Jason Consultants

London – Geneva – Washington DC – San Diego

A FIRST STAGE REPORT PREPARED FOR

EMPRESA DE ACUEDUCTO Y ALCANTARILLO DE BOGOTA ESP

STABILITY OF THE UPSTREAM SLOPE

OF THE

SAN RAFAEL DAM, BOGOTA

BY

Jason Consultants International Inc

Washington D.C.

Principal Geotechnical Consultant – Dr. Terence Ingold

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1.0 Introduction

1.1 The San Rafael dam, located north of Bogota, was designed by Ingetec S.A and was constructed between 1992 and 1994. The reservoir was filled to 85 % of its storage capacity by January 1997.

1.2 Instability of the riprap on the upstream slope was noticed in the summer of 1997 following a drawdown of some 20 m over a period of about 4 months.

1.3 At the request of Empresa de Acueducto y Alcantarillado de Bogota ESP (EAAB), Jason Consultants International Inc have undertaken the first stage of an investigation into the stability of the upstream slope of the San Rafael dam.

1.4 In particular, EAAB have expressed concern regarding distress to the riprap armour to the upstream slope. Accordingly, the objective of this first stage is to report on the condition of the upstream slope and to identify mechanisms causing distress.

1.5 In the course of a visit to Bogota, between 3 and 10 January 2000 he dam was inspected and information was gathered by Dr. Terence Ingold and James Thomson regarding the design and post construction behaviour of the dam.

2.0 Site inspection

2.1 The site was visited on 4th January when a walk-over survey was conducted and information gathered on the post construction behaviour of the dam.

2.2 The inspection of the grassed down stream slope showed this to be substantially planar so suggesting no superficial instability.

2.3 Inspection of the main gallery, which is lined with shotcrete, showed no substantial cracking so suggesting no major instability in the main body of the fill. This was confirmed by inspection of the asphalt to the road running along the crest of the dam which showed no serious longitudinal cracking.

2.4 The dam is of zoned fill construction with seepage controlled by an inclined chimney drain which discharges, via a horizontal drainage blanket, at the down stream toe of the dam. Discharge is into a stilling pond with the discharge flow rate measured by a v-notch weir.

2.5 The down stream slope was found to be dry, so suggesting that the chimney drain was adequately intercepting up stream seepage, while water discharging from the v-notch weir was observed to be clear, so suggesting adequacy of the chimney drain filter and therefore no internal erosion.

2.6 Inspection of the freeboard of the upstream slope, showed this to be armoured with unusual riprap in the form of irregular shaped, rough hewn, sandstone slabs. The slabs were laid with dry vertical and horizontal joints which were generally infilled with loose random stone with a nominal maximum particle size of around 150 mm.

2.7 The riprap appeared to have been laid directly on the Zone 1 fill, comprising the main body of the upstream slope, and no graded filter layer was found between the riprap and Zone 1 fill.

2.8 No inspection was made of the riprap below water level but construction drawings, such as Plano 2 of *Informe de Orba Constuida No. OC-06* prepared by Ingetec S.A in February 1995, show the main slope riprap to extend down to the upstream berm at level 2738.00.

2.9 Several areas of riprap showed signs of superficial instability in the form of either open joints and planar sliding down slope or back tilting of individual armour slabs. The degree of instability varied randomly along the length of the slope with this variability probably reflecting variability in the coefficient of permeability of the Zone 1 fill.

2.10 Down slope movement of individual armour slabs seems to have resulted from washing out of the loose stone fill on the lower horizontal armour slab joint followed by downwards sliding of individual armour slabs under drawdown of the reservoir.

2.11 Although the reservoir is sheltered from wind, and the fetch of about 1500 m is small, EAAB estimated the wave height to be about 15 to 30 cm. Such a wave height would be not be expected to dislodge individual armour slabs but could extract the finer loose stone filling to the joints. This was apparent from the loose stone infill which had washed out from joints higher up the slope and had cascaded down to a lower level.

2.12 That down slope sliding of individual armour slabs had occurred was apparent from the distribution of the horizontal joints. In several locations the lower horizontal joint had effectively closed such that the lower edge of one armour slab was in contact with the upper edge of the armour slab below. Where armour slabs higher up the slope had not moved, upper horizontal joints had opened, by up to one metre, so suggesting down slope sliding of lower armour slabs.

2.13 Immediately above the water line, several of the individual armour slabs showed a pronounced backwards tilt which is typical of localised shallow circular slips in the Zone 1 fill.

2.14 The overall impression created by the walk-over survey was that the dam was operating within normal parameters and showed no signs of major instability. However, there were localised signs of distress to the upstream riprap which, without remedial works, might worsen and so lead to more serious stability problems in the longer term.

2.15 Following the walk-over survey, a brief meeting was held at the site office when a copy of Documento CHSR-IM/004-044, dated September 1999 and entitled *Monitoreo del Comportamiento de las Estructuras Civiles de los Embalses de Chuza y San Rafael* was provided.

3.0 Original dam design

3.1 The dam was designed by Ingetec S.A and was constructed between 1992 and 1994. The reservoir was filled to 85 % of its storage capacity by January 1997.

3.2 Requests were made for sight of the original design, details of the design philosophy, and details of design parameters assumed for the various zoned fills. However, all that was provided was a one page note, given here as Appendix A, setting out design shear strengths and permeabilities assumed for the Zones 1 and 2 fills and permeabilities for the Zones 3 and 3A filter and chimney drain fills.

3.3 The only other design information came from EAAB who had been advised by Ingetec S.A that the thickness of Zone 1 fill on the upstream slope had been constructed 2.5 m thicker than indicated by design.

3.4 Based on Plano 2 of *Informe de Orba Constuida No. OC-06* prepared by Ingetec S.A in February 1995 two aspects of the riprap look odd. The first is the total thickness of the riprap. The second is the lack of an underlying filter layer.

3.5 Concerning the thickness of the riprap, Plano 2 shows the horizontal thickness to be 2.5 m. Since the majority of the upstream slope is constructed at a batter of 1:2.5 this suggests a vertical thickness of riprap of 1.0 m. Based on the site inspection, this thickness does not seem to have been achieved.

3.6 As to the particle size of the riprap, Plano 2 tabulates particle sizes in the range 30 to 60 cms for the Zone 5 riprap whereas paragraph 2.4.3 of the same report suggests blocks of 45 to 60 cm in diameter. What actually seems to have been used are flat slabs with some having a plan area of several square meters. On rapid drawdown, such slabs are likely to allow significant pore water pressures to exist beneath the slabs, so encouraging down slope sliding, and high exit gradients at the open joints, so encouraging loss of fines from the Zone 1 fill.

3.7 No filter layer was observed between the riprap and underlying Zone 1 fill. The design rationale for this is not clear and such an omission is contrary to standard practice.

3.8 For example, Sherard et al (1963) at page 458 of *Earth and Earth-Rock Dams* state "*A layer of filter material consisting of gravel or crushed rock is always required under riprap blankets*". Golze (1977) at page 311 of the *Handbook of Dam Engineering* states "*The bedding layer beneath the riprap should be designed as a filter*". Cedergren (1967) at page 181 of *Seepage, Drainage and Flow Nets* states "*Soil erosion under rock slope protection usually can be prevented by the placement of a filter layer of intermediate-sized material between the soil and the rock*".

3.9 Where rapid drawdown occurs it is important that the filter beneath the riprap should be as free draining as possible so as to depress phreatic surfaces which might otherwise develop close to the surface of the slope. As will be demonstrated in the next section of this report, phreatic surfaces allowed to develop close to the surface of the slope can cause instability of both the slope and the riprap under sudden drawdown.

3.10 It is interesting to note that instability of the riprap was first noticed in the summer of 1997 following a drawdown of some 20 m over a period of about 4 months. (See Figure 11 of Documento CHSR-IM/004-044, dated September 1999 and entitled *Monitoreo del Comportamiento de las Estructuras Civiles de los Embalses de Chuza y San Rafael* which is reproduced here in Appendix B)

4.0 Slope stability analyses

4.1 The main upstream slope is constructed at a batter of 1:2.5 giving rise to a slope angle, ß, of 21.8° with the upper 3 m or so constructed at a batter of 1:2.0 giving rise to a slope angle, ß, of 26.6°. The Ingetec S.A design was based on an assumed Zone 1 fill shear strength of $c'=0$ and $\phi'=32°$ as indicated in Appendix A.

4.2 Overall stability of the upstream face, for various phreatic surfaces, has been assessed using circular slip analyses, based on the Bishop Routine Method, using the programme Talren. Results of these analyses, using the above parameters, are given as Talren graphic and parameter files RANA1 to RANA3 in Appendix C.

4.3 Talren file RANA1 considers rotational stability of the upstream slope, with water impounded to the maximum level of 2772.00, and returns a minimum detected calculated factor of safety of 1.37. The critical slip surface falls above the water line, on the 1:2.0 batter, so indicating calculated factors of safety greater than 1.37 below the impounded water level.

4.4 Talren file RANA2 considers rotational stability of the upstream slope with the impounded water level drawn down to a minimum recorded level of 2748.36. Based on the assumed Ingetec S.A Zone 1 fill ϕ' value of 32° and coefficient of permeability of $6x10^{-6}$ cm/s, the draw down is considered to be sudden and so the phreatic surface in the upstream slope, above a level of 2748.36, is considered to lay immediately below the riprap. These assumptions lead to a minimum detected calculated factor of safety of 0.91 which implies failure.

4.5 Clearly, no such failure has occurred and this suggests that either the phreatic surface within the Zone 1 fill is drawn down in sympathy with the impounded water level and/or the actual ϕ' value is greater than the assumed value of 32°.

4.6 Results for piezometers P-10 and P-11, given in Figure 11 of Documento CHSR-IM/004-044 and reproduced here in Appendix B, suggest that drawdown of the phreatic surface in the Zone 1 fill is instantaneous and almost exactly follows drawdown of the impounded water level. This seems unlikely if the coefficient of permeability of the Zone 1 fill assumes the Ingetec S.A design value of $6x10^{-6}$ cm/s.

4.7 With any piezometer system there is a finite lag time between the recorded and true piezometric level. Consequently, actual phreatic levels tend to be higher than recorded levels. So, for design, it is prudent to assume a high phreatic surface associated with sudden drawdown as is the case in Talren file RANA2.

4.8 That no overall circular slip failure has been observed in the Zone 1 fill is more likely to be associated with the actual ϕ' value being larger than the value of 32° assumed by Ingetec S.A in their design. In reviewing *Informe de Orba Constuida No. OC-06*, which deals with construction of the dam, there seemed to be no reference to testing to determine the actual ϕ' value.

4.9 According to the grading curve given in Plano 2 of *Informe de Orba Constuida No. OC-06* the Zone 1 fill is a coarse material with a maximum particle size of around 150 mm (6") and such a material, if well compacted, would be expected to display a ϕ' value greater than the 32° assumed by Ingetec S.A in their design.

4.10 Like Talren file RANA2, Talren file RANA2A considers rotational stability of the upstream slope with the impounded water level drawn down to a minimum recorded level of 2748.36 and a phreatic surface in the upstream slope immediately below the riprap. However, in RANA2A the ϕ' value has been increased by 3° from 32° to 35°. The effect of this small increment in ϕ' is to increase the calculated factor of safety from 0.91 to 1.02 so demonstrating the sensitivity of calculated stability to small changes in ϕ'.

4.11 Talren file RANA3 again considers rotational stability of the upstream slope with the impounded water level drawn down to a minimum recorded level of 2748.36 but in this analysis the phreatic surface within the upstream shoulder of the dam is also assumed to be drawn down to a level of 2748.36. As expected, these assumptions lead to a minimum detected calculated factor of safety of 1.37 with the critical slip surface falling near the crest of the dam where the slope batter increases to 1:2.0.

4.12 Local stability of the riprap slabs may be investigated using simple *infinite slope analysis* assuming a potential failure plane, parallel to the 1:2.5 batter, at the interface of the riprap slabs and the Zone 1 fill. For simplicity, the interface friction angle between the riprap and Zone 1 fill is assumed to be 32° per the Ingetec S.A design.

4.13 For seepage parallel to the batter the general expression for the factor of safety, F, is $F = (1- [h\gamma_w] / [z\gamma]) (\tan\phi'/\tan\beta)$ where h is the vertical height of the phreatic surface above the failure plane, γ_w is the unit weight of water, z is the vertical depth of the failure plane which in this case is taken to be the declared vertical depth of the riprap of 1 m, γ is the unit weight of the riprap, ϕ' is the interface friction angle between the riprap and Zone 1 fill and ß is the slope angle for the 1:2.5 batter. Taking $\gamma_w / \gamma \approx 0.5$ the above expression for F reduces to $F = (1 - 0.5\ h/z) (\tan\phi'/\tan\beta)$.

4.14 If, on sudden drawdown, the phreatic surface immediately drops to the interface between the riprap slabs and the Zone 1 fill, then h=0 and $F = (\tan\phi'/\tan\beta)$. For $\phi'=32°$ and, for the 1:2.5 batter, $\beta=21.8°$ then F = 1.56 which is adequate.

4.15 However if, on sudden drawdown, water briefly ponds in the upper horizontal joint of a riprap slab the mean pore water acting at the interface of the 1 m thick riprap slab and the Zone 1 fill is 0.5 m. So, for h=0.5m and z=1.0 m, this leads to a calculated factor of safety of (1-0.5x0.5 /1)x1.56 =1.17 which is inadequate.

4.16 The above cases relate to seepage parallel to the slope, however, it is possible that water might seek to exit the Zone 1 fill by horizontal seepage. For this condition the factor of safety, F, is given by the expression $F = \{z (\gamma \cos^2\beta - \gamma_w) \tan\phi'\} / \{z\gamma \sin\beta \cos\beta\}$ which, for the relevant numerical values of the various parameters, leads to a calculated factor of safety of only 0.66 which is clearly inadequate.

4.17 It is probable that the actual ϕ' value is higher than the 32° assumed by Ingetec S.A. Until a representative ϕ' value is determined by testing, the above calculations are illustrative. Nonetheless they indicate the potential instability of the riprap which has already manifested itself on parts of the upstream slope.

5.0 Summary

5.1 Within the first year of operation of the San Rafael dam, instability has occurred in the riprap armour to the upstream slope. Although, at present, the instability is minor, the situation is likely to worsen in the future.

5.2 At the request of EAAB, Jason Consultants S.A inspected the dam and confirmed that there were indeed areas of instability in the riprap with instability likely to worsen over time. It was noted that no filter layer had been provided between the riprap and Zone 1 fill.

5.3 Jason Consultants S.A subsequently prepared this report which considers the mechanisms most likely involved in the instability of the riprap.

5.4 Although piezometer readings suggest that the phreatic surface within the upstream shoulder of the dam draws down instantaneously with drawdown in impounded water level this is considered to be unlikely. Consequently, short lived high phreatic surfaces within the upstream slope are likely to cause down slope slippage of the riprap slabs.

5.5 Although wave action is minimal it is sufficient to dislodge the finer rock fill used to dry pack the joints between the large riprap slabs. Loss of such fill on horizontal joints facilitates down slope movement of the riprap slabs.

5.6 The original specification called for riprap with a nominal diameter of 45 to 60 cm, however, extensive use has been made of large riprap slabs with some of these measuring several square metres in plan. On sudden drawdown, such large slabs prevent uniform discharge of water trapped in the Zone 1 fill and instead concentrate outflow at joints where high exit velocities facilitate loss of the finer rock fill used in the joints and could ultimately facilitate wash-out of the Zone 1 fill.

6.0 Recommendations

6.1 Although there is no immediate concern regarding stability of the upstream slope it is likely that the existing riprap will become progressively more unstable over time.

6.2 It is recommended that basic geotechnical properties of the Zone 1 fill beneath the riprap be assessed to permit the design of suitable remedial works. Geotechnical properties to be determined by specified testing include grading, insitu density and shear strength. Sampling and testing should be carried out by an approved, competent, local geotechnical testing house.

6.3 Based on the geotechnical properties derived from testing, remedial works should be designed which prevent erosion of the Zone 1 fill and suppress high phreatic surfaces within the Zone 1 fill, following rapid drawdown, which might otherwise induce instability in the riprap.

Appendix A - Design information provided by Ingetec S.A

HOJA DE TRABAJO PROYECTO ______ CARGO ______

DESCRIPCION DEL TRABAJO ______

PARAMETROS DE LOS RELLENOS DE LA PRESA DE SAN RAFAEL CONSIDERADOS EN EL DISEÑO

- ESPALDONES DE LA PRESA – ZONAS 1 y 2

  Cohesión = 0
  Angulo de fricción, $\phi' = 32°$
  Permeabilidad, $k = 6 \times 10^{-6}$ cm/s

- FILTROS y DREN – ZONAS 3 y 3A

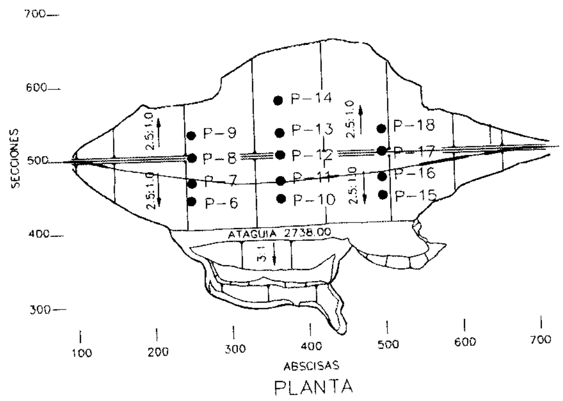
  Permeabilidad – zona 3, $k = 6 \times 10^{-3}$ cm/s
  Permeabilidad – zona 3A, $k = 3$ cm/s

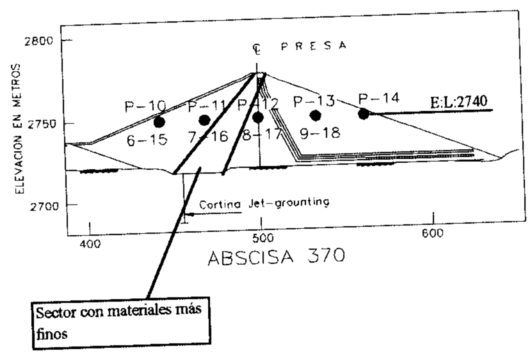
Especif:

Pleanners

Appendix B - Figure 11 of Documento CHSR-IM/004-044

EMBALSE SAN RAFAEL
PIEZÓMETROS NEUMÁTICOS INSTALADOS EN EL RELLENO (EL.2740)
ELEVACIONES PIEZOMÉTRICAS





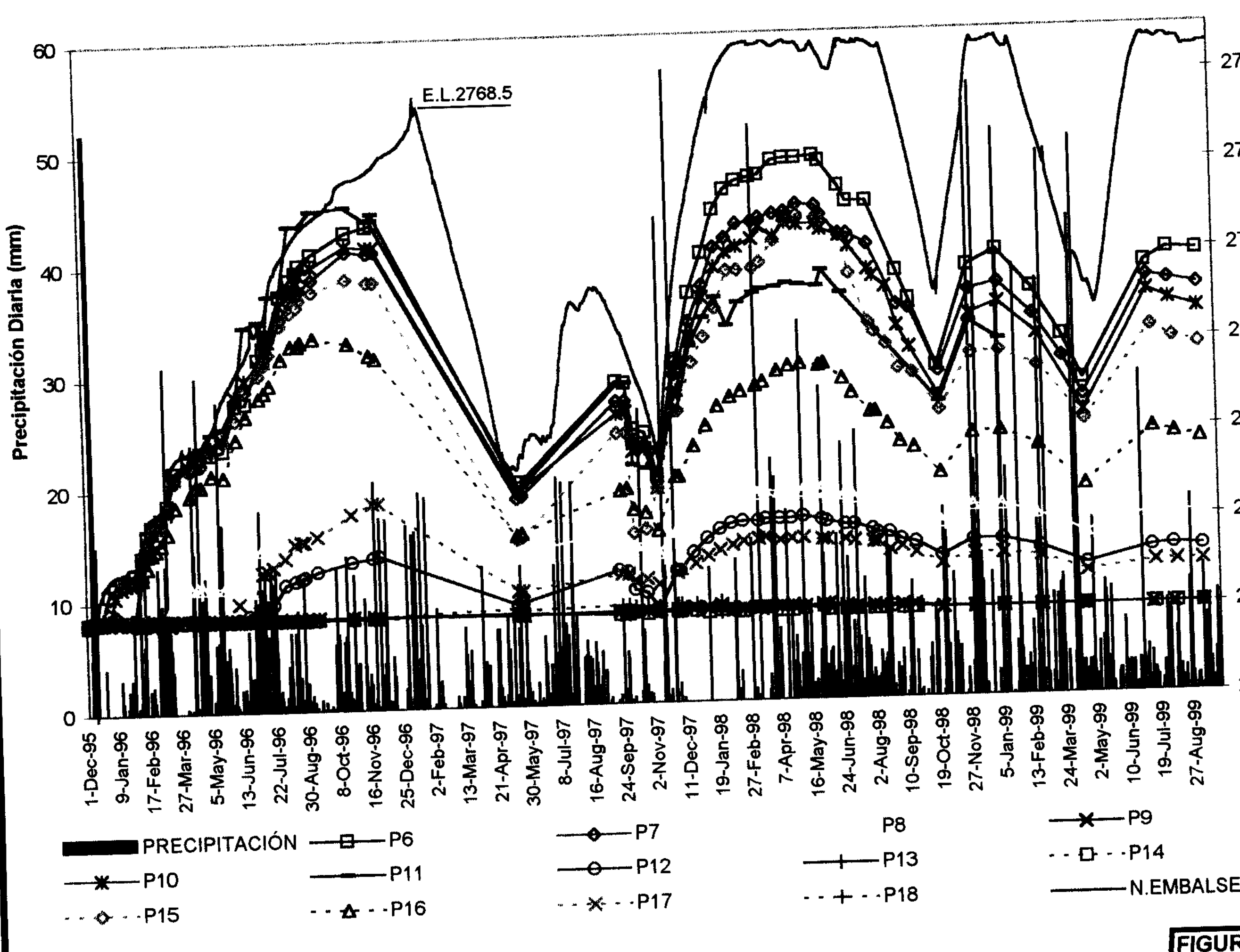


FIGURA No. 11

Appendix C - Talren stability analyses

Soil	1	2	3
γ	20.0	20.0	20.0
Γs1	1.000	1.000	1.000
c	.0	.0	1000.0
Δc[z]	.00	.00	.00
Γc	1.000	1.000	1.000
ϕ	32.0	32.0	.0
Γϕ	1.000	1.000	1.000
ru	.00	.00	.00

Units in kN, meter and degrees
Calculation method:BISHOP

996,00 6,72 3,24 2,13 1,64 1,45 1,55 1,59 1,59
996,00 6,03 2,92 1,88 1,37 1,49 1,57 1,59 1,58
996,00 5,36 2,60 1,58 1,46 1,53 1,58 1,61 1,60
996,00 4,70 2,26 1,55 1,48 1,58 1,60 1,60 1,59
996,00 4,07 1,88 1,50 1,52 1,60 1,59 1,58 1,61
996,00 3,43 1,71 1,47 1,60 1,58 1,62 1,61 1,60
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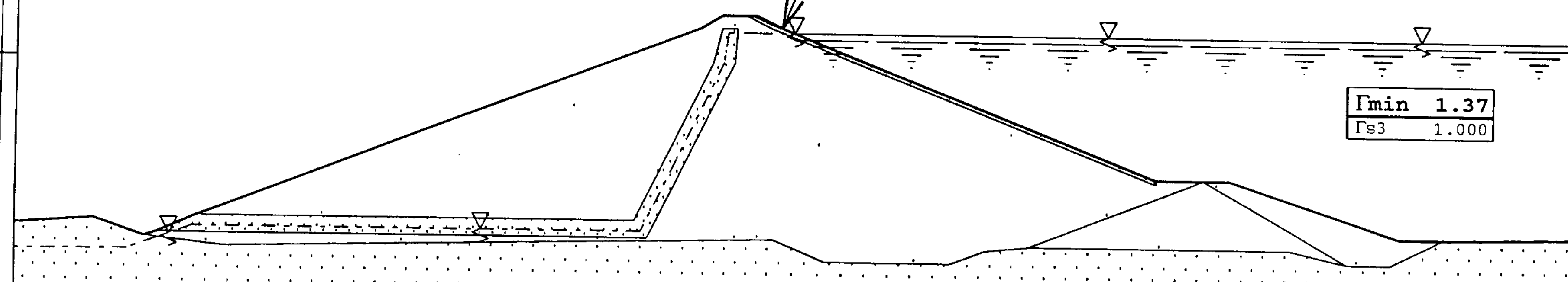


Γmin	1.37
Γs3	1.000

Scale :
50 100

Date : 11/30/1999 Time : 15h 3mn

TALREN
V3.1 of 03/15/96

STATIC ANALYSIS OF UPSTREAM SLOPE
MAXIMUM WATER LEVEL 2772.00
SCALE 1:1500
File: **RANA1** Proj: **SANRAPHA**

STUDY MADE BY :
JASON S.A

Figure

SOILS

No	γ	Γs1	c	Δc(z)	Γc	ϕ	Γϕ	ru	qs	pl	Ks.B
1	20.0	1.000	.0	.0	1.000	32.0	1.000	.0	.0	.0	.0
2	20.0	1.000	.0	.0	1.000	32.0	1.000	.0	.0	.0	.0
3	20.0	1.000	1000.0	.0	1.000	.0	1.000	.0	.0	.0	.0

UNIT WEIGHT OF WATER: 9.81

UNITS in kN, meter and degrees
Calculation method: BISHOP

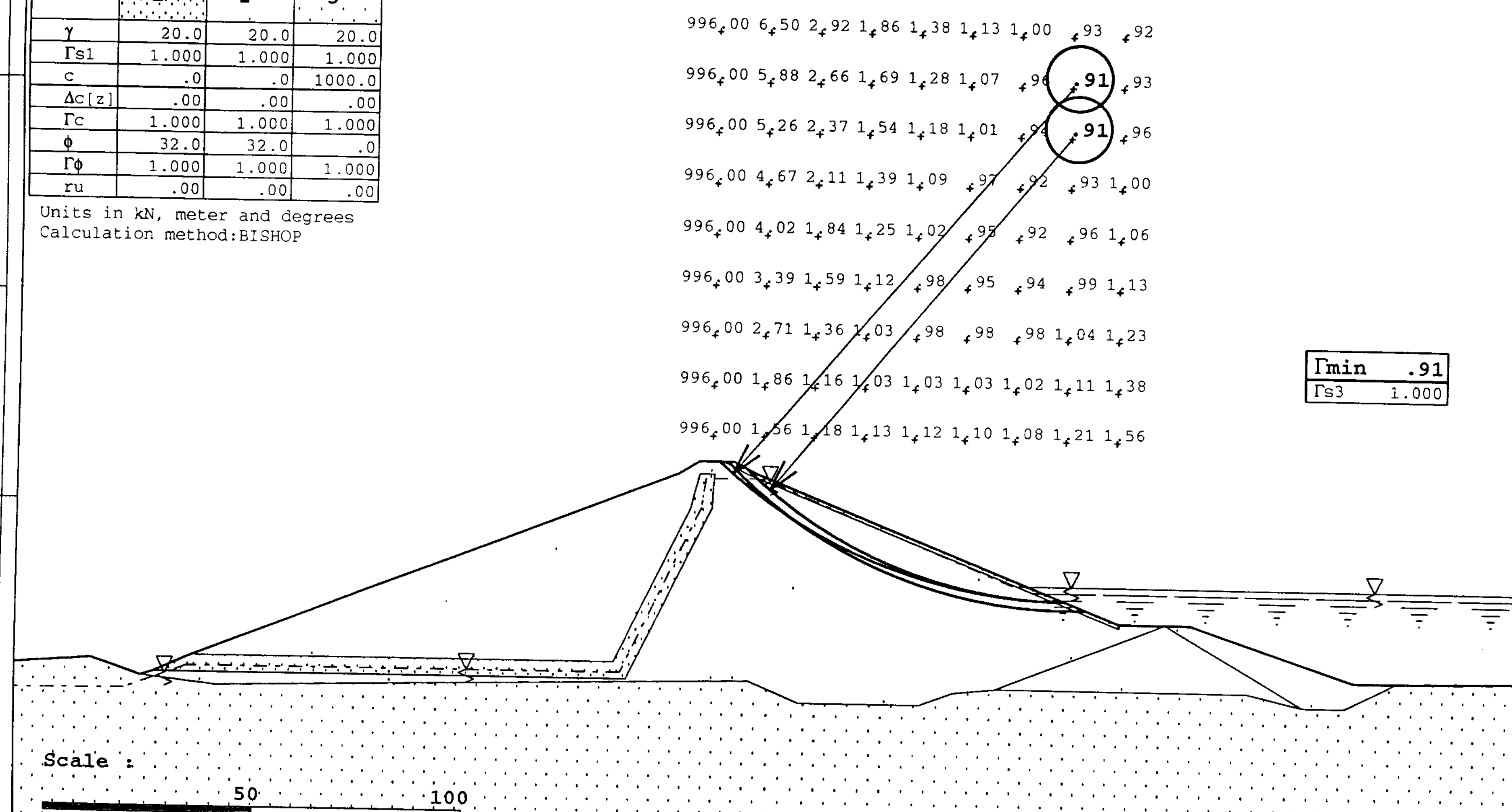
Date:Nov 30 1999 Time:15h 3mn 44

Project:	File No:	
SANRAPHA	RANA1	**STATIC ANALYSIS OF UPSTREAM SLOPE** MAXIMUM WATER LEVEL 2772.00 SCALE 1:1500

TALREN V3.1 of 03/15/96	STUDY MADE BY : **JASON S.A**	CALCULATION PARAMETERS: Pertaining to **Figure**

Soil	1	2	3
γ	20.0	20.0	20.0
Γs1	1.000	1.000	1.000
c	.0	.0	1000.0
Δc[z]	.00	.00	.00
Γc	1.000	1.000	1.000
φ	32.0	32.0	.0
Γφ	1.000	1.000	1.000
ru	.00	.00	.00

Units in kN, meter and degrees
Calculation method:BISHOP



Date : 12/ 1/1999 Time : 3h 4mn

TALREN
V3.1 of 03/15/96

STATIC ANALYSIS OF UPSTREAM SLOPE
MINIMUM RECORDED WATER LEVEL 2748.36
RAPID DRAWDOWN SCALE 1:1500
File: **RANA2** Proj: **SANRAPHA**

STUDY MADE BY :
JASON S.A

Figure

Copyright (c) 1981 TALREN - TERRASOL

SOILS

No	γ	Γs1	c	Δc(z)	Γc	φ	Γφ	ru	qs	pl	Ks.B
1	20.0	1.000	.0	.0	1.000	32.0	1.000	.0	.0	.0	.0
2	20.0	1.000	.0	.0	1.000	32.0	1.000	.0	.0	.0	.0
3	20.0	1.000	1000.0	.0	1.000	.0	1.000	.0	.0	.0	.0

UNIT WEIGHT OF WATER: 9.81

UNITS in kN, meter and degrees

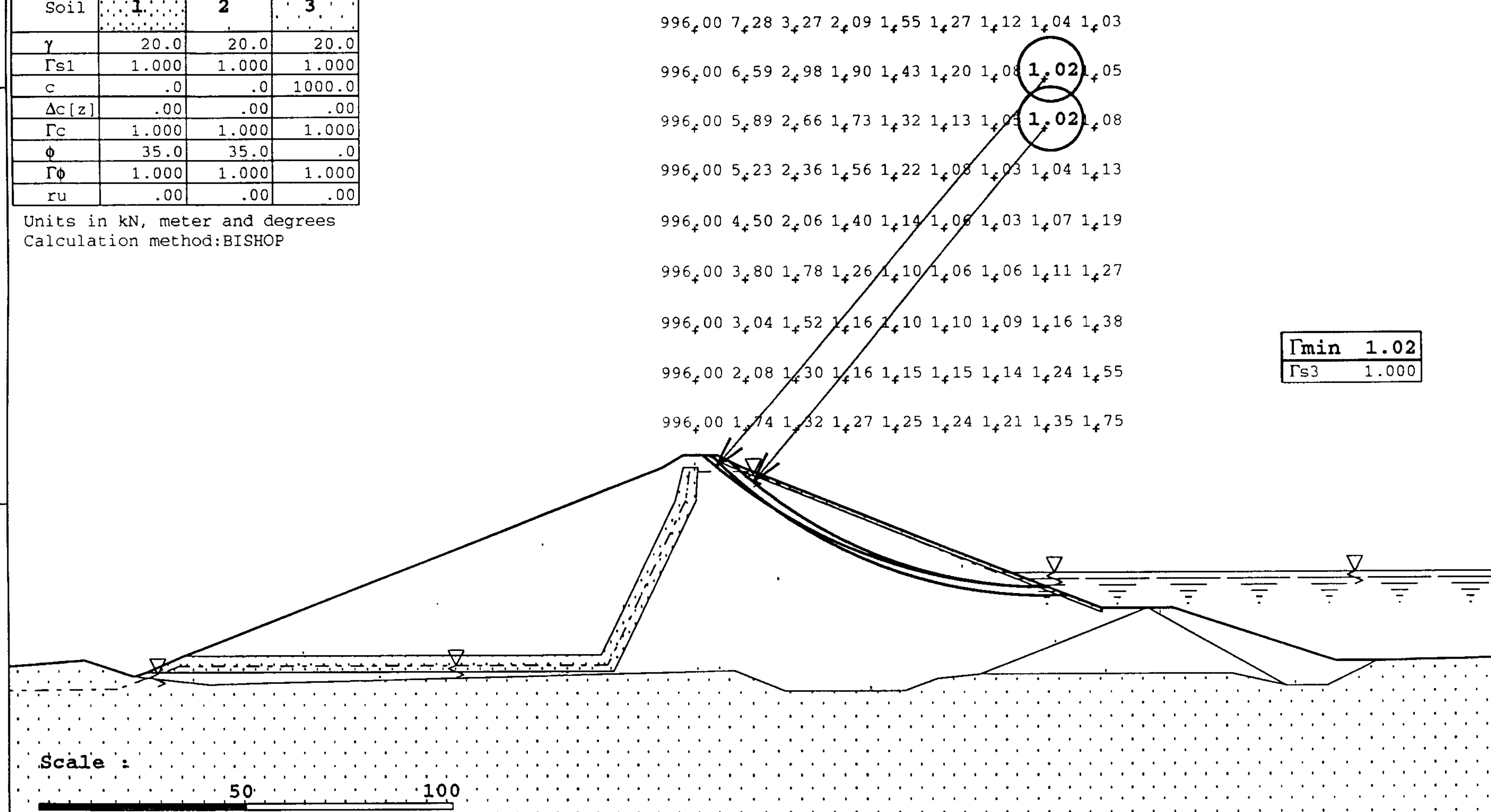
Calculation method: BISHOP

Date:Dec 1 1999 Time: 3h 4mn 59

Project: SANRAPHA	File No: RANA2	STATIC ANALYSIS OF UPSTREAM SLOPE MINIMUM RECORDED WATER LEVEL 2748.36 RAPID DRAWDOWN SCALE 1:1500	
TALREN V3.1 of 03/15/96		STUDY MADE BY : JASON S.A	CALCULATION PARAMETERS: Pertaining to **Figure**

Soil	1	2	3
γ	20.0	20.0	20.0
Γs1	1.000	1.000	1.000
c	.0	.0	1000.0
Δc[z]	.00	.00	.00
Γc	1.000	1.000	1.000
φ	35.0	35.0	.0
Γφ	1.000	1.000	1.000
ru	.00	.00	.00

Units in kN, meter and degrees
Calculation method:BISHOP



Date : 12/ 2/1999 Time : 0h 51mn

TALREN V3.1 of 03/15/96	STATIC ANALYSIS OF UPSTREAM SLOPE MINIMUM RECORDED WATER LEVEL 2748.36 RAPID DRAWDOWN SCALE 1:1500 File: **RANA2A** Proj: **SANRAPHA**	STUDY MADE BY : **JASON S.A**	Figure

SOILS

No	γ	Γs1	c	Δc(z)	Γc	ϕ	Γϕ	ru	qs	pl	Ks.B
1	20.0	1.000	.0	.0	1.000	35.0	1.000	.0	.0	.0	.0
2	20.0	1.000	.0	.0	1.000	35.0	1.000	.0	.0	.0	.0
3	20.0	1.000	1000.0	.0	1.000	.0	1.000	.0	.0	.0	.0

UNIT WEIGHT OF WATER: 9.81

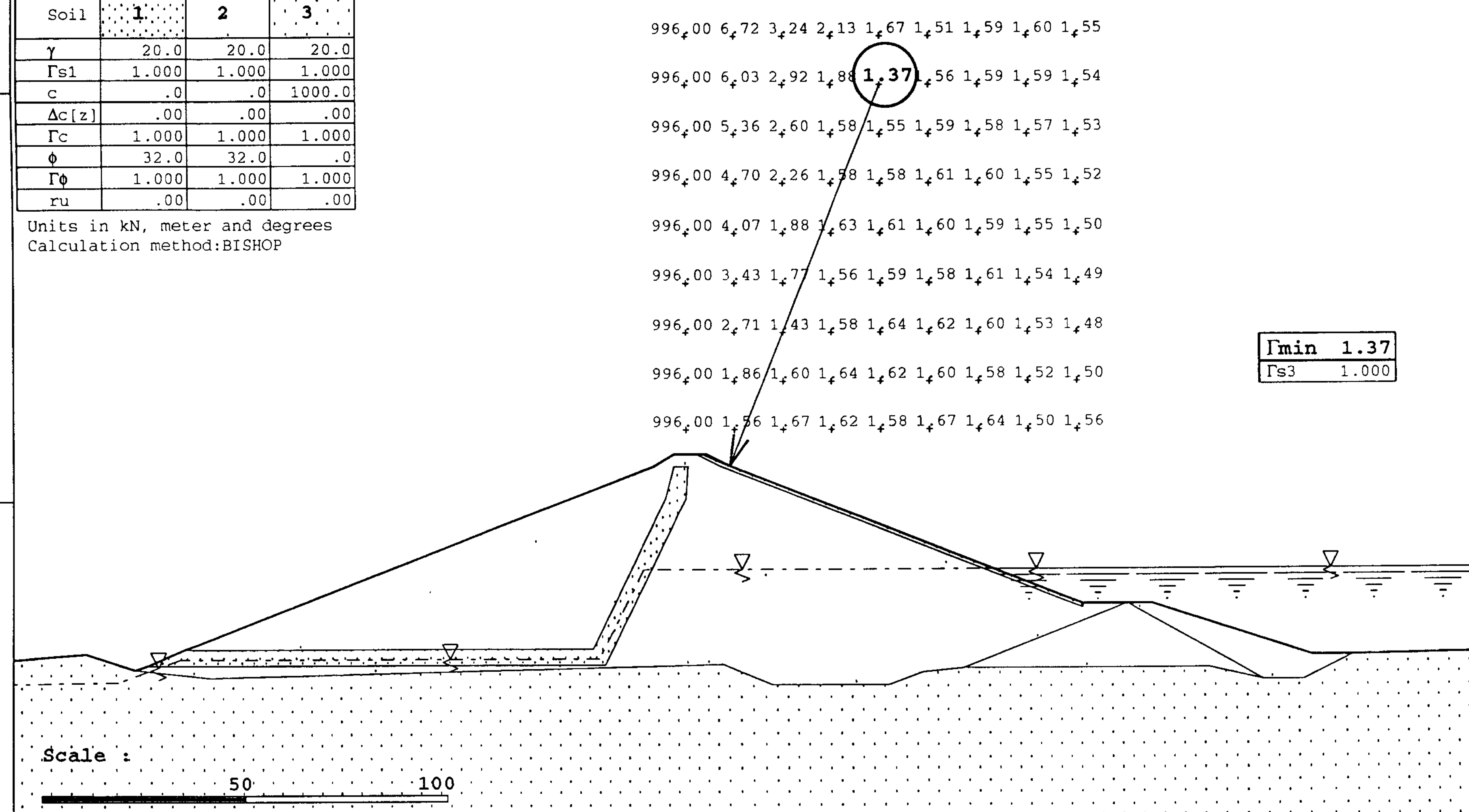
UNITS in kN, meter and degrees
Calculation method: BISHOP

Date:Dec 2 1999 Time: 0h 51mn 55

Project: SANRAPHA	File No: RANA2A	STATIC ANALYSIS OF UPSTREAM SLOPE MINIMUM RECORDED WATER LEVEL 2748.36 RAPID DRAWDOWN SCALE 1:1500	
TALREN V3.1 of 03/15/96		STUDY MADE BY : JASON S.A	CALCULATION PARAMETERS: Pertaining to Figure

Soil	1	2	3
γ	20.0	20.0	20.0
Γs1	1.000	1.000	1.000
c	.0	.0	1000.0
Δc[z]	.00	.00	.00
Γc	1.000	1.000	1.000
φ	32.0	32.0	.0
Γφ	1.000	1.000	1.000
ru	.00	.00	.00

Units in kN, meter and degrees
Calculation method:BISHOP



Date : 12/ 1/1999 Time : 3h 34mn

TALREN V3.1 of 03/15/96	STATIC ANALYSIS OF UPSTREAM SLOPE MINIMUM RECORDED WATER LEVEL 2748.36 DRAWDOWN PER PIEZO P10 & 11 SCALE 1:1500 File: **RANA3** Proj: **SANRAPHA**	STUDY MADE BY : **JASON S.A**	**Figure**

SOILS

No	γ	Γs1	c	Δc(z)	Γc	ϕ	Γϕ	ru	qs	pl	Ks.B
1	20.0	1.000	.0	.0	1.000	32.0	1.000	.0	.0	.0	.0
2	20.0	1.000	.0	.0	1.000	32.0	1.000	.0	.0	.0	.0
3	20.0	1.000	1000.0	.0	1.000	.0	1.000	.0	.0	.0	.0

UNIT WEIGHT OF WATER: 9.81

UNITS in kN, meter and degrees

Calculation method: BISHOP

Date:Dec 1 1999 Time: 3h 34mn 59

Project: SANRAPHA	File No: RANA3	STATIC ANALYSIS OF UPSTREAM SLOPE MINIMUM RECORDED WATER LEVEL 2748.36 DRAWDOWN PER PIEZO P10 & 11 SCALE 1:1500	
TALREN V3.1 of 03/15/96		STUDY MADE BY : JASON S.A	CALCULATION PARAMETERS: Pertaining to **Figure**