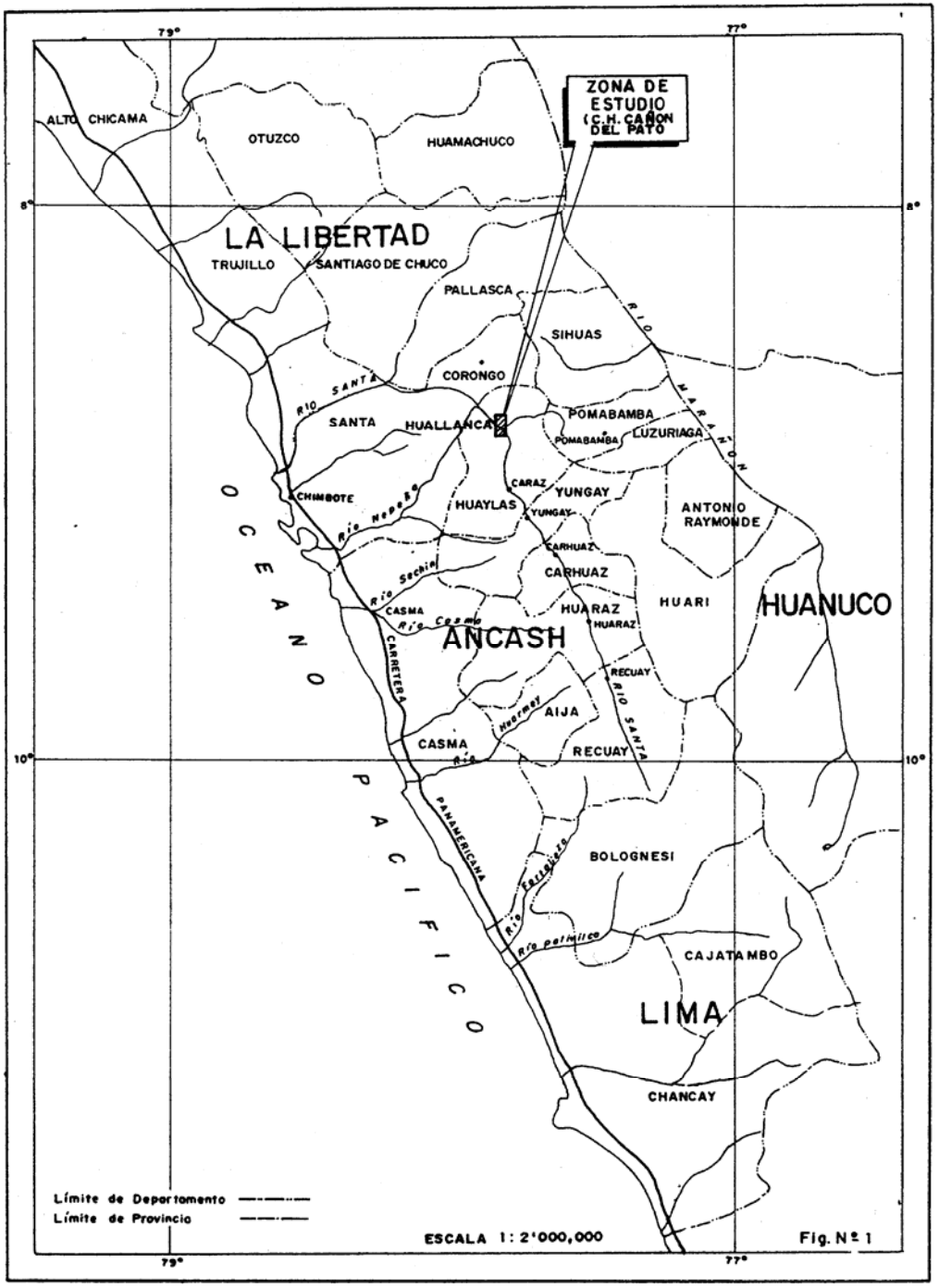
SLOPE STABILIZATION AT CANON DEL PATO HYDROELECTRIC PROJECT, PERU – PART 1: BACKGROUND AND SITE STUDIES

Malcolm F. Schaeffer
Devine Tarbell & Associates, Inc.
Charlotte, NC

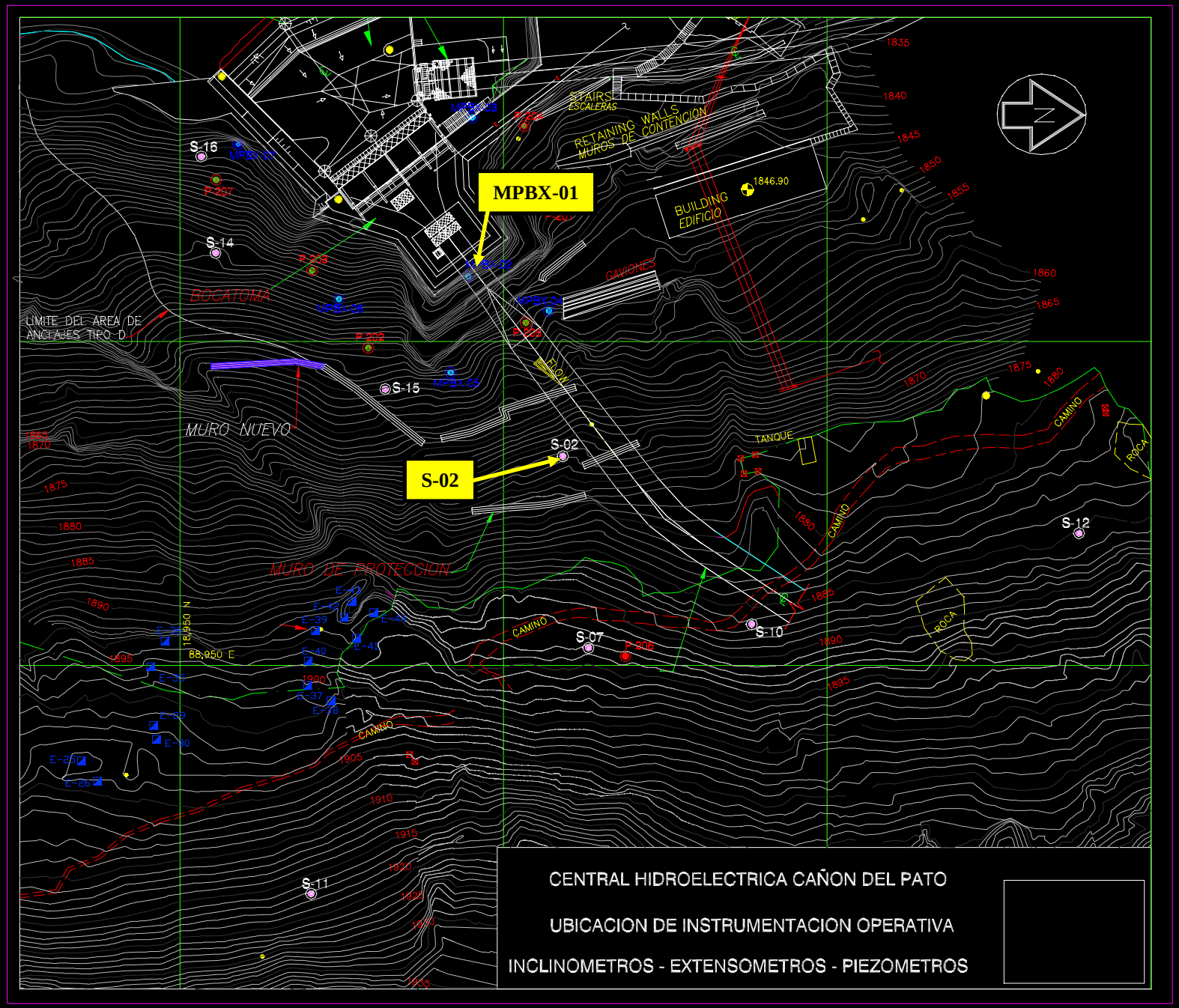
30/11/98 Bocatoma - Vista de la excavación después del deslizamiento.


ZONA DE ESTUDIO (C.H. CAÑON DEL PATO)
79°
77°
8°
10°
ALTO CHICAMA
OTUZCO
HUAMACHUCO
LA LIBERTAD
TRUJILLO
SANTIAGO DE CHUCO
PALLASCA
SIHUAS
CORONGO
RIO SANTA
SANTA
HUALLANCA
POMABAMBA
LUZURIAGA
RIO MARAÑON
CHIMBOTE
Río Nepeña
HUAYLAS
CARAZ
YUNGAY
ANTONIO RAYMONDE
CARHUAZ
Río Sechín
CASMA
Río Casma
HUARAZ
HUARI
HUANUCO
ANCASH
CARRETERA
RECUAY
RIO SANTA
Huarmey
AIJA
CASMA
Río
RECUAY
OCEANO PACIFICO
PANAMERICANA
BOLOGNESI
Río Fortaleza
Río Pativilca
CAJATAMBO
LIMA
CHANCAY
Límite de Departamento
Límite de Provincia
ESCALA 1: 2'000,000
Fig. Nº 1

Phase I

- <u>September 1998 to March 2000</u>
  - Construction of the Complementary Intake Structure
    - A-Anchor Installation
    - Drainage Holes
    - Initial Instrumentation Installed – Piezometers, Inclinometers, and Extensometers

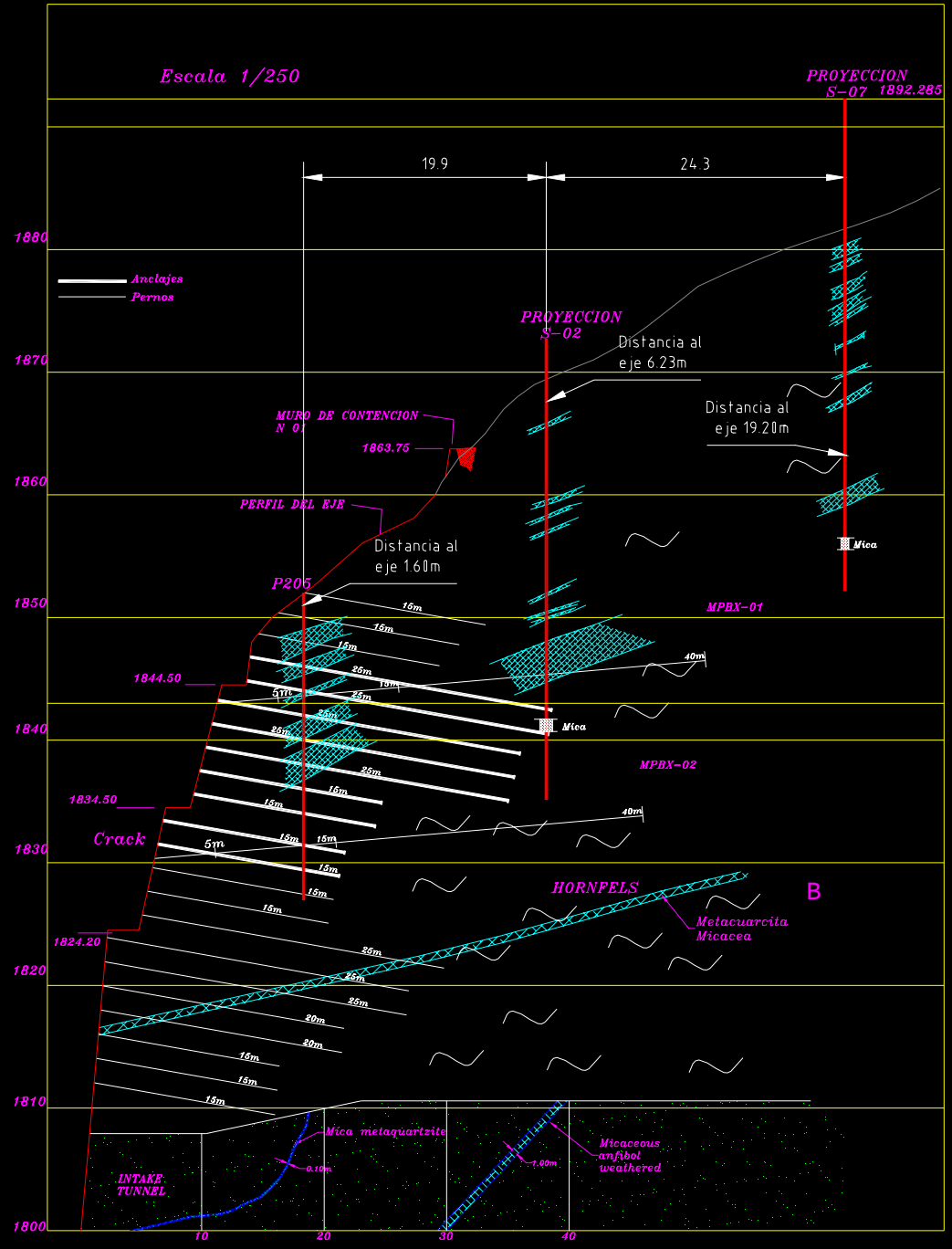
8 Trabajos en **Túnel Principal** y Túnel de **Purga**. Observamos **Grua Gigante**

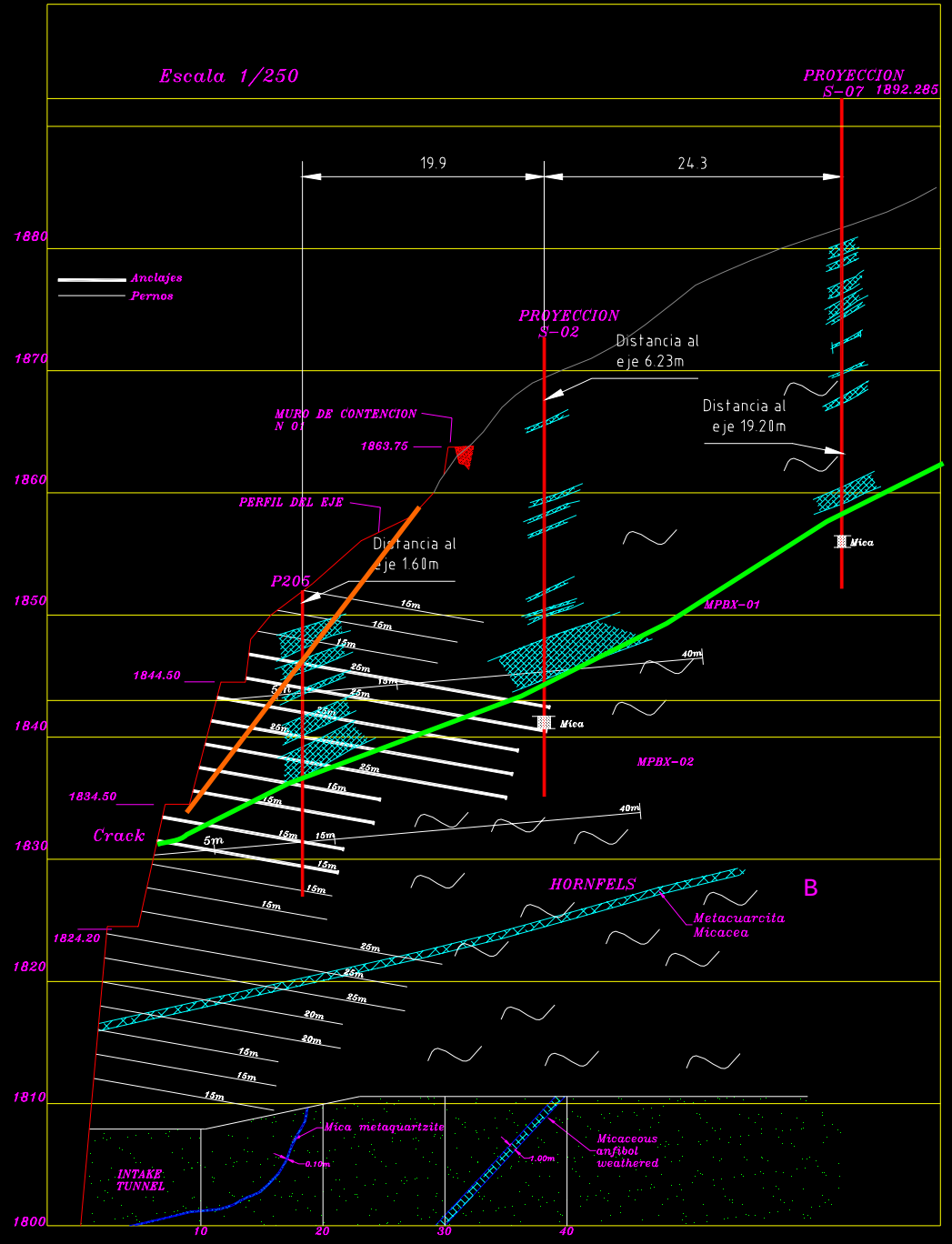


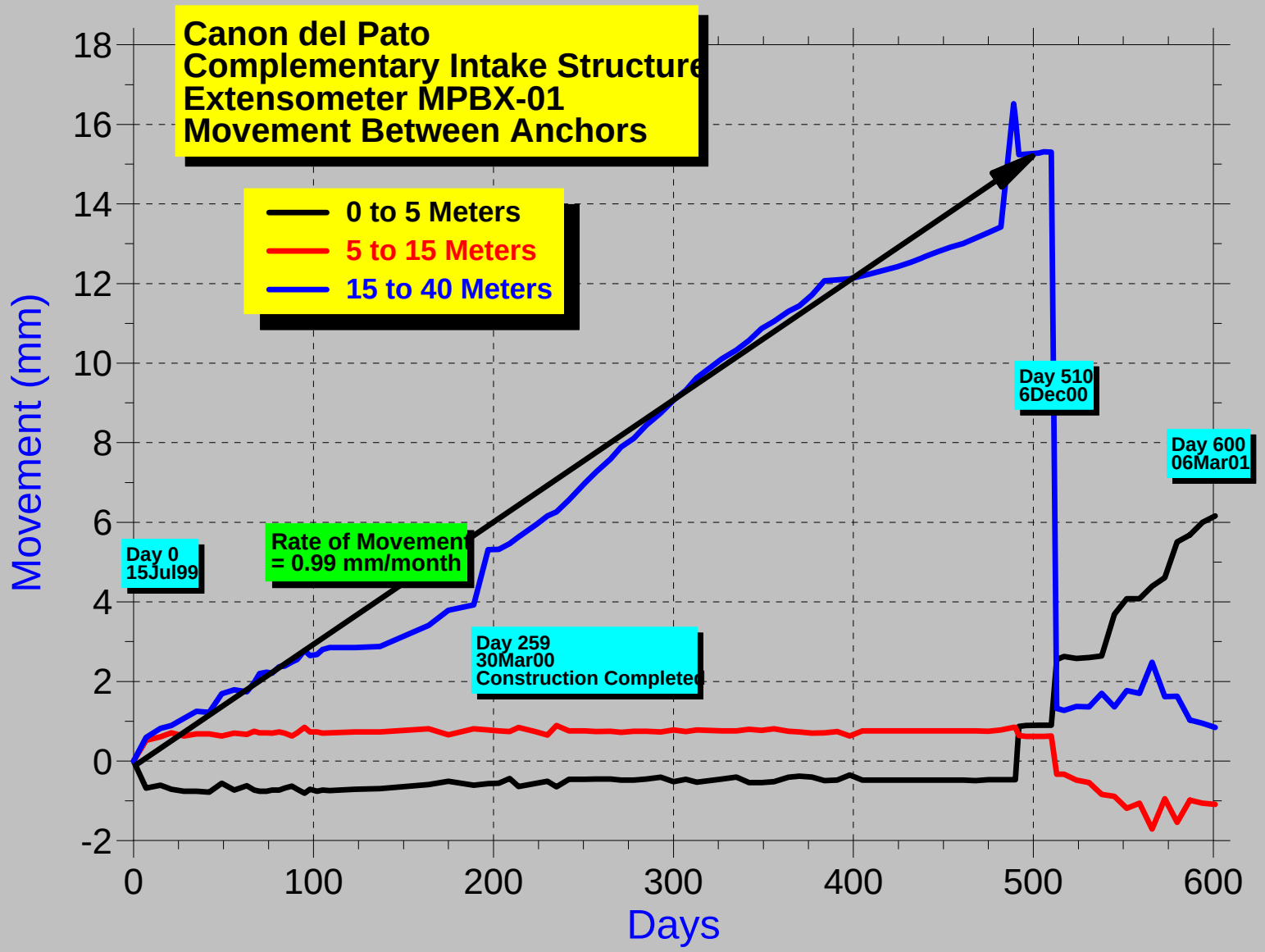
CENTRAL HIDROELECTRICA CAÑON DEL PATO

UBICACION DE INSTRUMENTACION OPERATIVA

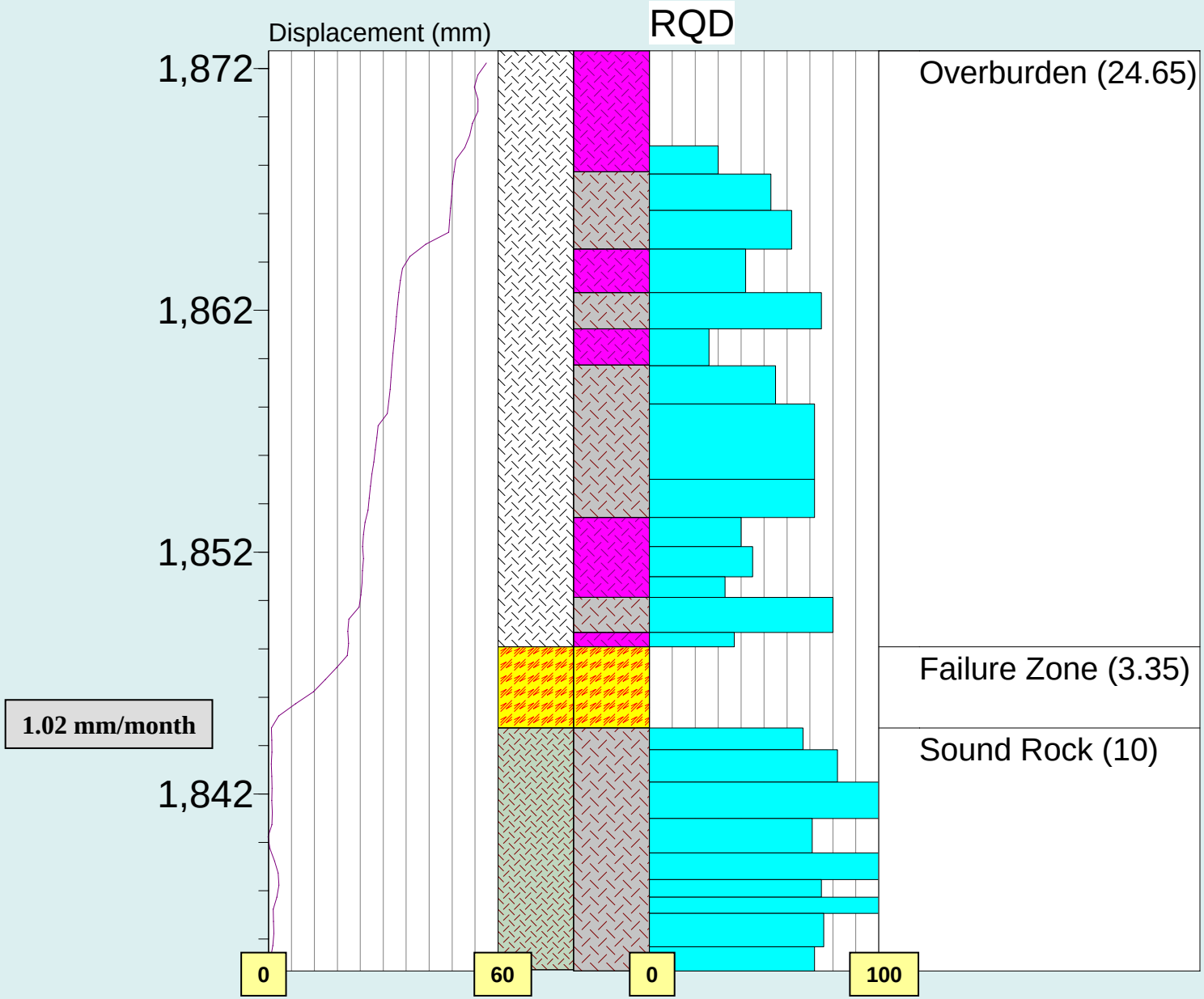
INCLINOMETROS - EXTENSOMETROS - PIEZOMETROS


Escala 1/250
PROYECCION
S-07 1892.285
19.9
24.3
1880
1870
1860
1850
1840
1830
1820
1810
1800
Anclajes
Pernos
PROYECCION
S-02
Distancia al
eje 6.23m
Distancia al
eje 19.20m
MURO DE CONTENCION
N 01
1863.75
PERFIL DEL EJE
Distancia al
eje 1.60m
P205
Mica
MPBX-01
MPBX-02
1844.50
1834.50
1824.20
Crack
HORNFELS
B
Metacuarcita
Micacea
INTAKE
TUNNEL
Mica metaquartzite
0.10m
1.00m
Micaceous
anfibol
weathered
10
20
30
40


Escala 1/250
PROYECCION
S-07 1892.285
19.9
24.3
1880
1870
1860
1850
1840
1830
1820
1810
1800
Anclajes
Pernos
PROYECCION
S-02
Distancia al
eje 6.23m
Distancia al
eje 19.20m
MURO DE CONTENCION
N 01
1863.75
PERFIL DEL EJE
Distancia al
eje 1.60m
P205
1844.50
1834.50
1824.20
Crack
5m
15m
25m
20m
40m
Mica
MPBX-01
MPBX-02
HORNFELS
Metacuarcita
Micacea
B
INTAKE
TUNNEL
Mica metaquartzite
0.10m
1.00m
Micaceous
anfibol
weathered
10
20
30
40


Canon del Pato
Complementary Intake Structure
Extensometer MPBX-01
Movement Between Anchors
0 to 5 Meters
5 to 15 Meters
15 to 40 Meters
Day 0
15Jul99
Rate of Movement
= 0.99 mm/month
Day 259
30Mar00
Construction Completed
Day 510
6Dec00
Day 600
06Mar01
Movement (mm)
Days
18
16
14
12
10
8
6
4
2
0
-2
0
100
200
300
400
500
600

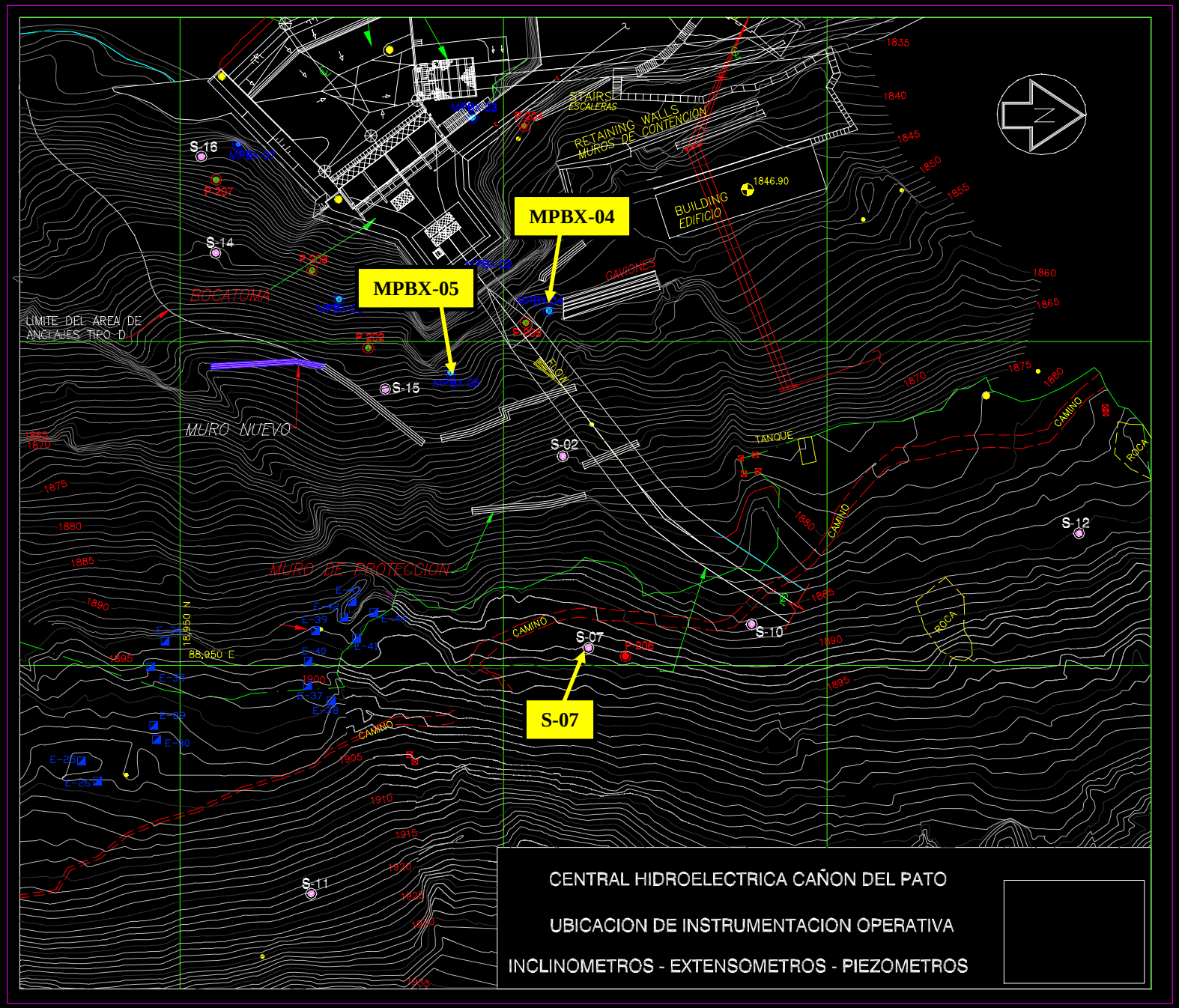
S02


Displacement (mm)
RQD
1,872
1,862
1,852
1,842
Overburden (24.65)
Failure Zone (3.35)
Sound Rock (10)
1.02 mm/month
0
60
0
100

Phase II

- <u>April 2000 to January 2001</u>
  - Design and Installation of Cable Anchors (C-Anchors) and Additional Instrumentation

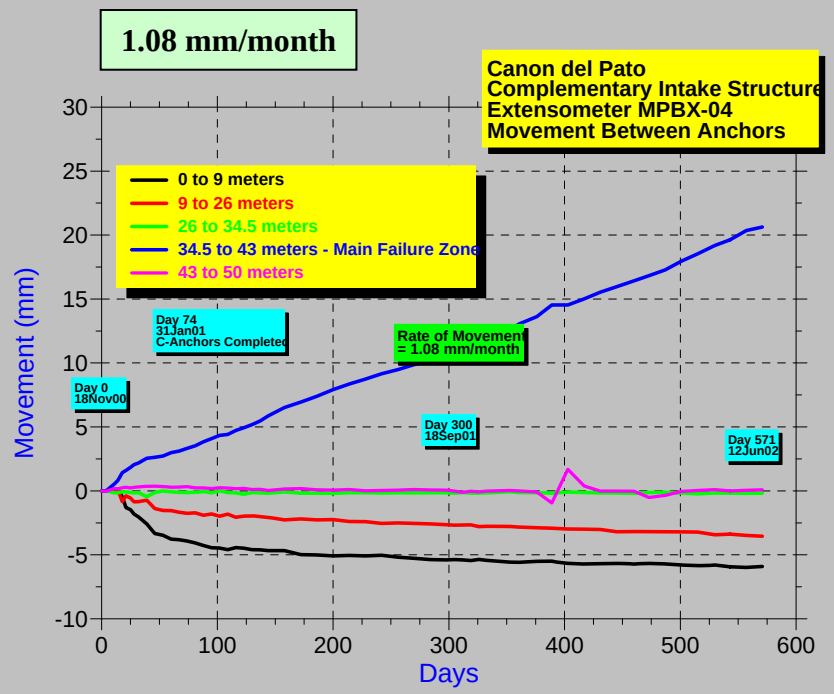

C-Anchors
46 Anchors @ 135 Tonnes (60% GUTS)
Total Working Load = 6210 Tonnes
22. 8. 2001



CENTRAL HIDROELECTRICA CAÑON DEL PATO

UBICACION DE INSTRUMENTACION OPERATIVA

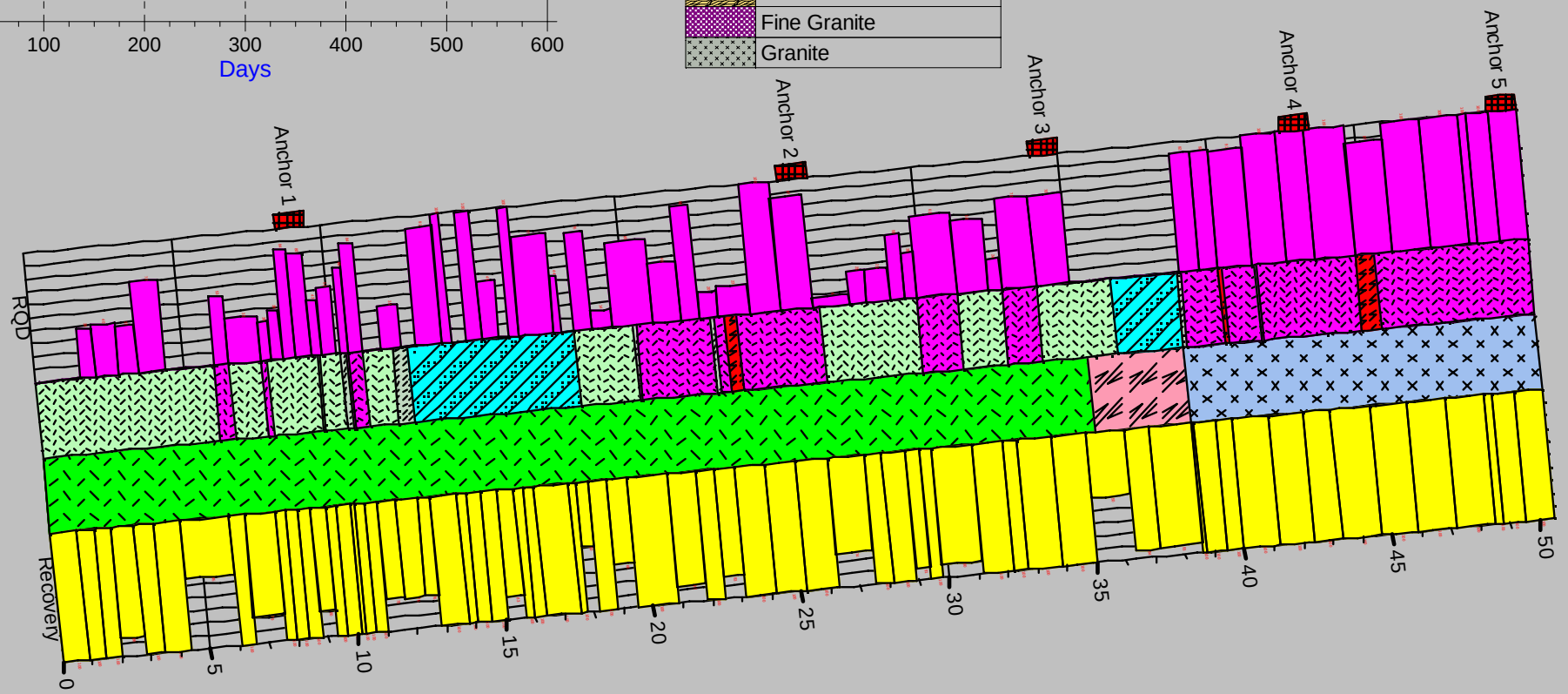
INCLINOMETROS - EXTENSOMETROS - PIEZOMETROS



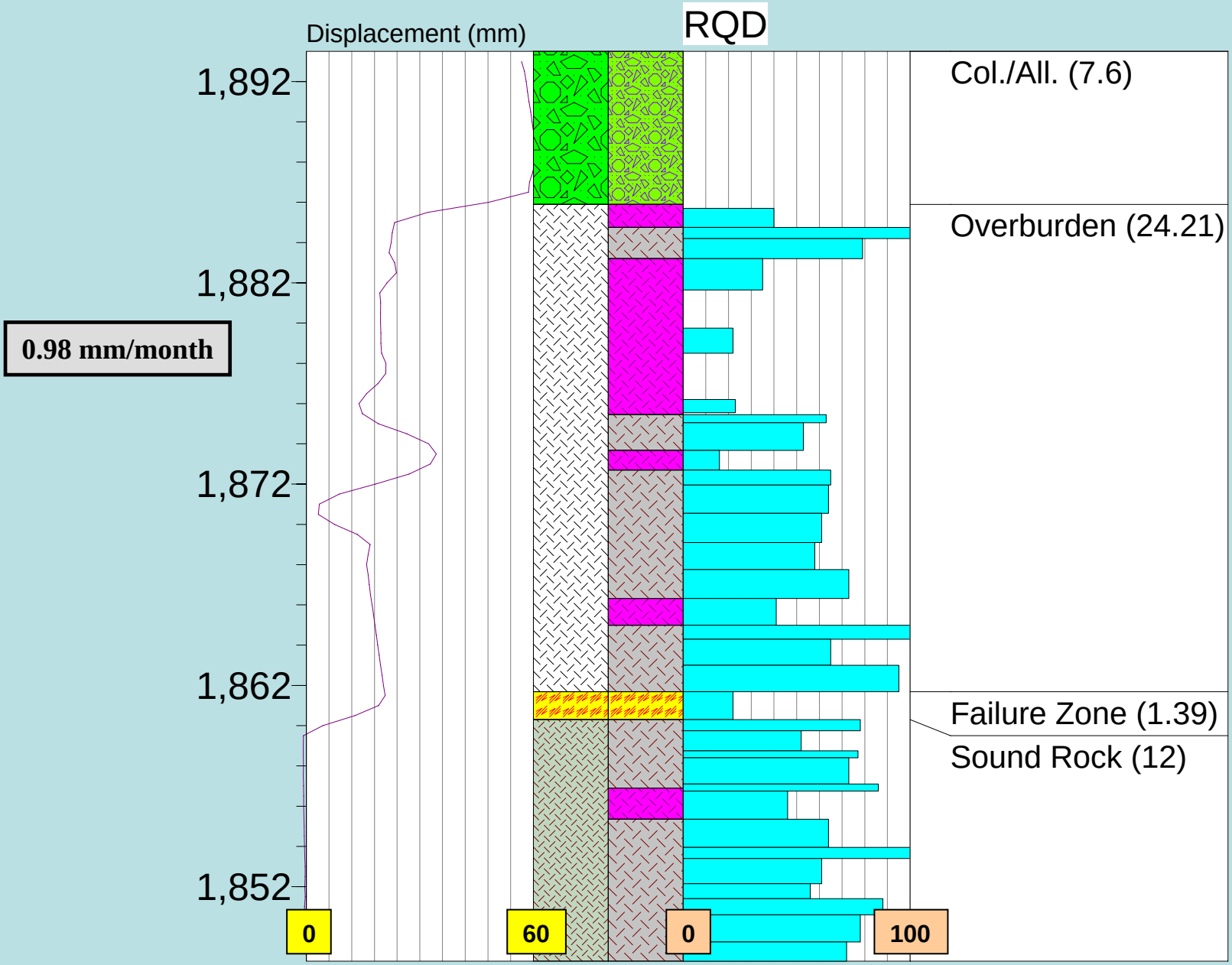
Explanation

- Fill
- Alluvium
- Colluvium
- VOID
- FAULT
- Breccia
- Hornfels-Wea/Frac
- Hornfels
- Mica Schist
- Int Hornfels/Schist
- Sheared Hornfels/Schist
- Pegmatite
- Mica Quartzite-Wea/Frac
- Mica Quartzite
- Quartzite
- Sheared Mica Schist
- Fine Granite
- Granite

MPBX-04



S07


Displacement (mm)
RQD
1,892
1,882
1,872
1,862
1,852
0.98 mm/month
0
60
0
100
Col./All. (7.6)
Overburden (24.21)
Failure Zone (1.39)
Sound Rock (12)

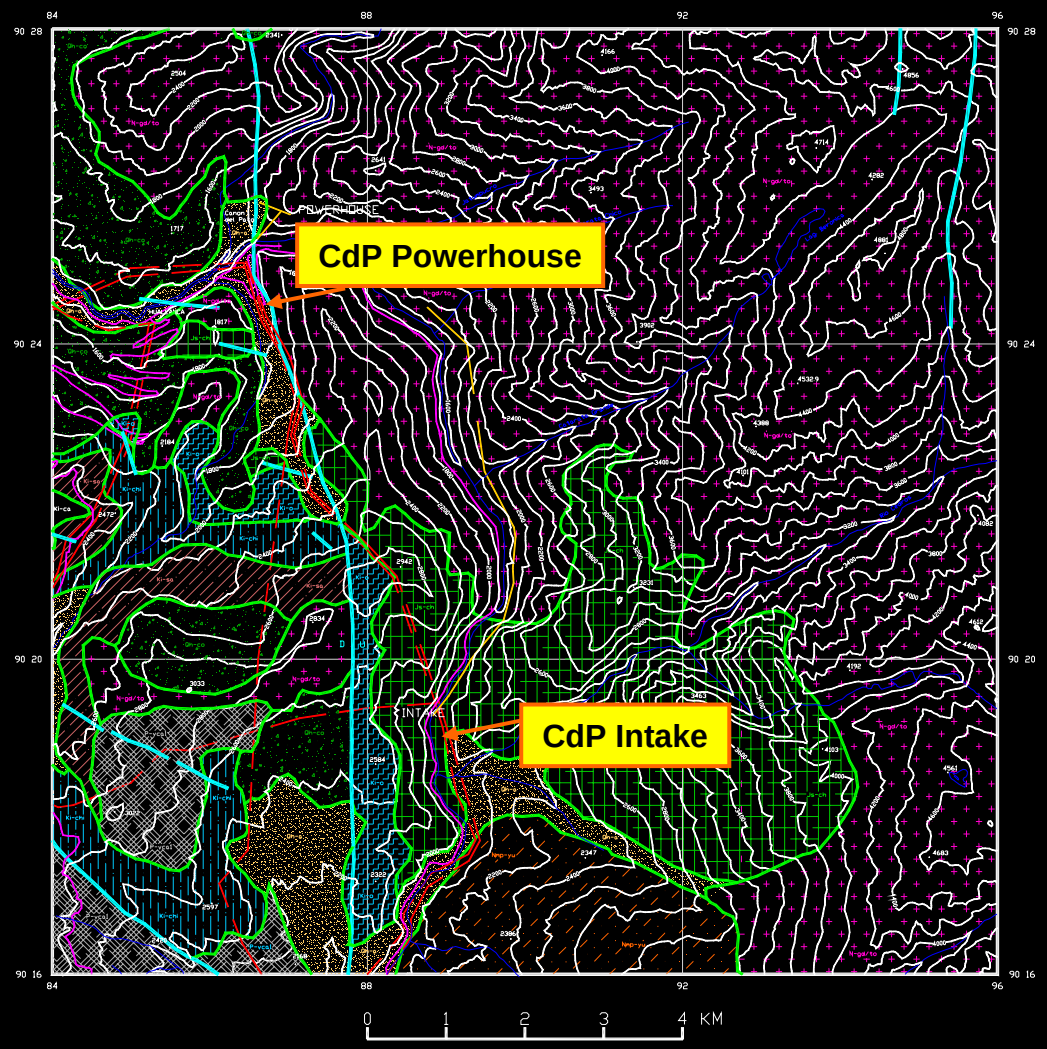
Phase III

- **<u>August 2001 to February 2002</u>**
  - **Geological/Geotechnical Investigation**

Phase III

- Crack Mapping – Concrete & Shotcrete
- Review of All Previous Geological and Geotechnical Work
- Air Photo Interpretation
- Boreholes with Inclinometers (7)
- Seismic Refraction Lines (1460 meters)
- Geologic Mapping
- Lift-Off Tests on A- and C-Anchors


A-Anchors
#10 Rock Bolts
1. 5. 2002



GEOLOGIC MAP OF THE VICINITY OF THE CANON DEL PATO HYDROELECTRIC PLANT, PERU

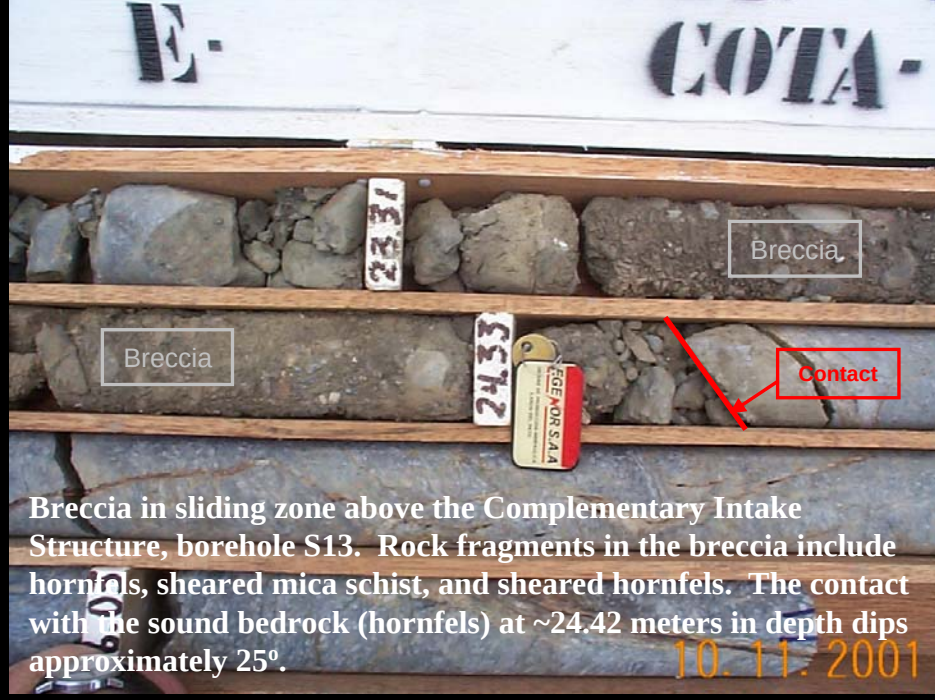
EXPLANATION

- ALLUVIUM.
- COLLUVIUM.
- YUNGAY FORMATION. Volcanic, pyroclastic rocks, primarily dacitic in composition.
- CORDILLERA BLANCA BATHOLITH. Granodiorite/Tonalite.
- CALIPUY FORMATION. Volcanic, pyroclastic rocks, agglomerates, lavas, and sub-volcanic intrusives. Rhyolitic-dacitic-andesitic composition.
- CARHUAZ FORMATION. Orthoquartzite with laminated silty shale and siltstone.
- SANTA FORMATION. Fossiliferous limestone with minor interbeds of laminated calcareous shale.
- CHIMU FORMATION. Orthoquartzite, conglomeritic in places, interbedded with subordinate beds of carbonaceous silty shale and coal seams.
- OYON FORMATION. Subgraywacke shale with interbedded carbonaceous and calcarous shale and coal seams.
- CHICAMA FORMATION. Shale with interbedded fine-grained sandstone. Metamorphosed near the Cordillera Blanca Batholith to hornfels and quartzite.
- D U Cordillera Blanca Fault - Normal.
- OTHER FAULTS.
- CONTACT.
- CONTOUR. 200 meter interval.
- ROAD.
- TUNNEL.
- TRANSMISSION LINE

Geology from: INGEMMET Bulletin No. 60, 1995.

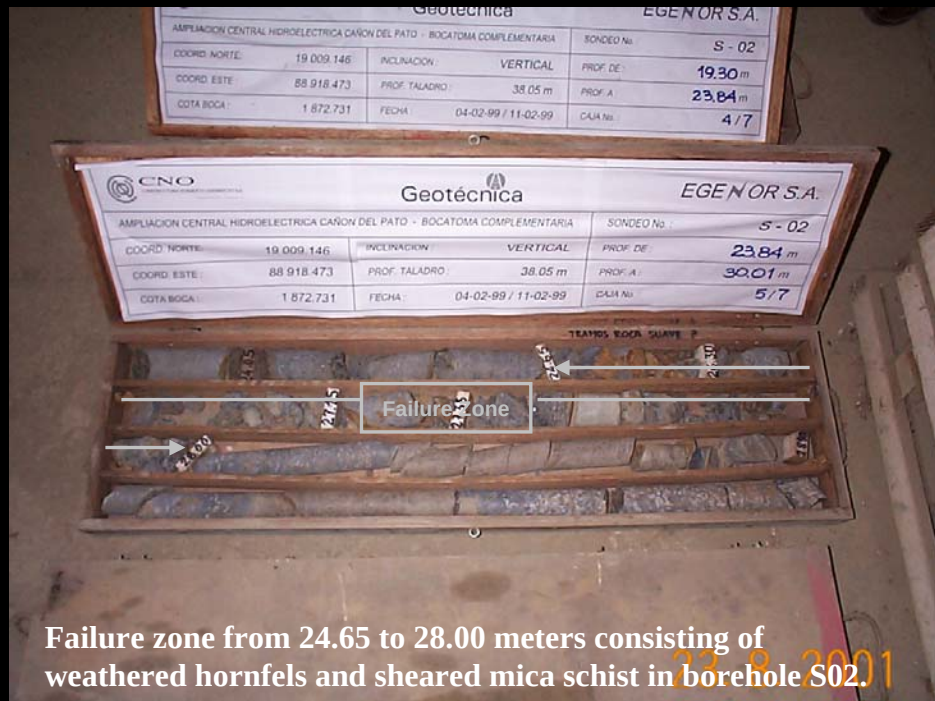
Figure 3

Sheared hornfels/mica schist, highly weathered and damp, along the failure surface in the south wall of the intake excavation. Note extensive cracking of the shotcrete.



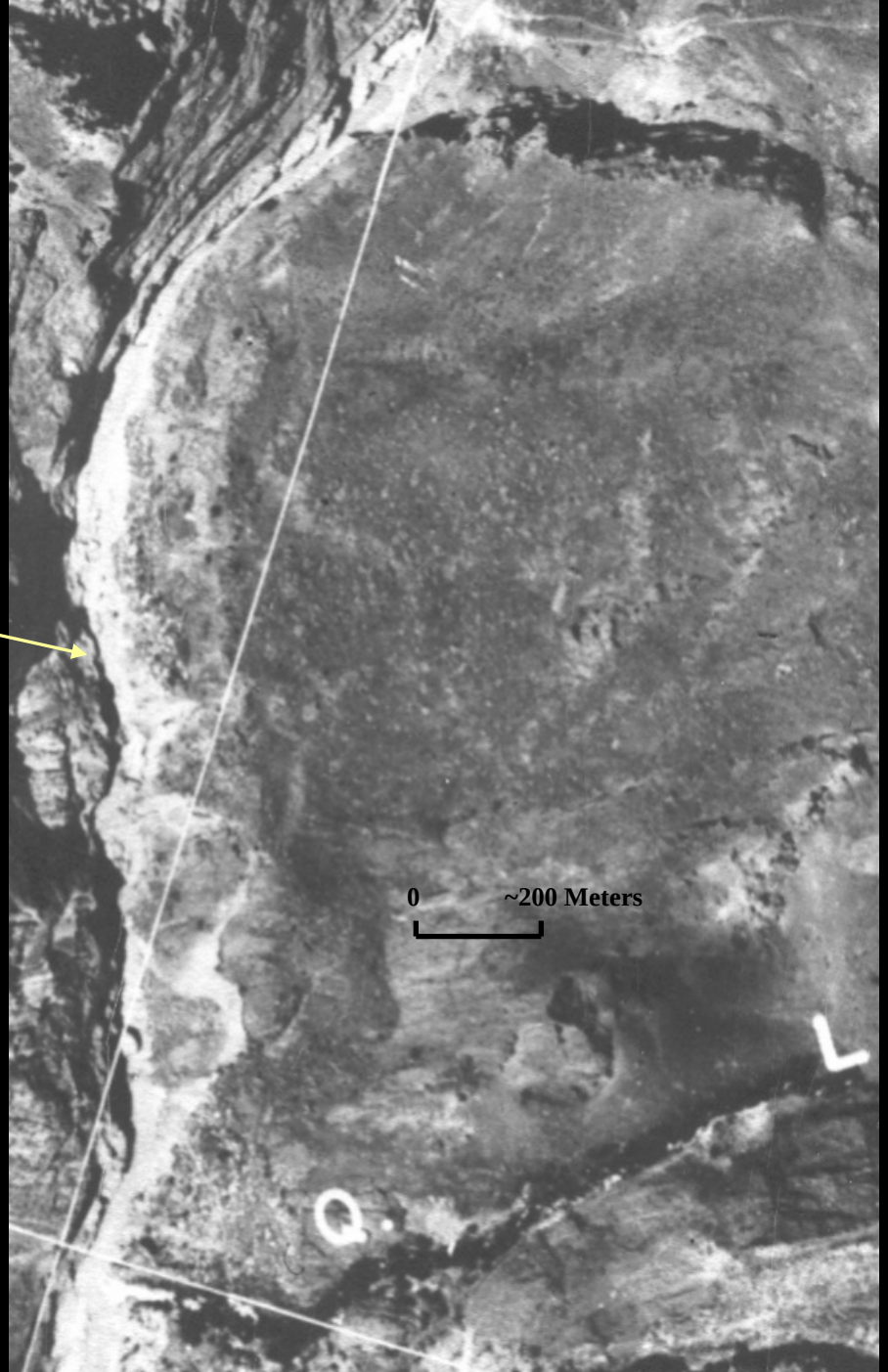
Breccia in sliding zone above the Complementary Intake Structure, borehole S13. Rock fragments in the breccia include hornfels, sheared mica schist, and sheared hornfels. The contact with the sound bedrock (hornfels) at ~24.42 meters in depth dips approximately 25º.

Photo 33: Failure zone from 21.23 to 22.10 meters consisting of weathered hornfels and sheared mica schist in borehole P207.

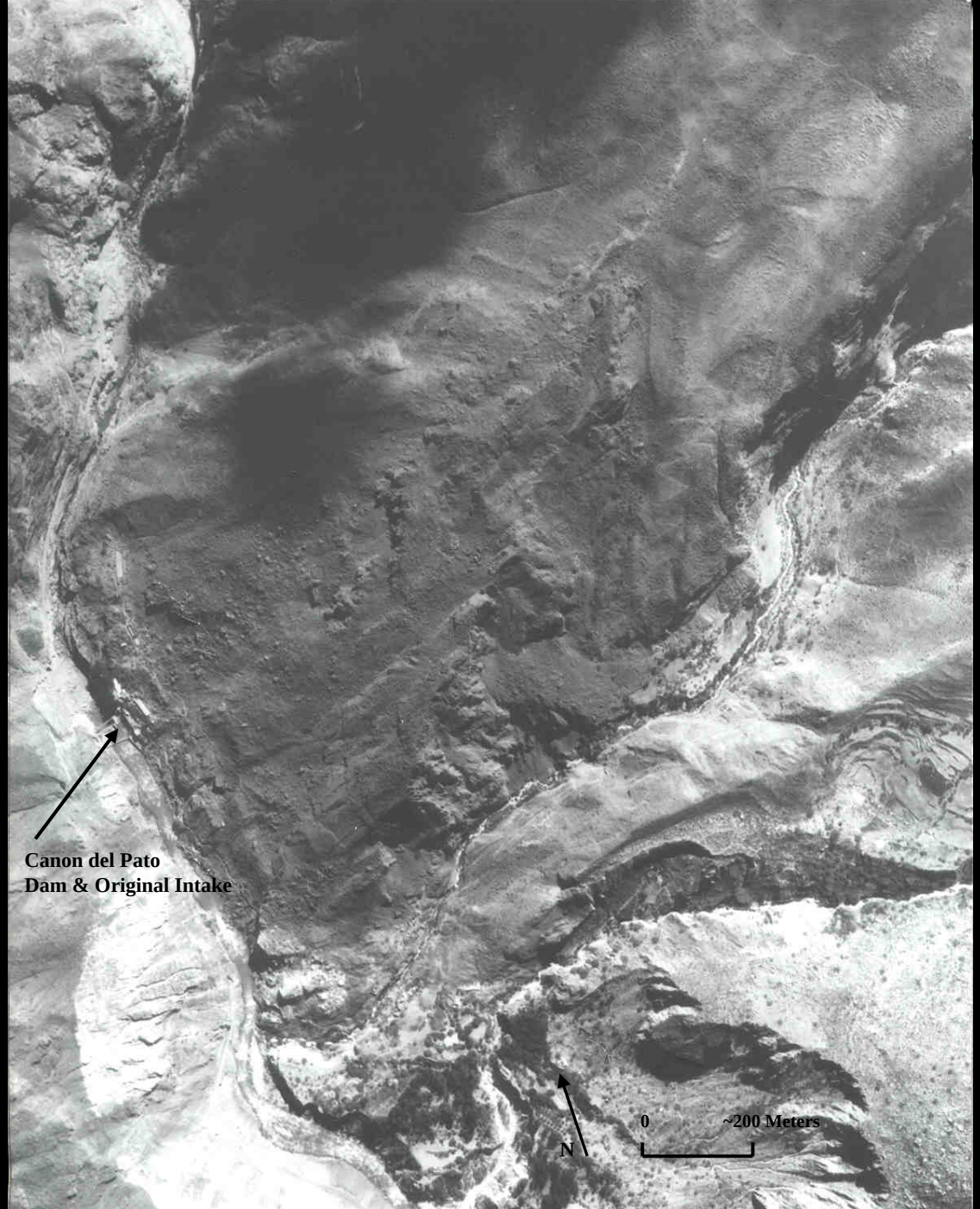


Failure zone from 24.65 to 28.00 meters consisting of weathered hornfels and sheared mica schist in borehole S02.

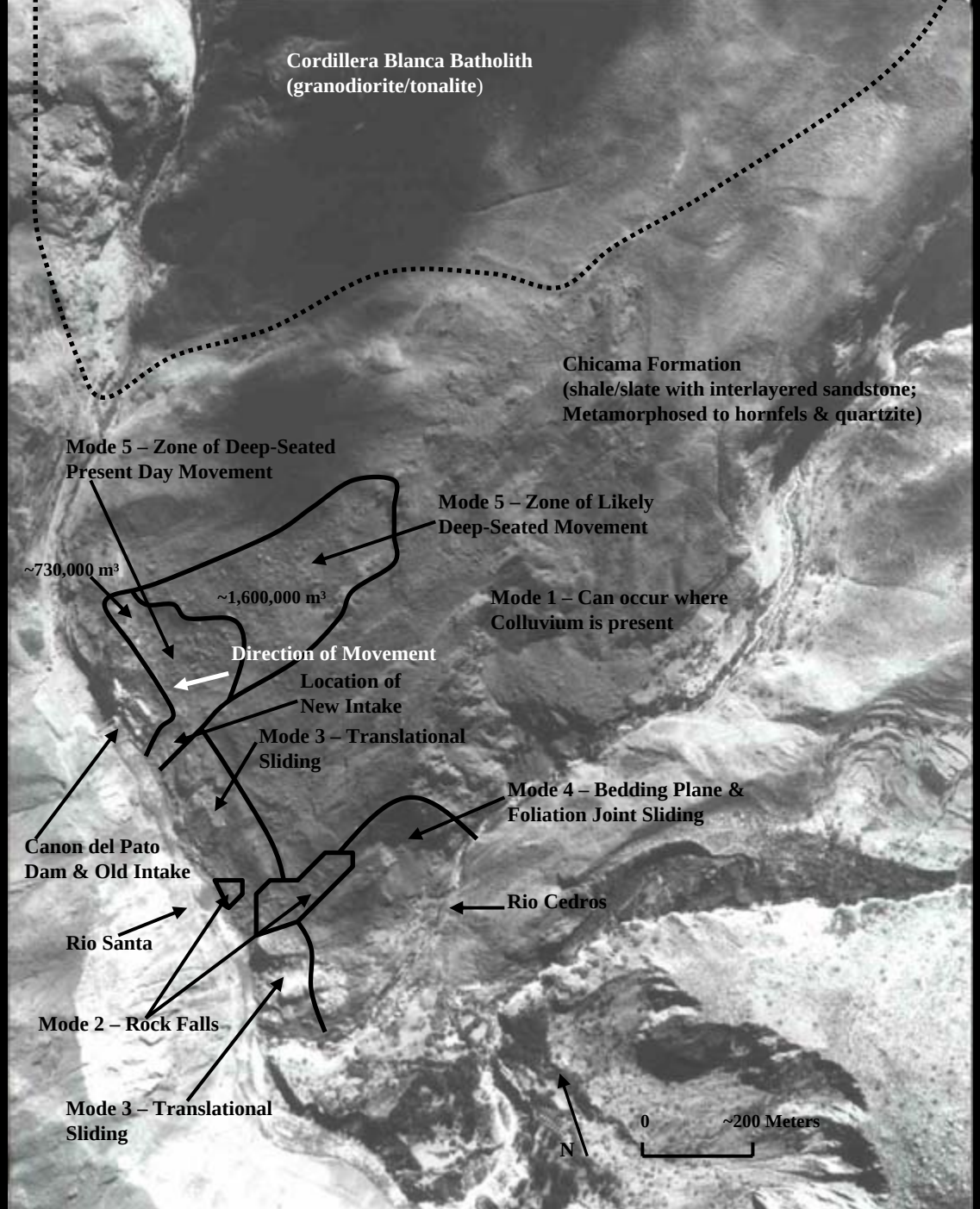
1942

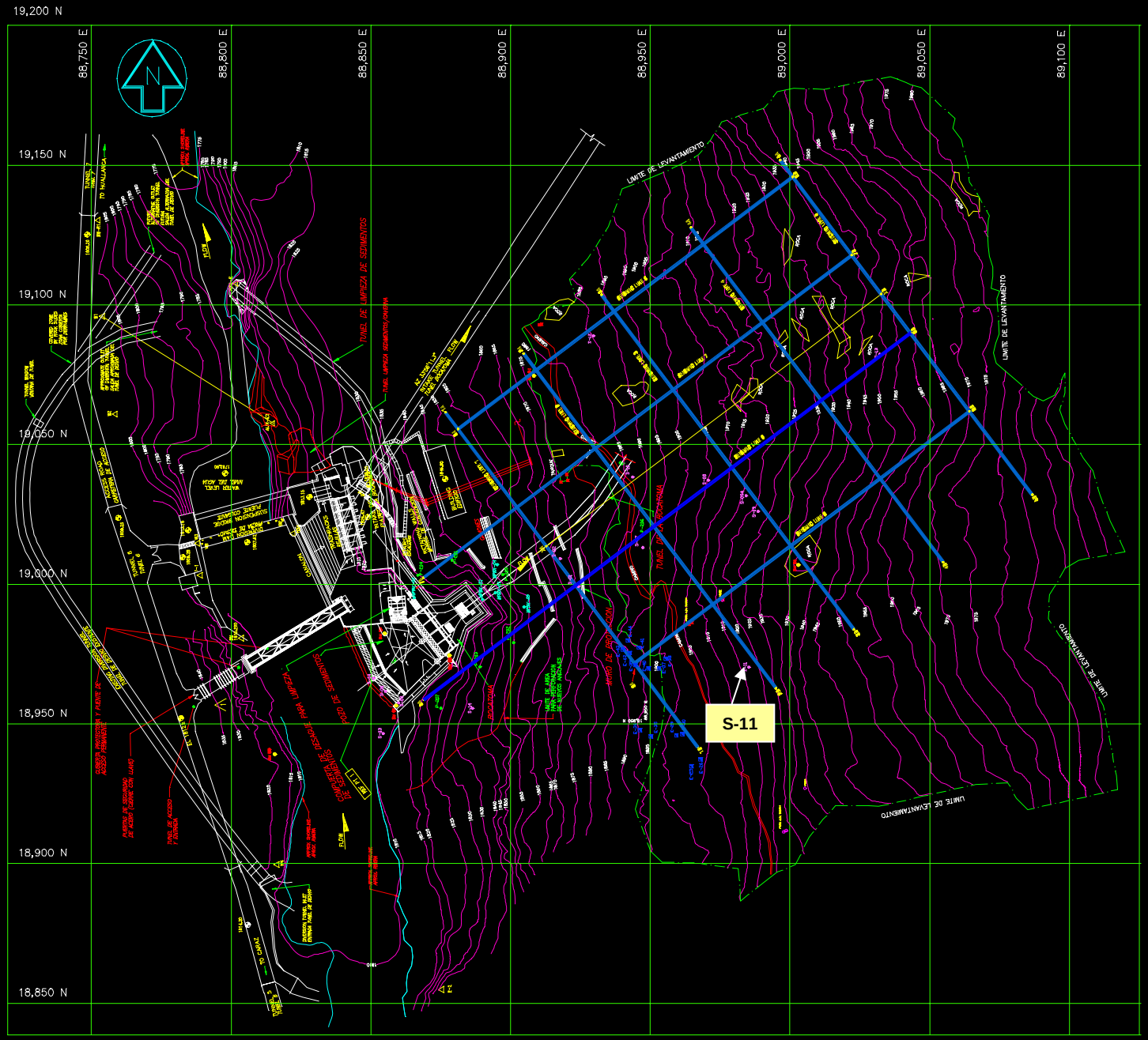

Future Location of
Canon del Pato
Dam & Original Intake
0
~200 Meters
L
Q.

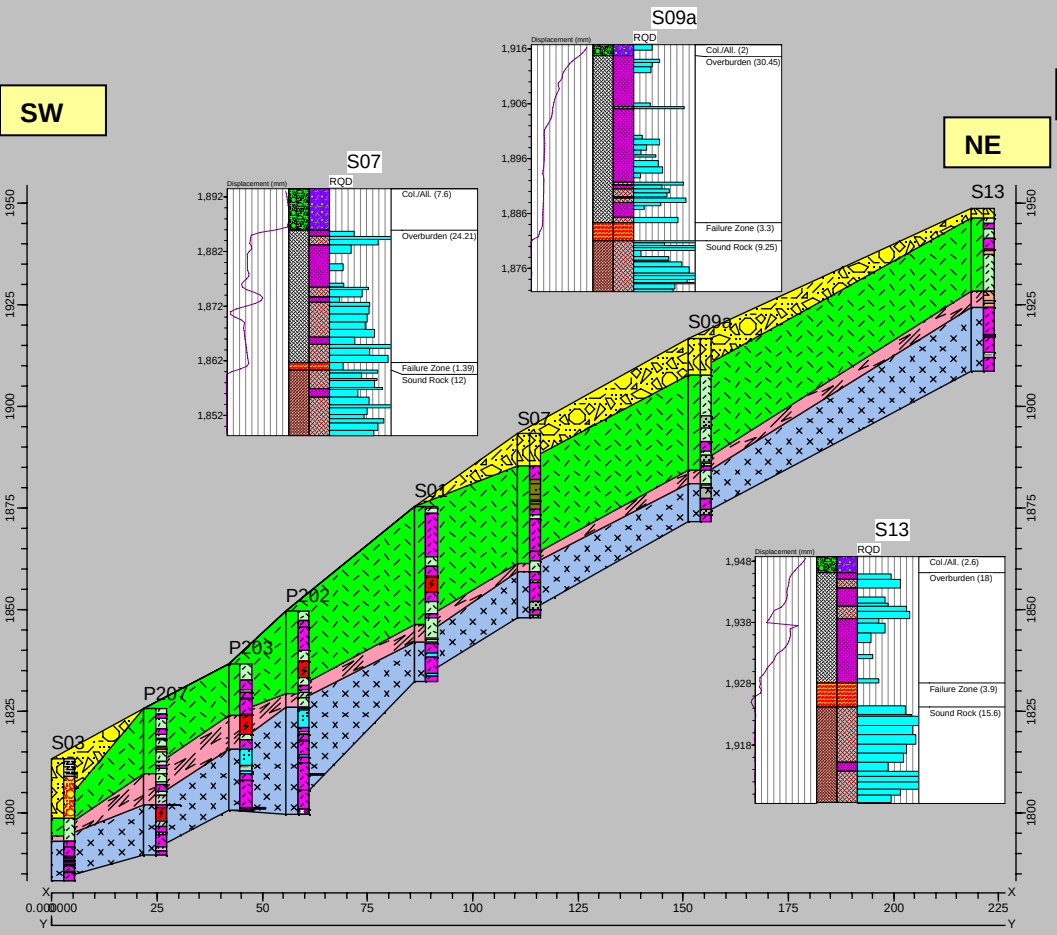
17/06/1997, 455-97-A,
23 Huaraz San, 6924

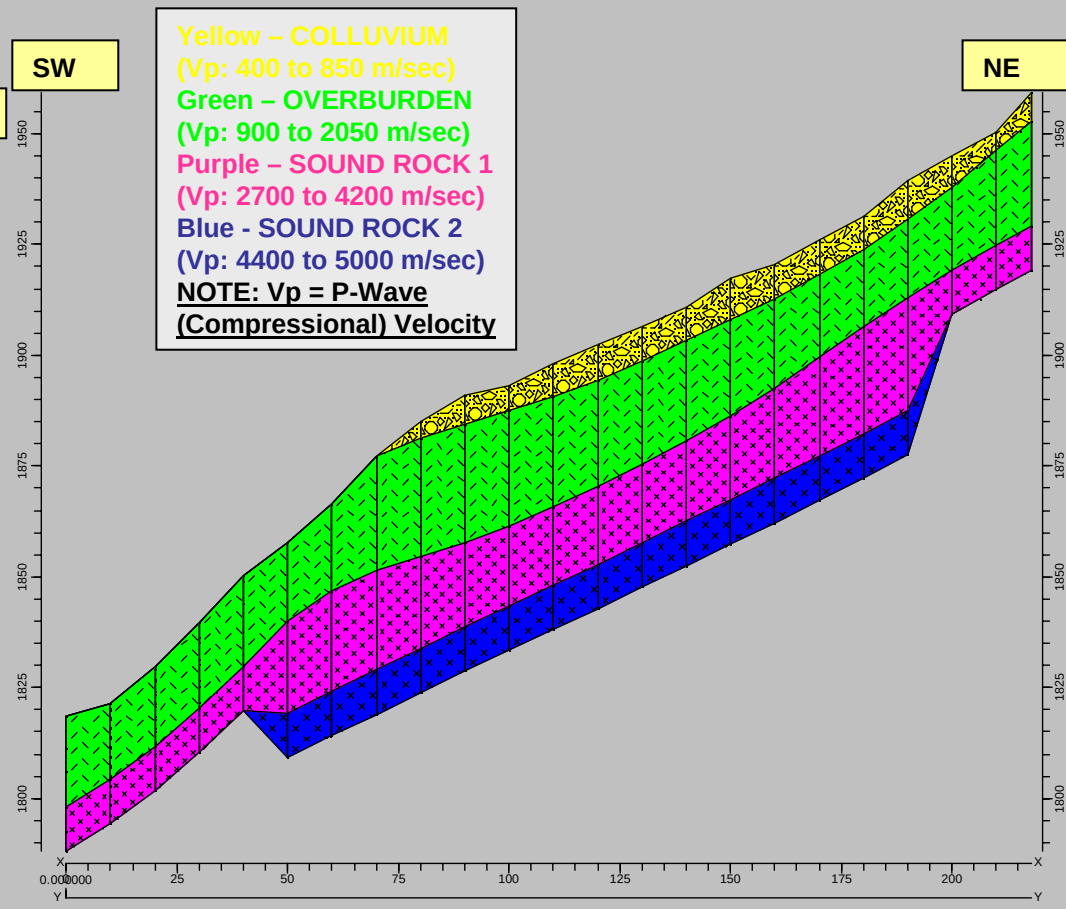


17/06/1997, 455-97-A,
23 Huaraz San, 6924




19,200 N
19,150 N
19,100 N
19,050 N
19,000 N
18,950 N
18,900 N
18,850 N
88,750 E
88,800 E
88,850 E
88,900 E
88,950 E
89,000 E
89,050 E
89,100 E
N
LIMITE DE LEVANTAMIENTO
LIMITE DE LEVANTAMIENTO
LIMITE DE LEVANTAMIENTO
LIMITE DE LEVANTAMIENTO
TUNEL DE LIMPIEZA DE SEDIMENTOS
TUNEL DE DESCARGA
S-11





Yellow – COLLUVIUM/ALLUVIUM/FILL
Green – OVERBURDEN
Pink – FAILURE ZONE
Blue – SOUND ROCK

Canon del Pato
Intake Slope
Geologic Section 3

Canon del Pato
Intake Slope
Seismic Section 8

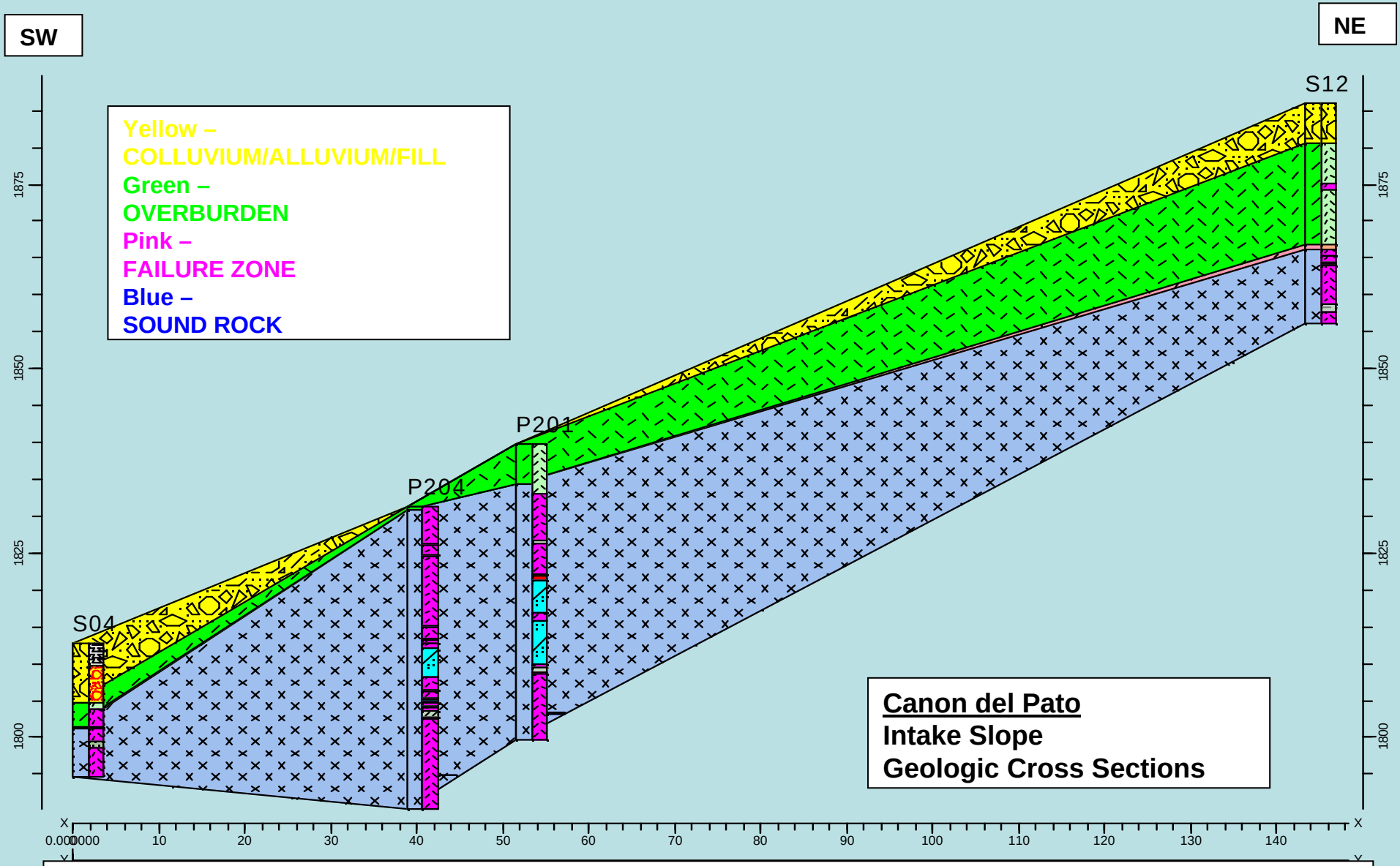


Figure 5: Geologic Section 1. Note that the Overburden is thin to not present in P201 and P204 and the Failure Zone is not present in either of these two borings. This is evidence that the area of potential sliding is not north of these borings at this location (see Drawing Geo-1 for this interpretation).

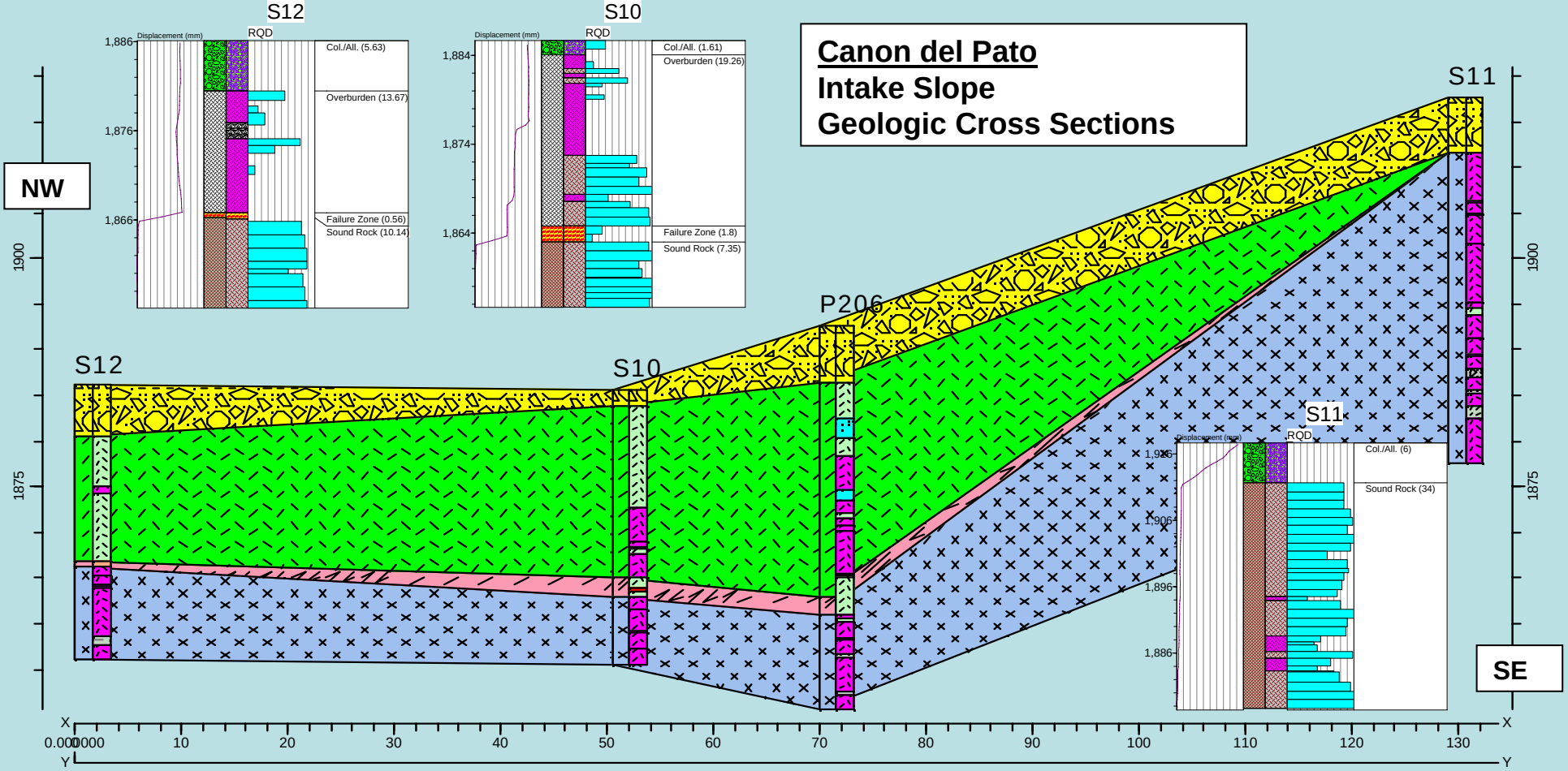


Figure 9: Geologic Section 5 – Note clear correlation of Overburden/Failure Zone from borehole S12 to P206. The failure zone is not present in S11. The computer program used to generate these cross-sections thins the failure zone from P206 to S11. The interpretation shown on the geologic map (Drawing Geo-1) and related cross-sections (Geo-8 and Geo-9) shows the failure zone truncated between P206 and S11 by a high angle fracture, probably related to the NE-striking joint set.

Yellow – COLLUVIUM/ALLUVIUM/FILL
Green – OVERBURDEN
Pink – FAILURE ZONE
Blue – SOUND ROCK

Photo 17: Slope above the dam and intake structure, looking southwest. Shows the contact (and contrast) between map units Hfc (hornfels with 0 to 2 meters colluvial cover) with Cu (2 to 5 meters of colluvium overlying hornfels) and Cy (Colluvium/Hornfels - area of movement). Note the larger rock blocks associated with unit Cy. Mode 5.

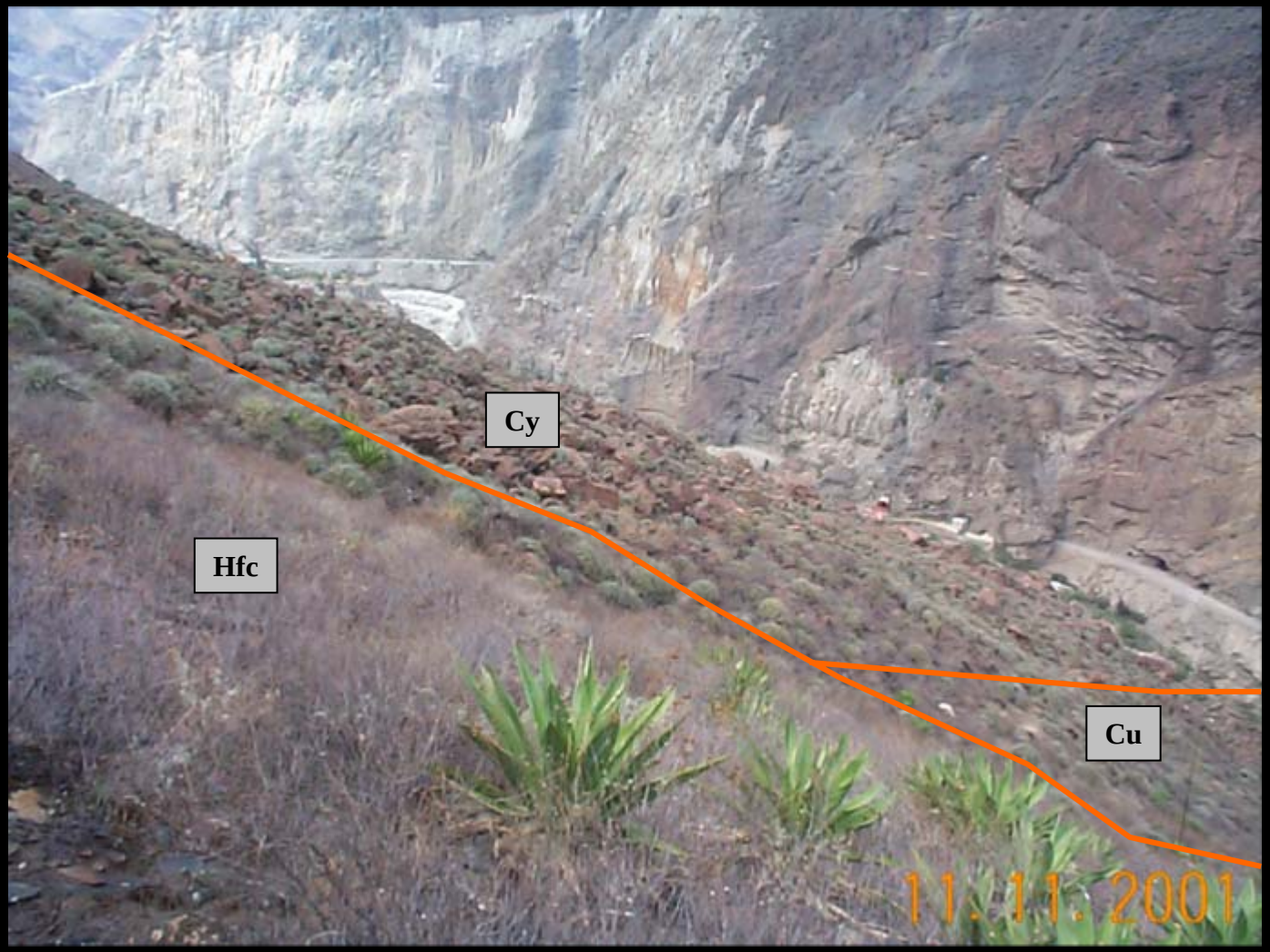
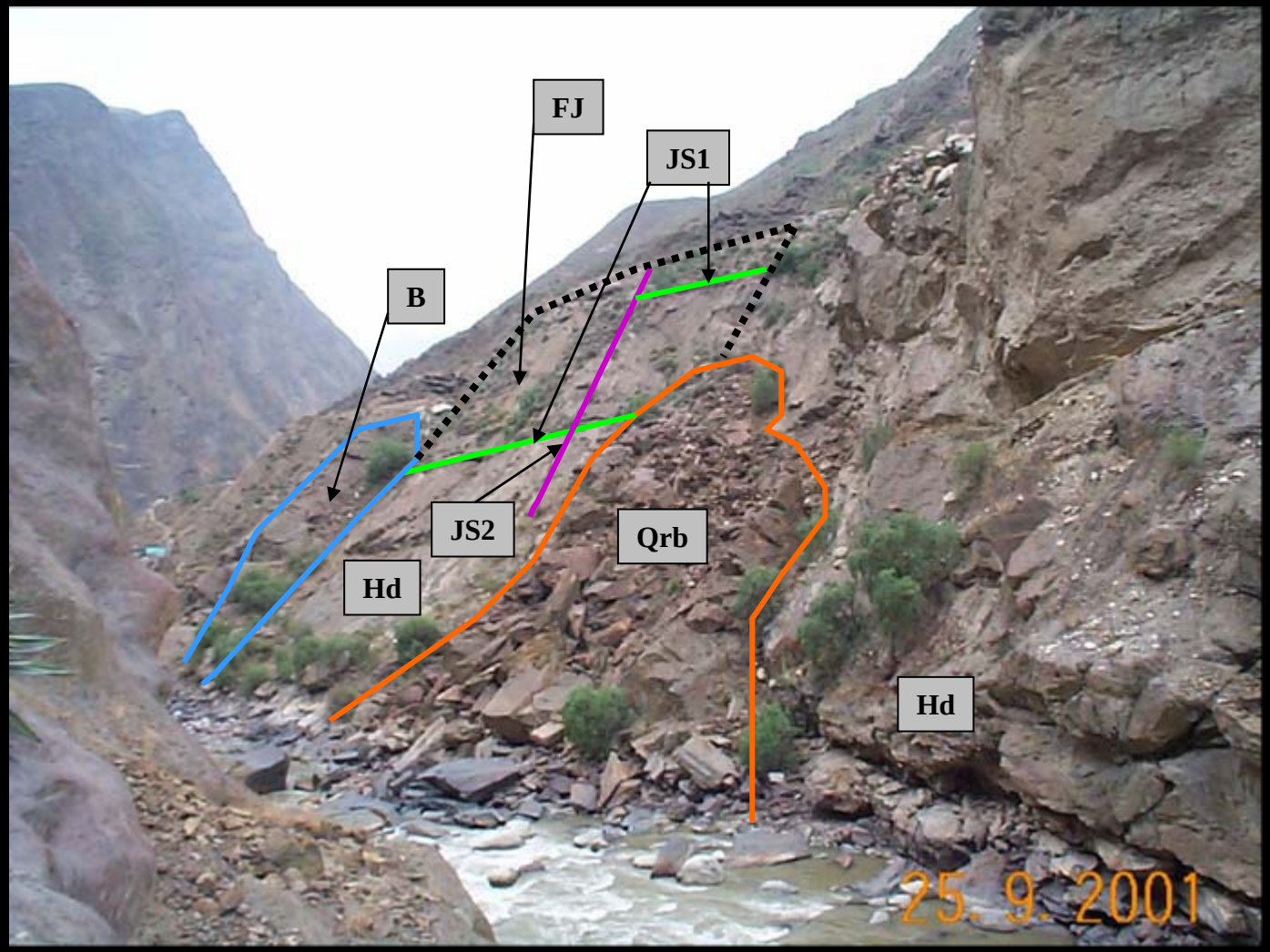
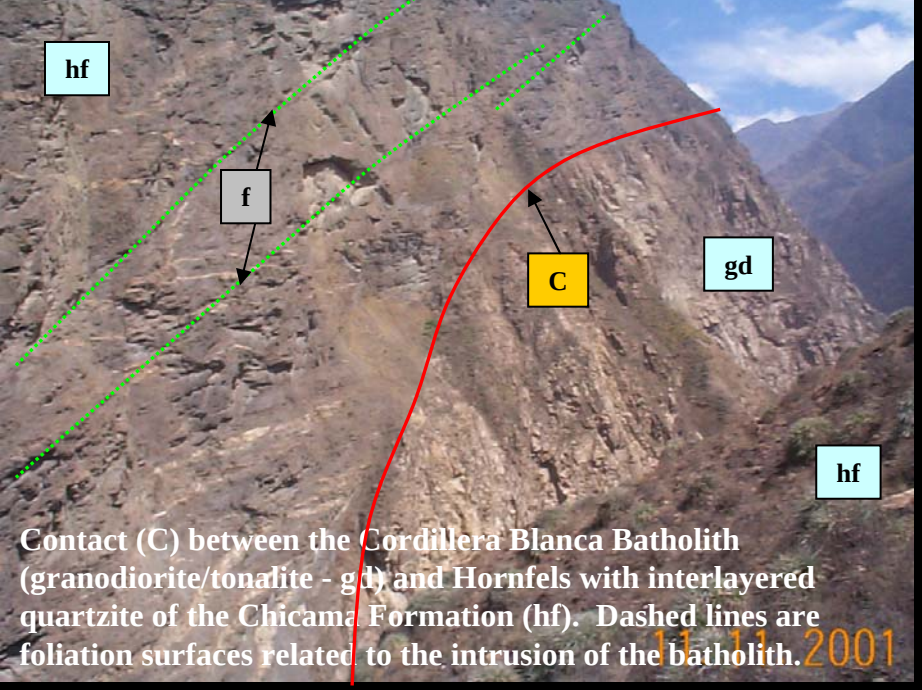
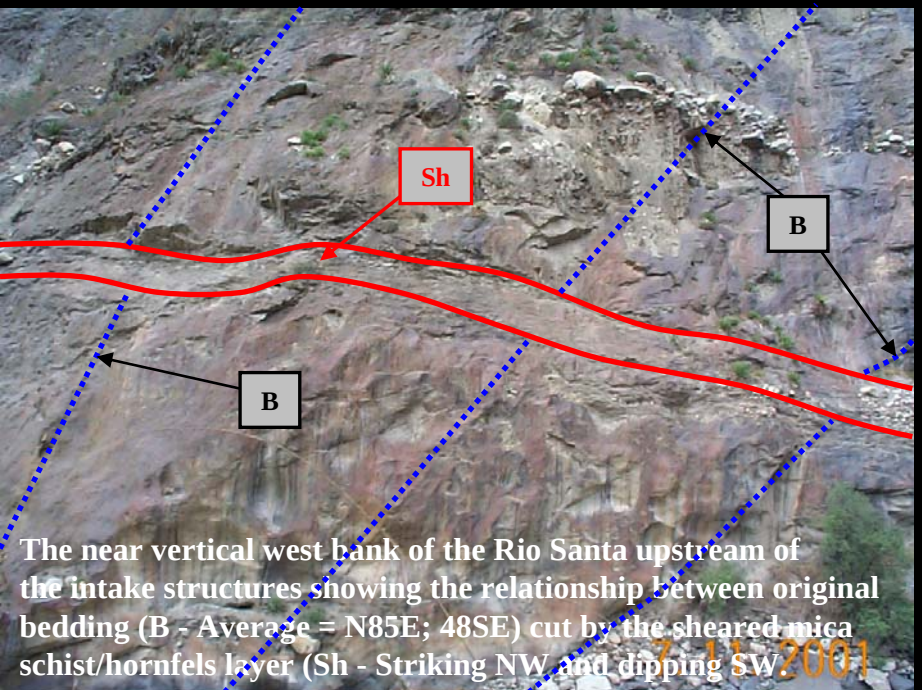


Photo 10: Area of major translational sliding (Mode 3) on the right (east) bank of the Rio Santa.
Hd - Hornfels that have been displaced in the slide area. Qrb - Recent rock fall material (Mode 2). B - Bedding Plane (~N85E; 48SE) that defines the northern limit of a rock block that slid on FJ - Foliation Joint (~N18W; 43SW).
JS1 - Joint Set 1 (~N48W; 73NE). JS2 - Joint Set 2 (~N49E; 82NW).

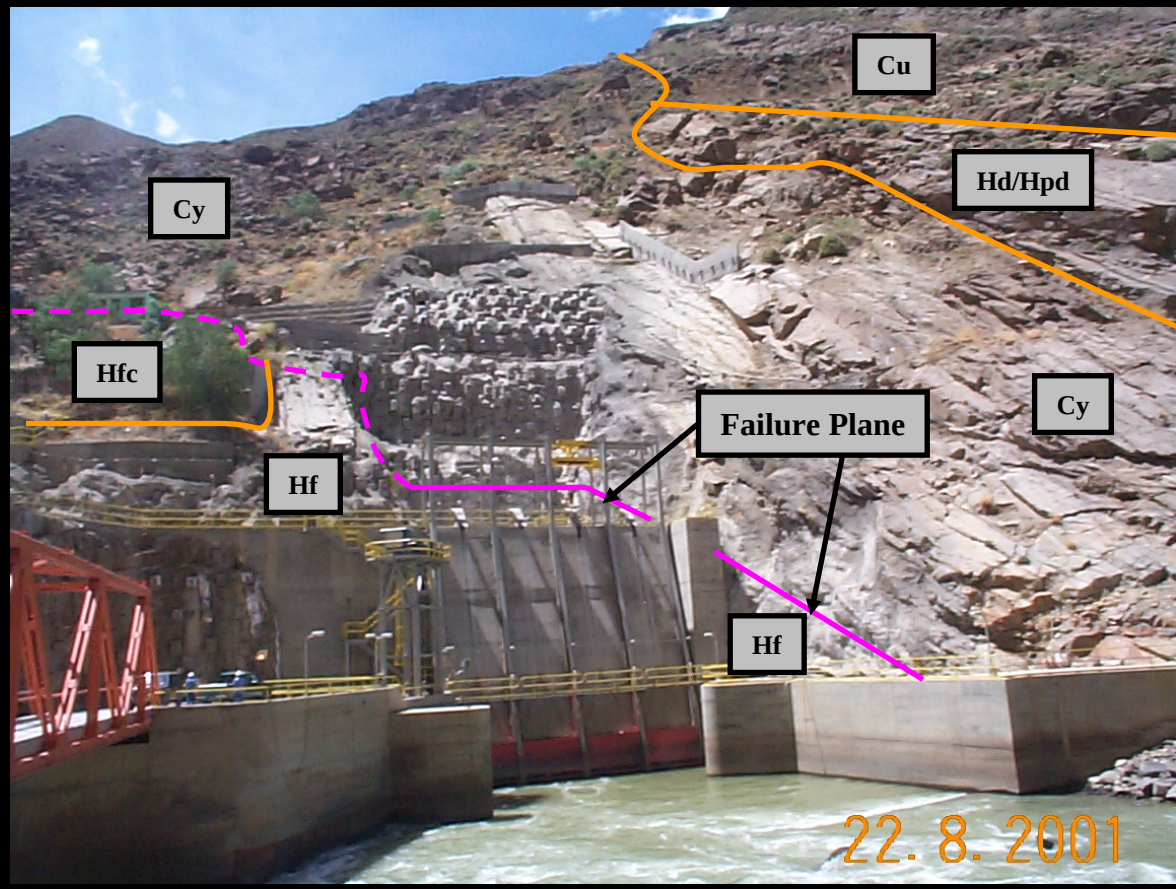




Contact (C) between the Cordillera Blanca Batholith (granodiorite/tonalite - gd) and Hornfels with interlayered quartzite of the Chicama Formation (hf). Dashed lines are foliation surfaces related to the intrusion of the batholith.

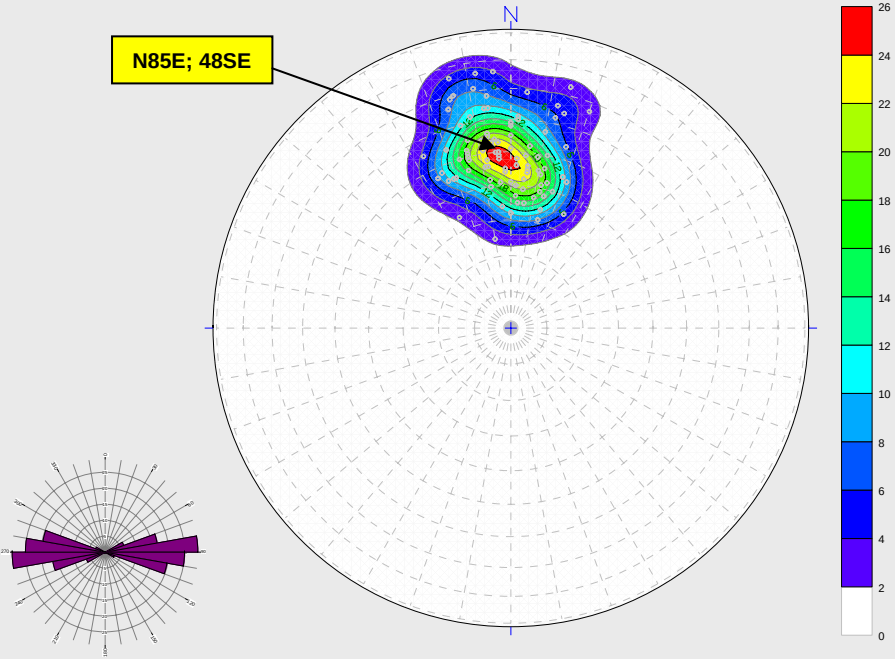


The near vertical west bank of the Rio Santa upstream of the intake structures showing the relationship between original bedding (B - Average = N85E; 48SE) cut by the sheared mica schist/hornfels layer (Sh - Striking NW and dipping SW.

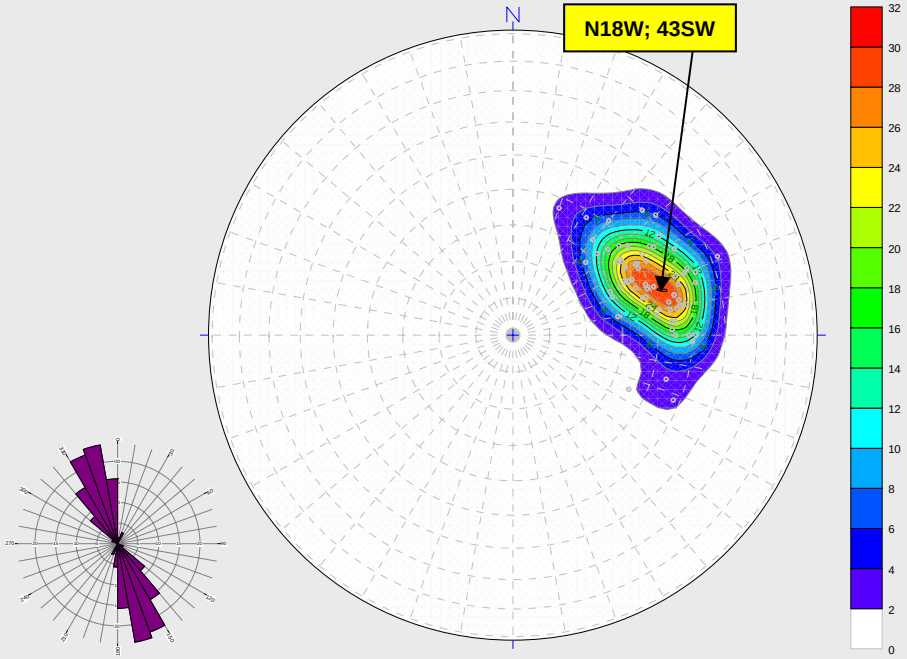


Complementary Intake Structure showing the location of the failure plane/zone (cracked shotcrete) and the distribution of geological map units Cy, Cu, Hfc, and Hd/Hpd. Unit Cy is moving.

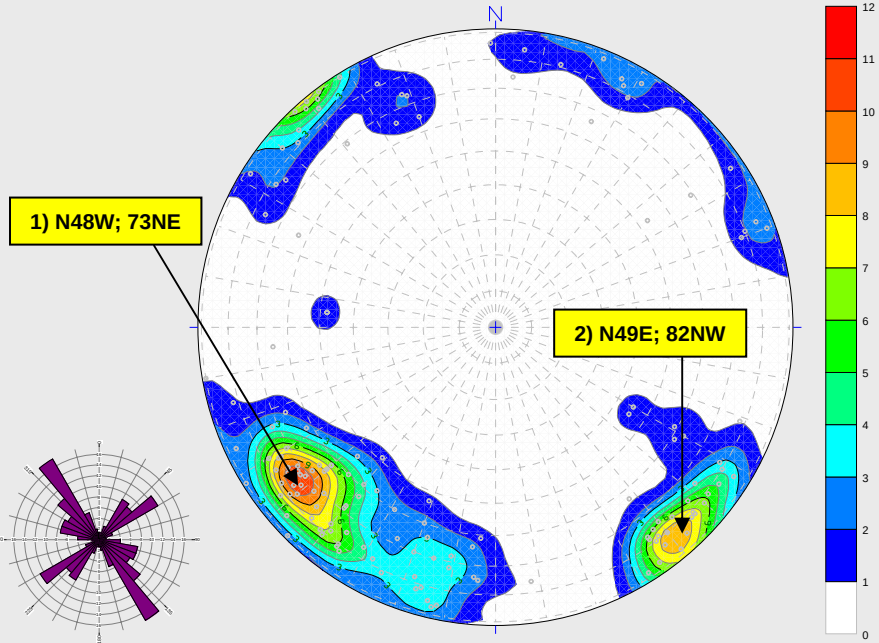
Bedding - Canon del Pato - N = 96 - Slide Area Only

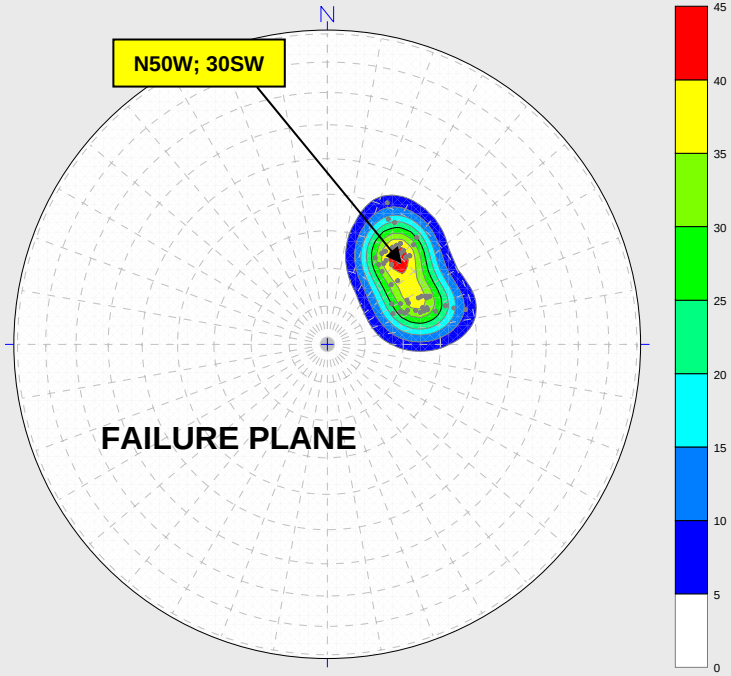


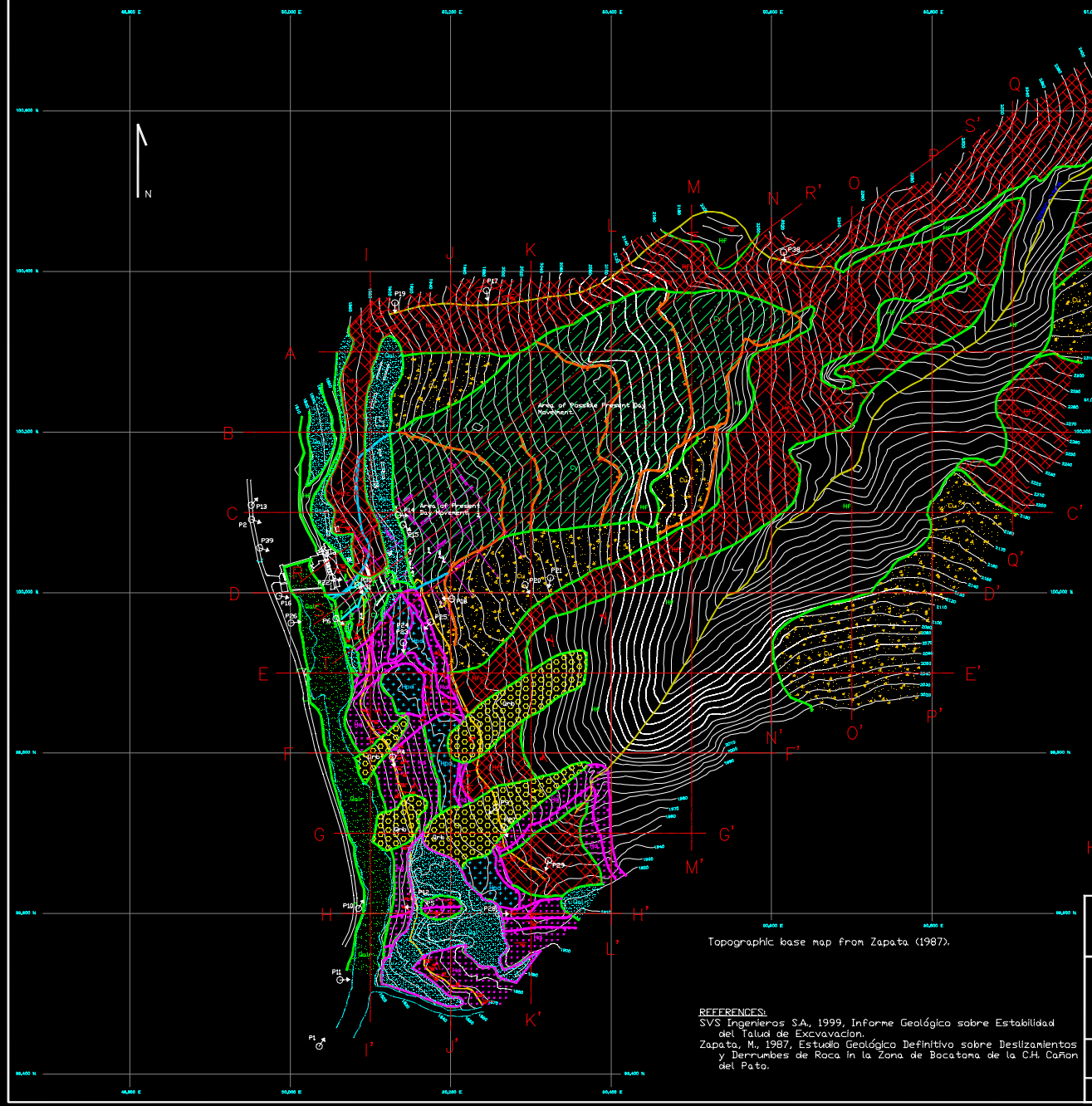
Foliation - Canon del Pato - N = 90



Joints - Canon del Pato - N = 149







Topographic base map from Zapata (1987).

REFERENCES:

SVS Ingenieros S.A., 1999, Informe Geológico sobre Estabilidad del Talud de Excavacion.

Zapata, M., 1987, Estudio Geológico Definitivo sobre Deslizamientos y Derrumbes de Roca in la Zona de Bocatoma de la C.H. Cañon del Pato.

EXPLANATION

- ROCK BLOCKS. Large rock blocks of different sizes related to recent rock falls.
- RECENT ALLUVIUM. Large rock fragments to gravels in silty sand matrix.
- ALLUVIUM (YOUNG TO OLD). Composed of blocks and smaller fragments of grano-diorite in a silty sand matrix.
- COLLUVIUM/HORNFELS. Large to small rock blocks up to 10 meters thick. Underlain by weathered/fractured Hornfels up to 40 meters thick. Colluvium not present in the area of the new Intake Structure.
- COLLUVIUM. Large to small rock blocks from 2 to 5 meters thick. Bedrock exposed in less than 5% of the unit.
- HORNFELS/COLLUVIUM. More than 80% of unit covered with less than 2 meters of colluvium.
- HORNFELS. Less than 20% of unit covered by colluvium (less than 2 meters thick).
- HORNFELS. Horizontal platforms in area of translational sliding.
- HORNFELS. Displaced and disturbed in areas of translational sliding.
- FRACTURE/SCARP TRACE. In area of translational sliding.
- SCARP. In area of present movement.
- CONTACT.
- LIMITS OF AREA WITH CONTINUING MOVEMENT.
- RIDGE CREST.
- BEDDING (STRATIFICATION). Strike and Dip.
- FOLIATION. Strike and Dip.
- DIAMOND CORE HOLES.
- H —— H' LOCATION OF CROSS-SECTIONS.
- P14 LOCATION OF PHOTO IN REPORT.

CROSS-SECTIONS ON DRAWINGS NO. Geo-2 to Geo-11

GEOLOGIC MAP OF THE AREA SURROUNDING THE DAM AND INTAKE STRUCTURES OF THE CAÑON DEL PATO HYDROELECTRIC PROJECT

PROVINCIA: HUAYLAS – DEPARTAMENTO; ANCASH

GEOLOGY: M. SCHAEFFER

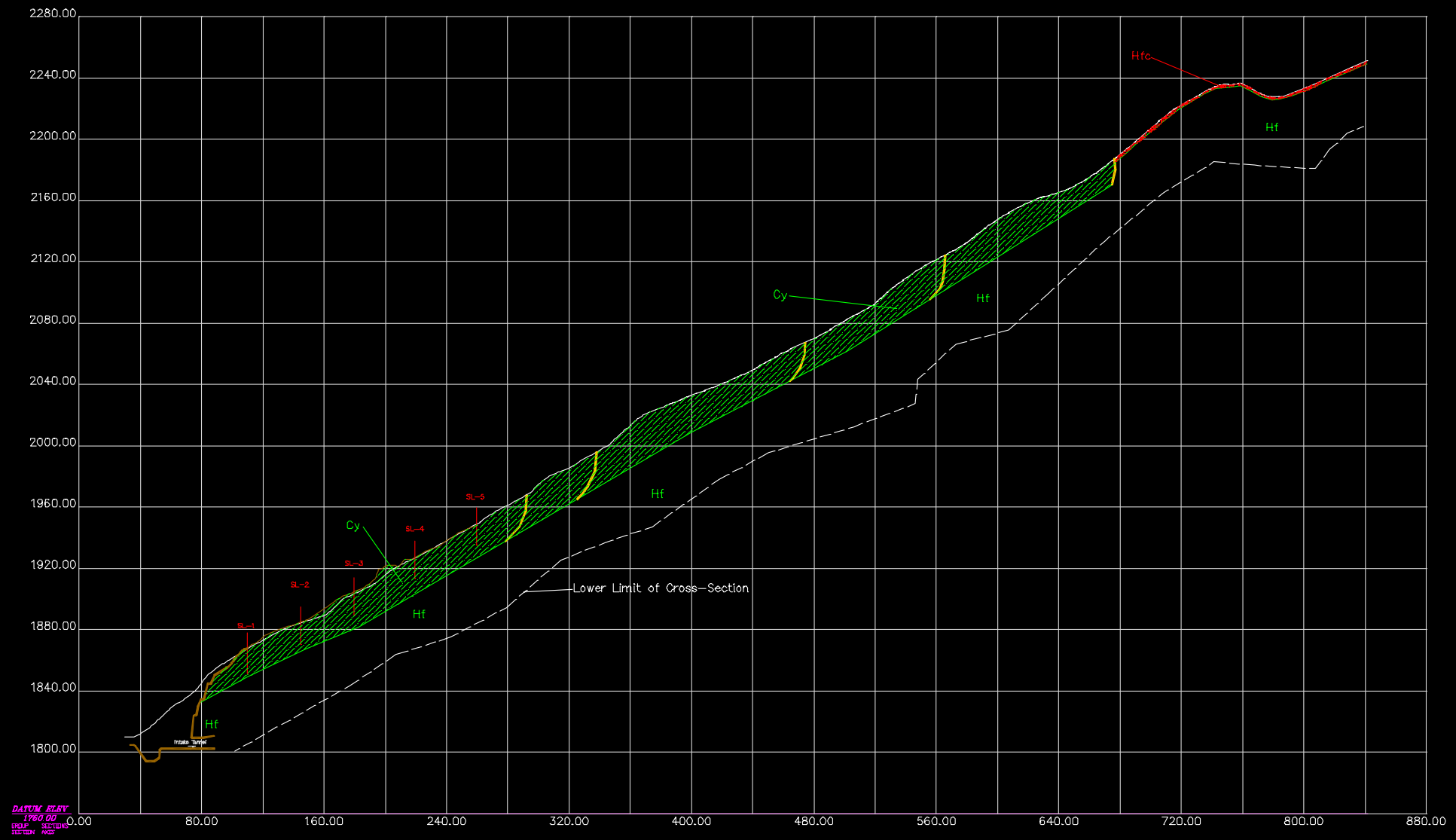
DRAWN BY: P. GONZALES/M. SCHAEFFER

BY:_____

APPROVED:_____

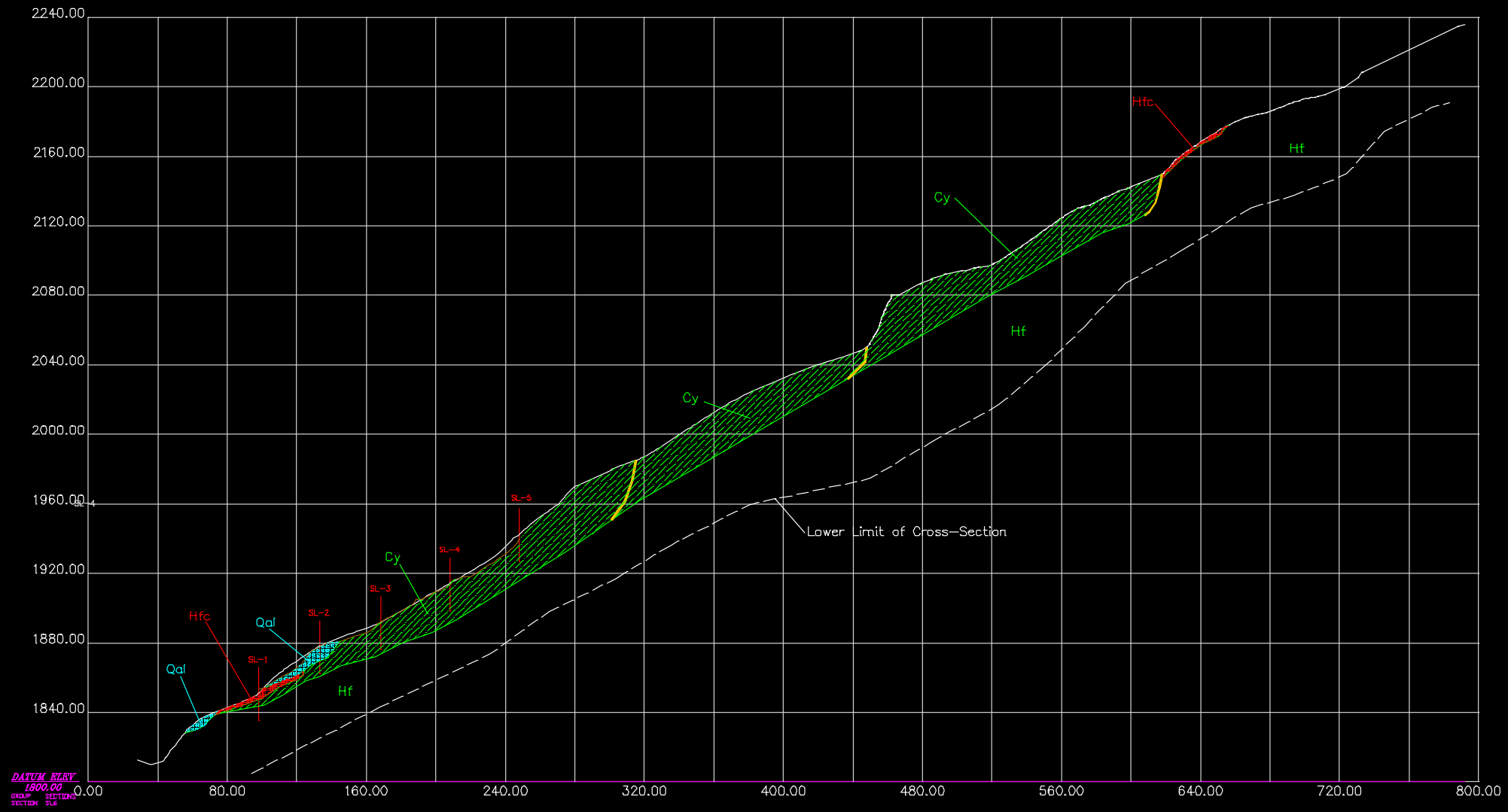
FEBRUARY 2002; SCALE 1:2000

Geo-1



Profile based on PTZ Ingenieros Survey Drawing.

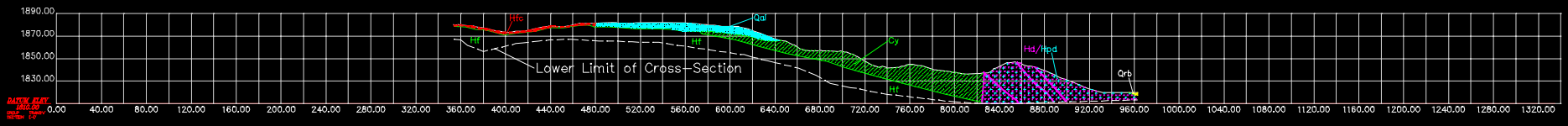
For EXPLANATION see Drawing Geo-1



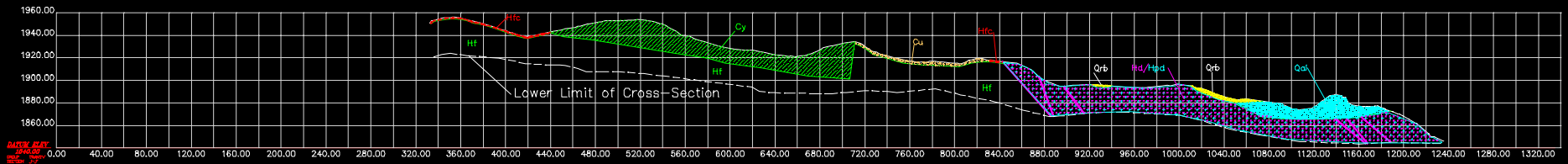
Profile based on PTZ Ingenieros Survey Drawing.

DRAWING N	SHT.	REV.	ROCK SLOPE MITIGATION
Geo-8	1	0	01

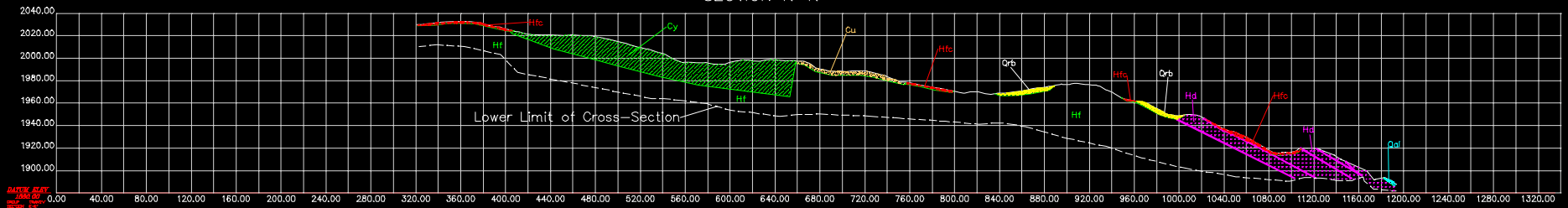
SECTION I–I'



SECTION J–J'



SECTION K–K'



For EXPLANATION see Drawing Geo–1

SCALE 100 0 100 200 300m

** Obtenido del plano del estudio geológico definitivo sobre deslizamientos y derrumbes de roca, en la zona de Bocatoma de la C.H. del Cañón del Pato Nov de 1987.

DEI / EGENOR S.A.

CAÑON DEL PATO HYDROELECTRIC PROJECT
NEW INTAKE

PROFILES - HIGH ZONE INTAKE

TRANSVERSAL SECTIONS

I-I' / J-J' / K-K'

For Duke Engineering & Services by Geosuelos S.A.		PROJECT: Rock Slope Mitigation
Drawn by: P. Gonzales	DATE: 22/Nov/01	DRAWING N°: Geo–8
Reviewed by: P. Rumeta	DATE: 24/Nov/01	SHEET 1 OF 1 REV. 0
Reviewed by: M. Schaeffer	DATE:	

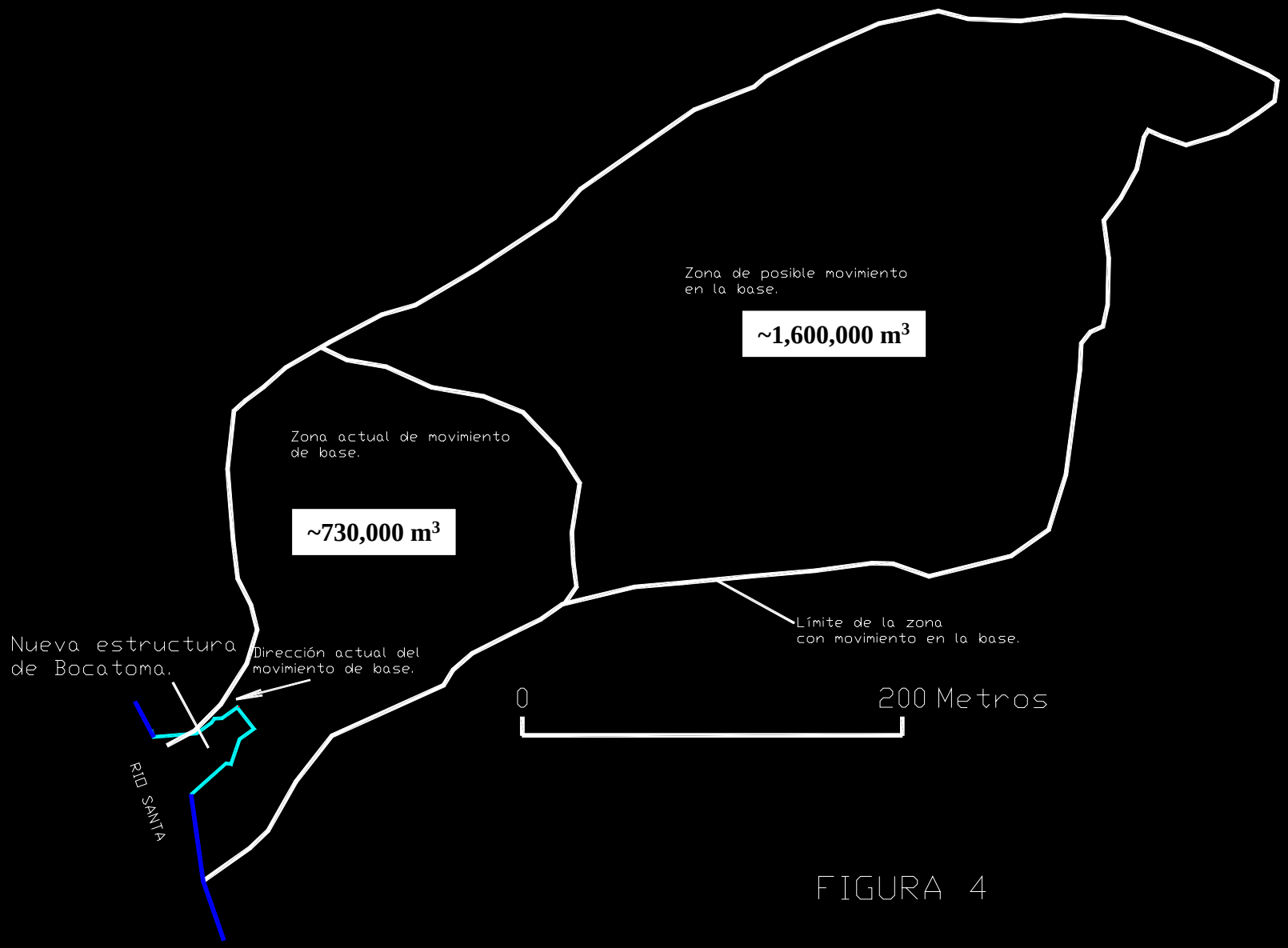
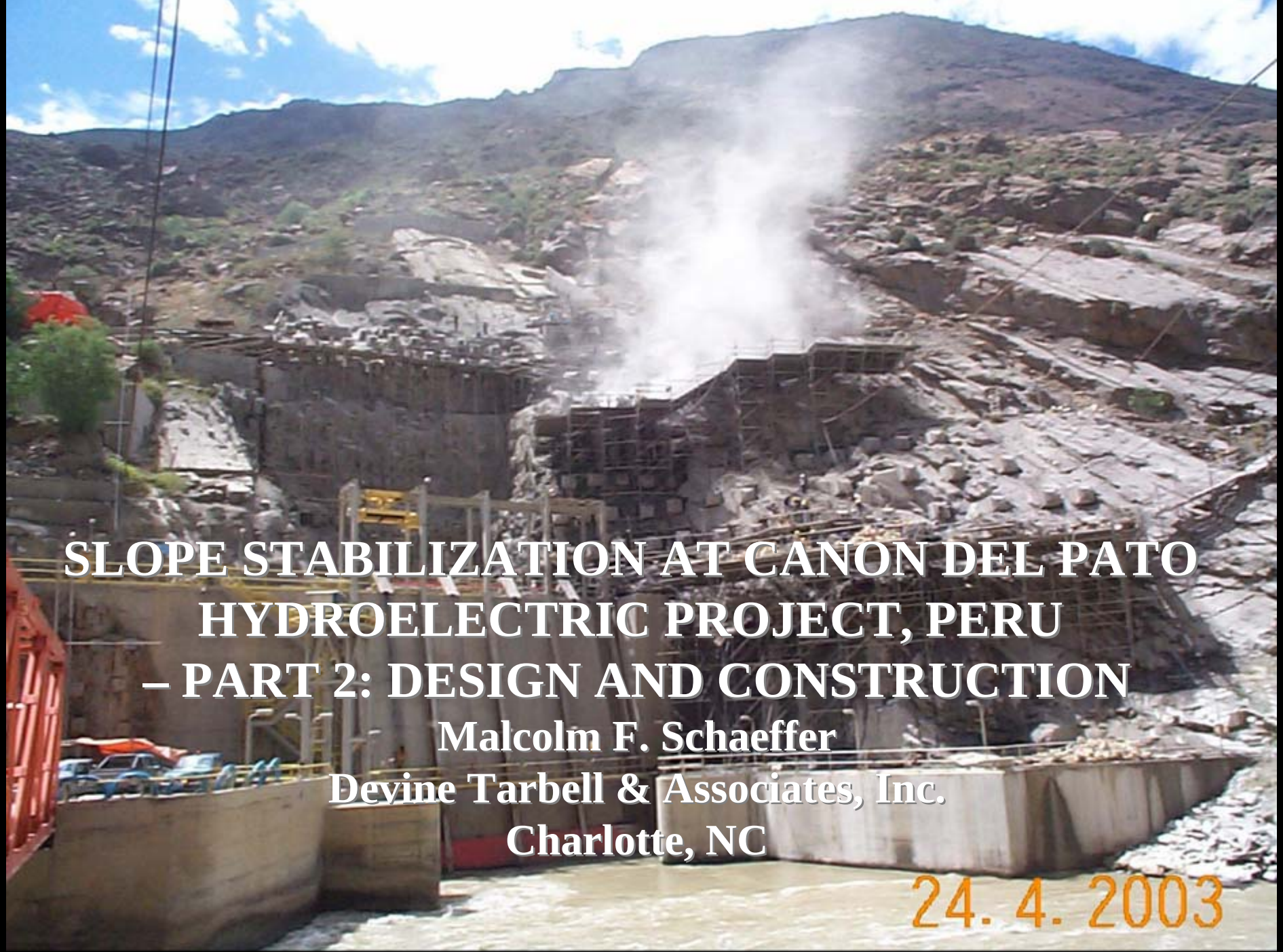

Zona de posible movimiento
en la base.
~1,600,000 m3
Zona actual de movimiento
de base.
~730,000 m3
Límite de la zona
con movimiento en la base.
Nueva estructura
de Bocatoma.
Dirección actual del
movimiento de base.
0
200 Metros
RIO SANTA

FIGURA 4



SLOPE STABILIZATION AT CANON DEL PATO HYDROELECTRIC PROJECT, PERU – PART 2: DESIGN AND CONSTRUCTION

Malcolm F. Schaeffer
Devine Tarbell & Associates, Inc.
Charlotte, NC

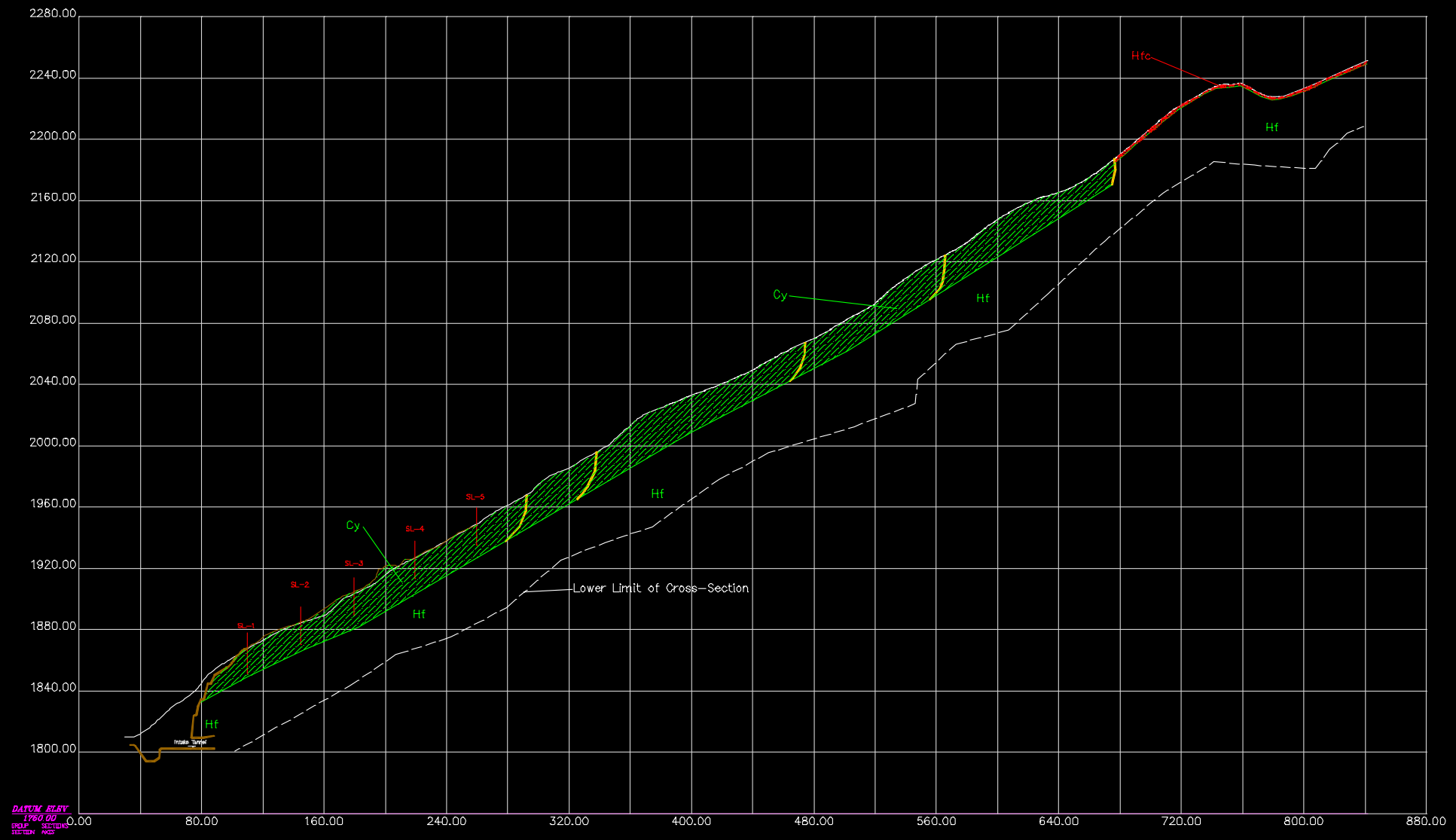
Phase IVb

March 2002 to May 2002

- Design, Cost Estimate, Technical Documents, and Specifications

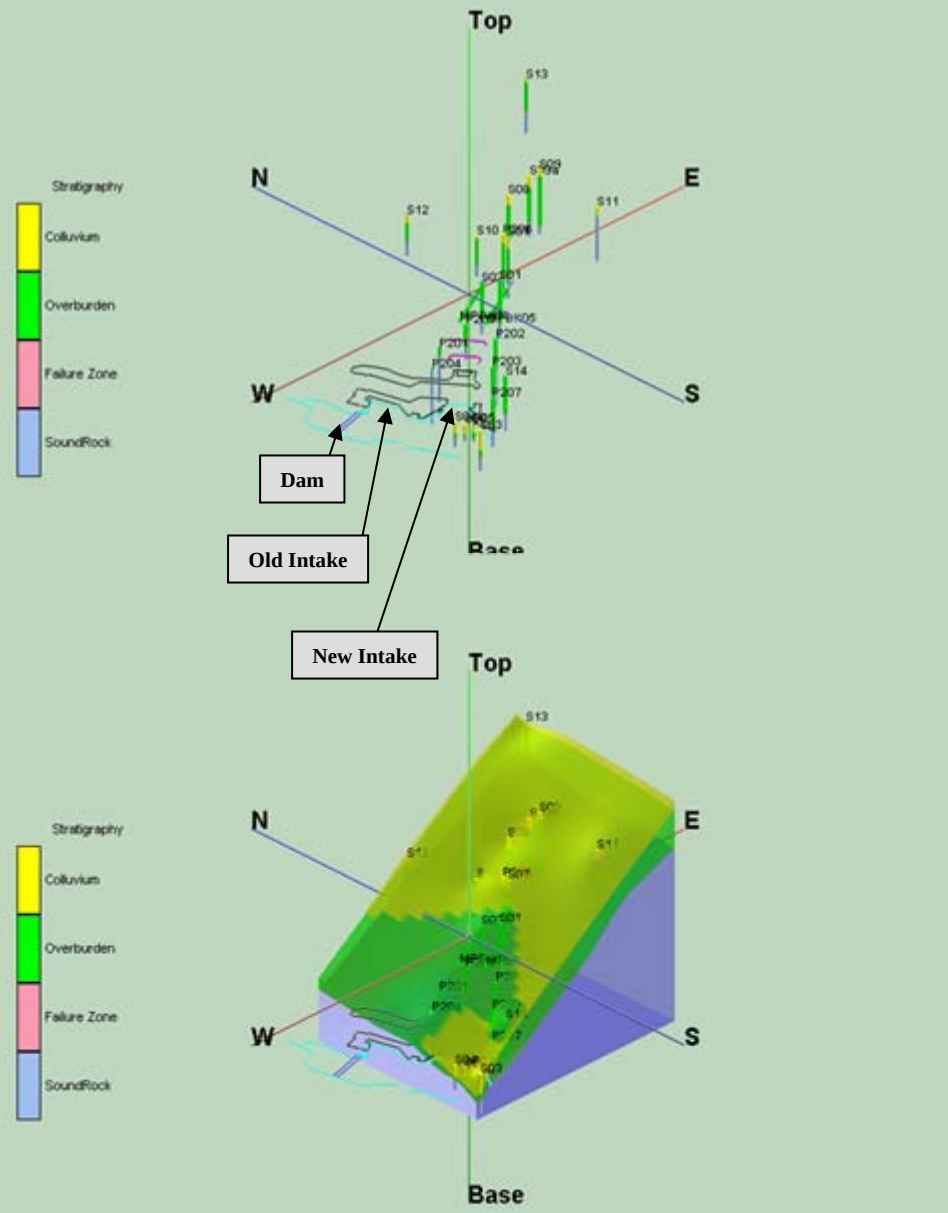
June 2002 to July 2002

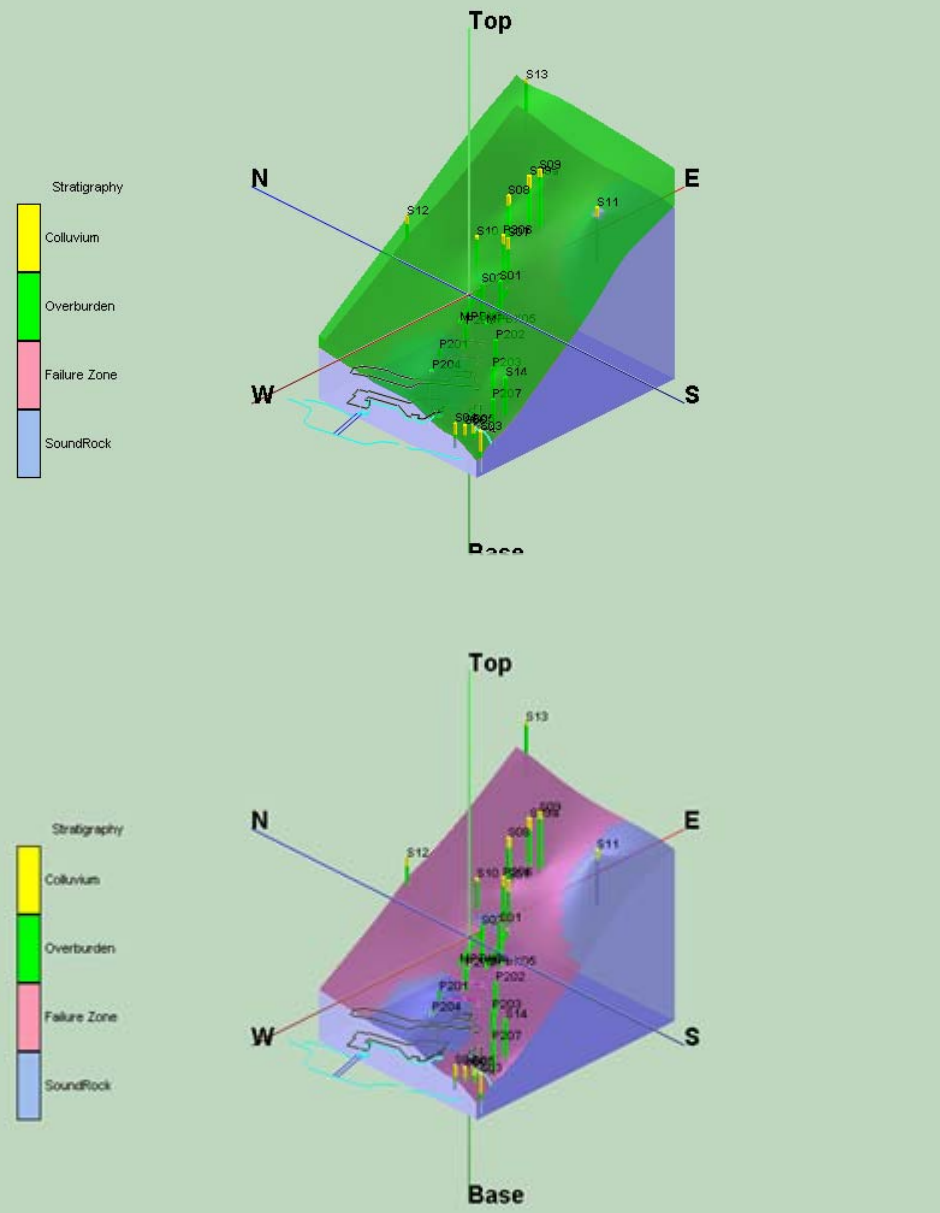
- Bid Process

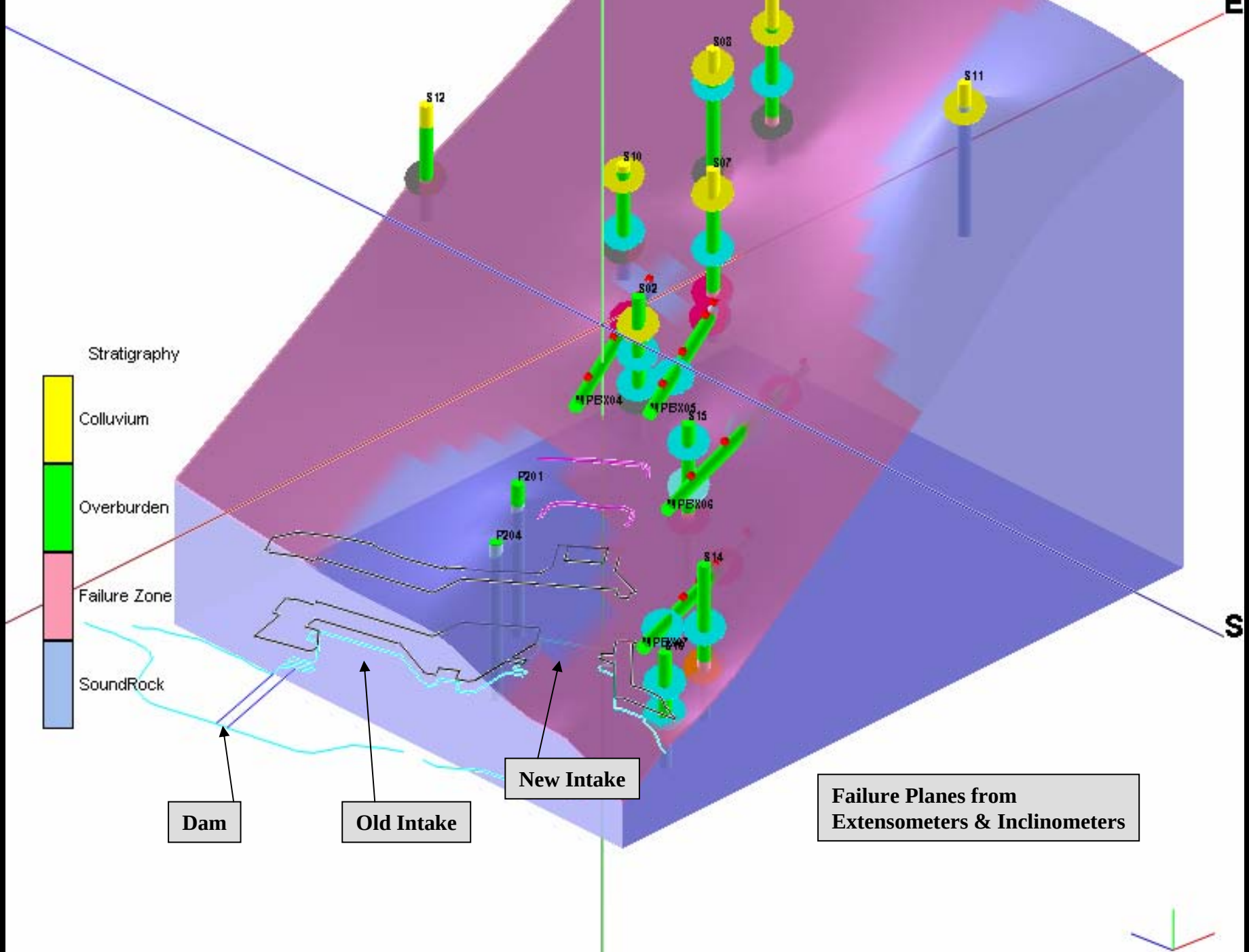


Profile based on PTZ Ingenieros Survey Drawing.

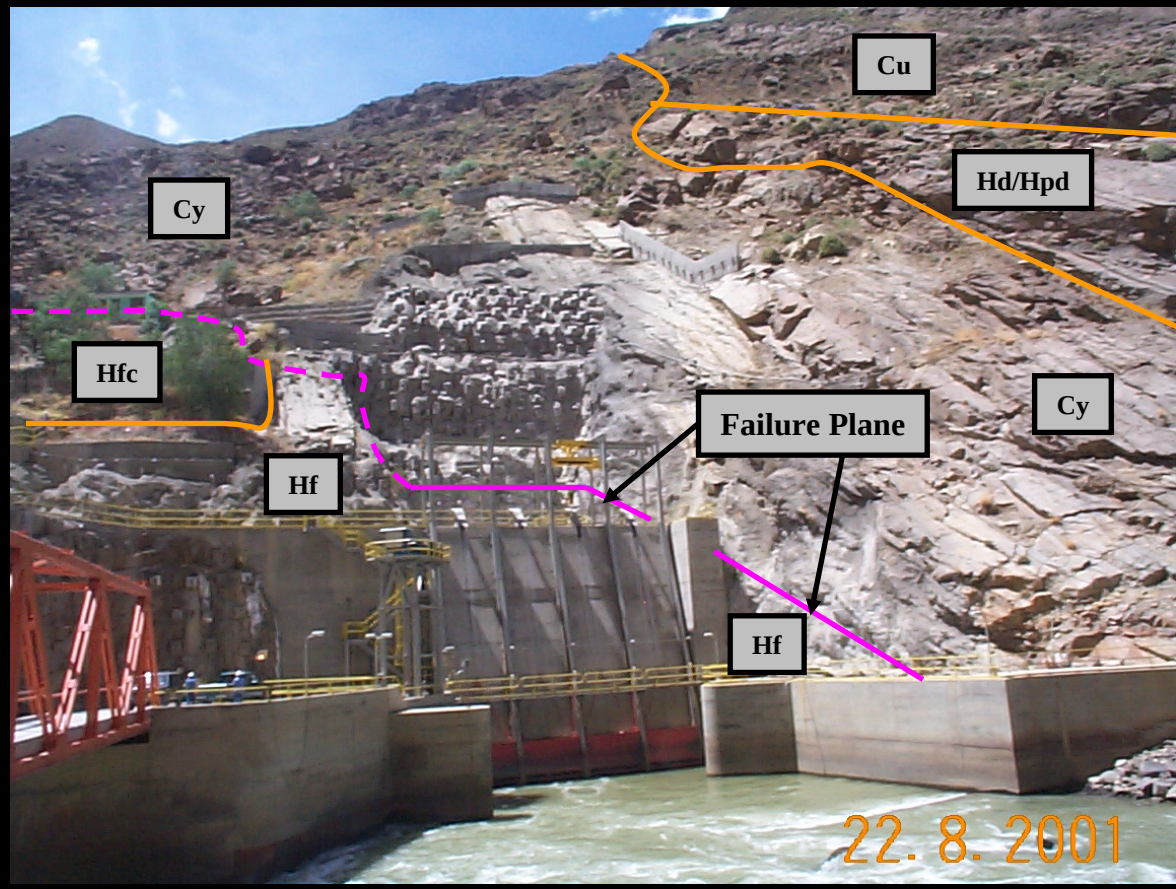
For EXPLANATION see Drawing Geo-1


Top
N
E
W
S
Base
Stratigraphy
Colluvium
Overburden
Failure Zone
SoundRock
Dam
Old Intake
New Intake


Top
N
E
W
S
Base
Stratigraphy
Colluvium
Overburden
Failure Zone
SoundRock


Stratigraphy
Colluvium
Overburden
Failure Zone
SoundRock
S12
S08
S11
S10
S07
S02
MPBX04
MPBX05
S15
MPBX06
P201
P204
S14
MPBX07
Dam
Old Intake
New Intake
Failure Planes from
Extensometers & Inclinometers


Area of Possible Present Day
Deep-Seated Movement.
Area of Present Day
Deep-Seated Movement.
Direction of Present
Day Deep-Seated
Movement
Boundary of Area with Deep-Seated
Movement.
New Intake
Structure
0
200 Meters
RIO SANTA
Area present mitigation effort is
designed to stop moving.



Complementary Intake Structure showing the location of the failure plane/zone (cracked shotcrete) and the distribution of geological map units Cy, Cu, Hfc, and Hd/Hpd. Unit Cy is moving.

CALCULATION OF THE NUMBER OF ROCK ANCHORS REQUIRED FOR A SAFETY FACTOR OF 1.20 FOR THE SLOPE AT THE INTAKE STRUCTURE

INTRODUCTION: This design does not attempt to stop the deformation in the east wall of the Intake Excavation @ Elevation 1832 meters. It intends to stop the movement of the slope south of the Intake excavation, that is, the movement that is affecting the concrete of the intake structure. The geologic studies (15 March 2002) indicates that the boundary of movement is south of the Intake excavation and potentially

***The slope can be modeled using a 2-dimensional analysis.**
***The failure plane daylights into the slope face.**
***The analysis is performed on a unit width of the slope.**
***All forces are assumed to act through the centroid of the wedge. Moments are not considered.**
***Assumed failure mode is translational sliding.**
***Release surfaces are present parallel to the cross-section of the analysis and provide negligible resistance to sliding at the lateral boundaries.**

the original design should have used anchors @ 60% GUTS per PTI for the normal loading case.] The above criteria cannot be met due to the large number of anchors required for stabilization and the limited area available for installing them (DRAWING 1). The cost would be prohibitive in relationship to the original cost of the Complementary Intake Structure. Regardless, it is unlikely the reinforcement would be effective under the design earthquake loading. Slope failures are likely at higher elevations in the various unstable zones delineated by the geologic mapping (15 March 2002 Report).

(A) It is thought that the wedge developed by the new rock anchors

Rev.	Orig.	Date	Chkd.	Date	Client/Project: DEI / Egenor
					Subject: CdP Complementary Intake - Slope Mitigation: Phase 4.
0	MFS	04/02/02	BAG	07/05/02	Calc. No.: CdP-009 Sht. 1 of 4

END (A)

will deflect the downhill movement away from the Intake Structure concrete (DRAWING 1). Continued monitoring of the loads and re-setting of working loads in the existing anchors in the east wall will be necessary. These anchors may take some of the deflected load.

The design is based on obtaining a safety factor of SF=1.2 for the normal loading without H_2O and seismic loadings. The seismic loading at a SF=1.00 using 100% GUTS will be determined for the new design.

PTIONS FOR ANCHORS REQUIRED FOR FS=1.20.

Cross-Section A is used for design as it has the largest sectional area and sliding plane. Drawing No. Calc_CdP-009; Sheet 1 of 3.

Lower Slope Angle = 63.67°
Height of Lower Slope = 24.69 m
Upper Slope Angle = 43.15°
Failure Plane Angle = 28.0°
Waviness Angle = 2.5° (Calculation No: CdP-006)
Tension Crack = 58.13m from crest
Unit weight of rock = 2.56 T/m³ (160 lbs/ft³)
Friction Angle ϕ = 23° (Calculation Nos: CdP-004, CdP-007, and CdP-008)
Cohesion = 0 T/m²; Length of Failure Plane = 79.68 m
Area of Sliding Zone = 2139 m² (from Drawing 1; horizontal)
Water Pressure = 0 (Based on Piezometer Data)
Seismic Coefficient = 0
No other external forces present

The major uncertainties in the calculation are the Failure Plane Angle, the friction angle, waviness angle, and the nature of the Geologic Boundary (Tension Crack). It is believed that the values used for the first three inputs are reasonable and conservative. It is assumed that the geologic boundary is the limit of the type of movement that is affecting the Intake Structure and the rock mass above this boundary is not moving downhill. This assumption based on the geologic studies (15 March 2002 Report) is reasonable. The geometry of Cross-Section A is reasonably accurate. It is based on a recent survey of the slope (13 April 2002 Report). A sensitivity

Rev.	Orig.	Date	Chkd.	Date	Client/Project: DEI / Egenor
					Subject: CdP Complementary Intake - Slope Mitigation: Phase 4
0	MFS	04/02/02			Calc. No.: CdP-009 Sht. 2 of 4

Duke Engineering & Services
A Duke Energy Company

analysis will be performed to address the affect of the different inputs on the calculated safety factor.

* SAFETY FACTOR OF SLOPE WITH NO SUPPORT

SF = 0.88; File Nos: CdPSectionA-1.rtf/.jpg

* CALCULATE NUMBER OF ANCHORS REQUIRED FOR SF = 1.20

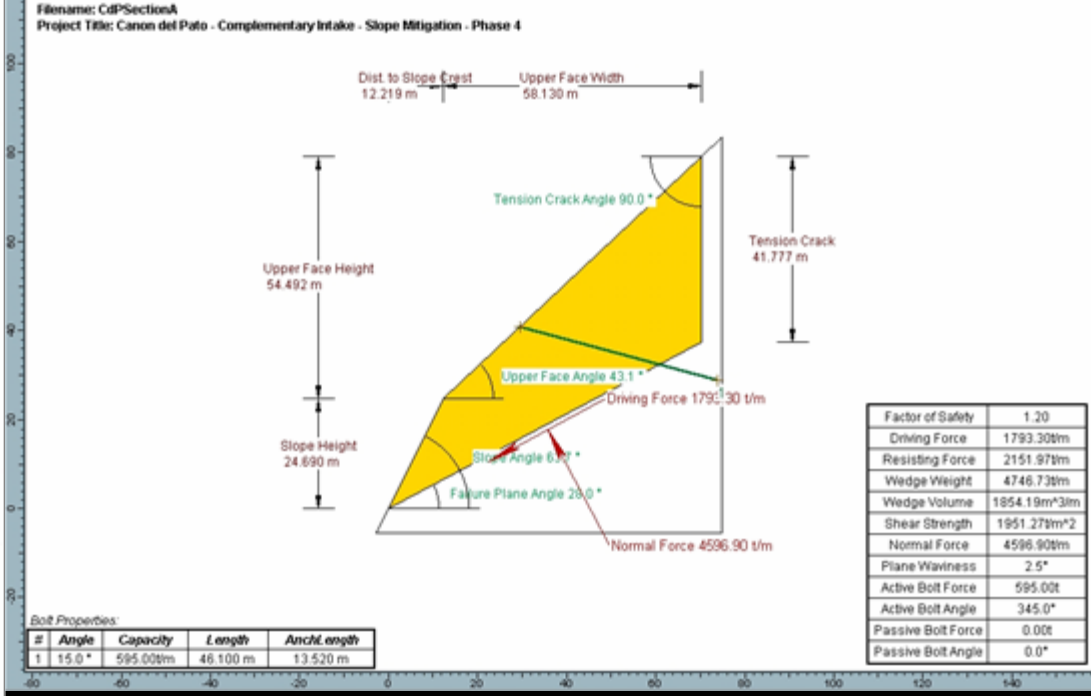
1. Set SF = 1.20; Calculate load per meter of slope required.
   Set Anchor Inclination to 15° down from horizontal.
   ↓
   Resultant Active Anchor Force Required = 595 T/m
   File Nos. CdPSectionA-2.rtf; CdPSectionA-2a.jpg; CdPSectionA-2b.jpg
2. Estimate width of slope to be stabilized:
   Horizontal Area = 2139 m^2
   Area on Failure Plane = 2139 m^2 / cos(28°) = 2423 m^2
   Width of Slope = Area of Failure Plane / Length of Failure Plane
   Width of Slope = 2423 m^2 / 79.68 m = 30.4 m
3. Total Anchor Load Required:
   595 T/m X 30.4 m = 18088 Tonnes
4. Estimate number of anchors:
   Use 12 strand-0.5" anchors, 100% GUTS = 225 Tonnes; 60% GUTS = 135 Tonnes, For normal loading use 60% GUTS.

   18088 Tonnes / 135 Tonnes/Anchor = <u>134 Anchors</u>

Anchors to be installed in an area (horizontal) of 1152 m^2.
[DRAWING 2]

Rev.	Orig.	Date	Chkd.	Date
0	MFS	9/24/02		

Client/Project: DEI/Eqenor
Subject: CdP Complementary Intake - Slope Mitigation: Phase 4
Calc. No.: CdP-009 Sht. 3 of 4



* SENSITIVITY ANAYLSIS

A sensitivity analysis was performed on the following inputs: slope Angle, Slope Height, Unit Weight, Failure Plane Angle, Plane Waviness, Distance of Tension Crack from Crest, Upper face Angle, and Friction Angle. The plot of the analysis (File No. CdPSect CdPSectionA-3.jpg) is in the attached computer file printout.

The analysis is most sensitive to the Failure Plane Angle and Friction Angle and least sensitive to the Plane Waviness Angle and the lower slope Angle.

* ESTIMATE SAFETY FACTOR AT SEISMIC LOADING = 0.27g.

Use same inputs as before; assume anchor loads at 100% GUTS (225 Tonnes).

$$\frac{595\,T/m}{135\,T} = \frac{X}{225\,T}$$

$X = 992\ T/m$ → Input into calculation.

SF = 0.76 @ Seismic Loading = 0.27g

File Nos: CdPSectionA-5.rtf/.jpg

* ESTIMATE SEISMIC LOADING AT SF = 1.00 WITH ANCHOR LOAD AT 100% GUTS (225 T):

Set SF = 1.00; Anchor load = 992 T/m.

Seismic Loading for SF = 1.00 is 0.15g

File Nos: CdPSectionA-4.rtf/.jpg

Rev.	Orig.	Date	Chkd.	Date	Client/Project: DEI/Egenor
					Subject: CdP Complementary Intake: Slope Mitigation: Phase 4
0	MFS	04/24/02			Calc. No.: CdP-009 Sht. 4 of 4

Calculate Conservatism of Design due to differences in volume of Sliding Rock Mass Assumed for Design and Calculated from Cross-Sections.

ASSUMPTIONS: All input values in CdP-009 are correct. Volume directly related to SF.

1. Calculate volume of sliding block using design values.

   Area of Section A = 1853.94 m²; Width of Slope = 30.41 (CdP-009)

   Volume A = 1853.94 m² X 30.41 m = 56,378.32 m³

2. Calculate volume of sliding block using Sections A, B, and C.

   Area of Block B = 837.54 m² for 5.5 m Section A for 13.9 m
   Area of Block C = 1159.20 m² for 11.0 m

   Volume of Block B = 837.54 m² X 5.5 m = 4606.47 m³
   Volume of Block C = 1159.20 m² X 11.0 m = 12751.20 m³
   Volume of Block A = 1853.94 m² X 13.9 m = 25769.77 m³
   TOTAL = 43127.44 m³

3. Calculate Ratio of Design Volume to Calculated Volume

$$\frac{56{,}378.32\ m^3}{43127.43\ m^3} = 1.30$$

4. Multiply Design SF by 1.30 to get Equivalent Smaller Volume SF with existing Support.

   1.2 X 1.3 = 1.56 = SF_E Files: CdPSectionA-6.rtf/.jpg

5. Use SF = 1.56 to calculate equivalent anchor load for Section A.

   Anchor $Load_E$ = 1038 T/m for SF = 1.56

6. Calculate SF for Seismic loading of 0.27g using 100% GUTS for Anchor $Load_E$.

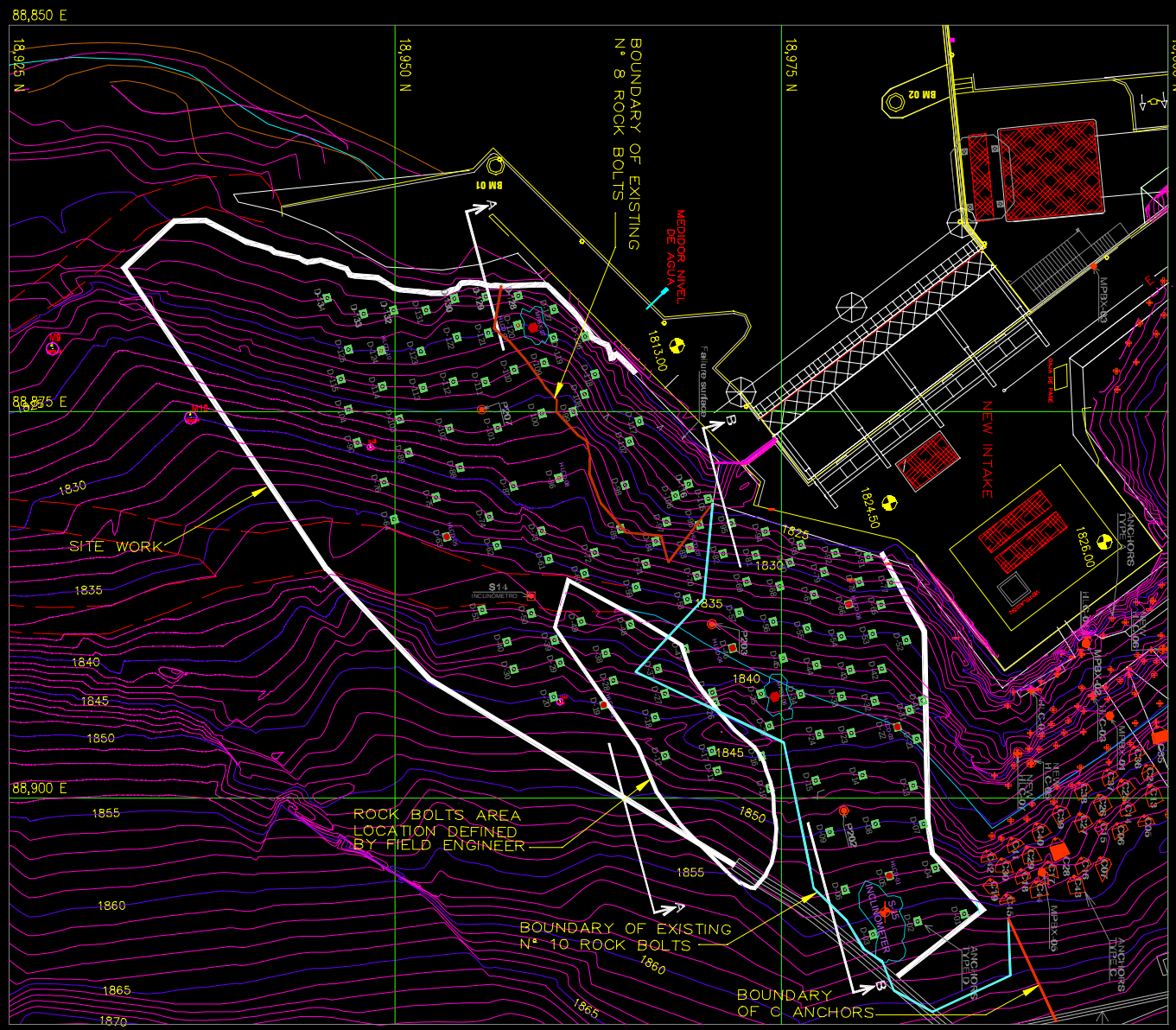
$$\frac{1038\ T/m}{135\ T} = \frac{X}{225\ T};\quad X = 1730\ T$$

SF = 1.07 Files: CdPSectionA-6a.rtf/.jpg

Files Attached.

Rev.	Orig.	Date	Chkd.	Date	Client/Project: DEI/Egenor
					Subject: CdP Complementary Intake - Slope Mitigation: Phase 4
0	MFS	04/22/02	BAG	02/07/02	Calc. No.: CdP-010 Sht. 1 of 1

DRAWING N.	SHT.	REV.	ROCK SLOPE MITIGATION
002	1	0	Phase 4



LEGEND

- ANCHOR TYPE A
- ANCHOR TYPE C
- ANCHOR TYPE D - NEW
- HYDRAULIC LOAD CELL ANCHOR TYPE A
- VIBRATING WIRE LOAD CELL ANCHOR TYPE C
- EXISTING INCLINOMETER
- EXISTING EXTENSOMETER MPBX
- EXISTING PIEZOMETER
- NEW EXTENSOMETER MPBX
- NEW INCLINOMETER
- NEW HYDRAULIC LOAD CELL ANCHOR TYPE A
- NEW HYDRAULIC LOAD CELL ANCHOR TYPE D

5 0 5 10 15 20

GRAPHICAL SCALE

DEI / EGENOR S.A.

CAÑON DEL PATO HYDROELECTRIC PLANT

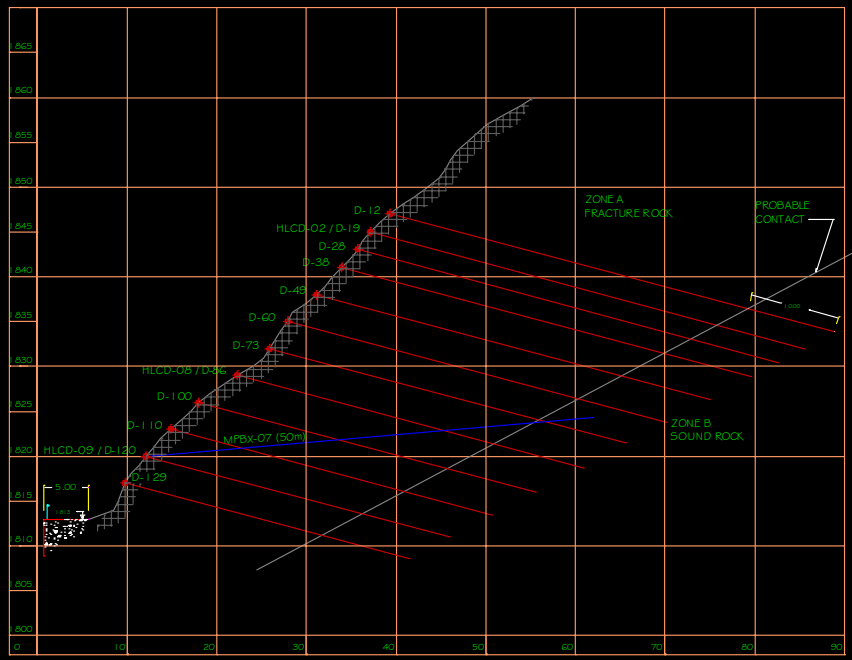
ANCHORS AND INSTRUMENTATION LAYOUT

PLAN VIEW

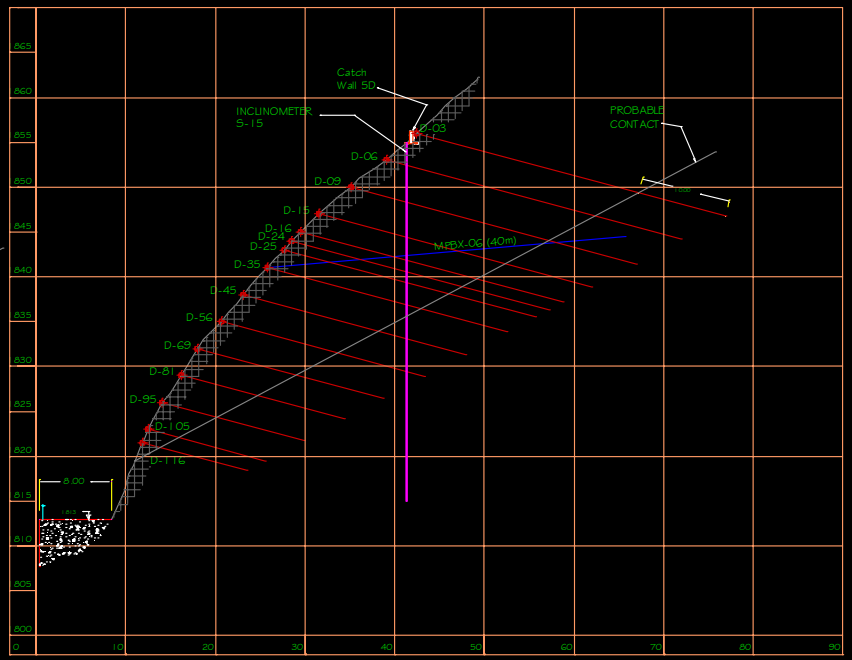
For FRAMATOME ANP DE&S by Geosuelos S.A.		PROJECT: Rock Slope Mitigation Phase 4
Drawn by P. Gonzales	DATE 26/Apr/02	DRAWING N° 002
Reviewed by P. Rueda	DATE 26/Apr/02	SHEET 1 OF 1
Reviewed by M. Schaefer	DATE 01/May/02	REV. 0

DRAWING N.	SHT.	REV.	ROCK SLOPE MITIGATION
003	1	0	Phase 4

SECTION A



SECTION B



GRAPHICAL SCALE

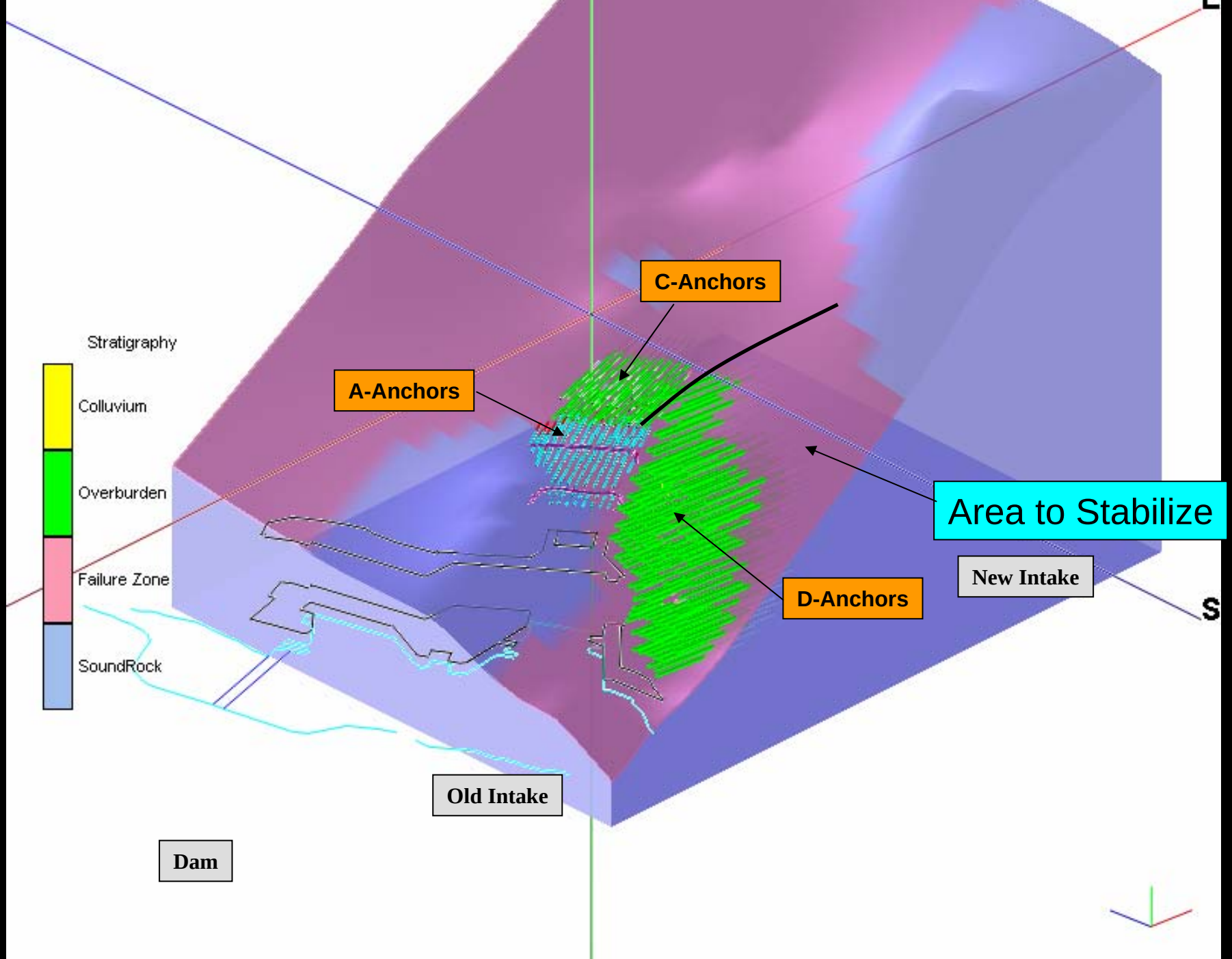
DEI / EGENOR S.A.

CAÑON DEL PATO HYDROELECTRIC PLANT

ANCHORS AND INSTRUMENTATION

CROSS SECTIONS A and B

FOR FINANCING AND BIDS by Geosuelos S.A.		
Drawn by P. Gonzales	DATE 28/Apr/02	PROJECT Rock Slope Mitigation-Phase 4
Reviewed by P. Rosario	DATE 28/Apr/02	DRAWING N° 003
Reviewed by M. Schaeffer	DATE 01/May/02	SHEET 1 OF 1 REV. 0

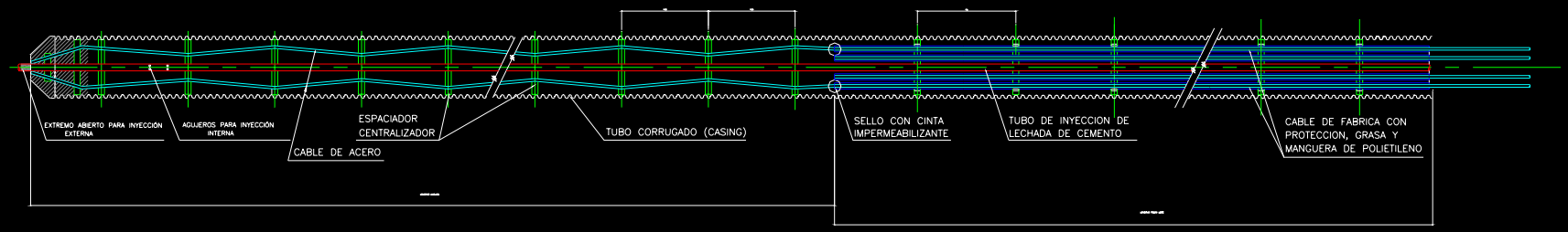

C-Anchors
A-Anchors
Stratigraphy
Colluvium
Overburden
Failure Zone
SoundRock
Area to Stabilize
New Intake
D-Anchors
Old Intake
Dam

Phase IVc

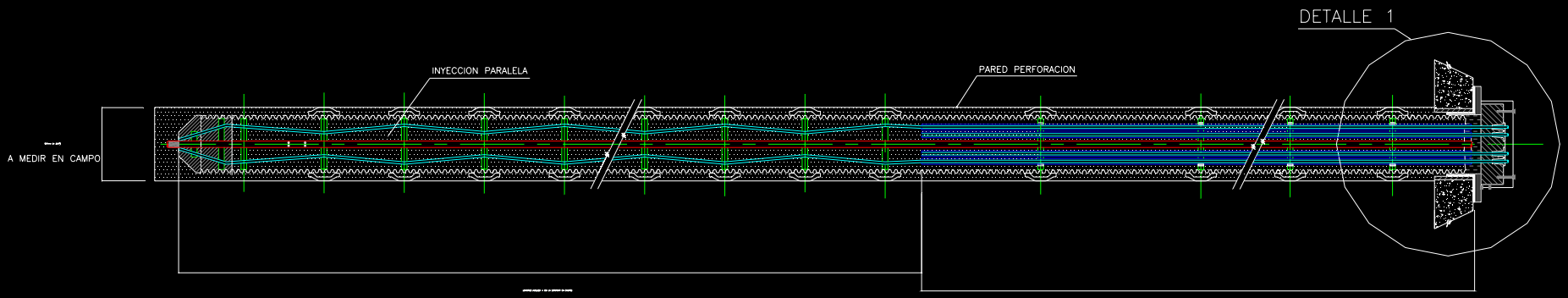
September 2002 to August 2003

- Installation of D-Anchors
- Installation of Rock Bolts
- New Catch Wall
- Lift-Off Tests on A- and C-Anchors
- Installation of New Instruments

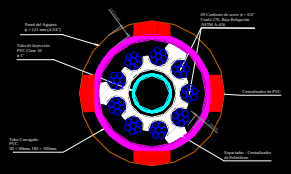
9 Cables of 15.24 mm (5/8”) diameter, 7 wires. Guaranteed Ultimate Tensile Strength (GUTS) of Anchor = 239 Tonnes. Working Load = 143.5 Tonnes (60% GUTS); Total Installed Working Load = 19,229 Tonnes.



CUERPO DEL ANCLAJE ANTES DE SU INSTALACION

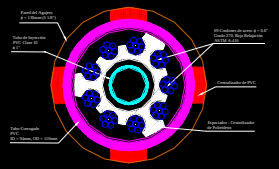


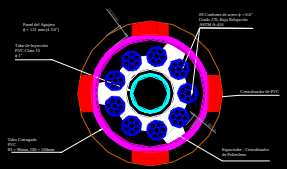
ANCLAJE INSTALADO Y TENSADO



CORTE TRANSVERSAL - TRAMO ANCLADO

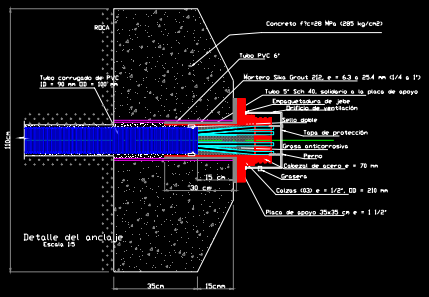
ESC. 1/2





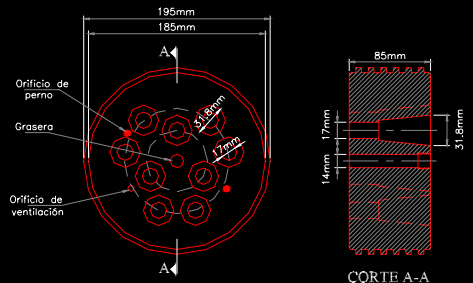
CORTE TRANSVERSAL - TRAMO LIBRE

ESC. 1/2



DETALLE 1

ESC. 1/100



CABEZAL DE ANCLAJE

ESC. 1/4


26/11/2002

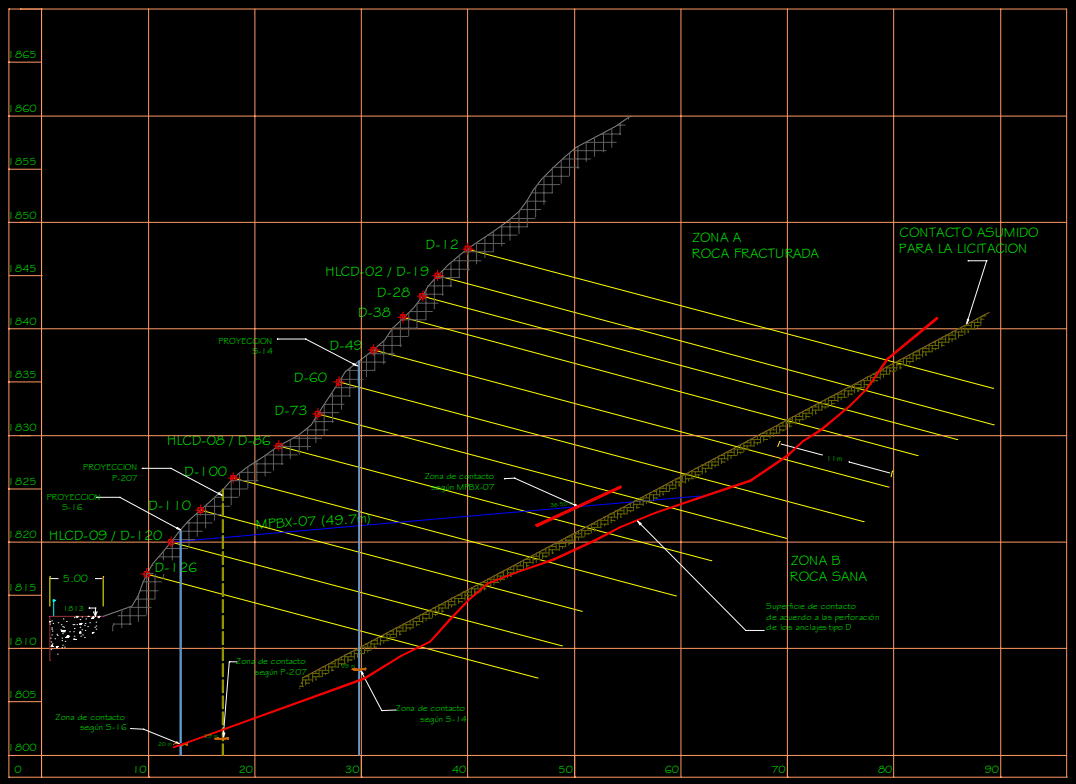

09/01/2003


13/02/2003

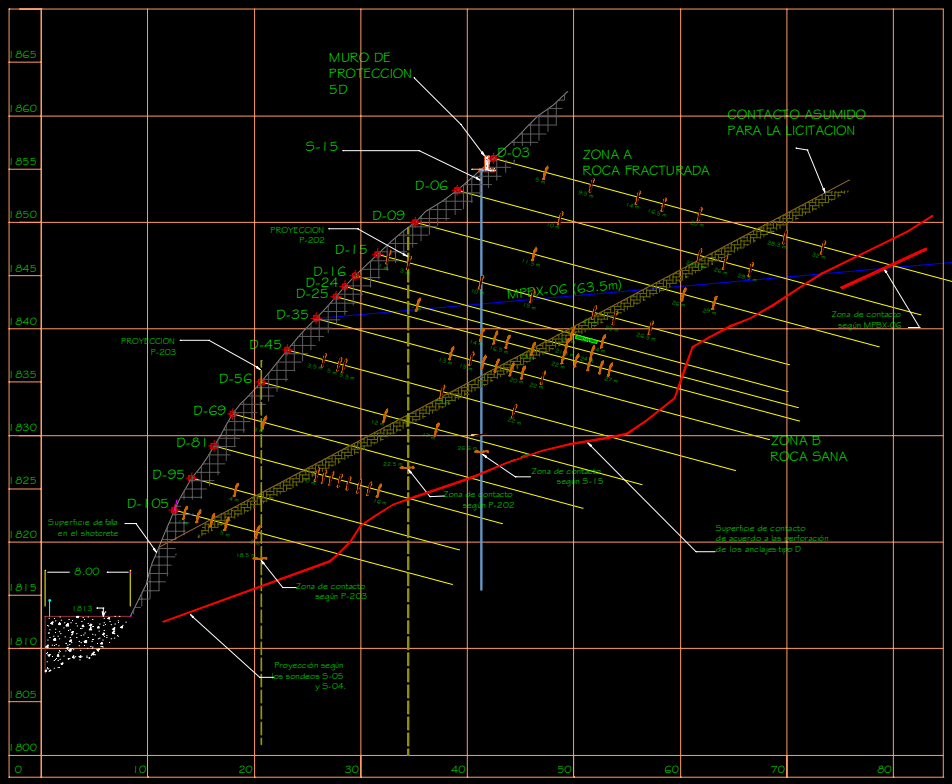

07/02/2003

PLANO N	HOJA	REV.	Mitigación del Talud de Roca
003	1	5	Fase 4

SECCION A



SECCION B



10 0 10 20 30m

ESCALA 1/400

"AS BUILT"

DEI / EGENOR S.A.

CENTRAL HIDROELECTRICA DEL CAÑON DEL PATO

DISPOSICION GENERAL / ANCLAJES E INSTRUMENTACION

SECCIONES TRANSVERSALES A y B

Proyectó DEBINE TARBELL & ASOCIATES por Geosuelos S.A.		
Dibujó por P. Gonzales	FECHA 26/Abr/02	PROYECTO Mitigación del Talud de Roca-Fase 4
Revisado por P. Ruesta	FECHA 02/Ago/03	PLANO N° 003
Revisado por M. Schaeffer	FECHA	HOJA 1 DE 1 REV 5

02 DE AGOSTO 2003

Re-Calculation of Safety Factor

	Original Design	Re-Analysis
Safety Factor (Design Basis-SF)	1.2	1.17
Equivalent Safety Factor (SF_E)	1.56	1.43
Equivalent Safety Factor (SF_E) for Earthquake Loading of 0.27g	1.07	0.96


07/02/2003


11/12/2002


22/03/2003


5-12-2002


5. 12. 2002


5. 12. 2002


5. 12. 2002


6. 2. 2003


5. 12. 2002


5. 12. 2002


5. 12. 2002


5. 12. 2002


5. 12. 2002


6. 2. 2003


14. 2. 2003


6. 2. 2003


6. 2. 2003


D 14
D 10
15. 4. 2003


6. 2. 2003


13/01/2003


31/01/2003


01/02/2003


21. 4. 2003


21. 4. 2003

	REPORTE DEL ENSAYO DE CARGA	Geotécnica

PROYECTO : MITIGACIÓN DEL MOVIMIENTO DEL TALUD - FASE IV. C. H. CAÑÓN DEL PATO

EQUIPO DE TENSADO		ANCLAJE Nº: D-02	LONG. TOTAL (m): 47.50
BOMBA HIDRAULICA:	MH-300/450	Nº DE CABLES: 9.0	LONG. EXTERNA (m): 0.36
MANOMETRO:	LEO 1 - KELLER - 3770	FECHA INSTALACION: 1/7/2003	LONG. LIBRE (m): 38.14
ALTURA GATA (m): 1.13	Cable cortado (m): 1.52	FECHA INYECCION: 1/7/2003	LONG. ANCLADA (m): 9.00
CARGA DE TRABAJO (Ton):	143.50	TIPO DE ENSAYO:	PERFORMANCE
CARGA DE ENSAYO(Ton):	191.40	FECHA DE ENSAYO: 24-Apr-03	LONG. VALORIZABLE.(m): 46.12

HORA	INTERVALO TIEMPO (min)	PRESION MANOMETRO (BAR)	CARGA (ton)	DESPLAZAMIENTOS (mm) BLOQUE DE TRANSFERENCIA LECTURA	Δ	TOTAL	ANCLAJE LECTURA	Δ	TOTAL
8:45:00		28.0	14.35	12.91		0.00	0.00		0.00
8:46:00	0:01:00	66.3	35.88	12.87	-0.04	-0.04	26.86	26.86	26.86
8:47:00	0:01:00	28.0	14.35	12.87	0.00	-0.04	2.98	-23.89	2.98
8:48:00	0:01:00	66.3	35.88	12.87	0.00	-0.04	26.39	23.42	26.39
8:49:00	0:01:00	130.1	71.77	12.87	0.00	-0.04	81.76	55.37	81.76
8:50:00	0:01:00	28.0	14.35	12.87	0.00	-0.04	5.12	-76.64	5.12
8:51:00	0:01:00	66.3	35.88	12.87	0.00	-0.04	32.72	27.60	32.72
8:52:00	0:01:00	130.1	71.77	12.87	0.00	-0.04	83.12	50.41	83.12
8:53:00	0:01:00	193.9	107.65	12.87	0.00	-0.04	135.97	52.85	135.97
8:55:00	0:02:00	28.0	14.35	12.87	0.00	-0.04	7.46	-128.51	7.46
8:56:00	0:01:00	66.3	35.88	12.87	0.00	-0.04	38.99	31.53	38.99
8:58:00	0:02:00	130.1	71.77	12.87	0.00	-0.04	87.45	48.46	87.45
9:00:00	0:02:00	193.9	107.65	12.87	0.00	-0.04	137.05	49.60	137.05
9:02:00	0:02:00	257.7	143.53	12.87	0.00	-0.04	191.03	53.99	191.03
9:04:00	0:02:00	28.0	14.35	12.87	0.00	-0.04	10.04	-181.00	10.04
9:06:00	0:02:00	66.3	35.88	12.87	0.00	-0.04	40.50	30.47	40.50
9:08:00	0:02:00	130.1	71.77	12.87	0.00	-0.04	88.60	48.10	88.60
9:10:00	0:02:00	193.9	107.65	12.87	0.00	-0.04	142.01	53.41	142.01
9:12:00	0:02:00	257.7	143.53	12.87	0.00	-0.04	193.44	51.43	193.44
9:14:00	0:02:00	308.7	172.24	12.87	0.00	-0.04	236.46	43.03	236.46
9:17:00	0:03:00	28.0	14.35	12.87	0.00	-0.04	12.04	-224.43	12.04
9:19:00	0:02:00	66.3	35.88	12.87	0.00	-0.04	39.32	27.28	39.32
9:21:00	0:02:00	130.1	71.77	12.87	0.00	-0.04	91.79	52.47	91.79
9:23:00	0:02:00	193.9	107.65	12.87	0.00	-0.04	144.37	52.59	144.37
9:25:00	0:02:00	257.7	143.53	12.87	0.00	-0.04	196.73	52.36	196.73
9:28:00	0:03:00	308.7	172.24	12.86	-0.01	-0.05	237.04	40.32	237.04
9:29:00	0:01:00	342.7	191.38	12.86	0.00	-0.05	271.93	34.89	271.93
9:30:00	0:01:00	342.7	191.38	12.67	-0.19	-0.24	272.01	0.08	272.01
9:31:00	0:01:00	342.7	191.38	12.67	0.00	-0.24	272.03	0.02	272.03
9:32:00	0:01:00	342.7	191.38	12.67	0.00	-0.24	272.03	0.00	272.03
9:33:00	0:01:00	342.7	191.38	12.67	0.00	-0.24	272.03	0.00	272.03
9:34:00	0:01:00	342.7	191.38	12.67	0.00	-0.24	272.04	0.00	272.04
9:35:00	0:01:00	342.7	191.38	12.67	0.00	-0.24	272.07	0.04	272.07
9:39:00	0:04:00	342.7	191.38	12.67	0.00	-0.24	272.15	0.08	272.15
9:42:00	0:03:00	28.0	14.35	12.67	0.00	-0.24	18.09	-254.07	18.09
9:45:00	0:03:00	289.6	161.50	12.06	-0.61	-0.85	230.60	212.51	230.60
						Creep (mm):	0.22		

OBSERVACIONES:

Lift off inicial:	Fecha-hora: 24 Abr 03 - 12:00	Presión (Bar)=	268	Carga (ton)= 149.33
2do. Lift off:	Fecha-hora: 07 Jul 03 - 13:25	Presión (Bar)=	267.7	Carga (ton)= 149.16

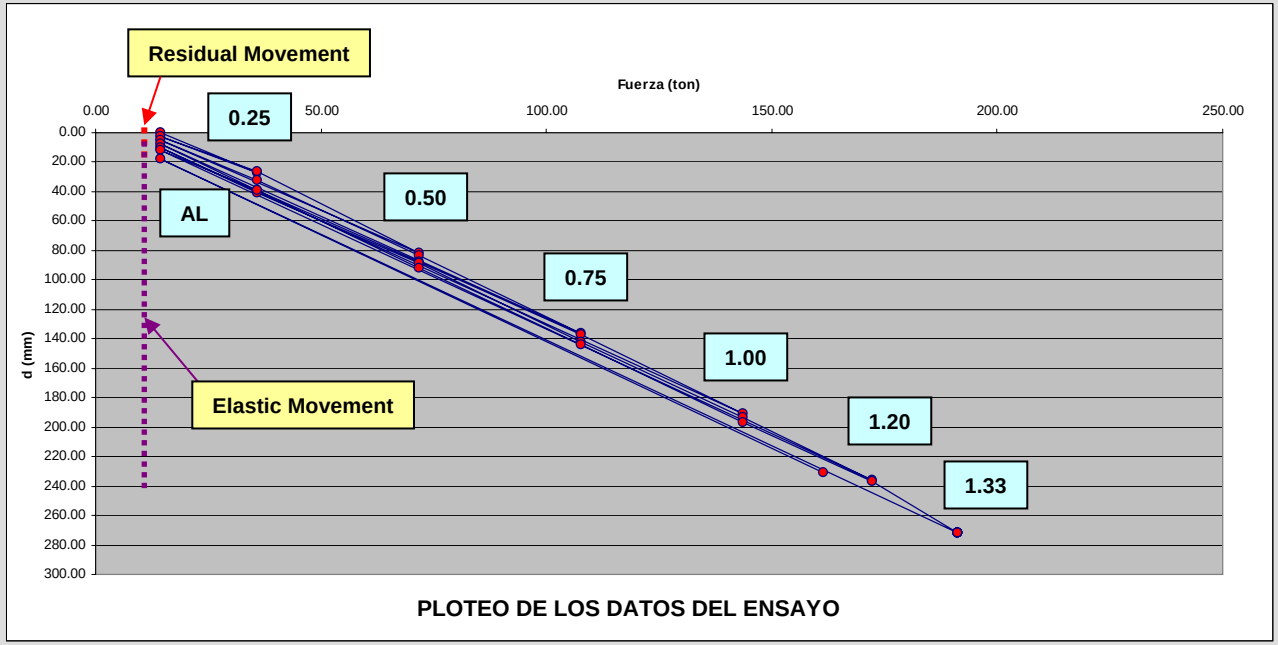
PERFORMANCE TEST

a) whether the anchor has sufficient load carrying capability

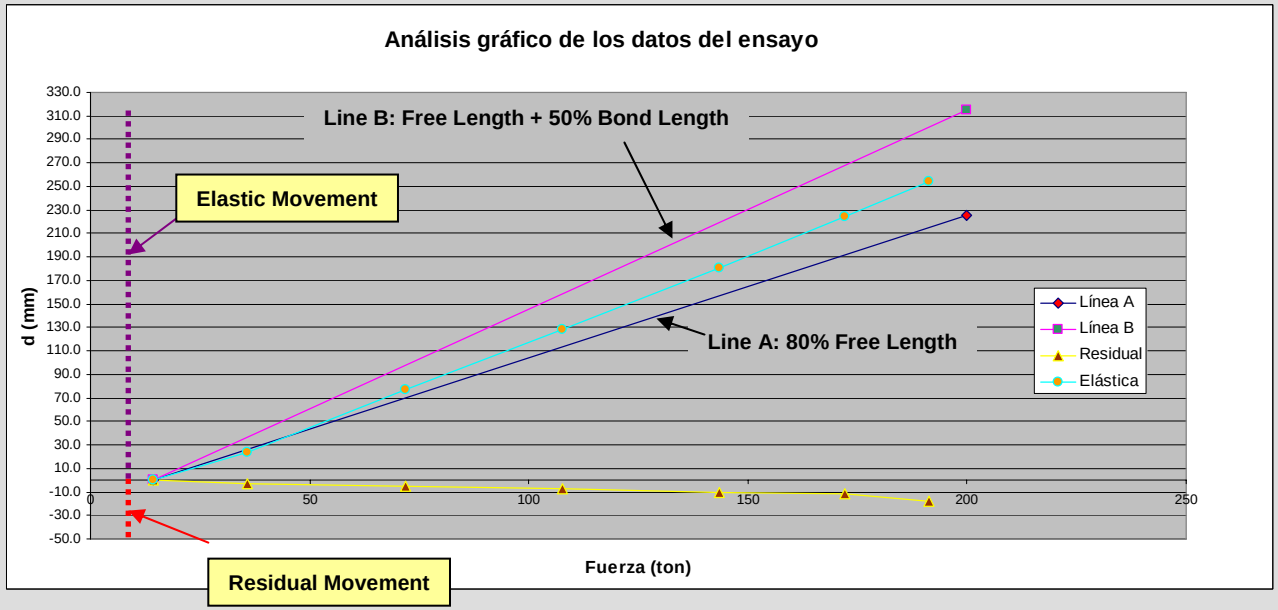
b) that the apparent tendon free length has been established

c) the magnitude of the residual movement

d) that the rate of creep stabilizes within the specified limts.



PLOTEO DE LOS DATOS DEL ENSAYO



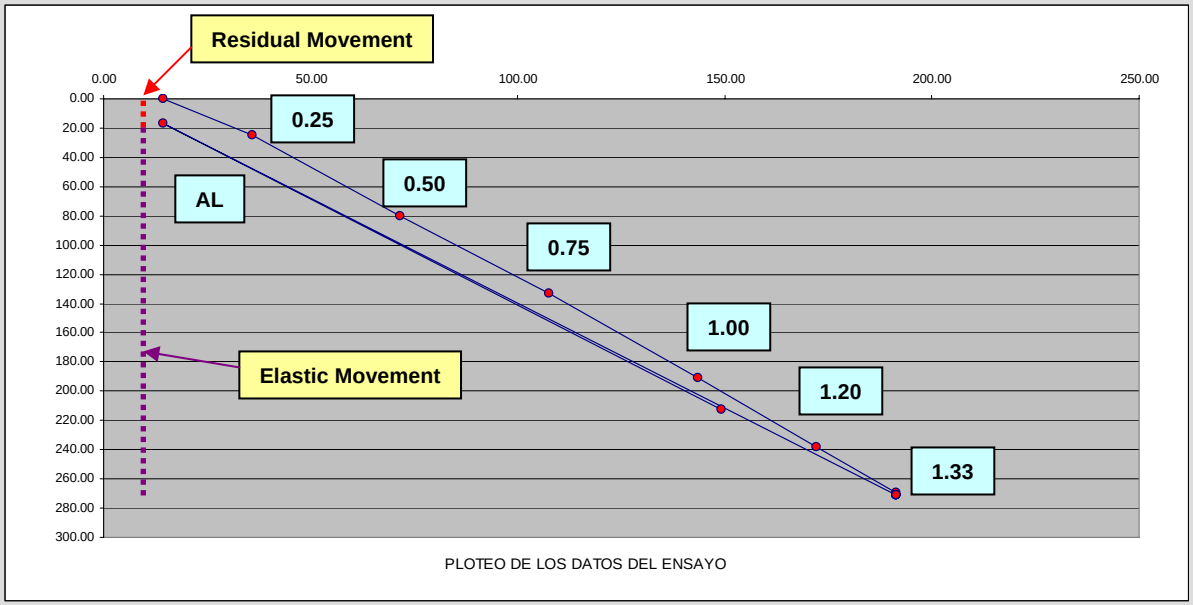
	REPORTE DEL ENSAYO DE CARGA	Geotécnica

PROYECTO : MITIGACIÓN DEL MOVIMIENTO DEL TALUD - FASE IV. C. H. CAÑÓN DEL PATO

EQUIPO DE TENSADO			ANCLAJE Nº:	D-91	LONG. TOTAL (m): 48.50
BOMBA HIDRAULICA:	MH-300/450		Nº DE CABLES:	9.0	LONG. EXTERNA (m): 0.26
MANOMETRO:	LEO 1 - KELLER - 3770		FECHA INSTALACION:	4/1/2003	LONG. LIBRE (m): 39.24
ALTURA GATA (m): 1.12	Cable cortado (m):	1.38	FECHA INYECCION:	4/1/2003	LONG. ANCLADA (m): 9.00

CARGA DE TRABAJO (Ton):	143.50	TIPO DE ENSAYO:	COMPROBACIÓN (PROOF TEST)
CARGA DE ENSAYO(Ton):	191.40	FECHA DE ENSAYO: 16-Jun-03	LONG. VALORIZABLE.(m): 47.23

HORA	INTERVALO TIEMPO (min)	PRESION MANOMETRO (BAR)	CARGA (ton)	DESPLAZAMIENTOS (mm) BLOQUE DE TRANSFERENCIA LECTURA	A	TOTAL	ANCLAJE LECTURA	A	TOTAL
17:09:00		28.0	14.35	35.50		0.00	0.00		0.00
17:10:00	0:01:00	66.3	35.88	35.49	-0.01	-0.01	25.27	25.27	25.27
17:12:00	0:02:00	130.1	71.77	35.52	0.03	0.02	80.29	55.03	80.29
17:14:00	0:02:00	193.9	107.65	35.66	0.14	0.16	133.45	53.16	133.45
17:15:00	0:01:00	257.7	143.53	35.53	-0.13	0.03	190.85	57.40	190.85
17:17:00	0:02:00	308.7	172.24	35.47	-0.06	-0.03	237.96	47.11	237.96
17:19:00	0:02:00	342.7	191.38	35.37	-0.10	-0.13	269.87	31.91	269.87
17:20:00	0:01:00	342.7	191.38	35.37	0.00	-0.13	270.78	0.91	270.78
17:21:00	0:01:00	342.7	191.38	35.32	-0.05	-0.18	271.13	0.35	271.13
17:22:00	0:01:00	342.7	191.38	35.32	0.00	-0.18	271.26	0.13	271.26
17:23:00	0:01:00	342.7	191.38	35.35	0.03	-0.15	271.30	0.04	271.30
17:24:00	0:01:00	342.7	191.38	35.32	-0.03	-0.18	271.33	0.03	271.33
17:25:00	0:01:00	342.7	191.38	35.33	0.01	-0.17	271.36	0.04	271.36
17:29:00	0:04:00	342.7	191.38	35.30	-0.03	-0.20	271.44	0.07	271.44
17:34:00	0:05:00	28.0	14.35	35.60	0.30	0.10	16.76	-254.68	16.76
17:37:00	0:03:00	267.9	149.30	35.46	-0.14	-0.04	212.20	195.44	212.20

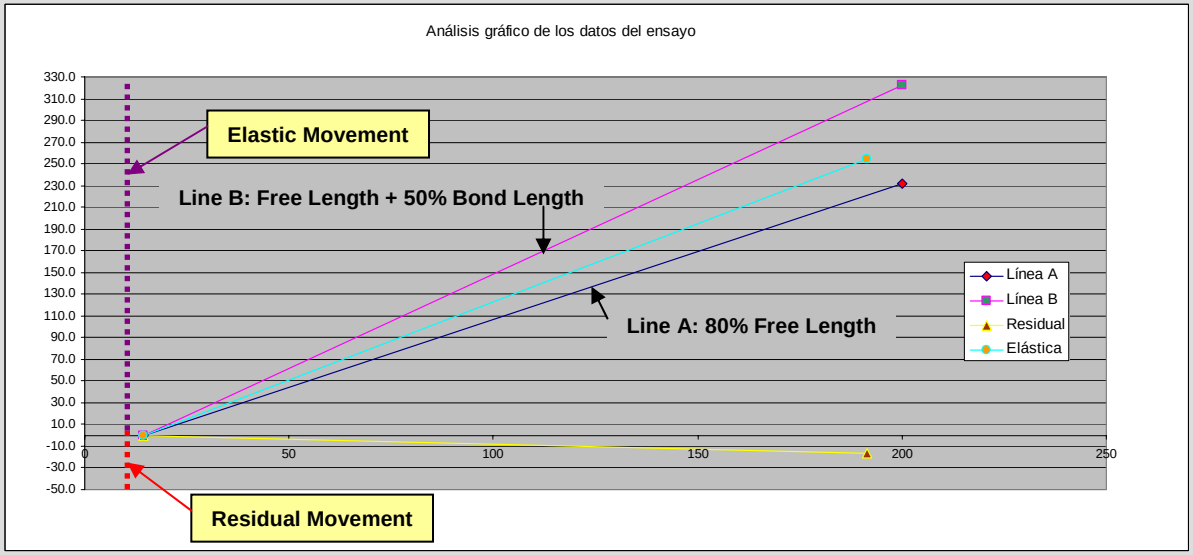


PROOF TEST

a) whether the anchor has sufficient load carrying capability

b) that the apparent tendon free length has been established

c) that the rate of creep stabilizes within the specified limts.




28/05/2003


D 02
25/04/2003


D 02
24. 4. 2003


16. 4. 2003


24. 4. 2003


D 123
D 129
01/08/2003


25/07/2003


13/06/2003

SUMMARY

- Installed 143 Multiple Strand Anchors with capacity of 239 Tonnes (100% GUTS) and a working load of 143.5 Tonnes (60% GUTS) each.
  - Total Length of Installed Anchors = 5591.79 meters; Average Length = 41.73 meters.
- Consolidation grouting with cement grout and mortar. Total bags of cement 12,455 (2.24 bags/m) and 24,306 (4.37 bags/m) bags, respectively. Maximum bags in one hole – 1376 bags in a 53 meter hole.
- Installation of 13 Hydraulic Load Cells. 10 with maximum capacity of 227 Tonnes; 3 with maximum capacity of 136 Tonnes.
- Installation of 2 extensometers and 3 inclinometers.


C-Anchors
Aug-2000 to Jan-2001
D-Anchors
Sep-2002 to Aug-2003
A-Anchors
Sep-1998 to Mar-2000
18/08/2003