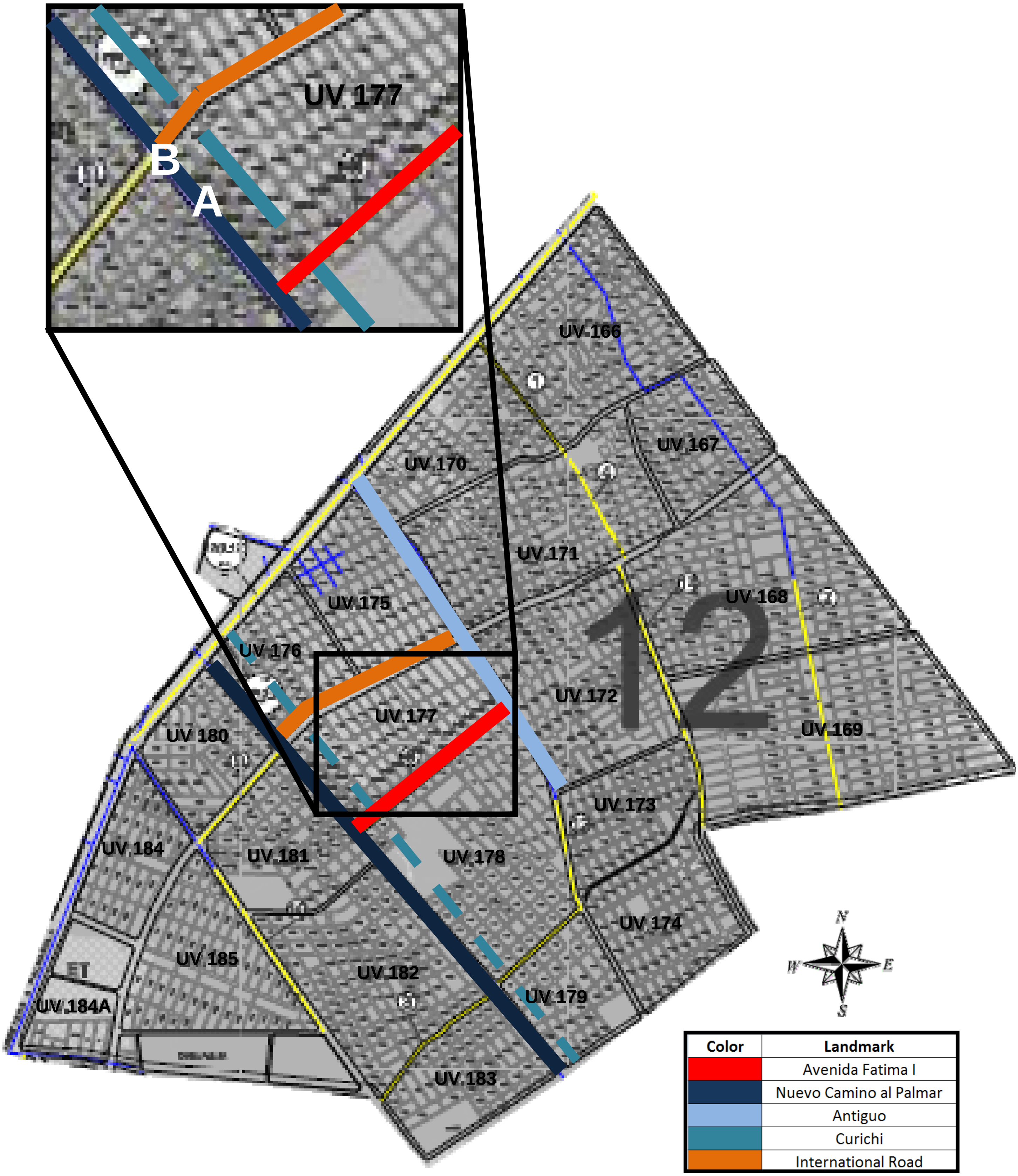


Figure 5.2: Curichi Diversion Locations.

Both locations contain existing drainage structures, with the structure at location B being the largest; two concrete pipes with inside diameters of one meter each, Figure 5.3.

(a) **(b)**

Figure 5.3: (a) Travis Velasco Measuring the Drainage Structure at Location B
(b) Drainage Structure at Location B.

Given minimal flow was found during C.C.E.'s inspection of the curichi, a stream velocity could not be attained. However, a conservative peak flow for the curichi was found by calculating the maximum attainable flow from the drainage structure at location B. The design flow of the curichi was found to be 3.5 cms. This results in a canal cross-section of 3.2 m^2. See Appendix I for calculations.

5.1.2 Curichi Diversion Recommendation

Both locations were evaluated for their advantages and disadvantages, which are listed below.

Location A

Advantage(s)	*Disadvantage(s)*
Minimum earthwork - existing road graded	Not aligned with International Road
	More homes are susceptible to flooding
	Existing structure too small

Location B

Advantage(s)	*Disadvantage(s)*
Existing drainage structure adequate	Most earthwork – existing road ungraded
Fewer homes susceptible to flooding	
Aligned with International Road	

Location B was chosen as the recommended diversion location due to:

1) Its alignment with International Road

2) Ability to utilize the existing drainage structure

3) Ability to prevent flooding and standing water for more homes within UV 177.

5.2 Pavement and Storm Drainage Design

Before beginning the design process, a list of project expectations and concerns was created from meetings with District 12 officials and observations made by C.C.E. while in Bolivia.

Expectations:

- Minimum two-way road for Avenida Fatima I connecting Nuevo Palmar and Antiguo roadways.
- Storm drainage structure that could support all of the storm water runoff directed towards Avenida Fatima I.
- Cost-effective design.
- Preference for Portland Cement (PC) concrete lined canal and PC pavement; however, asphalt concrete was stated to be acceptable.

Concerns:

- Safety of users of Avenida Fatima I; any open drainage structure would have to account for the safety of local residents, children, animals, and vehicles that use the roadway.
- Proposed drainage structure must account for almost all of the storm water runoff entering Avenida Fatima I from the northwest, Figure 4.5, given the watershed area lies mainly in that direction.

- Avenida Fatima I and surrounding area have a relatively flat topography. Any large changes in the existing ground level could change the direction of storm water drainage. Therefore, the proposed design should following the existing topography, as much as possible, to ensure proper drainage.

- Maintenance of the drainage structure must comply with the twice per year schedule typical in District 12.

- Environmental responsibility; a concrete lined canal and roadway would reduce the amount of storm water infiltration in the Avenida Fatima I watershed. This would negatively affect local aquifers.

Based on the expectations and concerns stated above, C.C.E. chose a basic design for the road and storm drainage system of Avenida Fatima I. This design would meet the needs of the residents, while complying with the concerns of C.C.E. From the basic design, three different options were found.

5.2.1 Basic Road and Storm Drainage Design

The new Avenida Fatima I will consist of a two way road, following the existing alignment and grade, as much as possible. Lanes will be divided by a center median/storm drainage structure that will be utilized as a traffic barrier and storm water conductor. Road and storm drainage designs are detailed further below.

Road Design

The road design will consist of a PC concrete roadway, with pavement sections conforming to typical Bolivian practice, see Figure 3.5. Reinforcement will be placed along the pavement joints to aid in the transfer of loads between pavement sections. Load transfer devices will be 25 mm or larger rebar, 18 cm in length, spaced 30 cm center to center, see Figure 5.4.

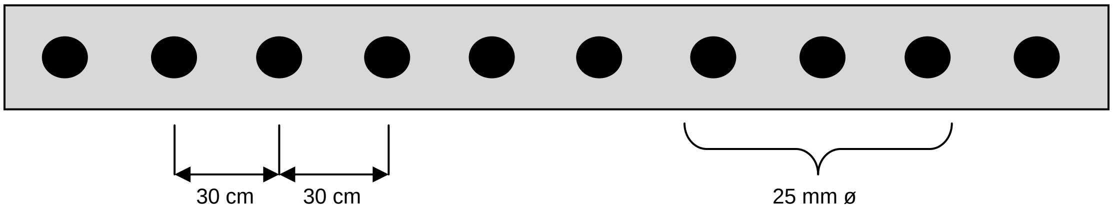


Figure 5.4: Load Transfer Device.

Lane sections will be 4.5 m wide along most of Avenida Fatima I; however, due to width restrictions in the southwest end of Avenida Fatima I, a 3.75 m wide section will be used in that area. This is 0.75 m shorter than the typical lane section of 4.5 m, per standard road drawings provided to C.C.E. as ISD reference materials. This design was chosen for Avenida Fatima I because:

1. **A high traffic load is expected along Avenida Fatima I**: While in Bolivia, C.C.E. was unable to perform a traffic count due to current road conditions, however Avenida Fatima I will be the only paved connecting road between Avenida Nuevo Palmar and Avenida Antiguo.

2. **Design was considered by C.C.E. to be typical construction practice**: Design was obtained from the project manual for the road connecting the 5th ring to Avenida San Martin at the 16.5 radial. Given this, it was considered that the design was standard in Santa Cruz and has been successfully used thus far.

3. **Lane widths are usable**: Standard lane widths in the United States range from 10 to 12 ft, with the lane width along the constricted section of Avenida Fatima I being just over 12 ft. While the lanes are smaller than typical roads in Bolivia, they are still usable by community members.

Storm Drainage Design

On either side of Avenida Fatima I are homes, businesses, and side roads. Placement of the drainage structure in the center median, in lieu of either side of the road, was based on safety, maintenance, and cost; which is detailed below.

Safety:

- By locating the drainage structure on either side of the road, increased pedestrian traffic around the structure would occur. Residents, business owners, and other pedestrians would have to cross over the drainage structure to enter homes or local businesses.

- By locating the drainage structure in the center median, the structure is protected from pedestrian access by two lanes of traffic. While this does not ultimately prevent access to the structure, it will deter most individuals and animals.

Maintenance:

- By locating the drainage structure on either side of the road:

    - If the drainage structure is uncovered, increased debris accumulation will occur, increasing maintenance costs.

    - If the drainage structure was covered, but not buried, increased degradation of the structure would occur. This would be due to an increase in the number of pedestrian and traffic loadings. Fatigue of the structure would occur more rapidly than if the structure were placed in the center.

Cost:

- By locating the drainage structure on either side of the road, vehicle and pedestrian bridges would be required for access to homes and all side roads or the structure would need to be underground. The center median drainage structure only requires vehicle and pedestrian bridges in several key areas.

- A center median drainage structure allows for design flexibility. If the drainage structures were placed on either side of the road, the design would be limited to a covered canal or underground storm sewer pipe for the safety and maintenance reasons listed above. Both of which are typically more expensive than an uncovered canal.

Given the storm drainage structure is in the center median, storm runoff will flow over the roadway. Therefore, pavement sections will be constructed with a two percent slope, with the low point occurring at the center median. Storm water will be directed towards the Antiguo Canal, Figure 4.3, which is in accordance with the slope of the existing topography. This will reduce changing the existing topography and ensure that the existing flow of storm water runoff is left intact.

5.2.2 Design Option 1 – Underground Storm Sewer Pipes

Design Option 1, Figure 5.5, is a continuous grade PC concrete roadway utilizing underground storm sewer pipes.

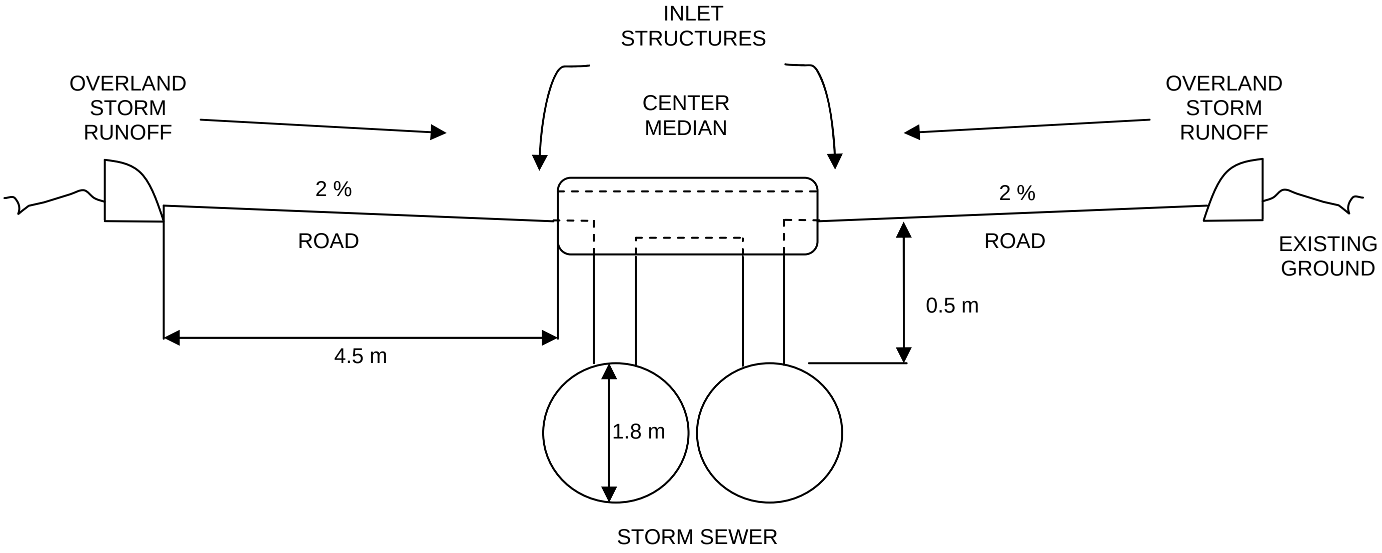


Figure 5.5: Design Option 1.

C.C.E. considered underground storm sewer pipes for four reasons:

1. **Safety**: Underground storm sewer pipes are inaccessible by residents, children, vehicles, and animals. A covered or underground system is the safest design for the community.
2. **Maintenance**: Much of the trash, sediment, and organic material would be prevented from entering the drainage structure. This would reduce maintenance costs and ensure adequate drainage performance.
3. **Environment**: With an underground system, the area between the inlet structures could be developed into green areas and allow infiltration of storm water into the ground water aquifer. This would prevent all of the storm water from being diverted away from the watershed area and would aid in replenishing the local aquifers.
4. **Accessibility**: Vehicle and pedestrian bridges are not needed since the pipes are buried far enough underground to sustain traffic and pedestrian loads. This would allow Avenida Fatima I and side roads to be accessible by pedestrians and traffic at any point along the road.

Storm sewer pipes would consist of two PC concrete pipes, 1.8 m in diameter each. Pipe cover would be 0.5 m. See Appendix I for calculations. Inlet structures would be modified to allow for storm water access to both pipes, Figure 5.6, since a majority of the storm water will enter the drainage structure from the northwest of Avenida Fatima I.

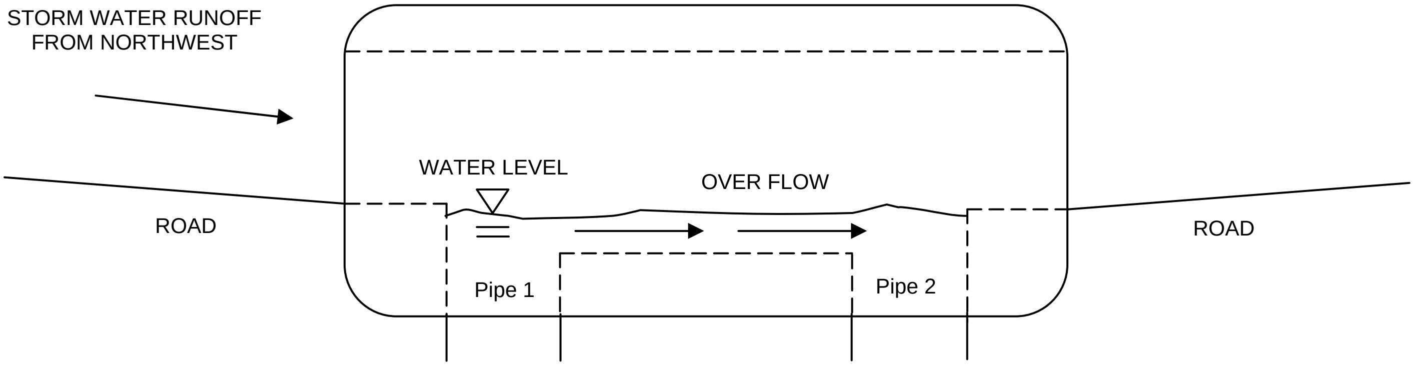


Figure 5.6: Design Option 1 Cross Section of Inlet Structure.

Instead of the traditional method of an inlet entering a single pipe, the inlets on the northwest side would need to be connected to both underground sewer pipes. In Figure 5.6 a general schematic of a possible drainage inlet is shown. In the case of an over flow in Pipe 1, excess storm water is diverted to Pipe 2.

The roadway and underground pipe grade would be sloped less than 0.1%, which is the approximate slope of the existing topography towards the Antiguo Canal. Given the required 0.5 m of pipe cover and 1.8 m pipe diameter, the slope of the existing topography is not possible. A steeper slope could be achieved by adding fill along Avenida Fatima I; however, the existing storm runoff drainage would be altered. Also, given such a small slope, any errors during construction would compromise the operability of the design.

For the following reasons, C.C.E. concluded that Design Option 1 would not be feasible for Avenida Fatima I:

1. Inadequate slope for adequate drainage.
2. Zero tolerance in construction of the underground storm sewer pipes.
3. Removing debris from the pipes would be difficult.

5.2.3 Design Option 2 – Box Culvert Canal

Design Option 2, Figure 5.7, is a continuous grade PC concrete roadway utilizing precast PC concrete box culverts for storm drainage.

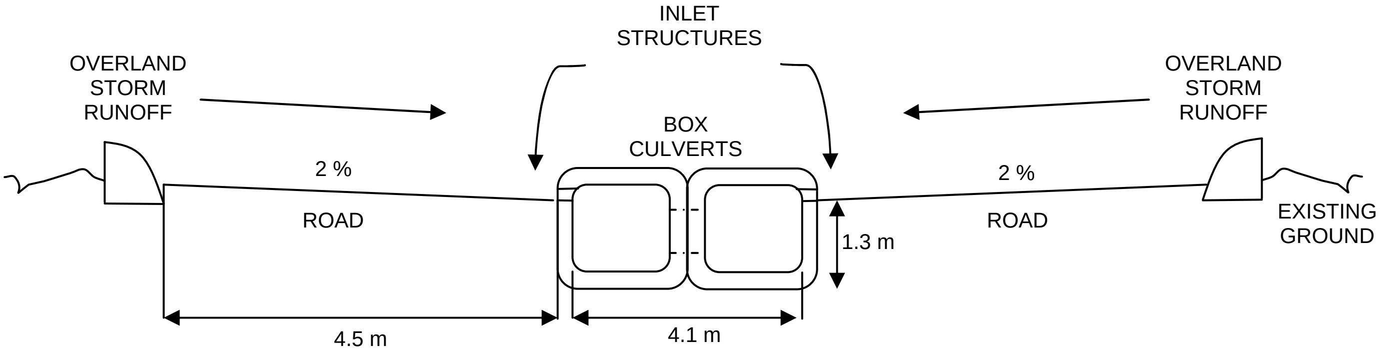


Figure 5.7: Design Option 2.

C.C.E. considered precast PC box culverts for three reasons:

1. **Safety**: A covered canal is inaccessible by residents, children, vehicles, and animals. A covered or underground system is the safest design for the community.
2. **Maintenance**: Much of the trash, sediment, and organic material would be prevented from entering the drainage structure. This would reduce maintenance costs and ensure adequate drainage performance.
3. **Accessibility**: Vehicle bridges are easily constructed and can be incorporated into the box culvert design. Pedestrian bridges are also not needed since the box culverts must be designed to support the weight of pedestrian loads.

The covered concrete canal would be composed of two precast box culverts with a depth of 1.5 m and a base of 2.05 m. Canal depth is limited to 1.3 m below the existing ground, by the existing topography; therefore, the top 0.2 m of the canal would act as a barrier curb for traffic. The canal and road will be sloped 0.1% toward the Antiguo canal and will follow the existing grade as much as possible.

Storm water will enter the canal through inlet structures placed about every 20 m on the upstream side and downstream side for consistency. To reduce costs, inlet structures on the downstream side can be minimized, given the majority of storm water flow is from the upstream side. Typical inlet structures can be seen in Figure 5.8 and are based off of designs provided in the Michigan Department of Transportation's (MDOT) Drainage Manual (17). Given catch basins are not being utilized in the design, the curb-opening inlet would be best option for Avenida Fatima I.

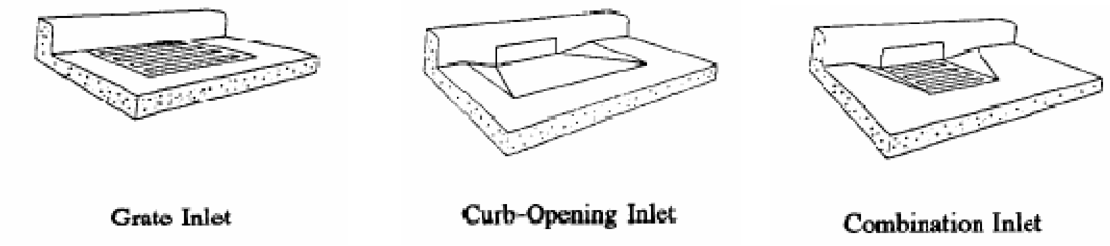


Figure 5.8: Typical Inlet Structures (17).

A majority of storm runoff flows from the northwest of Avenida Fatima I and a section cutout would be required to aid transport of storm water between box culverts, Figure 5.9.

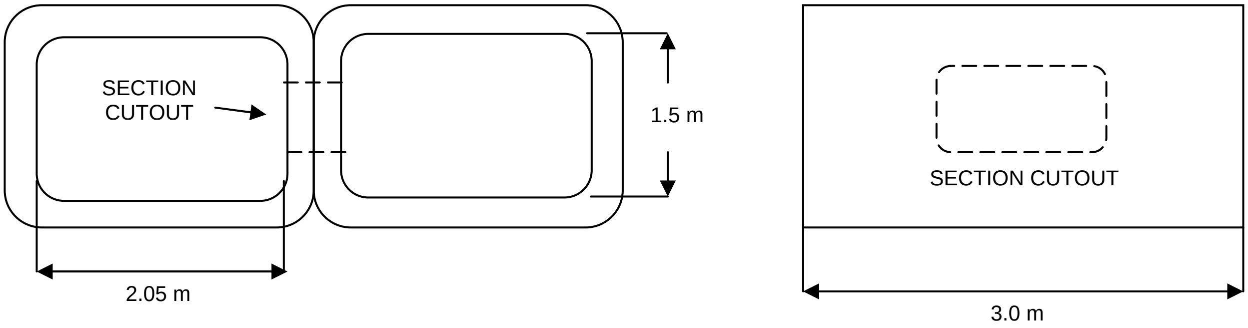


Figure 5.9: Design Option 2 Precast Box Culverts.

In the last 250 m of the southwest end of Avenida Fatima I, the useable cross section width reduces to 8.0 m, which can be seen highlighted in yellow on Figure 5.11 on the next page. However, the required width for Design Option 2 is around 13.5 m. In this section of road, underground storm sewer pipes will be placed under the center line of the road to allow for a narrower cross section. The lane widths will also transition from 4.5 to 3.75 m wide.

The underground storm sewer pipes will follow the road and box culvert grade of 0.1% and will direct storm water towards the Antiguo canal. To allow for the smaller storm sewer pipes, pipes will be designed based on the contributing portion of the watershed only, which can be seen bordered in blue in Figure 5.11. Two PC concrete storm sewer pipes of 1.0 m in diameter will be used. Cover will be 0.3 m and pavement sections will be sloped towards the center line, where drop-in grates will connect directly to the storm sewer pipes, Figure 5.10. Grates will alternate along the reduced section to ensure that storm water runoff is evenly distributed between the two pipes. Both the pipe and drainage grates should be designed by a Professional Engineer to make certain that they can withstand the maximum traffic loads of 11,000 kg/axle.

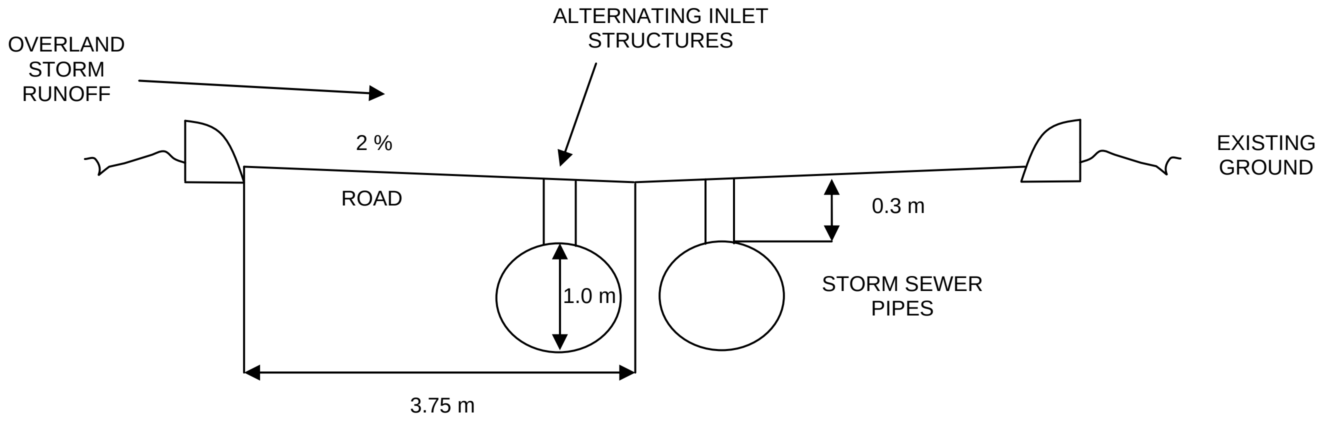


Figure 5.10: Design Option 2 - Underground Storm Sewer Pipe.

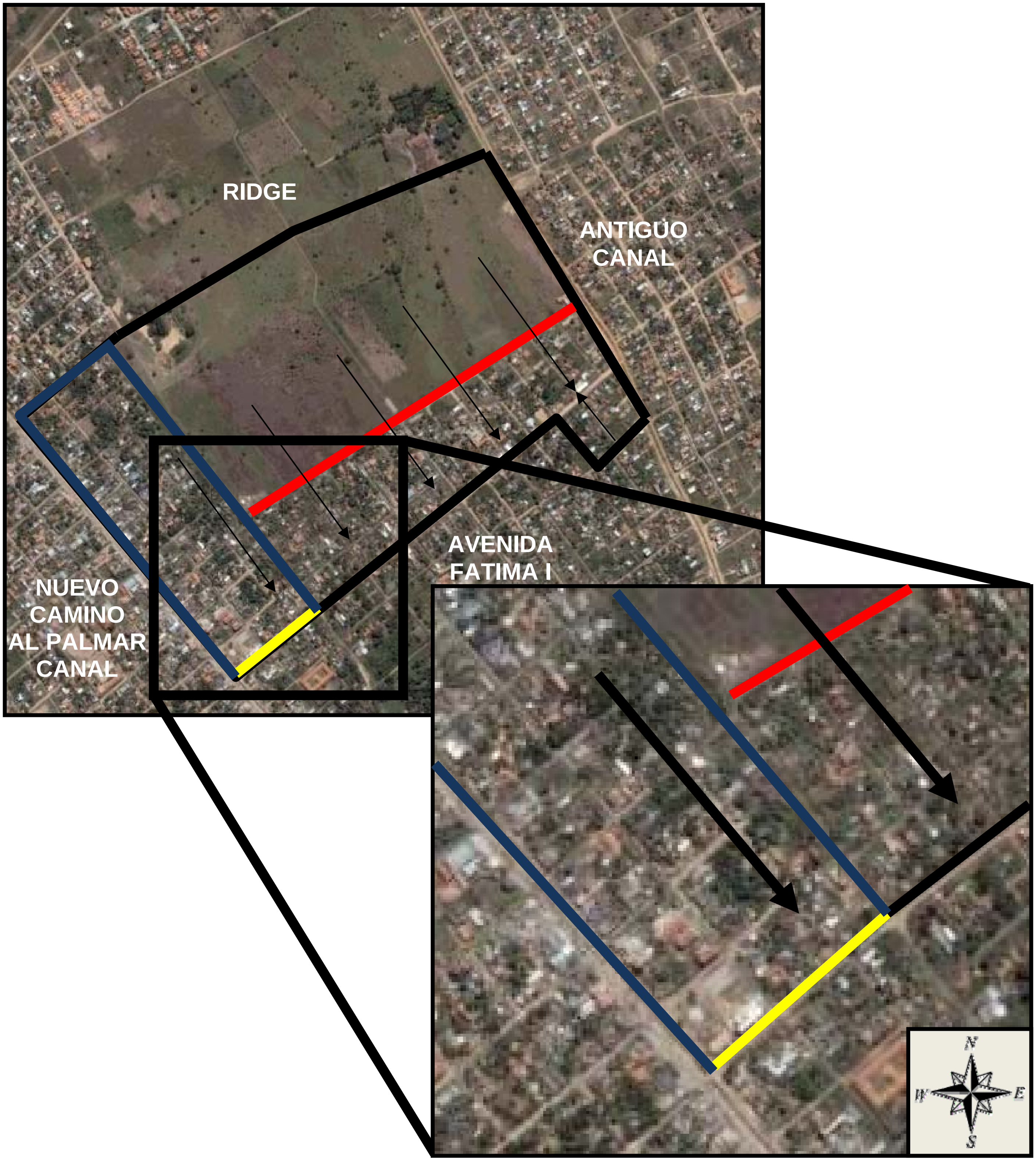


Figure 5.11: Design Option 2 Underground Storm Sewer Pipes

While this option is feasible, safe, and lower in maintenance than an open channel system, there are several concerns.

1. **Safety**: The 4.1 m center median will be larger than the road sections and would be able to fit a vehicle on top. However, the structure will not be designed for this type of loading. If the box culverts were implemented, proper signage or fencing would need to be implemented to ensure that traffic does not occur within the center median.

2. **Constructability**: The box culvert cutout is not typically practiced and constructability is unknown.

3. **Performance**: The box culvert cutout is not typically practiced. However, the cutout is required to allow water to flow between culverts. Because of this, performance of the structure in the field is unknown.

4. **Aesthetic**: The 4.1 m center median will be larger than the road sections, which may not be pleasing to the residents.

5.2.4 Design Option 3 – Open Rectangular Canal

Design Option 3, Figure 5.12, is a continuous grade PC concrete roadway utilizing an open rectangular PC concrete canal for storm drainage.

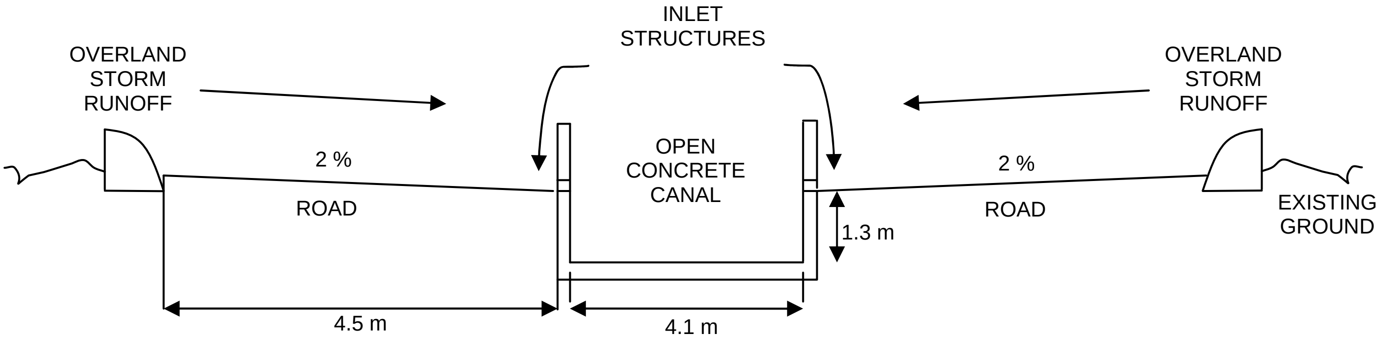


Figure 5.12: Design Option 3.

C.C.E. considered an open rectangular canal for three reasons:

1. **Cost**: An open rectangular canal was foreseen as a cost-effective design by C.C.E. Given the limiting depth of 1.3 m, the canal width is required to be 4.1 m. The covered canal, Design Option 2, requires two box culverts to be constructed to meet these requirements. An open canal would allow for a single structure to be designed that will be able to handle the entire watershed.

2. **Typical Practice**: Open channels were observed to be typical in District 12, as seen by C.C.E. on the recent construction of the Nuevo Camino al Palmar and Antiguo canals which are both open trapezoidal canals. An open rectangular canal was also suggested by Ing. Humberto Calbimonte, who is a practicing civil engineer in Cochabamba, Bolivia. See Appendix F for meeting minutes.

3. **Accessibility for Maintenance**: An open channel will be easiest for maintenance crews to access. Larger equipment can also be utilized during maintenance, because space constraints are not a concern.

Both the road and canal will be sloped 0.1% towards the Antiguo canal. This slope would utilize the existing topography and ensure that the current flow of storm water runoff is left intact. Canal width would be 4.1 m and canal depth would be 1.3 m. The canal depth is limited by the existing topography and cannot exceed 1.3 m in order to meet the specified 0.1% slope.

The canal sides would extend 0.5 m above the road elevation and would act as a barrier curb for traffic and safety precaution for pedestrians. Storm drainage inlets would also be incorporated into the canal sides. Storm water runoff would flow over the roadway and into the canal through the drainage inlets. Drainage inlets would be spaced about every 20 m on both the upstream side and downstream side for consistency. Curb-opening inlets, Figure 5.8, would be utilized, similar to Design Option 2. Inlet structures on the downstream side can be minimized, given the majority of storm water flow is from the upstream side.

In the last 250 m of the southwest end of Avenida Fatima I, the useable cross section width reduces to 8.0 m. The required width for Design Option 3 is around 13.5 m. Underground storm sewer pipes and a narrower pavement width will be utilized in this area, similar to Design Option 2, to allow for a narrower cross section width.

Within Design Option 3, there are two additional alternatives for the canal design:

- **Alternative 3-1**: Utilization of a trapezoidal canal along Avenida Fatima I.
- **Alternative 3-2**: Utilization of the emergency canal to the northwest of Avenida Fatima I, which would reduce the required capacity of the drainage structure.

Alternative 3-1

A trapezoidal canal shape versus a rectangular shape was considered. The trapezoidal canal design would be similar to the rectangular canal design described in Design Option 3, except it would have a side slope of 1.3:1.0, horizontal to vertical, Figure 5.13. This would require a canal bottom width of 2.8 m, canal top width of 5.4 m, and canal depth of 1.3 m.

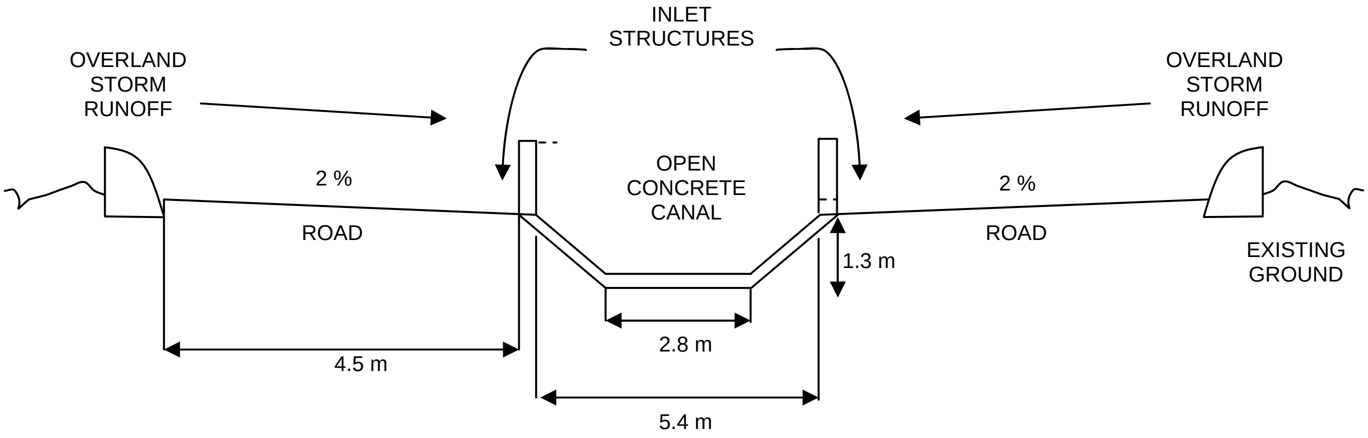


Figure 5.13: Alternative 3-2.

The trapezoidal canal would provide increased flow properties over the rectangular canal; however, the effective width would be 1.3 m longer than the rectangular width. Given the dimensions for the rectangular canal are already similar to the road way widths, a larger canal width may detract from the overall appearance of the structure. For these reasons C.C.E. concluded that the trapezoidal canal would not be feasible for Avenida Fatima I.

Alternative 3-2

The earthen emergency ditch to the northwest of Avenida Fatima I could also be utilized to handle some of flow from the Avenida Fatima I watershed, Figure 4.5. The emergency canal was not incorporated into previous design options, because C.C.E. was told by Sub Alcalde Ing. Victor P. Escobar Díaz and District 12 engineer, Javier Marín, to exclude the canal from storm water runoff calculations. However, after calculating the required dimensions for drainage structures, it may be useful to utilize this canal in conjunction with a drainage structure along Avenida Fatima I, which would reduce overall costs.

Existing topography is the main limiting factor for the drainage structure along Avenida Fatima I. Due to the existing topography, relatively little elevation difference occurs between the either ends of Avenida Fatima I. This makes it difficult to achieve adequate slopes for the drainage structure and is the reason that the drainage structure depth is limited to 1.3 m. If the earthen emergency ditch to the northwest was excavated and utilized in diverting 3.0 cms of the storm water runoff of the Avenida Fatima I watershed, then the width of the open rectangular canal would be reduced to 2.25 m, Figure 5.14.

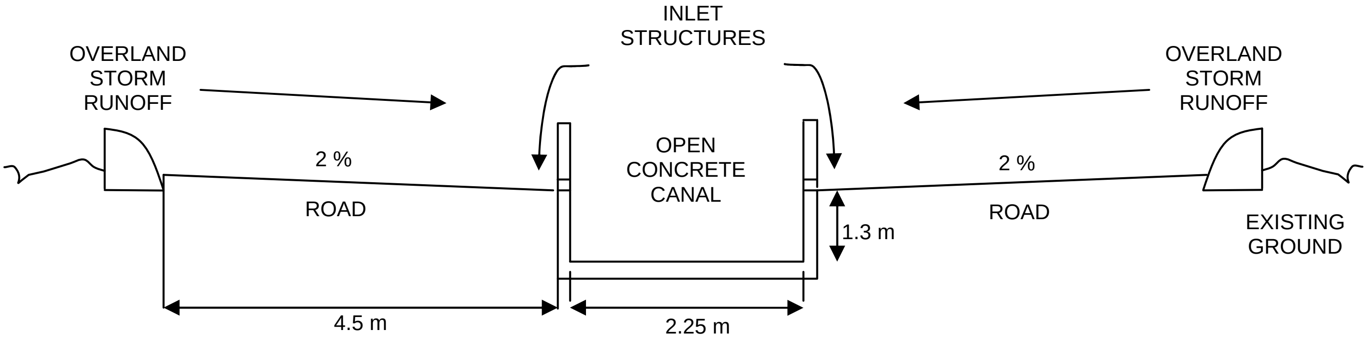


Figure 5.14: Alternative 3-3.

Given Sub Alcalde Ing. Victor P. Escobar Díaz and Ing. Javier Marín told C.C.E. not to incorporate the earthen emergency ditch into the design for Avenida Fatima I, this alternative is not feasible. However, if a future drainage structure is expected to be developed in place of the earthen emergency ditch, it may be cost effective to develop both drainage designs simultaneously.

While this Design Option 3 is feasible and also standard practice in District 12, there are some concerns.

1. **Maintenance**: An open channel will accumulate more sediment, trash, and other debris than a closed or underground drainage structure. Maintenance (cleaning of the canal) must be done regularly to achieve adequate performance of the structure.
2. **Safety**: While a barrier wall is provided to prevent traffic, residents, children, and animals from entering the canal, there is still the risk of access to the canal since it is not covered or underground.

5.3 Pavement Options

C.C.E. considered alternative pavement materials, like asphalt or compacted dirt, in lieu of PC concrete, Figure 5.15.

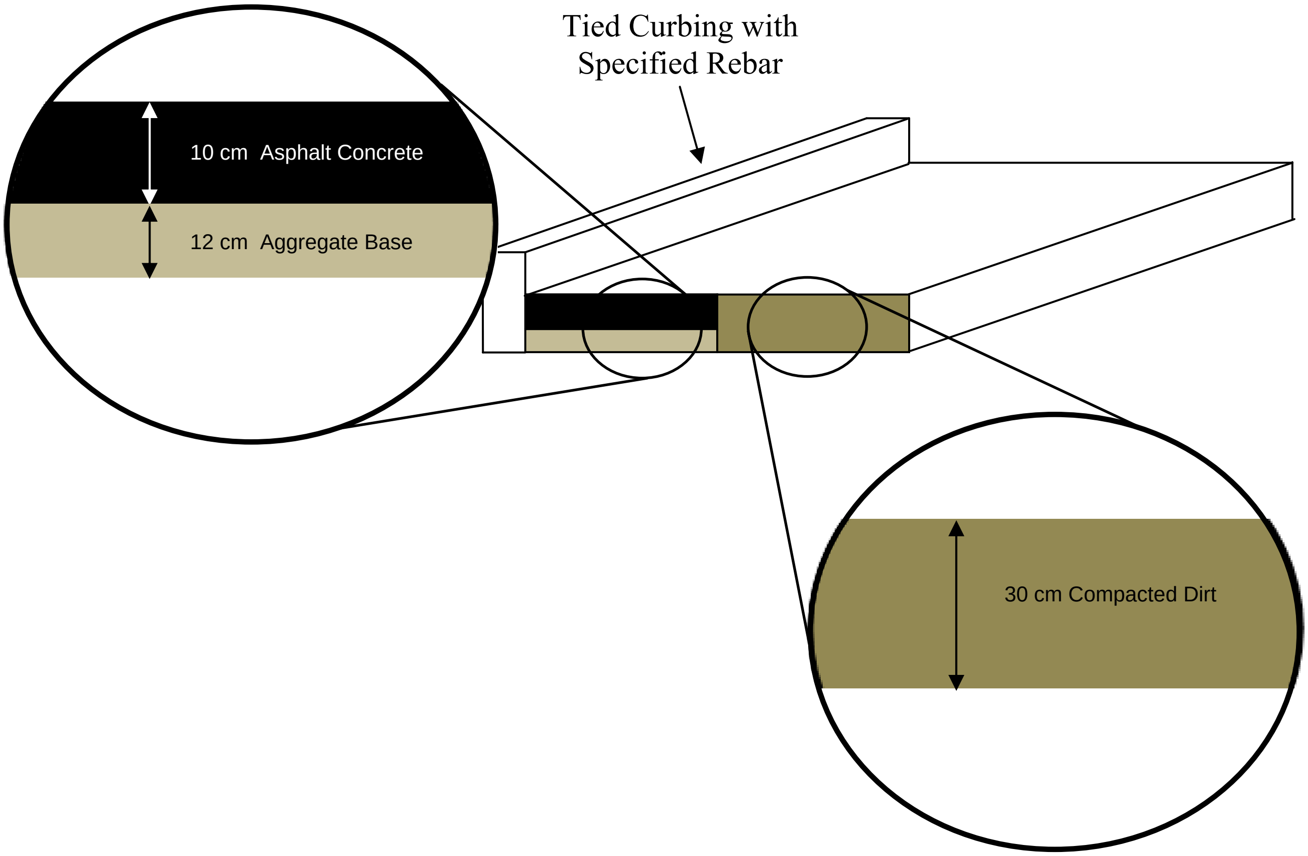


Figure 5.15: Alternative Pavement Cross Sections.

Below the advantages and disadvantages of each material are highlighted.

Portland Cement Concrete Pavement

Advantage(s)	*Disadvantage(s)*
Maximum durability	Environmental – impermeable material
Common construction material	
Minimum maintenance	
Improved road quality	
Reduced dust irritation	

Asphalt Concrete Pavement

Advantage(s)	*Disadvantage(s)*
Less maintenance than compacted dirt	More expensive than compacted dirt and PC concrete
Improved road quality	More maintenance than PC concrete
Reduced dust irritation	Environmental – impermeable material

Compacted Dirt Pavement

Advantage(s)	*Disadvantage(s)*
Least expensive material	Least durable
Utilize existing ground – minimum earthwork	Poor road quality
	Does not reduce dust irritation
	Most required maintenance
	Difficult to control road grade

6.0 Environmental

During field observation, C.C.E. noted several environmental concerns; one of which is a problem with the local sanitary infrastructure. This problem, however, will be addressed by another ISD group. The second concern is that all storm water runoff in District 12 is directed away from the district using canals along the rings and radials. After relaying this observation to project mentors and class instructors, several environmental disadvantages related to this method were noted. Disadvantages are explained:

- Recharge of subsurface aquifers is prevented by diverting storm water away from the source location.

- Increased pollution of surface water bodies by storm water runoff carrying contaminants and trash.

- Sedimentation of surface water bodies by storm water runoff carrying sediment.

Low impact development (LID) for storm drainage is focused on maintaining pre-development conditions for both source and output locations. C.C.E. was hoping to incorporate the LID focus in the design of Avenida Fatima I using detention basins, pervious materials, and sediment traps (19). The first two practices aid in retaining storm water at the source through increased infiltration of storm water. The latter practice aids in capturing sediment and reducing the amount of sedimentation that occurs in output water bodies. A fourth practice that was not researched for implementation in Avenida Fatima I, but may be of interest, is wetland restoration.

Detention Basins

Detention basins operate by retaining excess storm water in a constructed earthen depression to allow time for infiltration into ground water aquifers. Given a large portion of the Avenida Fatima I watershed is undeveloped to the northwest, Figure 4.5, C.C.E. thought that placement of a detention basin in this area would be possible. By incorporating the detention basin, the disadvantages listed above would be reduced, along with a reduction in the required capacity of the drainage structure along Avenida Fatima I. However, upon further research, C.C.E. decided that a detention basin would not be feasible for the Avenida Fatima I drainage plan for two reasons:

1. **Low infiltration rates:** Given the soil in District 12 was found to contain clay; low infiltration rates of storm water are expected. During the rainy season, the storm water is not expected to infiltrate at a fast enough rate; therefore, standing water would persist.
    a. Standing water would support mosquito populations.

    b. Large bodies of standing water would pose a safety risk in the neighborhood.

2. **High water table:** Given there is a high water table throughout District 12, the detention basin would be limited in depth; therefore, a larger area would be required.

Pervious Materials

Pervious materials, which are materials that allow some water to flow through the material itself, were also seen as a possibility along Avenida Fatima I. Pervious materials include some asphalts, concretes, and paving stones. C.C.E. was hoping to utilize these materials a an alternative pavement material. This would reduce the imperviousness of the roadway and reduce the effects of the disadvantages listed above. However, upon further research, C.C.E. decided that pervious materials would not be feasible for the Avenida Fatima I drainage plan for three reasons:

1. **Conditions along Avenida Fatima I are not optimal for pervious materials:** Pervious materials rely on larger void contents within the microstructure. This allows for the flow of water through the materials.
    a. The topsoil along Avenida Fatima I consists mostly of sands, which would clog the microstructure of the pervious material. To combat this problem, increased maintenance would be required. However, if this problem is not dealt with, decreased or no water infiltration can be expected.
    b. Due to the larger void content, materials are more suited for lower traffic areas (i.e. parking lots or sidewalks) (19). Avenida Fatima I is expected to encounter high traffic loads and frequency.
2. **Low infiltration rates:** Given the soil in District 12 was found to contain clay; low infiltration rates of storm water are expected. In addition, the length of road is relatively short in comparison to surrounding roads, thus the effects of utilizing a pervious material in these conditions may not have a large impact on the overall amount of storm water infiltration in the Avenida Fatima I watershed.
3. **Non-typical practice:** Usage of pervious materials within District 12 was not encountered by C.C.E. during field observation and is not considered by C.C.E. to be a typical construction practice in Bolivia. Implementation of the construction material may be difficult and expensive.

Sediment Traps

Sediment traps capture sediment carried by storm water runoff before it reaches the output water body. This can be accomplished in several ways; however, C.C.E. thought that a settling tank concept would be the best approach for Avenida Fatima I. In this concept, depressed sections are placed along the canal to allow for settlement of sediment and other debris, Figure 6.1.

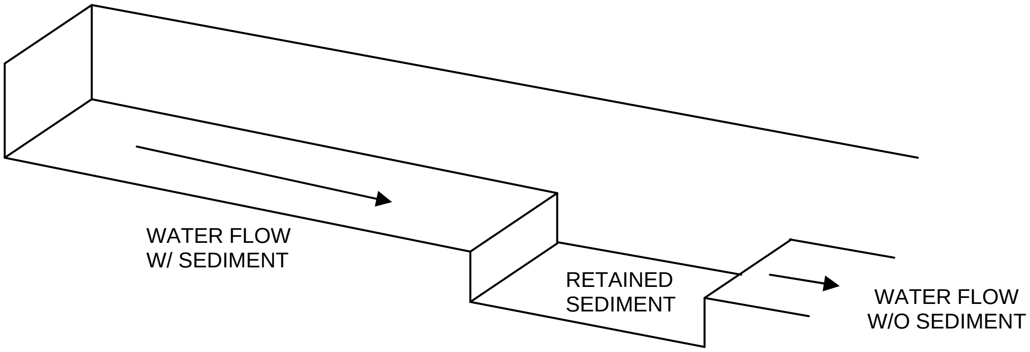


Figure 6.1: Sediment Trap

Trap dimensions were found using the critical settling velocity of the smallest sediment particle desired to be removed from the storm water runoff. Equations for critical settling velocity, retention time, and sediment trap length can be seen in Equations 5 – 7 (16).

$$v_s = \left[\frac{4g(\rho_s - \rho)d}{3C_D\rho}\right]^{1/2} \quad (Equation\ 5)$$

v_s = Settling Velocity (m/s)
g = Gravitational Constant (9.81 m/s^2)
ρ_S = Density of Particle (kg/m^3)
ρ = Density of Fluid (kg/m^3)
d = Particle Diameter (m)
C_D = Coefficient of Drag (unit less)

$$\tau = \frac{h}{v_S} \quad (Equation\ 6)$$

τ = *Retention Time (s)*
h = *Tank Depth (m)*

$$L_s = V_c * \tau \quad (Equation\ 7)$$

L_S = *Sediment Trap Length (m)*
V_C = *Channel Velocity (m/s)*
τ = *Retention Time (s)*

Sediment traps within the Avenida Fatima I drainage plan would reduce sedimentation of the output water body and also prevent other debris from polluting the water body. C.C.E., therefore, recommends that sediment traps of 9.0 m in length be placed every 81 m, center-to-center along the Avenida Fatima I drainage structure. See Appendix I for calculations.

Wetland Restoration

Wetland restoration is another alternative that is possible for District 12; however, it's applicability for Avenida Fatima I is unknown. The source of the curichi is a quebrada to the northwest of Avenida Fatima I, beyond the watershed boundaries, and may be beneficial in capturing excess storm water runoff at the source. While standing water is typically seen as a detriment because it supports the reproduction of mosquitoes, some studies have shown that healthy wetlands are not susceptible to large mosquito populations like once thought (18). A healthy wetland supports a range of creatures, some of which are predators to mosquitoes. Through utilization of animals that prey on mosquitoes, a wetland can be established that does not support mosquito populations, but does retain storm water and reduce flooding.

(a) (b)

Figure 6.2: (a) and (b) Photographs of Wetlands Taken in May of 2008 by Ing. Linda Phillips.

Wetlands, like those pictured in Figure 6.2, must be maintained and protected in order to aid in water retention.

7.0 Cost - Benefit Analysis

Cost data was obtained from the Planification's Department in Santa Cruz's main office. The data is based on several sources, which include company estimates and experience. Each design option was broken down into a set of activities. A takeoff for each activity was completed and the estimated quantity was used to obtain an estimated cost. The costs and benefits of Design Options 2 and 3, along with the alternative materials are shown. Costs were rounded to the nearest thousand. See Appendix J for a detailed cost breakdown.

Table 7.1: Cost Estimate for Design Option 2.

Design Option 2	
Activity	**Cost (Bs)**
Mobilization and Site Layout (Pavement and Drainage)	21,000
PC Concrete Pavement and Curb	1,679,000
Precast PC Concrete Box Culverts	5,037,000
PC Concrete Storm Drainage Pipe	454,000
Connection to Antiguo Canal	82,000
Erosion Control	5,000
Total	**7,278,000**
Total USD	**1,026,500**

Design Option 2 Benefits

1. **Safety**: Drainage structure is covered and prevents residents, children, animals, or traffic along Avenida Fatima I from entering the canal.

2. **Maintenance**: Drainage structure is covered and prevents some sediment, trash, and other debris from entering the canal.

Table 7.2: Cost Estimate for Design Option 3.

Design Option 3	
Activity	**Cost (Bs)**
Mobilization and Site Layout (Pavement and Drainage)	21,000
PC Concrete Pavement and Curb	1,679,000
PC Concrete Open Rectangular Canal	2,782,000
PC Concrete Storm Drainage Pipe	454,000
Connection to Antiguo Canal	82,000
Erosion Control	5,000
Total	**5,023,000**
Total USD	**708,500**

Design Option 3 Benefits

1. **Cost**: Design Option 3 is the less expensive option of the two feasible design options.

2. **Standard Design**: An open channel has been observed to be standard practice in District 12 and design and constructability will be familiar.

    a. A civil engineer from Cochabamba, Bolivia, Ing. Humberto Calbimonte, also suggested this design option and said that it would probably be the most appropriate and cost effective design, given the conditions.

Table 7.3: Cost Estimate for Alternative Pavement Materials.

Alternative Pavement Materials	
PC Concrete Pavement	
Activity	**Cost (Bs)**
Earthwork	93,000
Level and Compact Existing Ground	51,000
Provide and Place Crushed Base	67,000
Concrete Slab Pavement	1,141,000
Rebar for Load Transfer	23,000
Delivery and Placement of Curb	123,000
Total	**1,498,000**
Total USD	**211,300**
Asphalt Concrete Pavement	
Activity	**Cost (Bs)**
Earthwork	93,000
Level and Compact Existing Ground	51,000
Provide and Place Crushed Base	67,000
Delivery and Placement of Asphalt	1,692,000
Delivery and Placement of Curb	123,000
Total	**2,025,000**
Total USD	**285,600**
Compacted Dirt	
Activity	**Cost (Bs)**
Earthwork	93,000
Level and Compact Existing Ground	51,000
Total	**144,000**
Total USD	**20,300**

PC Concrete Pavement Benefits

1. **Standard Practice**: While in Bolivia, PC concrete pavement was observed by C.C.E. to be a typical pavement material. Use of asphalt pavement was not observed and use of compacted dirt was noticed in the outer rings, where development is still progressing.

2. **Durable**: PC concrete pavement is the most durable of the three pavement materials and will require the least amount of maintenance.

3. **Cost**: PC concrete pavement is less expensive than asphalt concrete pavement and is still a durable pavement material.

4. **Quality of Life**: PC concrete pavement will reduce the amount of exposed sandy soil along Avenida Fatima I. This will reduce the discomfort of residents and increase visibility.

Asphalt Concrete Pavement Benefits

1. **Durable**: Asphalt concrete pavement is more durable than a compacted dirt road and will require less maintenance. However, it is not as durable as PC concrete.

2. **Quality of Life**: Asphalt concrete pavement will reduce the amount of exposed sandy soil along Avenida Fatima I. This will reduce the discomfort of residents and increase visibility.

Compacted Dirt Pavement Benefits

1. **Cost**: Compacted dirt pavement is the least expensive pavement material. However, over the design life of the road, it will require more maintenance than both PC and asphalt concrete pavements.

8.0 Recommendations

After considering the previously discussed design options, C.C.E. decided that the open rectangular canal utilizing sediment traps with PC concrete pavement, Design Option 3, is the most feasible option for Avenida Fatima I. This design option must utilize a temporary diversion canal in Location B of Figure 5.2. The temporary diversion will direct the curichi away from UV 177 towards the Nuevo Camino al Palmar canal. In the future, International Road will be developed and the temporary diversion will be incorporated into the drainage design of that road. This design option was recommended for the following reasons:

1. **Constructible**: Underground storm sewer pipe, Design Option 1, while being safest, is limited to a non-constructible slope due to the topography along Avenida Fatima I. Therefore, the design is not feasible due to constructability.

2. **Standard Practice**: An open channel is a standard storm drainage design for areas in and around District 12. PC concrete pavement is also standard practice, no asphalt pavements were observed by C.C.E. while in Bolivia. Compacted dirt pavements were observed; however, only in the outer rings, where development is still progressing. In the inner rings, pavement materials were composed of PC concrete.

3. **Cost**: An open channel is least costly of the two feasible design options. When broken down into pavement costs, PC concrete is less expensive than asphalt concrete pavement.

4. **Environment**: Sediment traps will reduce the amount of sediment that is transported to output bodies of water, which in the end reduces the amount of sedimentation that occurs in those bodies of water.

5. **Maintenance**: PC concrete pavement is more durable than both asphalt concrete and compacted dirt. It will require less maintenance throughout the year.

6. **Quality of Life**: PC concrete pavement will reduce the amount of exposed sandy soil along Avenida Fatima I. This will reduce the discomfort of residents and increase visibility.

Additional areas that should be researched for this design are the implementation of pedestrian and vehicle bridges and supplementary soil bores. Given the members of C.C.E. are not licensed as Professional Engineers, the structural design of pedestrian and vehicle bridges was not completed for safety reasons. However, two to three bridges of both styles should be implemented along Avenida Fatima I to allow traffic to access both sides of the road. Bridges were not included in the cost estimate; therefore, an estimation of the additional cost of these structures should be included in the final design. Also, while in Bolivia, C.C.E. was unable to perform several procedures. Procedures include additional soil bores, traffic count, and calculation of stream velocity of the curichi. These tests should be performed, with additional soil bores being completed every 100 to 150 m at depths of 1.5 to 3.0 m.

The total cost for this option is **$5,023,000 Bs** or **$708,500 USD**. The project time line should be about six calendar months, see Appendix K for more information.

9.0 Summary and Conclusion

A PC concrete roadway and open rectangular canal is recommended for implementation along Avenida Fatima I. The canal will collect overland storm runoff coming off the Avenida Fatima I watershed, Figure 4.5, and direct it towards the Antiguo canal to the north. An assessment of the Antiguo canal must be performed to ensure that the structure can handle the additional storm water runoff. District 12 should also try to coordinate the Avenida Fatima I drainage structure with additional or future drainage structures in the watershed area. If a paved road and drainage structure are expected to be developed along the emergency canal to the northwest, a combined design incorporating both structures should be developed. This will reduce redundancy and decrease costs.

The recommended drainage structure was based on the 10 year storm. However, C.C.E. is aware that this level of risk may not be appropriate for District 12. Figure 9.1 depicts the change in cost of the rectangular canal, given a varying level of risk. In this case risk is associated with the design storm recurrence interval for determination of the over land storm runoff.

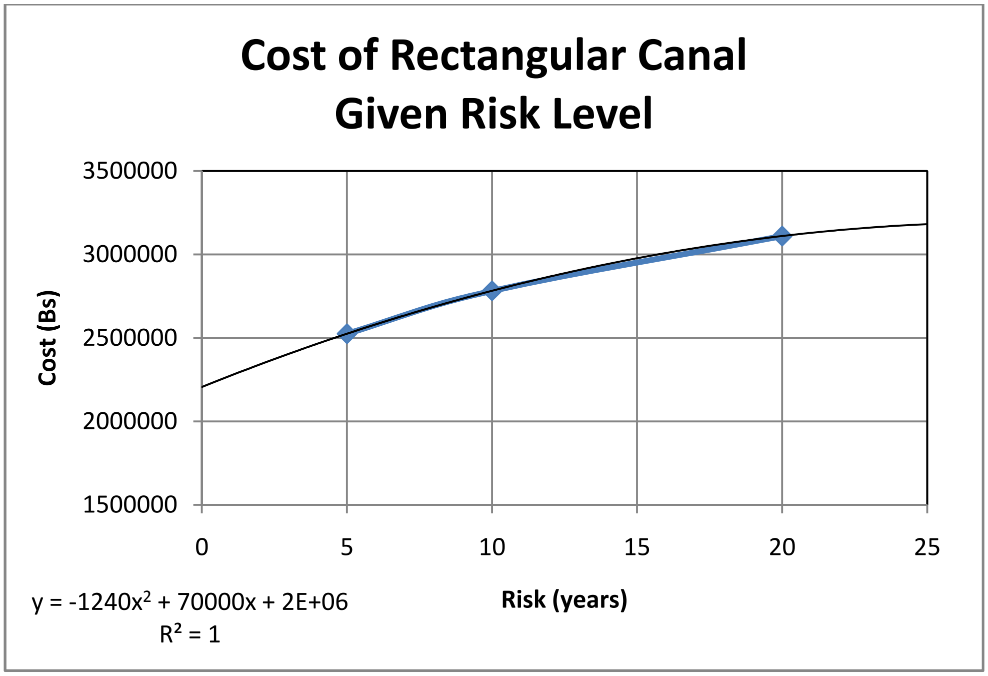


Figure 9.1: Cost of Rectangular Canal Given Risk Level.

10.0 References

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Appendix A – Precipitation Data

Agrotechnologica Amazonica is an organization dedicated towards the mission of "Contributing to the understanding and preservation of natural resources in Tropical America (1)." Online, they provide compiled climate and soil data for the Amazon regions and South America. Figure A 1 through Figure A 5 detail precipitation in the department of Santa Cruz. Figures were created from data compiled from the Compendio Meteorologico del Departamento de Santa Cruz 1992.

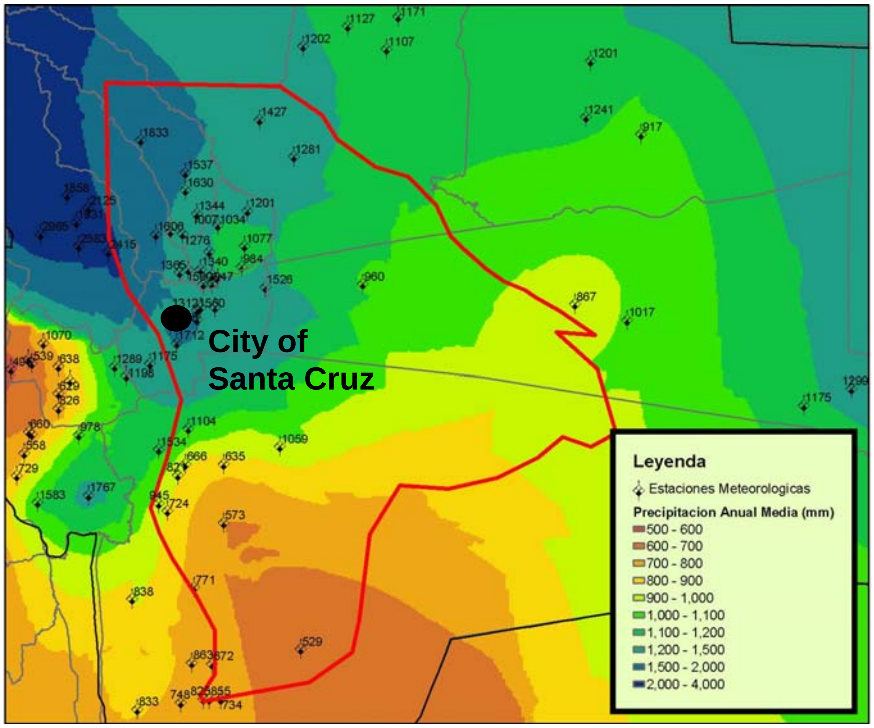


Figure A 1: Historical Precipitation for the Department of Santa Cruz

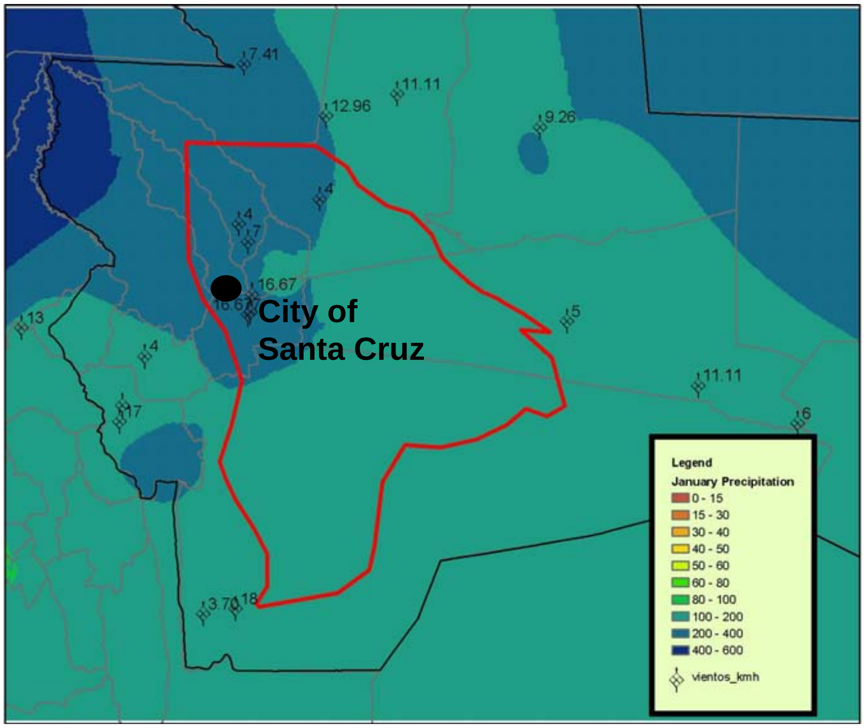


Figure A 2: Historic Precipitation for the Month of January in the Department of Santa Cruz

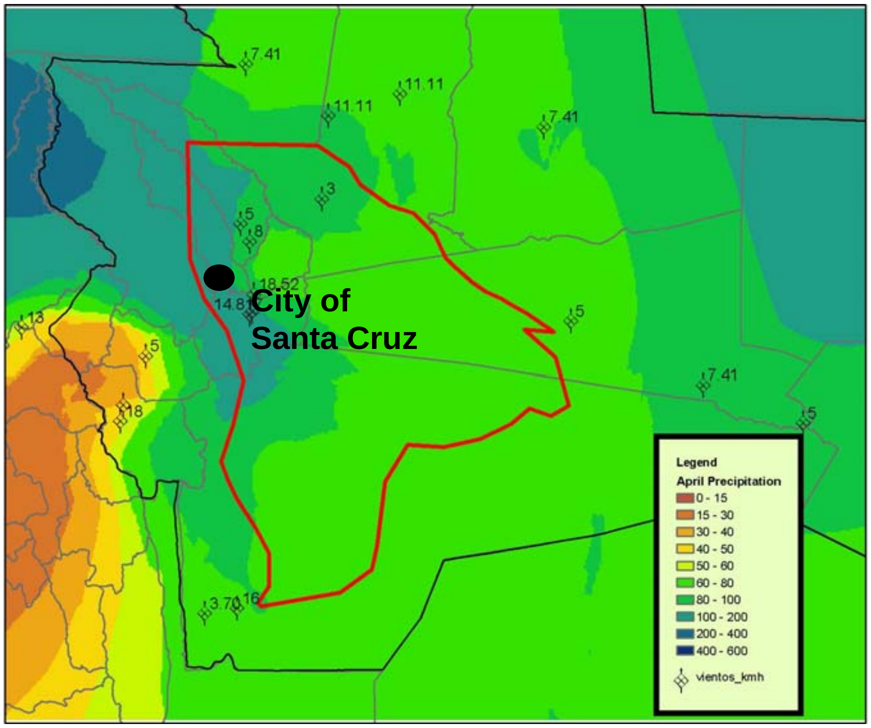


Figure A 3: Historic Precipitation for the Month of April in the Department of Santa Cruz

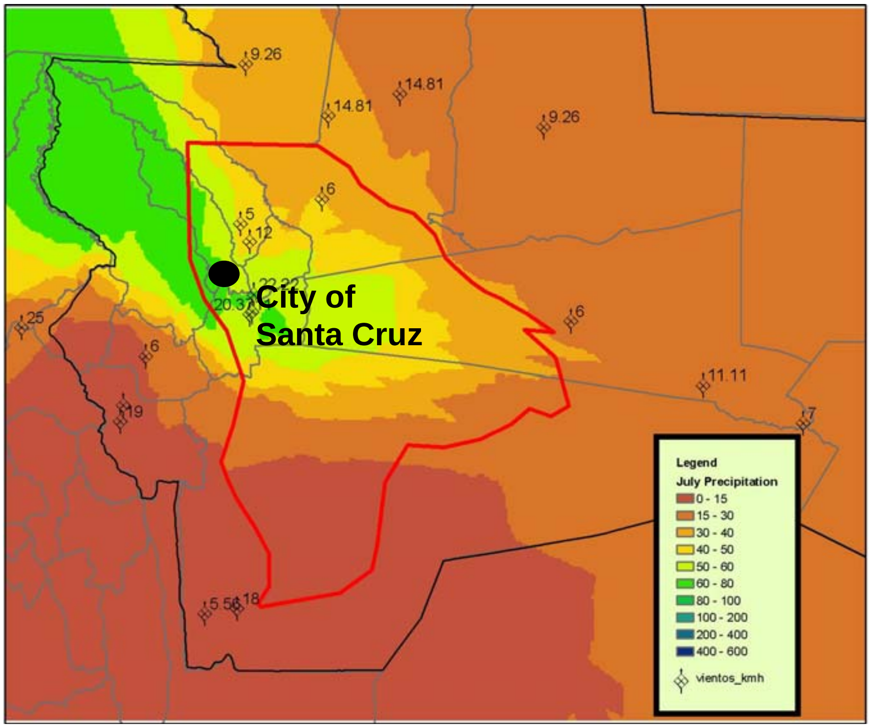


Figure A 4: Historic Precipitation for the Month of July in the Department of Santa Cruz

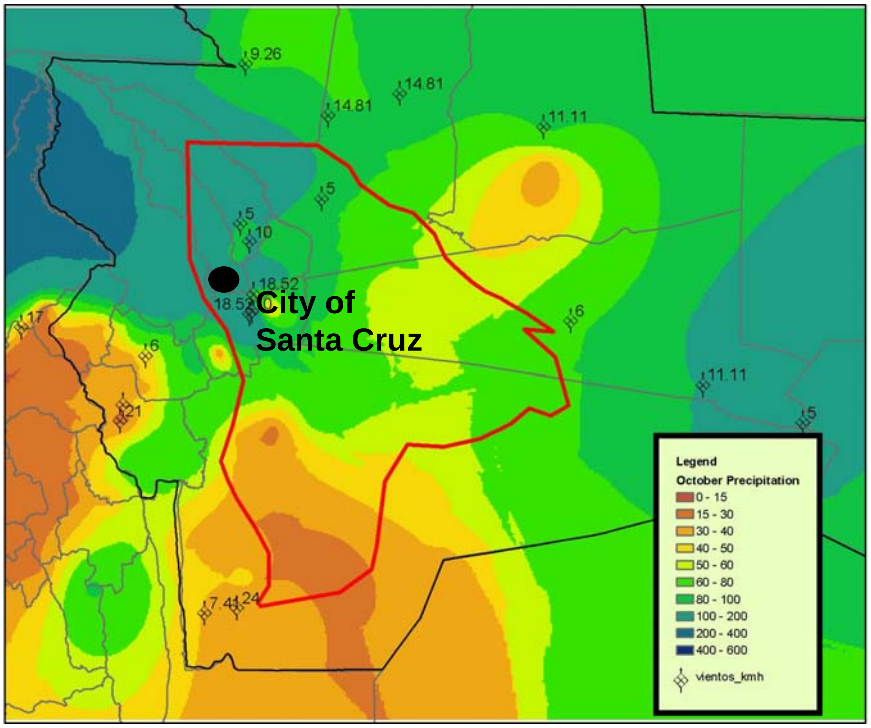


Figure A 5: Historic Precipitation for the Month of October in the Department of Santa Cruz

Appendix B – Health Summary

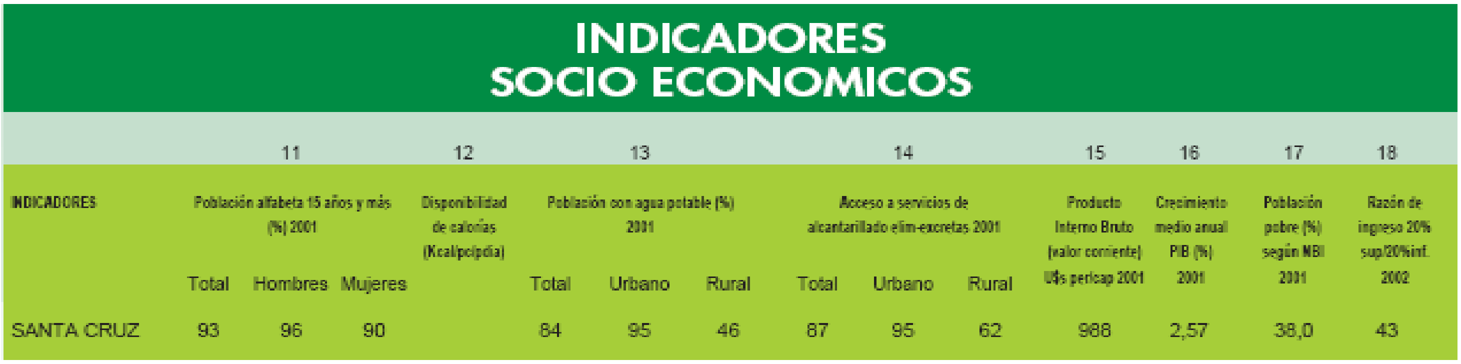
Health data was obtained from the **Bolivia - Situación de Salud, Indicadores Básicos 2003**, which is a collaborative effort of: the Ministerio de Salud y Deportes, Organización Panamericana de la Salud, and Instituto Nacional de Estadística. The following excerpts are specific to the department of Santa Cruz.

DEMOGRAPHIC INDICATORS

INDICADORES DEMOGRAFICOS

	1	2	3	4	5	6	7	8	9	10		
INDICADORES	Población total (miles) 2001	Tasa cruda natalidad (1,000 hab) 2001	Media anual nacimientos (miles) 2001	Tasa cruda mortalidad (miles) 2000-2005	Media anual defunciones (miles) 2001	Crecimiento demográfico anual (%) 2001	Tasa global fecundidad (hijos/mujer) 2001	Población urbana (%) 2001	Razón de dependencia (1,000 hab) 2001	Esperanza de vida al nacer (años) 2000-2005		
										Total	Hombres	Mujeres
SANTA CRUZ	2,029	27,7	56,1	5,9	12,0	4,29	4,2	76,2	76	67,7	66	69,6

SOCIAL/ECONOMIC INDICATORS



INDICADORES SOCIO ECONOMICOS

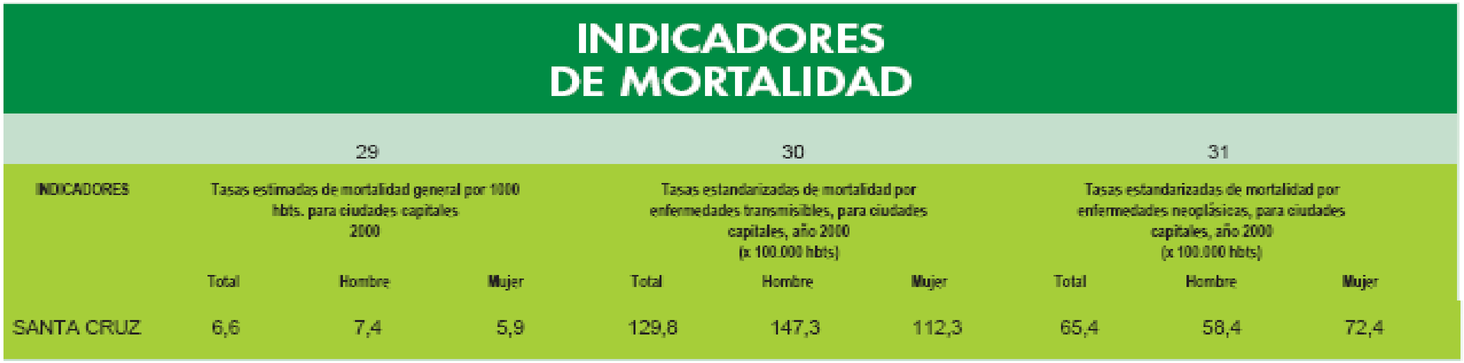
	11			12	13			14			15	16	17	18
INDICADORES	Población alfabeta 15 años y más (%) 2001			Disponibilidad de calorías (Kcal/pc/pdia)	Población con agua potable (%) 2001			Acceso a servicios de alcantarillado elim-excretas 2001			Producto Interno Bruto (valor corriente) U$s per/cap 2001	Crecimiento medio anual PIB (%) 2001	Población pobre (%) según NBI 2001	Razón de ingreso 20% sup/20%inf. 2002
	Total	Hombres	Mujeres		Total	Urbano	Rural	Total	Urbano	Rural				
SANTA CRUZ	93	96	90		84	95	46	87	95	62	988	2,57	38,0	43

MORTALITY INDICATORS

INDICADORES DE MORTALIDAD

	19	20	21	22	23		24	25	26	27	28
INDICADORES	tasa de mortalidad materna (x 1.000 nv) 1994	tasa de mortalidad infantil (x 1.000 nv) 2001	tasa de mortalidad < 5 años (x 1.000 nv) 1998	Causas de defunciones en hospitales < 5 años por:			Defunciones registradas por:				Sobreregistro de mortalidad (%) 2000
				Diarrea (%) 2000	Neumonía (%) 2000	Otras (%) 2000	Homicidio 2002 Nº	Suicidio 2002 Nº	Accidente de vehículo Nº 2002	Causa mal definida (%) 2001	
SANTA CRUZ		54	64	23	14	63	62	63	121	4,3	76

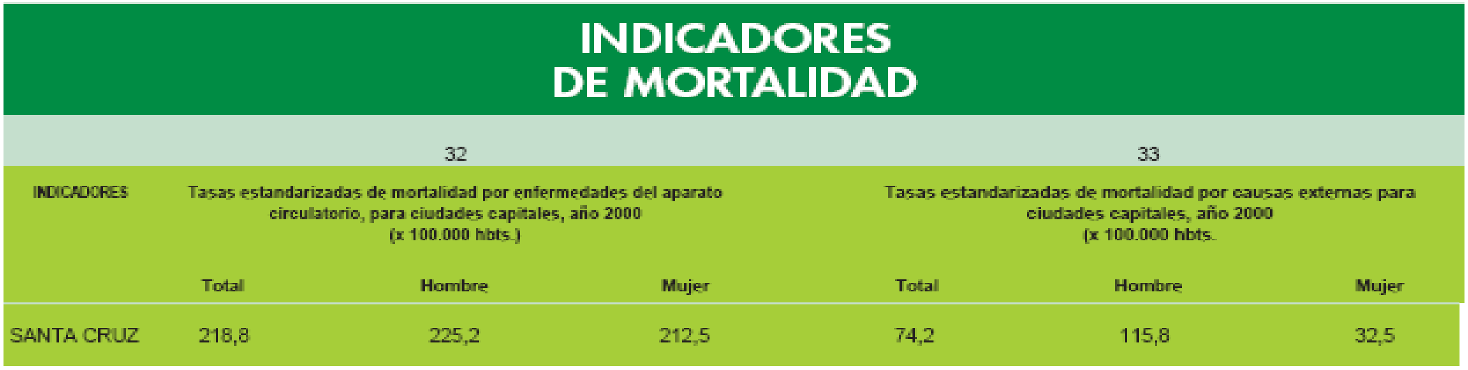
MORTALITY INDICATORS



INDICADORES DE MORTALIDAD

	29			30			31		
INDICADORES	Tasas estimadas de mortalidad general por 1000 hbts. para ciudades capitales 2000			Tasas estandarizadas de mortalidad por enfermedades transmisibles, para ciudades capitales, año 2000 (x 100.000 hbts)			Tasas estandarizadas de mortalidad por enfermedades neoplásicas, para ciudades capitales, año 2000 (x 100.000 hbts)		
	Total	Hombre	Mujer	Total	Hombre	Mujer	Total	Hombre	Mujer
SANTA CRUZ	6,6	7,4	5,9	129,8	147,3	112,3	65,4	58,4	72,4

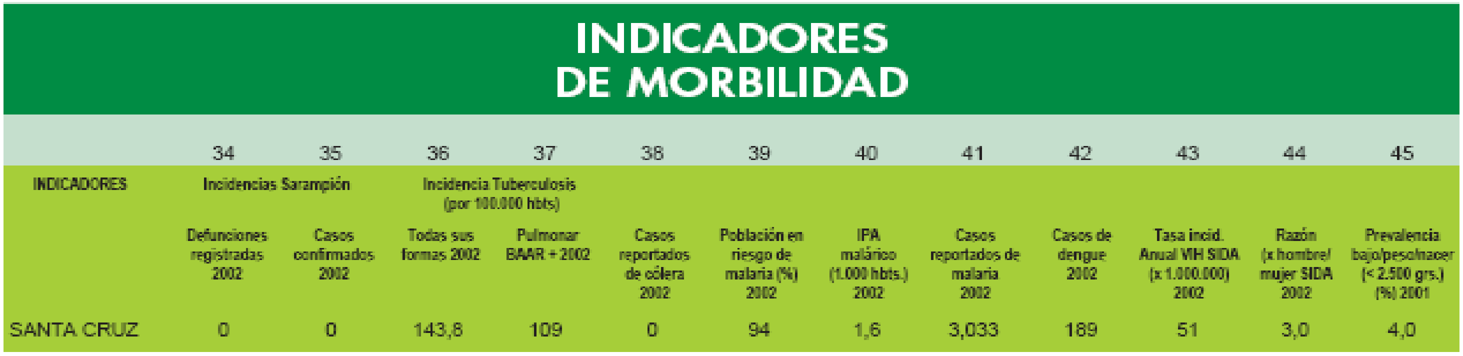
MORTALITY INDICATORS



INDICADORES DE MORTALIDAD

	32			33		
INDICADORES	Tasas estandarizadas de mortalidad por enfermedades del aparato circulatorio, para ciudades capitales, año 2000 (x 100.000 hbts.)			Tasas estandarizadas de mortalidad por causas externas para ciudades capitales, año 2000 (x 100.000 hbts.		
	Total	Hombre	Mujer	Total	Hombre	Mujer
SANTA CRUZ	218,8	225,2	212,5	74,2	115,8	32,5

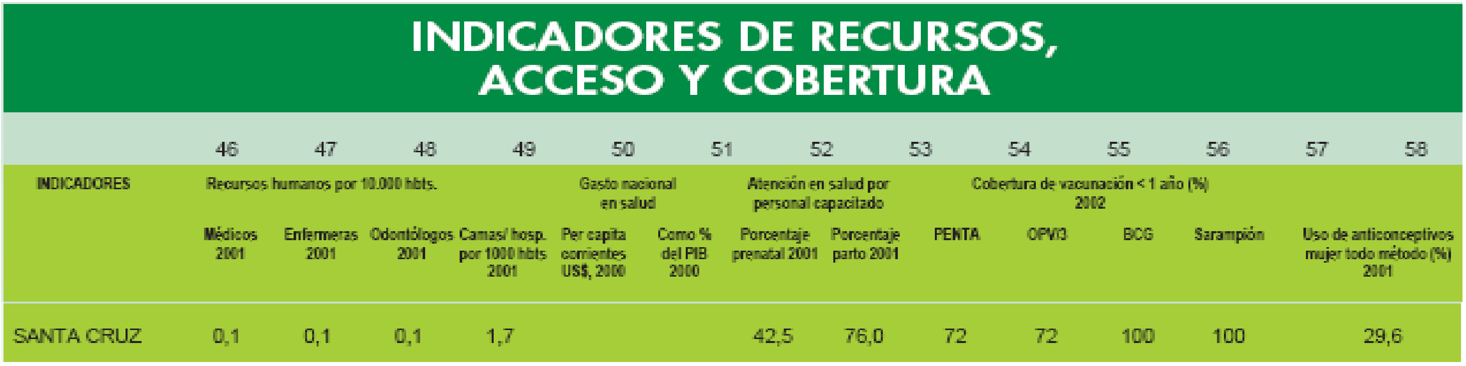
MORBIDITY INDICATORS



INDICADORES DE MORBILIDAD

	34	35	36	37	38	39	40	41	42	43	44	45
INDICADORES	Incidencias Sarampión		Incidencia Tuberculosis (por 100.000 hbts)									
	Defunciones registradas 2002	Casos confirmados 2002	Todas sus formas 2002	Pulmonar BAAR + 2002	Casos reportados de cólera 2002	Población en riesgo de malaria (%) 2002	IPA malárico (1.000 hbts.) 2002	Casos reportados de malaria 2002	Casos de dengue 2002	Tasa incid. Anual VIH SIDA (x 1.000.000) 2002	Razón (x hombre/ mujer SIDA 2002	Prevalencia bajo/peso/nacer (< 2.500 grs.) (%) 2001
SANTA CRUZ	0	0	143,8	109	0	94	1,6	3,033	189	51	3,0	4,0

RESOURCES, ACCESS AND COVER INDICATORS



INDICADORES DE RECURSOS, ACCESO Y COBERTURA

	46	47	48	49	50	51	52	53	54	55	56	57	58
INDICADORES	Recursos humanos por 10.000 hbts.				Gasto nacional en salud		Atención en salud por personal capacitado		Cobertura de vacunación < 1 año (%) 2002				
	Médicos 2001	Enfermeras 2001	Odontólogos 2001	Camas/ hosp. por 1000 hbts 2001	Per capita corrientes US$, 2000	Como % del PIB 2000	Porcentaje prenatal 2001	Porcentaje parto 2001	PENTA	OPV3	BCG	Sarampión	Uso de anticonceptivos mujer todo método (%) 2001
SANTA CRUZ	0,1	0,1	0,1	1,7			42,5	76,0	72	72	100	100	29,6

Appendix C – Topographic Survey

Topographic Survey Procedure

1. Setup Top Con on tripod over control point and level the instrument.
2. Connect the TDS data recorder.
3. Measure the height of instrument and prism to put into data recorder.
4. Backsight previous control point.
5. Take necessary sideshots while utilizing radio communication to verify when point was taken properly.
6. Check data collected in data recorder to verify accuracy.
7. Traverse to next location and repeat steps 1-6.
8. Input data into PC using Foresight Program.

Google images of Avenida Fatima I were utilized to identify existing streets and infrastructure. Traverse points and benchmarks were noted on these images during surveying and are provided below, along with photographs of each benchmark.

Figure B 1: Google Image of Avenida Fatima I (2)

Figure B 2: Google Image of Northeast End of Avenida Fatima I

NOTES

TR – 1: Traverse point 1 and start of survey at northeast end of Avenida Fatima I
TR – 2: Traverse point 2
TR – 3: Traverse point 3
TR – 4: Traverse point 4
TR – 5: Traverse point 5

BM – 1: Benchmark 1 set by C.C.E. and marked BM1 ISD M-08. Benchmark location is on the southwest corner of the Antiugo bridge to the northeast of Avenida Fatima I. Upon returning to BM 1 it was found that recent construction had covered the benchmark location. However, dimensional data taken during the survey can be used to relocate the BM 1and is provided below.

BM – 2: Benchmark 2 set by C.C.E. and marked BM2 ISD M-08. Benchmark location is on a concrete slab located near the northeast end of Avenida Fatima I. Dimensional data was also taken for BM 2 and is provided below.

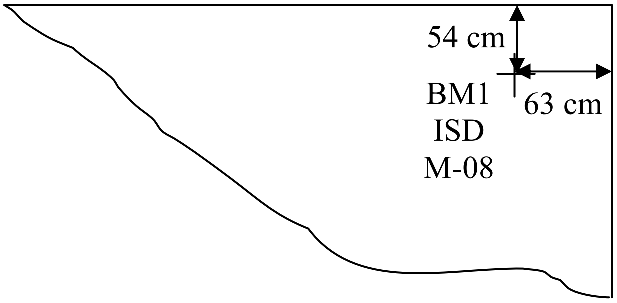
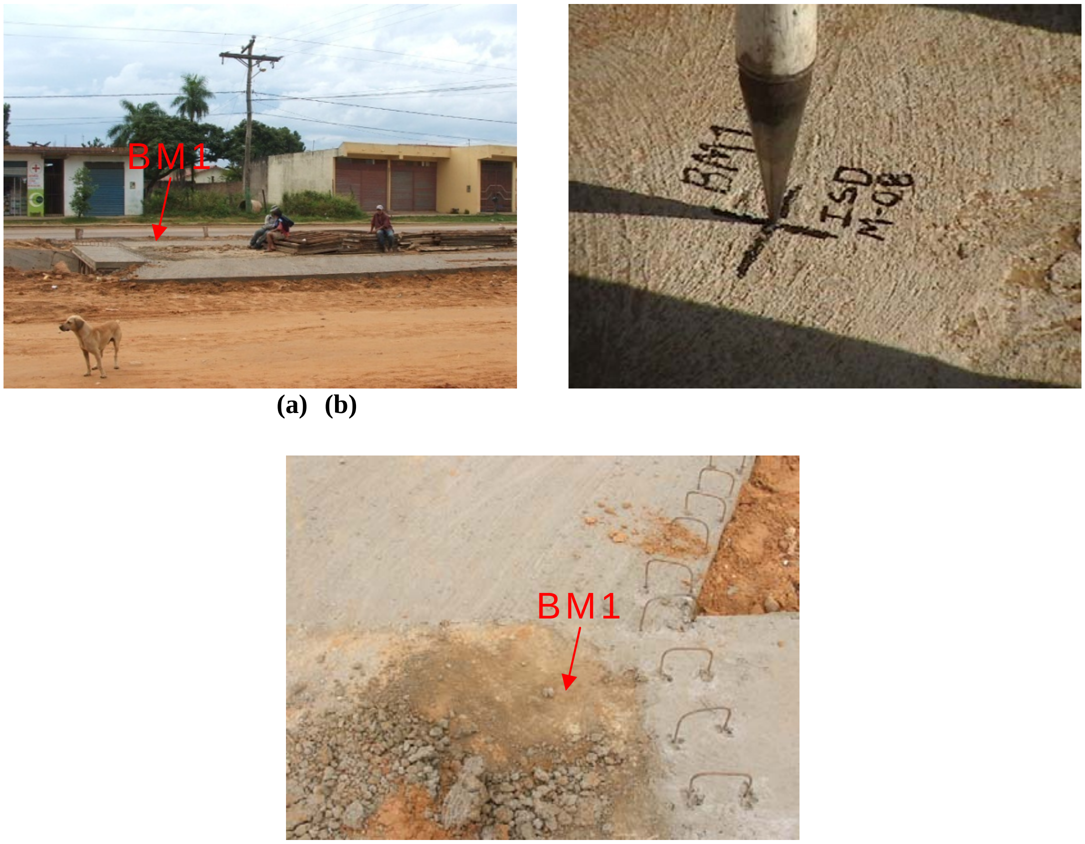


Figure B 3: Dimensional Data for BM 1.



(a) (b)

(c)

Figure B 4: (a) Location of BM 1 on the Bridge Crossing the Antiuguo Canal (b) Photograph of BM 1 Before Construction (c) Photograph of BM 1 After Construction: Photographs Taken in May of 2008 by C.C.E.

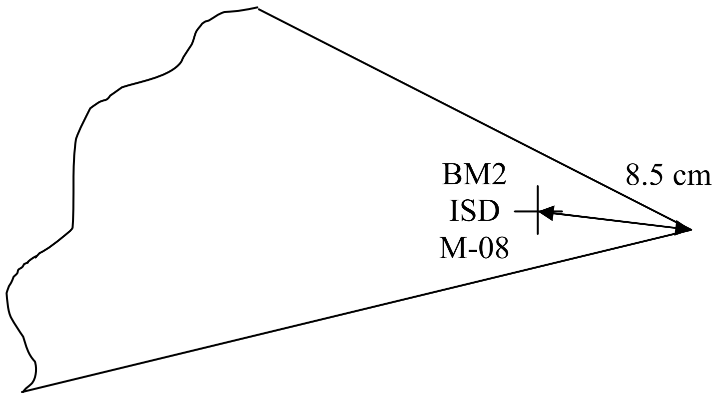


Figure B 5: Dimensional Data for BM 2.

(a) (b)

(c)

Figure B 6: (a) Location of BM 2 on the Northeast Section of Avenida Fatima I (b) Close-up of BM 2 Location (c) Photograph of BM 2: Photographs Taken in May of 2008 by C.C.E.

Figure B 7: Google Image of Middle Section of Avendia Fatima I

NOTES

TR – 6: Traverse point 6
TR – 7: Traverse point 7. While in Bolivia, all points taken after TR-7 were found to be rotated. To remedy this situation, an additional survey session was completed where a straight line from TR-6 to Nuevo Camino al Palmar was shot. Upon returning to the US the points from TR-7 on were rotated to align with the control line found in the field. Error associated with this procedure is +/- 8 cm.

BM – 3: Benchmark 3 set by C.C.E. and marked BM3 ISD M-08. Benchmark location is on a concrete slab in the middle section of Avenida Fatima I.

(a) (b)

(c)

Figure B 8: (a) Location of BM 3 in the Middle Section of Avenida Fatima I (b) Close-up of BM 3 Location (c) Photograph of BM 3: Photographs Taken in May of 2008 by C.C.E.

Figure B 9: Google Image of Southwest End of Avenida Fatima I

NOTES

TR – 7: Traverse point 7
TR – 8: Traverse point 8
TR – 9: Traverse point 9
TR – 10: Traverse point 10
TR – 11: Traverse point 11

BM – 4: Benchmark 4 set by C.C.E. and marked BM4 ISD M-08. Benchmark location is on a concrete slab in the southwest end of Avenida Fatima I.

BM – 5: Benchmark 5 set by C.C.E. and marked BM5 ISD M-08. Benchmark location is on the Nuevo Camino al Palmar bridge to the southwest of Avenida Fatima I.

BB – 1: Bolivian Benchmark 1 was set by the municipality of Santa Cruz. Benchmark location is along the northern side of the Nuevo Camino al Palmar canal, one block west of the Policia Nacional.

(a) (b)

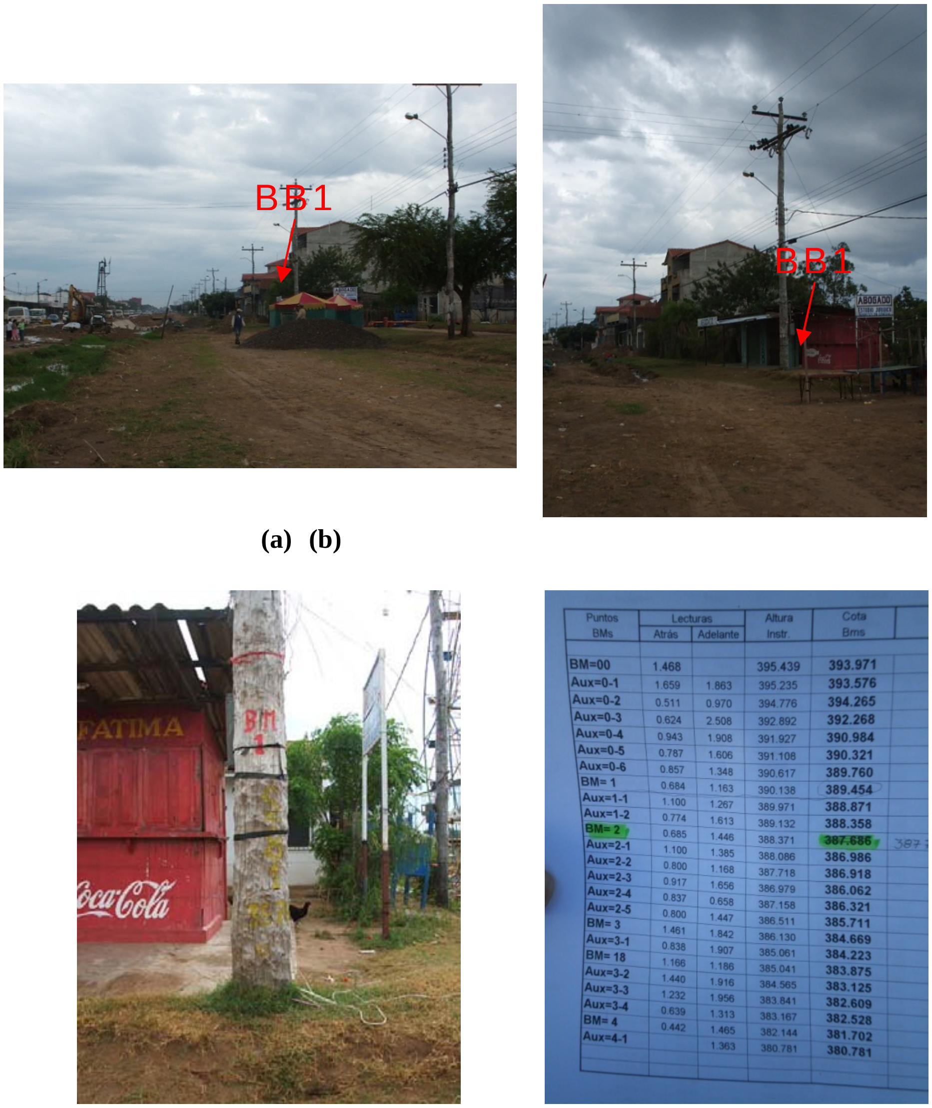
(c)

Figure B 10: (a) Location of BM 4 in the Southwest End of Avenida Fatima I (b) Close-up of BM 4 Location (c) Photograph of BM 4: Photographs Taken in May of 2008 by C.C.E.

(a) (b)

(c)

Figure B 11: (a) Location of BM 5 on the Nuevo Camino al Palmar Bridge to the Southwest of Avenida Fatima I (b) Close-up of BM 5 Location (c) Photgraph of BM 5: Photographs Taken in May of 2008 by C.C.E.



(a) (b)

Puntos BMs	Lecturas		Altura Instr.	Cota Bms
	Atrás	Adelante		
BM=00	1.468		395.439	393.971
Aux=0-1	1.659	1.863	395.235	393.576
Aux=0-2	0.511	0.970	394.776	394.265
Aux=0-3	0.624	2.508	392.892	392.268
Aux=0-4	0.943	1.908	391.927	390.984
Aux=0-5	0.787	1.606	391.108	390.321
Aux=0-6	0.857	1.348	390.617	389.760
BM= 1	0.684	1.163	390.138	389.454
Aux=1-1	1.100	1.267	389.971	388.871
Aux=1-2	0.774	1.613	389.132	388.358
BM= 2	0.685	1.446	388.371	387.686
Aux=2-1	1.100	1.385	388.086	386.986
Aux=2-2	0.800	1.168	387.718	386.918
Aux=2-3	0.917	1.656	386.979	386.062
Aux=2-4	0.837	0.658	387.158	386.321
Aux=2-5	0.800	1.447	386.511	385.711
BM= 3	1.461	1.842	386.130	384.669
Aux=3-1	0.838	1.907	385.061	384.223
BM= 18	1.166	1.186	385.041	383.875
Aux=3-2	1.440	1.916	384.565	383.125
Aux=3-3	1.232	1.956	383.841	382.609
Aux=3-4	0.639	1.313	383.167	382.528
BM= 4	0.442	1.465	382.144	381.702
Aux=4-1		1.363	380.781	380.781

(c) (d)

Figure B 12: (a) Location of BB 1 along the Nuevo Camino al Palmar Canal (b) Close-up of BB 1 Location (c) Photograph of BB 1 (d) Topographic Data for BB 1: Photographs Taken in May of 2008 by C.C.E.

Figure B 13: Google Image of Diversion Sites Surveyed Near Avenida Fatima I.

NOTES

TR – 12: Traverse point 12
TR – 13: Traverse point 13
TR – 14: Traverse point 14
TR – 15: Traverse point 15

BM – 6: Benchmark 6 set by C.C.E. and marked BM6 ISD M-08. Benchmark location is on the Nuevo Camino al Palmar canal in District 12.

(d) (b)

Figure B 14: (a) Location of BM 6 on the Nuevo Camino al Palmar Canal (b) Photograph of BM 6: Photographs Taken in May of 2008 by C.C.E.

Appendix D – Soil Field Data and Documents

Soil Bore Procedure (Hand Auger):

1. Choose bore location
2. Turn soil auger
3. Remove soil and deposit next to hole
4. Measure depth
5. Record soil description
6. Bag and seal soil and label bag

A single soil bored was performed using a hand auger at the intersection of the curichi and Avenida Fatima I, seen in red in Figure D 1. The soil bore was used to identify a general description of the sub-surface soil strata along Avenida Fatima I and groundwater level. Additional bores made by Design-Build firms Spam Jammel and La Gente are included to substantiate C.C.E.'s findings. All bores were made in District 12 in the month of May, 2008.

Figure D 1: Location of Soil Bore

Cinco Cero Engineering	**CLIENT** DISTRICT 12 - ING. VICTOR P. ESCOBAR	**LOG OF BORING NUMBER** CURICHI
	PROJECT NAME AVENIDA FATIMA I ROAD AND STORM DESIGN	**ARCHITECT-ENGINEER** CINCO CERO ENGINEERING

SITE LOCATION
AVENIDA FATIMA I - SANTA CRUZ, BOLIVIA

-○- UNCONFINED COMPRESSIVE STRENGTH TONS/FT.2 1 2 3 4 5

PLASTIC LIMIT % ✕ — WATER CONTENT % ● — LIQUID LIMIT % △
10 20 30 40 50

⊗ STANDARD PENETRATION BLOWS/(FT)
10 20 30 40 50

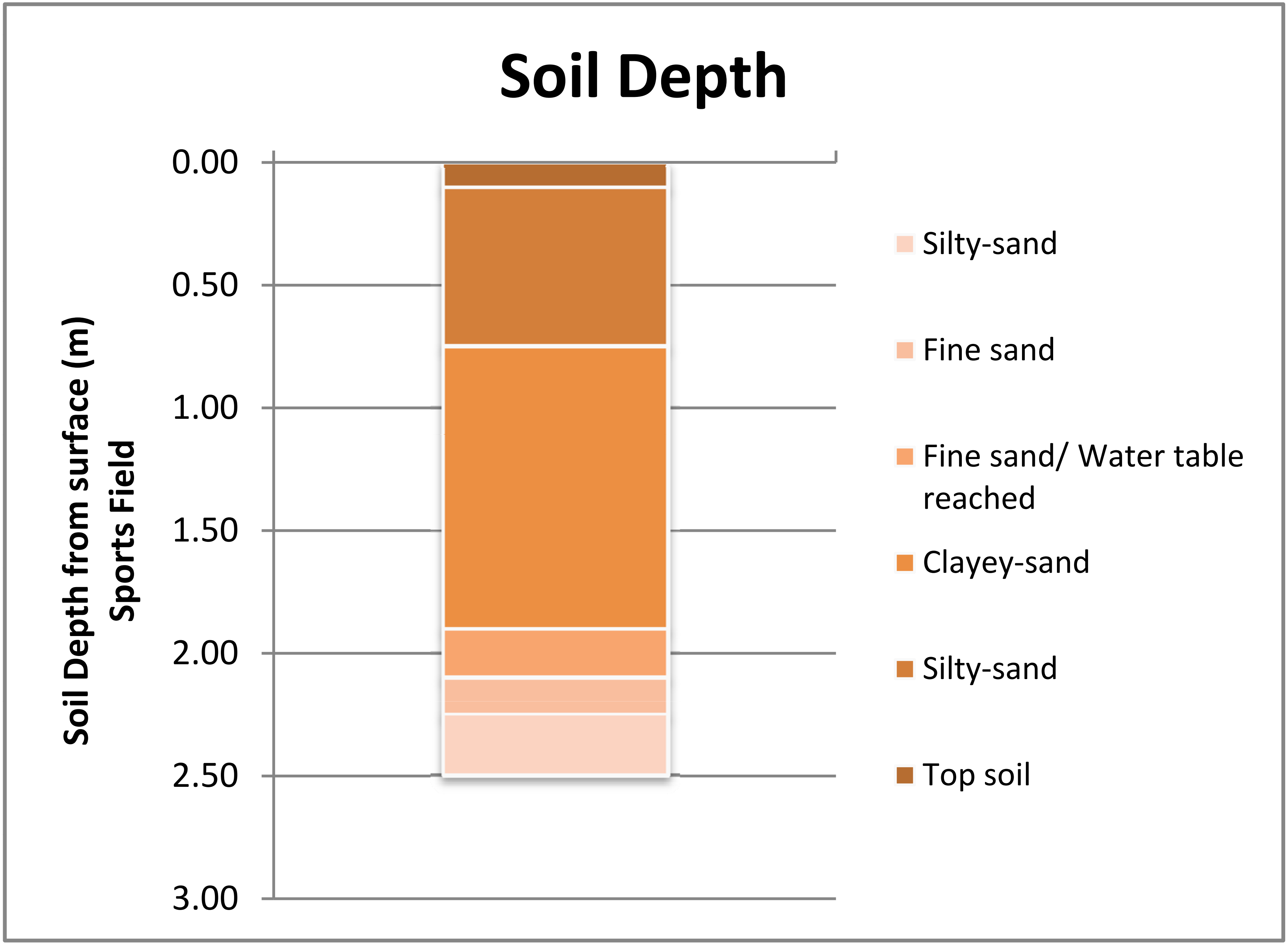
SURFACE ELEVATION +389.3 m

DEPTH(M)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DISTANCE	RECOVERY		DESCRIPTION OF MATERIAL	UNIT DRY WT. LBS./FT.3
	1	HAND AUGER			0.1	silty, SAND, fine to medium, black, organics present, dry	
					0.2	silty, SAND, fine to medium, black, organics present, moist	
					0.3	silty, SAND, fine to medium, gray, with brick, moist	
					0.4	silty, SAND, fine to medium, gray, with brick, moist	
0.5	2	HAND AUGER			0.55	clay, SAND, fine to medium, black, moist	
					0.7	organic clay, SAND, fine to medium, black, moist	
					0.81	organic clay, SAND, fine to medium, black to gray, moist	
	3	HAND AUGER			0.92	sandy, CLAY, black/gray/orange, moist, trace silt and gravel	
1.0					1.02	sandy, CLAY, black/gray/orange, moist, trace silt and gravel (stratification of soil noted in pictures)	
					1.15	sandy, CLAY, black/gray/orange, moist, trace silt and gravel	
					1.26	sandy, CLAY, black/gray/orange, moist, trace silt and gravel	
					1.41	sandy, CLAY, gray, moist, trace silt and gravel	
1.5					1.52	sandy, CLAY, stiff to very stiff, gray/brown, moist, trace silt	
	4	HAND AUGER			1.66	clay, SAND, fine to medium, gray, moist	
	5	HAND AUGER			1.90	silty, SAND, fine to medium	
2.0							

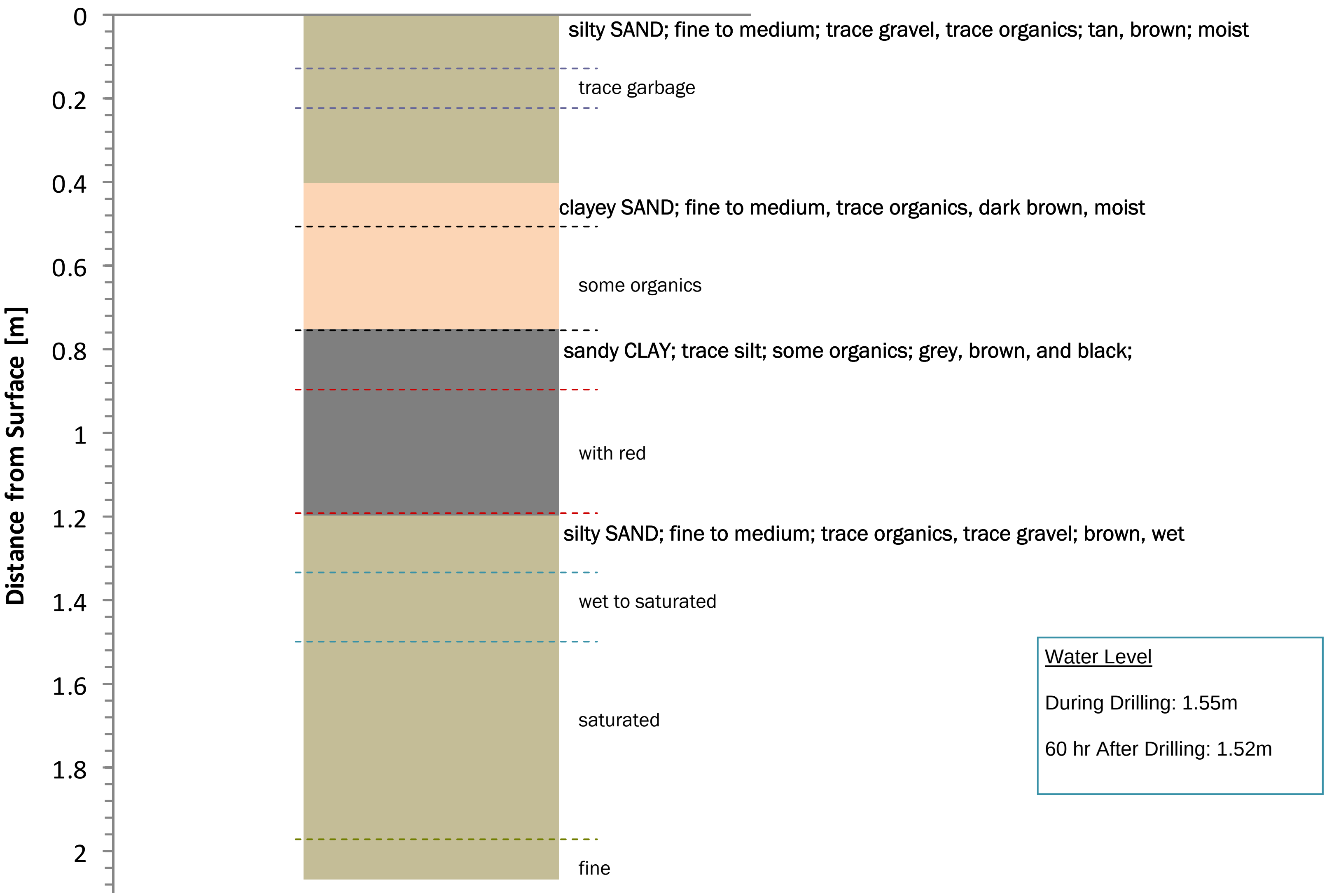
The stratification lines represent the approximate boundary lines between soil types: in situ, the transition may be gradual.

WL 1.6 m (5/24/08)	BORING STARTED: ING. CARLIN FITZGERALD AND KARI KLABOE	
WL 0.1 m (5/26/08)	BORING COMPLETED: ING. CARLIN FITZGERALD AND KARI KLABOE	ENTERED BY: KARI KLABOE
WL	RIG/FORMEAN: TEODARDO GANDARILLAS AND ERICA AKEHURST	APP'D BY SHEET NO. 1 OF 1

Escuela San Luis Espinal Soil Boring from Soccer Field	
Depth Range (meters)	**Soil Description**
0.0-0.1	Topsoil
0.1-0.2	Silty-sand, fine to medium, tr. Organics, brown, moist
0.2-0.3	Same as above
0.3-0.45	Same as above
0.45-0.6	Same as above
0.6-0.75	Same as above; gray & brown, wet
0.75-0.9	clayey-sand, fine-med, tr. Silt, tr. Organics, wet
0.9-1.05	Same as above
1.05-1.25	Same as above
1.25-1.8	Same as above
1.8-1.9	Same as above; clayey-sand, brown to gray
1.9-2.1	Fine sand; Water table reached
2.1-2.25	fine sand, saturated
2.25-2.5	silty-sand, fine, brown, saturated
End of Boring @ 2.5m	
2.1m	Water level during boring
1.55m	Water level after boring
May 19th	**Boring conducted by Ray's Well Drilling**
	Samples classified by Spam Jammel and Carlin Fitzgerald


Soil Depth
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Soil Depth from surface (m)
Sports Field
Silty-sand
Fine sand
Fine sand/ Water table reached
Clayey-sand
Silty-sand
Top soil

Project :	Ponderosa School Onsite Storm and Wastewater Treatment Design
Boring Location:	Ponderosa School Outside Front Gate
Date Drilled	19 May 2008
Drilling Company	La Gente Engineering
Drilling Method	Hand Auger
Soil Classification System:	USCS



Water Level

During Drilling: 1.55m

60 hr After Drilling: 1.52m

Boring Number: Boring Near TR 6017 (carichi)

Project No. Avenida Fatima Uno ----
Project Name:
Project Location:
Client:
A/E:
Project Name:
Total Depth:
Date Started: 5-19-08

Elevation:
X Coordinate:
Y Coordinate:
Driller:
Rig No:
Classified by: Carlin
Checked By:
Date Completed: ~~5~~ 5/24/08

dry
moist
md

Depth Range	Soil Description	USCS Symbol
0 - 0.1m	silty SAND, fine to medium, black	
	w/ organics, dry	
0.1 - 0.2m	same, moist	
0.2 - 0.3m	~~silty~~ same, gray, w/ brick, moist	
0.3 - 0.4m	same,	
0.4m - 0.55m	clay SAND, fine to medium, black, moist	
0.55m - 0.7m	organic-clay SAND, fine to med, black,	
	moist	
0.7m - 0.81	same black to gray	
0.81m - 0.92m	sandy ~~SA~~ CLAY, , black + gray + brown, moist	
	trace silt and trace gravel	
0.92m - 1.02m	same (stratification noted in pictures)	
1.02m - 1.15m.	same	
1.15m - 1.26m	same	
1.26m - 1.41m	same gray "	
1.41m - 1.52m	sandy CLAY stiff to very stiff,	
	moist, gray-brown, trace silt	
1.52m - 1.66m	clay SAND, gray, moist, fine to med (strat change)	
1.66m - 1.90	silt, SAND, fine to med	
	END OF BORING AT ________ Feet	

NOTES: 1) Indicated stratification lines are approximate.
2) ________
3) ________

1.66m During Drilling
.9m After Drilling
________ Water Level at
________ Hrs after Drilling
________ Borehole Cave-in

Drill Method ________ Boring Backfilled with ________

Traverse 8 - right next to trash near bridge, but closest to Police Station

Boring Number: ____________________

Project No. Avenida Fatima
Project Name: ____________________
Project Location: ____________________
Client: ____________________
A/E: ____________________
Project Name: ____________________
Total Depth: ____________________
Date Started: 5/19/08

Elevation: ____________________
X Coordinate: ____________________
Y Coordinate: ____________________
Driller: ____________________
Rig No: ____________________
Classified by: Kari & Travis
Checked By: ____________________
Date Completed: 5/24/08

Depth Range	Soil Description	USCS Symbol
0 - 0.4m	silty SAND, fine to medium, dark	SM
	brown, w/ organics, slightly moist	
0.4-0.81m	clay SAND, fine to med, black,	SC
	moist (organic - clay)	non-plastic
	med. to small amt. of clay, trace silt	
0.81 -1.52m	sandy CLAY, dark brown, moist,	CL
	trace silts	~~moderately non~~ low
		plastic
1.52-1.66m.	clay SAND, gray, moist, fine to	SC
	med, trace silts	non-plastic
1.66m-1.9m.	silt SAND fine to med	SM
	(from water table)	
shine test		
	END OF BORING AT ____________ Feet	

NOTES: 1) Indicated stratification lines are approximate.
2) ____________________
3) ____________________

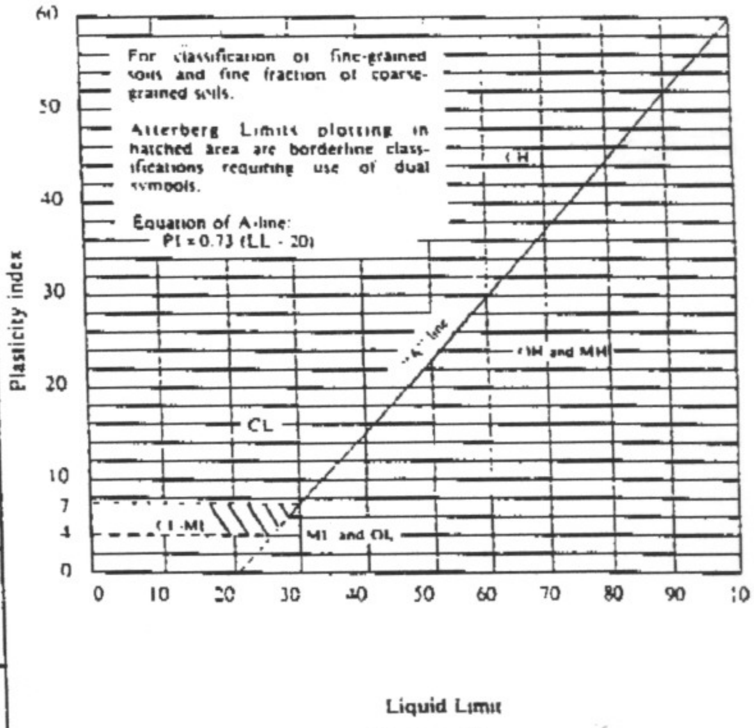
____________ During Drilling
____________ After Drilling
____________ Water Level at
____________ Hrs after Drilling
____________ Borehole Cave-in

Drill Method ____________________ Boring Backfilled with ____________________

STS Soil Classification System

UNIFIED SOIL CLASSIFICATION

Major Divisions			Group symbols		Typical names	Laboratory classification criteria		
Coarse-grained soils (More than half of material is *larger* than No. 200 sieve size)	Gravels (More than half of coarse fraction larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW		Well-grades gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse grained soils are classified as follows: Less than 5 per cent . . . GW, GP, SW, SP More than 12 per cent . . . GM, GC, SM, SC 5 to 12 per cent . . . *Borderline* cases requiring dual symbols	$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP		Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM	d	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols
				u				
			GC		Clayey gravels, gravel-sand-clay mixtures		Atterberg limits above "A" line with P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW		Well-graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP		Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	d	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Limits plotting in hatched zone with P.I. between 4 and 7 are *borderline* cases requiring use of dual symbols
				u				
			SC		Clayey sands, sand-clay mixtures		Atterberg limits above "A" line with P.I. greater than 7	
Fine-grained soils (More than half of material is *smaller* than No. 200 sieve)	Silts and clays (Liquid limit less than 50)		ML		Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity			
			CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL		Organic silts and organic silty clays of low plasticity			
	Silts and clays (Liquid limit greater than 50)		MH		Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts			
			CH		Inorganic clays of high plasticity, fat clays			
			OH		Organic clays of medium to high plasticity, organic silts			
	Highly organic soils		Pt		Peat and other highly organic soils			



For classification of fine-grained soils and fine fraction of coarse-grained soils.

Atterberg Limits plotting in hatched area are borderline classifications requiring use of dual symbols.

Equation of A-line:
$PI = 0.73 (LL - 20)$

Plasticity Chart

There are numerous simple tests that can be done on the soil to judge its clay content as explained in Figure 7-10.

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 fingernail 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 10cm long. The thread should not be sticky but able to be rolled to 3mm diameter w/o breaking. Place thread in the palm of one hand and hold the end b/w thumb and forefinger. Flatten and advance thread b/w thumb and forefinger. Form largest ribbon possible before breaking.	Long ribbon, 20-25cm:	Contains large amount of clay.
		Short ribbon, 5-10cm:	Contains medium to small amount of clay.
		No ribbon:	Contains little or no clay.

Figure 7-10: Tests to Estimate Clay Content in a Sample of Soil (Adapted from…

In addition to these tests, the soil sample should be fired to check for crumbling (i.e., flaking). A sample of soil can be test fired by first creating a small ball of about 5 cm in diameter and letting the ball dry in the sun. After drying, the sample is placed on hot coals for one hour. Remove the sample and allow it to cool. The sample should not crumble. Rub the ball to check for crumbling. If the surface crumbles easily, you will have to locate a better soil. If the sample cracks this is not disastrous because this is expected without the addition of sand to the sample.

[redacted]

Appendix E – Soil Laboratory Data

U.A.G.R.M.
LABORATORIO DE ING. CIVIL
DIR:AV. BUSCH UV.32 TEL: 3542013

- *MECANICA DE SUELOS*
- MATERIALES Y HORMIGONES
- ASFALTOS

CODIGO:0068

ENSAYO DE COMPACTACION

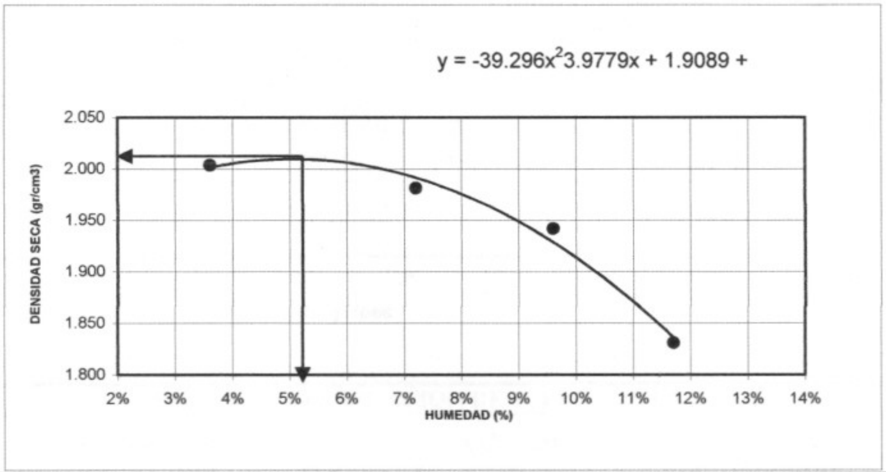
EMPRESA : **LINDA PHILLIPS-MICHIGAN TECHNOLOGICAL**
OBRA : **FATIMA 1 DISTRITO 12** FECHA : **23/05/2008**
UBICACION : **DISTRITO 12**
NORMA : **ASTM D 1557 / AASHTO T - 180** MUESTRA : **UNICA**

Peso del molde :	**6610 gr**	Golpes por capa :	**56**	P.martillo :	**10,0 Lb.**
Molde Volumen :	**2137.0 cm3**	Numero de capas :	**5**	Alt.caida :	**18" (45.72cms)**

TIPO DE PROCTOR : **T-180 MODIFICADO**

DETALLE	**1**	**2**	**3**	**4**		
Peso muestra humeda + molde	11046	11149	11158	10981		
Peso muestra humeda	4436	4539	4548	4371		
DENSIDAD HUMEDA	2.076	2.124	2.128	2.045		
Recipiente No.						
Peso muestra humeda + tara	201.7	208.7	214.4	256.7		
Peso muestra seca + tara	197.4	200.3	202.2	240.4		
Peso del recipiente	78.2	83.7	75.1	101.1		
Peso del agua	4.3	8.4	12.2	16.3		
Peso muestra seca	119.2	116.6	127.1	139.3		
Humedad (%)	**3.61%**	**7.20%**	**9.60%**	**11.70%**		
DENSIDAD SECA (grs/cm3)	**2.004**	**1.981**	**1.942**	**1.831**		

DENSIDAD MÁX. (gr/cm^3) : **2.010 gr/cm3**
HUMEDAD OPTIMA (%) : **5.06 %**



OBSERVACIONES: EL MUESTREO DEL MATERIAL FUE REALIZADO POR PERSONAL DE LABORATORIO.

EJECUTADO POR:	REVISADO POR:	APROBADO POR:
TEC. JOHNNY ARTEAGA	TEC. MARCELO MUJICA	Ing. José de la Cruz Quilla V. JEFE LABORATORIO ING. CIVIL U.A.G.R.M.

LABORATORIO ING. CIVIL

[redacted]

U. A. G. R. M.
LABORATORIO DE ING. CIVIL
ENSAYO DE CLASIFICACION DE SUELOS

Empresa: LINDA PHILLIPS-MICHIGAN TECHNOLOGICAL
Proyecto: FATIMA 1 DISTRITO 12
Ubicación: FATIMA 1 DISTRITO 12
Muestra: Fecha: 23/05/2008

ESTUDIO DE MECANICA DE SUELOS, ASFALTOS Y HORMIGONES

Ubicación: Av. Busch Modulos
Telf-Fax: 3542013
CODIGO: 0068

(SISTEMA DE CLASIFICACION DE SUELOS A.S.S.H.T.O. M-145-66)

% DE HUMEDAD NATURAL		GRANULOMETRIA					
		TAMIZ	P. RET. C/TAMIZ	P. RET. ACUM.	% RET. C/TAMIZ	% Q' PASA C/TAMIZ	ESPECIFICACIONES
Tara							
P. Tara		Nº4	73.10	73.10	1.91	98.09	
P.Hum.+Tara		Nº10	27.10	100.20	0.71	97.38	
P.Seco+Tara		Nº40	389.40	489.60	10.19	87.19	
%Humedad		Nº200	2613.40	3103.00	68.40	18.78	
P.Seco ant lav	**3820.60**	BASE	32.70	3135.70	0.86	17.93	

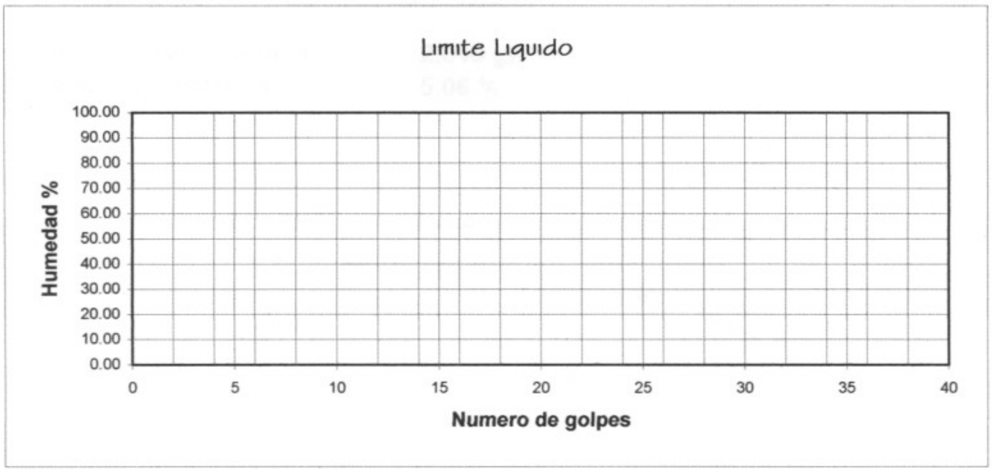
LIMITES DE ATTERBERG

LIMITE LIQUIDO A.A.S.H.T.O. T89-68

Nº Tara	P. Tara	Golpes	P. Humedo+Tara	P. Seco+Tara	% Humedad
1					
2					
3					

LIMITE PLASTICO A.S.S.H.T.O. T90-70

Nº Tara	P. Tara	P. Humedo+Tara	P. Seco+Tara	P. del agua	% Humedad



Nº Golpes:	**0**
Humed(%):	**0.0**
LL:	**0.0**
LP:	**0.0**
IP:	**0.0**
IG:	**0**

SISTEMA DE CLASIFICACION DE SUELOS DE LA H. R. B.	
Tipo de Suelo:	**A-2-4 (0)**

DESCRIPCION:n SUELO ARENA LIMOSA
OBSERVACIONES:Muestra suministrada por la empresa solicitante del ensayo.

Ing. José de la Cruz Quilla V.
JEFE LABORATORIO ING. CIVIL
U.A.G.R.M.

[redacted]

Appendix F – Meetings

Below is a summary of C.C.E.'s meetings during the Avenida Fatima I project. Meetings included in person conversations and emails.

Date: 4/29/08
Location: U.P. Engineers and Architects, Houghton, MI - USA
Attendees: Ing. Eric Waara and C.C.E.

Summary

In this meeting we reviewed some of the initial field questions that the team had with a practicing engineering in storm water and road design, Ing. Eric Waara. We covered survey and soil bore procedures, field observations tips, estimating, and important questions to ask locals. Several tips that he provided included:

- Drive/walk the site two or three times with a video camera, so that you capture all the information you could possible need.
- Always jot down notes from conversations.
- Design: Go up off the current base and add a 2% crown. Have the asphalt 3" or 4" if you can.

Date: 5/12/08
Location: M.C.C. Santa Cruz, Bolivia
Attendees: Ing. Rufino Arano and May ISD Students and Mentors

Summary

In this meeting the May group discussed the environmental impact requirements in Bolivia with Ing. Rufino Arano. From this discussion we found out the following:

- Environmental Impact Statements are mandatory for all projects in Santa Cruz, before the start of construction.
- The statement is submitted to the Municipal government.
- There are three categories to the statement, depending on what size of impact you have.
- The current drainage plan of Santa Cruz was explained; however it is not completely established. Storm water is directed towards collector canals. From there the water is taken to the rings and then to two separate watersheds, one to the NW and the Rio Grande to the SE.
- Rainfall data is attainable at the University, which has a database. An invitation is needed for the data.
- The current sanitary plan of Santa Cruz was explained. Sanitary systems exist until the 4th /5th rings, from there development is still progressing. Saguapac and other water companies are in charge of establishing sanitary systems. The 5th and 6th ring systems are expected to completed in the next 20 years.

- Soil contamination in Santa Cruz reaches 70 m below surface and is approaching the aquifer. Soil contamination is due to a lack of sanitary systems.

Date: 5/13/08
Location: M.C.C. Santa Cruz, Bolivia
Attendees: Ing. Humberto Calbimonte and C.C.E.

<u>Summary</u>

In this meeting we discussed watershed delineation, canal design, the curichi near our project, and the overall environmental impact with Ing. Humberto Calbimonte. From this discussion we concluded:

- When conducting the topographic survey, the watershed boundary is found at a peak or flow structure.
- We should consider utilizing the curichi for detention of storm water.
- Typical Bolivian designs use the Rational Method and a 25 year storm recurrence interval. The standard rainfall intensity equation for Santa Cruz is provided in the Norma Boliviana NB 688.
- Lag time equation can utilize the NRCS curve number method, pg. 478 in *Water Resources Engineering* by Ralph A. Wurbs and Wesley P. James. Humberto's recommendation can be found on the R-drive.
- HEC analysis and land use should be recorded.
- The illegal connections should be noted for the environmental impact and make a case on why they need to be controlled, perhaps by constructing their own sanitary systems.
- Possible considerations when placing the canals is if crossings to homes will be needed. These may be wood or concrete structures.

Date: 5/13/08
Location: MCC Santa Cruz, Bolivia
Attendees: Sub Alcalde Ing. Victor P. Escobar Díaz, Ing. Javier Marín, Presidenta señora Loretto, May ISD Students and Mentors, Ing. Humberto Calbimonte, Ing. Linda Phillips

<u>Summary</u>

In this meeting the May ISD group discussed District 12's concerns, funding sources, population growth and size, design and cost estimate, standard procedures, and existing plans. From this discussion we concluded:

- Three main issues for District 12 are water drainage, waste water, and a high water table.
- Right now an immediate solution to the flooding is needed. The district is currently formulating a drainage plan.

- The bordering canals (Antiguo and Nuevo Camino al Palmar) manage approximately 40% of the total flooding.
- Districts 9 and 10 drain into District 12, which does not help the flooding problem.
- Sanitary systems are also needed due to illegal discharge by residents into the streets and other areas. Dry wells don't function correctly here due to the high water table.
- Schools must do maintenance weekly.
- Funding is from the municipality. The community notifies the Sub Alcalde of an issue, the Sub Alcalde gets the project design and cost estimate, and then the design and estimate are sent to the drainage department (or appropriate department) in the municipality. Municipality approves funding; however, it is usually only half of the needed funding.
- District 12 is relatively new, 9 years, and has approximately 150,000 people, 4,300 hectares, 42 UVs, and 76 barrios. Annual population growth is 3%.
- If project is from the municipality no impact report is required.
- Project permits are given by the city planning office if it fits the urbanization plan.
- Standards are the same for all districts; however, no set standards exist.
- Design of an Avenue is typically 20 m wide.
- A general plan exists for urbanization.
- Lower income families move outward as development occurs.

Date: 5/15/08
Location: Subalcadía Districto Municipal N°12 Santa Cruz, Bolivia
Attendees: Sub Alcalde Ing. Victor P. Escobar Díaz, Ing. Javier Marín, C.C.E., Giancarlo Calbimonte, Ing. Humberto Calbimonte, and Ing. Linda Phillips

Summary

In this meeting C.C.E. discussed Avenida Fatima I with the Sub Alcalde and District 12's engineer. Topics covered include project expectations, community expectations, information on canals, quebrada, illegal sanitary connections, demographics, and earthen canal to the NW of Avenida Fatima I. From this discussion we concluded:

- Pavement type is to be determined by the team.
- They don't want an earthen canal.
- No budget for the project has been set.
- Maintenance of canals is conducted twice a year, with manual labor and backhoe.
- 100,000 m^2 of pavement is planned for the year.
- 95% of roads are dirt. A grader goes to a different barrio each day to service dirt roads.
- Essential information for the project includes survey, watershed analysis, and cost estimate.
- Residents complained about people building houses in the middle of the stream flow path.

- Route Antiguo canal is completed and Nuevo Palmar was suppose to be completed on May 6th, 2008; however, it will be completed next March due to expense issues.
- A foreign company did a flooding report on District 12, we were unable to obtain that report.
- No current utilities are under Avenida Fatima I.
- The urbanization plan for the area is residential.
- Utilizing the quebrada for detention is an option; however, they want to fill it.
- The only deterrent for illegal sanitary connections to the roadway is to cut them and fine the resident.
- When creating canal crossings, they use prefabricated bridges or concrete pipes.
- There are no speed limits, they depend on the city.
- The earthen canal to the NW is an emergency ditch only.
- This project was previously started, but abandoned due to a lack of drainage analysis.
- A diversino of the quebrada is needed, we are to size it and figure out a possible location until a permanent solution can be implemented.

Documents Obtained

- Plans and specifications for the two canals under construction.
- Typical cross-section of a similar sized road.
- Demographic study of the district was obtained.

Date: 5/16/08
Location: M.C.C. Santa Cruz, Bolivia
Attendees: Dr. Dan Hinojosa, Paul Palacios, and C.C.E.

Summary

In this meeting Dr. Dan Hinojosa provided a background on Bolivia and Paul Palacios described Bolivia's art history. From this discussion we concluded:

- Current President of Bolivia is indigenous, Evo Morales, by a majority vote.
- Nationalization of oil and gas to take over private foreign companies.
- Attempt to rewrite the constitution due to its age resulted in strikes.
- 2004 referendum about autonomy, NE and SE said yes, NW and SW said no.
- May 5, 2008 referendum results in Santa Cruz were 85.6% yes and 14.4% no.
- Two proposals for departments: Autonomy or Indigenous Autonomy.
- The goverenment has no idea how autonomy will work.
- All departments will have a vote on August 10, 2008 and will have to choose between the president or govenor.
- The largest social problem is government corruption.
- Bolivia gained independence from Spain in 1825 and was not ready for it.
- Dengue, yellow fever, malarai, and paludism are main mosquito borne illneses. Mosquitoes breed in standing clear water.

- Dengue is carried by the Stegomyia Aedus species of mosquito. Dengue is called bone break fever and is relieved without taking drugs. An IV is sued if dehydrated; eventually it will go away.
- Malaria is carried by the anopheles mosquito and is a parasite that reproduces in the liver, which causes inflammation and pain. Symptoms are cured with antibiotics.
- Yellow fever is a virus carried by the same species of mosquito as dengue. It causes jaundice and attacks to the liver, eventually destroying it.
- Culex is the most common mosquito species and transfers the West Nile virus.
- Disability adjusted years; diarrhea = 2 years and malaria = 4 years world wide.
- Santa Cruz de la Sierra has so far had 17 dengue cases in 2008 and 63 dengue cases in 2007.
- Campaigns to rid mosquitoes that cause dengue is an organic poison that only affects mosquitoes.
- Main problems in Bolivia in descending order are: acute respitory disease, diarrhea, diabetes, cardiovascular, and car accidents.
- Diabetes is growing very fast and causing obesity problems.
- Infant mortality 20 years ago was 500/1000, now it's 59/1000.
- Some data can be found at www.ine.gov.bo

Date: 5/24/08
Location: M.C.C. Santa Cruz, Bolivia
Attendees: Ing. Linda Phillips, Ing. Carlin Fitzgerald, and C.C.E.

Summary

In this meeting C.C.E. discussed final project details in Bolivia with Ing. Linda Phillips and Ing. Carlin Fitzgerald. From this discussion we concluded that:

- Responsibilities: Kari = Report Writing, Travis = AutoCAD, Dyland and Kari = Calculations, and Dylan = Review Humberto's documents.
- Specifications are to be done by Dylan by June with Linda.
- Design Options are the team's responsibility.
- Week 1 Objectives: ABET Report, Intro/Background, understanding of received documents, map overlay, and watershed size known.
- Month 1 Objectives: Pictures and video organized, watershed/storm drainage calculated, 3D model completed, all design options done, Introduction, Background, Existing Conditions, Procedures, drawings, and tests complete, canal diversion complete.
- Month 2 Objectives: Design options prioritized and completed, cost estimates and recommendations, report finished and all drawings, specifications written, presentation completed, poster printed.
- Roadway should be 18 cm of concrete non-reinforced, CBR 10 @ 100%, 18 @ 95%, 65% for base, use example road reports.
- Note errors in drawings.

- Contact Carlin about road.

Date: 6/5/08
Location: DOW Environmental Sciences Bldg, MTU Campus, Houghton, MI - USA
Attendees: Dr. Brian Barkdoll and C.C.E.

Summary

The team updated Dr. Barkdoll on the project location and scope, team progression, and schedule of tasks. Topics covered include: design options, watershed analysis, storm runoff calculations, and team schedule. Comments made by Dr. Barkdoll were:

- Given there is a clay layer beneath the watershed area, it would be reasonable to assume the whole watershed area is impermeable.
- The team should make a profile drawing that includes the canal bottom elevations, existing ground, and bank elevations of the road.
- HMS modeling would be beneficial. The intensity equations, reccurrence interval, and C coefficients all seemed reasonable and no comments were made.
- The team should also look into more environmentally friendly design options. Given the community is expecting a concrete drainage canal and road; we should list that as an option. However, detention ponds and other methods of capturing storm water and housing it within the neighborhood should be evaluated and suggested in the final report.
- With respect to our drainage canal, we will be limited byour flat topography and available area. For canals that don't have a lot of slope, you typically compensate by increasing the width or depth or both. In our case, we may not be able to do that and so there may be an upper limit to our design risk or the recurrence interval at which we design for. Right now we will be designing for 25 years, as suggested by Ing. Humberto. But, that recurrence interval may not be attainable.
- In our final report we should supply a risk vs. cost graph. This way if our risk level is too costly for the community, they can reduce their risk to obtain an appropriate or attainable cost.

Date: 6/18/08
Location: DOW Environmental Sciences Bldg, MTU Campus, Houghton, MI - USA
Attendees: Ing. Linda Phillips, Ing. Dennis Magolan, and C.C.E.

Summary

The team updated Linda and Dennis on the project progression and design concerns. Topics covered included design options and environmental options. Comments made by both were:

- We should look into using underground storm sewer pipes along our road. Some of the ground cover above the pipes can be used for storm water infiltration and would allow more water to be retained at the source. Every few meters a large intake could be designed and this is where the water would enter the drainage structure. At the intake we could look into doing a sediment trap design with a rebar cover. This will make it easy for maintenance crews to see if sediment or trash are clogging the pipes.

- We could also do a covered or open canal design. Eventually it was suggested that an open canal design would be best. A dozer could be lowered into the canal and could be used for maintenance.
- A detention basin could be utilized in the undeveloped land to the northwest of Avenida Fatima I. The detention basin could collect water and detain it until it is allowed enough time to infiltrate into the ground. However, there is one dilemma with our watershed. The Fatima watershed is composed of clayey soils; therefore infiltration rates are expected to be low.
- A better environmental approach may be wetland restoration in District 12. Wetlands in the district could be used to hold excess storm water and prevent flooding. While there is the worry of mosquito reproduction in the wetlands, some studies have shown that healthy wetlands do not promote mosquitoes.

Date: 6/24/08
Location: Email Correspondence
Attendees: Ing. Carlin Fitzgerald and C.C.E.

Summary

C.C.E. emailed Ing. Carlin Fitzegarld about lateral earth pressures on the drainage canal walls. Below her response was documented:

Hi Kari (and Dylan and Travis)

I am guessing the AutoCAD file you sent to me is in 2008 format. I cannot open it because the old platform will not support the new format. So, you will need to plot it to PDF. When you go to plot, Adobe should be one of the printer options. Essentially you will be printing to a file. You will want to do this anyway to include in your report.

As for your Phi angle, what are you basing your other angle values on for other soils? Without blow-count information from drilling, you really can't assume any frictional properties. There are typically reasonable ranges of values for a particular soil (i.e. sand is often between 27-32 degrees). But, that is a pretty large range, especially when dealing with horizontal pressures.

I usually use a reference published by NAVDOCS DM-7. But, you will need blow counts to establish an average standard penetration and relative density (which you also don't have) to use those graphs (which give internal friction angles). You might try "Basic Soils Engineering", Hough, 1957 (there probably is a newer version). I only have a few pages photocopied that I use regularly so there might be some information in that book that could be of use to you.

Carlin

Date: 6/25/08
Location: Dr. Hiller's Office, Dillman, MTU Campus, Houghton, MI - USA
Attendees: Dr. Hiller, Kari Klaboe, and Travis Velasco

Summary

In this meeting we informed Dr. Hiller of our project scope and asked for his advice on the pavement design of our road. His suggestions were:

- If we have a standard Bolivian pavement section, we should just go with that design. It has been used successfully and is probably what they would prefer to do.
- One thing that may be of benefit to add is joint load transfer devices between pavement sections. This would consist of around No. 8 epoxy coated rebar or larger, 7 inches in length, spaced around 12 inches center-to-center.
- Previously, Dr. Hiller had assisted the Vallegrande project. He suggested to them to use the typical Bolivian pavement, except design a more robust pavement section and suggest it as an alternative. They used his Doctorate thesis to design the robust pavement.

Documents Obtained

- Papagiannakis, A.T., and Masad, E.A., Pavement Design and Materials. John Wiley and Sons, Inc. 2007.

Date: 6/30/08
Location: DOW Environmental Sciences Bldg., MTU Campus, Houghton, MI - USA
Attendees: Ing. Mike Drewyor and Kari Klaboe

Summary

In this meeting we discussed the project design options. Ing. Mike Drewyor suggested:

- Suggested that the rebar canal topping may be an expensive design option. We should look into it more.
- We should place a barrier wall on the side of the open canal for safety reasons. This wall should be about 36 to 40 inches high. We can check this height with the Building Code.
- We can use the standard reinforcement plans found on the R-drive. However, we should analyze the canal section based on a reinforced concrete design. We can use the procedures we learned for beam designed in Structures II.

Date: 7/2/08
Location: DOW Environmental Sciences Bldg., MTU Campus, Houghton, MI - USA
Attendees: Ing. Dennis Magolan and C.C.E.

Summary

In this meeting we updated Dennis on our project concerns and went over some design options. Dennis' suggestions were:

- Connecting to Antiguo further downstream is reasonable. However, we should connect with a 45° bend.
- A covered canal would have to have a center support, because the width of 4.1 m is too large of an unsupported span.
- With the precast box culverts we have to have an opening between the two precast box culverts. This will allow water coming from the northwest, which is a majority of the water, to enter both culverts.

Date: 7/3/08 – 7/5/08
Location: Email Correspondence
Attendees: Ing. Humberto Calbimonte and C.C.E.

Summary

C.C.E. emailed Ing. Humberto Calbimonte of Cochabamba, Bolivia for advice on: lateral earth pressures, vehicle and pedestrian bridges, design options, and pavement design. Below are his responses, which were documented in three different emails.

Email correspondence 7/3/08

Hola Kari

Gusto de saludarte, al igual que los demás compañeros de clase. Como les va por alli?. El tiempo aqui está bien, un poco frio en las mañanas (-1° C), pero en la tarde llega hasta 26°C.

Al igual que tu en español, mi inglés es malo, por lo que contesto en español, espero que haya alguien que te ayude a traducir. En cuanto a las preguntas:

1) El canal está situado entre las dos vias (roads), no recibirán directamente la carga de los vehículos (traffic loading), pero sí la presión lateral del terreno, por eso se debe verificar la resistencia al empuje lateral. Cuando no tenemos datos precisos, adoptamos un angulo interno de fricción de 30°. El espesor de los muros varía con las dimensiones del canal, tambien, si el canal es rectangular o trapecial, son situaciones distintas. En ambos casos se tiene que verificar el espesor de muros.

2) En cuanto se refiere a los puentes vehiculares, se debe primeramente hacer un diseño estructural del mismo, de manera que resista un camión H20, mando un ejemplo de cálculo de la losa en excel. Se deben realizar posteriormente los costos de acuerdo a el análisis elaborado por los técnicos de Santa Cruz, Giancarlo tiene los datos.

Ire leyendo las otras preguntas, tengo un poco de dificultad para entender, pedire ayuda, contesto luego.

Email correspondence 7/4/08

Hola Keri

Perdona la demora en contestar, pero necesitaba ayuda para entender. No está Giancarlo, pero mi esposa habla Inglés correctamente y me ayudó. Continuando con el tema. Quiero contestar a partir de las 3 opciones de diseño:

A) Canal abierto entre las dos vías. Esta opción me parece mas adecuada para la zona. Es una opción más económica y el mantenimiento resulta más fácil. Como tu dices existe el peligro para vehículos (cars), niños y animales. El muro corto de 0.75m no me parece adecuado, porque no permite el ingreso del agua, Sería mejor colocar unos elementos metálicos como los que se usan en carreteras. Pero no se los costos. Los puentes vehiculares y peatoneles son necesarios, son fáciles de construir y no representan un costo muy alto comparado con las otras dos opciones. Es necesario adicionar el diseño de bocatormentas laterales, que faciliten el ingreso de las aguas pluviales.

B Y C) Estas dos opciones son mas caras, y en Bolivia el costo es un factor muy importante; además presentan el problema de que las aguas de tormenta no ingresan facilmente al canal. Las rejillas de ingreso generalmente se tapan fácilmente con la basura y no funcionan bien, por lo que están opciones no las recomiendo, a menos que se trate de caudales menores (inferiores a 1.0 m3/s).

Mañana escribiré un poco mas, luego de ver los planos que mandaron y les comento un poco.

Muchos saludos

Email correspondence 7/5/08

Hola Kari

Estoy otra vez en linea, espero que hayan podido entender lo que les escribo. He visto los planos que mandaron, son los usuales, de todas manera se debe respaldar con el cálculo estructural para verificar las dimensiones de los muros.

3) La opción de canal trapecial (canal3) es mas económica, solamente que requiere mucho mas espacio, comiéndose las áreas verdes. Los huecos están bien como se ve en el plano. Creo que para el proyecto Av. Fatima se adecua mejor un canal rectangular (canal2). El acero de refuerzo se debe calcular de acuerdo a las dimensiones del canal, tomando en cuenta la presión lateral del suelo.

4) Creo que no es necesario en refuerzo adicional del pavimento para la transmisión de las cargas, sin embargo se debe tomar en cuenta la experiencia de los técnicos de Santa Cruz. Un saludo para todo el grupo,

Appendix G – AutoCAD

AutoCAD Civil 3D 2008 Procedure:

1. Import survey data.
2. Fix alignment issue.
3. Fix labeling error.
4. Use a polyline to create an alignment and profile of the existing conditions.
5. Create a topographic map of the data.
6. Connect and label key points.
7. Draw recommended roadway and canal design.
8. Create cross sections every 20 m.
9. Create details.
10. Plot drawings.

Points were imported into AutoCAD Civil 3D 2008 as a text file, Table G 1 is an example of the survey data imported. Survey points can be viewed on the attached CD.

Table G 1: Sample AutoCAD Points

ID	Northing	Easting	Elevation	Label
872	9706.423339	8497.091787	391.077428	ss
873	9706.354494	8497.014821	391.095262	ss
874	9705.026966	8499.361811	391.033413	1.0conc.pipe
875	9704.833493	8499.417939	392.1604	1.0conc.pipe
876	9703.72298	8502.132865	391.011795	1.0conc.pipe
877	9703.603392	8502.21296	392.108394	1.0conc.pipe
878	9699.181786	8515.363388	392.783479	tp
879	9696.053655	8515.088394	392.653545	rd
880	9686.950701	8515.70864	391.286079	fn

Appendix H – Pavement Design

Roadway Design

The design of the typical section for Avenida Fatima Uno was based on the request for Portland Cement Concrete by the Sub Alcalde, foreseen traffic loads, and standard Bolivian design for main roads.

The typical section consists of the following:

- Minimum 18cm of Portland Cement Concrete
- Minimum 12cm of aggregate base
- Minimum 4.5m joint spacing
- Joint load transfer reinforcing
- Tied curbing with specified rebar

Pavement and Base

The maximum standard design load for major Bolivian loads is 11,000 kg/axel with a 28 day compressive strength (f'_c) of 230kg/cm^2. The section used for these major roads with a factor of safety of 20% is 18cm of Portland Cement Concrete and 12cm of aggregate base. This design was chosen for Avenida Fatima Uno since it will be the only paved connecting road in the area and a high traffic load is expected. Furthermore, the Bolivians are familiar with the design and have been using it successfully thus far. A comparison to United States' Interstate design is shown below.

Bolivian Maximum Load = 11,000 kg/axel X SF 1.2 X 2.205 lb/kg = 29,106 lb/axel
United States = 20,000lb/axel

The bottom of slab maximum stresses for both dual wheeled single and tandem axels are as follows.

Dual wheeled single axel: $\sigma = 450$ psi
Dual wheeled tandem axel: $\sigma = 250$ psi

Given f'_c = 230kg/cm^2 is equivalent to 3,709 psi, the tensile strength can be determined with the empirical equation:

$$f_t = .75 \sqrt{f'_c} = .75 \sqrt{3{,}709} = 456.8 \text{ psi}$$

Although the Bolivian design for maximum load is considerably higher and should be adequate for Avenida Fatima Uno, the tensile strength marginally exceeds the stress of the dual wheeled single axel. Since the stress is approaching the strength, fatigue failure is more apt to occur. Furthermore, Cinco Cero was unable to perform a traffic count due to current road conditions to adequately predict the frequency of high loading. Therefore, further research should be performed to determine the sufficiency of the recommended section. Some possible tests include; further concrete strength and variance analysis, traffic counts, and the day to day temperature variance for the area. Once these tests are performed, the section can be checked using the *AASHTO Guide for Design of Pavement Structures* (AASHTO 1993) for rigid pavements.

Joint Load Transfer Reinforcing

For a Portland Cement Concrete thickness of 18cm, Dowel (rebar) diameter should be 2.5cm or greater, length should be 36 cm and should be spaced 30cm center to center (Papagiannakis). This joint will occur at least every 4.5m.

References

Papagiannakis, A.T., and Masad, E.A., Pavement Design and Materials. John Wiley and Sons, Inc. 2007.

Appendix I – Canal Design

Watershed Analysis

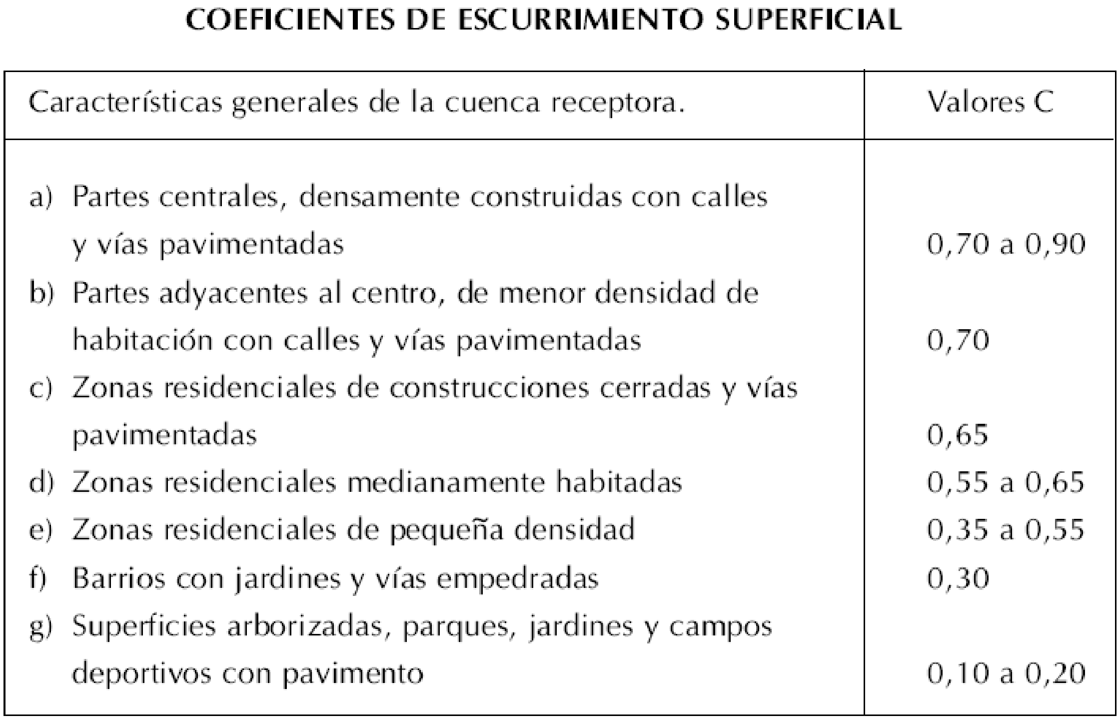
Area

First for the watershed calculations C.C.E. had to find the total area of the watershed. This was done with Civil 3D 2008. The total watershed area was 996,023 m^2 or about 1 km^2. Roughly half of this area was open field but since there are plans in the near future to develop this field it will be treated as a developed residential area.

C Coefficient

In NB 688, C.C.E. found a table of Coefficients of Superficial Drainage, Table I 1. This listed different types of terrain common in Bolivia and the C coefficient associated with them.

Table I 1: Table 1 from Chapter 6 in NB 688 for Coefficients of Superficial Drainage.



COEFICIENTES DE ESCURRIMIENTO SUPERFICIAL

Características generales de la cuenca receptora.	Valores C
a) Partes centrales, densamente construidas con calles y vías pavimentadas	0,70 a 0,90
b) Partes adyacentes al centro, de menor densidad de habitación con calles y vías pavimentadas	0,70
c) Zonas residenciales de construcciones cerradas y vías pavimentadas	0,65
d) Zonas residenciales medianamente habitadas	0,55 a 0,65
e) Zonas residenciales de pequeña densidad	0,35 a 0,55
f) Barrios con jardines y vías empedradas	0,30
g) Superficies arborizadas, parques, jardines y campos deportivos con pavimento	0,10 a 0,20

Since the whole watershed area was treated as a developed residential area, C.C.E. used the type c coefficient for moderately inhabited residential zones. This had a C value of .55-.65, for a more conservative approach the greater value was used; C = 0.65.

Rainfall Intensity

The Bolivian rainfall intensity, Equation I-1, was used which is provided in NB 688, Chapter 6, Section 5.1.1.

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

I = Rainfall Intensity (mm/hr)
f = Storm Frequency (years)
t = Storm Duration (minutes)

With a storm frequency, *f*, of 10 years and several different storm durations, *t*, it was possible to calculate the rainfall intensity for any duration of storm, including the time of concentration. A storm duration equal to the time of concentration was suggested by Giancarlo Calbimonte as the typical Bolivian practice. A sample calculation can be seen in Equation I-2 below.

$$I = \frac{393.7 * 10^{.3556}}{93.6^{0.7016}} = 36.9\, mm/hr \quad (Equation\ I-2)$$

Time of Concentration

To find the time of concentration C.C.E. was given a Bolivian equation called the Kirpich equation, Equation I-3, from ISD May mentor Giancarlo Calbimonte, see Appendix F Meeting Minutes.

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

t_c =Time of Concentration (hr)
L = Hydraulic Length (km)
S = Watershed Slope (decimal percent)

Using the length and slope from the furthest point on the edge of the watershed to the proposed channel, and then the slope from that point to the Antiguo channel, it was possible to find the total time of concentration. The hydraulic length and slope of the watershed were 0.825 km and .005 respectively. The hydraulic length and slope of the channel were 1.2 km and .001 respectively. The resulting time of concentration was 1.6 hours and can be seen in Equation I-4.

$$t_c = 0.06626 * \left(\frac{.825^2}{.005}\right)^{0.385} + 0.06626 * \left(\frac{1.25^2}{.001}\right)^{0.385} = 1.56\, h \quad (Equation\ I-4)$$

Flow Rate

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 I -5. The design overland storm runoff can be seen calculated in Equation I-6.

$$Q = C * I * A \quad (Equation\ I - 5)$$

Q =Overland Storm Runoff (m^3/s)
A = Watershed Area (m^2)

$$Q = 0.65 * \left(36.9\,\frac{mm}{hr} * \frac{1m}{1000\,mm} * \frac{1\,hr}{3600\,s}\right) * 1{,}000{,}000\ m^2\ = 6.64\ cms\ \ (Equation\ I - 6)$$

Main Channel Sizing

Using the flow rate value from the time of concentration storm duration, it was possible to calculate the size of the canal required to divert the water and a velocity fast enough to limit blockage by sedimentation and slow enough as to not do damage to the channel lining. Area and velocity can be solved for simultaneously by using Equation I-7 and Equation I-8 to create Equation I-9. Equation I-9 is solved for A, using the required overland storm runoff. A is then used to find the velocity of the channel.

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

V = Channel Velocity (m/s)

$$V = \left(\frac{C_m}{n}\right) * \left(\frac{A}{P}\right)^{2/3} * {S_0}^{1/2} \quad (Equation\ I - 8)$$

C_m = 1 Constant for British Gravitational Units
n = Manning's Roughness Coefficient
P = Wetted Perimeter (m)
S_0 = Channel Slope (decimal percent)

$$\frac{Q}{A} = \left(\frac{C_m}{n}\right) * \left(\frac{A}{P}\right)^{2/3} * {S_0}^{1/2} \rightarrow \ Q = \left[\left(\frac{C_m}{n}\right) * \left(\frac{A}{P}\right)^{2/3} * {S_0}^{1/2}\right] * A \ \ (Equation\ I - 9)$$

Channel slope is similar to the natural topography and is .001 and the channel material is concrete, which has a conservative Manning's Roughness value of .015. Additional Manning's Roughness values can be seen in Table I 2 on the next page. These values were taken from *Water Resources Engineering* by Ralph A. Wurbs and Wesley P. James.

Table I 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

The channel is limited in depth, due to the existing canal elevations of the Nuevo Camino al Palmar and Antiguo canals. The limited depth we can use is 1.3 meters to achieve a slope of 0.1%. C.C.E. decided to use a normal flow height of 1 meter and calculated the required free board using Equation I-10.

$$FB = C_{FB} * {Y_n}^{0.5} \quad (Equation\ I - 10)$$

FB = *Free Board (m)*
C_{FB} = *Coefficient for Free Board Equation*
Y_n = *Normal Flow Depth (m)*

C_{FB} is a coefficient that varies from 0.6 for small channels to 0.9 for large channels (Wurbs). C_{FB} was assumed to be 0.8 for Avenida Fatima I. A required free board height was found to be 0.8, Equation I-11; however a freeboard height of 0.3 m was used because of channel depth limitations.

$$FB = 0.8 * 1.0^{0.5} = 0.8\, m \quad (Equation\ I - 11)$$

The resulting area of the required channel was found to be 4.1 m^2 and the velocity is 1.6 m/s.

Rectangular Canal Design

In the rectangular canal the design is most efficient when the base is twice the size of the depth. Since the channel is limited by area and depth, the base, B, is required to be 4.1 m to achieve these requirements. The flow depth, Y_n, is 1.0 m and the total depth, flow and free board, is 1.3 m.

Trapezoidal Canal Design

In a trapezoidal canal design the most efficient design occurs when the base is the same size as the water depth. Again since the channel is limited by depth and area the base, B, was required to be 2.8 m. This flow depth, Y_n, is 1.0 m and the total depth is 1.3 m.

Since in this design the top width will be larger than the bottom width, following Bolivian standards provided in detail drawings, C.C.E. chose a side slope of 1.3H:1V. Using this side slope the top width can be found by using Equation I-12.

$$T = B + (2 * SS * Y_n) \quad (Equation\ I - 12)$$

T = *Top Width of Trapezoidal Canal (m)*
B = *Base Width of Canal (m)*
SS = *Side Slope*

The top width was found to be 5.4 m, Equation I-13 below.

$$T = 2.8\, m + (2 * 1.3\, m * 1.0\, m) = 5.4\, m \quad (Equation\ I - 13)$$

The Froude number, Equation I-14, must be below .6 to avoid standing waves in the channel. For both the trapezoidal and rectangular designs the Froude number met this criterion, Equation I-15 and Equation I-16.

$$Fr = \frac{V}{(g * Y_n)^{0.5}} \quad (Equation\ I-14)$$

Fr = Froude Number
g = Gravitational Constant (9.81 m/s^2)

Rectangular

$$Fr = \frac{1.62\ m/s}{(9.81 \frac{m}{s^2} * 0.76)^{0.5}} = 0.52 \quad (Equation\ I-15)$$

Trapezoidal

$$Fr = \frac{1.62\ m/s}{(9.81 \frac{m}{s^2} * 1.0)^{0.5}} = 0.59 \quad (Equation\ I-16)$$

The option of using two pipes was considered, Equation I-17, but due to the slight slope the pipe diameters required, Equation I-18, were too large to fit the depth limitation of 1.3 m.

$$D = \left[\frac{3.21 * Q * n}{C_m * S_0^{0.5}}\right]^{3/8} \quad (Equation\ I-17)$$

D = Pipe Diameter (m)

$$D = \left[\frac{3.21 * 3.32cms * 0.015}{1 * (.001)^{0.5}}\right]^{3/8} = 1.8\ m \quad (Equation\ I-18)$$

Diversion Canal Sizing

To divert the river that flows perpendicular to Fatima, C.C.E. had to size a temporary diversion to be used until a permanent solution can be found. Assuming the worst scenario through the two '1 meter' diameter culverts already installed, it was possible to find the maximum flow through the culvert and size and earthen culvert to handle the flow.

Outlet and Inlet Flow

Using Manning's equation for outlet controlled culverts, Equation I-19, and in let controlled culverts, Equation I-20, it was possible to find the maximum flow through the culverts.

$$Q = N_p * A_p * C_c * \sqrt{2 * g * HL} \quad (Equation\ I - 19)$$

N_P = *Number of Pipes*
A_P = *Area of the Pipe* (m^2)
C_C = *Loss Coefficient*
HL = Maximum Height of Headloss from Entrance to Exit

$$Q = N_p * A_e * C_o * \sqrt{2 * g * \left(H - \frac{D}{2}\right)} \quad (Equation\ I - 20)$$

A_e = *Area of the Pipe Entrance* (m^2)
C_0 = *Orifice Coefficient*
H = Head (m)

C_C can be found using Equation I-21 and Equation I-22.

$$C_C = (K_e + K_f + 1)^{\ -0.5} \quad (Equation\ I - 21)$$

K_e = *Entrance Coefficient*
K_f = *Friction Loss Coefficient*

$$K_f = \frac{L_C * n^2 * 2 * g}{R^{4/3} * {C_m}^2} \quad (Equation\ I - 22)$$

L_C = *Pipe Length (m)*
R = Hydraulic Radius, A/P, (m)

HL was 1.0 m, K_e is 0.8 for protruding entrances, the length of the structure was 3.05 m, and C_0 is 0.7 for sharp edged entrances. Using these variables C.C.E. could find the additional required inputs, Equation I-23 and Equation I-24, and resulting outlet and inlet controlled flow rates, Equation I-25 and Equation I-26.

$$K_f = \frac{3.05\ m * 0.015^2 * 2 * 9.81\ \frac{m}{s^2}}{\left(\frac{\pi * (0.5\ m)^2}{\pi * 1.0\ m}\right)^{4/3} * (1.0)^2} = 2.85\ (Equation\ I - 23)$$

$$C_C = (0.8 + 2.85 + 1)^{-0.5} = 0.46 \quad (Equation\ I - 24)$$

$$Q = 2 * (\pi * (0.5\ m)^2) * 0.46 * \sqrt{2 * 9.81 \frac{m}{s^2} * 1.0\ m} = 3.20\ \frac{m^3}{s} \quad (Equation\ I - 25)$$

$$Q = 2 * (\pi * (0.5\ m)^2) * 0.7 * \sqrt{2 * 9.81 \frac{m}{s^2} * \left(1.0\ m - \frac{1.0\ m}{2}\right)} = 3.32\ \frac{m^3}{s} \quad (Equation\ I - 26)$$

Diversion Sizing

Using a flow rate of 3.32 m^3/s the area was found using Equation I-7 above.
Assuming the velocity is 1.1m/s which is the maximum velocity recommended for a silty clay canal, the required area was found in Equation I-27.

$$A = \frac{3.32\ \frac{m^3}{s}}{1.1\ m/s} = 3.02\ m^2 \quad (Equation\ I - 27)$$

Palmar Piping

On the Palmar or south side of Fatima the usable cross section decreases due to encroachment of telephone poles and sidewalk. The width decreases enough that the proposed 4.1m wide channel will not fit in this section. To counter this problem C.C.E. decided to use underground pipes that will interfere less with the proposed road. Since Fatima slopes away from this section it will have no flow from the rest of the watershed. Therefore the runoff into this section can be found utilizing only the contribution portion of the watershed, which is 188,845 m^2. The same C and I values were used from the initial Watershed Analysis.

$$Q = 0.65 * \left(36.3\,\frac{mm}{hr} * \frac{1\,m}{1000\,mm} * \frac{1\,hr}{3600\,s}\right) * 188{,}845\,m^2 = 1.24\,\frac{m^3}{s} \quad (Equation\ I-28)$$

With the flow into the twp pipes known the diameter of the pipes can be found with the Equation I-17 above.

$$D = \left[\frac{3.21 * \left(\frac{1.24\frac{m^3}{s}}{2}\right) * 0.015}{1.0 * (.001)^{0.5}}\right]^{3/8} = .98\,m\ each \quad (Equation\ I-29)$$

Using manning’s equation, Equation I-30, C.C.E. could find the full capacity of the pipe, Equation I-31.

$$Q_{full} = \left(\frac{C_m}{n}\right) * A_p * R^{2/3} * {S_0}^{0.5} \quad (Equation\ I-30)$$

Q_{full} = *Capacity of Pipe Flowing Full* (m^3/s)

$$Q_{full} = \left(\frac{1.0}{0.015}\right) * \left(\pi * \left(\frac{1.0\,m}{2}\right)^2\right) * \left(\frac{\pi * \left(\frac{1.0\,m}{2}\right)^2}{\pi * 1.0\,m}\right)^{2/3} * (.001)^{\,0.5} = 0.66\,\frac{m^3}{s} \quad (Equation\ I-31)$$

The flow depth was then found using the ratio between the required flow, Q, and the full capacity flow, Q_{full}, which is 0.94. Figure 5.3 on page 258 of *Water Resources Engineering* by R. A. Wurbs and W. P. James. The flow depth, Y_n, was found to be 0.8 m using this graph. The maximum velocity was found using Equation I-7, and was found to be 0.89 m/s, Equation I-32.

$$V_{max} = \frac{\left(\frac{1.24\frac{m^3}{s}}{2}\right)}{\pi * \left(\frac{1.0\,m}{2}\right)^2} = 0.84\,m/s \quad (Equation\ I-32)$$

Antiguo culvert

Using a slope of .1% on the Fatima channel left a problem of limited slope to connect the channel into the perpendicular Antiguo channel. To counter this problem C.C.E. decided to use angled pipes to reach a lower section of the Antiguo channel. This increased the maximum possible slope of the tie in to 8%. Since all the flow at this section will be from the Fatima channel it will have the design flow rate of 6.53 m^3/s.

Using this flow rate it was possible to find the diameter of the pipes required to handle the water, using Equation I-11 above. The required length of pipes is 23.5 m.

$$D = \left[\frac{3.21 * \left(\frac{6.64 \frac{m^3}{s}}{2} \right) * 0.015}{1.0 * (.008)^{0.5}} \right]^{3/8} = 1.24\, m \quad (Equation\ I - 33)$$

Using manning's equation, Equation I-30, C.C.E. could find the full capacity of the pipe.

$$Q_{full} = \left(\frac{1.0}{0.015} \right) * \left(\pi * \left(\frac{1.25\, m}{2} \right)^2 \right) * \left(\frac{\pi * \left(\frac{1.25\, m}{2} \right)^2}{\pi * 1.25\, m} \right)^{2/3} * (.008)^{\,0.5} = 3.37\, \frac{m^3}{s} \quad (Equation\ I - 34)$$

The required to full capacity ratio is 0.8. This results in a flow depth of 0.8 m. The maximum velocity was then found, Equation I-7, and is 22 m/s.

$$V_{max} = \frac{\left(3.37 \frac{m^3}{s} \right)}{\pi * \left(\frac{1.25\, m}{2} \right)^2} = 2.7\, m/s \quad (Equation\ I - 35)$$

Since this section of piping will have water on both ends it will also depend on the entrance controlled and outlet controlled discharge for culverts

Entrance controlled

Using Equation I-20 for entrance controlled flow, H is equal to the normal depth, which is 1.0 m.

$$Q = 2 * (\pi * (0.5\, m)^2) * 1 * \sqrt{2 * 9.81 \frac{m}{s^2} * \left(1.0 - \frac{1.25\, m}{2} \right)} = 6.66\, \frac{m^3}{s} \; (Equation\ I - 36)$$

Outlet controlled

Using Equation I-19, Equation I-21, and Equation I-22 for outlet controlled culverts.

$$K_f = \frac{36\,m * 0.015^2 * 2 * 9.81\,\frac{m}{s^2}}{\left(\frac{\pi * (1.25\,m)^2}{\pi * 1.25\,m}\right)^{4/3} * (1.0)^2} = 0.75\ (Equation\ I - 37)$$

$$C_C = (0.8 + 0.75 + 1)\ ^{-0.5} = .63\ \ (Equation\ I - 38)$$

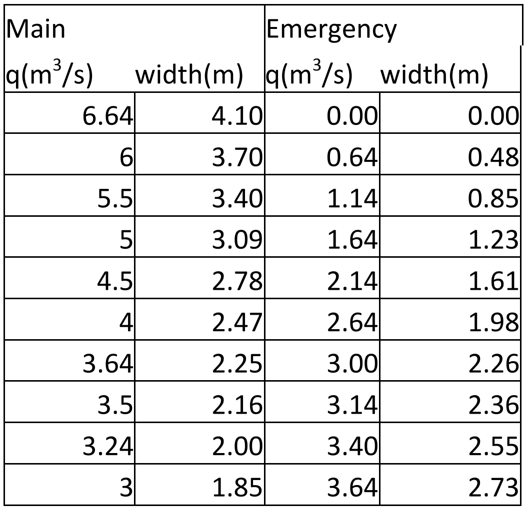
$$Q = 2 * (\pi * (1.25\,m)^2) * 0.63 * \sqrt{2 * 9.81\frac{m}{s^2} * 1.25\,m} = 6.64\ \frac{m^3}{s}\ \ (Equation\ I - 39)$$

The Outlet controlled value is the same as the maximum flow of the piping; 6.64 m^3/s. So the pipes will be able to handle the designed flow.

Emergency ditch

The emergency ditch that runs parallel and north of Fatima was not originally factored into the calculations on the request of Ing. Javier Marín and the Sub Alcalde Ing. Victor P. Escobar Díaz. Once the main channel was sized and found it would be 1.3 m deep by 4.1 m wide, C.C.E. decided the emergency ditch could be expanded to take some of the load from the Fatima channel. Assuming it would still be an earthen ditch it could handle a maximum velocity of 1.1 m/s, due to the limitations of the soil.

With the information from the main channel and the maximum velocity of the emergency ditch it was possible to calculate a chart of the different flow rates in both the channel and the ditch.



Main		Emergency	
q(m^3/s)	width(m)	q(m^3/s)	width(m)
6.64	4.10	0.00	0.00
6	3.70	0.64	0.48
5.5	3.40	1.14	0.85
5	3.09	1.64	1.23
4.5	2.78	2.14	1.61
4	2.47	2.64	1.98
3.64	2.25	3.00	2.26
3.5	2.16	3.14	2.36
3.24	2.00	3.40	2.55
3	1.85	3.64	2.73

Using the emergency ditch provides the option to decrease the width of the Fatima channel which is too wide to be as efficient as possible.

Drainage Inlets

Two types of inlets had to be designed for the design options.

First for the open rectangular section of the channel gutter inlets were needed, Equation I-40.

$$Q_i = C_w * (L + 1.8 * W) * d^{3/2} \quad (Equation\ I - 40)$$

Q_i = *Flow Rate of Inlet* (m^3/s)
C_w = *Constant, for British Gravitational Units it is 1.25*
L = *Length of Inlet (m)*
W = *Width of Inlet (m)*
d = *Water Depth (m)*

First a length of the inlets was decided on by C.C.E.; this was not based on a reference standard and can be changed to accommodate needs. The length was chosen to be 0.5 m. The *Water Resources Engineering* textbook by R. A. Wurbs and W. P. James recommended using a width between .3m-.6m. C.C.E. decided to use 0.6 m. Finally the water depth was assumed to be the full height of the inlet, 0.15 m, because intense storms are expected with large volumes of water running towards Avenida Fatima I.

With these values it was possible to calculate the flow through each inlet, Equation I-41.

$$Q_i = 1.25 * (0.5\ m + 1.8 * 0.6\ m) * (0.15\ m)^{3/2} = .11\,\frac{m^3}{s} \quad (Equation\ I - 41)$$

Since the total runoff into this section is 5.38 m^3/s it is possible to find the number of inlets required, Equation I-42 and Equation I-43.

$$NI = \frac{Q_C}{Q_i} \quad (Equation\ I - 42)$$

NI = *Number of Inlets*
Q_C = *Flow Towards Open Rectangular Channel* (m^3/s)

$$NI = \frac{5.38\,\frac{m^3}{s}}{.11\,\frac{m^3}{s}} = 49\ inlets \quad (Equation\ I - 43)$$

Since the channel is 950m long with 3m sections, C.C.E. decided to put these inlets every 18m or 6 sections, providing 53 inlets total.

The second type of inlet that needed to be designed was the slotted drain inlets for the double pipes on the Palmar or south side of the channel. These inlets will be placed alternating on pipes to allow storm water access to both pipes.

Dimensions for the inlets on these sides were chosen to be a circular inlet with a diameter of .6m, and water depth of 0.15 m. With all of these values it was possible to calculate the flow through each inlet, using Equation I-44 from the *Water Resources Engineering* textbook by R. A. Wurbs and W. P. James.

$$Q_i = 0.6 * A * 2 * g * d \quad (Equation\ I - 44)$$

Q_i = *Flow Rate of Inlet* (m^3/s)
C_w = *Constant, for British Gravitational Units it is 1.25*
A = *Area of Inlet* (m^2)
d = *Water Depth (m)*

$$Q_i = 0.6 * (\frac{\pi.* 6m\verb|^|2}{4}) * 2 * 9.81\frac{m^2}{s} * 0.15\ m = .29\ \frac{m^3}{s} \quad (Equation\ I - 45)$$

Since the total runoff into this section is the total watershed runoff minus the runoff into the open channel. The flow into the pipe section would be 1.24 m^3/s, as mentioned in the Palmar Piping section.

It was possible to find how many inlets would be needed, Equation I-46.

$$NI = \frac{1.24\ \frac{m^3}{s}}{.29\ \frac{m^3}{s}} = 5\ inlets \quad (Equation\ I - 46)$$

Since the road section is 250 m long with 4.5 m sections, C.C.E. decided to put these inlets every 51m center-to-center, on alternating sides of the road.

Sediment Trap Design

To calculate the required dimensions of the sediment traps, the critical velocity of sediment particles of varying diameters was calculated using Equation I-47 below.

$$v_s = \left[\frac{4g(\rho_s - \rho)d}{3C_D\rho}\right]^{1/2} \quad (Equation\ I-47)$$

v_s = Critical Settling Velocity (m/s)
g = Gravitational Constant (9.81 m/s^2)
ρ_S = Density of Particle (kg/m^3)
ρ = Density of Fluid (kg/m^3)
d = Particle Diameter (m)
C_D = Coefficient of Drag (unit less)

Assumptions for the variables in Equation I-47 can be seen in Table I 3 and a sample calculation can be seen in Equation I-48.

Table I 3: Values for Equation I-1

Variable	Value
g	9.81 m/s^2
ρ_s	1314 kg/m^3
ρ	983.2 kg/m^3
d	Ranges from 8.0 to 0.149 mm
C_D	0.4 for Turbulent Flow

$$v_s = \left[\frac{4 * \left(9.81\frac{m^2}{s}\right) * \left(1314\,\frac{kg}{m^3} - 983.2\,\frac{kg}{m^3}\right) * (.008\,m)}{3 * 0.4 * 983.2\,\frac{kg}{m^3}}\right]^{1/2} = \ .287\,\frac{m}{s} \ \ (Equation\ I-48)$$

The critical settling velocity of each particle, v_s, was then used to find the required retention time in the sediment trap using Equation I-49, a sample calculation can be seen in Equation I-50. A sediment trap depth of 0.3 m was used; this was based off of the discretion of C.C.E.

$$\tau = \frac{h}{v_S} \quad (Equation\ I-49)$$

τ = Retention Time (s)
h = Tank Depth (m)

$$\tau = \frac{0.3\,m}{0.287\,m/s} = 1.05\,s \quad (Equation\ I-50)$$

The channel velocity was used to find the required length of the sediment trap, Equation I-51, with a sample calculation in Equation I-52.

$$L_s = V_c * \tau \quad (Equation\ I - 51)$$

V_c = *Velocity of the Channel (m/s)*

$$L_s = 1.6\frac{m}{s} * 1.05\ s = 1.7\ m \quad (Equation\ I - 52)$$

Below V_S, τ, and L_S were found for sediment diameters ranging from 8.0 mm to 0.149 mm.

Table I 4: Sediment Trap Design

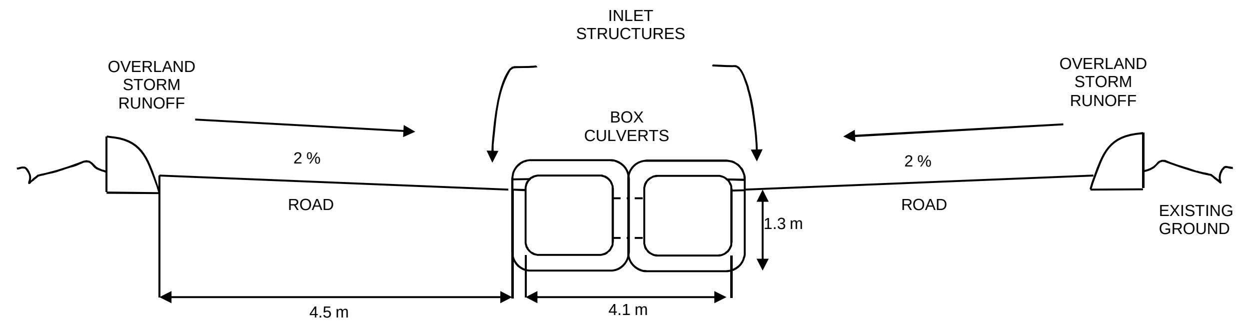
US Sieve Size	Diameter (mm)	Diameter (m)	v_S (m/s)	τ (s)	L_S (m)
-	8.000	0.008	0.29667	1.01	1.6
-	6.730	0.00673	0.27211	1.10	1.8
No. 3.5	5.660	0.00566	0.24954	1.20	1.9
No. 4	4.760	0.00476	0.22884	1.31	2.1
No. 50	4.000	0.004	0.20978	1.43	2.3
No. 60	3.360	0.00336	0.19227	1.56	2.5
No. 70	2.830	0.00283	0.17645	1.70	2.7
No. 80	2.380	0.00238	0.16182	1.85	3.0
No. 100	2.000	0.002	0.14834	2.02	3.2
No. 12	1.680	0.00168	0.13595	2.21	3.5
No. 14	1.410	0.00141	0.12455	2.41	3.9
No. 16	1.190	0.00119	0.11442	2.62	4.2
No.18	1.000	0.001	0.10489	2.86	4.6
No. 20	0.841	0.000841	0.09619	3.12	5.0
No. 25	0.707	0.000707	0.08820	3.40	5.4
No. 30	0.595	0.000595	0.08091	3.71	5.9
No. 35	0.500	0.0005	0.07417	4.04	6.5
No. 40	0.420	0.00042	0.06798	4.41	7.1
No. 45	0.354	0.000354	0.06241	4.81	7.7
No. 50	0.297	0.000297	0.05716	5.25	8.4
No. 60	0.250	0.00025	0.05245	5.72	9.2
No. 70	0.210	0.00021	0.04807	6.24	10.0
No. 80	0.177	0.000177	0.04413	6.80	10.9
No. 100	0.149	0.000149	0.04049	7.41	11.9

C.C.E. wanted to retain the entire coarse fraction of sediment The coarse fraction is defined as the No. 40 sieve and higher, therefore a minimum sediment trap length of 7.1 m was required. However, to increase constructability the length was increased to 9.0 m, which is equivalent to three canal sections. This would mean that sediment with a diameter of 0.297 mm and greater will be retained.

The final sediment trap dimensions are a length of 9.0 m, depth of 0.3 m, and width equivalent to the canal width.

Appendix J – Cost Estimate

DESIGN OPTION 2



Description: Design Option 2 is a continuous grade PC concrete pavement utilizing precast PC box culverts for storm drainage. The roadway will consist of two lanes, divided by a center median, with 4.5 m lane widths each. Precast PC box culverts will be utilized in as the center median and barrier curb for traffic. Storm drainage inlets will aslo be located in the center median, therefore pavement sections will be sloped towards the center 2%. Storm water will flow over the roadway sections and into the box culverts through the drainage inlets. Storm drainage inlets will be spaced every 90 m on both sides of the median. Given almost all of the storm water will come from the northwest of Avenida Fatima I, fewer drainage inlets can be implemented on the southeastern side of the road to reduce costs. Also, an opening will be cut in each box culvert to allow flow between the two box culverts.

ID	ACTIVITY	RATIO	COST	UNIT	QUANTITY								TOTAL COST
					LENGTH	*Unit*	*WIDTH*	*Unit*	*DEPTH*	*Unit*	**TOTAL**	**Unit**	
	MOBILIZATION & SITE LAYOUT	TOTAL	21137.90										
DRE 001	MOBILIZATION - DRAINAGE	-	3402.70	GL.	-	-	-	-	-	-	1	GL.	3402.70
INS 001	(MTL) MOBILIZATION	1.00	3150.00	GL.							1	GL.	
AL 350	(MP) BRICK LAYER	11.00	8.20	h							11	h	
AL 355	(MP) ASSISTANT	25.00	6.50	h							25	h	
PA 004	MOBILIZATION - PAVEMENT	-	3285.50	GL.	-	-	-	-	-	-	1	GL.	3285.50
MT 001	(MTL) SEVERAL MATERIALS	1.00	3000.00	GL.							1	GL.	
AL 350	(MP) BRICK LAYER	15.00	8.20	h							15	h	
AL 355	(MP) ASSISTANT	25.00	6.50	h							25	h	
DRE 002	SITE LAYOUT (SEWERS, CANALS, BRIDGES)		10.68	MI.	1200	m	-	-	-	-	1200	m	12810.60
MA 019	(MTL) WOOD STAKES 2"X2"X30cm	1.00	3.00	PZA							1200	PZA	
PT 002	(MTL) PAINTING LATEX	0.01	72.00	GAL							12	GAL	
HI 001	(MTL) INDENTED IRON	0.01	11.55	kg							12	kg	
AL 365	(MP) TOPOGRAPHER	0.20	12.00	h							240	h	
AL 366	(MP) PAINTER	0.20	8.20	h							240	h	
MQ 022	(T&E) TOPOGRAPHIC TEAM	0.07	40.00	h							84	h	
PA 005	SITE LAYOUT (PAVEMENT)	-	1365.92	km	1200	m	-	-	-	-	1.2	km	1639.10
MA 019	(MTL) WOOD STAKES 2"X2"X30cm	165.00	3.00	PZA							198	PZA	
PT 007	(MTL) OIL FOR PAINTING	0.40	30.50	LT							0.48	LT	
HI 001	(MTL) NAIL	1.00	12.72	kg							1.2	kg	
AL 365	(MP) TOPOGRAPHER	10.00	12.00	h							12	h	
AL 366	(MP) PAINTER	30.00	8.20	h							36	h	
MQ 022	(T&E) TOPOGRAPHIC TEAM	12.00	40.00	h							14.4	h	
	PAVEMENT & SIDE CURB	TOTAL	1279494.44										
EXC 002	EARTHWORK	-	9.25	m^3	From Cut and Fill Calculations						10000	m^3	92500.00
AL 355	(MP) ASSISTANT	0.50	6.50	h							5000	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.02	200.00	h							200	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							100	h	
EXC 006	LEVEL AND COMPACT EXISTING GROUND	-	16.35	m^3	950	m	9	m	0.3	m	2565	m^3	41937.75
AL 360	(MP) COMPACTOR OPERATOR	2.10	6.00	h							5386.5	h	
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							384.75	h	
PA 029	PROVIDE & PLACE CRUSHED BASE (15 cm)	-	49.64	m^3	950	m	9	m	0.12	m	1026	m^3	50931.67
AG 015	(MTL) CAPA BASE	0.18	230.00	m^3							184.68	m^3	
AL 385	(MP) OPERATOR	0.03	8.50	h							30.78	h	
AL 362	(MP) ASSISTANT	0.02	6.50	h							20.52	h	
MQ 001	(T&E) BULLDOZER 120 G	0.008	284.00	h							8.208	h	
MQ 028	(T&E) VIBRATORY COMPACTOR	0.008	284.00	h							8.208	h	
MQ 027	(T&E) PNEUMATIC COMPACTOR	0.008	284.00	h							8.208	h	
MQ 004	(T&E) WATER BEARER "AGUATERO"	0.008	130.00	h							8.208	h	
PA 039	CONCRETE SLAB PAVEMENT (18 cm)	-	91.24	m^2	950	m	9	m	-	-	8550	m^2	936102.91
AG 901	(MTL) CEMENT	55.00	0.94	kg							564300	kg	
AG 001	(MTL) RIVER SAND	0.09	60.00	m^3							923.4	m^3	
AG 002	(MTL) WASHED DEBRIS	0.12	140.00	m^3							1231.2	m^3	
FP 001	(MTL) PLASTIC FIBER	0.16	8.10	kg							1641.6	kg	
AI 004	(MTL) ANTISOL	0.12	10.13	LT							1231.2	LT	
AI 001	(MTL) TAR	0.15	8.50	kg							1539	kg	
AG 007	(MTL) WATER	25.00	0.10	LT							256500	LT	
AL 354	(MP) OVERSEERER	0.095	9.00	h							974.7	h	
AL 350	(MP) LABORER	0.195	6.50	h							2000.7	h	
AL 355	(MP) ASSISTANT	0.38	6.50	h							3898.8	h	
AL 364	(MP) DRIVER	0.185	6.00	h							1898.1	h	
MQ 024	(T&E) MIXER	0.006	324.00	h							61.56	h	
MQ 025	(T&E) VIBRATORY MACHINE	0.01	40.50	h							102.6	h	
MQ 009	(T&E) BUCKET 10 m^3	0.015	200.00	h							153.9	h	
HIE 001	REBAR (LOAD TRANSFER FOR ROAD)	-	14.07	kg	2700.8	m	-	-	-	-	4321.28	kg	60808.62
HI 002	(MTL) INDENTED IRON	1.008	11.55	kg							4355.9	kg	
HI 003	(MTL) MOORING WIRE	0.15	12.73	kg							648.2	kg	
AL 350	(MP) LABORER	0.08	6.50	h							345.7	h	
PA 011	DELIVERY AND PLACEMENT OF CURB	-	51.17	ML	1900	m	-	-	-	-	1900	ML	97213.50
AG 901	(MTL) CEMENT	0.25	0.94	kg							475	kg	
AG 001	(MTL) RIVER SAND	0.006	60.00	m^3							11.4	m^3	
AG 916	(MTL) PREFABRICATED CORD	1.00	42.00	ML							1900	ML	
AL 354	(MP) OVERSEERER	0.08	9.00	h							152	h	
AL 350	(MP) LABORER	0.10	6.50	h							190	h	
AL 355	(MP) ASSISTANT	0.80	6.50	h							1520	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							19	h	
	PAVEMENT - SIDE ROADS	TOTAL	127982.22										
EXC 002	EARTHWORK	-	9.25	m^3	240	m	3.5	m	0.3	m	252	m^3	2331.00
AL 355	(MP) ASSISTANT	0.50	6.50	h							126	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.02	200.00	h							5.04	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							2.52	h	
EXC 006	LEVEL AND COMPACT EXISTING GROUND	-	16.35	m^3	240	m	3.5	m	0.3	m	252	m^3	4120.20
AL 360	(MP) COMPACTOR OPERATOR	2.10	6.00	h							529.2	h	
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							37.8	h	
PA 029	PROVIDE & PLACE CRUSHED BASE (15 cm)	-	49.64	m^3	240	m	3.5	m	0.12	m	100.8	m^3	5003.81
AG 015	(MTL) CAPA BASE	0.18	230.00	m^3							18.144	m^3	

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MQ 028	(T&E) VIBRATORY COMPACTOR	0.008	284.00	h							0.8064	h	
MQ 027	(T&E) PNEUMATIC COMPACTOR	0.008	284.00	h							0.8064	h	
MQ 004	(T&E) WATER BEARER "AGUATERO"	0.008	130.00	h							0.8064	h	
PA 039	CONCRETE SLAB PAVEMENT (18 cm)	-	91.24	m^2	240	m	3.5	m	-	-	840	m^2	91968.00
AG 901	(MTL) CEMENT	55.00	0.94	kg							55440	kg	
AG 001	(MTL) RIVER SAND	0.09	60.00	m^3							90.72	m^3	
AG 002	(MTL) WASHED DEBRIS	0.12	140.00	m^3							120.96	m^3	
FP 001	(MTL) PLASTIC FIBER	0.16	8.10	kg							161.28	kg	
AI 004	(MTL) ANTISOL	0.12	10.13	LT							120.96	LT	
AI 001	(MTL) TAR	0.15	8.50	kg							151.2	kg	
AG 007	(MTL) WATER	25.00	0.10	LT							25200	LT	
AL 354	(MP) OVERSEERER	0.095	9.00	h							95.76	h	
AL 350	(MP) LABORER	0.195	6.50	h							196.56	h	
AL 355	(MP) ASSISTANT	0.38	6.50	h							383.04	h	
AL 364	(MP) DRIVER	0.185	6.00	h							186.48	h	
MQ 024	(T&E) MIXER	0.006	324.00	h							6.048	h	
MQ 025	(T&E) VIBRATORY MACHINE	0.01	40.50	h							10.08	h	
MQ 009	(T&E) BUCKET 10 m^3	0.015	200.00	h							15.12	h	
PA 011	DELIVERY AND PLACEMENT OF CURB	-	51.17	ML	480	m	-	-	-	-	480	ML	24559.20
AG 901	(MTL) CEMENT	0.25	0.94	kg							120	kg	
AG 001	(MTL) RIVER SAND	0.006	60.00	m^3							2.88	m^3	
AG 916	(MTL) PREFABRICATED CORD	1.00	42.00	ML							480	ML	
AL 354	(MP) OVERSEERER	0.08	9.00	h							38.4	h	
AL 350	(MP) LABORER	0.10	6.50	h							48	h	
AL 355	(MP) ASSISTANT	0.80	6.50	h							384	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							4.8	h	
	COVERED CANAL & CENTER MEDIAN	TOTAL	5037310.57										
DRE 004	EXCAVATION WITH MACHINERY	-	14.40	m^3	950	m	4.5	m	1.3	m	5557.5	m^3	80028.00
AL 361	(MP) BACKHOE OPERATOR	0.32	6.00	h							1778.4	h	
AL 362	(MP) ASSISTANT	0.32	6.50	h							1778.4	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.04	200.00	h							222.3	h	
MQ 008	(T&E) WATER SPRAYER OF 4"	0.12	20.00	h							666.9	h	
DRE 005	MANUAL SLOPE SHAPING (SIDES & BOTTOM)	-	2.37	m^2	950	m	7.1	m	-	-	6745	m^2	16002.51
AL 350	(MP) LABORER	0.18	6.50	h							1214.1	h	
AL 362	(MP) ASSISTANT	0.185	6.50	h							1247.825	h	
DRE 006	REINFORCED CONCRETE LINING FOR CANALS: 20 cm	-	91.07	m^2	950	m	9.3	m	-	-	8835	m^2	3218247.70
AG 901	(MTL) CEMENT	26.00	0.94	kg							918840		
AG 002	(MTL) WASHED DEBRIS	0.062	140.00	m^3							2191.08		
AG 001	(MTL) RIVER SAND	0.05	60.00	m^3							1767		
MA 004	(MTL) CONSTRUCTION WOOD	0.04	6.50	m^2							1413.6		
HI 001	(MTL) NAIL	0.02	12.72	kg							706.8		
AI 004	(MTL) ANTISOL	0.20	10.13	LT							7068		
HI 002	(MTL) INDENTED IRON	2.53	11.55	kg							89410.2		
HI 003	(MTL) MOORING WIRE	0.08	12.73	kg							2827.2		
AI 003	(MTL) GEOTEXTILES OP-20 (200 g/m^2)	0.30	8.00	m^2							10602		
AL 363	(MP) OPERATOR OF LIGHT FIELD EQUIP.	0.04	6.00	h							1413.6		
AL 350	(MP) LABORER	0.95	6.50	h							33573		
AL 355	(MP) ASSISTANT	1.90	6.50	h							67146		
HO 901	(T&E) MIXER OF 350 LTS	0.04	25.00	h							1413.6		
HOR 045	REINFORCED CONCRETE SLAB LID	-	1751.45	m^3	950	m	4.1	m	0.25	m	973.75	m^3	1705474.44
AG 901	(MTL) CEMENT	350.00	0.94	kg							340812.5	kg	
AG 001	(MTL) RIVER SAND	0.65	60.00	m^3							632.9375	m^3	
AG 002	(MTL) WASHED DEBRIS	0.85	140.00	m^3							827.6875	m^3	
HI 002	(MTL) INDENTED IRON	50.00	11.55	kg							48687.5	kg	
MA 001	(MTL) BOARD OF WOOD	60.00	2.80	ft^2							58425	ft^2	
HI 001	(MTL) NAIL	1.00	12.72	kg							973.75	kg	
HI 003	(MTL) MOORING WIRE	1.00	12.73	kg							973.75	kg	
AL 350	(MP) LABORER	39.00	6.50	h							37976.25	h	
AL 355	(MP) ASSISTANT	35.00	6.50	h							34081.25	h	
HO 901	(T&E) MIXER OF 350 LTS	0.50	25.00	h							486.875	h	
DRE 014	SEAL FISSURES IN CONCRETE LINED CANAL	-	6.74	ML	2500	m	-	-	-	-	2500	m	16845.00
AG 901	(MTL) CEMENT	3.00	0.94	kg							7500	kg	
AG 001	(MTL) RIVER SAND	0.0008	60.00	m^3							2	m^3	
HI 002	(MTL) INDENTED IRON	0.20	11.55	kg							500	kg	
AL 350	(MP) LABORER	0.12	6.50	h							300	h	
AL 355	(MP) ASSISTANT	0.12	6.50	h							300	h	
DRE 016	CONCRETE INTAKE (0.1m THICKNESS)	-	91.10	m^2	26	m	0.2	m	-	-	5.2	m^2	473.69
AG 901	(MTL) CEMENT	30.00	0.94	kg							156	kg	
AG 001	(MTL) RIVER SAND	0.06	60.00	m^3							0.312	m^3	
AG 002	(MTL) WASHED DEBRIS	0.08	140.00	m^3							0.416	m^3	
MA 001	(MTL) BOARD OF WOOD	4.00	2.80	ft^2							20.8	ft^2	
HI 003	(MTL) MOORING WIRE	0.10	12.73	kg							0.52	kg	
HI 001	(MTL) NAIL	0.10	12.72	kg							0.52	kg	
HI 002	(MTL) INDENTED IRON	1.00	11.55	kg							5.2	kg	
AG 007	(MTL) WATER	14.00	0.10	LT							72.8	LT	
AL 350	(MP) LABORER	1.30	6.50	h							6.76	h	
AL 355	(MP) ASSISTANT	1.30	6.50	h							6.76	h	
HO 901	(T&E) MIXER OF 350 LTS	0.18	25.00	h							0.936	h	
HIE 009	METAL LID 80cmX80cm	-	79.74	PZA	-	-	-	-	-	-	3	PZA	239.22
HI 033	(MTL) ANGULAR IRON 3/4"X1/8"	1.00	53.74	PZA							3	PZA	
AL 350	(MP) LABORER	2.00	6.50	h							6	h	
AL 355	(MP) ASSISTANT	2.00	6.50	h							6	h	
	PAVEMENT & SIDE CURB NEAR PALMAR	TOTAL	271999.85										
EXC 002	EARTHWORK	-	9.25	m^3	250	m	7.5	m	0.3	m	562.5	m^3	5203.13
AL 355	(MP) ASSISTANT	0.50	6.50	h							281.25	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.02	200.00	h							11.25	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							5.625	h	
EXC 006	LEVEL AND COMPACT EXISTING GROUND	-	16.35	m^3	250	m	7.5	m	0.3	m	562.5	m^3	9196.88
AL 360	(MP) COMPACTOR OPERATOR	2.10	6.00	h							1181.25	h	
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							84.375	h	

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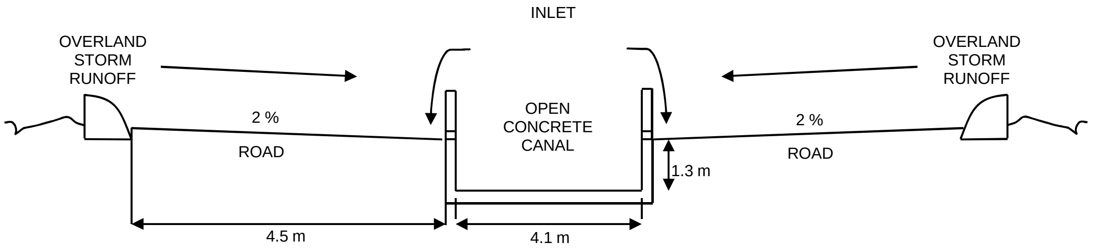
AL 385	(MP) OPERATOR	0.03	8.50	h							6.75	h	
AL 362	(MP) ASSISTANT	0.02	6.50	h							4.5	h	
MQ 001	(T&E) BULLDOZER 120 G	0.008	284.00	h							1.8	h	
MQ 028	(T&E) VIBRATORY COMPACTOR	0.008	284.00	h							1.8	h	
MQ 027	(T&E) PNEUMATIC COMPACTOR	0.008	284.00	h							1.8	h	
MQ 004	(T&E) WATER BEARER "AGUATERO"	0.008	130.00	h							1.8	h	
PA 039	CONCRETE SLAB PAVEMENT (18 cm)	-	91.24	m^2	250	m	7.5	m	-	-	1875	m^2	205285.73
AG 901	(MTL) CEMENT	55.00	0.94	kg							123750	kg	
AG 001	(MTL) RIVER SAND	0.09	60.00	m^3							202.5	m^3	
AG 002	(MTL) WASHED DEBRIS	0.12	140.00	m^3							270	m^3	
FP 001	(MTL) PLASTIC FIBER	0.16	8.10	kg							360	kg	
AI 004	(MTL) ANTISOL	0.12	10.13	LT							270	LT	
AI 001	(MTL) TAR	0.15	8.50	kg							337.5	kg	
AG 007	(MTL) WATER	25.00	0.10	LT							56250	LT	
AL 354	(MP) OVERSEERER	0.095	9.00	h							213.75	h	
AL 350	(MP) LABORER	0.195	6.50	h							438.75	h	
AL 355	(MP) ASSISTANT	0.38	6.50	h							855	h	
AL 364	(MP) DRIVER	0.185	6.00	h							416.25	h	
MQ 024	(T&E) MIXER	0.006	324.00	h							13.5	h	
MQ 025	(T&E) VIBRATORY MACHINE	0.01	40.50	h							22.5	h	
MQ 009	(T&E) BUCKET 10 m^3	0.015	200.00	h							33.75	h	
HIE 001	REBAR (LOAD TRANSFER FOR ROAD)	-	14.07	kg	691.2	m	-	-	-	-	1105.92	kg	15562.40
HI 002	(MTL) INDENTED IRON	1.008	11.55	kg							1114.8	kg	
HI 003	(MTL) MOORING WIRE	0.15	12.73	kg							165.9	kg	
AL 350	(MP) LABORER	0.08	6.50	h							88.5	h	
PA 011	DELIVERY AND PLACEMENT OF CURB	-	51.17	ML	500	m	-	-	-	-	500	ML	25582.50
AG 901	(MTL) CEMENT	0.25	0.94	kg							125	kg	
AG 001	(MTL) RIVER SAND	0.006	60.00	m^3							3	m^3	
AG 916	(MTL) PREFABRICATED CORD	1.00	42.00	ML							500	ML	
AL 354	(MP) OVERSEERER	0.08	9.00	h							40	h	
AL 350	(MP) LABORER	0.10	6.50	h							50	h	
AL 355	(MP) ASSISTANT	0.80	6.50	h							400	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							5	h	
	STORM DRAINAGE PIPE NEAR PALMAR	TOTAL	453647.47										
DRE 004	EXCAVATION WITH MACHINERY	-	14.40	m^3	250	m	2.5	m	1.4	m	875	m^3	12600.00
AL 361	(MP) BACKHOE OPERATOR	0.32	6.00	h							280	h	
AL 362	(MP) ASSISTANT	0.32	6.50	h							280	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.04	200.00	h							35	h	
MQ 008	(T&E) WATER SPRAYER OF 4"	0.12	20.00	h							105	h	
DRE 026	DELIVERY & PLACEMENT OF 2 REINFORCED CONCRETE PIPE (1.0 m Diam)	-	876.07	ML	500	m	-	-	-	-	500	m	438035.00
AG 001	(MTL) RIVER SAND	0.034	60.00	m^3							17	m^3	
AG 901	(MTL) CEMENT	9.00	0.94	kg							4500	kg	
HS 145	(MTL)RC PIPE (1.5 m ϕ)	1.02	796.00	ML							510	ML	
AL 350	(MP) LABORER	1.80	6.50	h							900	h	
AL 355	(MP) ASSISTANT	3.30	6.50	h							1650	h	
MQ 013	(T&E) TELESCOPIC CRANE	0.10	205.00	h							50	h	
EXC 003	FILL & COMPACT WITH PLATE	-	15.78	m^3	250	m	2.5	m	0.3	m	187.5	m^3	2957.81
AL 355	(MP) ASSISTANT	1.85	6.50	h							346.875		
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							28.125		
DRE 016	CONCRETE INTAKE (0.1m THICKNESS)	-	91.10	m^2	2	m	0.3	m	-	-	0.6	m^2	54.66
AG 901	(MTL) CEMENT	30.00	0.94	kg							18	kg	
AG 001	(MTL) RIVER SAND	0.06	60.00	m^3							0.036	m^3	
AG 002	(MTL) WASHED DEBRIS	0.08	140.00	m^3							0.048	m^3	
MA 001	(MTL) BOARD OF WOOD	4.00	2.80	ft^2							2.4	ft^2	
HI 003	(MTL) MOORING WIRE	0.10	12.73	kg							0.06	kg	
HI 001	(MTL) NAIL	0.10	12.72	kg							0.06	kg	
HI 002	(MTL) INDENTED IRON	1.00	11.55	kg							0.6	kg	
AG 007	(MTL) WATER	14.00	0.10	LT							8.4	LT	
AL 350	(MP) LABORER	1.30	6.50	h							0.78	h	
AL 355	(MP) ASSISTANT	1.30	6.50	h							0.78	h	
HO 901	(T&E) MIXER OF 350 LTS	0.18	25.00	h							0.108	h	
	CONNECTION TO ANTIGUO CANAL	TOTAL	81988.02										
DRE 004	EXCAVATION WITH MACHINERY	-	14.40	m^3	36	m	2	m	2	m	144	m^3	2073.60
AL 361	(MP) BACKHOE OPERATOR	0.32	6.00	h							46.08	h	
AL 362	(MP) ASSISTANT	0.32	6.50	h							46.08	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.04	200.00	h							5.76	h	
MQ 008	(T&E) WATER SPRAYER OF 4"	0.12	20.00	h							17.28	h	
DRE 026	DELIVERY & PLACEMENT OF REINFORCED CONCRETE PIPE (1.25 m IN DIAMETER)	-	876.07	ML	72	m	-	-	-	-	72	m	78846.30
AG 001	(MTL) RIVER SAND	0.034	60.00	m^3							3.06	m^3	
AG 901	(MTL) CEMENT	9.00	0.94	kg							1620	kg	
HS 145	(MTL)RC PIPE (1.5 m ϕ)	1.02	796.00	ML							183.6	ML	
AL 350	(MP) LABORER	1.80	6.50	h							324	h	
AL 355	(MP) ASSISTANT	3.30	6.50	h							594	h	
MQ 013	(T&E) TELESCOPIC CRANE	0.10	205.00	h							18	h	
EXC 003	FILL & COMPACT WITH PLATE	-	15.78	m^3	36	m	2	m	0.8	m	57.6	m^3	908.64
AL 355	(MP) ASSISTANT	1.85	6.50	h							106.56		
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							8.64		
HIE 009	METAL LID 80cmX80cm	-	79.74	PZA	-	-	-	-	-	-	2	PZA	159.48
HI 033	(MTL) ANGULAR IRON 3/4"X1/8"	1.00	53.74	PZA							2	PZA	
AL 350	(MP) LABORER	2.00	6.50	h							4	h	
AL 355	(MP) ASSISTANT	2.00	6.50	h							4	h	
	EROSION CONTROL	TOTAL	5400.00										
OT 014	(MTL) BLACK DIRT	-	30.00	m^3	1200	m	2	m	0.075	m	180	m^3	5400.00
												TOTAL	$7,278,960.46

DESIGN OPTION 3



Description: Design Option 3 is a continuous grade PC concrete pavement utilizing an open rectangular canal. The roadway will consist of two lanes, divided by the canal, with 4.5 m lane widths each. The side walls of the canal will extend 1.0 m above ground level and will act as a barrier to traffic and safety precaution for pedestrians. Storm drainage inlets will also be located in the canal side walls, therefore pavement sections will be sloped towards the canal 2%. Storm water will flow over the roadway sections and enter the canal through the storm drainage inlets.

ID	ACTIVITY	RATIO	COST	UNIT	QUANTITY								TOTAL COST
					LENGTH	*Unit*	*WIDTH*	*Unit*	*DEPTH*	*Unit*	**TOTAL**	**Unit**	
	MOBILIZATION/SITE LAYOUT	TOTAL	21137.90										
DRE 001	MOBILIZATION - DRAINAGE	-	3402.70	GL.	-	-	-	-	-	-	1	GL.	3402.70
INS 001	(MTL) MOBILIZATION	1.00	3150.00	GL.							1	GL.	
AL 350	(MP) BRICK LAYER	11.00	8.20	h							11	h	
AL 355	(MP) ASSISTANT	25.00	6.50	h							25	h	
PA 004	MOBILIZATION - PAVEMENT	-	3285.50	GL.	-	-	-	-	-	-	1	GL.	3285.50
MT 001	(MTL) SEVERAL MATERIALS	1.00	3000.00	GL.							1	GL.	
AL 350	(MP) BRICK LAYER	15.00	8.20	h							15	h	
AL 355	(MP) ASSISTANT	25.00	6.50	h							25	h	
DRE 002	SITE LAYOUT (SEWERS, CANALS, BRIDGES)		10.68	MI.	1200	m	-	-	-	-	1200	m	12810.60
MA 019	(MTL) WOOD STAKES 2"X2"X30cm	1.00	3.00	PZA							1200	PZA	
PT 002	(MTL) PAINTING LATEX	0.01	72.00	GAL							12	GAL	
HI 001	(MTL) INDENTED IRON	0.01	11.55	kg							12	kg	
AL 365	(MP) TOPOGRAPHER	0.20	12.00	h							240	h	
AL 366	(MP) PAINTER	0.20	8.20	h							240	h	
MQ 022	(T&E) TOPOGRAPHIC TEAM	0.07	40.00	h							84	h	
PA 005	SITE LAYOUT & TOPOGRAPHIC CONTROL	-	1365.92	km	1200	m	-	-	-	-	1.2	km	1639.10
MA 019	(MTL) WOOD STAKES 2"X2"X30cm	165.00	3.00	PZA							198	PZA	
PT 007	(MTL) OIL FOR PAINTING	0.40	30.50	LT							0.48	LT	
HI 001	(MTL) NAIL	1.00	12.72	kg							1.2	kg	
AL 365	(MP) TOPOGRAPHER	10.00	12.00	h							12	h	
AL 366	(MP) PAINTER	30.00	8.20	h							36	h	
MQ 022	(T&E) TOPOGRAPHIC TEAM	12.00	40.00	h							14.4	h	
	PAVEMENT & SIDE CURB	TOTAL	1279494.44										
EXC 002	EARTHWORK	-	9.25	m^3	From Cut & Fill Calculations						10000	m^3	92500.00
AL 355	(MP) ASSISTANT	0.50	6.50	h							5000	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.02	200.00	h							200	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							100	h	
EXC 006	LEVEL AND COMPACT EXISTING GROUND	-	16.35	m^3	950	m	9	m	0.3	m	2565	m^3	41937.75
AL 360	(MP) COMPACTOR OPERATOR	2.10	6.00	h							5386.5	h	
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							384.75	h	
PA 029	PROVIDE & PLACE CRUSHED BASE (15 cm)	-	49.64	m^3	950	m	9	m	0.12	m	1026	m^3	50931.67
AG 015	(MTL) CAPA BASE	0.18	230.00	m^3							184.68	m^3	
AL 385	(MP) OPERATOR	0.03	8.50	h							30.78	h	
AL 362	(MP) ASSISTANT	0.02	6.50	h							20.52	h	
MQ 001	(T&E) BULLDOZER 120 G	0.008	284.00	h							8.208	h	
MQ 028	(T&E) VIBRATORY COMPACTOR	0.008	284.00	h							8.208	h	
MQ 027	(T&E) PNEUMATIC COMPACTOR	0.008	284.00	h							8.208	h	
MQ 004	(T&E) WATER BEARER "AGUATERO"	0.008	130.00	h							8.208	h	
PA 039	CONCRETE SLAB PAVEMENT (18 cm)	-	91.24	m^2	950	m	9	m	-	-	8550	m^2	936102.91
AG 901	(MTL) CEMENT	55.00	0.94	kg							564300	kg	
AG 001	(MTL) RIVER SAND	0.09	60.00	m^3							923.4	m^3	
AG 002	(MTL) WASHED DEBRIS	0.12	140.00	m^3							1231.2	m^3	
FP 001	(MTL) PLASTIC FIBER	0.16	8.10	kg							1641.6	kg	
AI 004	(MTL) ANTISOL	0.12	10.13	LT							1231.2	LT	
AI 001	(MTL) TAR	0.15	8.50	kg							1539	kg	
AG 007	(MTL) WATER	25.00	0.10	LT							256500	LT	
AL 354	(MP) OVERSEERER	0.095	9.00	h							974.7	h	
AL 350	(MP) LABORER	0.195	6.50	h							2000.7	h	
AL 355	(MP) ASSISTANT	0.38	6.50	h							3898.8	h	
AL 364	(MP) DRIVER	0.185	6.00	h							1898.1	h	
MQ 024	(T&E) MIXER	0.006	324.00	h							61.56	h	
MQ 025	(T&E) VIBRATORY MACHINE	0.01	40.50	h							102.6	h	
MQ 009	(T&E) Bucket 10 m^3	0.015	200.00	h							153.9	h	
HIE 001	REBAR (LOAD TRANSFER FOR ROAD)	-	14.07	kg	2700.8	m	-	-	-	-	4321.28	kg	60808.62
HI 002	(MTL) INDENTED IRON	1.008	11.55	kg							4355.9	kg	
HI 003	(MTL) MOORING WIRE	0.15	12.73	kg							648.2	kg	
AL 350	(MP) LABORER	0.08	6.50	h							345.7	h	
PA 011	DELIVERY AND PLACEMENT OF CURB	-	51.17	ML	1900	m	-	-	-	-	1900	ML	97213.50
AG 901	(MTL) CEMENT	0.25	0.94	kg							475	kg	
AG 001	(MTL) RIVER SAND	0.006	60.00	m^3							11.4	m^3	
AG 916	(MTL) PREFABRICATED CORD	1.00	42.00	ML							1900	ML	
AL 354	(MP) OVERSEERER	0.08	9.00	h							152	h	
AL 350	(MP) LABORER	0.10	6.50	h							190	h	
AL 355	(MP) ASSISTANT	0.80	6.50	h							1520	h	
MQ 009	(T&E) Bucket 10 m^3	0.01	200.00	h							19	h	
	PAVEMENT - SIDE ROADS	TOTAL	127982.22										
EXC 002	EARTHWORK	-	9.25	m^3	240	m	3.5	m	0.3	m	252	m^3	2331.00
AL 355	(MP) ASSISTANT	0.50	6.50	h							126	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.02	200.00	h							5.04	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							2.52	h	
EXC 006	LEVEL AND COMPACT EXISTING GROUND	-	16.35	m^3	240	m	3.5	m	0.3	m	252	m^3	4120.20
AL 360	(MP) COMPACTOR OPERATOR	2.10	6.00	h							529.2	h	
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							37.8	h	
PA 029	PROVIDE & PLACE CRUSHED BASE (15 cm)	-	49.64	m^3	240	m	3.5	m	0.12	m	100.8	m^3	5003.81
AG 015	(MTL) CAPA BASE	0.18	230.00	m^3							18.144	m^3	
AL 385	(MP) OPERATOR	0.03	8.50	h							3.024	h	
AL 362	(MP) ASSISTANT	0.02	6.50	h							2.016	h	
MQ 001	(T&E) BULLDOZER 120 G	0.008	284.00	h							0.8064	h	

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MQ 004	(T&E) WATER BEARER "AGUATERO"	0.008	130.00	h							0.8064	h	
PA 039	CONCRETE SLAB PAVEMENT (18 cm)	-	91.24	m^2	240	m	3.5	m	-	-	840	m^2	91968.00
AG 901	(MTL) CEMENT	55.00	0.94	kg							55440	kg	
AG 001	(MTL) RIVER SAND	0.09	60.00	m^3							90.72	m^3	
AG 002	(MTL) WASHED DEBRIS	0.12	140.00	m^3							120.96	m^3	
FP 001	(MTL) PLASTIC FIBER	0.16	8.10	kg							161.28	kg	
AI 004	(MTL) ANTISOL	0.12	10.13	LT							120.96	LT	
AI 001	(MTL) TAR	0.15	8.50	kg							151.2	kg	
AG 007	(MTL) WATER	25.00	0.10	LT							25200	LT	
AL 354	(MP) OVERSEERER	0.095	9.00	h							95.76	h	
AL 350	(MP) LABORER	0.195	6.50	h							196.56	h	
AL 355	(MP) ASSISTANT	0.38	6.50	h							383.04	h	
AL 364	(MP) DRIVER	0.185	6.00	h							186.48	h	
MQ 024	(T&E) MIXER	0.006	324.00	h							6.048	h	
MQ 025	(T&E) VIBRATORY MACHINE	0.01	40.50	h							10.08	h	
MQ 009	(T&E) BUCKET 10 m^3	0.015	200.00	h							15.12	h	
PA 011	DELIVERY AND PLACEMENT OF CURB	-	51.17	ML	480	m	-	-	-	-	480	ML	24559.20
AG 901	(MTL) CEMENT	0.25	0.94	kg							120	kg	
AG 001	(MTL) RIVER SAND	0.006	60.00	m^3							2.88	m^3	
AG 916	(MTL) PREFABRICATED CORD	1.00	42.00	ML							480	ML	
AL 354	(MP) OVERSEERER	0.08	9.00	h							38.4	h	
AL 350	(MP) LABORER	0.10	6.50	h							48	h	
AL 355	(MP) ASSISTANT	0.80	6.50	h							384	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							4.8	h	
	OPEN RECTANGULAR CANAL	TOTAL	2781815.93										
DRE 004	EXCAVATION WITH MACHINERY	-	14.40	m^3	950	m	4.5	m	1.3	m	5557.5	m^3	80028.00
AL 361	(MP) BACKHOE OPERATOR	0.32	6.00	h							1778.4	h	
AL 362	(MP) ASSISTANT	0.32	6.50	h							1778.4	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.04	200.00	h							222.3	h	
MQ 008	(T&E) WATER SPRAYER OF 4"	0.12	20.00	h							666.9	h	
DRE 005	MANUAL SLOPE SHAPING (SIDES & BOTTOM)	-	2.37	m^2	950	m	7.1	m	-	-	6745	m^2	16002.51
AL 350	(MP) LABORER	0.18	6.50	h							1214.1	h	
AL 362	(MP) ASSISTANT	0.185	6.50	h							1247.825	h	
DRE 006	REINFORCED CONCRETE LINING FOR CANALS: 20 cm	-	91.07	m^2	950	m	7.7	m	-	-	7315	m^2	2664570.68
AG 901	(MTL) CEMENT	26.00	0.94	kg							760760	kg	
AG 002	(MTL) WASHED DEBRIS	0.062	140.00	m^3							1814.12	m^3	
AG 001	(MTL) RIVER SAND	0.05	60.00	m^3							1463	m^3	
MA 004	(MTL) CONSTRUCTION WOOD	0.04	6.50	m^2							1170.4	m^2	
HI 001	(MTL) NAIL	0.02	12.72	kg							585.2	kg	
AI 004	(MTL) ANTISOL	0.20	10.13	LT							5852	LT	
HI 002	(MTL) INDENTED IRON	2.53	11.55	kg							74027.8	kg	
HI 003	(MTL) MOORING WIRE	0.08	12.73	kg							2340.8	kg	
AI 003	(MTL) GEOTEXTILES OP-20 (200 g/m^2)	0.30	8.00	m^2							8778	m^2	
AL 363	(MP) OPERATOR OF LIGHT FIELD EQUIP.	0.04	6.00	h							1170.4	h	
AL 350	(MP) LABORER	0.95	6.50	h							27797	h	
AL 355	(MP) ASSISTANT	1.90	6.50	h							55594	h	
HO 901	(T&E) MIXER OF 350 LTS	0.04	25.00	h							1170.4	h	
DRE 028	BOTTOM CANAL DRAIN	-	40.25	m^3	-	-	-	-	-	-	122	m^3	4904.58
AI 006	(MTL) POLYTHENE 200 m	8.00	3.00	m^2							975	m^2	
AL 350	(MP) LABORER	1.00	6.50	h							122	h	
AL 355	(MP) ASSISTANT	1.50	6.50	h							183	h	
DRE 029	SIDE SLOPE DRAIN	-	5.53	PZA	-	-	-	-	-	-	668	PZA	3690.70
AL 350	(MP) LABORER	0.40	6.50	h							267.2	h	
AL 355	(MP) ASSISTANT	0.45	6.50	h							300.6	h	
DRE 020	DRAIN PIPES FOR CANALS (PVC ϕ 2")	-	3.38	PZA	-	-	-	-	-	-	1002	PZA	3386.36
HI 003	(MTL) MOORING WIRE	0.02	12.73	kg							20.04	kg	
HS 138	(MTL) PVC PIPE 6"	0.08	35.00	ML							80.16	ML	
AL 350	(MP) LABORER	0.025	6.50	h							25.05	h	
AL 355	(MP) ASSISTANT	0.025	6.50	h							25.05	h	
DRE 014	SEAL FISSURES IN CONCRETE LINED CANAL	-	6.74	ML	1300	m	-	-	-	-	1300	m	8759.40
AG 901	(MTL) CEMENT	3.00	0.94	kg							3900	kg	
AG 001	(MTL) RIVER SAND	0.0008	60.00	m^3							1.04	m^3	
HI 002	(MTL) INDENTED IRON	0.20	11.55	kg							260	kg	
AL 350	(MP) LABORER	0.12	6.50	h							156	h	
AL 355	(MP) ASSISTANT	0.12	6.50	h							156	h	
DRE 016	CONCRETE INTAKE (0.1m THICKNESS)	-	91.10	m^2	26	m	0.2	m	-	-	5.2	m^2	473.69
AG 901	(MTL) CEMENT	30.00	0.94	kg							156	kg	
AG 001	(MTL) RIVER SAND	0.06	60.00	m^3							0.312	m^3	
AG 002	(MTL) WASHED DEBRIS	0.08	140.00	m^3							0.416	m^3	
MA 001	(MTL) BOARD OF WOOD	4.00	2.80	ft^2							20.8	ft^2	
HI 003	(MTL) MOORING WIRE	0.10	12.73	kg							0.52	kg	
HI 001	(MTL) NAIL	0.10	12.72	kg							0.52	kg	
HI 002	(MTL) INDENTED IRON	1.00	11.55	kg							5.2	kg	
AG 007	(MTL) WATER	14.00	0.10	LT							72.8	LT	
AL 350	(MP) LABORER	1.30	6.50	h							6.76	h	
AL 355	(MP) ASSISTANT	1.30	6.50	h							6.76	h	
HO 901	(T&E) MIXER OF 350 LTS	0.18	25.00	h							0.936	h	
	PAVEMENT & SIDE CURB NEAR PALMAR	TOTAL	271999.85										
EXC 002	EARTHWORK	-	9.25	m^3	250	m	7.5	m	0.3	m	562.5	m^3	5203.13
AL 355	(MP) ASSISTANT	0.50	6.50	h							281.25	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.02	200.00	h							11.25	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							5.625	h	
EXC 006	LEVEL AND COMPACT EXISTING GROUND	-	16.35	m^3	250	m	7.5	m	0.3	m	562.5	m^3	9196.88
AL 360	(MP) COMPACTOR OPERATOR	2.10	6.00	h							1181.25	h	
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							84.375	h	
PA 029	PROVIDE & PLACE CRUSHED BASE (15 cm)	-	49.64	m^3	250	m	7.5	m	0.12	m	225	m^3	11169.23
AG 015	(MTL) CAPA BASE	0.18	230.00	m^3							40.5	m^3	
AL 385	(MP) OPERATOR	0.03	8.50	h							6.75	h	
AL 362	(MP) ASSISTANT	0.02	6.50	h							4.5	h	
MQ 001	(T&E) BULLDOZER 120 G	0.008	284.00	h							1.8	h	

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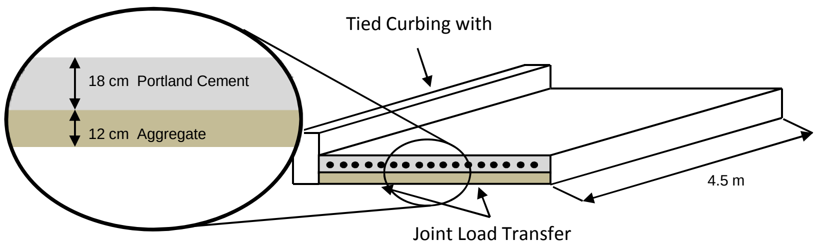
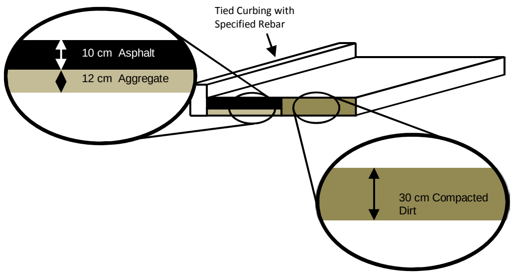
MQ 004	(T&E) WATER BEARER "AGUATERO"	0.008	130.00	h							1.8	h	
PA 039	CONCRETE SLAB PAVEMENT (18 cm)	-	91.24	m^2	250	m	7.5	m	-	-	1875	m^2	205285.73
AG 901	(MTL) CEMENT	55.00	0.94	kg							123750	kg	
AG 001	(MTL) RIVER SAND	0.09	60.00	m^3							202.5	m^3	
AG 002	(MTL) WASHED DEBRIS	0.12	140.00	m^3							270	m^3	
FP 001	(MTL) PLASTIC FIBER	0.16	8.10	kg							360	kg	
AI 004	(MTL) ANTISOL	0.12	10.13	LT							270	LT	
AI 001	(MTL) TAR	0.15	8.50	kg							337.5	kg	
AG 007	(MTL) WATER	25.00	0.10	LT							56250	LT	
AL 354	(MP) OVERSEERER	0.095	9.00	h							213.75	h	
AL 350	(MP) LABORER	0.195	6.50	h							438.75	h	
AL 355	(MP) ASSISTANT	0.38	6.50	h							855	h	
AL 364	(MP) DRIVER	0.185	6.00	h							416.25	h	
MQ 024	(T&E) MIXER	0.006	324.00	h							13.5	h	
MQ 025	(T&E) VIBRATORY MACHINE	0.01	40.50	h							22.5	h	
MQ 009	(T&E) BUCKET 10 m^3	0.015	200.00	h							33.75	h	
HIE 001	REBAR (LOAD TRANSFER FOR ROAD)	-	14.07	kg	691.2	m	-	-	-	-	1105.92	kg	15562.40
HI 002	(MTL) INDENTED IRON	1.008	11.55	kg							1114.8	kg	
HI 003	(MTL) MOORING WIRE	0.15	12.73	kg							165.9	kg	
AL 350	(MP) LABORER	0.08	6.50	h							88.5	h	
PA 011	DELIVERY AND PLACEMENT OF CURB	-	51.17	ML	500	m	-	-	-	-	500	ML	25582.50
AG 901	(MTL) CEMENT	0.25	0.94	kg							125	kg	
AG 001	(MTL) RIVER SAND	0.006	60.00	m^3							3	m^3	
AG 916	(MTL) PREFABRICATED CORD	1.00	42.00	ML							500	ML	
AL 354	(MP) OVERSEERER	0.08	9.00	h							40	h	
AL 350	(MP) LABORER	0.10	6.50	h							50	h	
AL 355	(MP) ASSISTANT	0.80	6.50	h							400	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							5	h	
	STORM DRAINAGE PIPE NEAR PALMAR	TOTAL	453647.47										
DRE 004	EXCAVATION WITH MACHINERY	-	14.40	m^3	250	m	2.5	m	1.4	m	875	m^3	12600.00
AL 361	(MP) BACKHOE OPERATOR	0.32	6.00	h							280	h	
AL 362	(MP) ASSISTANT	0.32	6.50	h							280	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.04	200.00	h							35	h	
MQ 008	(T&E) WATER SPRAYER OF 4"	0.12	20.00	h							105	h	
DRE 026	DELIVERY & PLACEMENT OF 2 REINFORCED CONCRETE PIPE (1.0 m Diam)	-	876.07	ML	500	m	-	-	-	-	500	m	438035.00
AG 001	(MTL) RIVER SAND	0.034	60.00	m^3							20.4	m^3	
AG 901	(MTL) CEMENT	9.00	0.94	kg							5400	kg	
HS 145	(MTL)RC PIPE (1.5 m ϕ)	1.02	796.00	ML							612	ML	
AL 350	(MP) LABORER	1.80	6.50	h							1080	h	
AL 355	(MP) ASSISTANT	3.30	6.50	h							1980	h	
MQ 013	(T&E) TELESCOPIC CRANE	0.10	205.00	h							60	h	
EXC 003	FILL & COMPACT WITH PLATE	-	15.78	m^3	250	m	2.5	m	0.3	m	187.5	m^3	2957.81
AL 355	(MP) ASSISTANT	1.85	6.50	h							346.875	h	
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							28.125	h	
DRE 016	CONCRETE INTAKE (0.1m THICKNESS)	-	91.10	m^2	2	m	0.3	m	-	-	0.6	m^2	54.66
AG 901	(MTL) CEMENT	30.00	0.94	kg							18	kg	
AG 001	(MTL) RIVER SAND	0.06	60.00	m^3							0.036	m^3	
AG 002	(MTL) WASHED DEBRIS	0.08	140.00	m^3							0.048	m^3	
MA 001	(MTL) BOARD OF WOOD	4.00	2.80	ft^2							2.4	ft^2	
HI 003	(MTL) MOORING WIRE	0.10	12.73	kg							0.06	kg	
HI 001	(MTL) NAIL	0.10	12.72	kg							0.06	kg	
HI 002	(MTL) INDENTED IRON	1.00	11.55	kg							0.6	kg	
AG 007	(MTL) WATER	14.00	0.10	LT							8.4	LT	
AL 350	(MP) LABORER	1.30	6.50	h							0.78	h	
AL 355	(MP) ASSISTANT	1.30	6.50	h							0.78	h	
HO 901	(T&E) MIXER OF 350 LTS	0.18	25.00	h							0.108	h	
	CONNECTION TO ANTIGUO CANAL	TOTAL	81988.02										
DRE 004	EXCAVATION WITH MACHINERY	-	14.40	m^3	36	m	2	m	2	m	144	m^3	2073.60
AL 361	(MP) BACKHOE OPERATOR	0.32	6.00	h							46.08	h	
AL 362	(MP) ASSISTANT	0.32	6.50	h							46.08	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.04	200.00	h							5.76	h	
MQ 008	(T&E) WATER SPRAYER OF 4"	0.12	20.00	h							17.28	h	
DRE 026	DELIVERY & PLACEMENT OF REINFORCED CONCRETE PIPE (1.25 m IN DIAMETER)	-	876.07	ML	72	m	-	-	-	-	72	m	78846.30
AG 001	(MTL) RIVER SAND	0.034	60.00	m^3							3.06	m^3	
AG 901	(MTL) CEMENT	9.00	0.94	kg							810	kg	
HS 145	(MTL)RC PIPE (1.5 m ϕ)	1.02	796.00	ML							91.8	ML	
AL 350	(MP) LABORER	1.80	6.50	h							162	h	
AL 355	(MP) ASSISTANT	3.30	6.50	h							297	h	
MQ 013	(T&E) TELESCOPIC CRANE	0.10	205.00	h							9	h	
EXC 003	FILL & COMPACT WITH PLATE	-	15.78	m^3	36	m	2	m	0.8	m	57.6	m^3	908.64
AL 355	(MP) ASSISTANT	1.85	6.50	h							106.56		
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							8.64		
HIE 009	METAL LID 80cmX80cm	-	79.74	PZA	-	-	-	-	-	-	2	PZA	159.48
HI 033	(MTL) ANGULAR IRON 3/4"X1/8"	1.00	53.74	PZA							2	PZA	
AL 350	(MP) LABORER	2.00	6.50	h							4	h	
AL 355	(MP) ASSISTANT	2.00	6.50	h							4	h	
	EROSION CONTROL	TOTAL	5400.00										
OT 014	(MTL) BLACK DIRT	-	30.00	m^3	1200	m	2	m	0.075	m	180	m^3	5400.00
												TOTAL	$5,023,465.83

ALTERNATIVE PAVEMENTS





ID	ACTIVITY	RATIO	COST	UNIT	QUANTITY								TOTAL COST
					LENGTH	*Unit*	*WIDTH*	*Unit*	*DEPTH*	*Unit*	**TOTAL**	**Unit**	
	ALTERNATIVE PAVEMENTS - CONCRETE	TOTAL	1498294.72										
EXC 002	EARTHWORK	-	9.25	m^3	From Cut & Fill Calculations						10,000	m^3	92500.00
AL 355	(MP) ASSISTANT	0.50	6.50	h							5000	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.02	200.00	h							200	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							100	h	
EXC 006	LEVEL AND COMPACT EXISTING GROUND	-	16.35	m^3	Calculated for Varying Pavement Width						3127.5	m^3	51134.63
AL 360	(MP) COMPACTOR OPERATOR	2.10	6.00	h							6567.75	h	
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							469.125	h	
PA 029	PROVIDE & PLACE CRUSHED BASE (15 cm)	-	49.64	m^3	Calculated for Varying Pavement Width						1355.25	m^3	67275.97
AG 015	(MTL) CAPA BASE	0.18	230.00	m^3							243.945	m^3	
AL 385	(MP) OPERATOR	0.03	8.50	h							40.6575	h	
AL 362	(MP) ASSISTANT	0.02	6.50	h							27.105	h	
MQ 001	(T&E) BULLDOZER 120 G	0.008	284.00	h							10.842	h	
MQ 028	(T&E) VIBRATORY COMPACTOR	0.008	284.00	h							10.842	h	
MQ 027	(T&E) PNEUMATIC COMPACTOR	0.008	284.00	h							10.842	h	
MQ 004	(T&E) WATER BEARER "AGUATERO"	0.008	130.00	h							10.842	h	
PA 039	CONCRETE SLAB PAVEMENT (18 cm)	-	91.24	m^2	Calculated for Varying Pavement Width						10425	m^2	1141388.63
AG 901	(MTL) CEMENT	55.00	0.94	kg							12672	kg	
AG 001	(MTL) RIVER SAND	0.09	60.00	m^3							20.736	m^3	
AG 002	(MTL) WASHED DEBRIS	0.12	140.00	m^3							27.648	m^3	
FP 001	(MTL) PLASTIC FIBER	0.16	8.10	kg							36.864	kg	
AI 004	(MTL) ANTISOL	0.12	10.13	LT							27.648	LT	
AI 001	(MTL) TAR	0.15	8.50	kg							34.56	kg	
AG 007	(MTL) WATER	25.00	0.10	LT							5760	LT	
AL 354	(MP) OVERSEERER	0.095	9.00	h							21.888	h	
AL 350	(MP) LABORER	0.195	6.50	h							44.928	h	
AL 355	(MP) ASSISTANT	0.38	6.50	h							87.552	h	
AL 364	(MP) DRIVER	0.185	6.00	h							42.624	h	
MQ 024	(T&E) MIXER	0.006	324.00	h							1.3824	h	
MQ 025	(T&E) VIBRATORY MACHINE	0.01	40.50	h							2.304	h	
MQ 009	(T&E) Bucket 10 m^3	0.015	200.00	h							3.456	h	
HIE 001	REBAR (LOAD TRANSFER FOR ROAD)	-	14.07	kg	2060.8	m	-	-	-	-	1648.64	kg	23199.50
HI 002	(MTL) INDENTED IRON	1.008	11.55	kg							1661.8	kg	
HI 003	(MTL) MOORING WIRE	0.15	12.73	kg							247.3	kg	
AL 350	(MP) LABORER	0.08	6.50	h							131.9	h	
PA 011	DELIVERY AND PLACEMENT OF CURB	-	51.17	ML	2400	m	-	-	-	-	2400	ML	122796.00
AG 901	(MTL) CEMENT	0.25	0.94	kg							600	kg	
AG 001	(MTL) RIVER SAND	0.006	60.00	m^3							14.4	m^3	
AG 916	(MTL) PREFABRICATED CORD	1.00	42.00	ML							2400	ML	
AL 354	(MP) OVERSEERER	0.08	9.00	h							192	h	
AL 350	(MP) LABORER	0.10	6.50	h							240	h	
AL 355	(MP) ASSISTANT	0.80	6.50	h							1920	h	
MQ 009	(T&E) Bucket 10 m^3	0.01	200.00	h							24	h	
	ALTERNATIVE PAVEMENTS - ASPHALT	TOTAL	2025381.77										
EXC 002	EARTHWORK	-	9.25	m^3	From Cut & Fill Calculations						10,000	m^3	92500.00
AL 355	(MP) ASSISTANT	0.50	6.50	h							5000	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.02	200.00	h							200	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							100	h	
EXC 006	LEVEL AND COMPACT EXISTING GROUND	-	16.35	m^3	Calculated for Varying Pavement Width						3127.5	m^3	51134.63
AL 360	(MP) COMPACTOR OPERATOR	2.10	6.00	h							6567.75	h	
HO 902	(T&E) PLATE COMPACTOR	0.15	25.00	h							469.125	h	
PA 029	PROVIDE & PLACE CRUSHED BASE (15 cm)	-	49.64	m^3	Calculated for Varying Pavement Width						1355.25	m^3	67275.97
AG 015	(MTL) CAPA BASE	0.18	230.00	m^3							243.945	m^3	
AL 385	(MP) OPERATOR	0.03	8.50	h							40.6575	h	
AL 362	(MP) ASSISTANT	0.02	6.50	h							27.105	h	
MQ 001	(T&E) BULLDOZER 120 G	0.008	284.00	h							10.842	h	
MQ 028	(T&E) VIBRATORY COMPACTOR	0.008	284.00	h							10.842	h	
MQ 027	(T&E) PNEUMATIC COMPACTOR	0.008	284.00	h							10.842	h	
MQ 004	(T&E) WATER BEARER "AGUATERO"	0.008	130.00	h							10.842	h	
PA 015	DELIVERY AND PLACEMENT OF ASPHALT CONCRETE	-	1622.71	m^3	Calculated for Varying Pavement Width						1042.5	m^2	1691675.18
AG 026	(MTL) 3/4" AGGREGATE	1.32	175.00	m^3							1376.1	kg	
AG 027	(MTL) FINE TN°4	0.32	68.00	m^3							333.6	m^3	
AG 912	(MTL) ASPHALT CEMENT (85-100)	140.00	9.00	kg							145950	m^3	
AL 354	(MP) OVERSEERER	0.12	9.00	h							125.1	kg	
AL 355	(MP) ASSISTANT	0.85	6.50	h							886.125	LT	
AL 385	(MP) OPERATOR	0.42	8.50	h							437.85	kg	
MQ 029	(T&E) ASPHALT PLANT	0.056	900.00	h							58.38	LT	
MQ 030	(T&E) ASPHALT TANK	0.056	300.00	h							58.38	h	
MQ 031	(T&E) GENERATOR OF 180 KVA	0.055	122.00	h							57.3375	h	
MQ 002	(T&E) SHOVEL SHIPPER 930	0.056	310.00	h							58.38	h	
MQ 032	(T&E) VIBRATING ROLLER	0.035	243.00	h							36.4875	h	
PA 011	DELIVERY AND PLACEMENT OF CURB	-	51.17	ML	2400	m	-	-	-	-	2400	ML	122796.00
AG 901	(MTL) CEMENT	0.25	0.94	kg							600	kg	
AG 001	(MTL) RIVER SAND	0.006	60.00	m^3							14.4	m^3	
AG 916	(MTL) PREFABRICATED CORD	1.00	42.00	ML							2400	ML	
AL 354	(MP) OVERSEERER	0.08	9.00	h							192	h	
AL 350	(MP) LABORER	0.10	6.50	h							240	h	
AL 355	(MP) ASSISTANT	0.80	6.50	h							1920	h	
MQ 009	(T&E) Bucket 10 m^3	0.01	200.00	h							24	h	
	ALTERNATIVE PAVEMENTS - COMPACTED DIRT	TOTAL	143634.63										
EXC 002	EARTHWORK	-	9.25	m^3	From Cut & Fill Calculations						10,000	m^3	92500.00
AL 355	(MP) ASSISTANT	0.50	6.50	h							5000	h	
MQ 007	(T&E) BACKHOE 85/100 HP	0.02	200.00	h							200	h	
MQ 009	(T&E) BUCKET 10 m^3	0.01	200.00	h							100	h	

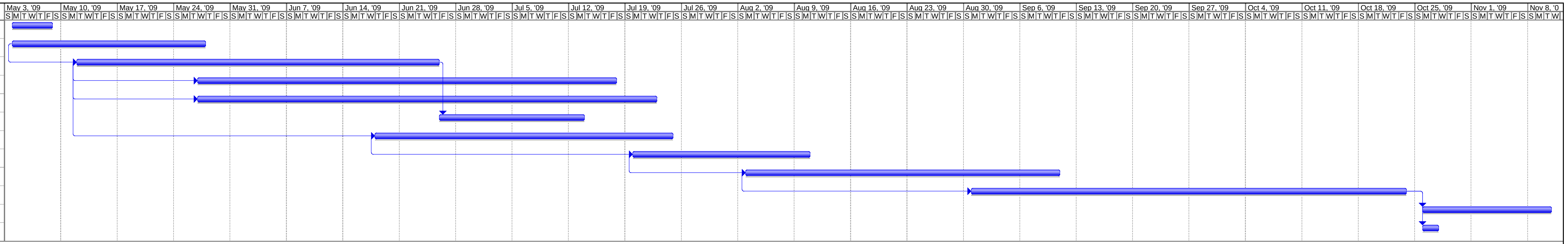
Appendix K – Project Schedule

A timeline for the recommend option, Design Option 3, was found to be **six calendar months**. This is a conservative estimate, utilizing five work days per week. The timeline was created using the required manpower and equipment hours for each construction activity. Table K 1 is a sample excerpt from the cost estimate, the second to last column shows the calculated manpower and equipment hours.

Table K 1: Project Schedule - Method

ID	**ACTIVITY**	**QUANTITY**							
		LENGTH	*Unit*	*WIDTH*	*Unit*	*DEPTH*	*Unit*	**TOTAL**	**Unit**
	MOBILIZATION/SITE LAYOUT								
DRE 001	MOBILIZATION - DRAINAGE	-	-	-	-	-	-	1	GL.
INS 001	(MTL) MOBILIZATION							1	GL.
AL 350	(MP) BRICK LAYER							11	h
AL 355	(MP) ASSISTANT							25	h
PA 004	MOBILIZATION - PAVEMENT	-	-	-	-	-	-	1	GL.
MT 001	(MTL) SEVERAL MATERIALS							1	GL.
AL 350	(MP) BRICK LAYER							15	h
AL 355	(MP) ASSISTANT							25	h
DRE 002	SITE LAYOUT (SEWERS, CANALS, BRIDGES)	1200	m	-	-	-	-	1200	m
MA 019	(MTL) WOOD STAKES 2"X2"X30cm							1200	PZA
PT 002	(MTL) PAINTING LATEX							12	GAL
HI 001	(MTL) INDENTED IRON							12	kg
AL 365	(MP) TOPOGRAPHER							240	h
AL 366	(MP) PAINTER							240	h
MQ 022	(T&E) TOPOGRAPHIC TEAM							84	h
PA 005	SITE LAYOUT & TOPOGRAPHIC CONTROL	1200	m	-	-	-	-	1.2	km
MA 019	(MTL) WOOD STAKES 2"X2"X30cm							198	PZA
PT 007	(MTL) OIL FOR PAINTING							0.48	LT
HI 001	(MTL) NAIL							1.2	kg
AL 365	(MP) TOPOGRAPHER							12	h
AL 366	(MP) PAINTER							36	h
MQ 022	(T&E) TOPOGRAPHIC TEAM							14.4	h

ID	ℹ	Task Name	Duration	Start	Finish	Predecessors
1		Mobilization	5 days	Mon 5/4/09	Fri 5/8/09	
2		Site Layout	18 days	Mon 5/4/09	Wed 5/27/09	
3	▦	Excavate Canal	33 days	Tue 5/12/09	Thu 6/25/09	2SS+6 days
4		Slope Shaping	38 days	Wed 5/27/09	Fri 7/17/09	3SS+11 days
5		PC Concrete Canal Lining	41 days	Wed 5/27/09	Wed 7/22/09	3SS+11 days
6		PC Concrete Storm Sewer Pipe	12 days	Fri 6/26/09	Mon 7/13/09	3
7		Pavement Earthwork	27 days	Thu 6/18/09	Fri 7/24/09	3SS+27 days
8		Level and Compact	16 days	Mon 7/20/09	Mon 8/10/09	7SS+22 days
9		Placement of Curb	29 days	Mon 8/3/09	Thu 9/10/09	8SS+10 days
10		Concrete Pavement	40 days	Mon 8/31/09	Fri 10/23/09	9SS+20 days
11		Clean-up	12 days	Mon 10/26/09	Tue 11/10/09	10
12		Demobilization	2 days	Mon 10/26/09	Tue 10/27/09	10



Project: Avenida Fatima I
Date: Mon 8/4/08

Task ▬ Split ┈ Progress ▬ Milestone ◆ Summary ▬ Project Summary ▬ External Tasks ▬ External Milestone ◆ Deadline ⇩

CONSTRUCTION DOCUMENTS

DOCUMENT 00010

TABLE OF CONTENTS

END OF DOCUMENT

DOCUMENT 00105

INVITATION TO BID

Project: Avenida Fatima I

Owner: Sub Alcalde Ing. Victor P. Escobar Díaz

Subalcadía Districto Municipal N°12
Avenida Nuevo Palmar
Santa Cruz, Bolivia

Architect/Engineer: Cinco Cero Engineering

1400 Townsend Drive
Houghton, MI 49931
United States of America

Date:

List of Bidders:

____

____

Your firm is invited to submit a Bid under seal to the Owner for construction of a road and storm drainage structure located at Avenida Fatima I, Districto 12. The Owner will receive Bids until 4:00 PM local standard time on the first day of April, 2009, for the following project:

Description:

A two way road and adjoining open rectangular drainage canal constructed of cast-in-place Portland Cement concrete. Road length is 1.2 km and lane widths are 4.5 m. Drainage canal has a base of 4.1 m and depth of 1.3 m. Portland Cement concrete barrier walls of 0.5 m height will be placed along each side of the canal.

The Owner requires the Project to be completed in six months from date of award of contract.

Bidding Documents for a Lump Sum contract may be obtained from the office of the Owner.

Documents can only be obtained by general contract and subcontract Bidders. Others may view the Bid Documents at the office of the Owner.

Refer to other bidding requirements described in Document 00200 - Instructions to Bidders.

Submit your Bid on the Bid Form provided. Bidders are required to complete Bid Form 00410.

Your Bid will be required to be submitted under a condition of irrevocability for a period of 30 days after Bid Closing.

The Owner reserves the right to accept or reject any or all Bids.

Sub Alcalde Ing. Victor P. Escobar Díaz

Signature ____________________

Enclosures:
- Bid Form 00410

END OF DOCUMENT

DOCUMENT 00200

INSTRUCTIONS TO BIDDERS

PART 1

1.1 SUMMARY

A. Document Includes:

1. Bid Submission.
2. Intent.
3. Contract Time.
4. Definitions.
5. Contract Documents Identification.
6. Availability of Documents.
7. Examination of Documents.
8. Inquiries and Addenda.
9. Product Substitutions.
10. Site Examination.
11. Submission Procedure.
12. Bid Ineligibility.
13. Bid Form Signature.
14. Bid Opening.
15. Duration of Offer.
16. Acceptance of Offer.

1.2 BID SUBMISSION

A. Bids signed and under seal, executed, and dated will be received by the Owner located at the Subalcaldía Districto Municipal N° 12 until 4:00 PM local standard time on the first day of April, 2009.

B. Amendments to submitted Bids will be permitted when received in writing prior to Bid Closing and when endorsed by the same party or parties who signed and sealed the Bid.

C. Bidders may withdraw their Bid by written request at any time before Bid Closing.

1.3 INTENT

A. The intent of this Bid request is to obtain an offer to perform work to complete the construction of a road and storm drainage structure located at Avenida Fatima I, Districto 12 for a Lump Sum contract, in accordance with Contract Documents.

1.4 CONTRACT TIME

A. Perform the Work in six calendar months. Bidders may suggest revisions to the Contract Time with a specific adjustment to Bid Sum.

1.5 DEFINITIONS

A. Bidding Documents: Contract Documents supplemented with Invitation to Bid, Instructions to Bidders, Bid Form identified.

B. Contract Documents: Defined in EJCDC 1910-8 Article 1, including issued Addenda.

C. Bid: Executed Bid Form and required attachments submitted in accordance with these Instructions to Bidders.

D. Bid Closing: Last date Owner will receive Bids. Bids submitted after will not be accepted.

E. Bid Sum: Monetary sum identified by the Bidder in the Bid Form.

1.6 CONTRACT DOCUMENTS IDENTIFICATION

A. The Contract Documents are identified as Project Avenida Fatima I as prepared by Engineer located at Cinco Cero Engineering, Houghton, Michigan, United States of America and identified in the Project Manual.

1.7 AVAILABILITY OF DOCUMENTS

A. Bidding Documents may be obtained at the office of the Owner located at the Subalcaldía Districto Municipal No° 12.

B. Partial sets of Bidding Documents will not be issued.

1.8 EXAMINATION OF DOCUMENTS

A. Upon receipt of Bidding Documents verify documents are complete. Notify Architect/Engineer if documents are incomplete.

B. Immediately notify Architect/Engineer upon finding discrepancies or omissions in Bidding Documents.

1.9 INQUIRIES AND ADDENDA

A. Direct questions in writing to Cinco Cero Engineering, at the office of the Architect/Engineer; facsimile Avenida Fatima I.

B. Verbal answers are not binding on any party.

C. Submit questions not less than 7 business days before Bid Closing. Replies will be made by Addenda.

D. Addenda may be issued during bidding period. Addenda will be sent to known Bidders and made available at the office of the Owner. Addenda become part of the Contract Documents. Include resultant costs in the Bid Sum.

1.10 PRODUCT SUBSTITUTIONS

A. Where Bidding Documents stipulate particular Products, substitution requests will be considered by Architect/Engineer up to 7 business days before Bid Closing. Approved substitutions will be identified by Addenda. Bidders shall include in their Bid, changes required in the Work to accommodate such approved substitutions.

1.11 SITE EXAMINATION

A. Examine Project site before submitting a Bid.

1.12 SUBMISSION PROCEDURE

A. Submit two copies of executed offer on Bid Forms provided, signed and sealed with required security deposit in a closed opaque envelope, clearly identified with Bidder’s name, Project name, and Owner's name on the outside.

1.13 BID INELIGIBILITY

A. Bids that contain irregularities of any kind will be declared unacceptable at Owner’s discretion.

1.14 BID FORM SIGNATURE

A. Sign Bid Form, as follows:

1. Sole Proprietorship: Signature of sole proprietor in the presence of a witness who will also sign. Insert the words "Sole Proprietor" under the signature. Affix seal.

2. Partnership: Signature of all partners in the presence of a witness who will also sign. Insert the word "Partner" under each signature. Affix seal to each signature.

3. Corporation: Signature of a duly authorized signing officers in their normal signatures. Insert the officer's capacity in which the signing officer acts, under each signature. Affix the corporate seal.

   If the Bid is signed by officials other than the president, secretary, or treasurer of the company, submit a copy of the by-law resolution of their board of directors authorizing them to do so, with the Bid Form in the bid envelope.

4. Joint Venture: Signature of each party of the joint venture under their respective seals in a manner appropriate to such party as described above, similar to requirements for Partnerships.

1.15 BID OPENING

A. Bids will be opened publicly immediately after the Bid Closing. Bidders may be present.

1.16 DURATION OF OFFER

A. Bids shall remain open to acceptance and shall be irrevocable for a period of 30 days after Bid Closing.

1.17 ACCEPTANCE OF OFFER

A. The Owner reserves the right to accept or reject any or all offers.

END OF DOCUMENT

DOCUMENT 00410

BID FORM

To: Sub Alcade Ing. Victor P. Escobar Díaz

Project: Avenida Fatima I

Date: ______________

Submitted by: ________________________
(full name)

(full address) ________________________

____

1.1 OFFER

Having examined the Place of The Work and all matters referred to in the Instructions to Bidders, Bid Documents and Contract Documents prepared by the Engineer for the above mentioned project, we the undersigned, hereby offer to enter into a Contract to perform the Work for the Contract Sum of:

$_______________________________ dollars, in lawful money of the United States of America.

Please write out Contract Sum:
____
____

All applicable taxes are included in the Bid Sum.

1.2 ACCEPTANCE

This offer shall be open to acceptance for thirty days from the Bid Closing.

If this bid is accepted by the Owner within the time period stated above, we will:

- Execute the Agreement within seven business days of receipt of Notice of Award.

If this bid is accepted within the time stated, and we fail to commence the Work or we fail to provide the required Bond(s), the security deposit shall be forfeited as damages to the Owner by reason of our failure, limited in amount to the lesser of the face value of the security deposit or the difference between this bid and the bid upon which a Contract is signed.

1.3 CONTRACT TIME

If this bid is accepted, we will:

Complete the Work in six calendar months from Notice of Award.

1.4 ADDENDA

The following Addenda have been received. The modifications to the Contract Documents noted therein have been considered and all costs thereto are included in the Bid Sum.

Addendum # ____ Dated ____________

Addendum # ____ Dated ____________

1.5 BID FORM SIGNATURES

The Corporate Seal of

____
(Bidder - print the full name of your firm)

was hereunto affixed in the presence of:

____
(Authorized signing officer Title)

(Seal)

____
(Authorized signing officer Title)

(Seal)

If the bid is a joint venture or partnership, add additional forms of execution for each member of the joint venture in the appropriate form or forms as above.

END OF DOCUMENT

DOCUMENT 00505

AGREEMENT AND GENERAL CONDITIONS – EJCDC

1.1 AGREEMENT

A. EJCDC No. 1910-8-A-1 (1996 Edition), Standard Form of Agreement Between Owner and Contractor on the Basis of a Stipulated Price, forms the basis of Agreement between the Owner and Contractor.

1.2 GENERAL CONDITIONS

A. EJCDC No. 1910-8 (1996 Edition), Standard General Conditions of the Construction Contract, is the General Conditions of the Contract.

1.3 SUPPLEMENTARY CONDITIONS

A. Refer to Document 00815 for amendments and supplements to General Conditions.

END OF DOCUMENT

DOCUMENT 00815

SUPPLEMENTARY CONDITIONS - EJCDC

1.1 SUPPLEMENTARY CONDITIONS

A. These Supplementary Conditions amend or supplement the Standard General Conditions of the Construction Contract, EJCDC No. 1910-8 1996 Edition, and other provisions of the Contract Documents as indicated below. All provisions which are not so amended or supplemented remain in full force and effect.

B. The terms used in these Supplementary Conditions which are defined in the Standard General Conditions of the Construction Contract, EJCDC No. 1910-8 1996 Edition, have the meanings assigned to them in the General Conditions.

SC-1.01.A Add the following new paragraph immediately after paragraph 1.01.A.33

33A. Products: Means materials and equipment that Contractor furnishes and provides, other than labor and services.

SC-2.03.A Amend the first sentence of paragraph 2.03A to read as follows:

Contract Times are identified in Document 00200 - Instructions to Bidders and Document 00410 - Bid Form.

SC-3.01.D Add the following new paragraph immediately after paragraph 3.01.C:

Sections of Division 1 - General Requirements govern the execution of the work of all sections of the specifications.

END OF DOCUMENT

SECTION 01001

BASIC REQUIREMENTS

PART 1 GENERAL

1.1 SECTION INCLUDES

- A. Summary:
  1. Contract description.
  2. Contractor’s use of premises.
  3. Specification conventions.

- B. Price and Payment Procedures:
  1. Schedule of values.
  2. Applications for payment.
  3. Change procedures.

- C. Administrative Requirements:
  1. Coordination.
  2. Field engineering.
  3. Site Mobilization Meetings.
  4. Progress meetings
  5. Cutting and patching.

- D. Submittals:
  1. Submittal procedures.
  2. Construction progress schedules.
  3. Product data.
  4. Shop drawings.

- E. Quality Requirements:
  1. Quality control.
  2. References.
  3. Testing and inspection laboratory services.
  4. Examination.
  5. Preparation.

- F. Temporary Facilities and Controls:
  1. Temporary electricity.
  2. Temporary lighting for construction purposes.
  3. Temporary water service.
  4. Temporary sanitary facilities.
  5. Access roads.
  6. Progress cleaning and waste removal.
  7. Barriers and fencing.

8. Protection of installed work.
9. Security.
10. Water control.
11. Pollution and environmental control.
12. Removal of utilities, facilities, and controls.

G. Product Requirements:
1. Products.
2. Delivery, handling, storage, and protection.
3. Product options.
4. Substitutions.

H. Execution Requirements:
1. Closeout procedures.
2. Final cleaning.
3. Protecting installed construction.
4. Project record documents.
5. Operation and Maintenance Data
6. Warranties.

1.2 CONTRACT DESCRIPTION

A. Work of the Project includes construction of a Portland Cement concrete two-way road and open rectangular canal.

B. Perform Work of Contract under a Lump Sum contract with Owner in accordance with Conditions of Contract.

1.3 CONTRACTOR’S USE OF PREMISES

A. Limit use of premises to allow:

1. Maintenance of traffic between Avenida Nuevo Palmar and Avenida Antiguo.
2. Use of premises by public.

1.4 SPECIFICATION CONVENTIONS

A. These specifications are written in imperative mood and streamlined form. This imperative language is directed to the Contractor, unless specifically noted otherwise. The words “shall be” are included by inference where a colon (:) is used within sentences or phrases.

1.5 SCHEDULE OF VALUES

A. Submit schedule on EJCDC Form 1910-8-E.

B. Submit Schedule of Values in duplicate within 15 days after date of Owner-Contractor Agreement.

1.6 APPLICATIONS FOR PAYMENT

A. Submit three copies of each application on EJCDC Form 1910-8-E.

B. Content and Format: Utilize Schedule of Values for listing items in Application for Payment.

C. Payment Period: Monthly.

1.7 CHANGE PROCEDURES

A. Price Change Order: Based on Notice of Change and Contractor's estimated price quotation or Contractor's request for Change Order as approved by Architect/Engineer.

B. Change Order Forms: EJCDC 1910-8-B.

1.8 COORDINATION

A. Coordinate scheduling, submittals, and Work of various sections of specifications to ensure efficient and orderly sequence of installation of interdependent construction elements.

B. Verify utility requirement characteristics of operating equipment are compatible with available utilities.

C. Coordinate space requirements and installation of Work as indicated diagrammatically on Drawings. Follow routing shown for pipes, canals, and roadways as closely as practicable.

1.9 FIELD ENGINEERING

A. Employ Land Surveyor to locate reference datum and protect survey control and reference points.

B. Establish elevations, lines, and levels and certify elevations and locations of the Work conform with Contract Documents.

C. Verify field measurements are as indicated on shop drawings or as instructed by manufacturer.

1.10 SITE MOBILIZATION MEETINGS

A. Owner will schedule site mobilization meeting after Notice of Award for affected parties.

1.11 PROGRESS MEETINGS

A. Schedule and administer meetings throughout progress of the Work at maximum bi-monthly intervals.

B. Preside at meetings, record minutes, and distribute copies within three business days to those affected by decisions made.

1.12 CUTTING AND PATCHING

A. Employ skilled and experienced installer to perform cutting and patching new Work; restore Work with new Products.

B. Submit written request in advance of cutting or altering structural or building enclosure elements.

C. Execute cutting, fitting, and patching including excavation and fill, to complete Work, and to:

1. Fit several parts together, to integrate with other Work.
2. Uncover Work to install or correct ill-timed Work.
3. Remove and replace defective and non-conforming Work.
4. Remove samples of installed Work for testing.
5. Provide openings in elements of Work for penetrations of drainage Work.

D. Cut masonry and concrete materials using masonry saw or core drill. Restore Work with new Products in accordance with requirements of Contract Documents.

E. Fit Work tight to adjacent elements.

F. Fit Work tight to pipes, sleeves, conduits, and other penetrations through surfaces.

G. Refinish surfaces to match adjacent finishes.

1.13 SUBMITTAL PROCEDURES

A. Submittal form to identify Project, Contractor, subcontractor or supplier; and pertinent Contract Document references.

B. Apply Contractor's stamp, signed or initialed, certifying that review, verification of Products required, field dimensions, adjacent construction Work, and coordination of information is in accordance with requirements of the Work and Contract Documents.

C. Identify variations from Contract Documents and Product or system limitations which may be detrimental to successful performance of completed Work.

D. Revise and resubmit submittals as required; identify changes made since previous submittal.

1.14 CONSTRUCTION PROGRESS SCHEDULES

A. Submit initial progress schedule in duplicate within 15 days after date established in Notice to Proceed for Architect/Engineer review.

B. Submit revised schedules with each Application for Payment, identifying changes since previous version. Indicate estimated percentage of completion for each item of Work at each submission.

C. Submit horizontal bar chart with separate line for each major section of Work or operation, identifying first work day of each week.

1.15 PRODUCT DATA

A. Product Data:

1. Submitted to Architect/Engineer for review for limited purpose of checking for conformance with information given and design concept expressed in Contract Documents.
2. After review, provide copies and distribute in accordance with SUBMITTAL PROCEDURES article and for record documents purposes as specified.

B. Submit number of copies which Contractor requires, plus two copies which will be retained by Architect/Engineer.

C. Mark each copy to identify applicable products, models, options, and other data. Supplement manufacturer’s standard data to provide information unique to this project.

1.16 SHOP DRAWINGS

A. Shop Drawings:

1. Submitted to Architect/Engineer for review for limited purpose of checking for conformance with information given and design concept expressed in Contract Documents.
2. After review, provide copies and distribute in accordance with SUBMITTAL PROCEDURES article and for record documents purposes as specified.

B. Submit in form of one reproducible transparency and one opaque reproduction.

1.17 QUALITY CONTROL

A. Monitor quality control over suppliers, manufacturers, Products, services, site conditions, and workmanship, to produce Work of specified quality.

B. Comply with specified standards as minimum quality for the Work except when more stringent tolerances, codes, or specified requirements indicate higher standards or more precise workmanship.

C. Ensure concrete, steel, and other materials used meet standards specified.

1.18 REFERENCES

A. Conform to reference standards by date of issue current as of date for receiving bids.

B. When specified reference standard conflict with Contract Documents, request clarification from Architect/Engineer before proceeding.

1.19 TESTING AND INSPECTION LABORATORY SERVICES

A. Owner will appoint, employ, and pay for specified services of independent firm to perform testing and inspection.

B. Independent firm will perform tests, inspections, and other services as required.

C. Cooperate with independent firm; furnish samples as requested.

D. Re-testing required because of non-conformance to specified requirements will be charged to Contractor.

1.20 EXAMINATION

A. Verify existing site conditions and substrate surfaces are acceptable for subsequent Work. Beginning new Work means acceptance of existing conditions.

B. Verify utility services are available, of correct characteristics, and in correct location.

1.21 PREPARATION

A. Clean substrate surfaces prior to applying next material or substance.

B. Apply manufacturer required or recommended substrate primer, sealer, or conditioner prior to applying new material or substance in contact or bond.

1.22 TEMPORARY ELECTRICITY

A. Contractor will pay Pay cost of electricity used. Provide separate metering and reimburse Owner for cost of electricity used.

B. Provide temporary electricity and power outlets for construction operations, connections, branch wiring, distribution boxes, and flexible power cords as required. Do not disrupt Owner's need for continuous service.

1.23 TEMPORARY LIGHTING FOR CONSTRUCTION PURPOSES

A. Provide and maintain temporary lighting for construction operations.

B. Provide branch wiring from power source to distribution boxes with lighting conductors, pigtails, and lamps as required.

C. Permanent building lighting may be utilized during construction. Repair, clean, and replace lamps at end of construction.

1.24 TEMPORARY WATER SERVICE

A. Provide, maintain and pay for suitable quality water service required.

1.25 TEMPORARY SANITARY FACILITIES

A. Provide and maintain required facilities and enclosures. Existing facilities may not be used.

B. Maintain in clean and sanitary condition.

1.26 ACCESS ROADS

A. Construct and maintain temporary roads accessing public thoroughfares to serve construction area.

B. Designated existing on-site roads may be used for construction traffic.

1.27 PROGRESS CLEANING AND WASTE REMOVAL

A. Collect and maintain areas free of waste materials, debris, and rubbish. Maintain site in clean and orderly condition.

1.28 BARRIERS AND FENCING

A. Provide barriers to prevent unauthorized entry to construction areas and to protect existing facilities and adjacent properties from damage.

B. Construction: Contractor's option.

C. Provide 1.8 m high fence around construction site; equip with vehicular and pedestrian gates with locks.

1.29 PROTECTION OF INSTALLED WORK

A. Protect installed Work and provide special protection where specified in individual specification sections.

B. Prohibit traffic or storage upon waterproofed or roofed surfaces.

1.30 SECURITY

A. Provide security and facilities to protect Work and existing facilities, and Owner's operations from unauthorized entry, vandalism, or theft.

1.31 WATER CONTROL

A. Maintain excavations free of water. Provide, operate, and maintain pumping equipment.

1.32 POLLUTION AND ENVIRONMENTAL CONTROL

A. Provide methods, means, and facilities to prevent contamination of soil, water, and atmosphere from discharge of noxious, toxic substances, and pollutants produced by construction operations.

B. Provide dust control, erosion and sediment control, noise control, pest control and rodent control to allow for proper execution of the Work.

C. Plan, design, and operate construction site land disturbance activities such that:

1. An approved erosion and sediment control plan or similar administrative document that contains erosion and sediment control provisions is prepared and implemented prior to land disturbance.
2. Erosion is reduced and, to the extent practicable, sediment is retained on-site during and after construction.
3. Good housekeeping practices are used to prevent off-site transport of waste material and chemicals.
4. The application and generation of pollutants, including chemicals are minimized.

1.33 REMOVAL OF UTILITIES, FACILITIES, AND CONTROLS

A. Remove temporary utilities, equipment, facilities, materials, prior to Substantial Completion review.

B. Remove underground installations. Grade site as indicated on Drawings.

C. Clean and repair damage caused by installation or use of temporary work.

D. Restore existing facilities used during construction to original condition. Restore permanent facilities used during construction to specified condition.

1.34 PRODUCTS

A. Products: Means new material, machinery, components, equipment, fixtures, and systems forming the Work, but does not include machinery and equipment used for preparation, fabrication, conveying and erection of the Work. Products may also include existing materials or components specifically identified for reuse.

B. Do not use materials and equipment removed from existing premises, except as specifically identified or allowed by the Contract Documents.

C. Provide interchangeable components of same manufacture for components being replaced.

1.35 DELIVERY, HANDLING, STORAGE, AND PROTECTION

A. Deliver, handle, store, and protect Products in accordance with manufacturer's instructions.

1.36 PRODUCT OPTIONS

A. Products Specified by Reference Standards or by Description Only: Any Product meeting those standards or description.

1.37 SUBSTITUTIONS

A. Instructions to Bidders specify time for submitting requests for Substitutions during bidding period.

B. Document each request with complete data substantiating compliance of proposed Substitution with Contract Documents.

1.38 CLOSEOUT PROCEDURES

A. Submit written certification Contract Documents have been reviewed, Work has been inspected, and Work is complete in accordance with Contract Documents and ready for Architect/Engineer's inspection.

B. Submit final Application for Payment identifying total adjusted Contract Sum, previous payments, and amount remaining due.

1.39 FINAL CLEANING

A. Execute final cleaning prior to final inspection.

B. Clean interior and exterior surfaces.

C. Clean debris from site, roofs, gutters, downspouts, and drainage systems.

D. Replace filters of operating equipment.

E. Remove waste and surplus materials, rubbish, and construction facilities from site.

1.40 PROTECTING INSTALLED CONSTRUCTION

A. Provide temporary and removable protection for installed products. Control activity in immediate work area to prevent damage.

B. Prohibit traffic or storage upon waterproofed or roofed surfaces. When traffic or activity is necessary, obtain recommendations for protection from waterproofing or roofing material manufacturer.

C. Prohibit traffic from landscaped areas.

1.41 PROJECT RECORD DOCUMENTS

A. Maintain on site one set of Contract Documents to be utilized for record documents.

B. Record actual revisions to the Work. Record information concurrent with construction progress.

C. Specifications: Legibly mark and record at each Product section description of actual Products installed.

D. Record Documents and Shop Drawings: Legibly mark each item to record actual construction.

E. Submit documents to Architect/Engineer with claim for final Application for Payment.

1.42 OPERATION AND MAINTENANCE DATA

A. Submit two sets prior to final inspection, bound in 8-1/2 x 11 inch (216 x 279 mm) text pages, three D side ring binders with durable plastic covers.

B. Prepare binder cover with printed title "OPERATION AND MAINTENANCE INSTRUCTIONS" and title of project.

C. Internally subdivide binder contents with permanent page dividers, logically organized, with tab titles legibly printed under reinforced laminated plastic tabs.

D. Contents:

1. Part 1: Directory, listing names, addresses, and telephone numbers of Architect/Engineer, Contractor, subcontractors, and major equipment suppliers.
2. Part 2: Operation and maintenance instructions, arranged by system.
3. Part 3: Project documents and certificates.

1.43 WARRANTIES

A. Provide duplicate notarized copies.

B. Execute and assemble transferable warranty documents from subcontractors, suppliers, and manufacturers.

C. Submit prior to final Application for Payment.

END OF SECTION

SECTION 02230

SITE CLEARING

PART 1 GENERAL

1.1 SUMMARY

A. Section Includes:

1. Removing surface debris, rock, concrete slabs and dirt mounds
2. Removing designated plant life.
3. Removing topsoil.
4. Removing subsoil.
5. Rough grading and site contouring.

PART 3 EXECUTION

3.1 PREPARATION

B. Call Local Utility Line Information service not less than five working days before performing Work.

1. Request underground utilities to be located and marked within and surrounding construction areas.

3.2 PROTECTION

C. Locate, identify, and protect utilities indicated to remain, from damage.

D. Protect trees, plant growth, and features designated to remain, as final landscaping.

E. Protect bench marks, survey control points, and existing structures from damage or displacement.

3.3 CLEARING

F. Remove surface debris, rock, concrete slabs and dirt mounds within marked areas.

G. Remove trees and shrubs within marked areas. Remove stumps, main root ball and root system.

3.4 ROUGH GRADING

H. Identify required lines, levels, contours, and datum.

I. Identify known underground, above ground, and aerial utilities. Stake and flag locations.

J. Notify utility company to remove and relocate utilities.

K. Excavate topsoil and subsoil from areas to be further excavated, re-landscaped or re-graded.

L. Stockpile topsoil and subsoil in area designated on site.

M. Remove excess topsoil and subsoil not being reused, from site.

3.5 CLEAN UP

N. Remove debris, rock larger than .125 cu m (4.41 cu ft), and extracted plant life from site.

END OF SECTION

SECTION 02300

EARTHWORK

PART 1 GENERAL

1.1 SUMMARY

A. Section includes site grading, removal of topsoil and subsoil, building excavating and trenching, backfilling, and compacting.

1.2 SUBMITTALS

A. Samples: Submit 4.5 kg (10 lb) sample of each type of imported fill to testing laboratory, in air tight containers.

PART 2 PRODUCTS

2.1 SOIL MATERIALS

A. Topsoil: Reusable excavated silty sand; free of subsoil, roots, grass, weeds, large stone, and foreign matter.

B. Subsoil: Excavated material, graded free of lumps larger than 150 mm (6 inches), rocks larger than 75 mm (3 inches), organic material, and debris.

2.2 FILL MATERIALS

A. Type A - Select Granular Material: Coarse stone: Angular, Crushed, washed natural stone; free of shale, clay, friable material, sand, debris.

   1. Grading: AASHTO M147; Grade 57.

B. Type B - Sand: Reused; free of clay, loam, friable or soluble materials, and organic matter.

C. Type C - Subsoil: Reused; free of rock larger than 75 mm (3 inch) size, and debris.

2.3 ACCESSORIES

A. Geotextile Fabric: OP-20 (200 g/m2).

B. Polyvinyl Chloride (PVC) Pipe: 2” diameter.

PART 3 EXECUTION

3.1 EXAMINATION AND PREPARATION

A. Call Local Utility Line Information service not less than five working days before performing Work.

1. Request underground utilities to be located and marked within and surrounding construction areas.

B. Identify required lines, levels, contours, and datum.

C. Notify Architect/Engineer of unexpected subsurface conditions and discontinue affected work in area until notified to resume work.

D. Maintain and protect existing utilities to remain.

3.2 PROTECTION OF ADJACENT WORK

A. Underpin adjacent structures which may be damaged by excavation work, including service utilities and pipe chases.

B. Grade excavation top perimeter to prevent surface water run-off into excavation or to adjacent properties.

3.3 TOPSOIL EXCAVATING

A. Do not excavate wet topsoil.

B. Excavate topsoil and stockpile in area designated on site. Remove excess topsoil not being reused from site.

3.4 SUBSOIL EXCAVATING

A. Remove groundwater by pumping to keep excavations dry.

B. Excavate subsoil from marked areas required for canal construction and other Work.

C. Slope banks to angle of repose or less, until shored.

D. Do not interfere with 45 degree bearing splay of foundations.

E. Proof roll bearing surfaces. Fill soft spots with Type C fill and compact uniformly to 95percent of maximum density.

F. Correct unauthorized excavation at no cost to Owner.

G. Fill over-excavated areas under structure bearing surfaces in accordance with direction by Architect/Engineer.

H. Stockpile subsoil in area designated on site. Remove excess subsoil not being reused from site.

3.5 TRENCHING

A. Excavate for storm drainage piping to existing drainage structures.

B. Cut trenches sufficiently wide to enable installation of utilities and allow inspection.

C. Hand trim excavation and leave free of loose matter.

D. Backfill trenches to required contours and elevations.

E. Place and compact fill materials as for Backfilling.

3.6 BACKFILLING

A. Backfill areas to contours and elevations. Use unfrozen and unsaturated materials.

B. Backfill systematically, as early as possible, to allow maximum time for natural settlement. Do not backfill over porous, wet, frozen, or spongy subgrade surfaces.

C. Place geotextile fabric over unstable subsoil and on all sides of the drainage structure.

D. Place material in continuous layers as follows:

1. Soil Materials: Maximum 300 mm (12 inches) compacted depth.
2. Fill Materials: Maximum 200 mm (8 inches) compacted depth.

E. Employ placement method so not to disturb or damage existing structures, Work completed, or utilities in trenches.

F. Maintain optimum moisture content of backfill materials to attain required compaction density.

G. Slope grade away from building minimum 150 mm in 3 m (2 inches in 10 ft), unless noted otherwise.

3.7 PLACING TOPSOIL

A. Place topsoil in areas where seeding is scheduled.

B. Fine grade topsoil eliminating rough or low areas. Maintain levels, profiles, and contours of subgrade.

C. Remove large stone, roots, grass, weeds, debris, and foreign material while spreading.

D. Lightly compact placed topsoil.

E. Leave stockpile area and site clean and raked, ready to receive landscaping.

3.8 TESTS

A. Perform laboratory material tests in accordance with ASTM D698.

B. Perform in place compaction tests in accordance with the following:

  1. Density Tests: ASTM D1556.

C. Frequency of Tests: Compaction tests should occur in 250 m intervals.

3.9 TOLERANCES

A. Top of Topsoil: Plus or minus 13 mm (½ inch).

END OF SECTION

SECTION 02630

STORM DRAINAGE

PART 1 GENERAL

1.1 SUMMARY

A. Section includes site storm sewer drainage piping, fittings and accessories; open canal drainage structure, fittings and accessories; connection of drainage system to municipal drainage structures and; site surface drainage; sediment traps.

1.2 SUBMITTALS

A. Product Data: Submit data indicating pipe and pipe accessories.

B. Manufacturer's Certificate: Certify that products meet or exceed specified requirements.

1.3 CLOSEOUT SUBMITTALS

A. Project Record Documents: Accurately record actual locations of pipe runs, canal top and bottom, connections, sediment traps, and invert elevations.

B. Identify and describe unexpected variations to subsoil conditions or discovery of uncharted utilities.

1.4 QUALITY ASSURANCE

A. Design under direct supervision of Professional Engineer experienced in design of this Work and licensed at Project location

PART 2 PRODUCTS

2.1 STORM DRAINAGE

A. Sewer Pipe Materials:

1. Reinforced Concrete Pipe: ASTM C76M, Class I-V with Wall Type A-C area acceptable; bar reinforcement; pipes as noted on Drawings and to be checked by a Professional Engineer.

2. Reinforced Concrete Pipe and Manhole Joint Device: ASTM C443M, rubber compression gasket joint.

B. Open Channel Canal Materials:

1. Cast-in-Place Reinforced Concrete: as specified in Section 03050.

2.2 ACCESSORIES

A. Fittings: Same material as pipe and canal molded or formed to suit connection size and end design, in required tee, bends, elbows, cleanouts, reducers, traps and other configurations required.

B. Filter Fabric: Geotextile OP-20 (200 g/m2).

C. Grout: Specified in Section 03050.

D. Storm Drainage Inlets-Canal: Same material as open channel canal.

E. Storm Drainage Inlets-Storm Sewer Pipe: As specified in Section 05500.

2.3 COVER MATERIALS

A. Cover: Fill as specified in Section 02300

2.4 SEDIMENT TRAPS

A. Material: Same material as open channel canal.

B. Dimensions as provided in Drawings.

PART 3 EXECUTION

3.1 EXAMINATION

A. Verify trench cut and excavation base is ready to receive work and excavations, dimensions, and elevations are as indicated on drawings.

3.2 PREPARATION

A. Hand trim excavations to required elevations. Correct over excavation with coarse aggregate.

B. Remove large stones or other hard matter capable of damaging piping or impeding consistent backfilling or compaction.

3.3 INSTALLATION - PIPE

A. Install pipe, fittings, and accessories in accordance with ASTM C12M Seal joints watertight.

B. Place pipe on firm and unyielding trench bottom.

C. Lay pipe to slope gradients noted on drawings with maximum variation from indicated slope of 3 mm (1/8 inch) in 3 m (10 feet).

D. Install aggregate over top of pipe. Install top cover to minimum compacted thickness of 120 mm (4.75 inches), compact to 95 percent.

E. Do not displace or damage pipe when compacting.

F. Connect to municipal storm sewer system and manholes.

G. Install trace wire continuous over top of pipe. Buried 150 mm (6 in) above pipe line.

3.4 INSTALLATION - OPEN CHANNEL CANAL

A. Install canal, fittings, and accessories in accordance with ASTM C12M Seal joints watertight.

B. Place canal on firm and unyielding trench bottom.

C. Lay canal to slope gradients noted on drawings with maximum variation from indicated slope of 3 mm (1/8 inch) in 3 m (10 feet).

D. Do not displace or damage canal when compacting.

E. Connect to municipal storm sewer system and manholes.

3.5 FIELD QUALITY CONTROL

A. Request inspection prior to and immediately after placing aggregate cover over pipe.

B. Compaction testing will be completed for storm sewer pipe only. Testing will be performed in accordance with ASTM D1556.

C. When tests indicate Work does not meet specified requirements, remove Work, replace and retest.

D. Frequency of Tests: Compaction tests should occur in 250 m intervals.

E. Protect pipe and aggregate cover from damage or displacement until backfilling operation is in progress.

1. Take care not to damage or displace installed pipe and joints during construction of pipe supports, backfilling, testing, and other operations.
2. Correct damaged or displaced pipe. Repeat tests for corrected sections of pipe.

END OF SECTION

SECTION 02750

RIGID PAVEMENT

PART 1 GENERAL

1.1 SUMMARY

A. Section Includes:

1. Concrete curbs.
2. Concrete roads.

1.2 SYSTEM DESCRIPTION

A. Paving and Base: Designed for movement of trucks up to 11,000 kg (24,250 lbs) per axle.

1.3 SUBMITTALS

A. Product Data: Submit product information.

B. Design Data: Submit mix design.

1.4 QUALITY ASSURANCE

A. Perform Work in accordance with Section 03050.

B. Maintain one copy of each document on site.

PART 2 PRODUCTS

2.1 PORTLAND CEMENT CONCRETE PAVEMENT

A. Concrete Materials: As specified in Section 03050.

B. Joint Filler: Asphalt impregnated wood fiberboard.

C. Reinforcing Steel: ASTM A615M; 413 MPa (60 ksi) yield grade; deformed billet steel bars, galvanized finish.

D. Welded Steel Wire Fabric: ASTM A185 Plain type, in flat sheets; galvanized finish.

E. Dowels: ASTM A615M Plain steel, galvanized finish.

F. Cement: ASTM C150 Normal Type Portland type, gray color.

G. Fine and Coarse Aggregates: ASTM C33.

H. Water: Clean and not detrimental to concrete.

I. Admixtures: ASTM C260.

J. Liquid Surface Sealer: Apply if applicable.

2.2 ACCESSORIES

A. Curb: Cast-in-Place concrete.

B. Load Transfer Reinforcement: Specified in Section 05500.

2.3 CONCRETE MIX

A. Mix and deliver concrete in accordance with ASTM C94 Option A.

PART 3 EXECUTION

3.1 EXAMINATION AND PREPARATION

A. Verify gradients and elevations of base.

B. Verify compacted subgrade is ready to support paving and imposed loads.

C. Moisten substrate to minimize absorption of water from fresh concrete.

3.2 FORMING

A. Place and secure forms to correct location, dimension, and profile.

B. Place joint filler in joints, vertical in position, in straight lines. Secure to formwork.

C. Place expansion joints at 4.5 m intervals (15 foot) as indicated on Drawings. Align joints.

D. Place joint filler between paving components and other appurtenances.

3.3 REINFORCEMENT

A. Place reinforcement in curbs as specified.

B. Tie curbs to pavement with reinforcement.

C. Place dowels to achieve pavement and curb alignment.

D. Place Load Transfer Reinforcement to achieve the transfer of loads between pavement sections.

3.4 PLACING CONCRETE

A. Place concrete in accordance with Section 03050.

B. Do not disturb reinforcement or formwork components during concrete placement.

C. Place concrete continuously between predetermined joints.

D. Place curbs secure.

3.5 FINISHING

A. Area Paving: Wood float.

B. Curbs: Light broom.

C. Apply curing compound on exposed concrete surfaces immediately after finishing.

END OF SECTION

SECTION 02900

PLANTING

PART 1 GENERAL

1.1 SUMMARY

A. Section Includes:

1. Preparation of soil
2. Seeding.

1.2 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: Include pruning objectives, types and methods; types, application frequency, and recommended coverage of fertilizer.

1.3 WARRANTY

A. Furnish one year warranty including one continuous growing season including coverage of plants from death or unhealthy conditions.

B. Replacements: Plants of same size and species as specified, planted in next growing season, with new warranty beginning on date of replacement.

PART 2 PRODUCTS

2.1 GRASS

A. Furnish materials in accordance with the Municipality of Santa Cruz de la Sierra.

2.2 SOIL AND SOIL MODIFICATION MATERIALS

A. Topsoil: Fertile, agricultural soil, typical for locality, capable of sustaining vigorous plant growth, free of subsoil, clay or impurities, plants, weeds and roots.

2.3 ACCESSORIES

A. Mulching Material: Oat or wheat straw, free from weeds, foreign matter detrimental to plant life, and dry. Hay or chopped cornstalks are acceptable.

PART 3 EXECUTION

3.1 EXAMINATION AND PREPARATION

A. Verify required underground utilities are in proper location.

B. Prepare subsoil to eliminate uneven areas. Maintain profiles and contours. Make changes in grade gradual. Blend slopes into level areas.

3.2 PLACING TOPSOIL

A. Spread topsoil to minimum depth of 75 mm (3 inches). Rake smooth.

B. Grade topsoil to eliminate rough, low or soft areas. Slope for positive drainage as indicated on Drawings.

3.3 SEEDING

A. Apply seed evenly in two intersecting directions.

B. Immediately following seeding, apply agricultural mulch to thickness of 3 mm (1/8 inches).

C. Apply water with fine spray immediately after each area has been mulched.

3.4 SCHEDULE - PLANT LIST

Key	Common Name	Location	Remarks
G-1	Black Dirt	Shoulder	Thickness of 7.5 cm.
G-2	Grass Seed	Shoulder	Spread evenly in two directions along shoulder.
G-3	Agricultural Mulch	Shoulder	Lay over seeding.

END OF SECTION

SECTION 03050

BASIC CONCRETE MATERIALS AND METHODS

PART 1 GENERAL

1.1 SUMMARY

A. Section Includes:

1. Formwork.
2. Reinforcement.
3. Accessories.
4. Cast-in place concrete.
5. Finishing and curing.

1.2 SUBMITTALS

A. Shop Drawings: Indicate pertinent dimensioning, form materials, arrangement of joints and ties, location of bracing and temporary supports, schedule of erection and stripping. Indicate reinforcement sizes, spacing, locations, and quantities, bending and cutting schedules, supporting and spacing devices. Indicate slabs-on-grade and interfering structures.

B. Product Data: Indicate anchors and reinforcement.

C. Design Data: Submit mix designs.

1.3 QUALITY ASSURANCE

A. Construct and erect concrete formwork in accordance with ACI 301.

B. Perform concrete reinforcing work in accordance with ACI 318M.

C. Perform cast-in-place concrete work in accordance with ACI 301.

D. Perform Work in accordance with Municipality of Santa Cruz de la Sierra. Where Municipality requirements conflict with ACI 301, follow ACI 301.

PART 2 PRODUCTS

2.1 FORM MATERIALS AND ACCESSORIES

A. Form Materials: At discretion of Owner. Use straight and new lumber.

B. Form Release Agent: Colorless mineral oil not capable of staining concrete or impairing natural bonding characteristics of coating intended for use on concrete.

2.2 REINFORCEMENT MATERIALS

A. Reinforcing Steel: ASTM A615M, 414 MPa (60 ksi) yield grade; plain billet steel bars, galvanized finish.

B. Chairs, Bolsters, Bar Supports, Spacers: Sized and shaped for support of reinforcing; plastic tipped or non-corroding.

C. Fabricate concrete reinforcing in accordance with ACI 318M.

2.3 CONCRETE MATERIALS

A. Cement: ASTM C150, Normal-Type I Portland type.

B. Fine and Coarse Aggregates: ASTM C33.

C. Water: Clean and not detrimental to concrete.

2.4 CONCRETE MIX

A. Mix and deliver concrete in accordance with ASTM C94, Option A.

B. Furnish concrete of strength specified by Architect/Engineer.

C. Add air entraining agent to concrete mix for concrete work exposed to exterior.

PART 3 EXECUTION

3.1 FORMWORK ERECTION

A. Erect formwork, shoring and bracing to achieve design requirements.

B. Camber slabs and framing to achieve ACI 301 tolerances.

C. Provide bracing to ensure stability of formwork.

D. Apply form release agent to formwork prior to placing form accessories and reinforcement.

E. Do not apply form release agent where concrete surfaces will receive special finishes or applied coverings affected by agent.

F. Clean forms as erection proceeds, to remove foreign matter.

3.2 INSERTS, EMBEDDED COMPONENTS, AND OPENINGS

A. Provide formed openings where required for work to be embedded in and passing through concrete members.

B. Coordinate work of other sections in forming and setting openings, slots, recesses, chases, sleeves, bolts, anchors, and other inserts.

C. Install concrete accessories straight, level, and plumb.

D. Install water stops continuous without displacing reinforcement. Heat seal joints watertight.

E. Place formed construction joint device in pavement slabs at specified joint locations in Section 02750.

F. Install void forms. Protect forms from moisture before concrete placement and from crushing during concreting.

3.3 REINFORCEMENT PLACEMENT

A. Place reinforcement, supported and secured against displacement.

B. Ensure reinforcing is clean, free of loose scale, dirt, or other foreign coatings.

3.4 PLACING CONCRETE

A. Prepare previously placed concrete by cleaning with steel brush and applying bonding agent.

B. Place concrete continuously between predetermined expansion, control and construction joints. Do not break or interrupt successive pours creating cold joints.

C. Where new concrete is doweled to existing work, drill holes in existing concrete, insert steel dowels and pack with non-shrink grout.

D. Screed slabs-on-grade and walls level.

3.5 FORM REMOVAL

A. Do not remove forms or bracing until concrete has gained sufficient strength to carry its own weight and imposed loads.

B. Remove formwork progressively and in accordance with code requirements.

3.6 CURING

A. Immediately after placement, protect concrete from premature drying.

B. Maintain concrete with minimal moisture loss at relatively constant temperature for period necessary for hydration of cement and hardening of concrete for not less than 7 days.

3.7 FORMED SURFACES

A. Provide concrete surfaces to be left exposed with smooth finish.

3.8 FIELD QUALITY CONTROL

A. Three (3) Concrete Test Cylinders: Taken for every 75 or less cu meters (100 or less cu yds) of concrete placed.

B. One (1) Additional Test Cylinder: Taken during hot weather concreting, and cured on job site under same conditions as concrete incorporated into the Work.

C. One (1) Slump Test: Taken for each set of test cylinders taken.

3.9 DEFECTIVE CONCRETE

A. Modify or replace concrete not conforming to required lines, details and elevations, as directed by Architect/Engineer.

END OF SECTION

SECTION 05500

METAL FABRICATIONS

PART 1 GENERAL

1.1 SUMMARY

A. Section Includes:

1. Shop fabricated ferrous metal items, galvanized.

1.2 SUBMITTALS

A. Shop Drawings: Indicate profiles, sizes, connection attachments, reinforcing, anchorage, size and type of fasteners, and accessories. Include erection drawings, elevations, and details where applicable.

1. Indicate welded connections using standard AWS A2.4 welding symbols. Indicate net weld lengths.

B. Samples: Submit one sample of each item for approval of Architect/Engineer.

1.3 QUALITY ASSURANCE

A. Finish joints in accordance with NOMMA Guideline 1.

B. Design under direct supervision of Professional Engineer experienced in design of this Work and licensed at Project location.

C. When Work is subject to special loadings (i.e. traffic loadings) ensure that Work is structurally sound.

PART 2 PRODUCTS

2.1 COMPONENTS

A. Steel Sections: ASTM A36M.

B. Steel Plate: ASTM A283M.

2.2 ACCESSORIES

A. Welding Materials: AWS D1.1.

B. Touch-Up Primer for Galvanized Surfaces: SSPC Paint 20.

C. Concrete and Reinforcement for Treads and Landings: Mesh and Bar types, Portland cement, as specified in Section 03050.

2.3 FABRICATION

A. General:

1. Fit and shop assemble items in largest practical sections, for delivery to site.
2. Continuously seal joined members by intermittent welds and plastic filler.
3. Grind exposed joints flush and smooth with adjacent finish surface. Make exposed joints butt tight, flush, and hairline. Ease exposed edges to small uniform radius.
4. Exposed Mechanical Fastenings: Flush countersunk screws or bolts, consistent with design of component.
5. Supply components required for anchorage of fabrications. Fabricate anchors and related components of same material and finish as fabrication.
6. Accurately form components required for anchorage of landings and railings to each other and to building structure.
7. Exposed Welded Joints: NOMMA Guideline 1 Joint Finish 1.

2.4 FINISHES

A. Clean surfaces of rust, scale, grease, and foreign matter prior to finishing.

B. Shop prime items with two coats. Do not prime surfaces in direct contact with concrete or where field welding is required.

PART 3 EXECUTION

3.1 EXAMINATION

A. Verify field conditions are acceptable and are ready to receive Work.

3.2 PREPARATION

A. Make provisions for erection stresses. Install temporary bracing to maintain alignment, until permanent bracing and attachments are installed.

B. Supply items required to be cast into concrete with setting templates, to appropriate sections.

3.3 INSTALLATION

A. Install items plumb and level, accurately fitted, free from distortion or defects.

B. Provide for erection loads and provide temporary bracing to maintain indicated alignment until completion of erection and installation of permanent attachments.

C. Field weld components indicated on shop drawings. Perform field welding in accordance with AWS D1.1.

D. Obtain approval prior to site cutting.

E. After erection, touch up welds, abrasions, and damaged finishes with prime paint or galvanizing repair paint to match shop finishes.

END OF SECTION

Avenida Fatima Uno

Roadway, Canal, and Pipe
System Design for District 12
Santa Cruz, Bolivia

5 Cinco Cero Engineering 0

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Draft Legend

- — Canal Invert
- — Proposed Drainage Grade
- — Proposed Road Grade
- — Existing Road Grade
- — Pipe Invert
- — Centerline
- ● Inlet Structure
- ▭ Sediment Trap
- → Drawing Note
- ▭ Existing Bridge

INDEX

Special Notes

- These drawings were created by students of Michigan Technological University and must be approved by a professional engineer before implementation.
- No pedestrian or traffic bridges were included in this design and must be designed by others and included in the final design.

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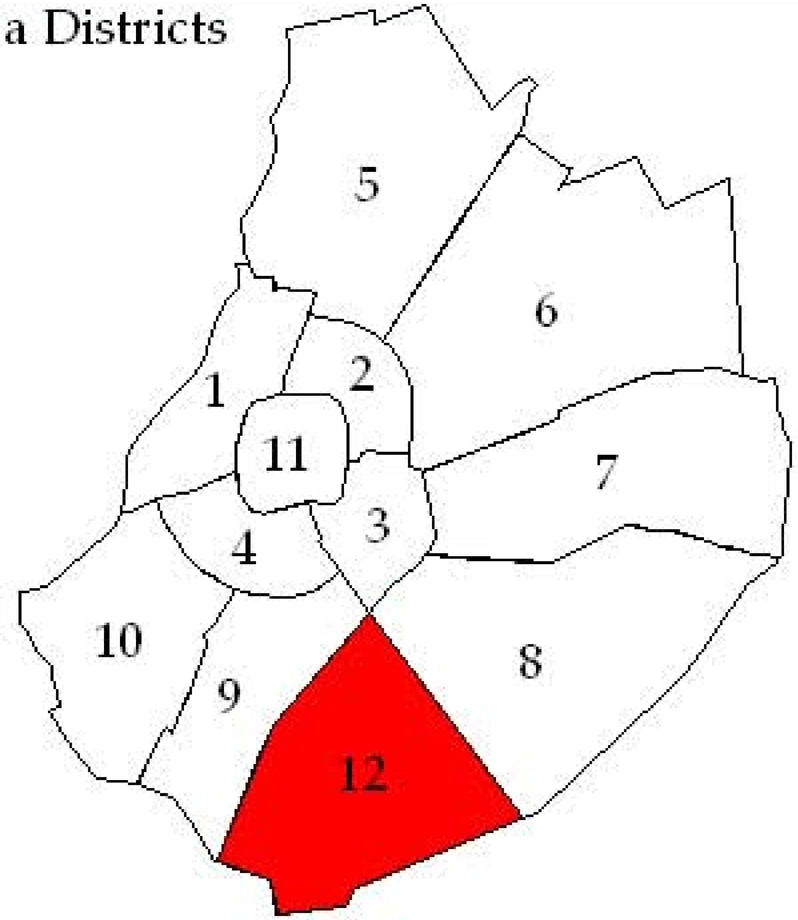
Bolivia Districts



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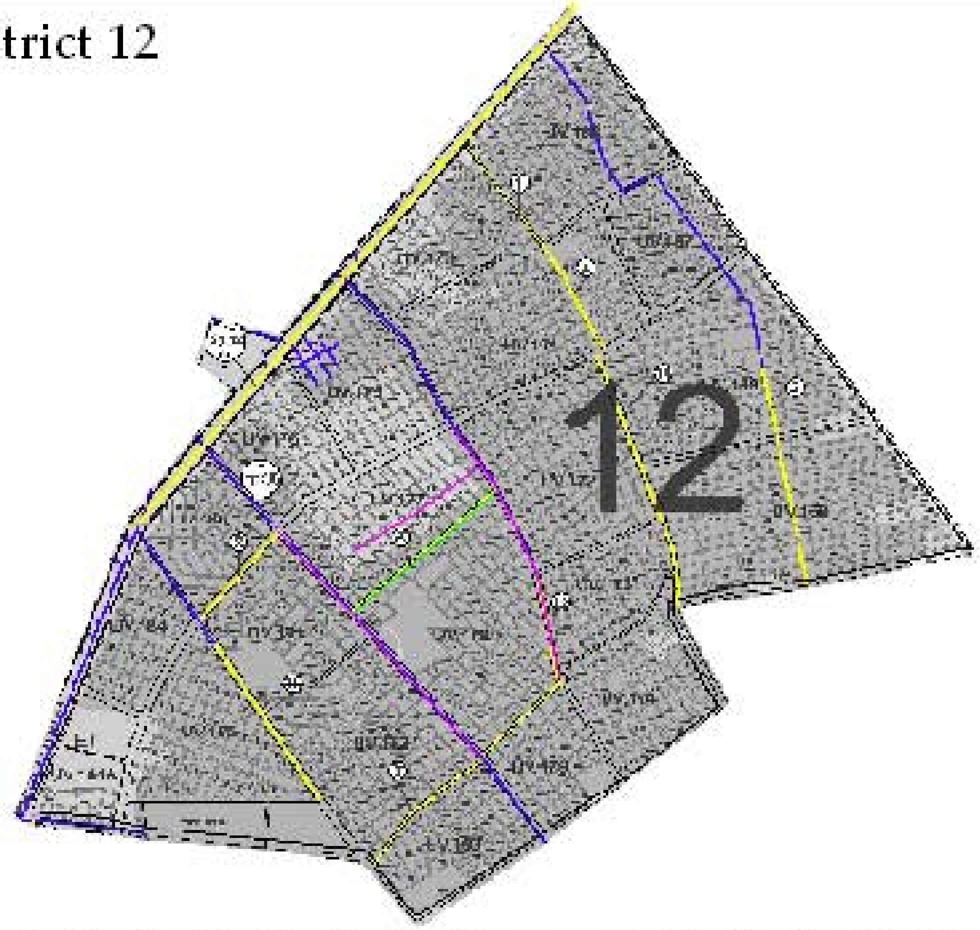

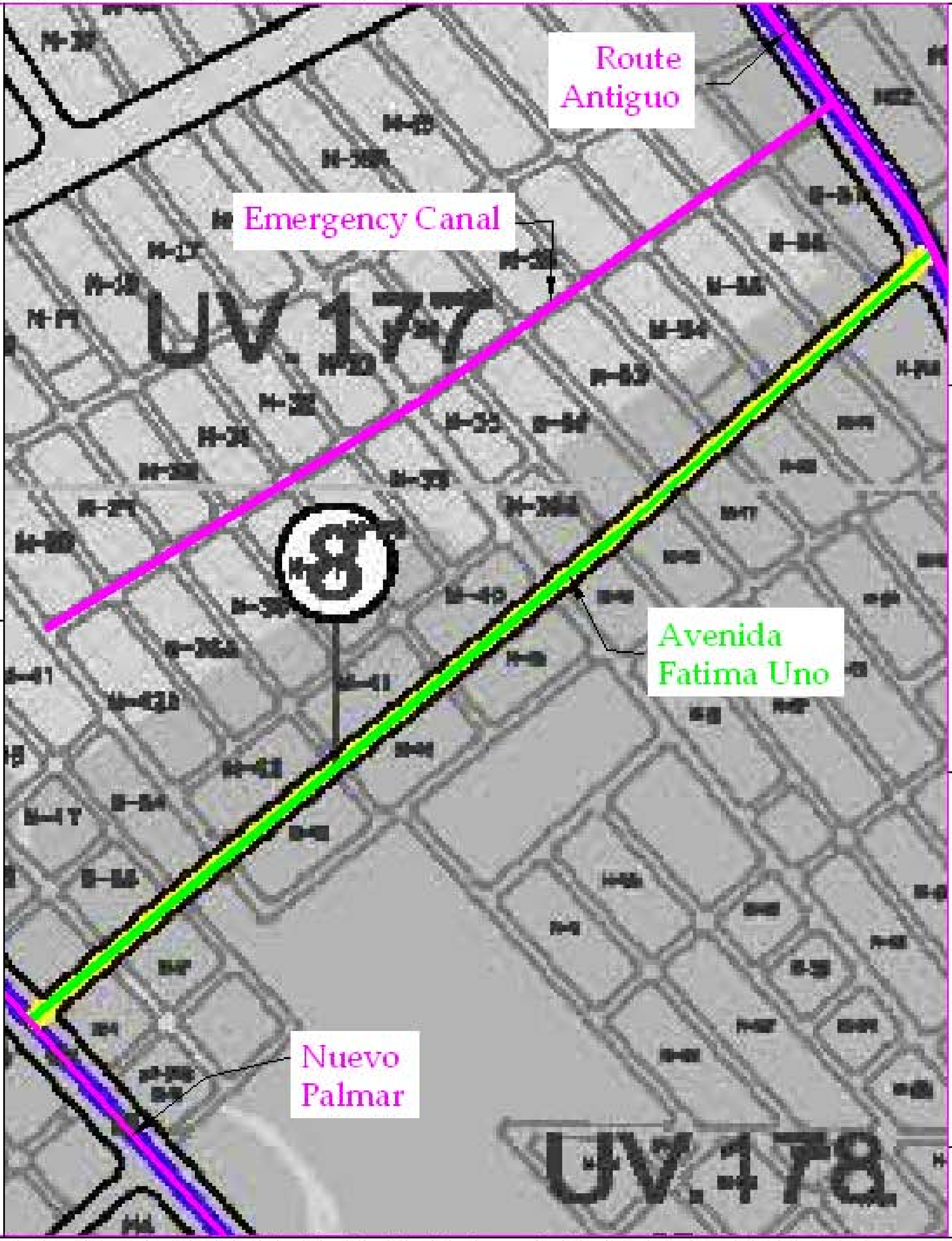

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Paper Size: 11X17
Units: Meters
Engineer: Travis Velasco

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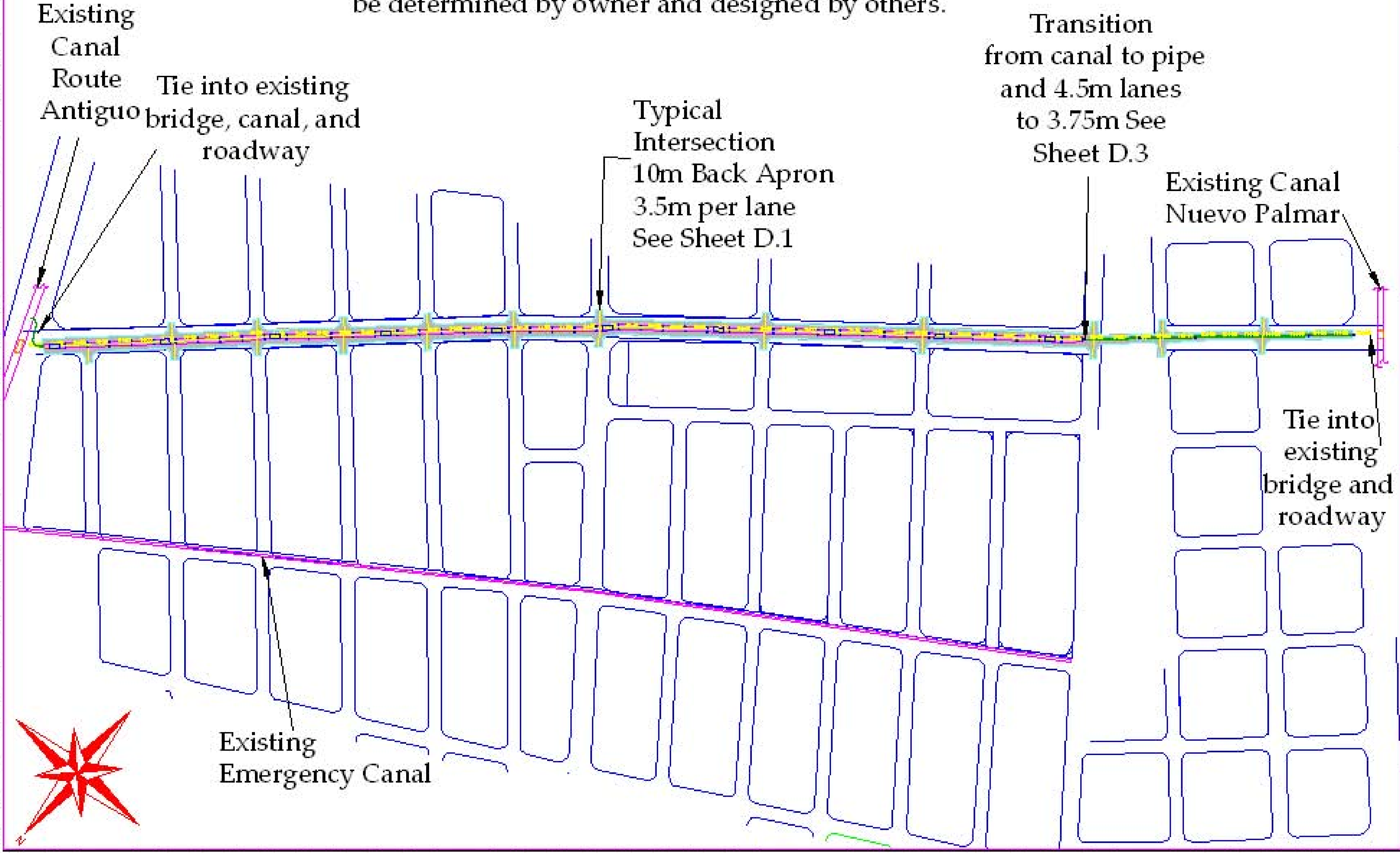
Avenida Fatima Uno
Road and Canal

Vicinity Map

A.1

Note: Minimal slope between Canal Route Antiguo and Nuevo Palmar, contractor must install canal and pipes with close tolerances.

Vehicular and pedestrian bridges: Number required and placement to be determined by owner and designed by others.



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Plan View

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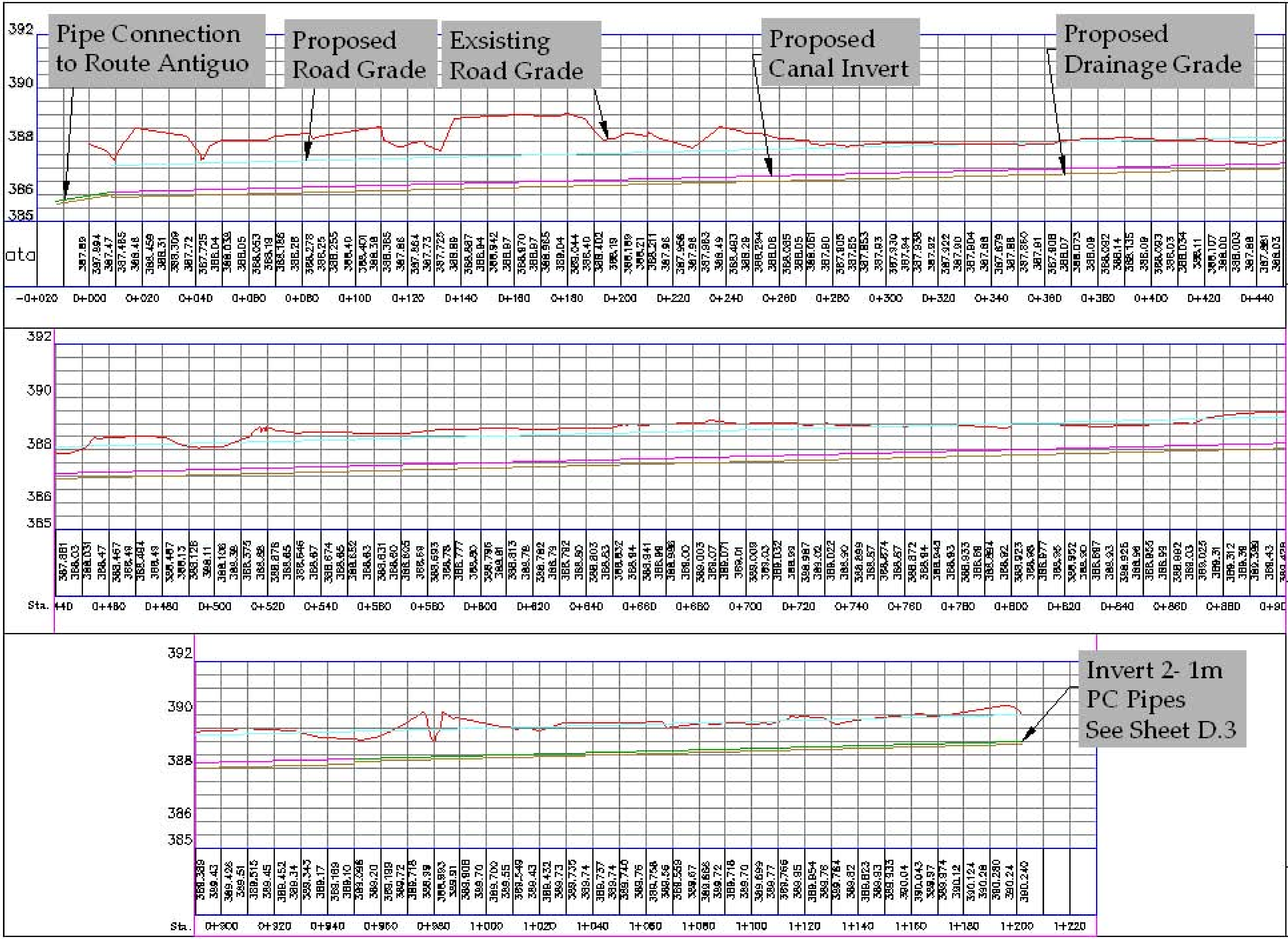

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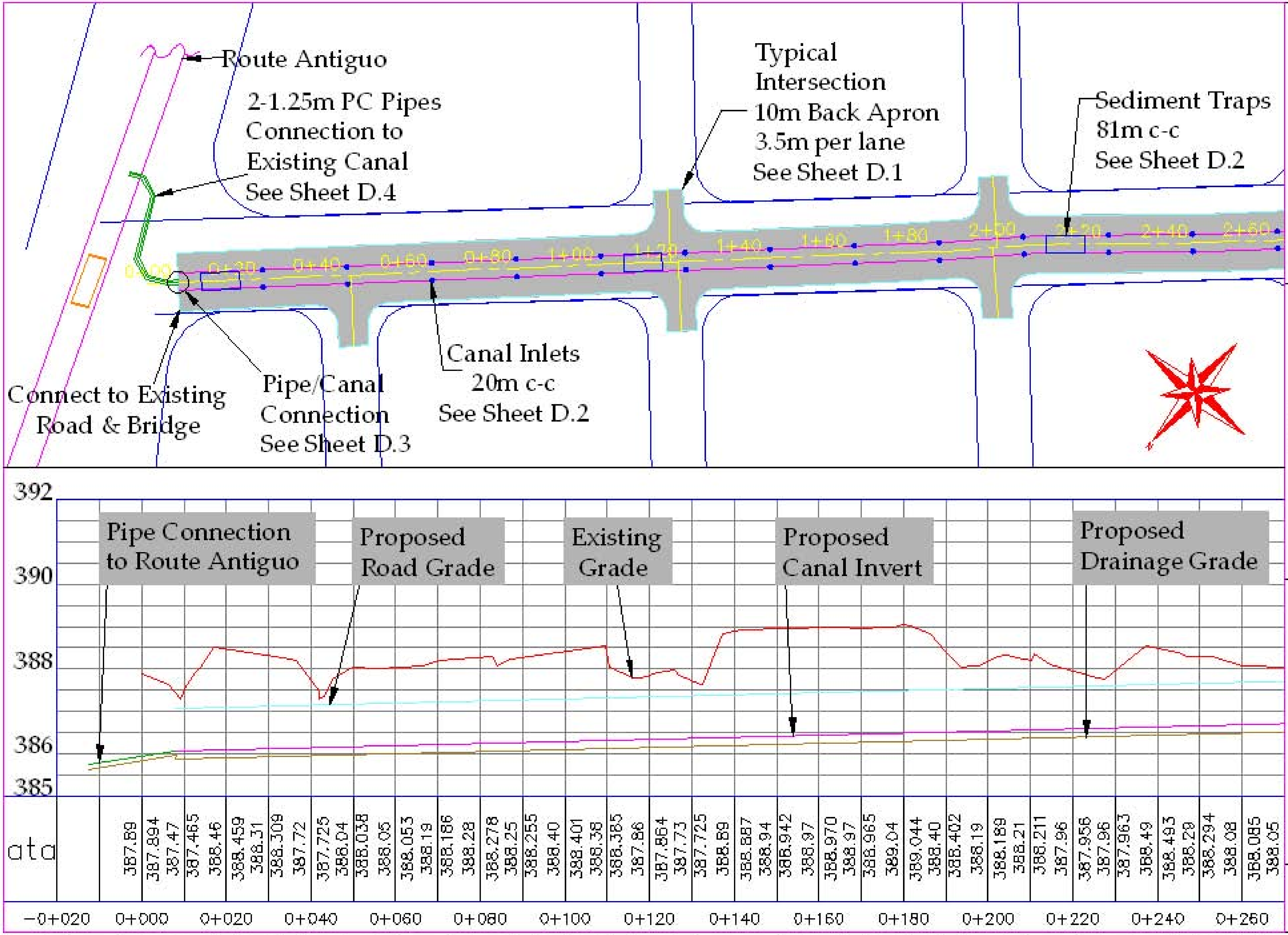
Profile View

B.2



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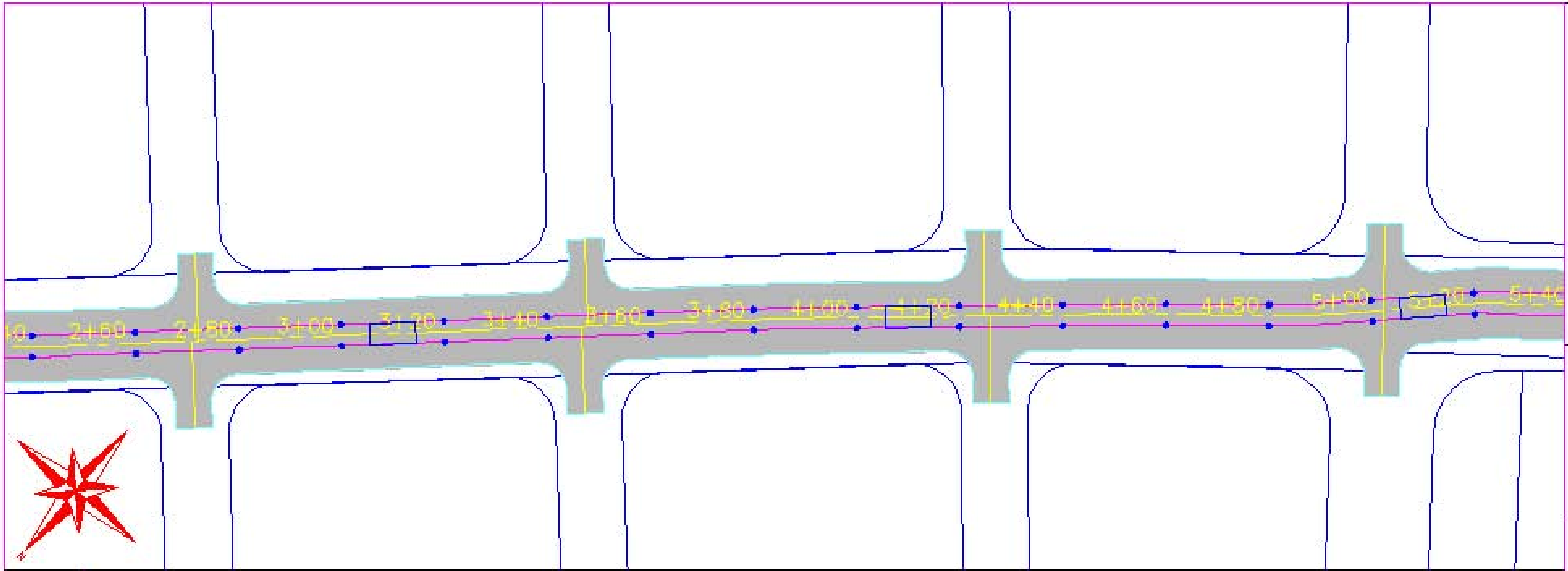
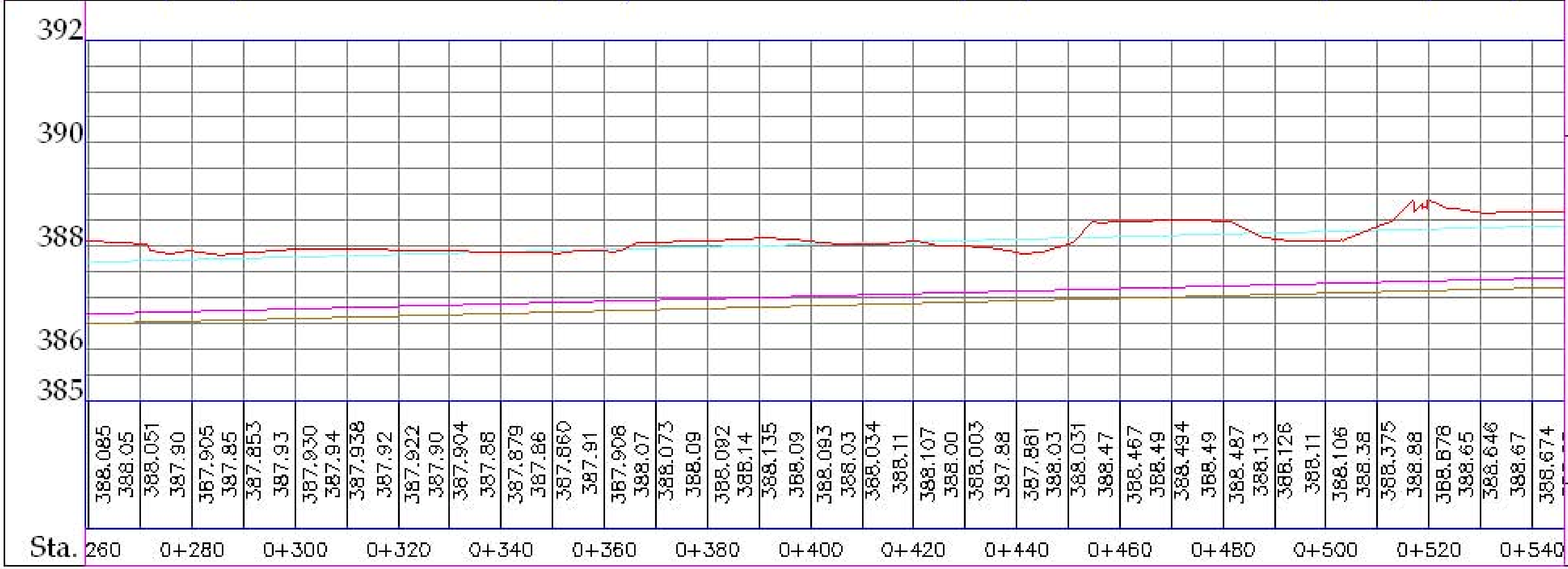
Plan and Profile

B.3





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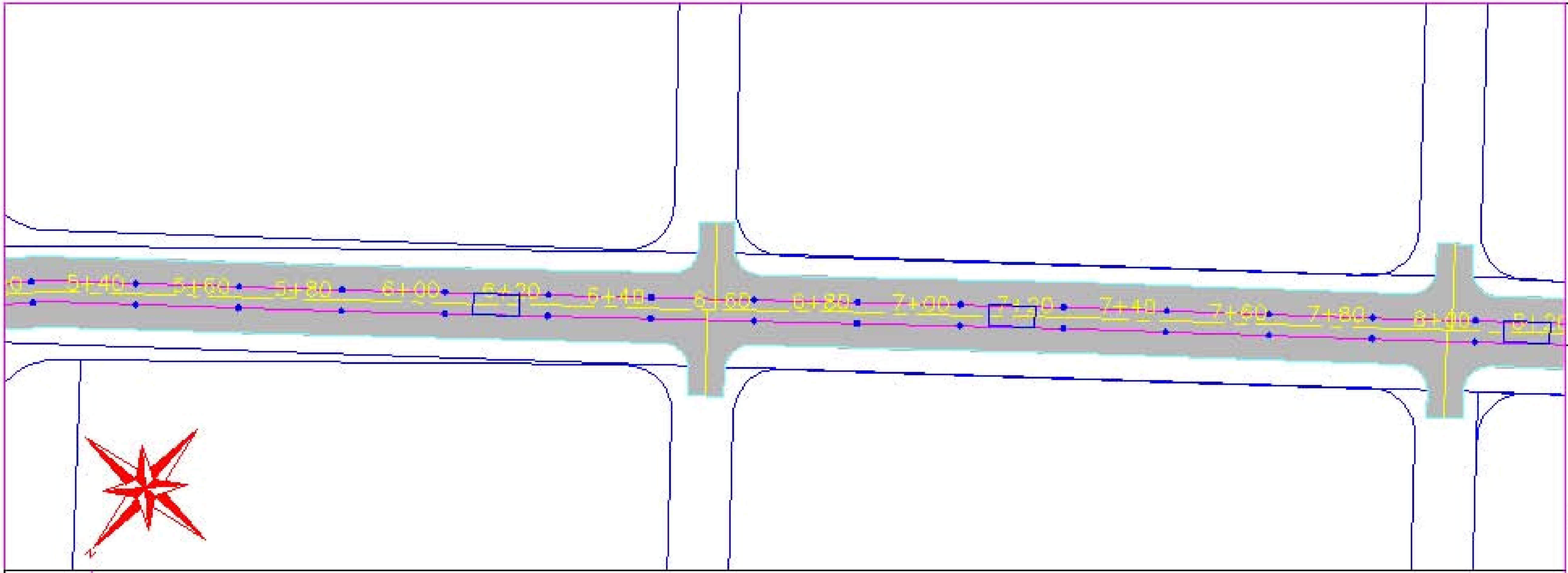

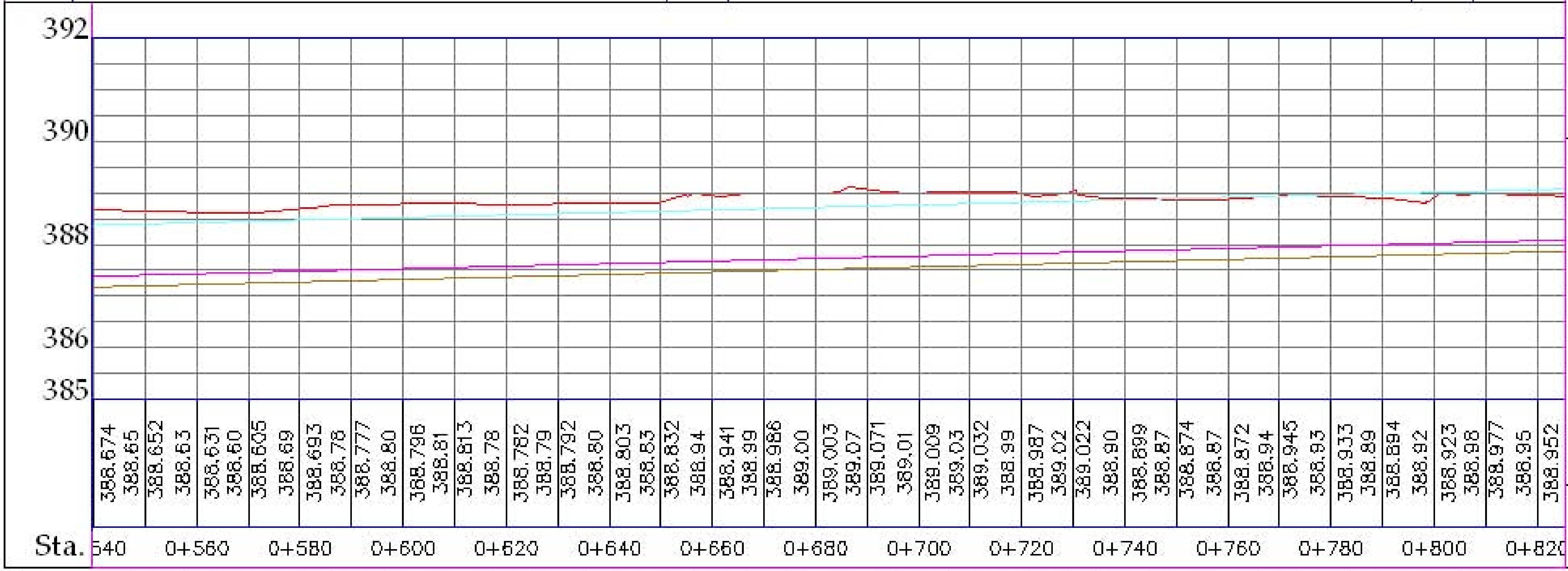

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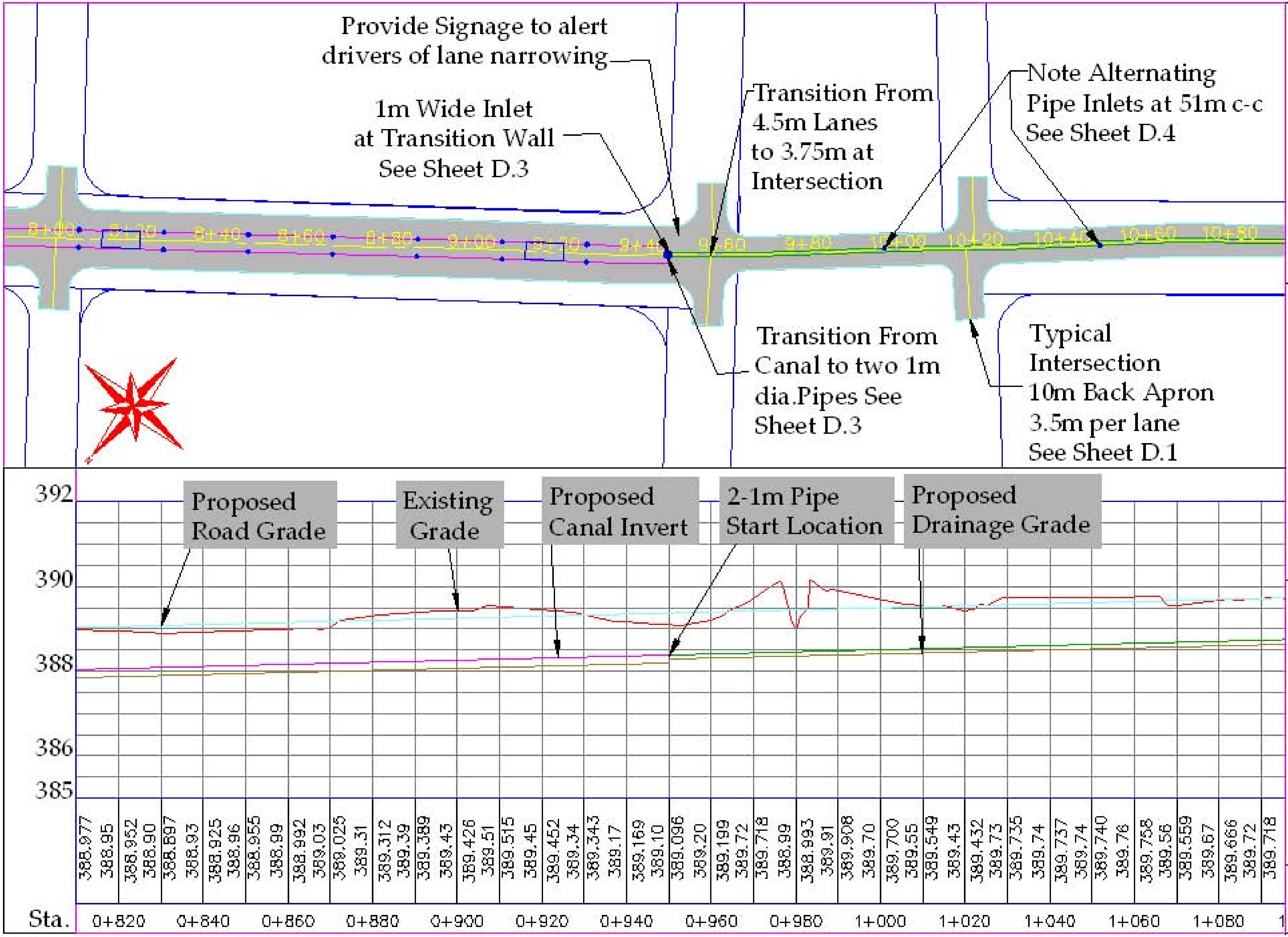
Avenida Fatima Uno
Road and Canal

Plan and Profile

B.5



Provide Signage to alert drivers of lane narrowing

1m Wide Inlet at Transition Wall See Sheet D.3

Transition From 4.5m Lanes to 3.75m at Intersection

Note Alternating Pipe Inlets at 51m c-c See Sheet D.4

Transition From Canal to two 1m dia.Pipes See Sheet D.3

Typical Intersection 10m Back Apron 3.5m per lane See Sheet D.1

Proposed Road Grade

Existing Grade

Proposed Canal Invert

2-1m Pipe Start Location

Proposed Drainage Grade

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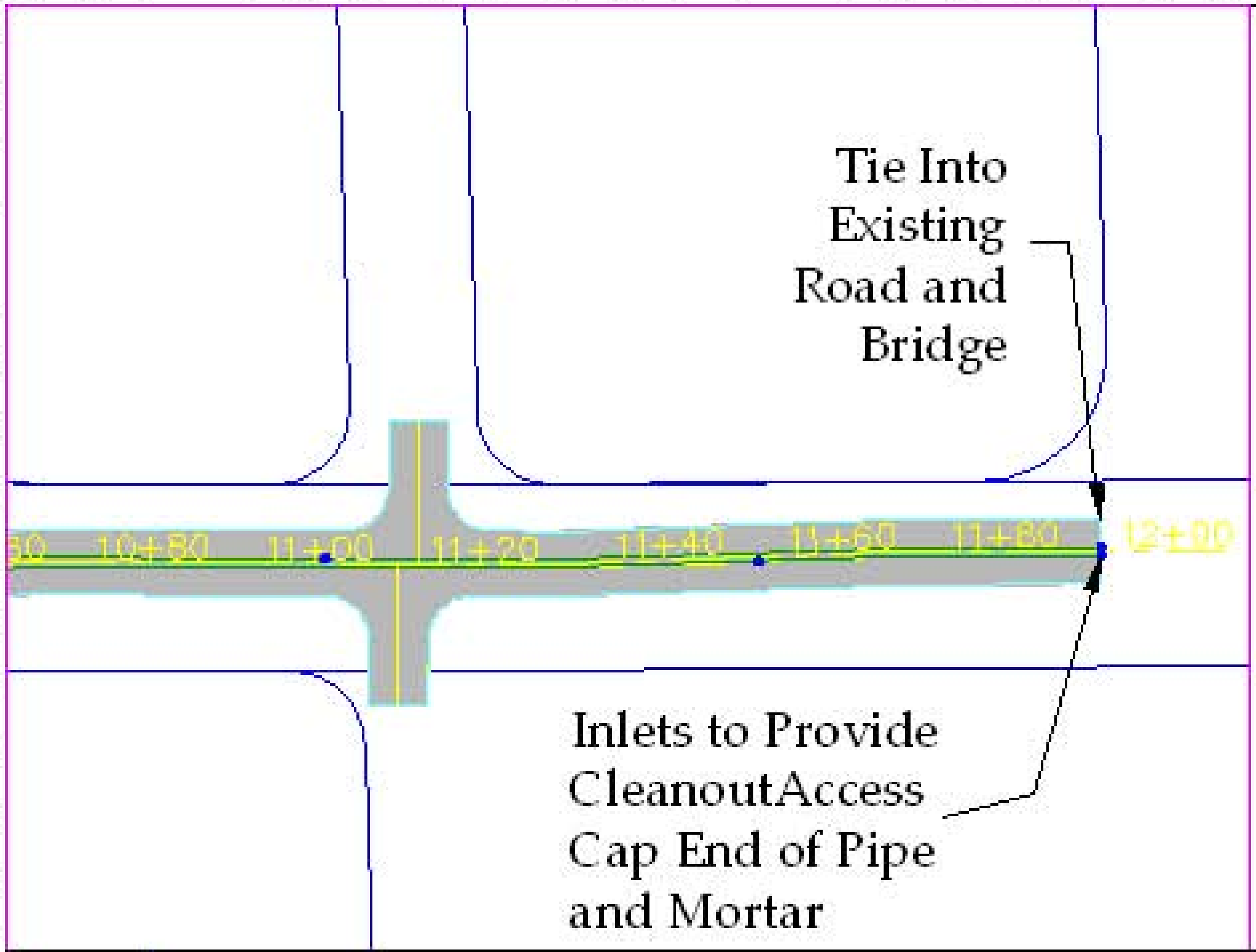
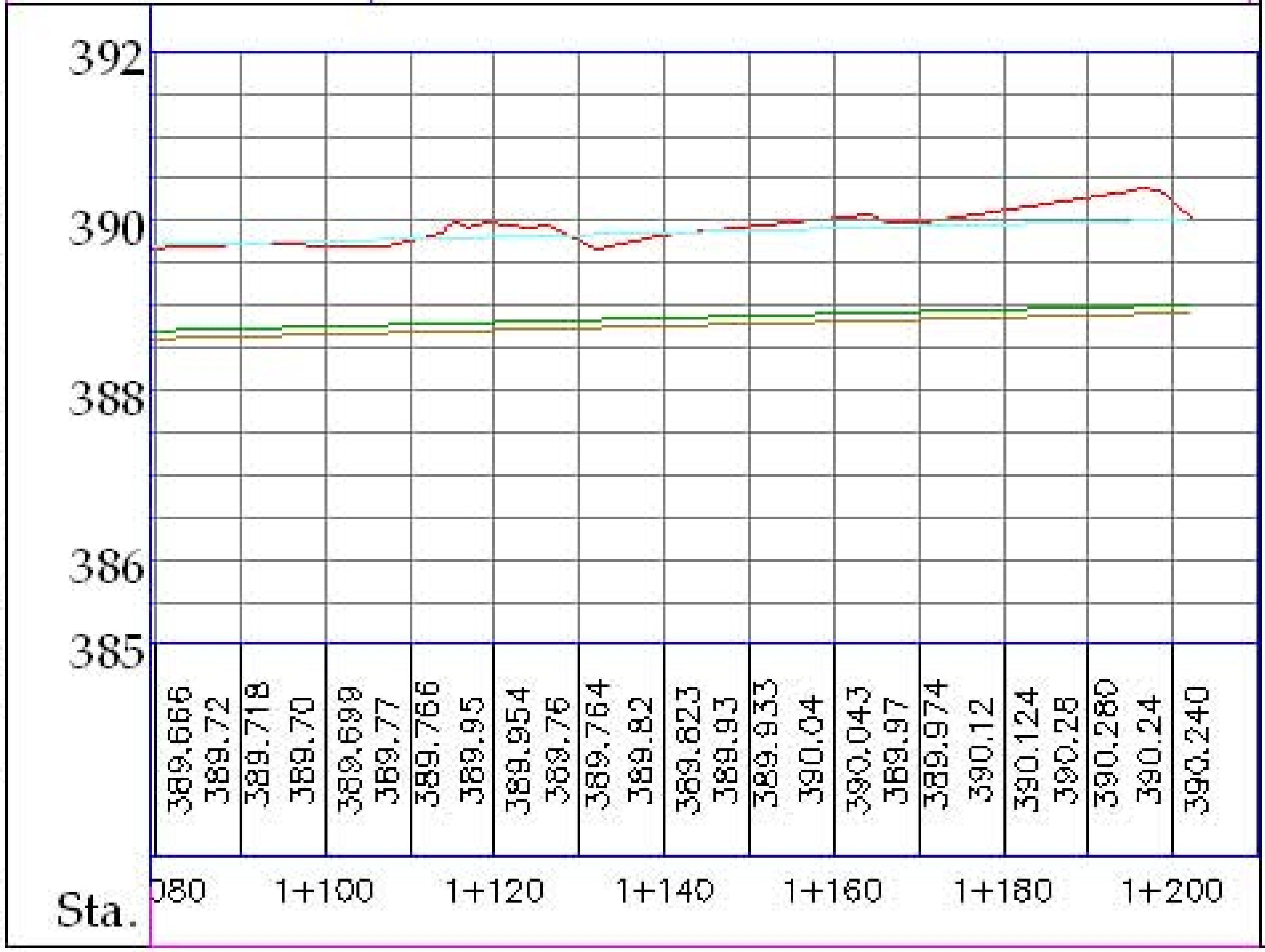
Plan and Profile

B.6





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B.7

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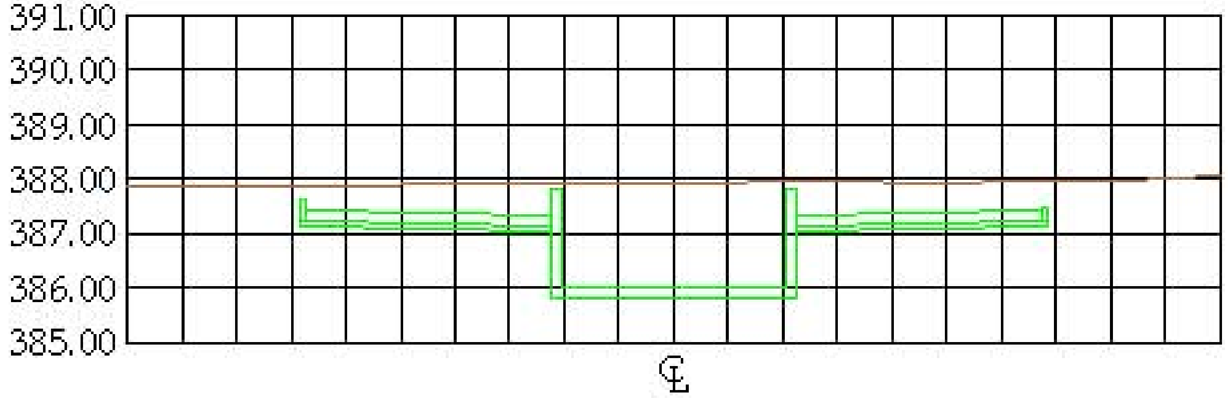

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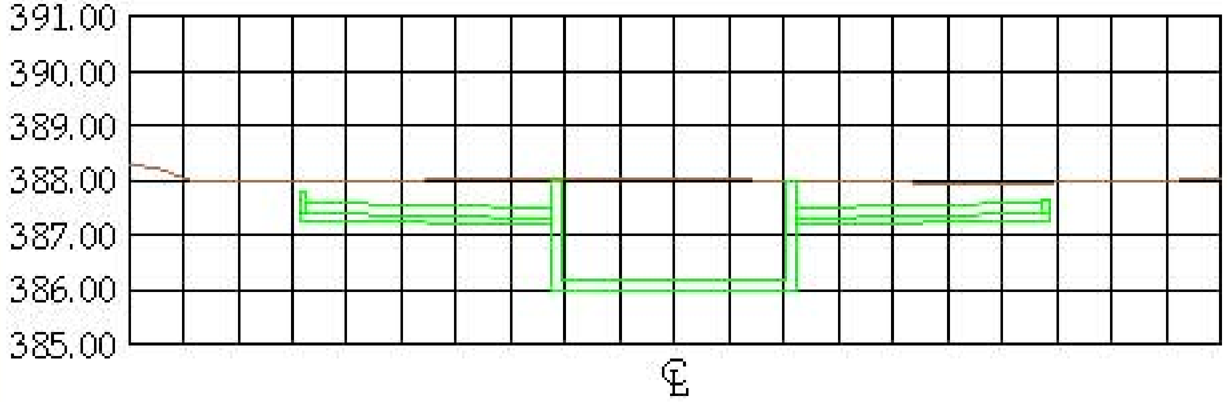

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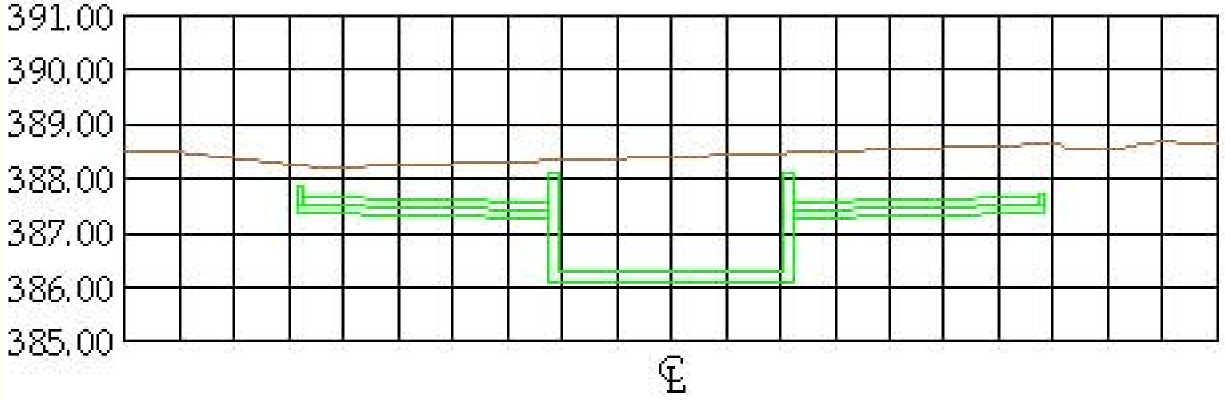

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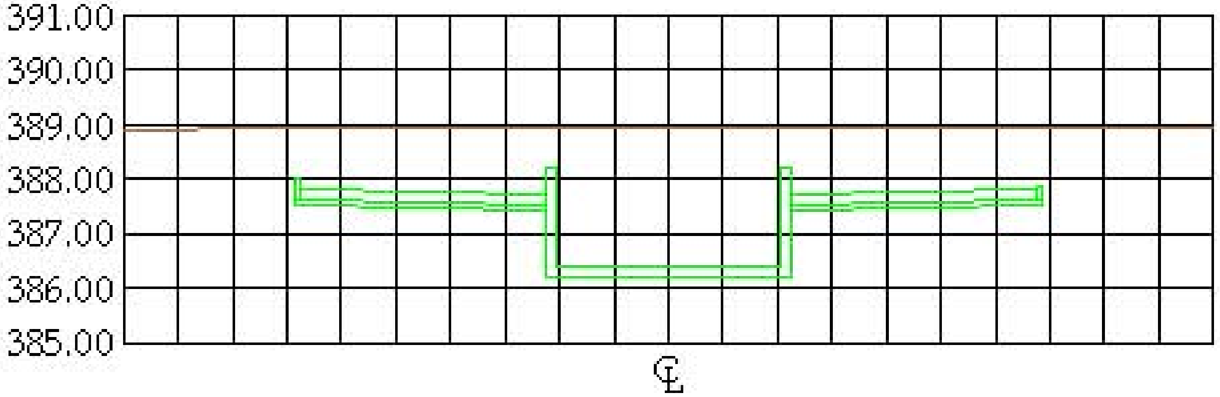

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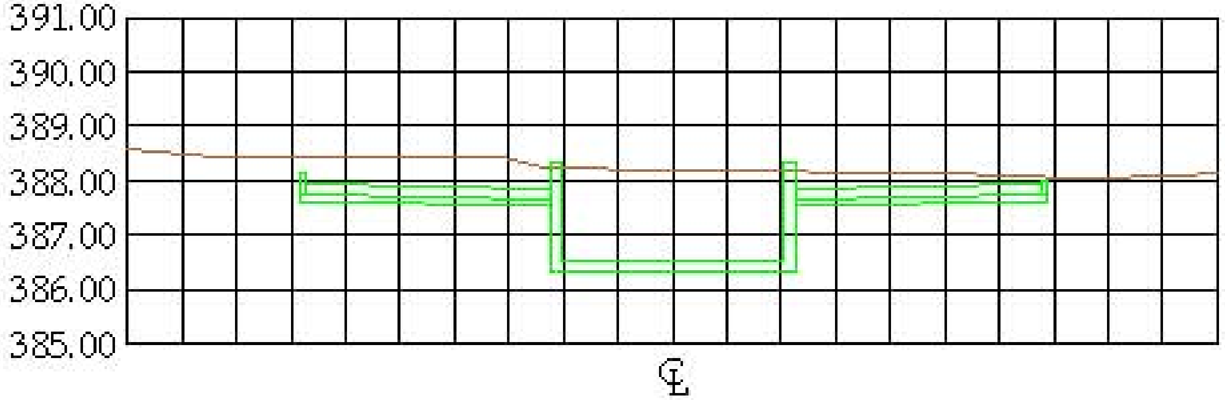

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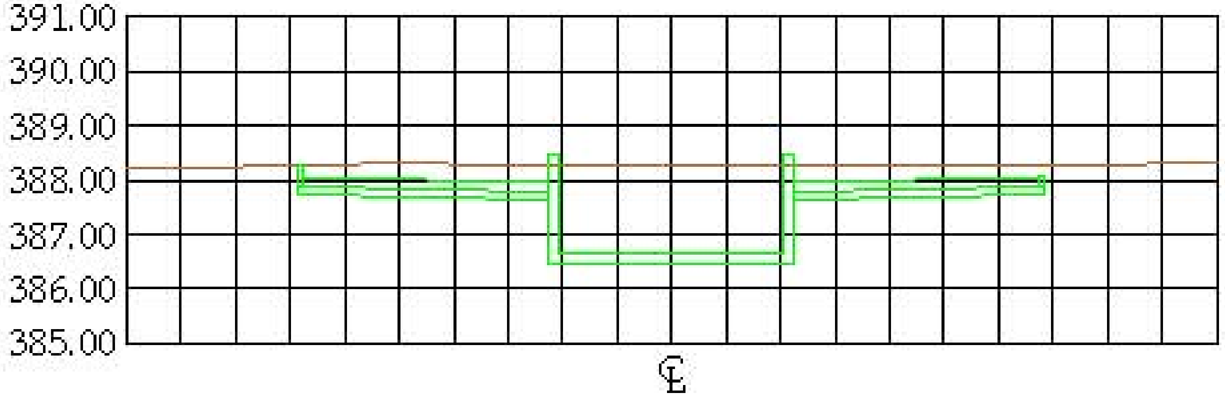

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Units:	Meters
Engineer:	Travis Velasco

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Avenida Fatima Uno Road and Canal

Cross Sections

C.1

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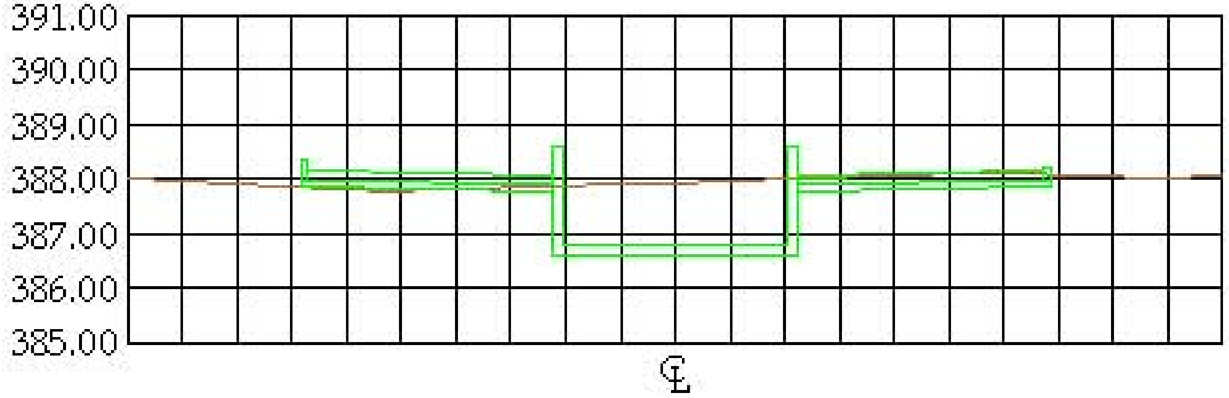

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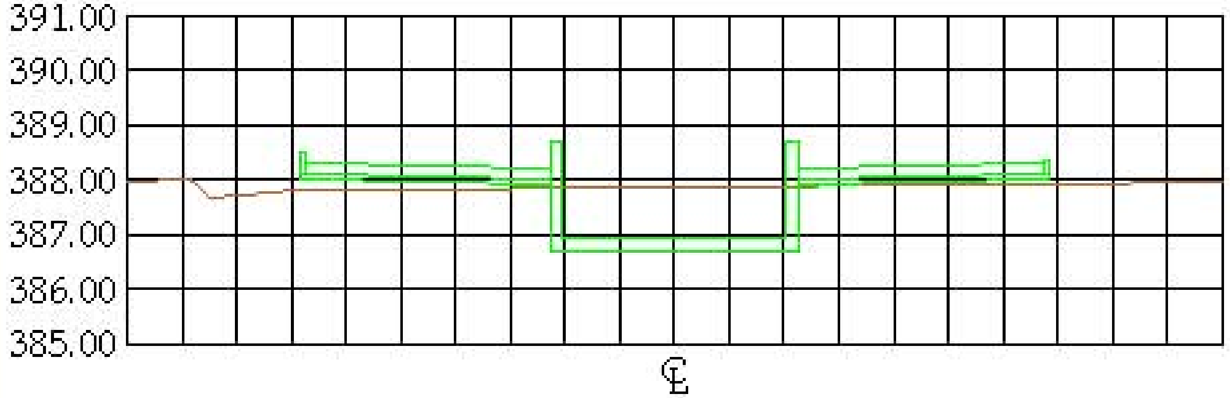

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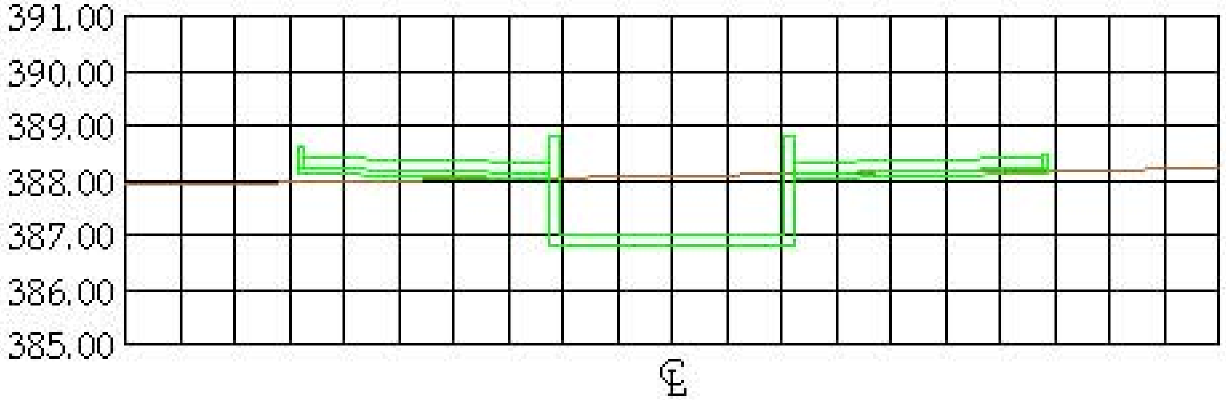

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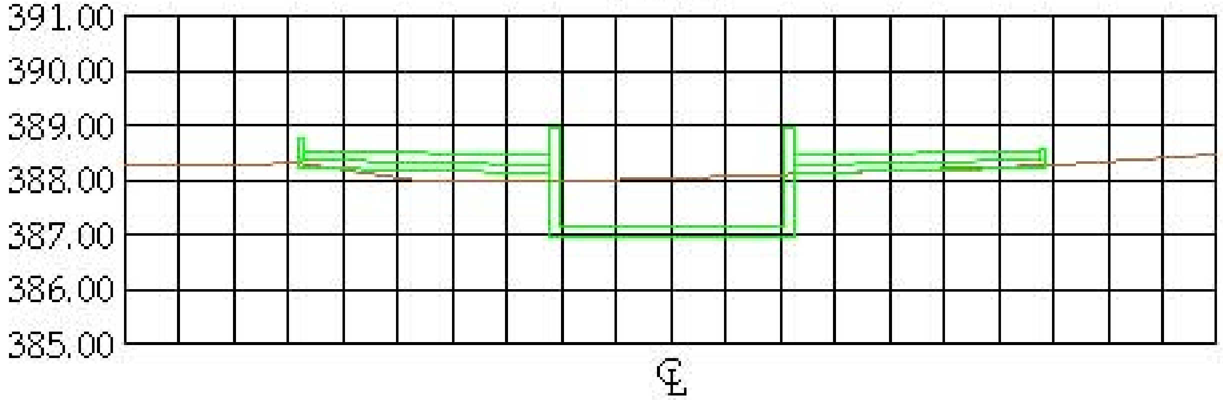

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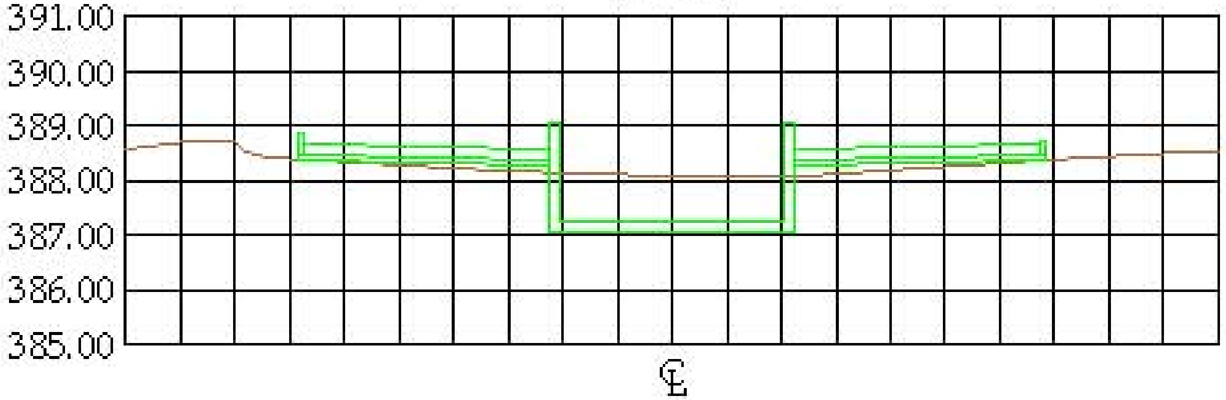

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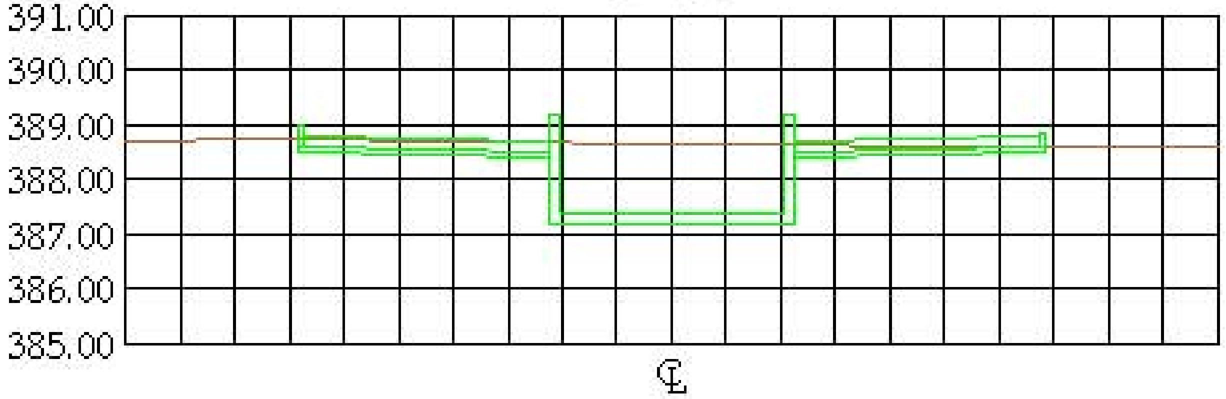

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Engineer: Travis Velasco

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Avenida Fatima Uno Road and Canal

Cross Sections

C.2

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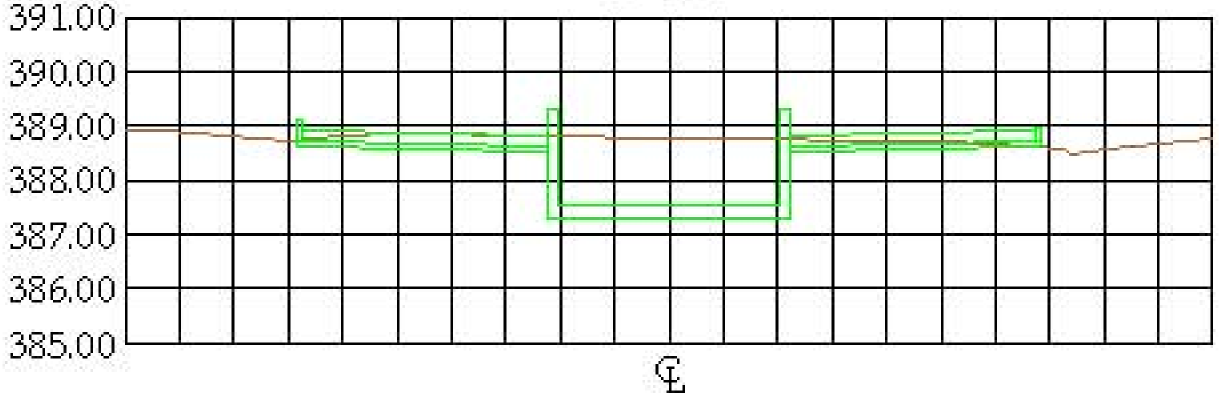

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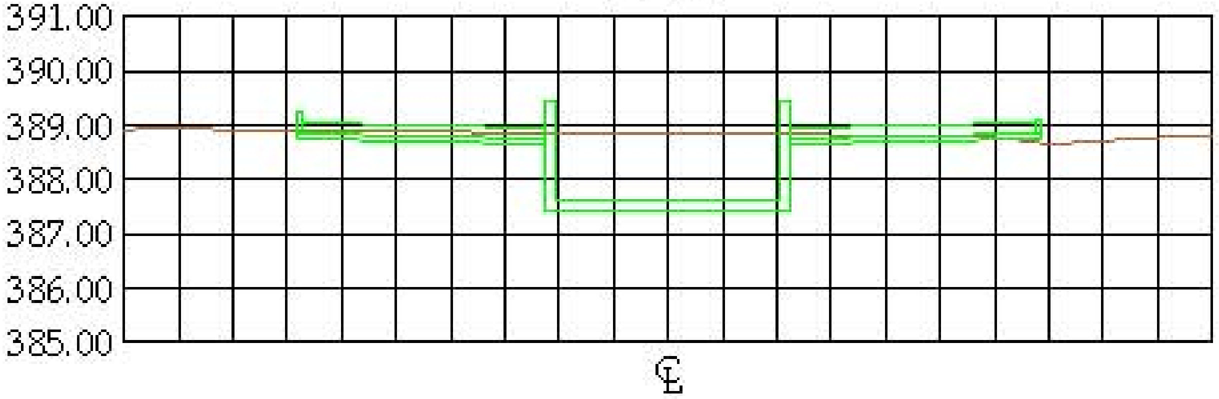

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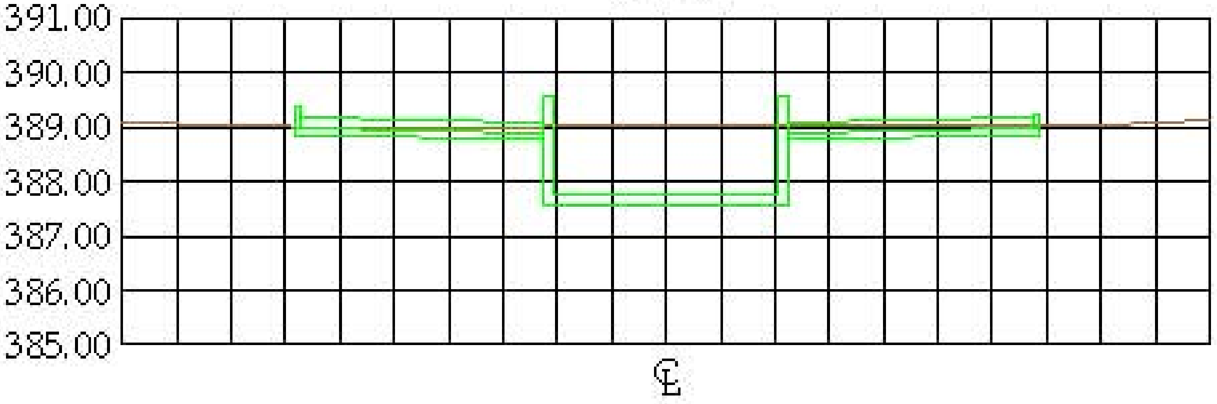

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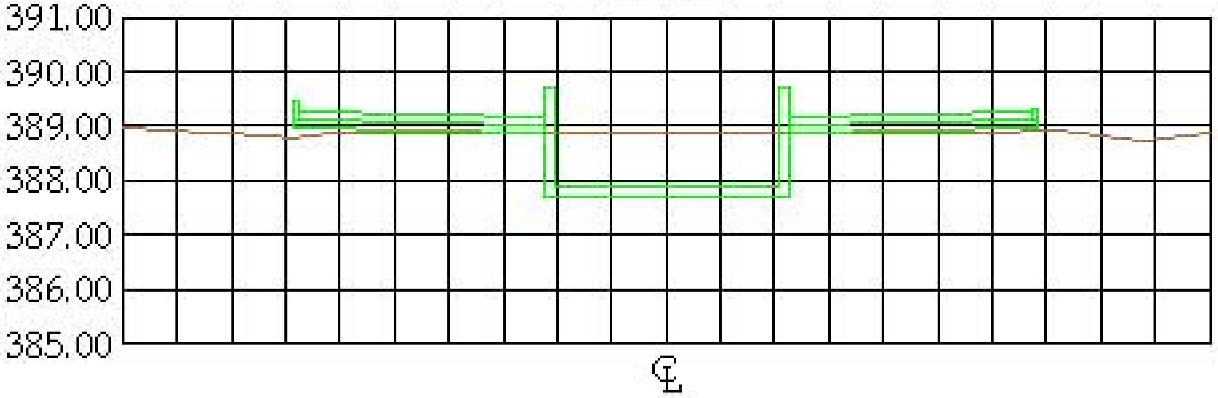

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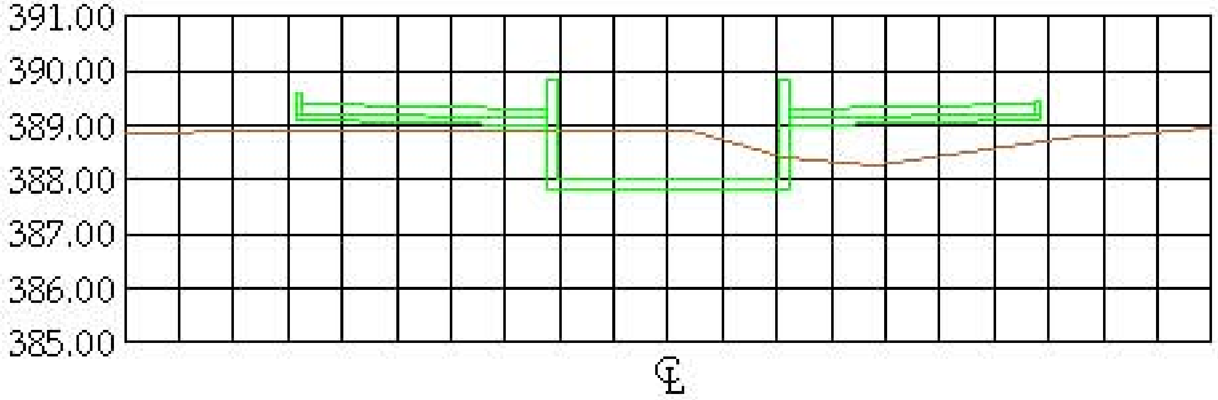

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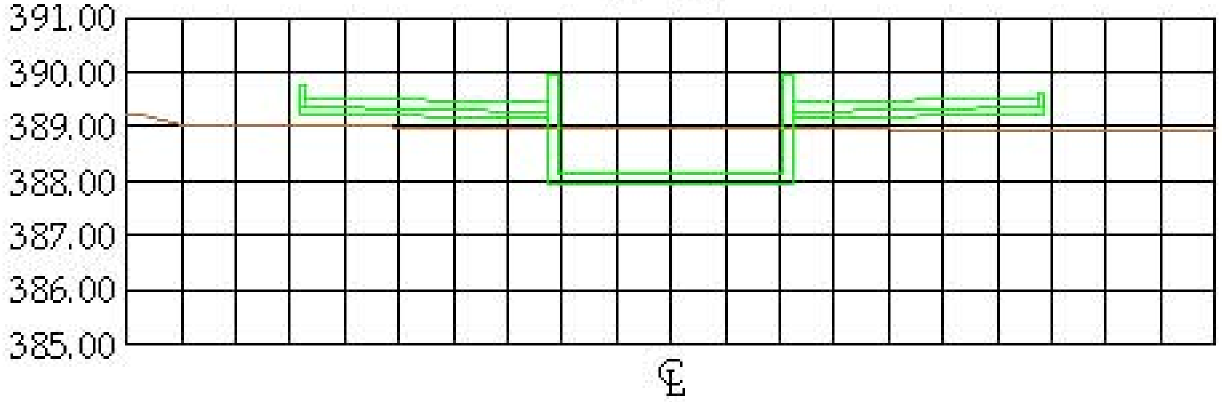

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Date:	07/28/2008
Paper Size:	11X17
Units:	Meters
Engineer:	Travis Velasco

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Avenida Fatima Uno
Road and Canal

Cross Sections

C.3

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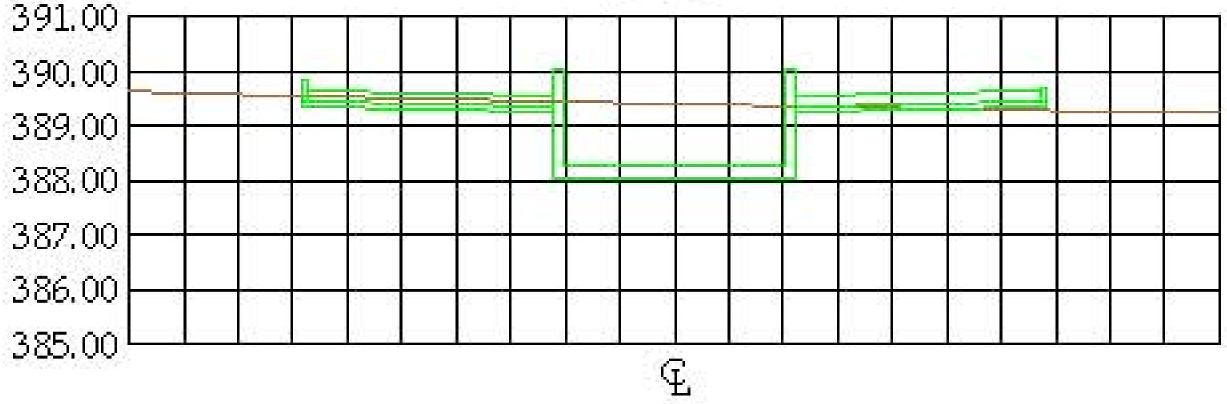

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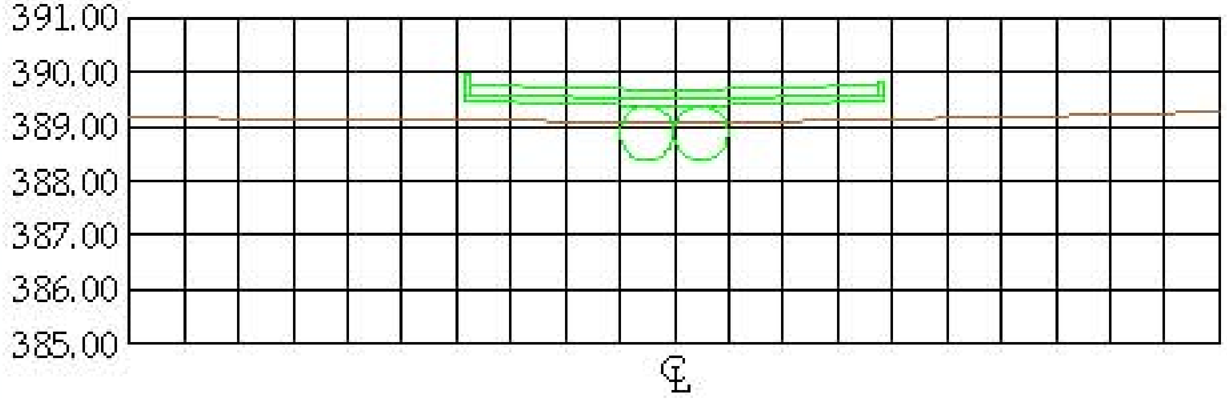

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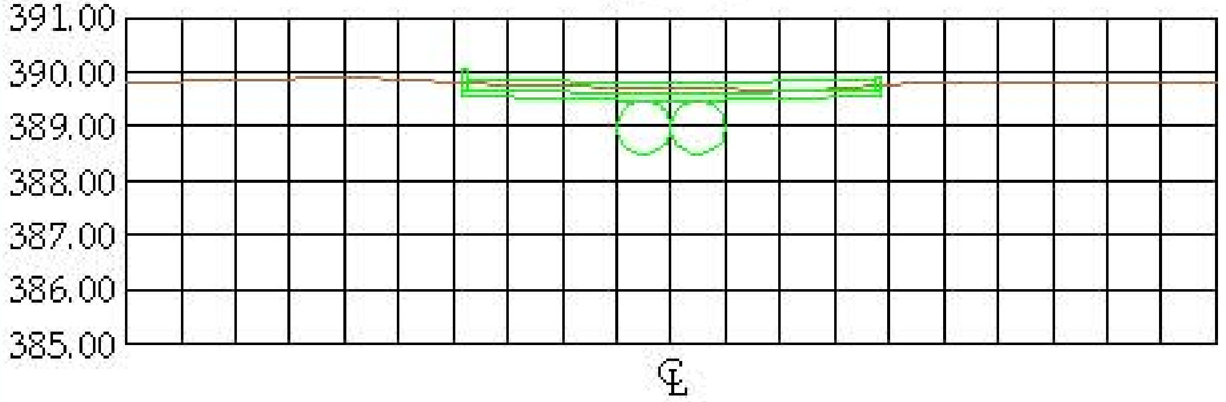
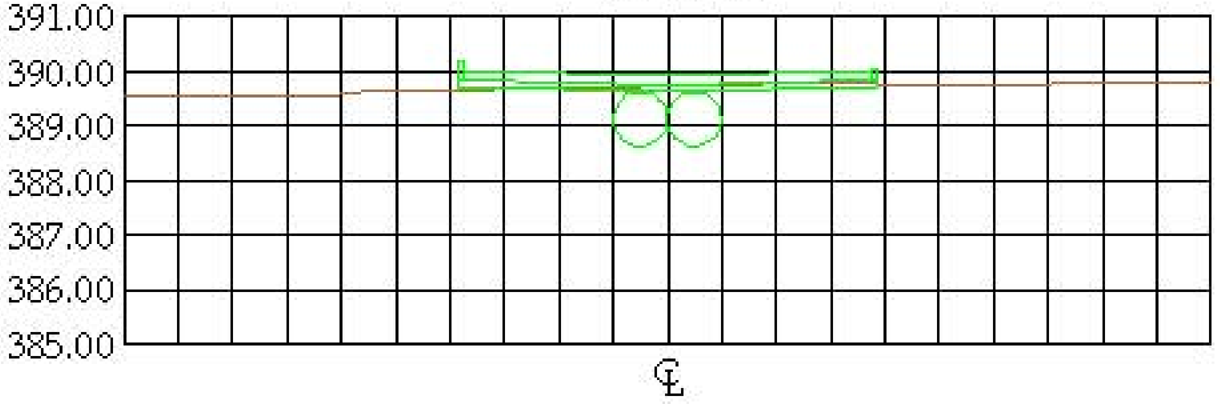
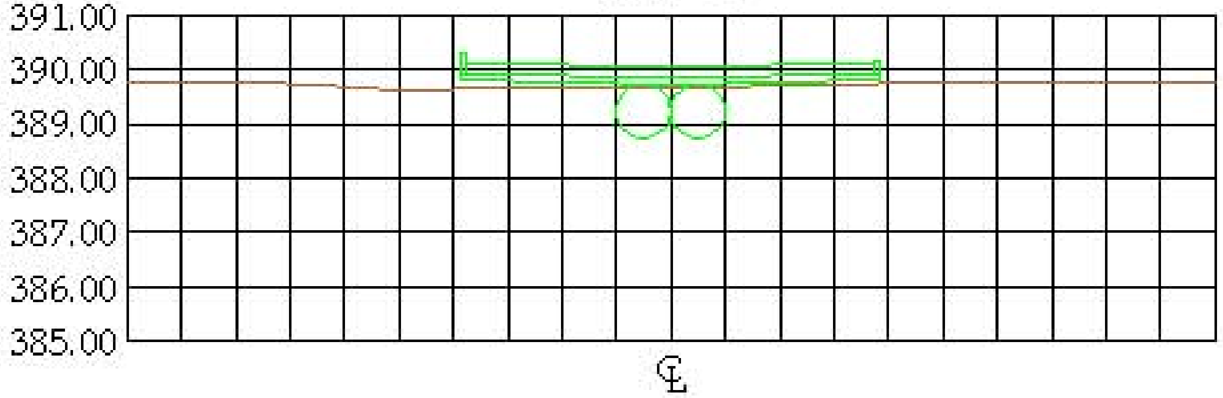


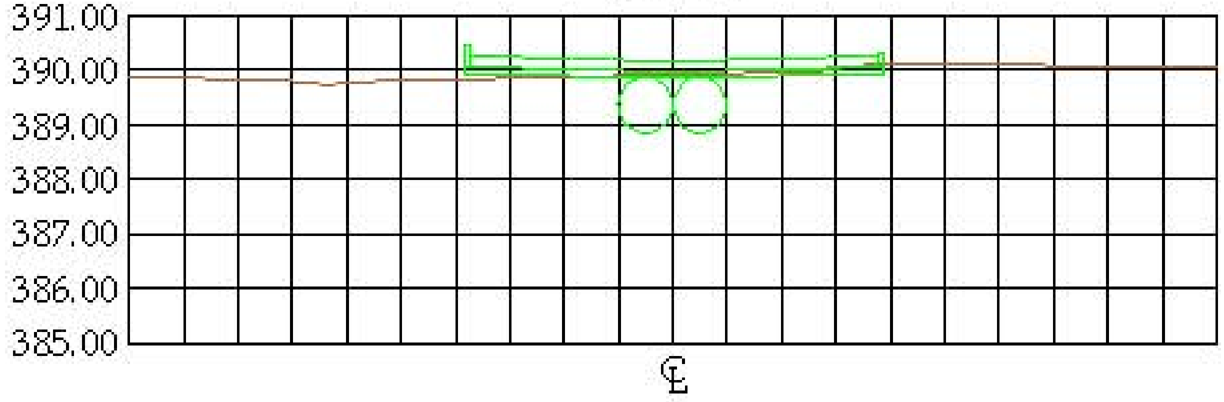
10+50



11+00



11+50



Drawing Title: Cross Sections
Date: 07/28/2008
Paper Size: 11X17
Units: Meters
Engineer: Travis Velasco

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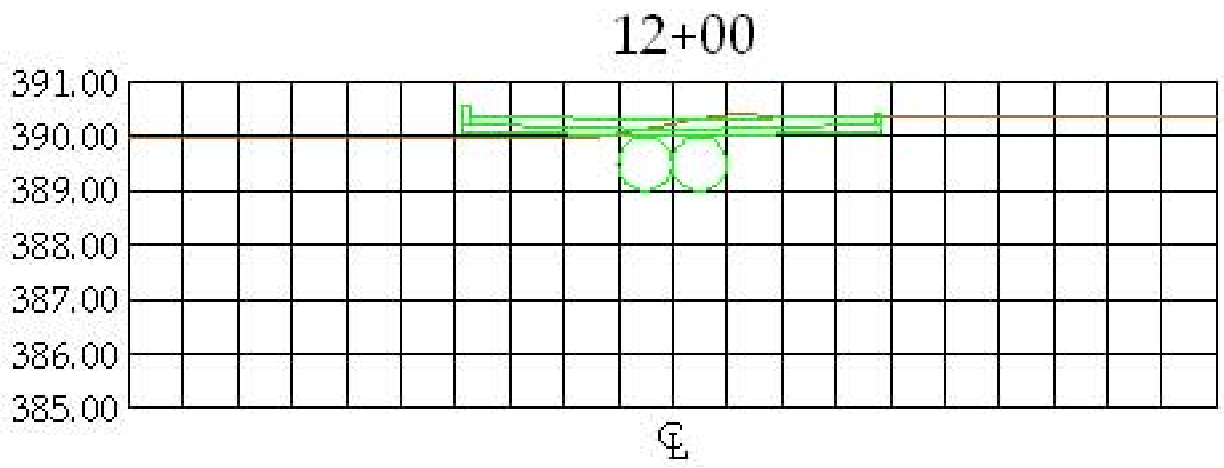
Houghton, MI 49931

Avenida Fatima Uno
Road and Canal

Cross Sections

C.4



Cut and Fill Volumes

Station	Fill Area (m^2)	Cut Area (m^2)	Shrinkage	Fill Volume (m^3)	Cut Volume (m^3)	Net Cut (m^3)	Cumulative Volume (m^3)
0+07.27	0	17.15					
-			1.1	0	781.894905	781.894905	781.894905
0+50	0	16.12					
-			1.1	0	998.8	998.8	1780.694905
1+00	0	20.2					
-			1.1	0	1263.625	1263.625	3044.319905
1+50	0	25.75					
-			1.1	0	1111	1111	4155.319905
2+00	0	14.65					
-			1.1	0	779.075	779.075	4934.394905
2+50	0	13.68					
-			1.1	3.85	574.75	570.9	5505.294905
3+00	0.14	7.22					
-			1.1	27.5	509.3	481.8	5987.094905
3+50	0.86	11.3					
-			1.1	33.275	479.875	446.6	6433.694905
4+00	0.35	6.15					
-			1.1	29.15	303.875	274.725	6708.419905
4+50	0.71	4.9					
-			1.1	37.95	264	226.05	6934.469905
5+00	0.67	4.7					
-			1.1	18.425	363	344.575	7279.044905
5+50	0	8.5					
-			1.1	0	468.875	468.875	7747.919905
6+00	0	8.55					
-			1.1	0.275	443.575	443.3	8191.219905
6+50	0.01	7.38					
-			1.1	0.275	435.875	435.6	8626.819905
7+00	0	8.27					
-			1.1	14.85	374	359.15	8985.969905
7+50	0.54	5.33					
-			1.1	110.825	270.325	159.5	9145.469905
8+00	3.49	4.5					
-			1.1	154.825	248.875	94.05	9239.519905
8+50	2.14	4.55					
-			1.1	60.5	327.525	267.025	9506.544905
9+00	0.06	7.36					
-			1.1	55.55	226.325	170.775	9677.319905
9+50	1.96	0.87					
-			1.1	53.9	116.875	62.975	9740.294905
10+00	0	3.38					
-			1.1	2.75	159.225	156.475	9896.769905
10+50	0.1	2.41					
-			1.1	18.7	113.3	94.6	9991.369905
11+00	0.58	1.71					
-			1.1	19.25	108.075	88.825	10080.19491
11+50	0.12	2.22					
-			1.1	8.25	146.85	138.6	10218.79491
12+00	0.18	3.12					
-							
			Totals	650.1	10868.89491		10218.79491

Drawing Title: Earthwork Summary
Date: 07/28/2008
Paper Size: 11X17
Units: Meters
Engineer: Travis Velasco

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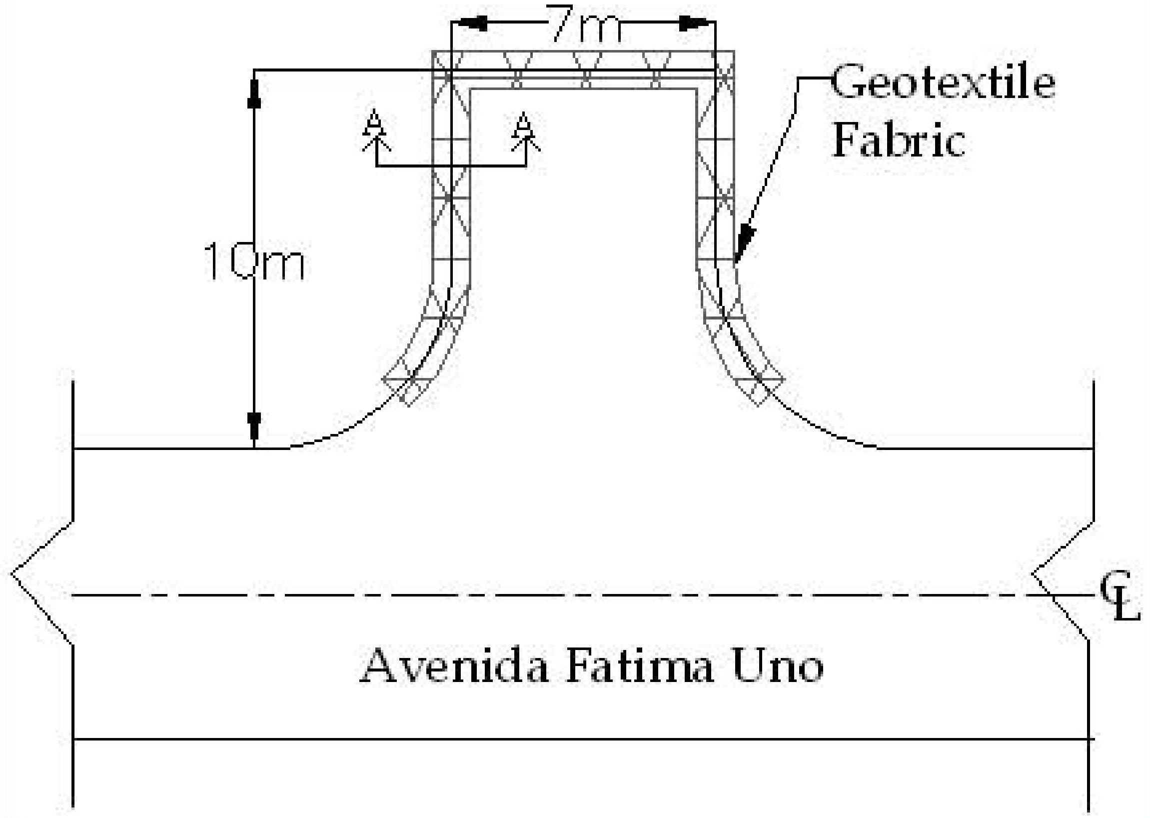
Avenida Fatima Uno Road and Canal

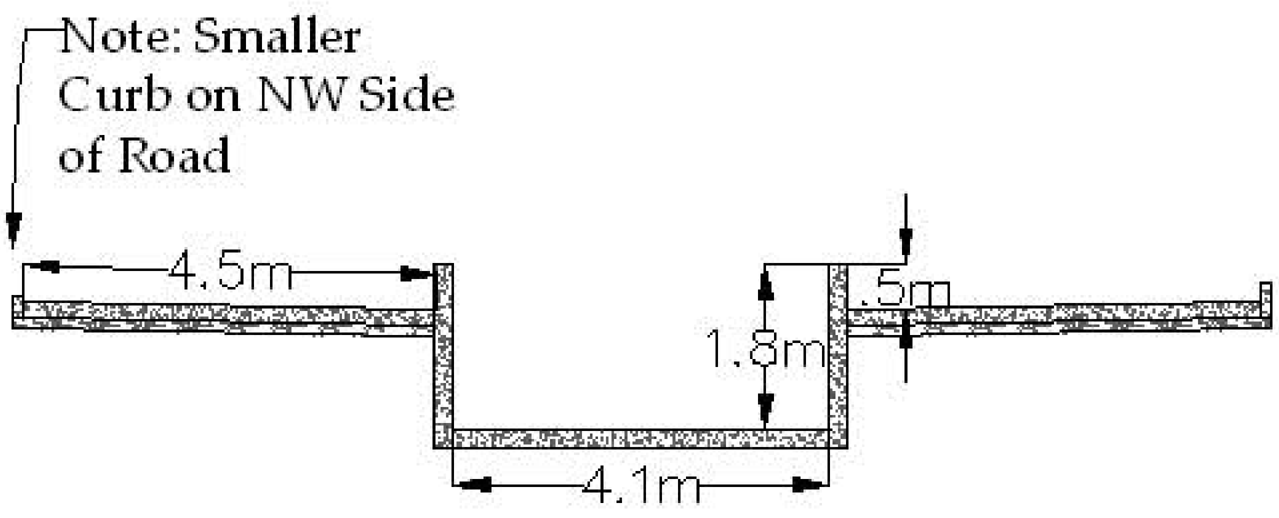
Earthwork Summary

C.5

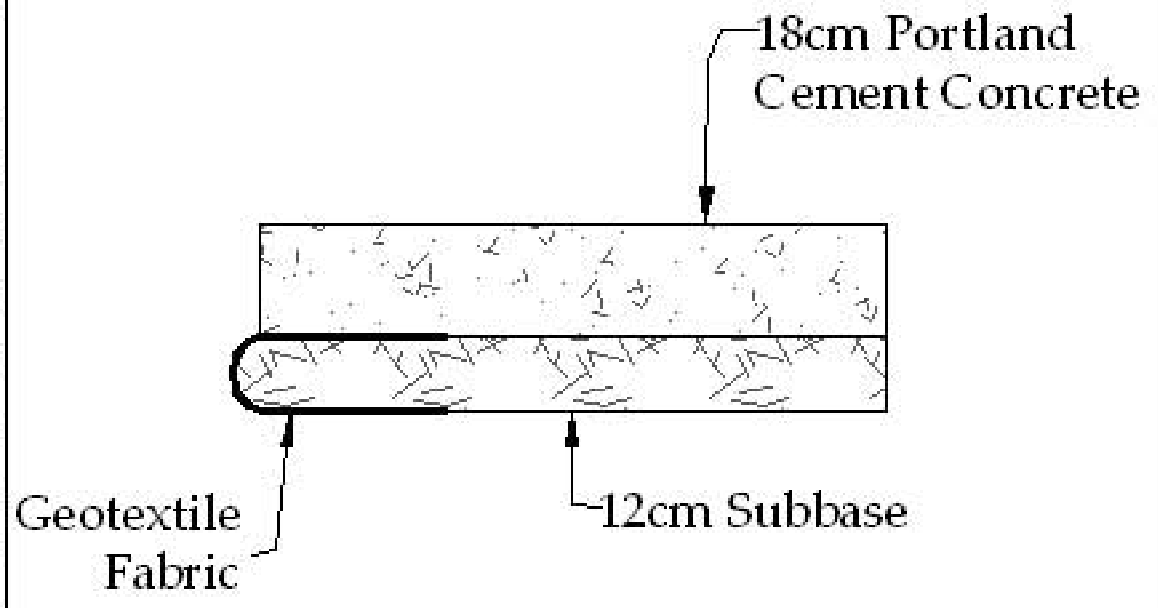
Typical Intersection



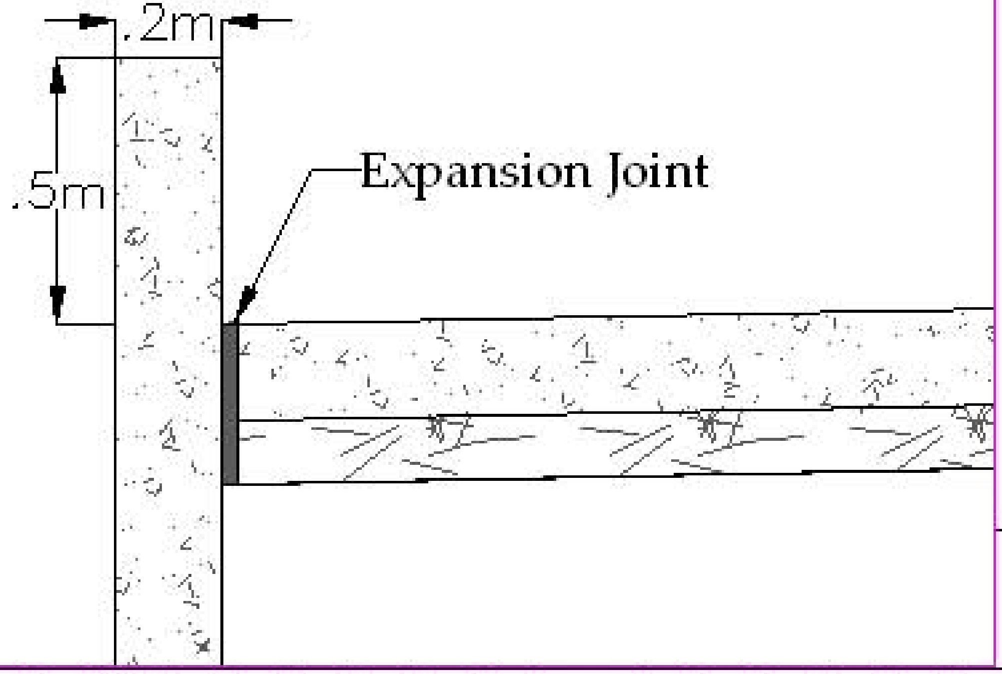
Typical Section (canal)



Section A-A



Canal/Road Connection



Drawing Title:	Details
Date:	07/28/2008
Paper Size:	11X17
Units:	Meters
Engineer:	Travis Velasco

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Michigan Technological University
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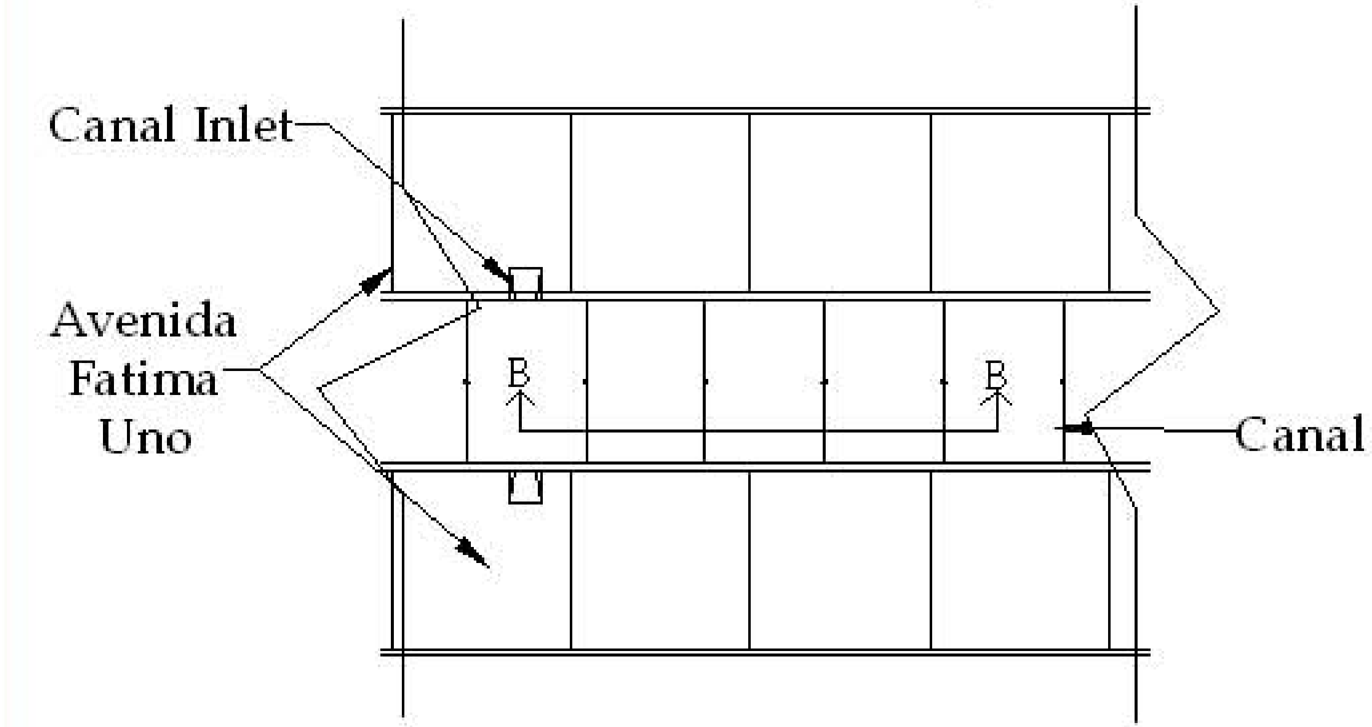
Houghton, MI 49931

Avenida Fatima Uno
Road and Canal

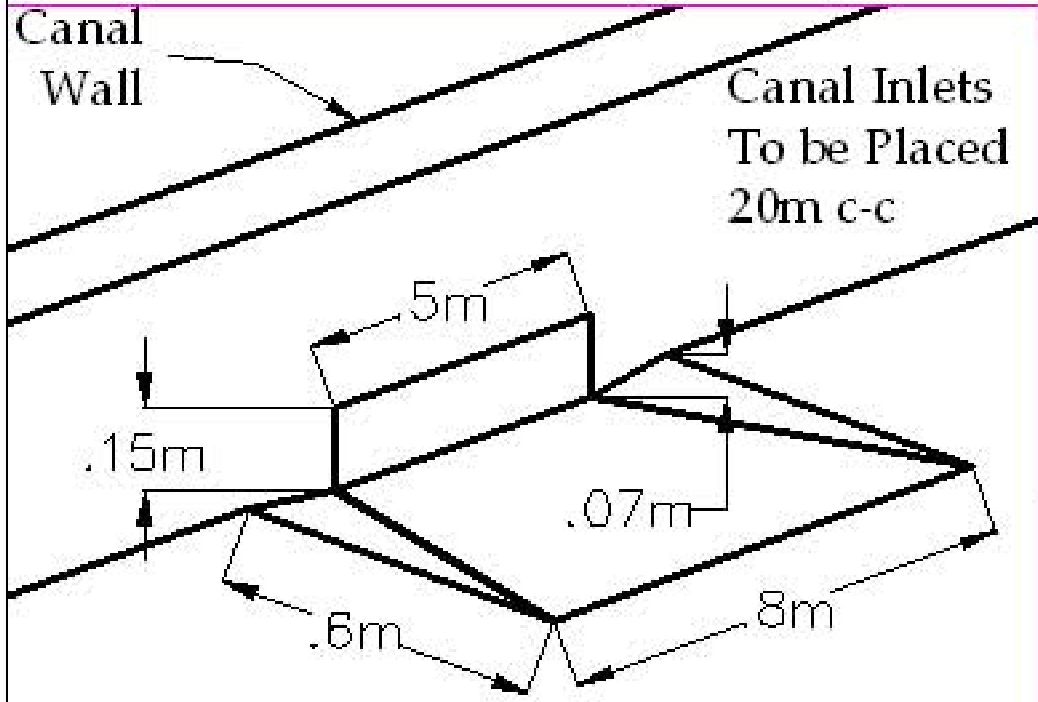
Details

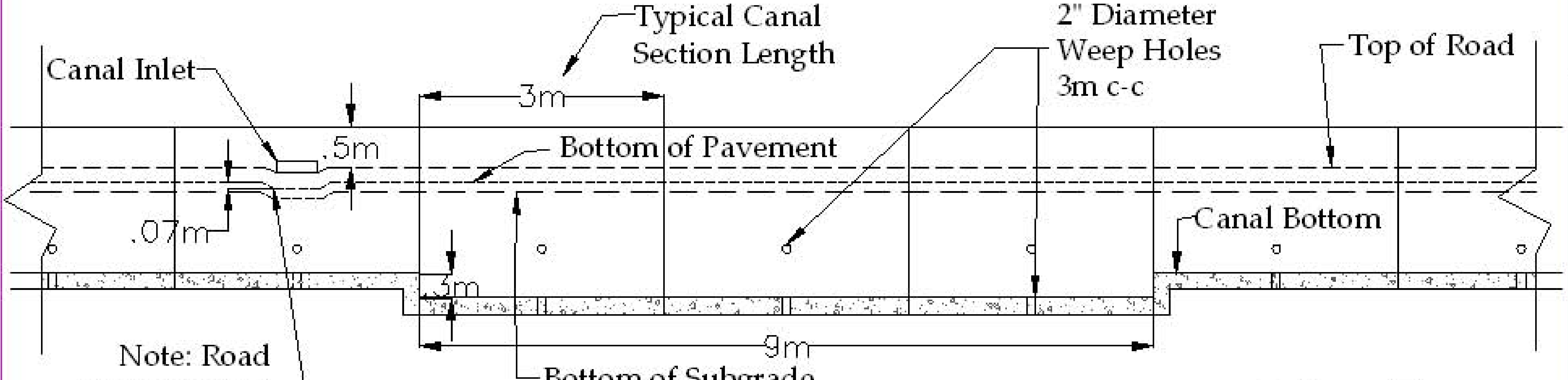
D.1

Canal Sediment Trap



Canal Inlet From Road





Note: Road
Pavement and
Subgrade Section
Dips at Canal Inlet

Section B-B

Sediment Traps
to Be Placed 51m c-c

Drawing Title: Details
Date: 07/28/2008
Paper Size: 11X17
Units: Meters
Engineer: Travis Velasco

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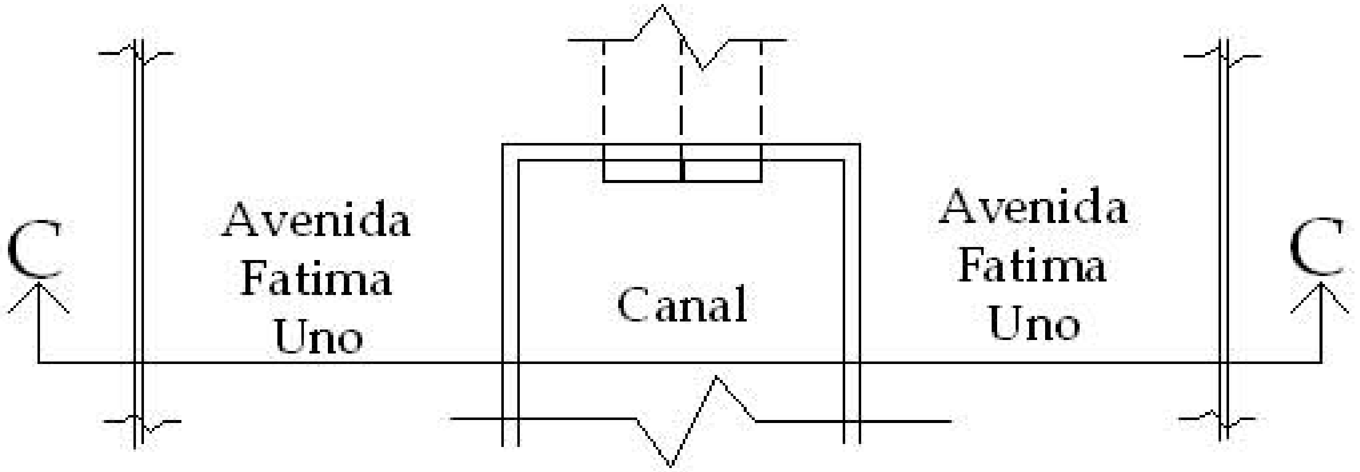
Avenida Fatima Uno
Road and Canal

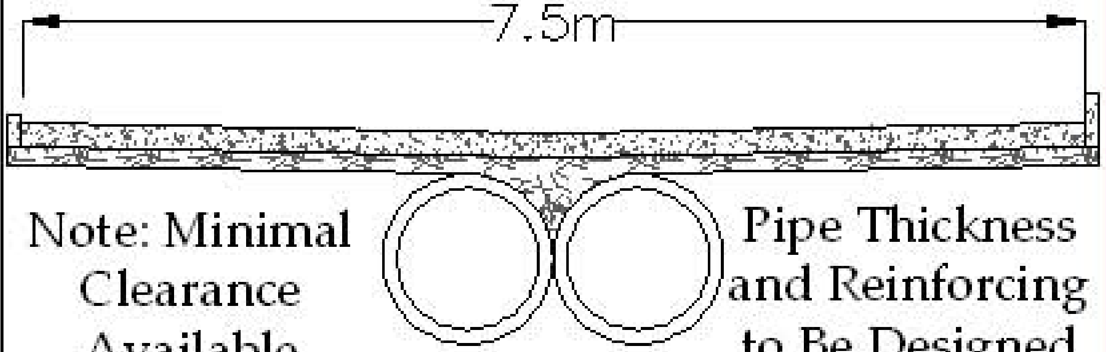
Details

D.2

Canal/Pipe Transition



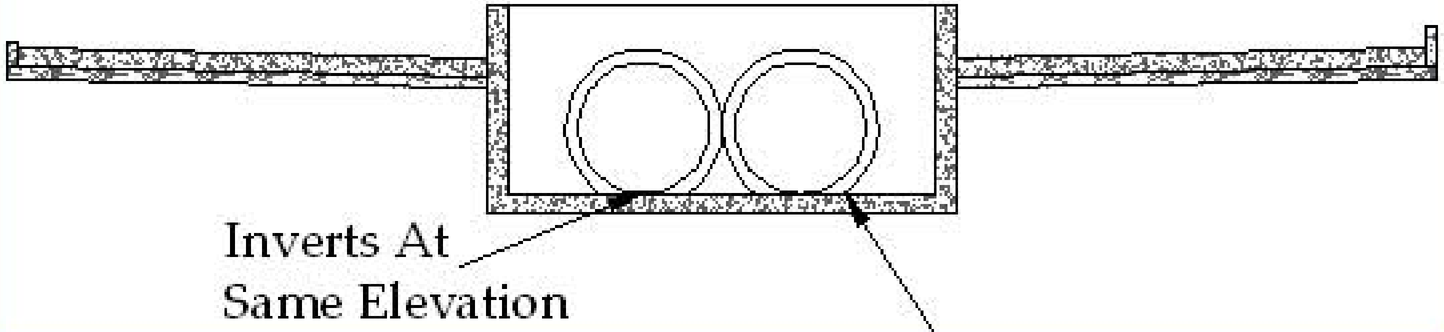
Typical Section (pipe)



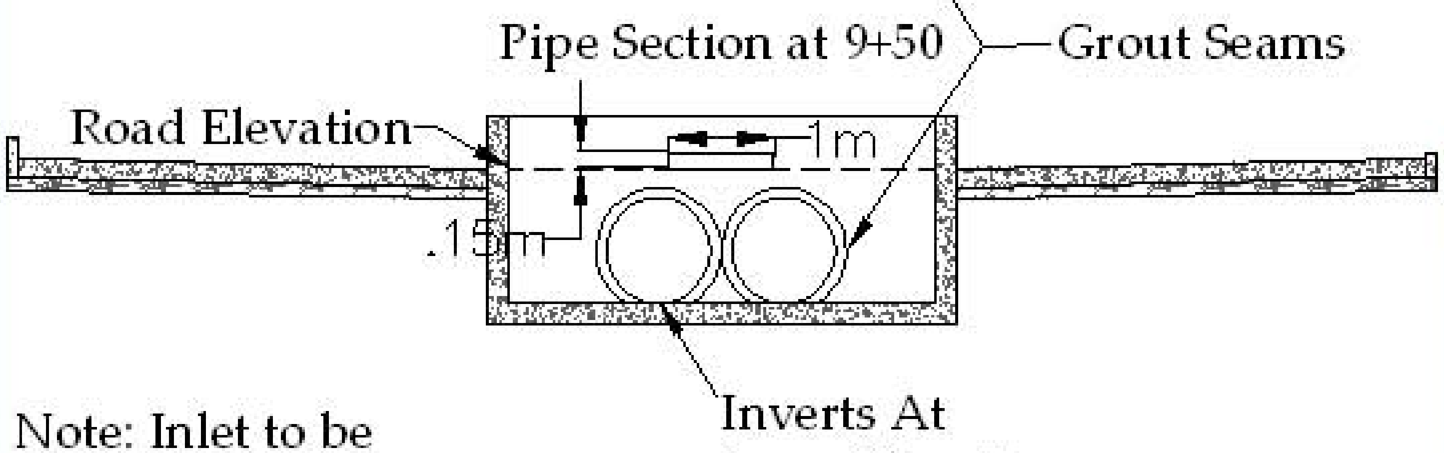
Note: Minimal Clearance Available between top of pipe and pavement

Pipe Thickness and Reinforcing to Be Designed By Others to Withstand a Load of 11,000 kg/axel

Pipe Section Towards Antiguo



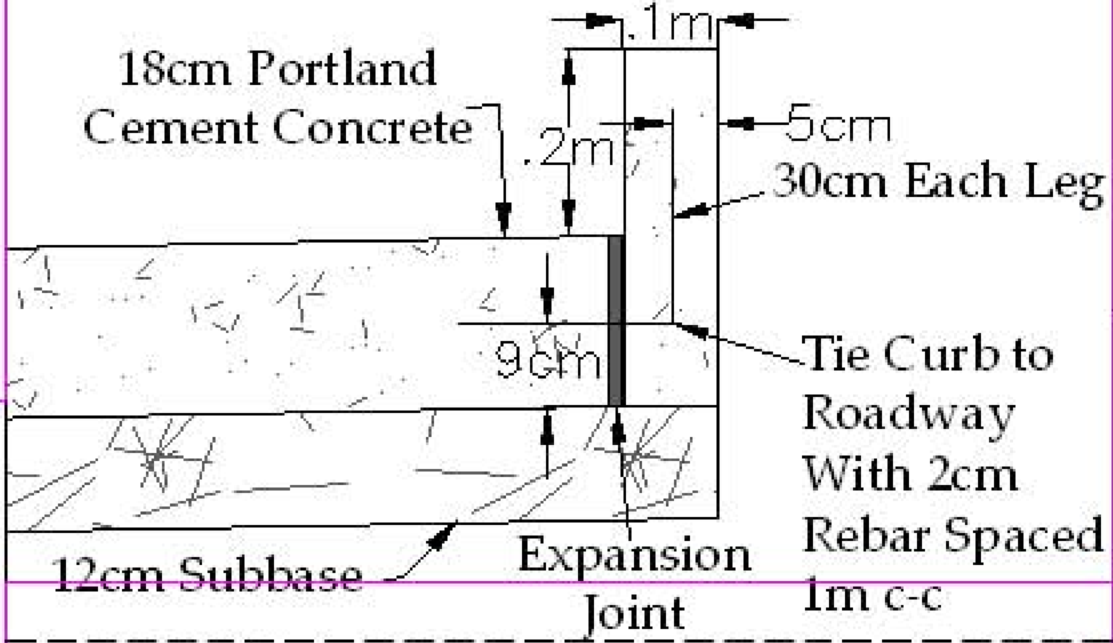
Pipe Section at 9+50

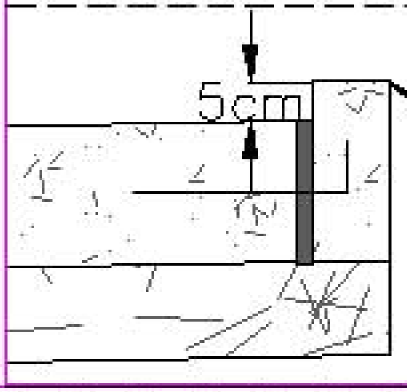


Note: Inlet to be Placed in Transition Wall

Section C-C

Typical Road and Curb Section





NOTE: North Western Side of Road to have 5cm curb

Drawing Title: Details
Date: 07/28/2008
Paper Size: 11X17
Units: Meters
Engineer: Travis Velasco

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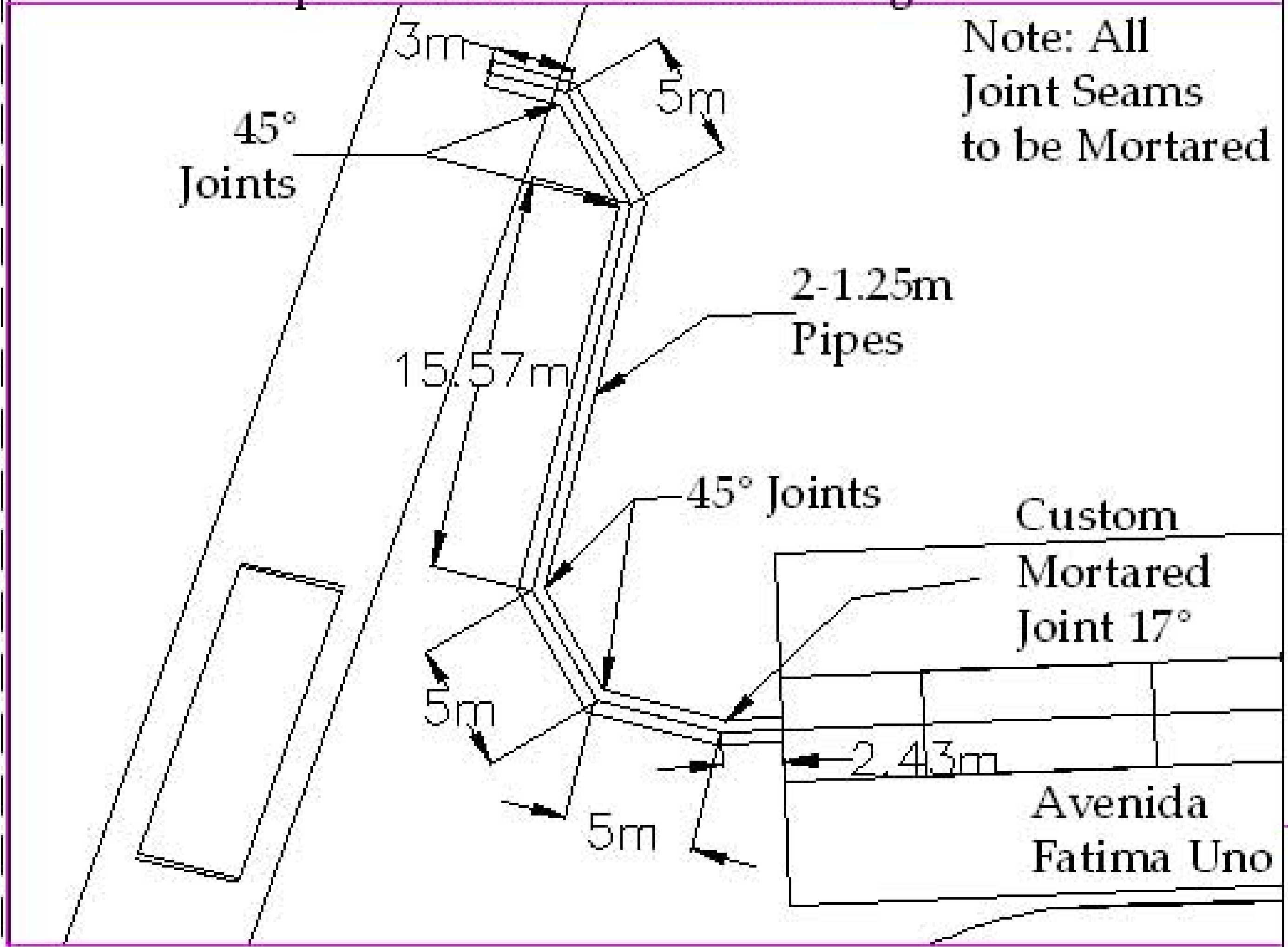
Avenida Fatima Uno
Road and Canal

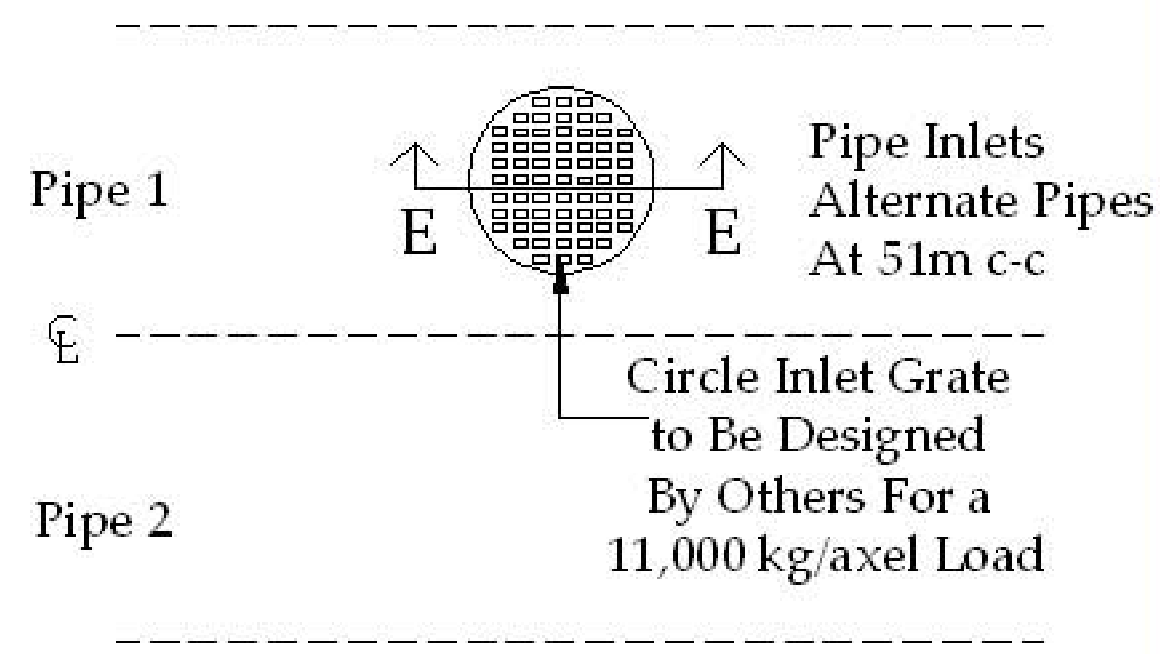
Details

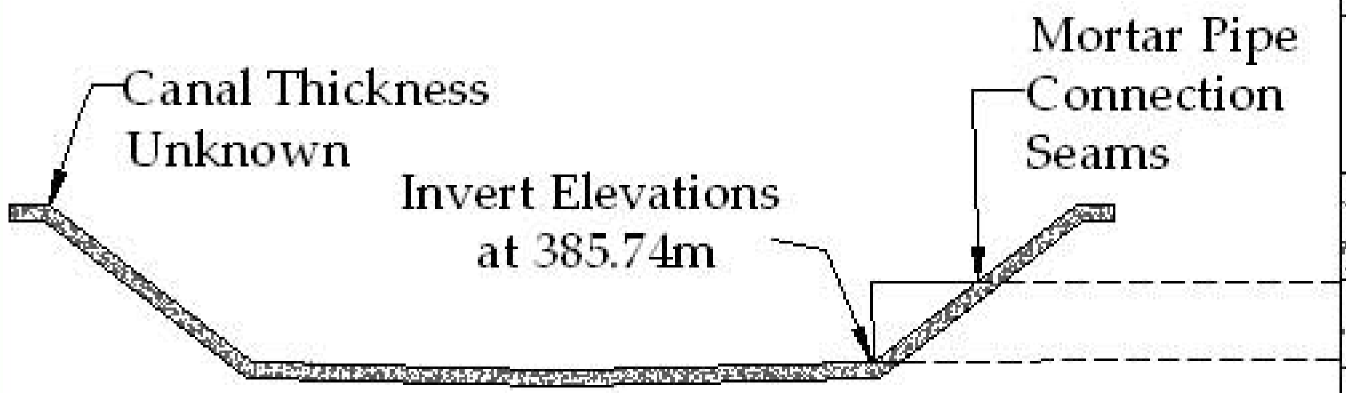
D.3

Pipe Connection to Route Antigua

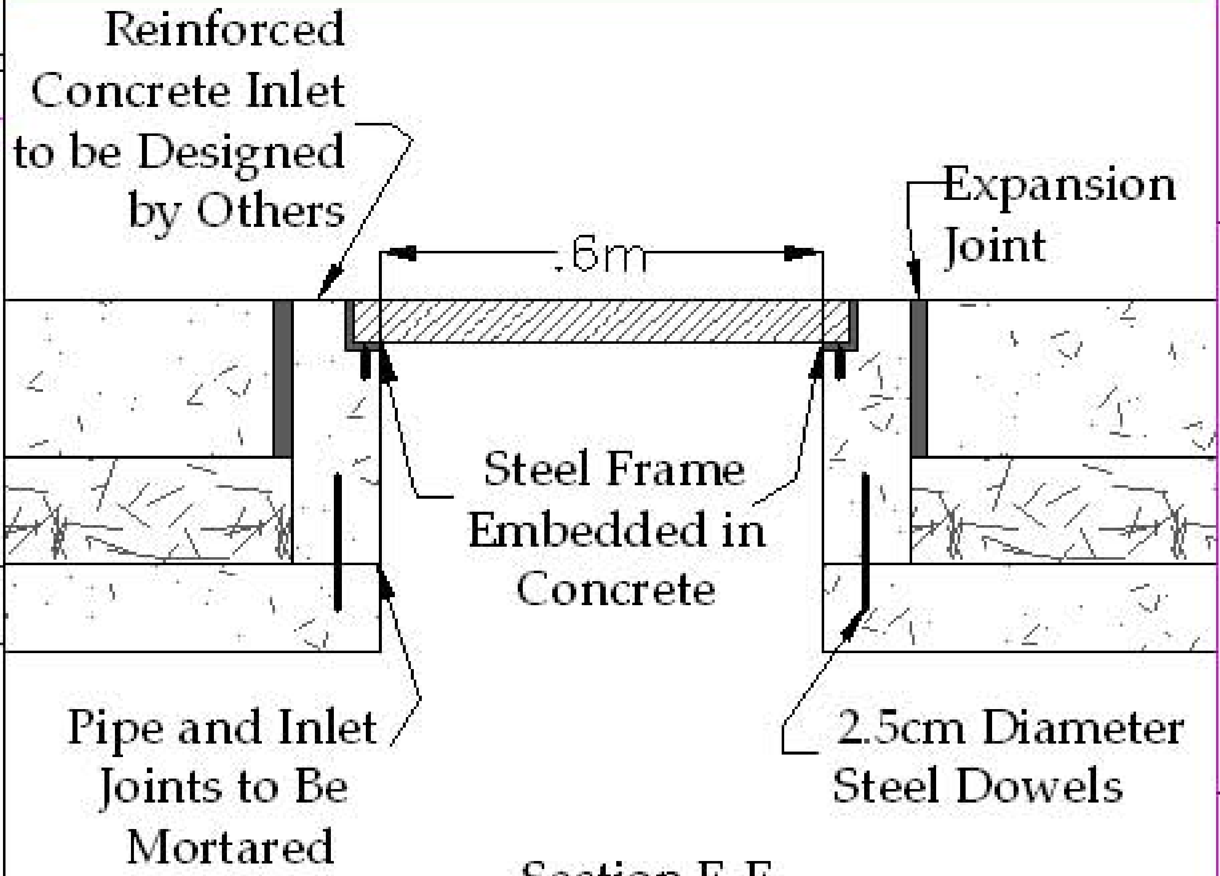


Pipe Inlet





Section D-D



Section E-E

Drawing Title: Details
Date: 07/28/2008
Paper Size: 11X17
Units: Meters
Engineer: Travis Velasco

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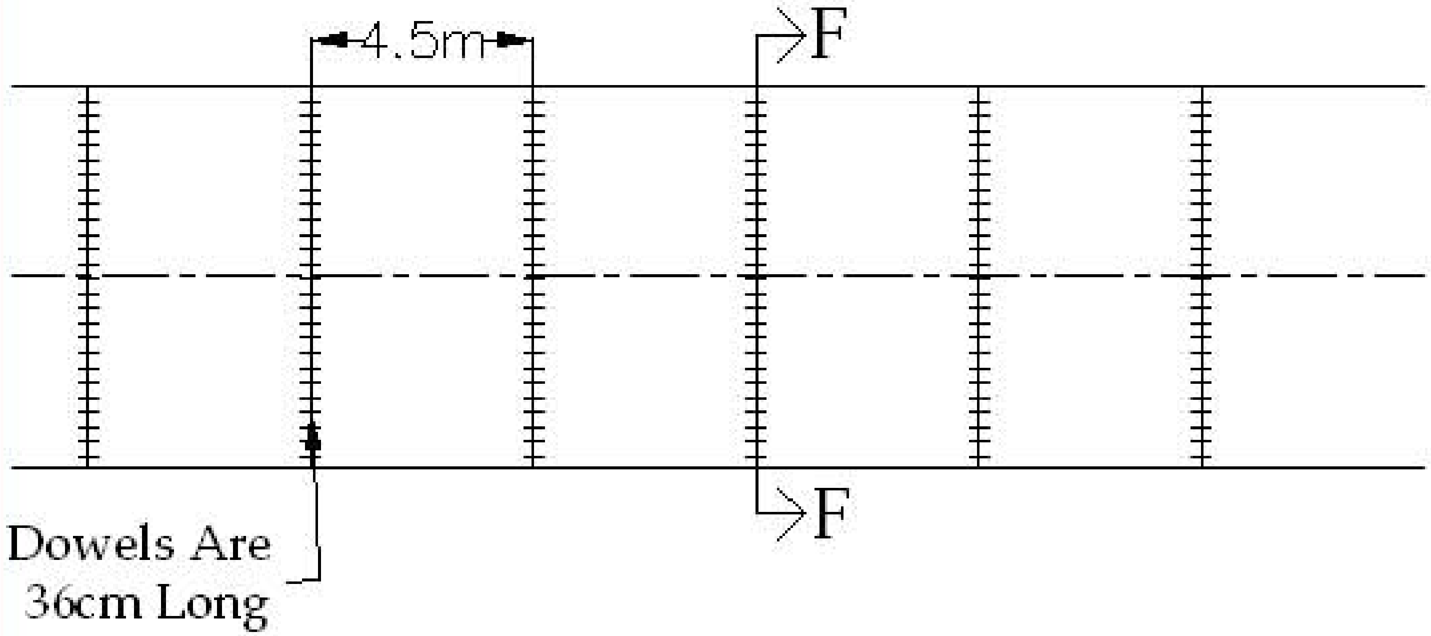
Avenida Fatima Uno
Road and Canal

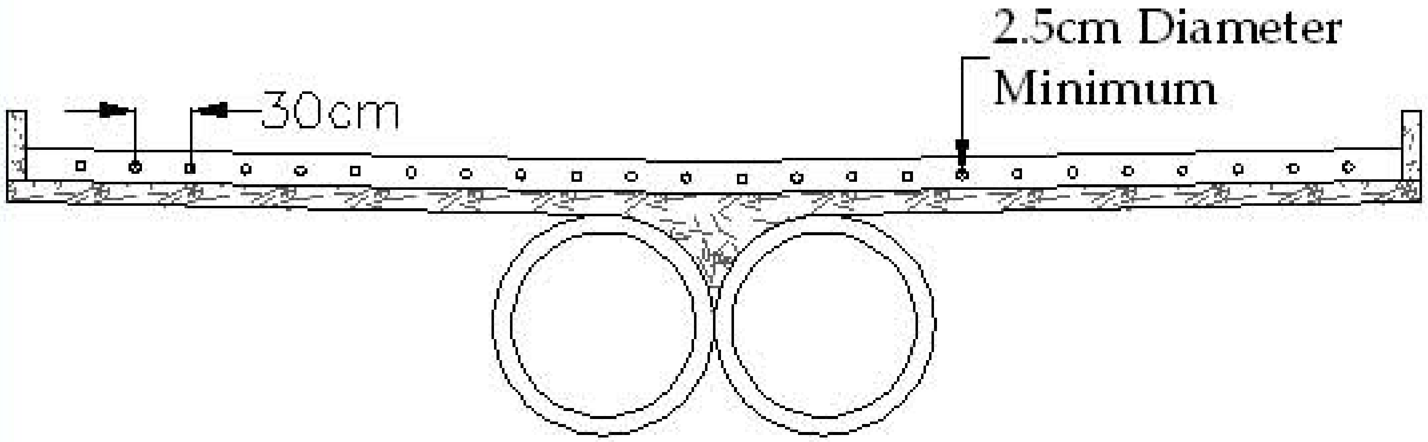
Details

D.4

Typical Roadway Joints



Note: Pipe Section Shown But Same Joint and Dowel Spacing and Size to be Used In Canal Section

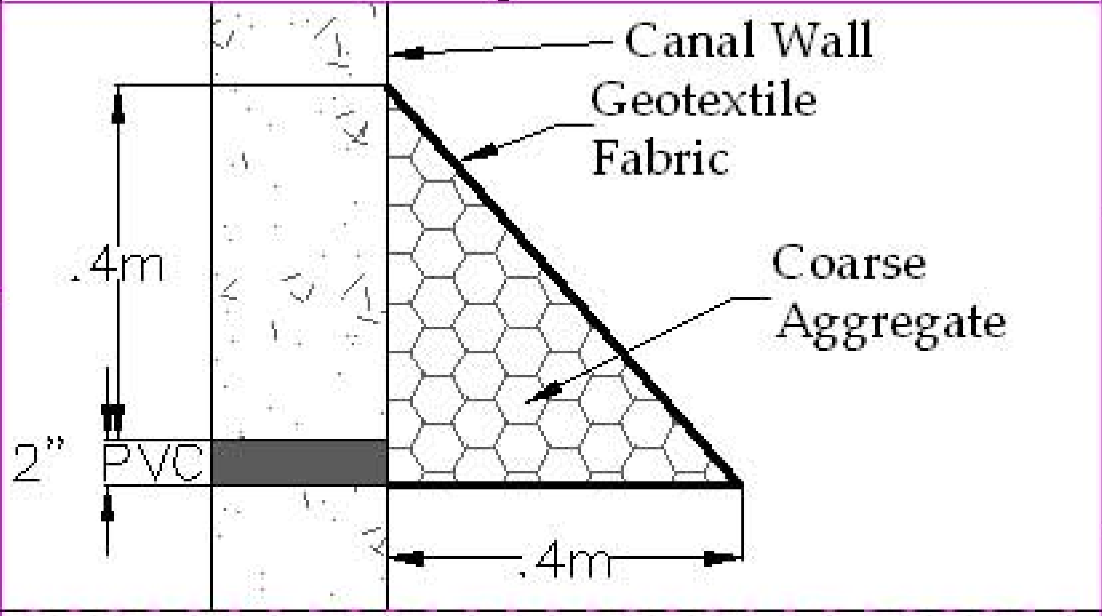


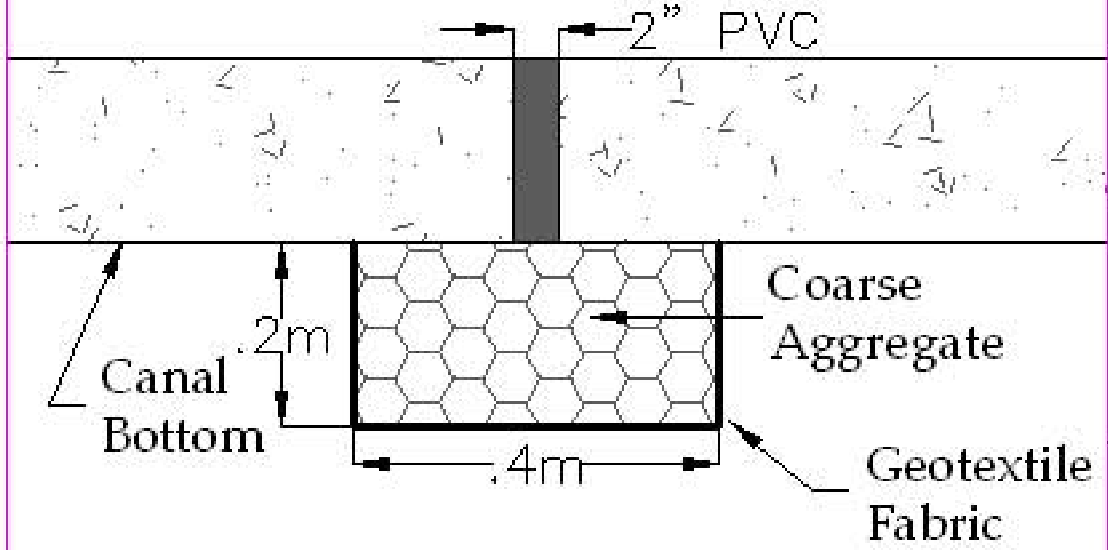
Section F-F

Pipe Schedule

Pipe #	Station Start	Station End	Pipe Diameter (m)	Length (m)	Slope (%)	Elevation Start	Elevation Finish
1	0+07.27	N/A	1.25	2.43	0.8	586.03	586.01
1	N/A	N/A	1.25	5	0.8	586.01	585.97
1	N/A	N/A	1.25	5	0.8	585.97	585.93
1	N/A	N/A	1.25	15.57	0.8	585.93	585.80544
1	N/A	N/A	1.25	5	0.8	585.80544	585.76544
1	N/A	N/A	1.25	2.6	0.8	585.76544	585.74504
1	9+50	12+00	1	250	0.1	589	588.36
2	0+07.27	N/A	1.25	2.43	0.8	586.03	586.01
2	N/A	N/A	1.25	5	0.8	586.01	585.97
2	N/A	N/A	1.25	5	0.8	585.97	585.93
2	N/A	N/A	1.25	15.57	0.8	585.93	585.80544
2	N/A	N/A	1.25	5	0.8	585.80544	585.76544
2	N/A	N/A	1.25	2.6	0.8	585.76544	585.74504
2	9+50	12+00	1	250	0.1	589	588.36
		Total Length (m)	1.25	71.6			
			1	500			

Weep Holes





Drawing Title: Details
Date: 07/28/2008
Paper Size: 11X17
Units: Meters
Engineer: Travis Velasco

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Avenida Fatima Uno
Road and Canal

Details

D.5