

CARTAGENA D.T. y C.

Puerta del Reloj

(The Clock's Door)



SUPPORT OF EMBANKMENTS ON VERY SOFT SOILS

SOILS

Geotechnical Experiences



Perimeter Road of La Virgen Sound– Cartagena de Indias



Perimeter Road of La Virgen Sound– Cartagena de Indias

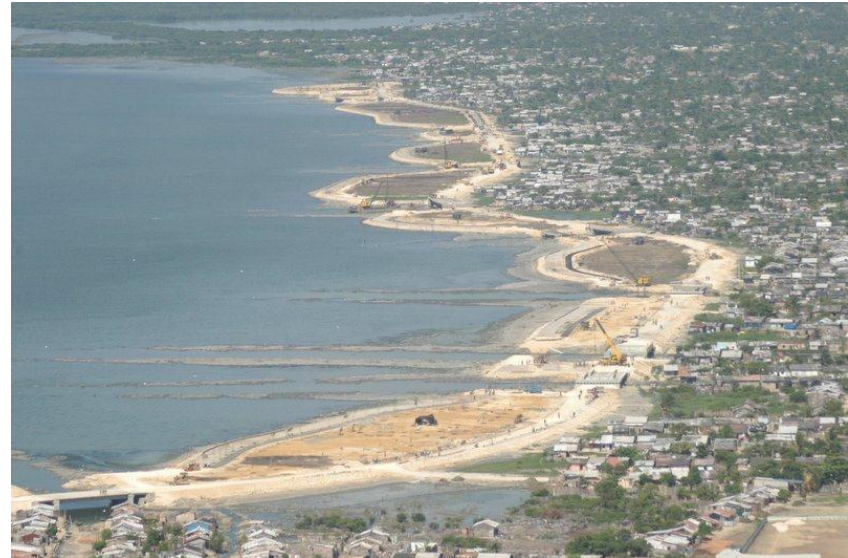
PARTICIPATING ENTITIES

INSTITUTIONS

- **COLDEPORTES, Owner**
- **FONADE, Project Manager**
- **INVIAS, Technical Advisor**
- **DISTRITO DE CARTAGENA, Social Management**

Institutional Consulting

Geotechnical Colombian Society



CONTRACTORS AND SUPERVISORS

- **Consorcio Rellenos Via Perimetral – UTE Bating**
- **Consorcio Puentes de Cartagena – UTE Bating**
- **Consorcio La Virgen – UTE Bating**
- **Consorcio AVE/Consorcio Avenida Cartagena 2005
UTE Interventoria La Cienaga**



Presentation Content

- **General Project Description**
- **Generalized Soil Profile**
- **Design Alternatives and Construction Process**
- **Instrumentation System (primary consolidation)**
- **In Situ Compression Load Tests**
- **Geotechnical Experiences**
- **Project Operation: Behaviour after Two Years**
- **Conclusions**



General Project Description



Via Perimetral Ciénaga de la Virgen – Cartagena de Indias

Project Relevant Features

- **Recuperation of La Virgen Sound**
- **Improvement of City Road Connectivity**
- **Urban Renovation**
- **Creation of a Public Promenade (Alameda)**

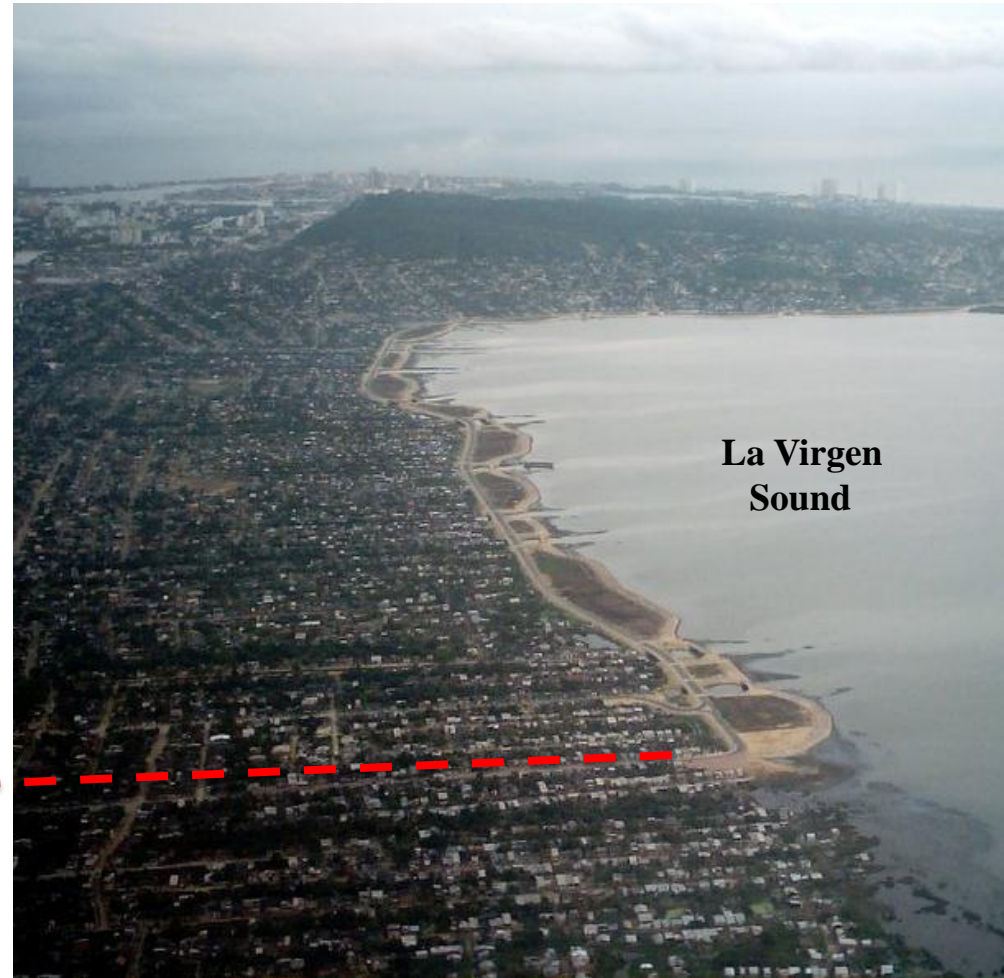


Perimeter Road of La Virgen Sound

Connection to City Sport Complex



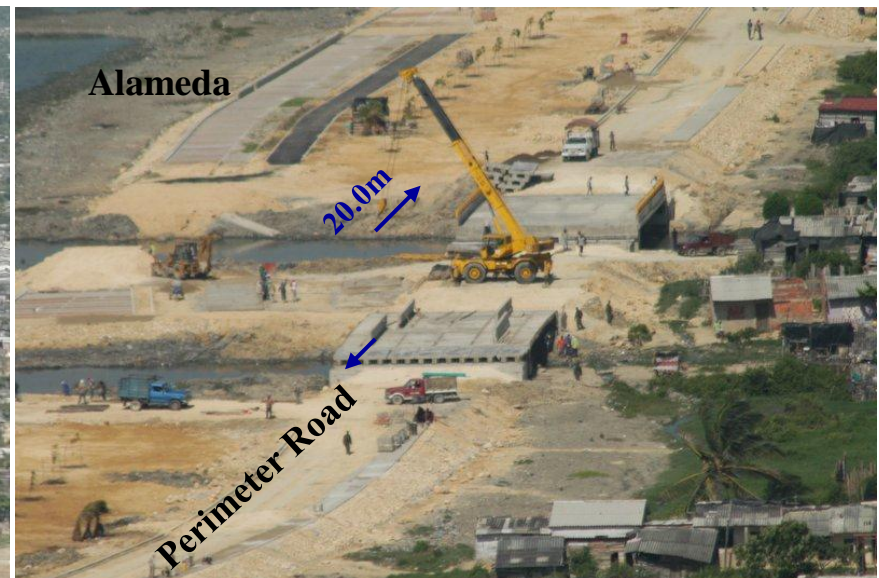
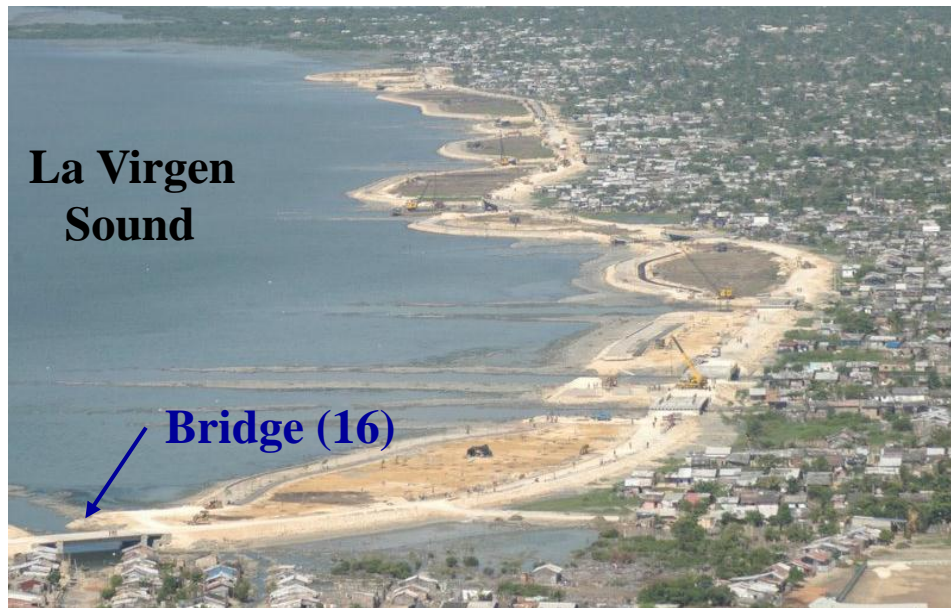
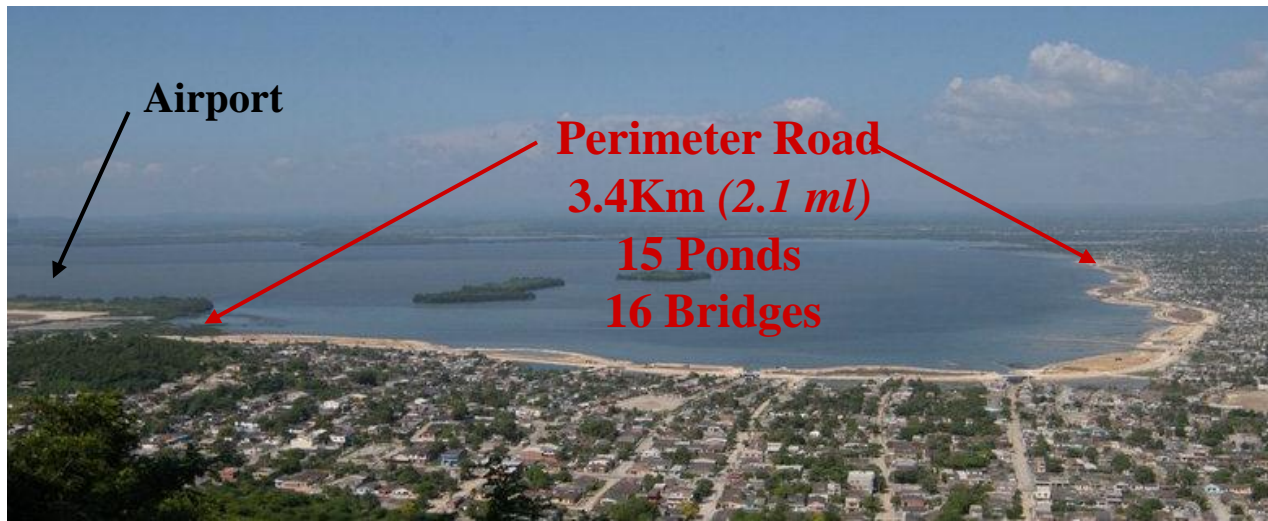
2006 Pan-American Games



La Virgen Sound



Perimeter Road of La Virgen Sound– Cartagena D.T.



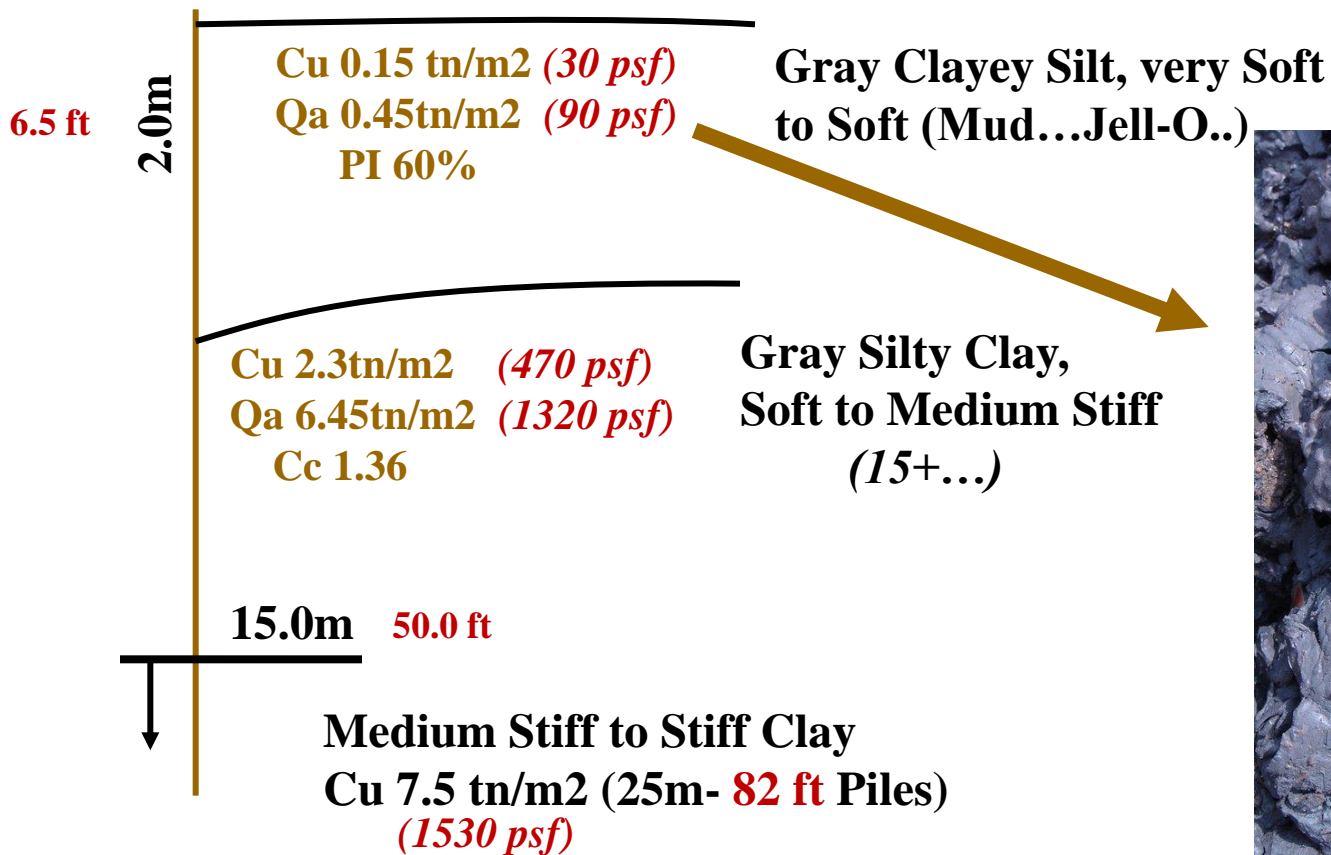
Generalized Soil Profile of La Virgen Sound Shore



Perimeter Road of La Virgen Sound– Cartagena de Indias

Generalized Soil Profile

Lake Deposit



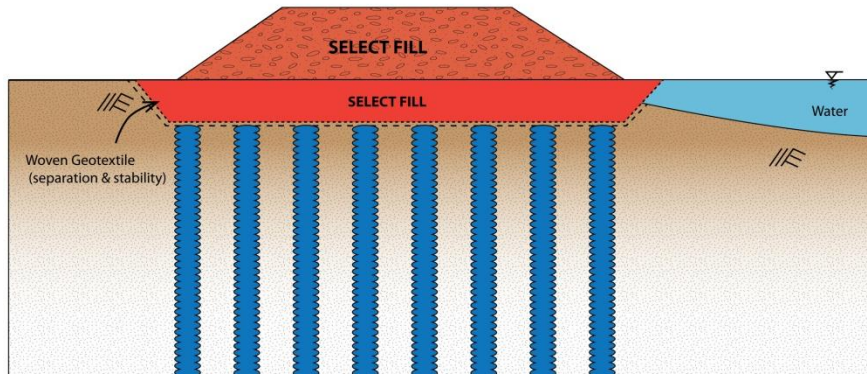
Design Alternatives and Construction Process

- **Dike Alternatives**
- **Zahorra Dikes**
- **Hydraulic Fill**
- **Bridge Approaches**

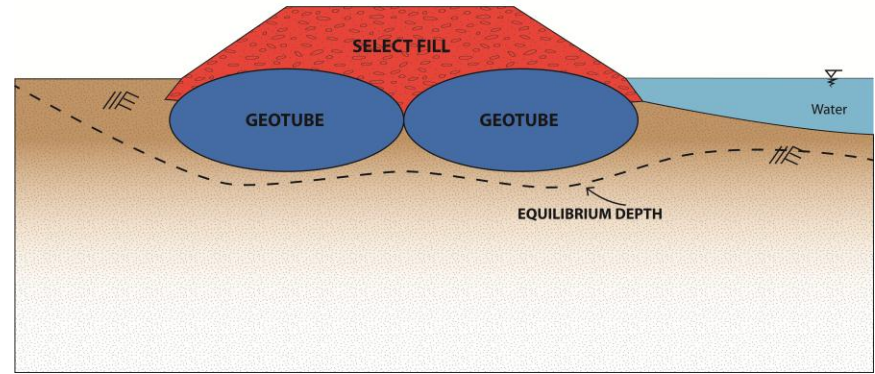


Perimeter Road Embankment/Dike Alternatives

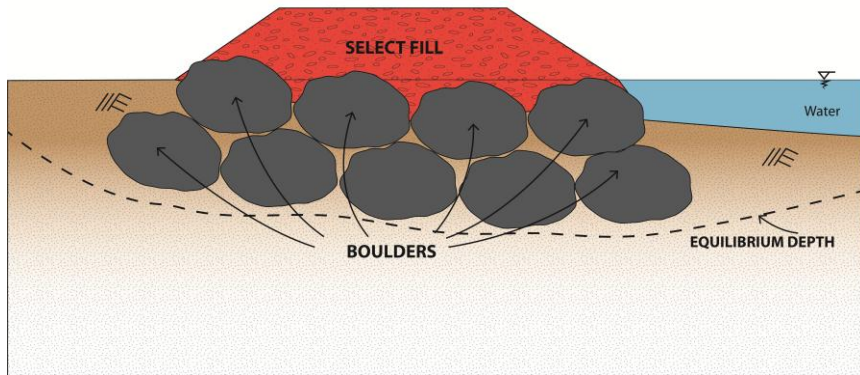
DENSIFIED AGGREGATE PIERS



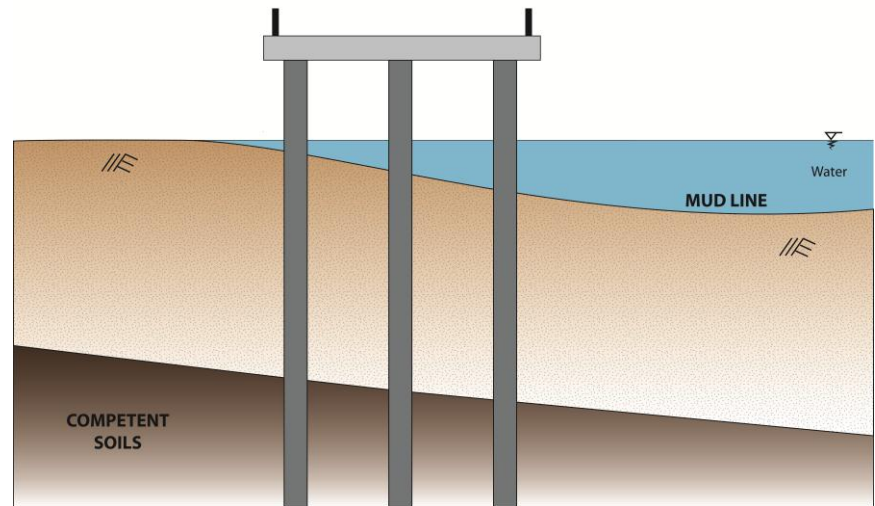
GEOUBE FOUNDATION



BOULDER FOUNDATION



BRIDGE OVER

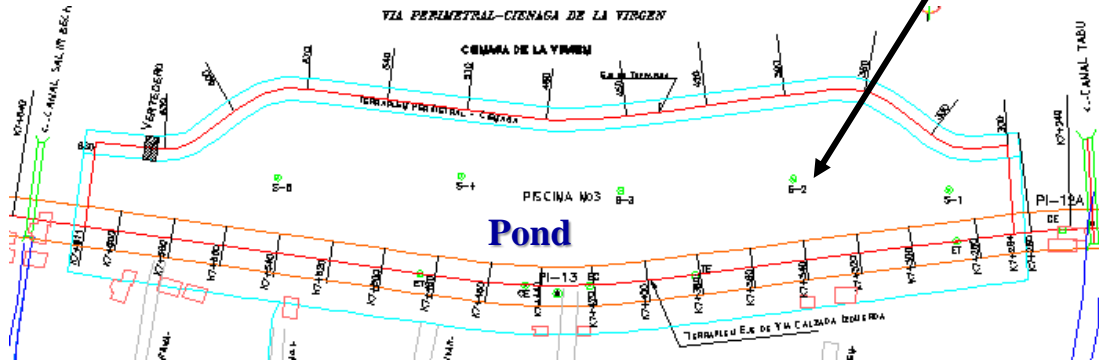


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Selected Alternative

Construction Process

Hydraulic Fill



Hydraulic Fill
(Dredging)

Fonade

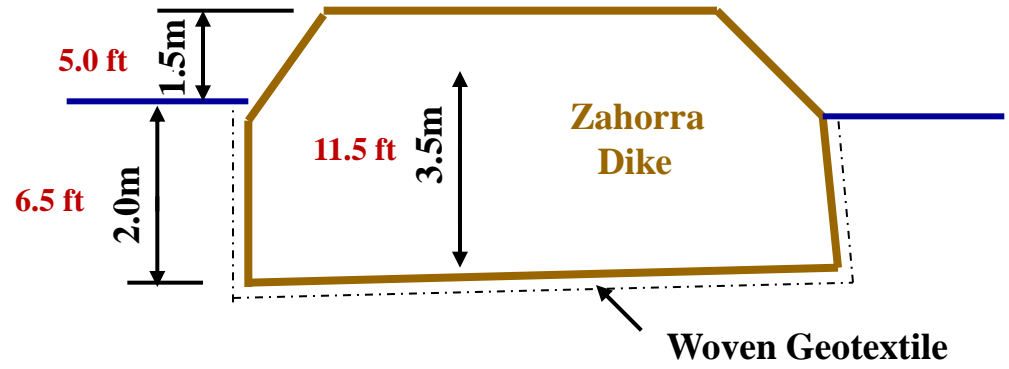


Road Embankment
(Zahorra Dike)

Sidewalk-Bike Trail Dike



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Zahorra Dike Construction Process

Zahorra: Limestone Quarry



General Dike/Embankment Construction Highlights



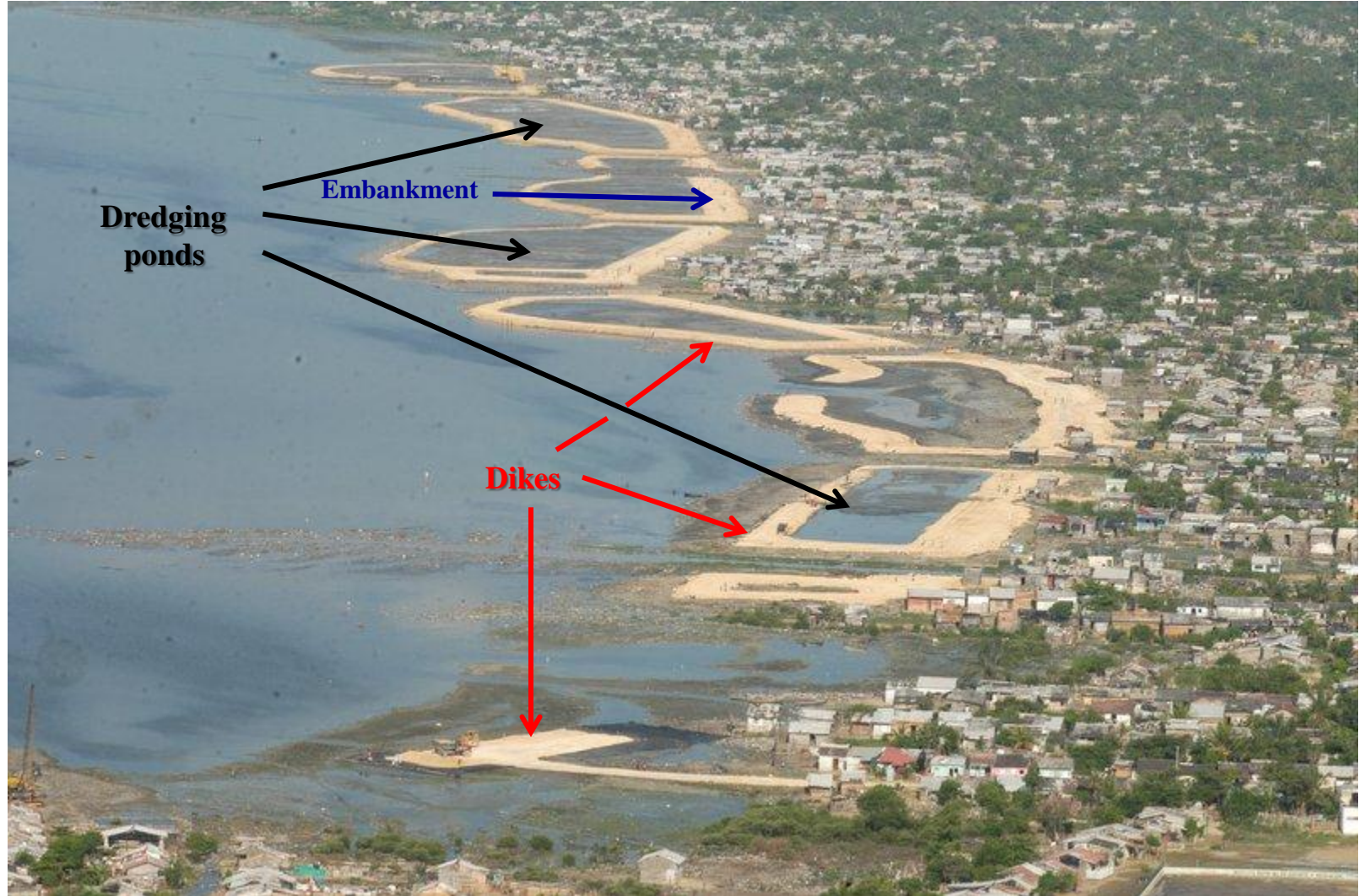
Sidewalk
Bike Trail



Mud line



Work Progress Embankment-Dike Construction



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Dredging Process

- Low Revolutions
- Close to Ponds (80m)
- **Purpose: To obtain clay pebbles or clay balls in a viscous-fluid matrix**



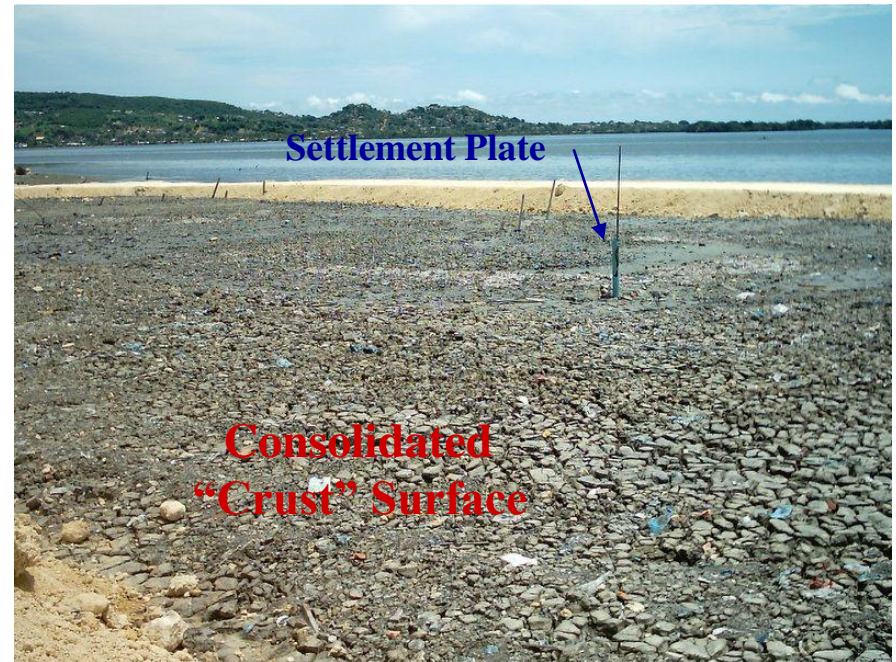
Perimeter Road of La Virgen Sound– Cartagena D.T.



“Clay Balls”



Drainage Ditch



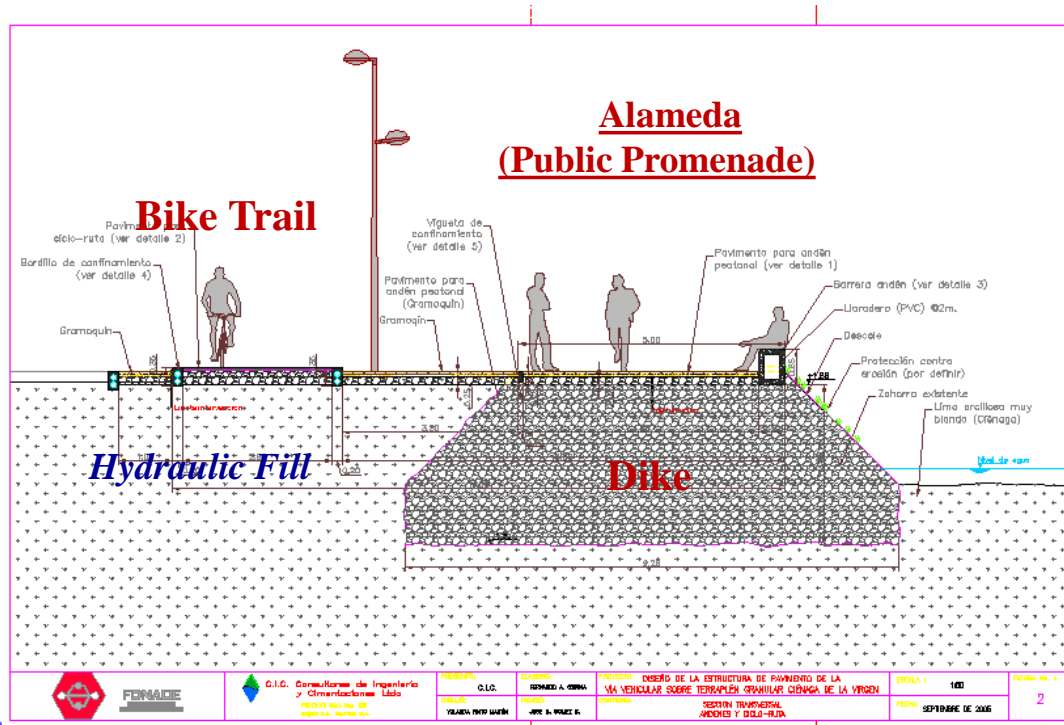
Settlement Plate

Consolidated “Crust” Surface



URBAN DESIGN

Bike Trails and Sidewalks



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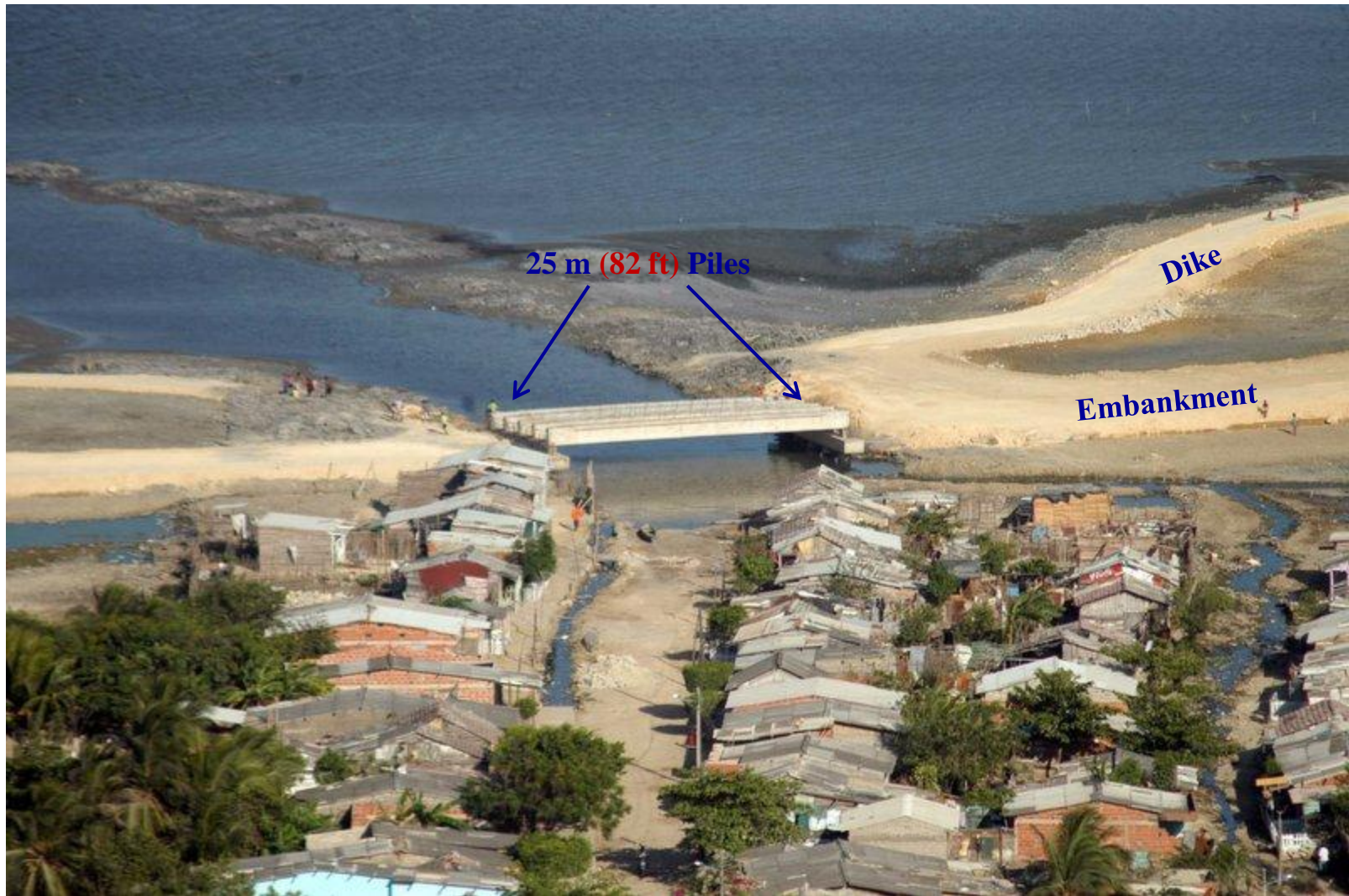
Bridges and Approaches



Bridge Sites

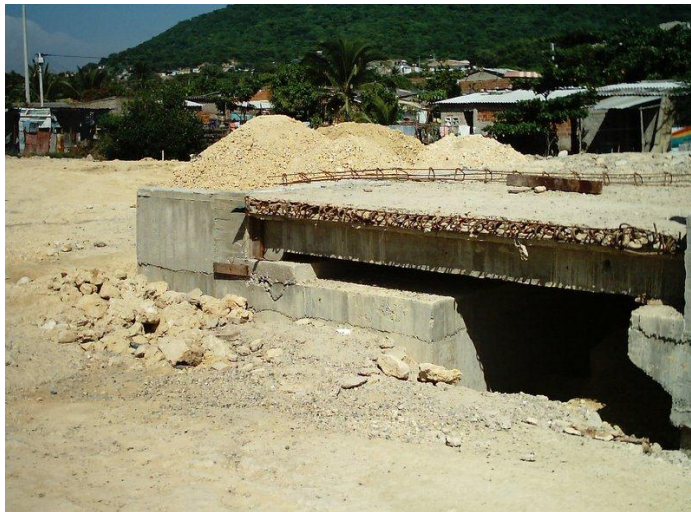
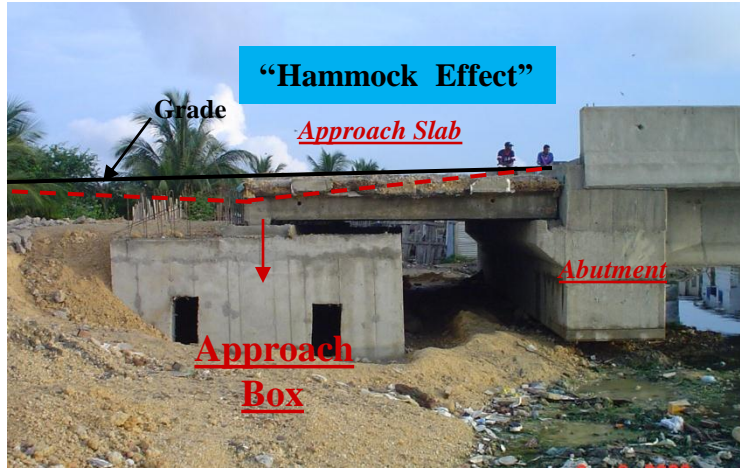


Bridge without Approaches



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Bridges and Approach Box Structure (Bridge “Bump” Preventer)



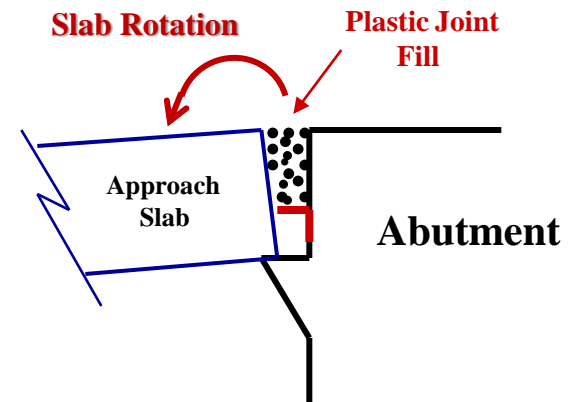
Perimeter Road of La Virgen Sound– Cartagena D.T.



Construction Joint Behaviour



Opening Joint



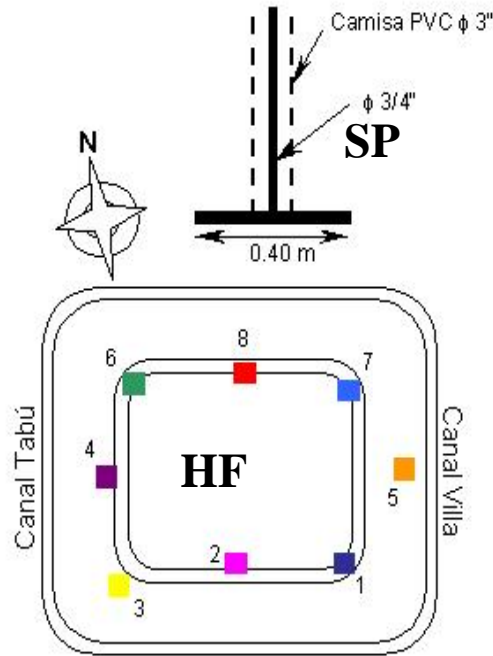
Instrumentation System (primary consolidation)

What about Settlements Rate??

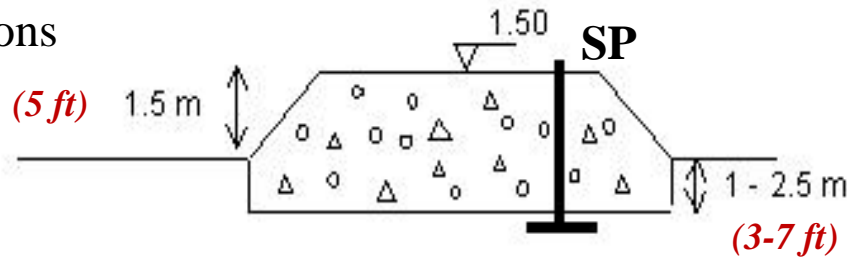


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Instrumentation System- Settlement Plates (SP)



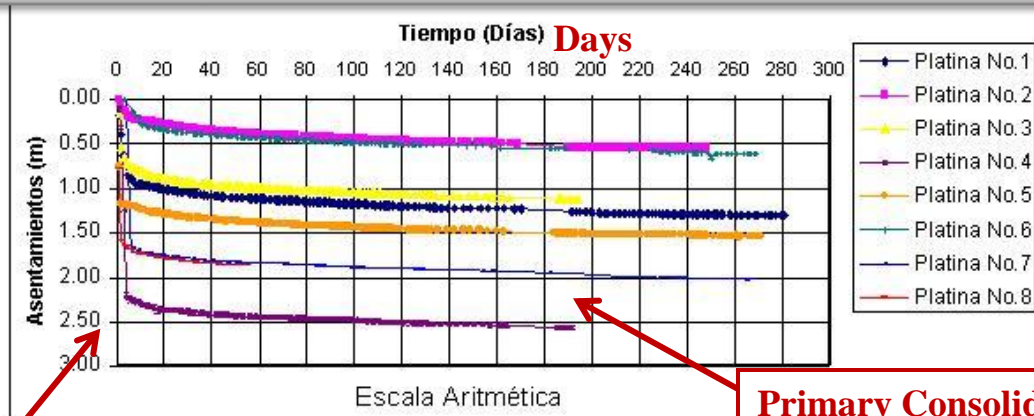
SP Locations



Typical Cross Section



Summary of Dike Construction Phase

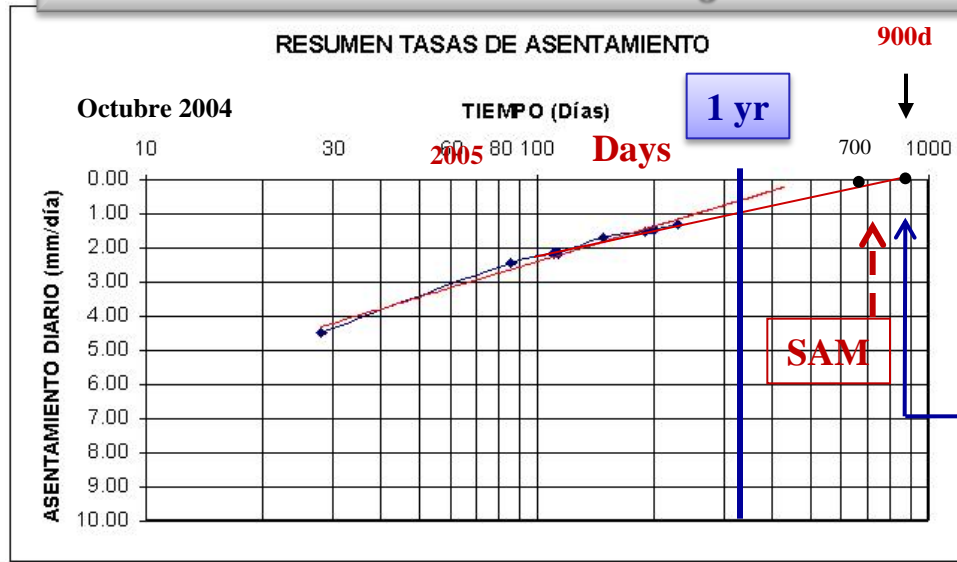


Primary Consolidation

Initial Soil Displacement
5-7 feet

Settlement Rate Projections

End of 1st year:
30-45 cm (12-18 in)



April 24 of 2007
St. Rate: 0.33mm/day
(0.01 inch/day)
915 days

Sand-Asphalt Mix (SAM)
Ready for Placement
(Pan-Games)



Primary Consolidation Analysis...

Settlement Rate reduction of 70% from 1st to 3rd yr
1mm/day to 0.33mm/day (*0.01 inch/day*)



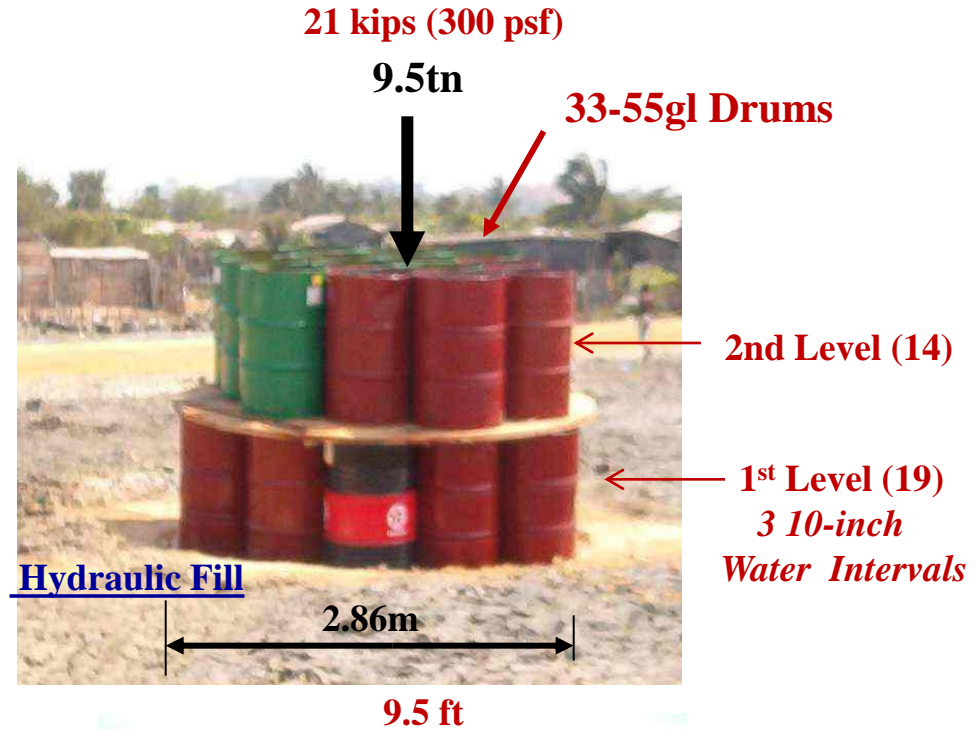
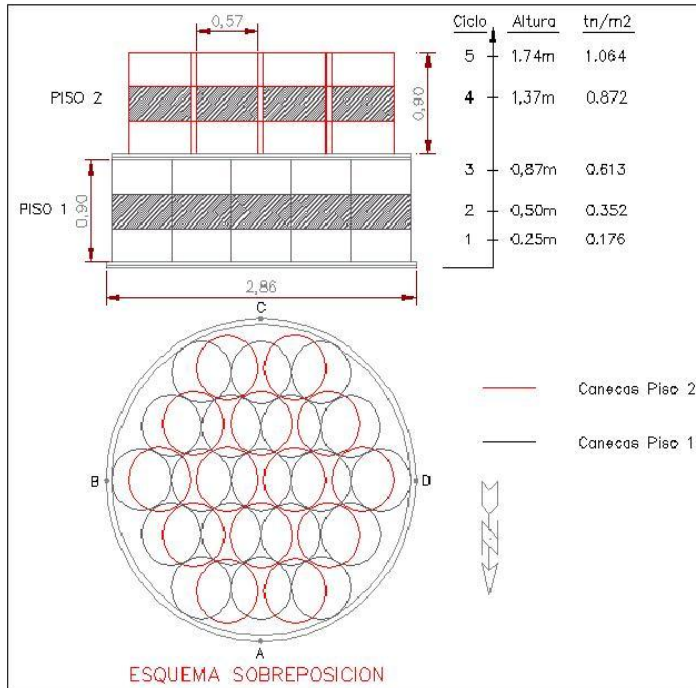
In Situ Compression Load Tests

What About Settlements??



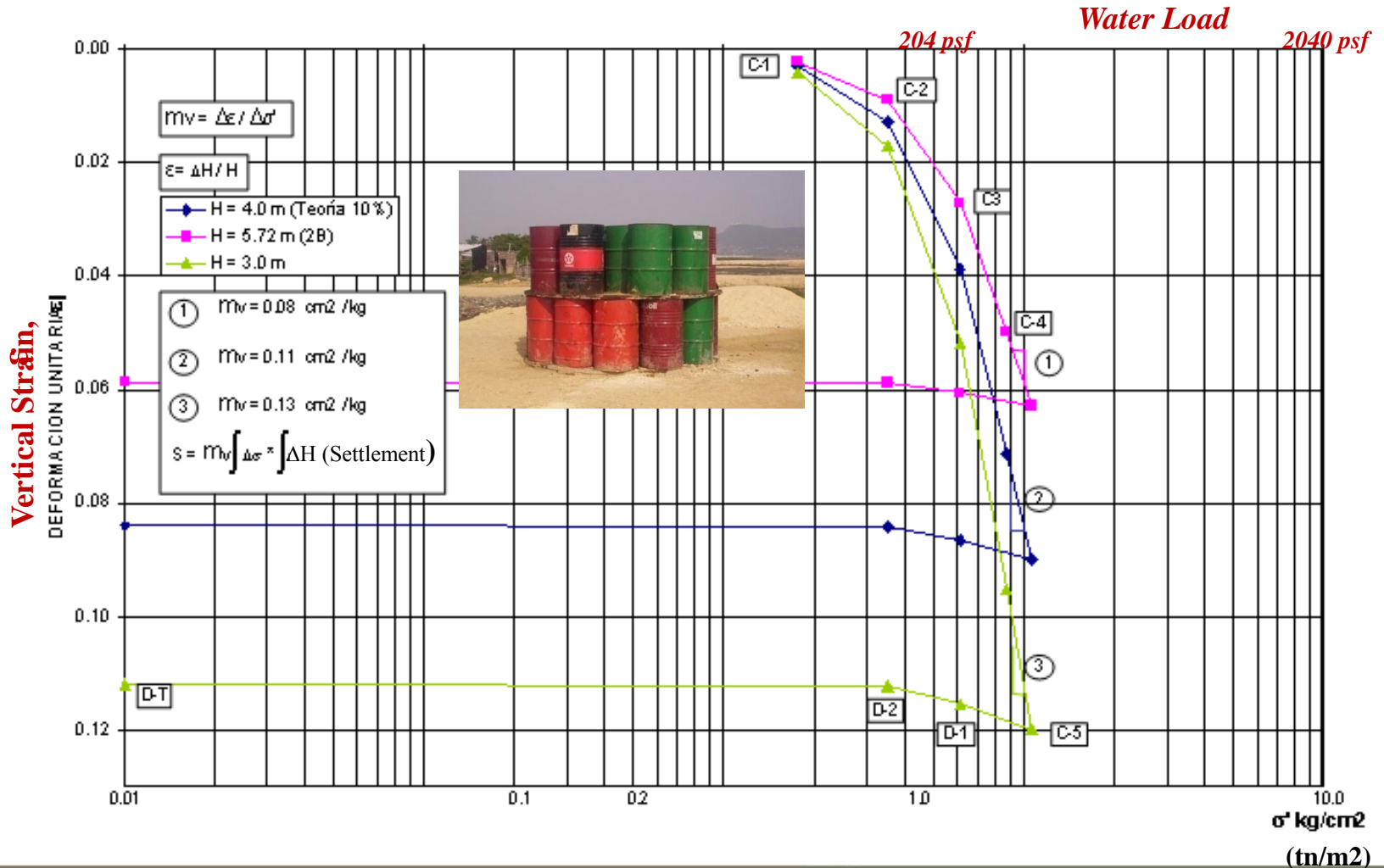
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In Situ Compression Load Tests

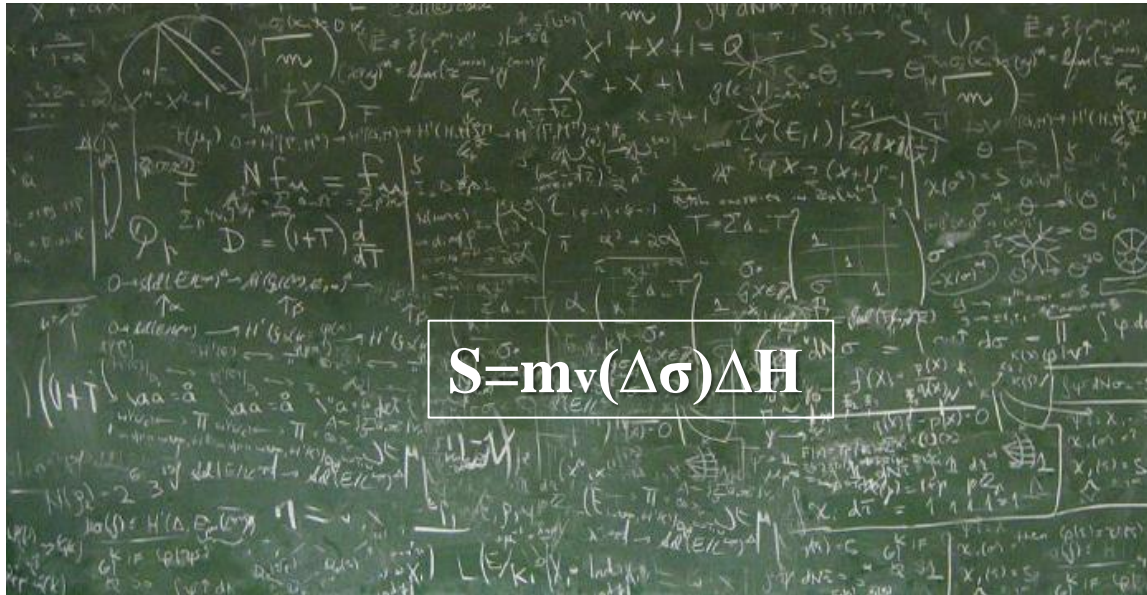


In Situ Compression Load Test (Stress-Strain)

Coefficient of Volume Compressibility (m_v)



Quick Settlement Estimation Dike Height = 2m



$m_v = 0.11 \text{ cm}^2/\text{kg}$ (*Coefficient of Volume Compressibility*)

$\Delta H = 13 \text{ m} = 1300 \text{ cm}$

$\Delta\sigma = 4.0 \text{ tn}/\text{m}^2 = 0.4 \text{ kg}/\text{cm}^2$ (*816 psf*)

$S = 0.11 \times 0.4 \times 1300$

$S = 57.2 \text{ cm}$ (*22.5 inches*)



Geotechnical Experiences and Lessons



**Bearing Capacity
Failure**

Hydraulic Fill



Perimeter Road of La Virgen Sound– Cartagena D.T.

Geotechnical Experiences and Lessons Typical Bearing Capacity Failure

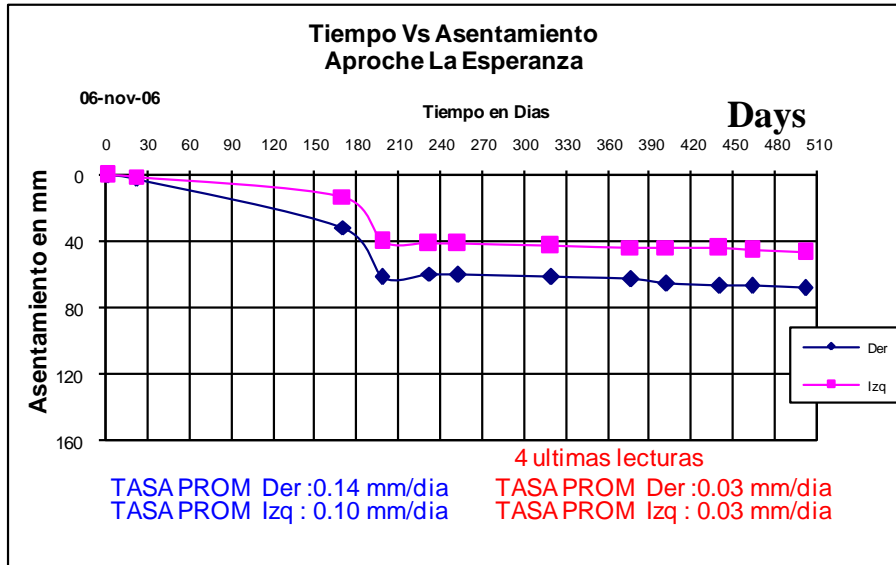


Project Operation: Behavior After Two (2) Years



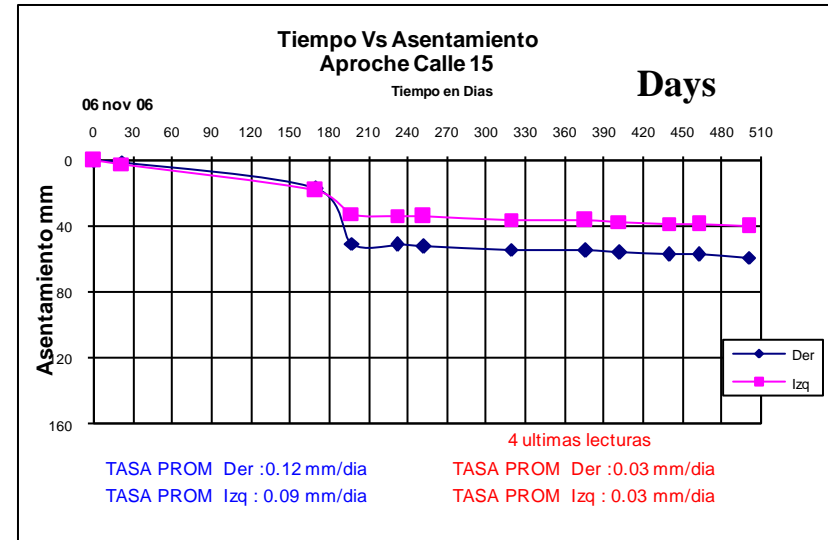
Approaches Settlements by March 2008 (1.5 yrs)

Settlements, mm

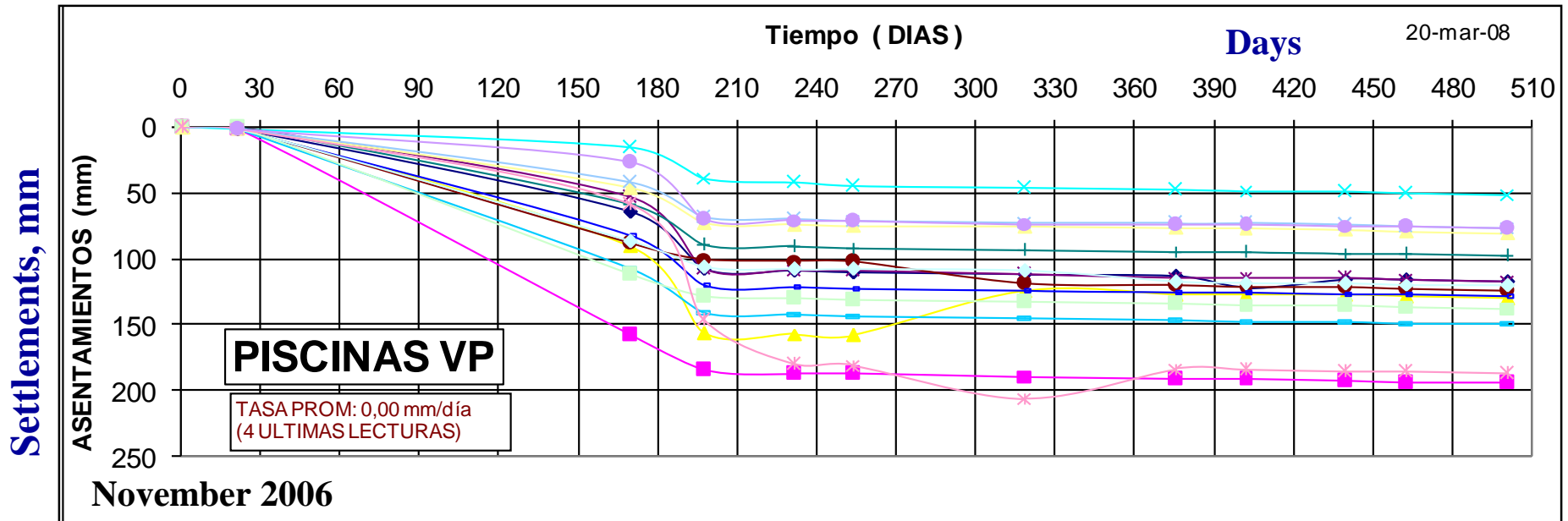


6.0 cm (2.4 inches)

Settlements, mm

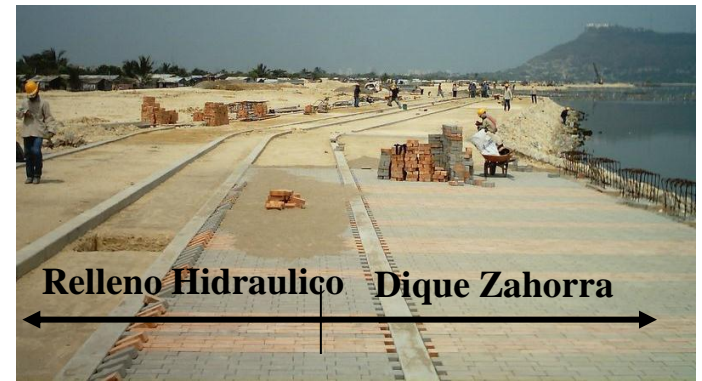
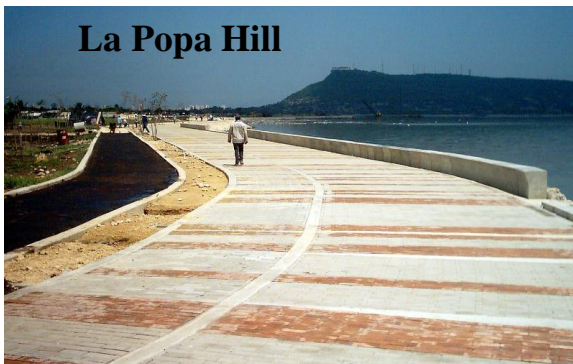
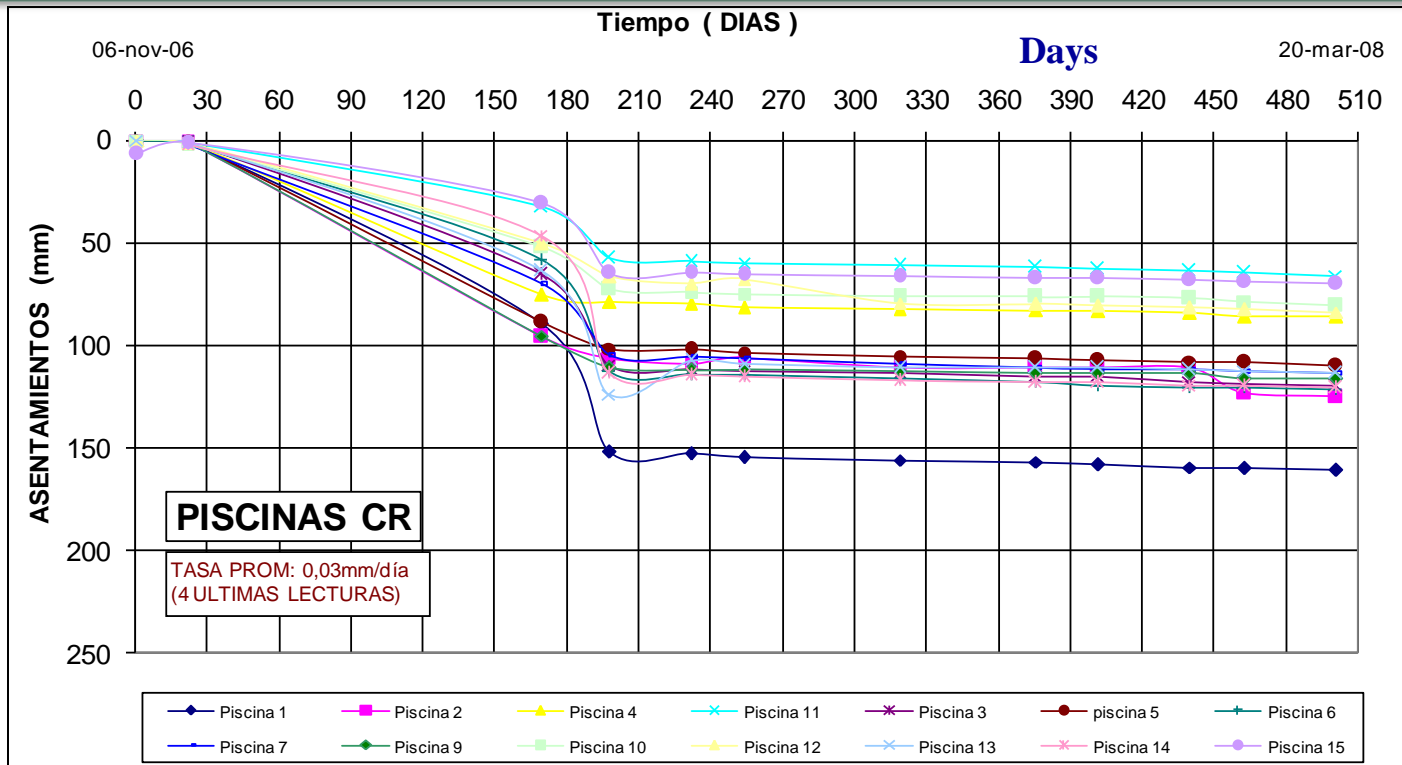


PERIMETER ROAD SETTLEMENTS



SIDEWALK DIKE SETTLEMENTS

Settlements, mm



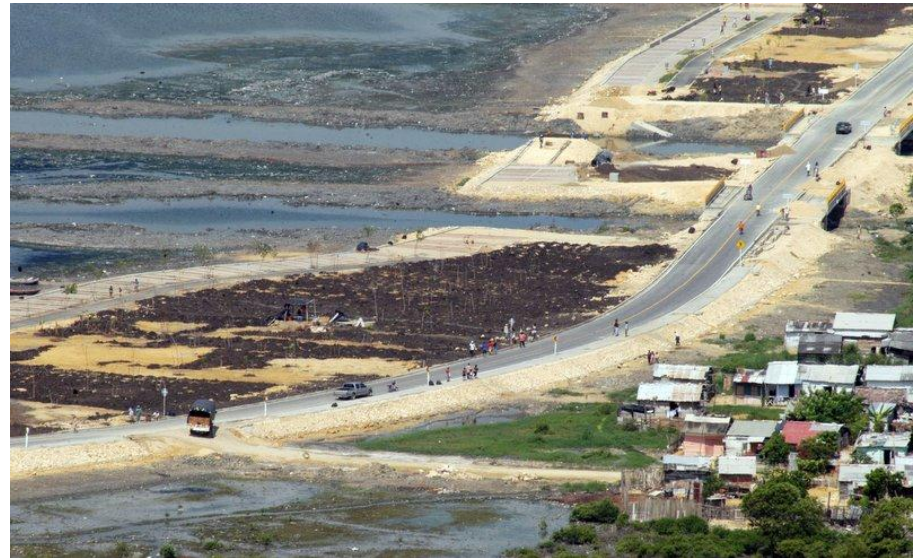
Recommendations Project Maintenance



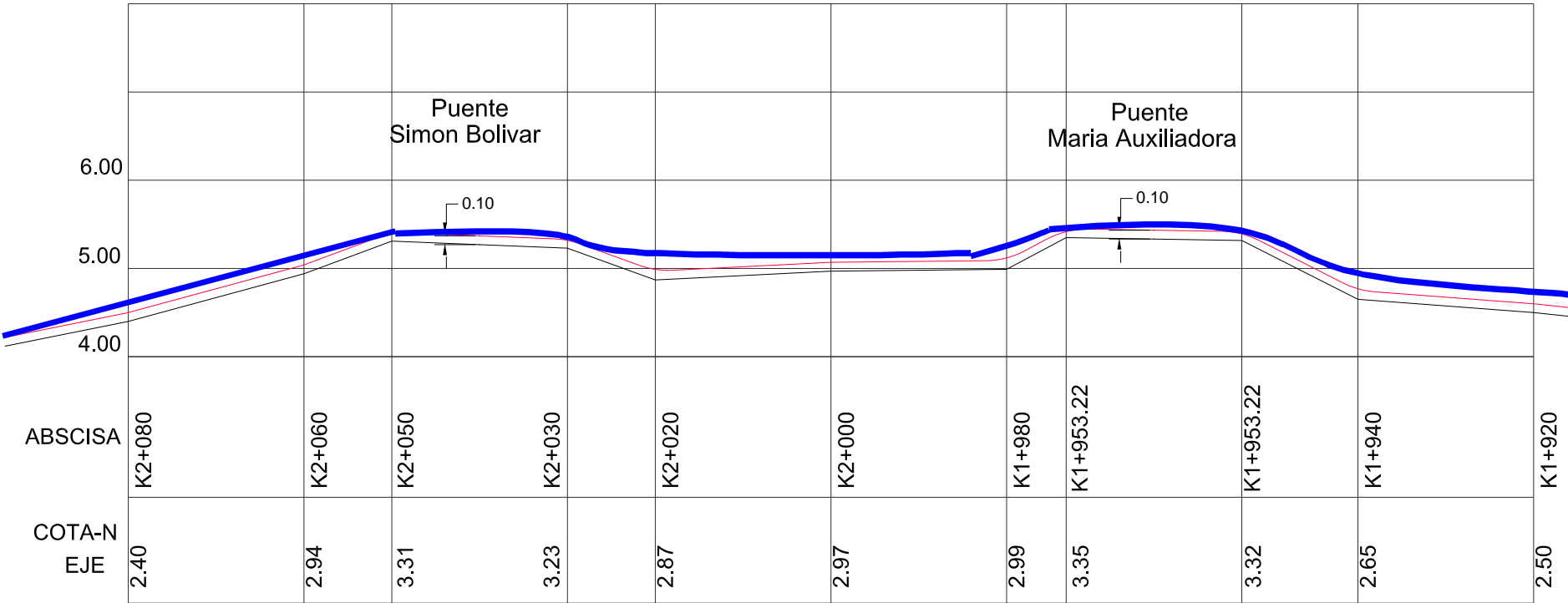
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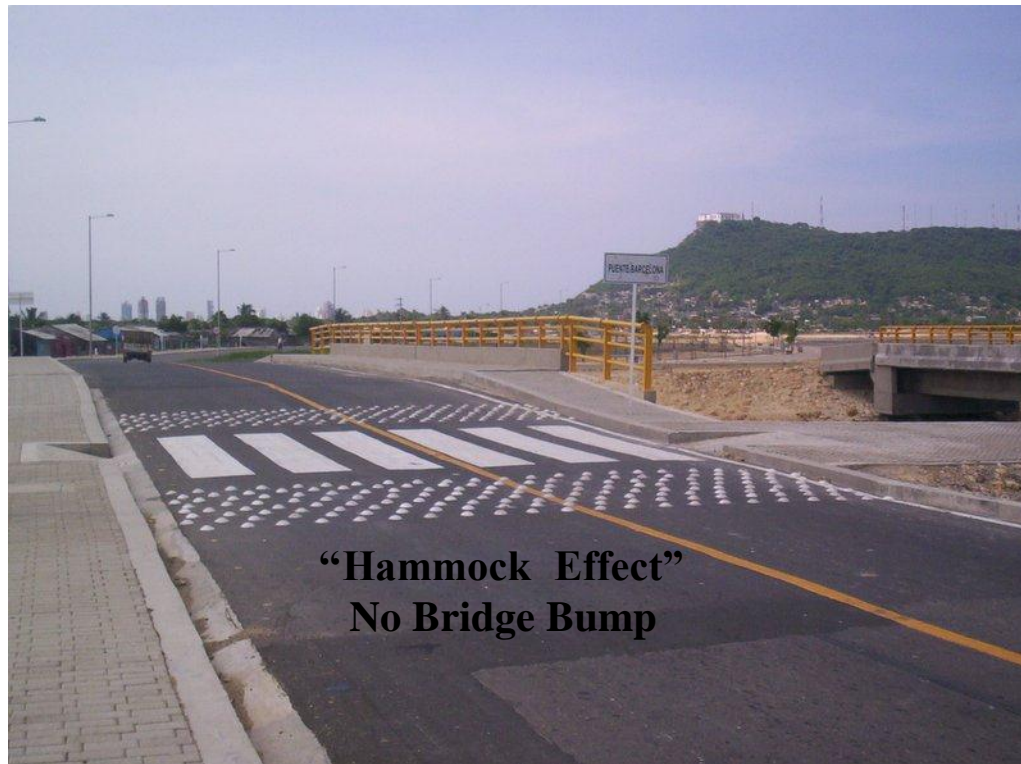
**Sand-Asphalt Mix (SAM)
Flexible Mix**



Perimeter Road Asphalt Overlay Plan



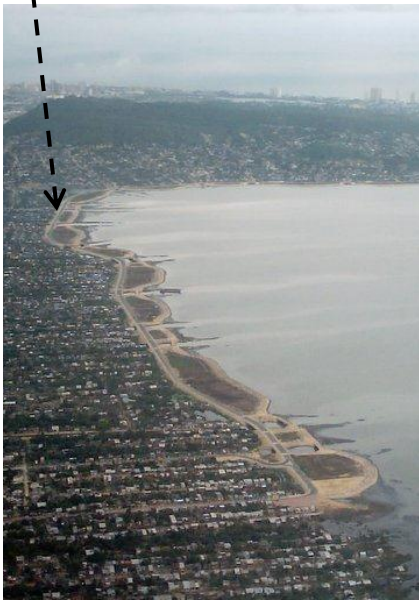
Barcelona Bridge Asphalt Overlay Completed



Some Recent Project Photos (late 2011)



Child' Social Garden



CONCLUSIONS

- **La Virgen Sound and Social Environment Recuperation**
- **Geotechnical Challenges: Case Model, Interpretation and Construction**
- **Team Work within Institutions to Accomplish Goals**
- **Real Scale Lab: Instrumentation System and Insitu Large Scale Tests**
- **Continued Project Follow Up and On Time Instrumentation System Interpretation allowed Predicting Embankments and Dikes Behaviour**



SPECIAL ACKNOWLEDGEMENTS

(Order does not change importance...)

- **Alcaldía Mayor de Cartagena de Indias**
- **Fonade y Coldeportes**
- **Unión Temporal Bating**
- **Consorcio Rellenos Vía Perimetral**
- **Topógrafos del Caribe**
- **Sociedad Colombiana de Geotecnia**
- **Colegas Geotecnistas “Grupo de Sabios”:**
 - Ing. Luis Pombo**
 - Ing. Álvaro I. Covo T.**
 - Ing. Jaime Bateman D.**
- **C.I.C. Consultores S.A.**
- **Others that I may have forgotten.....**



Via Perimetral Cienaga de la Virgen – Cartagena Indias

- **Recuperation of La Virgen Sound**
- **Improvement of City Road Connectivity**
- **Urban Renovation**
- **Creation of a Public Promenade (Alameda)**



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