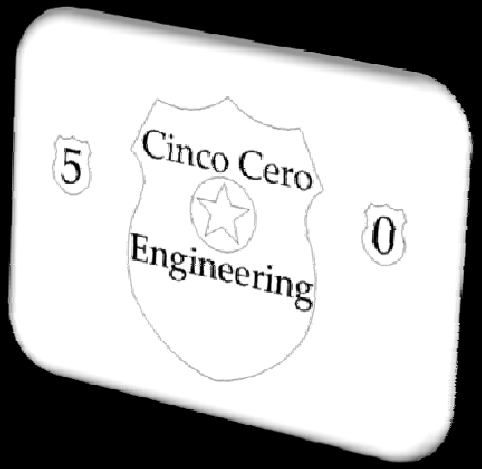
Cinco Cero Engineering



Bolivia and Back

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Cinco Cero Engineering: Design-Build Firm

Created: April, 2008

Purpose:

Design a functional road and storm drainage system for Avenida Fatima I in District 12 of Santa Cruz, Bolivia.

Dylan Gerhart

B.S. Civil Engineering

Graduation: December 2008

Plans:

- ALSTOM: International Work
- Future President

Kari Klaboe

B.S. Civil Engineering

Graduation: May 2009

Plans:

- Graduate School
- Master Angler

Travis Velasco

B.S. Civil Engineering

Graduation: December 2008

Plans:

- Bechtel: International Work
- Lots of Travel

The Team

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- **Background**
- **Problem Identification**
- **Methods and Procedures**
  - Field Work
  - Design and Calculations
- **Environmental Concerns**
- **Design Options**
  - Option 1 – Underground Pipe
  - Option 2 – Covered Canal
  - Option 3 – Open Canal
- **Cost Estimate**
  - Risk vs. Cost graph
- **Recommendation**

Outline

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District 12

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District 12 Concerns

- Drainage
- Wastewater
- High water table

Result:

- 2 New Canals
  - Nuevo Camino al Palmar
  - Antiguo
- Avenida Fatima I

District 12

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Avenida Fatima I

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Topographic Survey

- Method
  - Topcon Total Station
- Goals
  - Location of Existing Structures
  - Land Slope
  - Watershed Area
- Results
  - Limited Slope

Field Work

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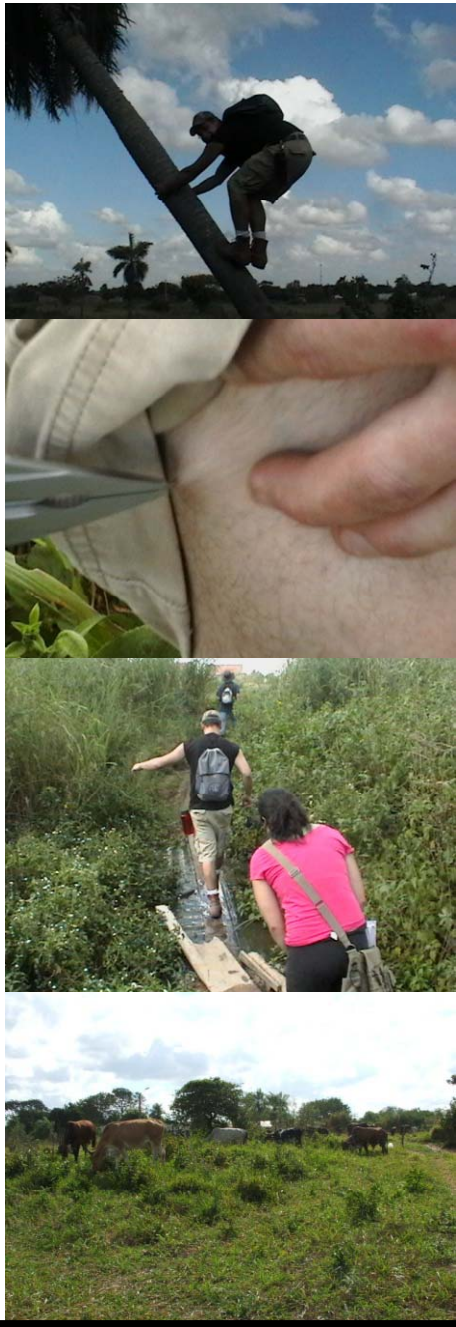
Watershed Delineation

- Method
  - Topographic Survey
  - Visual Identification
- Goals
  - Watershed Boundaries
  - Watershed Area
  - Land Use
- Results
  - 1km^2 Watershed
  - Diversion Location



Field Work

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Soil Bore

- Method
  - Manual Soil Auger
- Goals
  - Sub-surface Soil Identification

Soil Tests

- Method
  - Standard Proctor
  - AASHTO Soil Identification
- Goals
  - Optimum Water Content
  - Maximum Dry Unit Weight
  - Lab-quality soil classification

Field Work

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Project Meetings

- Goals
  - Familiarize ourselves:
    - Culture
    - Construction practices
    - Concerns
- Data Obtained
  - District 12 development plans
  - Health data
  - Canal drawings

Subalcade
Ing. Victor P. Escobar

District 12 Residents
Ing. Javier Marin
Presidenta Loreto Moreno
Head Surveyor

Community Members
Dr. Dan
Paul

Local Engineers
Ing. Rofino
Ing. Humberto Calbimonte
Ing. Cuadros

Field Work

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- **Garbage**
- **Illegal Connections**
- **Low Impact Storm Drainage**
  - Storm Water at Source
- **Sediment**
  - Dust Control
  - Sedimentation

Environmental Concerns

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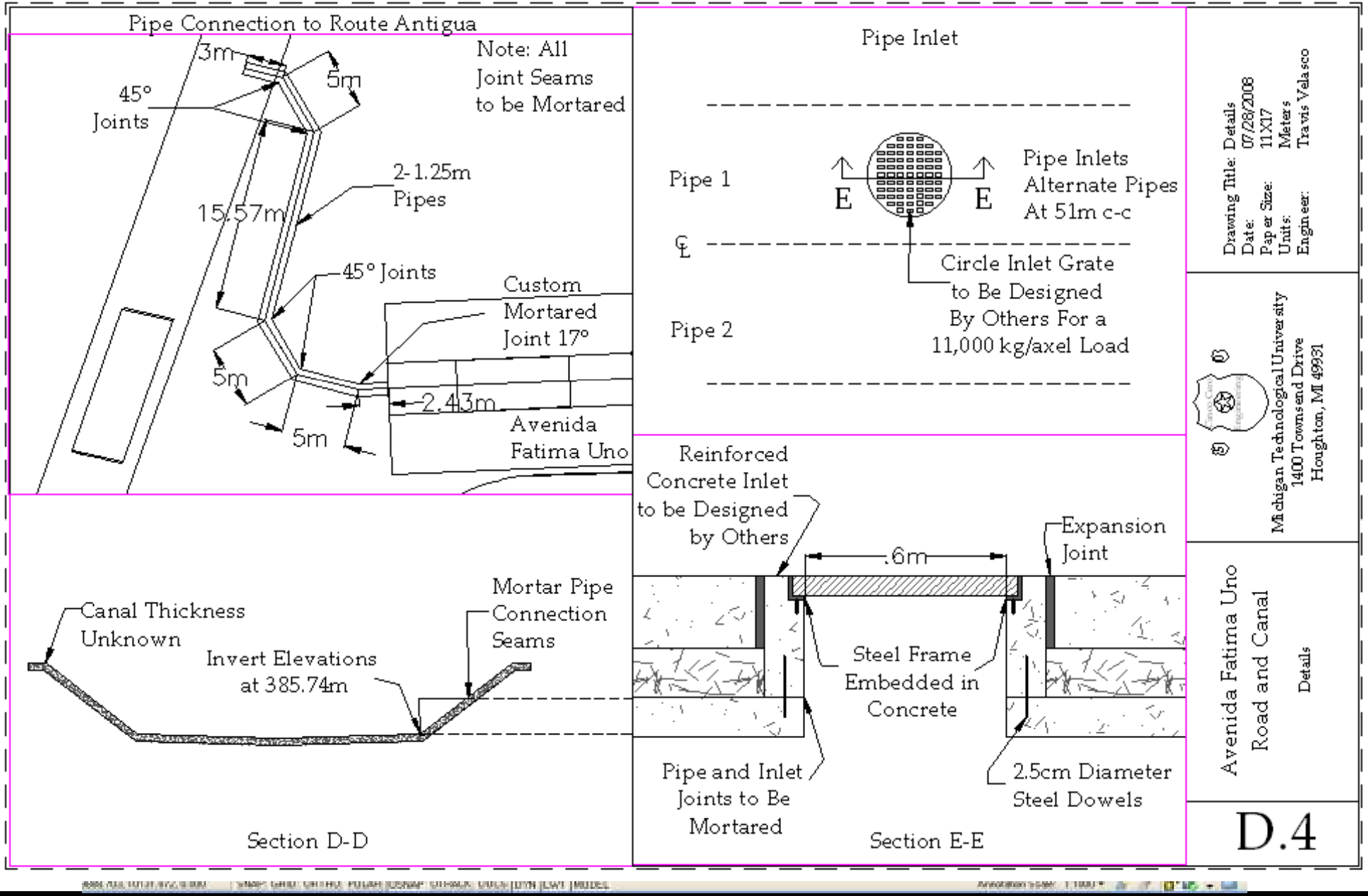

Design & Calculations

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Storm Water Runoff

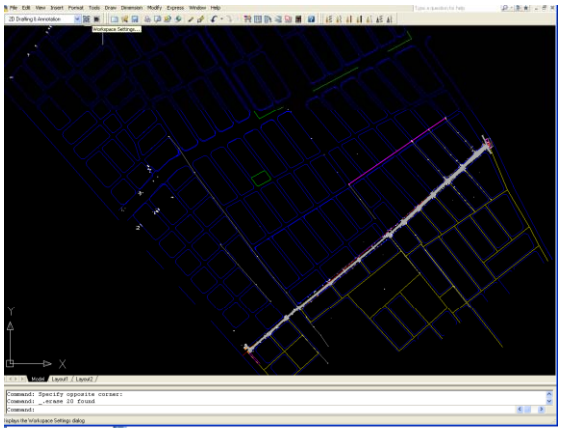
- Method
  - Rational Method $Q = C \cdot I \cdot A$
- Assumptions
  - Field converted to urban residential

General characteristics of the receiving river basin	Value of C
Central parts, densley constructed with streets and paved routes	0.70 - 0.90
Adjacent parts to the center, of smaller densidad of room with paved streets and routes	0.70
Residentional zones of closed constructions and paved routes	0.65
Residential zones moderately inhabited	0.55 - 0.65
Residential zones of small densidad	0.35 - 0.55
Districts with gardens and spotted routes	0.30
Arborizadas surfaces, sport parks, gardens, and fields with pavement	0.10 - 0.20

Land Use Coefficient ***C***

$$\text{Santa Cruz } I = \frac{393.70\ f^{0.3556}}{t^{0.7016}} \quad (mm/h)$$

Rainfall Intensity ***I***



Watershed Area ***A***

Design & Calculations

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Storm Water Runoff

$Q = C \cdot I \cdot A$

- Variables
  - C = .65
  - Rainfall Intensity = 1.025×10^{-5} m/s
  - Area = 996024 m^2
- Output
  - Q = 6.6 m^3/s

Design & Calculations

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Canal Design Options

- Pipe Culvert
- Box Culvert
- Open Channel

- Slope = 0.1%
- Length=1200 m
- Manning Roughness Value = 0.015
- Peak Flow = 6.6 m^3/s
- Velocity=.6 m/s - 3 m/s
- Limiting Width = 16.8 m

Design & Calculations

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Canal Design

- Method
  - Simultaneously solving
    - Rational method Equation $Q=V \bullet A$
    - Manning's Equation $V=(Cm/n) \bullet (A/P)^{2/3} \bullet So^{1/2}$
      - » Assumed safe velocity of 1.6 m/s
- Output
  - 4.1 m^2 area channel






Design & Calculations

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Canal Design

- Limitations
  - Slope
    - .1%
  - Depth
    - 1.3m
  - Freeboard Height
    - Suggested .8m
    - Chosen .3m
  - Normal Water Flow Height
    - 1m
  - Width
    - 4.1m

Design & Calculations

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Diversion of Curichi

Design & Calculations

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Diversion of Curichi

- Method
  - Sized two 1.0 m pipe culverts upstream
- Output
  - Maximum flow = 3.32 m^3/s

Design & Calculations

Temporary Diversion

- Channel Properties
  - Earthen lined channel
  - Silty Clay
  - Maximum Velocity of 1.1 m/s
- Output
  - $Q = V \bullet A$
  - Area=3.0m^2

Design & Calculations

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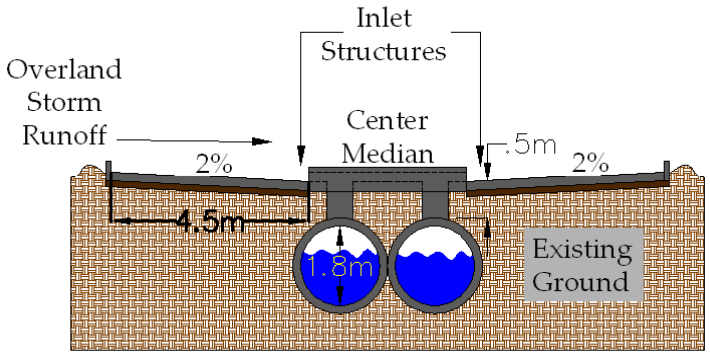
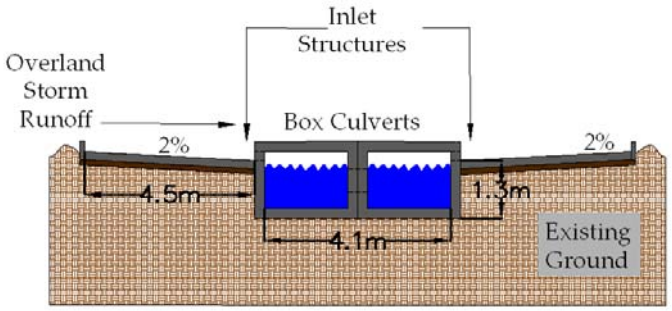
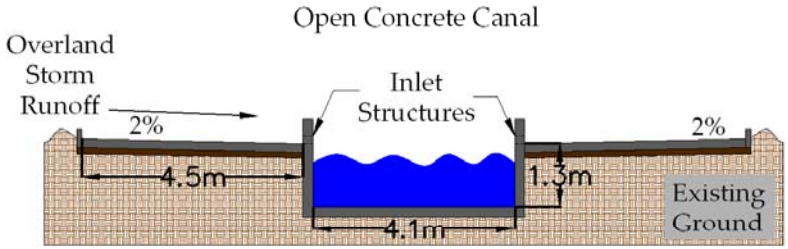
- **Design Option 1**
  - Underground Storm Sewer Pipe
- **Design Option 2**
  - Precast Box Culverts
- **Design Option 3**
  - Open Rectangular Channel
- **Alternative Pavements**







Design Options

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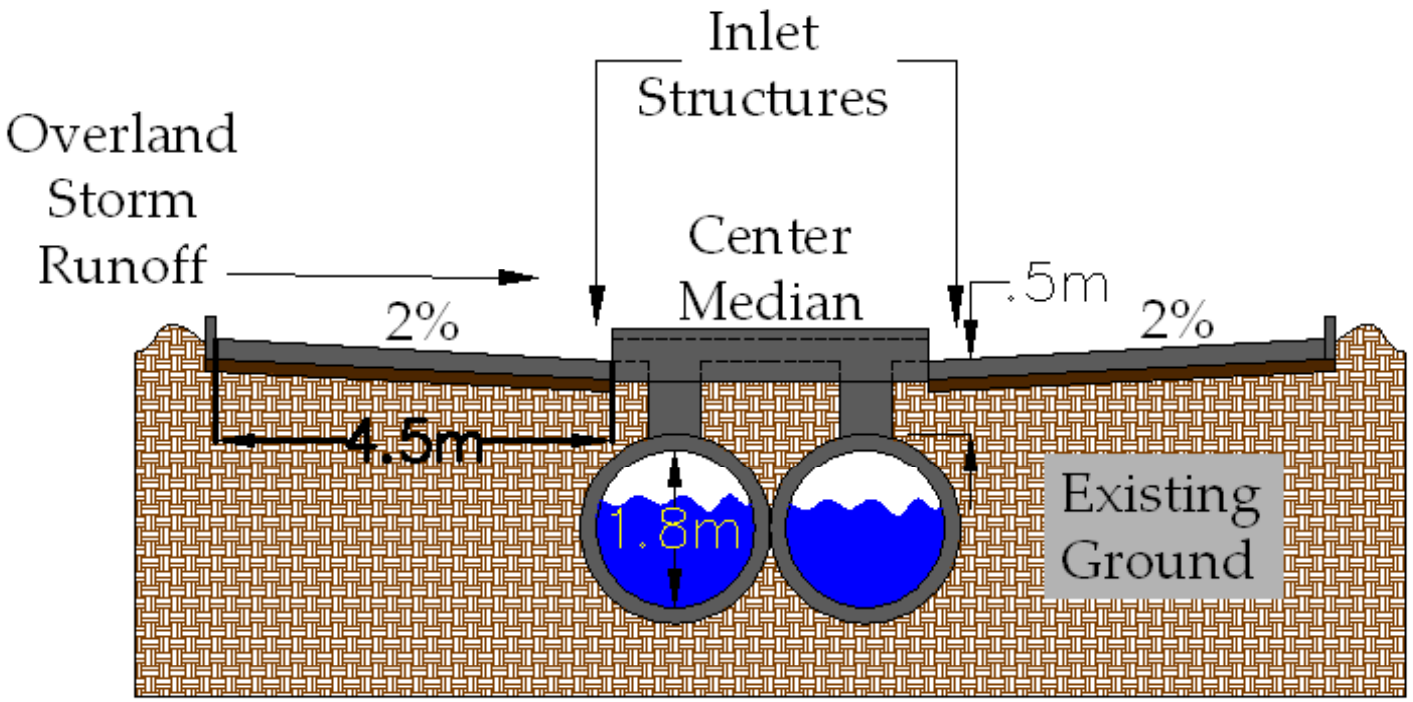
Underground Storm Sewer Pipes



Safety

Maintenance

Environment

Road

Accessibility

Design Option 1

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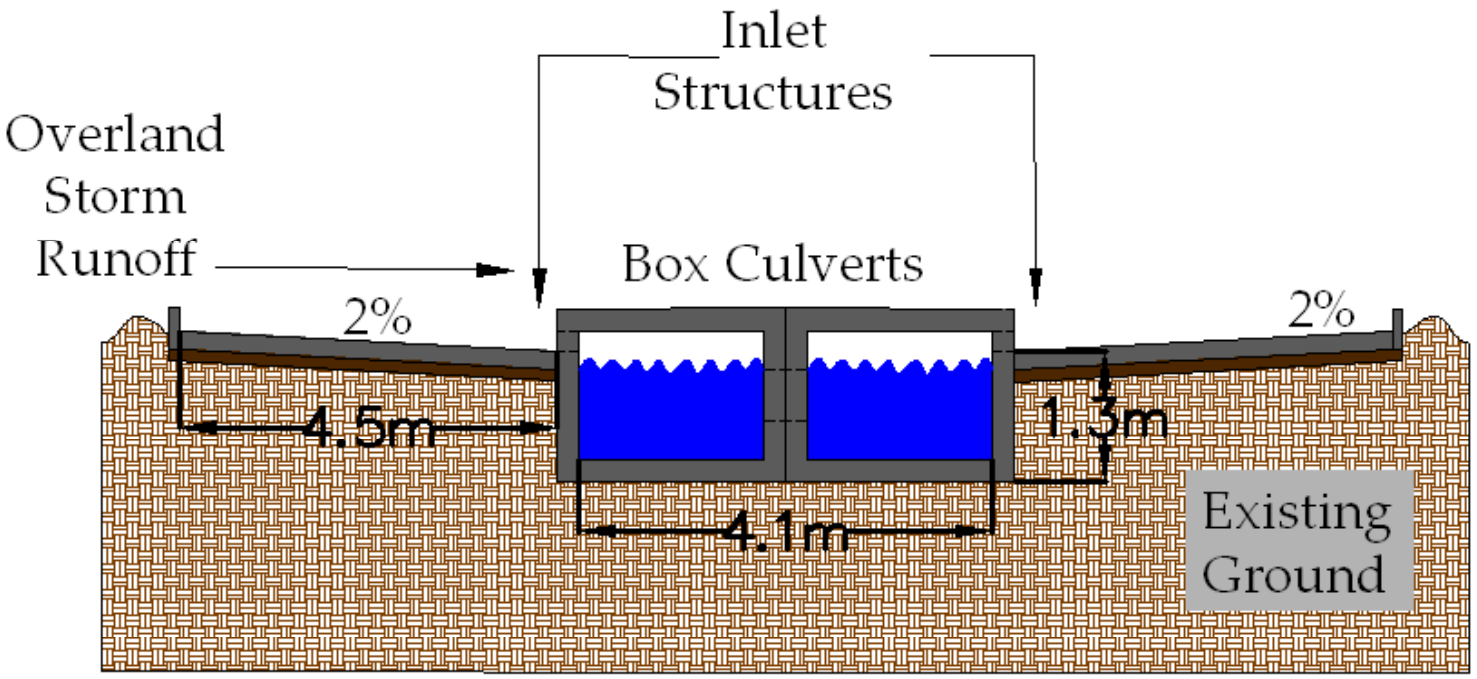
Box Culvert Canal



Safety

Maintenance

Road

Accessibility

Design Option 2

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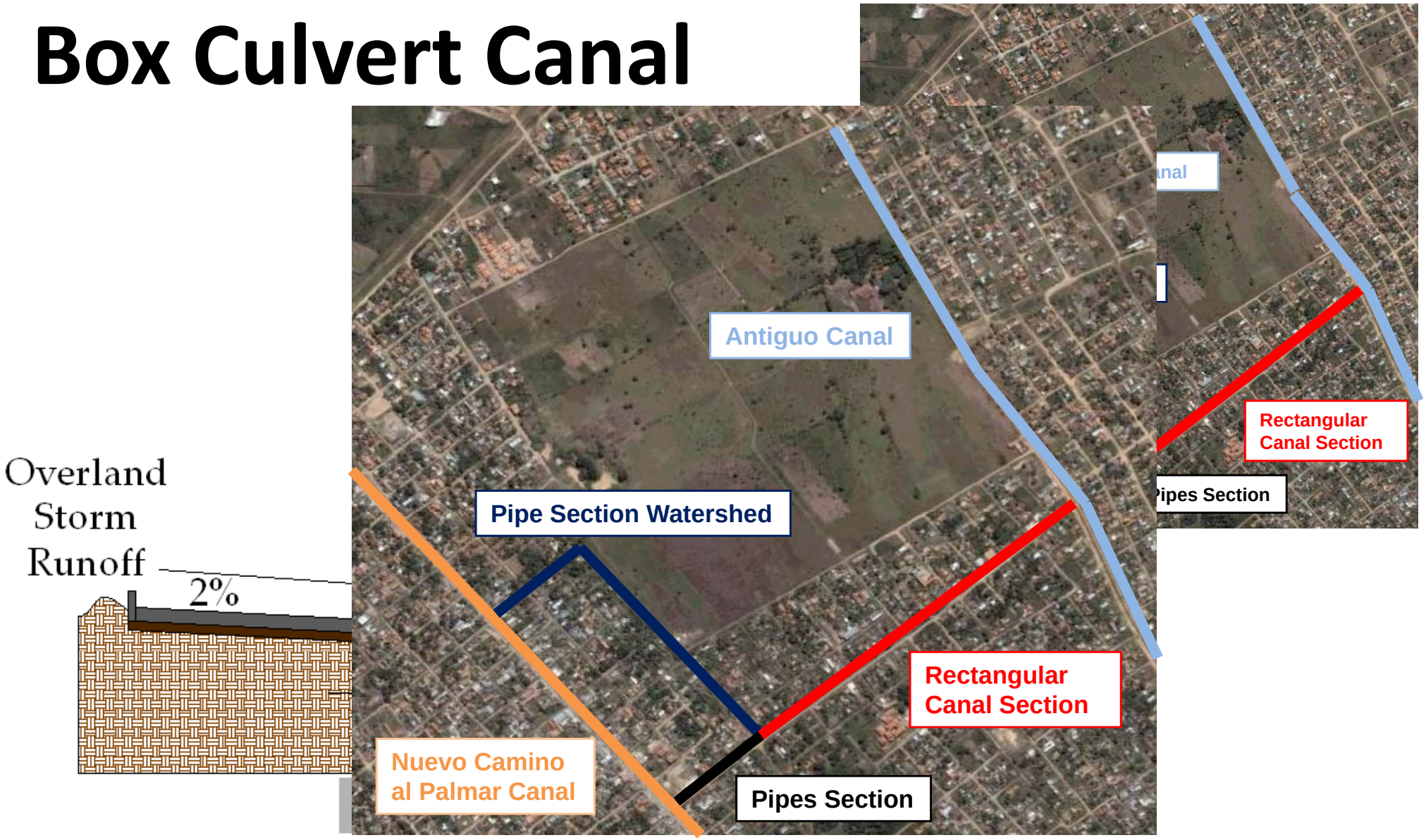
Box Culvert Canal



Design Option 2

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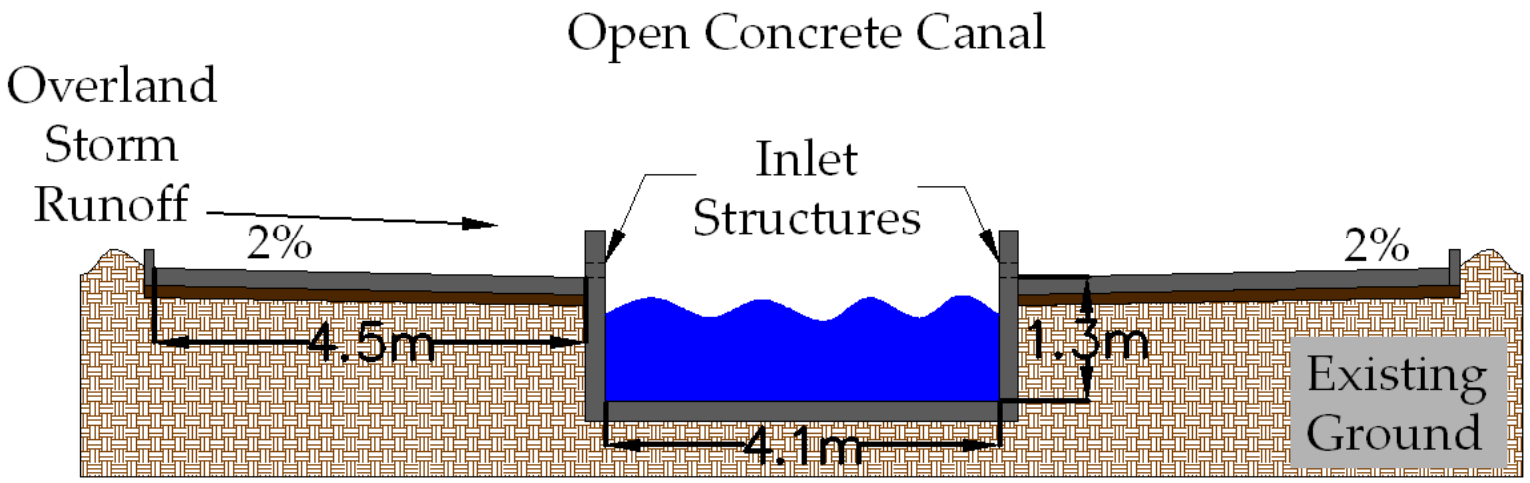
Open Rectangular Canal



Cost

Standard

Practice

Maintenance

Design Option 3

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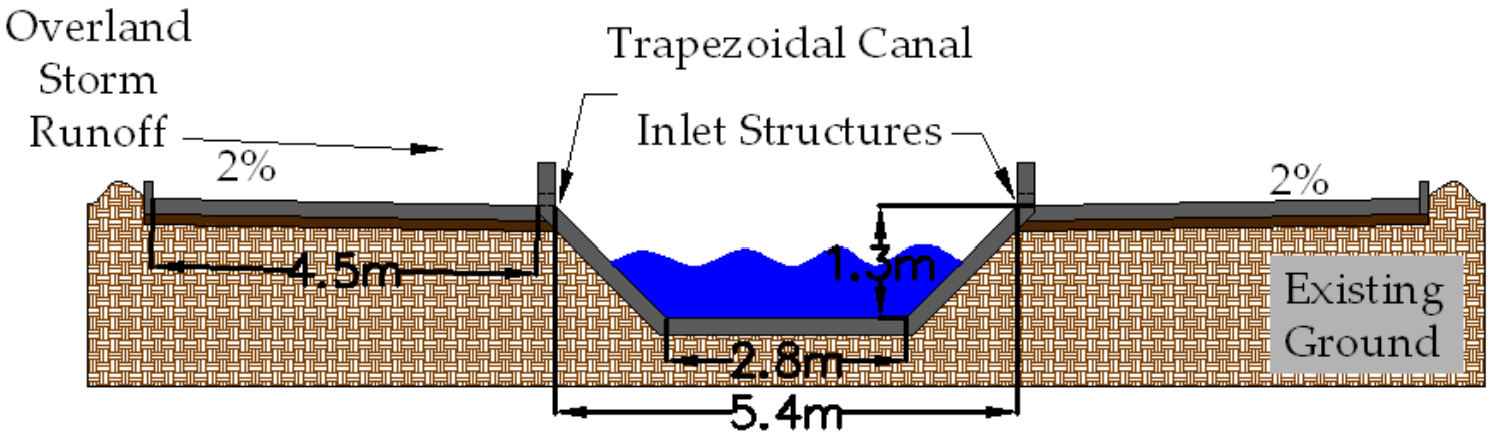
Open Trapezoidal Canal



Better Flow

Standard

Practice

Design Option 3 - Alternative

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Earthen Emergency Ditch

Design Option 3 - Alternate

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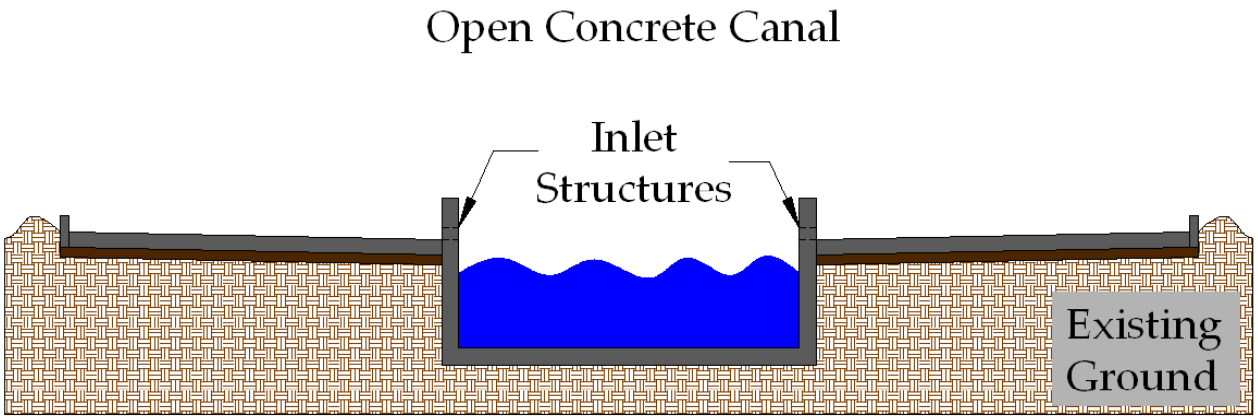
Utilization of Emergency Ditch



The expanded ditch will reduce flow into Fatima channel

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	0.58
5.5	3.40	1.14	1.03
5	3.09	1.64	1.49
4.5	2.78	2.14	1.94
4	2.47	2.64	2.40
3.64	2.25	3.00	2.72
3.5	2.16	3.14	2.85
3.24	2.00	3.40	3.09
3	1.85	3.64	3.31

Design Option 3 - Alternate

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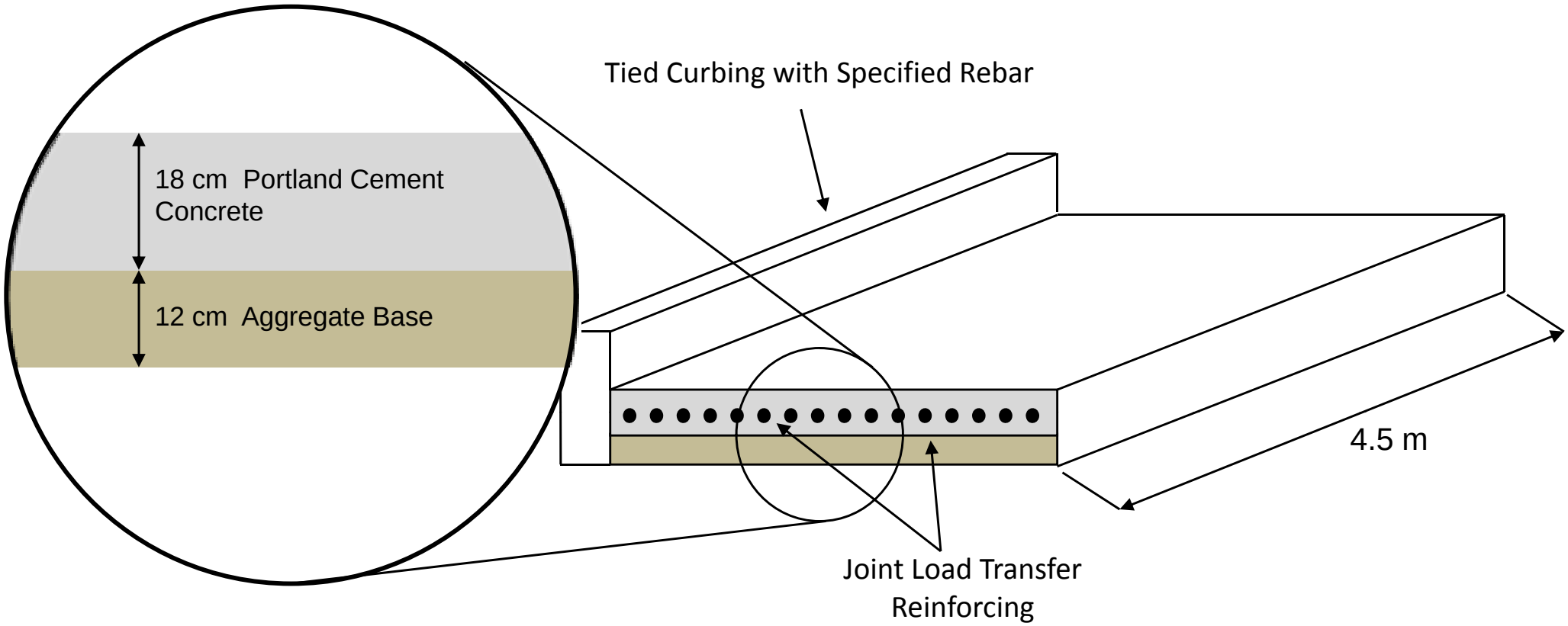
Pavement Design

– Standard Concrete Design



Alternative Pavements

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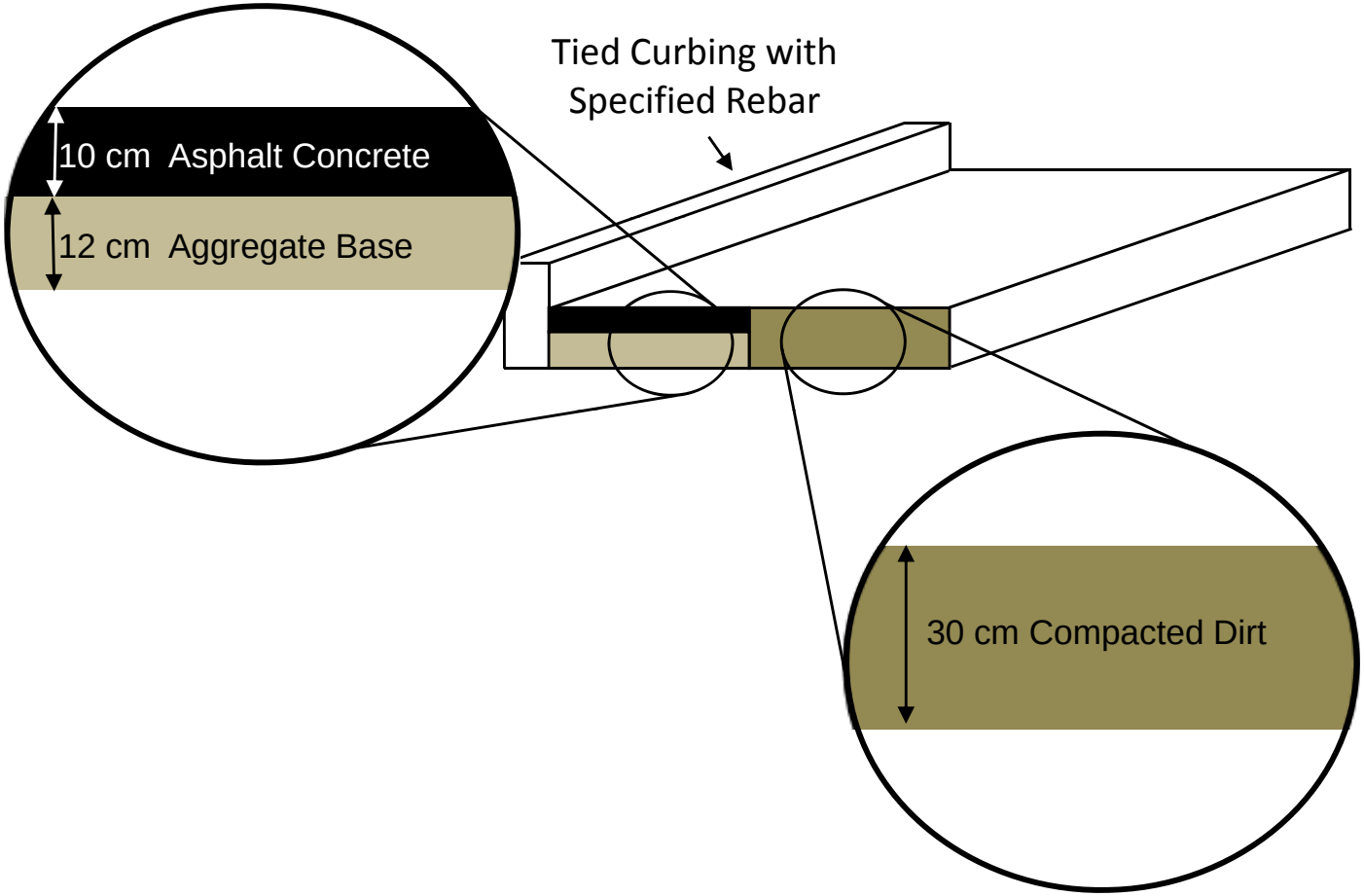
Pavement Design

– Options



Alternative Pavements

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Pavement Design

- **Cost analysis**

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**

Alternative Pavements

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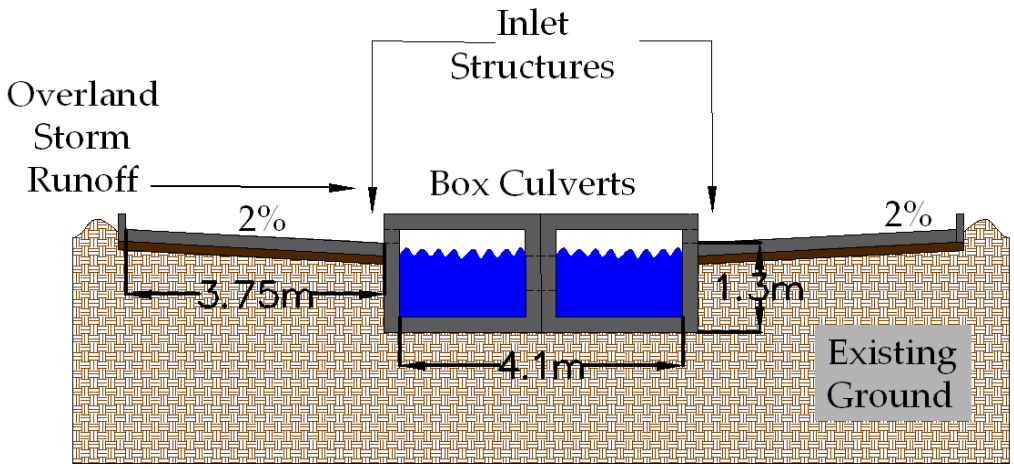
Design Option 2

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	87,000
Erosion Control	5,000
Total	**7,278,000**
Total USD	**1,026,500**

Box Culvert Canal



Cost Estimate

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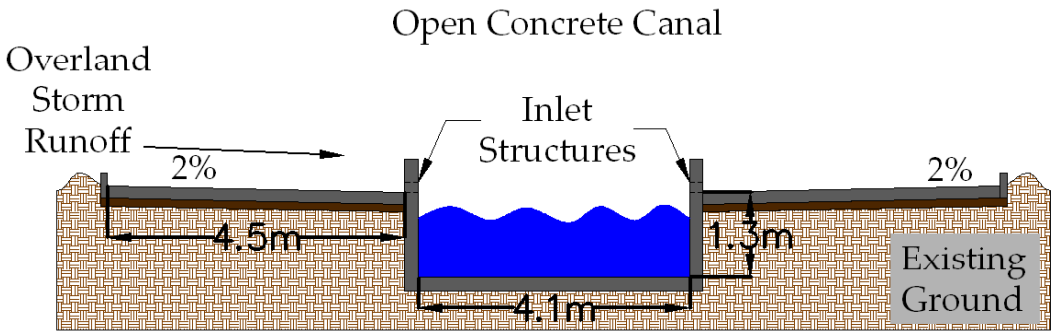
Design Option 3

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**

Open Rectangular Canal



Cost Estimate

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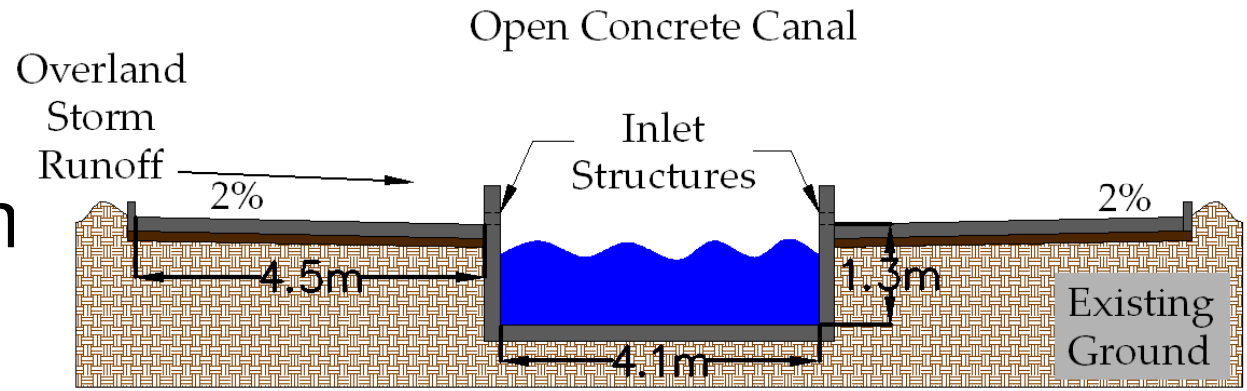
Avenida Fatima Rectangular Channel

- Standard Practice
- Sediment traps limit particle flow into waterways
- Least Costly Option
- Easy Maintenance
- Limit Dust around Avenida Fatima



Recommendations

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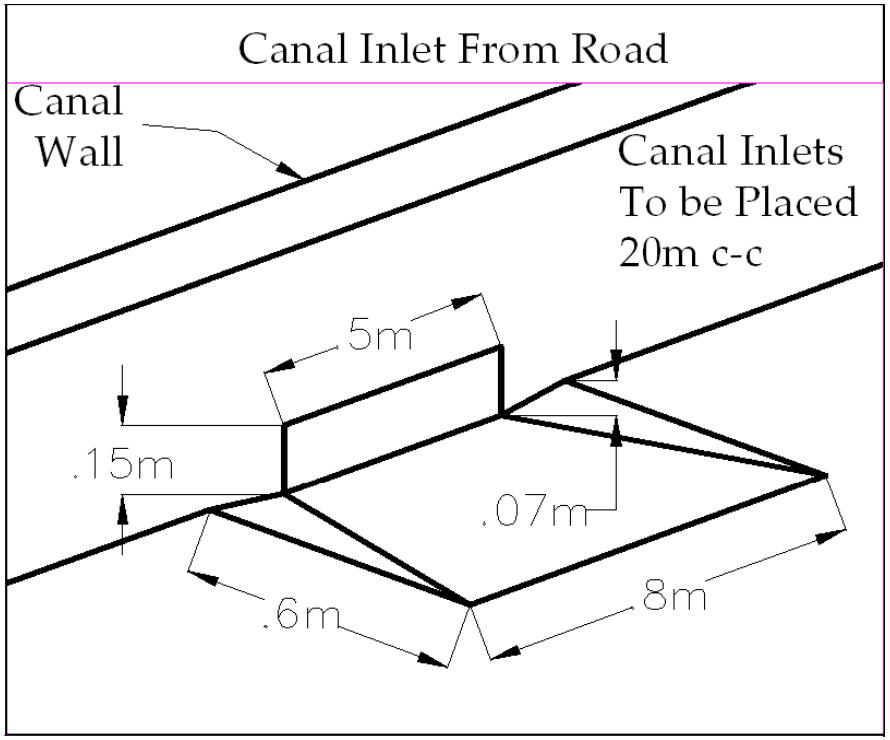
Avenida Fatima Rectangular Channel Gutters

- Curb-Opening Inlet Structure
  - Runoff into Gutters=5.4m^3/s
- Output
  - 53 inlets
  - Q=.11m^3/s per inlet
  - Length=.5m
  - Height=.15m



Recommendations

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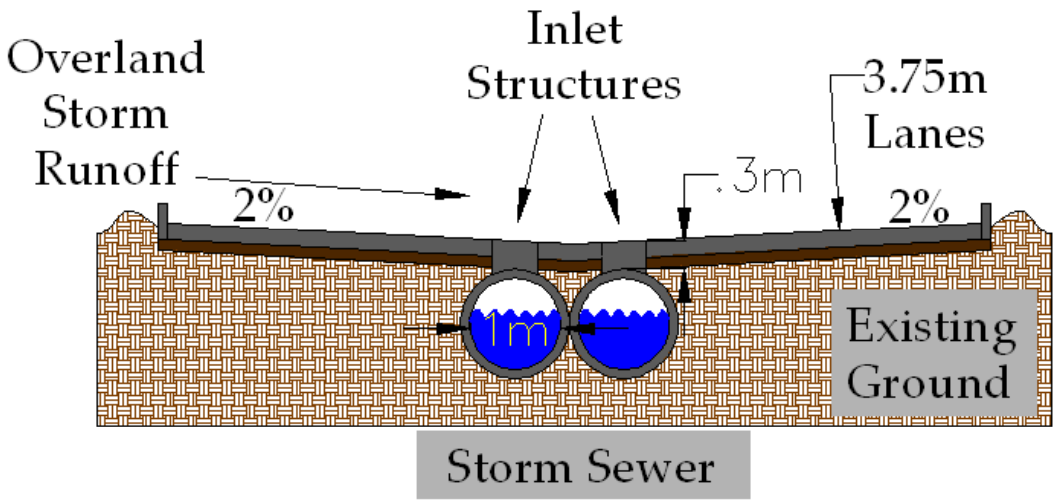
Nuevo Camino al Palmar Canal

- To narrow for rectangular channel in the 250m closest to Palmar Canal
- Will use underground pipes
- Collects Runoff and flows towards Antiguo Canal
- Runoff Flow
  - Q=1.25m^3/sec



Recommendations

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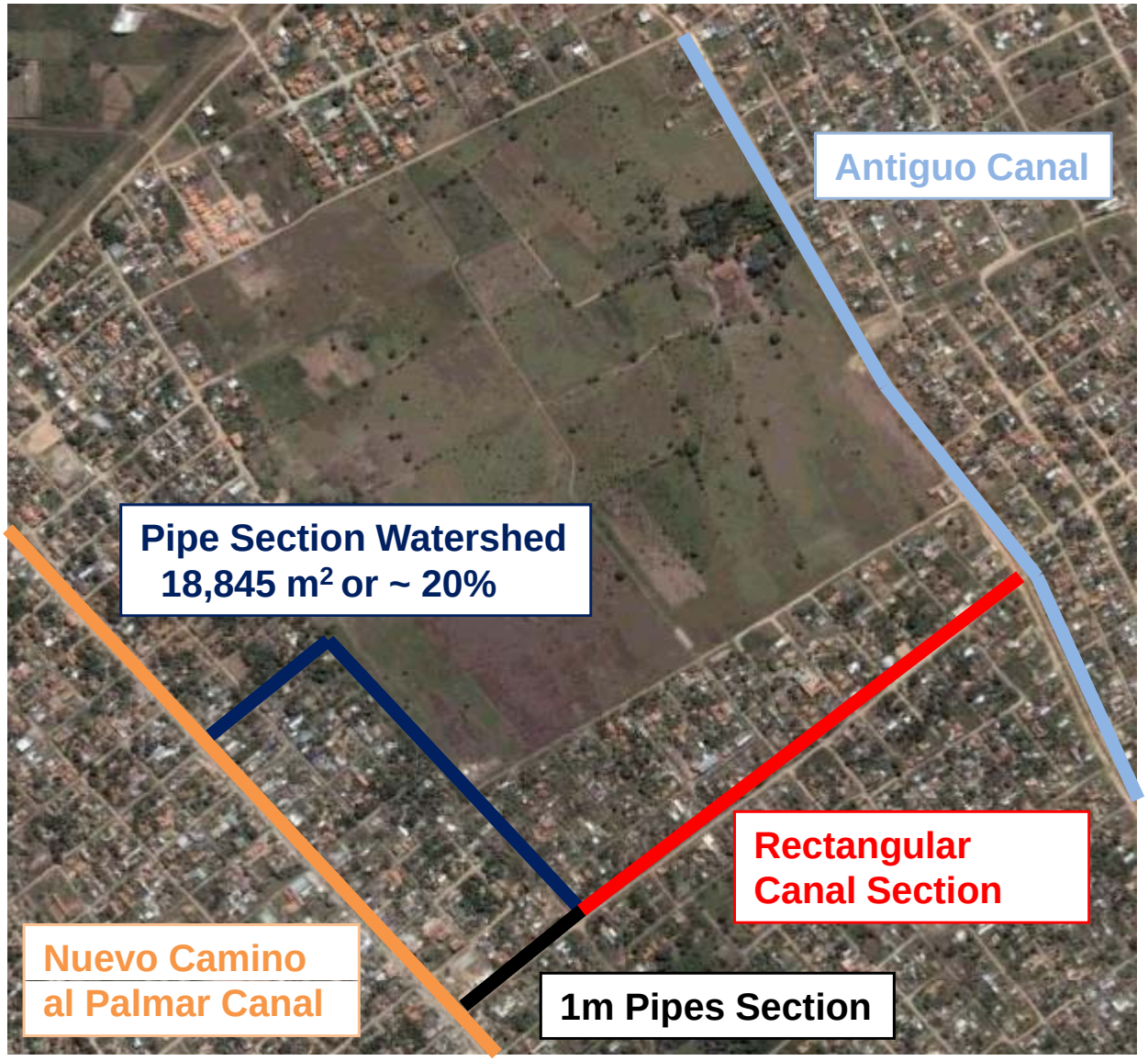
Pipe Section Watershed



Recommendations

Michigan Tech
Create the Future

Nuevo Camino al Palmar Canal Section

- Two pipes to handle flow
- Output
  - Two 1m pipes
  - Full flow height = .94 m
  - Pipe velocity= .84 m/s

Recommendations

Michigan Tech
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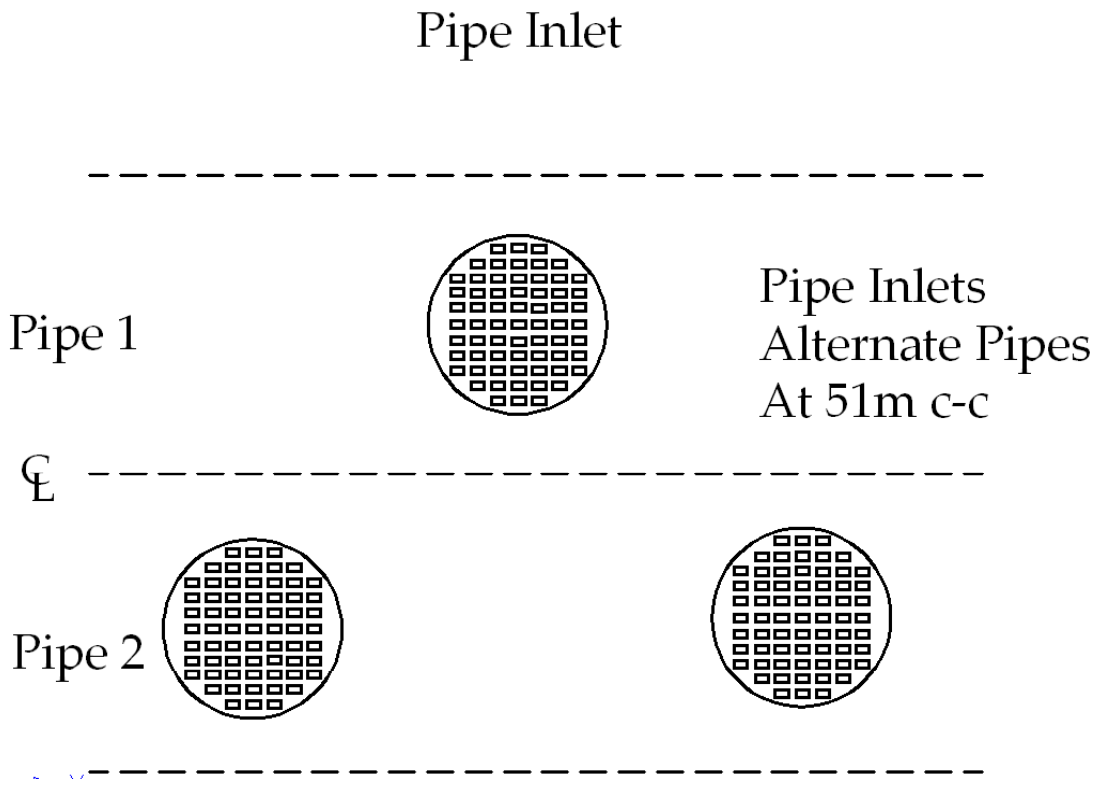
Nuevo Camino al Palmar Canal Section Gutters

- Slotted Inlet Drains on alternating pipe
- Runoff into Gutters= 1.25 m^3/s
- Output
  - 5 inlets
  - Q= .29 m^3/s per inlet
  - Diameter= .6 m



Recommendations

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Antiguo Canal Connection

- Not enough slope to connect Fatima channel to Antiguo Canal
- Will angle culvert downstream to lower point on Antiguo Canal, to achieve greater slope

Recommendations

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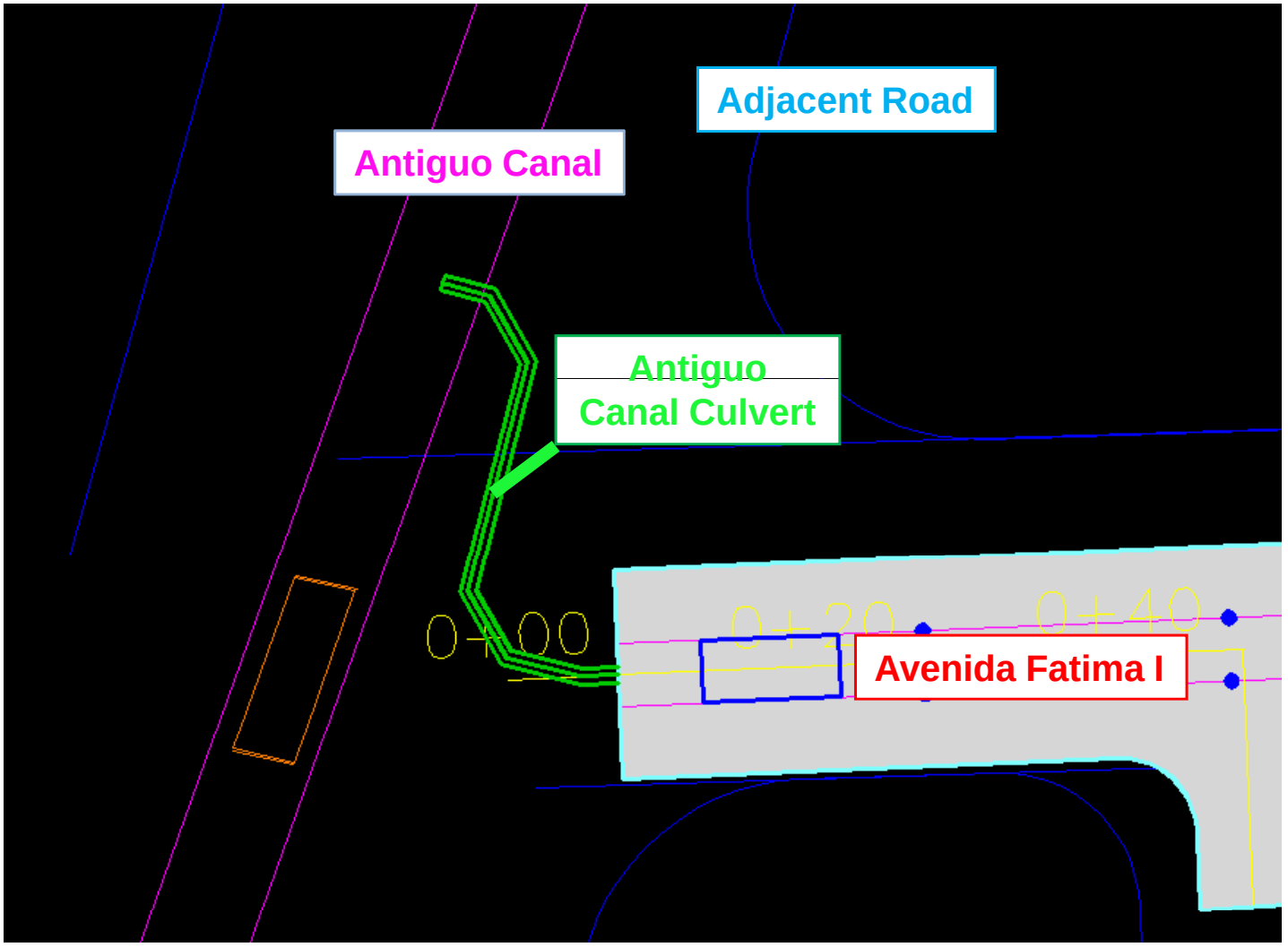
Angled Culvert



Recommendations

Michigan Tech
Create the Future

Antiguo Canal Culvert

- Two pipes to handle flow
- Culvert Properties
  - Slope=.8%
  - Length = 36.0m
- Output
  - Two 1.25 m pipes
  - Full flow height = 1.23m
  - Pipe velocity = 2.7m/s

Recommendations

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Conclusion



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ISD Advisors and Mentors

Ing. Linda Phillips – ISD Advisor
Ing. Dennis Magolan – ISD Advisor
Ing. Mike Drewyor – ISD Advisor
Ing. Carlin Fitzgerald – ISD May Mentor
Ing. Lauren Hubbel – ISD May Mentor
Giancarlo Calbimonte – ISD May Mentor

Bolivian Friends and Mentors

Sub Alcalde Ing. Victor P. Escobar Díaz
Ing. Javier Marín – Distrito 12 engineer
Presidenta Loreto Moreno
Community members of District 12
Moisés Rico – Director Colegio Walter Henry School
Faculty and Staff of the Colegio Walter Henry School
Lic. Carmen A. Palacios
Paul Palacios
Jhimmy Augusto
Dr. Dan Hinojosa and family
Ing. Humberto Calbimonte
Ing. Augusto Cuadros
Ing. Rufino Arano
Sr. Teodardo Gandarillas
U. A. G. R. M. Laboratorio de Ing. Civil

US Friends and Mentors

Dr. Brian Barkdoll
Dr. Jacob Hiller
Ing. Dana Volk
Ing. Eric Waara

Fellow MAY ISDers

Spam Jammel
La Gente
C & C Consulting

Friends and family that have supported us during our ISD experience.

Acknowledgements

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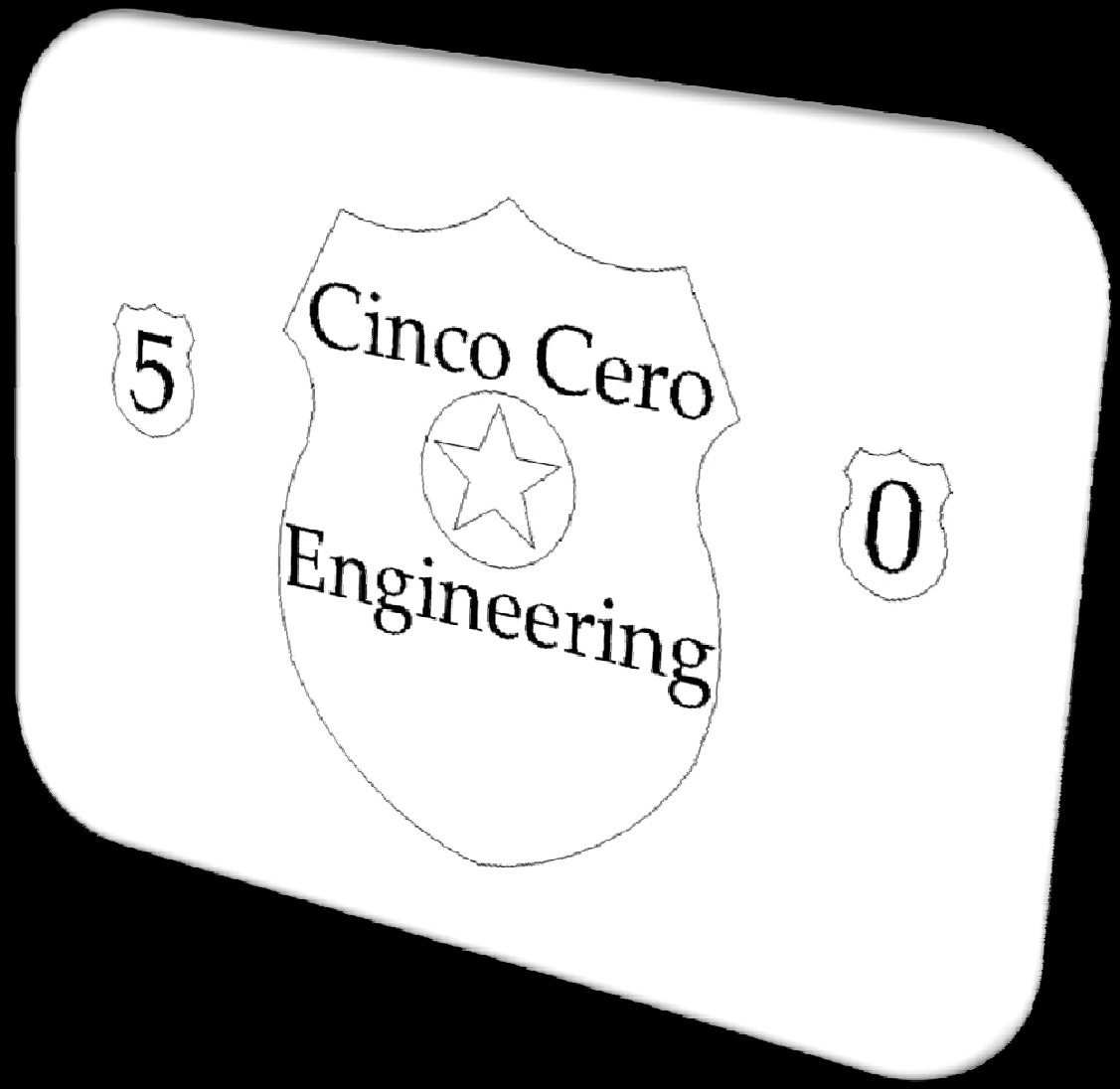

Questions?

D80 CENTER

engineering development for humanity

Programs

- Engineers Without Borders
- Aqua Terra Tech Enterprise
- International Sustainable Development Engineering Certificate
- International Senior Design
- International Sustainable Development Engineering Research Experiences
- Master's International Peace Corps

2nd Annual Conference - November 8, 2008