ORGANISATION POUR LA MISE EN VALEUR DU FLEUVE SENEGAL

DEPARTEMENT DE L'INFRASTRUCTURE REGIONALE
GROUNDWATER MONITORING PROJECT
OMVS/USAID PROJECT 625-0958
ST-LOUIS / SENEGAL

REPERTOIRE

AND

HYDROGEOLOGICAL SYNTHESIS REPORT

ENVIRONS OF MANANTALI DAM
BAFOULABE MAP (27)

(OBSERVATION PERIOD 1988 - 1989)

VOLUME 3

WRITTEN JOINTLY BY
* OMVS/DIR/PES
* ISTI INC.

FINAL REPORT, JUNE 1990

WP.5 FILE : VOL.3.ENG.TXT

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TABLE OF CONTENTS

LIST OF ANNEXES

LIST OF TABLES

LIST OF FIGURES

1 PROJECT PRESENTATION

1.1 Project origin

The Senegal River Development Organization (L'Organisation pour la Mise en Valeur du Fleuve Sénégal, OMVS) and the United States Agency for International Development (USAID) signed a Grant Agreement for the Groundwater Monitoring Project 625-0958, on August 30 1983. This grant agreement was made possible following an environmental study by Gannet Fleming in 1970, reviewed in 1979 by Mr. George C. Taylor.

The project commenced field activities in January 1985 and concluded them on June 30, 1990.

1.2 Project objectives

The goals and expected outputs (short and medium term objectives) listed in the Project Paper Document were:

1) development of a master plan for the management of surface and groundwater,

2) development of a data management system for the OMVS,

3) development of a data compilation and analysis system,

4) training of OMVS personnel for the management of surface and groundwater according to the master plan,

5) construction of an OMVS piezometric network.

Objective 1) and, subsequently, objective 4) were revised and redefined during the course of the project through the interventions of short term consultants, Mr. M. Vandenbeusch of BRGM, Mr. E. Bolke of USGS, and Mr. E. Weiss of USGS. This point is treated in detail in the project's final evaluation report (Ref.: Reeser and Dendrou). Objective 1) was replaced with the obligation to write two synthesis reports: Volume II - dealing with the Senegal River delta region, and Volume III - dealing with the environs of Manantali Dam.

This present report constitutes Volume III, covering the environs of Manantali Dam.

In general, project activities, covering the entire Senegal River valley and the area near Manantali dam, were focused on the collection and analysis of hydrogeological, climatic and water level data, and the development of a computerized data management system. These were obtained:

* first of all, by the construction of the OMVS piezometric network which contains 569 piezometers located in the Senegal River valley between Bakel and Diama Dam and 20 piezometers in the area near Manantali Dam,

* by the inclusion of village wells to the OMVS piezometric networks, bringing the total number of hydrogeological observation points to 1151 sites,

* thereafter, by the hydrogeological follow-up of the network,

* by the collection of water level and climatic data recorded by other organizations.

Through this project, OMVS aimed to acquire a hydrogeological observation system which would permit it to monitor the evolution of the upper aquifer in relation to current and future development works in the Senegal River valley (dams and irrigated perimeters).

Analysis of the collected data should permit the study of:

a) the impact of the Diama and Manantali dams on the aquifers in contact with the river bed,

b) the rise of saline groundwater within the irrigated perimeters, especially downstream of Podor,

c) the natural recharge of alluvial aquifers and deep aquifers underlying the Senegal River valley,

d) groundwater contamination mechanisms related to the use of fertilizers and pesticides,

e) the hydrogeological potential of the different aquifers with respect to agricultural development.

1.3 Report authors

This report, available in French and English, was written by Mr. Denis Richard, consulting engineer (ISTI), in collaboration with Mr. A. Diagana, D.E.A. in hydrogeology, Chiekh Anta Diop University, Dakar, following utilization of the GES data base (a project output) and Groundwater software, in addition to many related computer software tools (WP5, Lotus, Surfer, Grapher and others).

Mr. Thomas Piekutowski, independent consultant, wrote annexes #5 and #6. Annex #5 presents hydrological data for Manatali Dam (3 year period: 1987-1989), and annex #6 treats average monthly climatic parameters (4 year period: 1986-1989).

1.4 Project contributors

The production of this report, covering the environs of Manantali Dam, was made possible through the combined efforts of many persons, among whom:

* the local personnel of the Manantali sector office, responsible for the collection and pre-analyses of field data,

* the local central office personnel (Mr. O. Ngom, project chief, Ndar Toute, St. Louis), responsible for coordination of the field activities of each sector office (Mr. L. Sangare, St. Louis, Senegal sector chief, Mr. A. Ndiayes, Rosso, Mauritania sector chief, and Mr. Toure, Manantali, Mali sector chief).

This project, implemented by OMVS/DIR (Département des Infrastructures Régionales), benefitted from the support of technical assistance; long-term (ISTI) and short-term (USGS, BRGM et INFORMISSION).

In order to attain project goals, ISTI provided project management assistance to OMVS by assigning a consulting engineer, Mr. D. Richard, to work with the Groundwater Monitoring Unit (PES) project chief.

INFORMISSION, a subcontractor to ISTI, was responsible for the development and installation of the computer data base (GES) through the contributions of computer specialists, Mr. M. Fortin, Mr. L. Brunelle and Mr. M. Migneault.

BRGM (Mr. M. Vandenbeusch, hydrogeologist) and USGS (Mr. E. Bolke, hydrogeologist, Mr. R. Hollway, computer specialist in hydrogeological applications, and Mr. E. Weiss, hydrogeological modelling specialist), participated in orienting the data interpretation and revising objective 1).

The upstream zone corresponds to the region occupied by the dam reservoir. The surface area[3] of the reservoir varies from 272 km^2 at an elevation of 187 m ASL to 477 km^2 at the elevation of maximum fill: 208 m ASL. The volume of water retained at the elevation of maximum fill is estimated to be 11 billion m^3 (according to Mr. KONARE, Director of Manantali Dam).

The downstream zone is the part of the hydrographic network with a water deficit related to the storage capacity of the dam.

This whole hydrographic network (principal and secondary watercourses) delimits, in the region of the dam, just part of a watershed of low surface area (see the map locating the OMVS piezometric network, 1/200,000).

2.3 Geology

2.3.1 Regional

Within the limits of Plateau Mandingue[4], the various geologic formations which have been mapped are:

* *the recent formations*: comprising ancient alluvium and terraces,

* *the Upper Proterozoic and Terminal Cover*: represented by the following successive groups; *Nioro* (dolomitic limestones, feldspathic sandstones, argillite, silexites and tillites), *Bakoye* (argillites, siltstones and sandstones), *Souroukoto* (sandstones, argillites).

* *the Lower Proterozoic Bedrock*: represented by the sedimentary and volcano-sedimentary Birrimian (grauwackes and conglomerates, metamorphic-sedimentary and complex volcano-sedimentary formations). These formations do not show on the surface within the limits of Plateau Mandingue.

Bakoye group formations occupy most of the surface area of the Manantali Dam region.

2.3.2 Local (near the Dam)

For the area close to Manantali Dam, the "Groupement de Manantali"[5], consortium responsible for the dam's construction, has codified the different formations in the Bakoye group lithostratigraphic series (see section 2.3.1) in order to perform a geotechnical analysis of the dam site.

On the following page, the reader will find schematic representations of the geologic sections and codes proposed by the Groupement de Manantali[6], subdivided as:

* Recent/Quaternary Formations
* Upper Complex / Bakoye series
* Lower Complex / Bakoye series

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[3] Ref.: Groupement de Manantali, 1979, Mission A2.1, Texts, p. 76.

[4] Ref.: Carte Photogéologique du Laboratoire de géologie Dynamique St-Jérôme Marseille en collaboration avec la Direction Nationale de Géologie et des Mines du Mali 1/200 000.

[5] Ref.: Groupement de Manantali, 1978, Mission a1.6, Volume 1, p. 19-23.

[6] Ref.:Groupement de Manantali, 1979, Mission A2.1, Text. p.19.

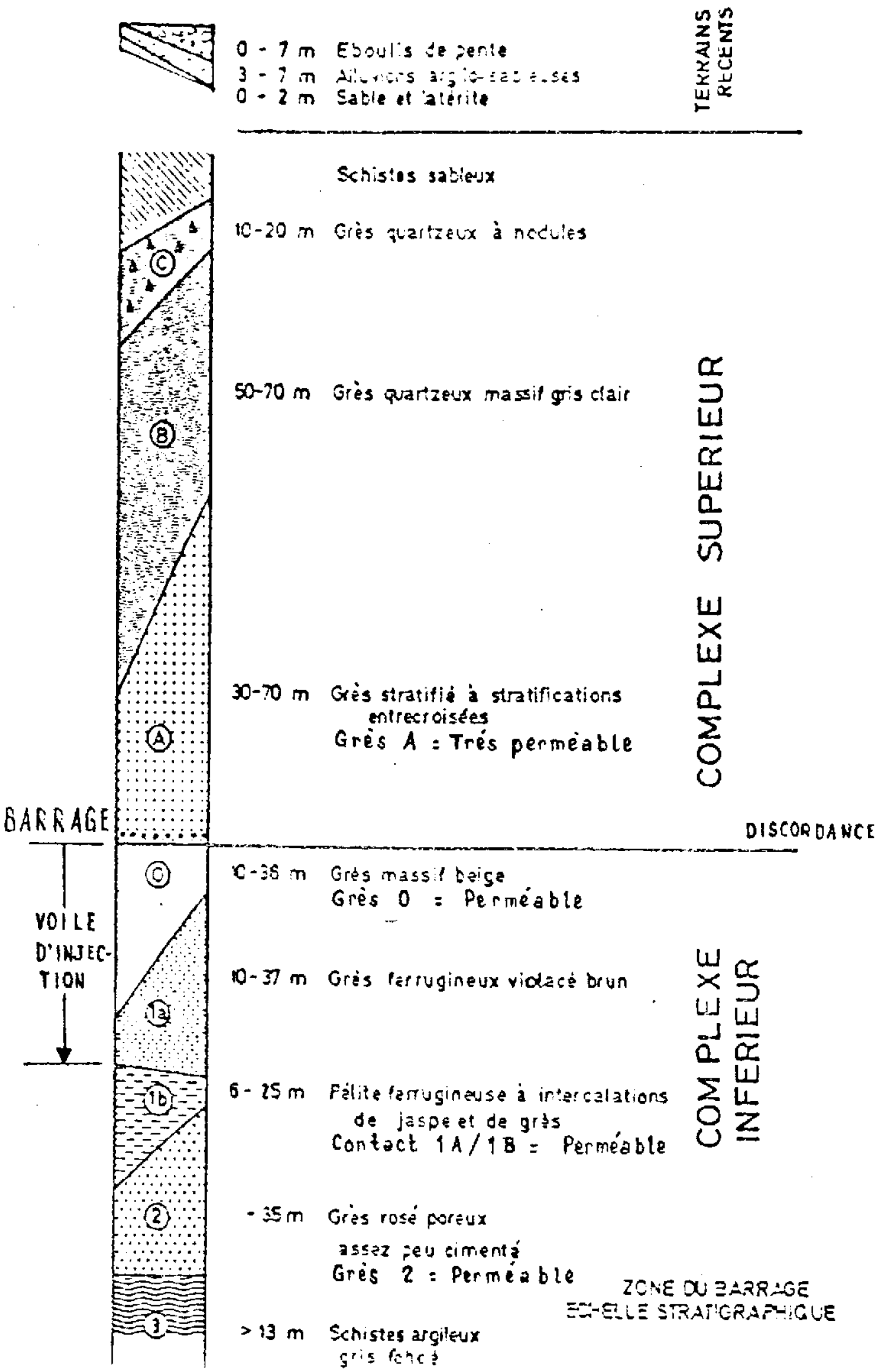
0 - 7 m Eboulis de pente
3 - 7 m Alluvions argilo-sableuses
0 - 2 m Sable et latérite
TERRAINS RECENTS
Schistes sableux
10-20 m Grès quartzeux à nodules
C
50-70 m Grès quartzeux massif gris clair
B
30-70 m Grès stratifié à stratifications entrecroisées
Grès A : Très perméable
A
COMPLEXE SUPERIEUR
BARRAGE
DISCORDANCE
VOILE D'INJECTION
10-36 m Grès massif beige
Grès 0 : Perméable
0
10-37 m Grès ferrugineux violacé brun
1a
6 - 25 m Pélite ferrugineuse à intercalations de jaspe et de grès
Contact 1A / 1B : Perméable
1b
COMPLEXE INFERIEUR
- 35 m Grès rosé poreux assez peu cimenté
Grès 2 : Perméable
2
> 13 m Schistes argileux gris foncé
3
ZONE DU BARRAGE
ECHELLE STRATIGRAPHIQUE

FIG. 1

The following descriptions are extracted from the Groupement de Manantali Report:

** Recent Formations*

These constitute the surface terrains that can be subdivided as follows:

- alluvium deposited by the Bafing, essentially clayish-silts containing traces of ferric oxide and organic matter. The thickness of these deposits varies from 3 to 7 m close to the river and lessening toward the valley slopes.

- laterally, these deposits progressively become a mixture of alluvial and colluvial (eroded from the valley walls) deposits. These deposits are between 1 and 5 m thick.

- the bottoms of the valley slopes are covered with talus, some blocks of which are many cubic meters in size. The thickness of these deposits can be up to 7 m.

- on the plateau, the surface cover is limited to small areas of organic soil and small accumulations of blocks.

** Upper Complex*:

It is represented by two types of sandstone formations that we distinguish from top to bottom:

Sandstone (C): hard, compact, massive quartzite sandstone. Highly recrystallized (metamorphosed) and fine grained. More than 50 m thick.

Sandstone (B): grey-green, compact, homogenous quartzite sandstone. Highly cemented with quartz. More than 50 m thick.

** Lower Complex*

It is represented by three types of sandstone formation and one pelitic formation:

Sandstone O: fine to medium grained sandstone, beige to brown-grey in color. Its thickness varies from 10 to 36 m.

Sandstone (1A): fine to medium grained, ferriferous sandstone, brown to purplish-brown in color. The quartz and feldspar grains are embedded in an essentially quartziferous and ferriferous groundmass. Its thickness varies from 10 to 37 m.

Pelite (1B): alternating layers of ferriferous pelite, limestone, jasper and/or volcanic tuff in which thin, interlaminate beds of fine to medium grained sandstones are laid. The pelitic layers of this formation are highly flaked. Its thickness varies from 6 to 25 m.

Sandstone (2): quartziferous sandstone, from brown grey to purple in color, progressive intrusions of lighter spots and ribbons. The essentially quartzo-feldspathic sandstone is bound by silicates. It can be as thick as 35 m.

Clay shale (3): dark grey. More than 13 m thick.

2.4 Structural considerations

The dam is located at a relatively pronounced encroachment of the nearly vertical cliffs which border the lower part of the Bafing valley.

The abrupt break in slope that marks the cliff bottoms corresponds, approximately, to a stratigraphic deformation of the sub-horizontal infra-Cambrian formations.

The valley slopes and the two plateaus bordering the site present similar structures capped by quartzite sandstone, about the same on both sides of the river. These are cut, sometimes deeply, by vertical fractures which can extend regionally[7]. These fractures have been studied by Groupement de Manantali as potential leaks from the reservoir. The boreholes made by Groupement de Manantali from on top of the plateaus showed the presence of a water table 30 m above the valley floor.

The median zone of the Bafing valley is characterized by a graben which is bordered on the north by a highly fractured zone wherein the layers are displaced by almost 70 m. This deformation is step-like. The width of the zone affected by the fault is on the order of 80 m. To the south, the graben is delimited by a fault into which was injected a dolerite dike 20 to 25 m wide. The vertical displacement along the graben is about 30 m. The total width affected by the graben is about 210 meters[8].

The covering terrain is thickest, about 9 m, in the graben zone where there is an ancient bed of the Bafing. These terrains are silt-clay to silt-sand deposits near the river, changing laterally to colluvial or eluvial deposits. Talus debris lays at the bottoms of both valley walls. The thickness of these deposits does not seem to exceed 8 m.

About half of the lower part of the valley is covered by a sometimes lateritic (ferricrete) pediment, and the rest by an alluvial terrace which borders the Bafing.

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[7] See the project map (partial compilation) and Groupement de Manantali, 1979, Mission A2.1, Text, fig. 2.

[8] ECBM, 1979, Mission A.2.1, Texts p.38.

Table #1 is a compilation made by the project, of data collected by Groupement de Manantali.

Table #1 - Manantali Dam - permeability of fractures near the dam

COMPLEX	FORMATION	ELEV. O ASL RB	LB	LUGEON L.U.	REMARKS
UPPER	SANDSTONE C	290	-	-	-
UPPER	SANDSTONE B	230	210	-	-
UPPER	SANDSTONE A	175	160	100	very permeable to 25-30 M
LOWER	SANDSTONE 0	140	145	30	permeable along fissures
LOWER	SANDSTONE 1A	130	130	4-5	impermeable except along 1A/1B
LOWER	PELITE 1B	110	110	2-12	practically impermeable
LOWER	SANDSTONE 2	?	?	5-27	permeable

LUGEON UNIT (L.U.) = Number of liters absorbed per minute per linear meter of borehole under a real pressure of 10 bars

Of the different fracture networks observed near the dam site, the principal fractures are oriented E-W and the secondary fractures N-E.

The fractures have three causes:

* tectonic (faults, fractures) associated with injected dolerite,

* diagenic, formed during rock consolidation and cementation

* erosive, associated with unstressed rock. These fractures are closely related to the topography. This type of fracture is rarely observed below a depth of 30 meters.

2.5 Groundwater

The fractured zone in the area near Manantali Dam is, hydrogeologically, poorly known.

Through their studies the Groupement de Manantali detected:

* a water table in the valley walls, above the Bafing valley floor elevation,

* an artesian aquifer located in the pelites (hydrostatic pressure 1 m above the river),

* a discontinuous aquifer in the alluvium.

Groupement de Manantali tried to evaluate the importance of water leaks near the dam (10-20 open fractures) and in the graben zone (fault 30 m wide) by assuming two permeability values: $4 * 10^{-5}$ m/sec (according to professor Hettfeld) and $5 * 10^{-6}$ m/sec (according to the Lugeon tests).

The total discharge of these fractures is on the order of 70 to 140 l/sec, for an annual discharge of 2,3 to $5 * 10^{6}$ m^3. These quantities are small.

3 AQUIFER CHARACTERISTICS

The aquifer near Manantali Dam is composed of consolidated fractured rock. The permeability of the aquifer is strictly related to the fracture network weaving through the different rock masses of the region. Before constructing piezometers in this terrain, the project decided to perform some geophysical exploration in order to locate in-situ the various structural alignments which had already been pre-mapped through photo-interpretation done by Groupement de Manantali.

3.1 Geophysical exploration

Geophysical exploration was performed by DNHE from 1/7/88 to 2/15/88. Electrical methods were used (profiling and sounding) which permitted localization of structural elements. Electromagnetic methods permitted localization of magmatic intrusions. The test results are included in the DNHE[9] report.

The geophysical test sites were chosen on the basis of the following criteria:

* immediate proximity of Manantali Dam, upstream and downstream,

* the presumed passage of a structural alignment or its extension, pre-localized from the "carte des grandes fractures aux environs du barrage, 1/40,000"[10] (map of large fractures near the dam).

At the 9 sites tested during this geophysical campaign, 13 structural accidents were detected.

In all the OMVS piezometric network has 20 piezometers[11]. Twenty out of twenty network piezometers were located on the geophysical accidents. In all, 7/9 of the geophysical test sites are located downstream of the dam and 2/9 are located upstream.

Fewer tests were made in the upstream section because of the zone's inaccessibility at the time.

3.2 Drilled structures

The Groundwater Project (Projet Eaux Souterraines - PES) financed and supervised, from 3/01/88 to 5/26/88, the construction by DNHE of the OMVS piezometric network (20 boreholes).

The technical characteristics of each of the 20 piezometers are listed in (2) tables on the following pages, both of which were generated with the "Rapport" function of the GES[12] data base:

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[9] Ref.: DNHE/OMVS, 1988.

[10] Ref.: Groupement de Manantali, 1979, mission A2.1, text, fig. 2.

[11] See the map locating the drilling work by the project.

[12] GES = computerized data base (Gestion des Eaux Souterraines) developed especially for the Groundwater Project for groundwater management.

1) "Table #2: Summary of basic parameters - all network sites"; (tableau de synthèse des paramètres de base - tous ouvrages confondus), listing for each piezometer, information relative to:
- the geographic situation,
- physical environment, and,
- related infrastructures (meteorological station and water level scale),

2) "Table #3: Summary of technical characteristics of the piezometers"; (tableau de synthèse des caractéristiques techniques des piézomètres), listing the following information for each piezometer:

- technical characteristics,
- hydraulic conductivity,
- dates of completion of various stages, and,
- periods of hydrogeological monitoring.

In these tables, the following codes signify:

HUE : Hors Unité Naturel d'Equipement, geographic concept with no signification in the Manantali Dam region, limited to the Senegal River valley,
MAN : capping formation of Plateau Mandingue
BA : Bakoye group lithostratigraphic series (see lithostratigraphic description, section 2.3).
N/R : Not completed

The column entitled "Strat. intake" designates the lithologic nature of the formation in which the piezometer intake is located, using the codes proposed by Groupement de Manantali. The reader will find lithostratigraphic descriptions of the codes in section 2.3.2 of this report. Annex #1 contains the technical and geological cross sections of the piezometers and annex #2 contains geologic profiles. Plotting of these sections and profiles was performed by the project with the Groundwater software.

3.3 Structural description of the dam surroundings

The construction of the OMVS piezometric network necessitated well-drilling (20 piezometers) for a total of 915.54 linear meters, drilled in bedrock. Many structural accidents (83) were intercepted of which (73) fractures and shear zones. These structural accidents were usually water bearing (W.B.) of some significance (93.98% of the structural accidents). Table #4 indicates the structural accidents (fractures and shear zones) and water bearing formations (W.B.), their distance and average separations (column: "M.DRILL/NUM W.B.").

Table #4: Structural accidents

TYPE ACCIDENT	NUMBER	BEDROCK DRILL(m)	M.DRILL/ NUM W.B.	M.DRILL/ NUM FRACT.	M.DRILL/ NUM SHEAR	M.DRILL/ NUM ACCID.	%ACCID.
W.B.	78	915.54	11.68	N/A	N/A	N/A	93.98%
FRACT.	73	915.54	N/A	12.54	N/A	N/A	87.95%
SHEAR ZONE	10	915.54	N/A	N/A	91.55	N/A	12.05%
ACCIDENT	83	915.54	N/A	N/A	N/A	10.98	100.00%

DATE : [illegible]/90

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PROJET OMVS/USAID 0625-0958

TABLEAU # 2 TABLEAU SYNTHESE DES PARAMETRES DE BASE - TOUS OUVRAGES CONFONDUS

OUVRAGES	UTM X	UTM Y	ALT. REF/IGN (M)	SITUATION GEOGRAPHIQUE VILLAGE/PERIMETRE	DIST. HORS PERIMETRE	CADRE PHYSIQUE U.H.E.	GEOM.	GEOL.	STATION METRO NOM	DIST.(KM)	ECHELLE LIMNIMETRIQUE NOM	DIST.(KM)	COURS D'EAU NOM	DIST.(M)
27-1B-MA[illegible]-HP	[illegible]	1464.2	130.937			HUE	MAN	BA	MANANTALI	15.500	MANANTALI/BARRAGE AMONT	15.500	BAFING	750
27-1B-MA[illegible] HP	[illegible]	1464.2	134.184			HUE	MAN	BA	MANANTALI	15.500	MANANTALI/BARRAGE AMONT	15.500	BAFING	750
27-2A-MA[illegible]-HP	[illegible]	1459.6	162.168			HUE	MAN	BA	MANANTALI	1.050	MANANTALI/BARRAGE AMONT	1.050	BAFING	650
27-2A-MA[illegible] HP	[illegible]	1459.6	162.137			HUE	MAN	BA	MANANTALI	1.000	MANANTALI/BARRAGE AMONT	1.000	BAFING	500
27-2A-MA[illegible]-HP	[illegible]	1459.7	161.124			HUE	MAN	BA	MANANTALI	0.450	MANANTALI/BARRAGE AMONT	0.450	BAFING	200
27-2A-MA[illegible] HP	[illegible]	1458.4	161.603			HUE	MAN	BA	MANANTALI	1.850	MANANTALI/BARRAGE AMONT	1.850	BAFING	750
27-2A-MA[illegible] HP	[illegible]	1452.0	280.619			HUE	MAN	BA	MANANTALI	5.250	MANANTALI/BARRAGE AMONT	5.250	BAFING	5000
27-2A-MA[illegible] HP	[illegible]	1459.6	162.119			HUE	MAN	BA	MANANTALI	0.200	MANANTALI/BARRAGE AMONT	0.200	BAFING	400
27-2A-MA[illegible] HP	[illegible]	1459.7	161.059			HUE	MAN	BA	MANANTALI	0.200	MANANTALI/BARRAGE AMONT	0.200	BAFING	400
27-2A-MA[illegible] HP	[illegible]	1459.8	164.295			HUE	MAN	BA	MANANTALI	0.200	MANANTALI/BARRAGE AMONT	0.200	BAFING	150
27-2A-MA[illegible] HP	[illegible]	1459.3	162.261			HUE	MAN	BA	MANANTALI	0.200	MANANTALI/BARRAGE AMONT	0.200	BAFING	250
27-2A-MA[illegible]-HP	[illegible]	1458.9	162.136			HUE	MAN	BA	MANANTALI	0.200	MANANTALI/BARRAGE AMONT	0.200	BAFING	250
27-2A-MA[illegible]4 HP	[illegible]	1458.9	162.184			HUE	MAN	BA	MANANTALI	0.200	MANANTALI/BARRAGE AMONT	0.200	BAFING	400
27-2A-MA[illegible] HP	[illegible]	1465.0	151.362			HUE	MAN	BA	MANANTALI	15.500	MANANTALI/BARRAGE AMONT	15.000	BAFING	1500
27-2B-MA[illegible]6 HP	[illegible]	1455.5	259.642			HUE	MAN	BA	MANANTALI	16.900	MANANTALI/BARRAGE AMONT	16.900	BAFING	10500
27-2B-MA[illegible] HP	[illegible]	1458.2	255.586			HUE	MAN	BA	MANANTALI	17.500	MANANTALI/BARRAGE AMONT	17.500	BAFING	11400
27-2B-MA[illegible] HP	[illegible]	1458.4	259.648			HUE	MAN	BA	MANANTALI	18.250	MANANTALI/BARRAGE AMONT	18.250	BAFING	11750
27-2C-MA[illegible] HP	[illegible]	1465.7	161.249			HUE	MAN	BA	MANANTALI	4.050	MANANTALI/BARRAGE AMONT	4.050	BAFING	750
27-2C-MA[illegible] HP	[illegible]	1465.6	160.030			HUE	MAN	BA	MANANTALI	4.150	MANANTALI/BARRAGE AMONT	4.150	BAFING	550
27-2C-MA[illegible] HP	[illegible]	1465.4	160.164			HUE	MAN	BA	MANANTALI	4.250	MANANTALI/BARRAGE AMONT	4.250	BAFING	150

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TABLEAU # 3 SYNTHESE DES CARACTERISTIQUES TECHNIQUES DES PIEZOMETRES

PIEZOMETRE	UTM X	UTM Y	ALT. REF/IGN (m)	PROF. (m/Sol) FOREE	PROF. (m/Sol) EQUIP.	CREPINE BAS (cm/Sol)	CREPINE HAUT (cm/Sol)	CREPINE LONG. (cm)	PVC (PCE)	STRAT. DROIT CREPINE	GEOLOGIE TYPE	GEOLOGIE ALT-TOIT (m/IGN)	VALEURS DE PERMEABILITES (cm/sec) SURFACE CREPINE KR1	KR2	ESSAI K KK	ESSAI Q K	DATES DE REALISATION IMPLANT.	NIVELLEM.	FORAGE	ESSAI K	ESSAI Q	SP OU PO	VISITES MENSUELLES 1ERE VISITE DATE	ROTATION	DERN. VISITE DATE	ROTATION	ANALYSES D'EAU
27-1B-MA0016-HP	[illegible]	1464.2	[illegible]	17.00	16.36	1616	1315	301	5"1/2	DOLERITE	HA	121.8	N/R	N/R	2.7E-3		05/03/88	05/04/89	21/05/88	26/05/88		29/09/88	1	29/11/89	66	1
27-1B-MA0017-HP	[illegible]	1464.2	164.184	44.05	40.90	4035	3734	301	5"1/2	GRES 2	HA	125.2	N/R	N/R	>1.0E-3		05/03/88	05/04/89	13/05/88	26/05/88		29/09/88	1	29/11/89	66	1
27-2A-MA0001-HP	[illegible]	1459.6	162.168	15.00	13.90	1133	1032	301	5"1/2	PELITE IN	HA	154.9	N/R	N/R	2.9E-3		01/03/88	04/04/89	22/04/88	27/04/88		30/09/88	1	27/11/89	66	1
27-2A-MA0002-HP	[illegible]	1459.6	162.127	44.63	43.60	4110	3722	588	5"1/2	GRES 2	HA	155.2	N/R	N/R	>1.0E-3		01/03/88	04/04/89	20/04/88	23/04/88		30/09/88	1	27/11/89	66	1
27-2A-MA0003-HP	[illegible]	1459.7	161.124	47.05	45.93	4550	4246	304	5"1/2	GRES 2	HA	157.8	N/R	N/R	1.4E-3		01/03/88	04/04/89	12/04/88	20/04/88		30/09/88	1	27/11/89	66	1
27-2A-MA0004-HP	[illegible]	1458.4	161.603	29.68	28.84	2810	2549	261	5"1/2	GRES 0	HA	155.4	N/R	N/R	>1.0E-3		02/03/88	29/03/89	25/04/88	05/05/88		01/10/88	1	27/11/89	66	1
27-2A-MA0005-HP	[illegible]	1452.0	[illegible]	50.20	45.54	4500	4199	301	5"1/2	GRES B	HA	286.7	N/R	N/R	>1.0E-3		26/05/88	07/04/89	04/06/88	01/02/89		05/02/89	6	29/11/89	66	1
27-2A-MA0009-HP	[illegible]	1459.6	162.139	40.22	33.65	3100	2712	588	5"1/2	GRES 2	HA	156.1	N/R	N/R	>1.0E-3		01/03/88	08/04/89	01/03/88	07/03/88		30/09/88	1	27/11/89	66	1
27-2A-MA0010-HP	[illegible]	1459.7	161.059	51.65	50.17	5000	4696	304	5"1/2	GRES 2	HA	157.6	N/R	N/R	5.1E-4		01/03/88	08/04/89	05/03/88	10/03/88		30/09/88	1	27/11/89	66	1
27-2A-MA0011-HP	[illegible]	1459.8	164.295	78.00	67.12	6684	6096	588	5"1/2	GRES 2	HA	158.9	N/R	N/R	8.4E-4		01/03/88	08/04/89	09/03/88	15/03/88		30/09/88	1	27/11/89	66	1
27-2A-MA0012-HP	[illegible]	1459.1	162.261	42.75	40.44	4000	3696	304	5"1/2	GRES 1A	HA	151.3	N/R	N/R	2.2E-4		02/03/88	28/03/89	16/03/88	07/04/88		01/10/88	1	27/11/89	66	1
27-2A-MA0013-HP	[illegible]	1458.9	162.176	26.63	25.00	2480	2179	301	5"1/2	GRES 0	HA	153.4	N/R	N/R	>1.0E-3		02/03/88	28/05/89	07/04/88	16/01/89		30/12/88	4	27/11/89	66	1
27-2A-MA0014-HP	[illegible]	1458.9	162.184	80.48	78.74	7800	7212	588	5"1/2	GRES 1A	HA	153.2	N/R	N/R	1.5E-3		02/03/88	28/03/89	24/03/88	14/04/88		01/10/88	1	27/11/89	66	1
27-2A-MA0015-HP	[illegible]	1465.0	[illegible]	21.70	22.00	2150	1849	101	5"1/2	GRES 0	HA	151.9	N/R	N/R	2.3E-3		05/03/88	06/04/89	07/05/88	27/12/88		30/12/88	4	29/11/89	66	1
27-2B-MA0006-HP	[illegible]	1455.5	[illegible]	70.83	63.90	6298	5997	101	5"1/2	GRES C	HA	253.7	N/R	N/R	3.0E-3		06/03/88	10/04/89	21/06/88	15/06/88		01/10/88	1	30/11/89	66	1
27-2B-MA0007-HP	[illegible]	1458.2	255.586	53.28	50.60	5001	4700	101	5"1/2	GRES C	HA	247.1	N/R	N/R	>1.0E-3		06/03/88	11/04/89	24/06/88	08/07/88		01/10/88	1	30/11/89	66	1
27-2B-MA0008-HP	[illegible]	1458.4	259.648	70.00	54.60	5297	4996	301	5"1/2	GRES C	HA	248.7	N/R	N/R	>1.0E-3		06/03/88	11/04/89	29/06/88	07/07/88		01/10/88	1	30/11/89	66	1
27-2C-MA0018-HP	[illegible]	1465.7	[illegible]	58.10	58.30	5800	5499	301	5"1/2	GRES 1A	HA	156.7	N/R	N/R	>1.0E-3		02/03/88	05/04/89	28/11/88	02/01/89		01/10/88	1	27/11/89	66	1
27-2C-MA0019-HP	[illegible]	1465.6	160.010	50.00	32.27	3200	2899	101	5"1/2	GRES 1A	HA	156.5	N/R	N/R	5.2E-4		02/03/88	05/04/89	16/11/88	26/11/88		01/01/89	4	27/11/89	66	1
27-2C-MA0020-HP	[illegible]	1465.4	160.164	73.00	72.00	7150	6849	301	5"1/2	GRES 2	HA	158.2	N/R	N/R	3.1E-3		02/03/88	07/04/89	21/11/88	26/11/88		01/01/89	4	27/11/89	66	1

Table #5 inventories the different structural accidents intercepted by the piezometers during the drilling and their appearance frequency per linear meter (column: "Freq.Accid./LM Drill"), as well as other basic statistics.

Table #5: Inventory of structural accidents by piezometer

Piezo #	W.B.	Bedrock Drill(m)	M.Drill/ Num W.B.	<Structural Num Fract.		Accident> Num Shear		M.Drill/ Num Accid.	Freq.Accid/ LM Drill
MA0001	2	8.80	4.40	2	F	0	N/A	4.40	0.23
MA0002	2	38.73	19.37	2	F	0	N/A	19.37	0.05
MA0003	3	42.75	14.25	3	F	0	N/A	14.25	0.07
MA0004	3	74.53	24.84	3	F	0	N/A	24.84	0.04
MA0005	3	48.10	16.03	3	F	4	S	6.87	0.15
MA0006	6	65.93	10.99	4	F	2	S	10.99	0.09
MA0007	3	50.36	16.79	0	N/A	3	S	16.79	0.06
MA0008	3	60.00	20.00	3	F	1	S	15.00	0.07
MA0009	5	36.00	7.20	5	F	0	N/A	7.20	0.14
MA0010	7	47.60	6.80	7	F	0	N/A	6.80	0.15
MA0011	6	73.55	12.26	6	F	0	N/A	12.26	0.08
MA0012	5	32.25	6.45	5	F	0	N/A	6.45	0.16
MA0013	2	18.86	9.43	2	F	0	N/A	9.43	0.11
MA0014	4	72.48	18.12	4	F	0	N/A	18.12	0.06
MA0015	2	23.25	11.63	2	F	0	N/A	11.63	0.09
MA0016	4	14.00	3.50	4	F	0	N/A	3.50	0.29
MA0017	6	36.05	6.01	6	F	0	N/A	6.01	0.17
MA0018	3	52.80	17.60	3	F	0	N/A	17.60	0.06
MA0019	4	47.50	11.88	4	F	0	N/A	11.88	0.08
MA0020	5	72.00	14.40	5	F	0	N/A	14.40	0.07

Piezo #	W.B.	Bedrock Drill(m)	M.Drill/ Num W.B.	<Structural Num Fract.		Accident> Num Shear		M.Drill/ Num Accid.	Freq.Accid/ LM Drill
NUMBER	20	20.00	20.00	20.0	N/A	20.0	N/A	20.00	20.00
MIN.	2	8.80	3.50	0.0	N/A	0.0	N/A	3.50	0.04
MAX.	7	74.53	24.84	7.0	N/A	4.0	N/A	24.84	0.29
AVERAGE	3.9	45.78	12.60	3.7	N/A	0.5	N/A	11.89	0.11
STD. DEV.	1.5	19.66	5.70	1.7	N/A	1.1	N/A	5.53	0.06

LEGEND

W.B.	: Water Bearing
M. Drill	: Number of meters drilled in the bedrock
Num Fract.	: Number of fractures intercepted in the bedrock
Num Shear	: Number of shear zones intercepted in the bedrock
Num Accid.	: Number of accidents (fractures + shear zones)
F	: Fractures
S	: Shear zones
N/A	: Non applicable

From table #5, a graph indicating the appearance frequency (AF) of the structural accidents per linear meter (column: "FREQ.ACCID./LM DRILL") as a function of depth (DEPTH) drilled in the bedrock (column: "BEDROCK DRILL (m)") was developed (see figure #2 on the next page). The data points were not connected and the best fit curve (formula type: $Y=aX^{n}$) was plotted with GRAPHER software. This curve is described by the following equation:

$$AF = 1.01915 * DEPTH^{-0.642231}$$

This equation indicates that the appearance frequency (AF) of the structural accidents diminishes with increasing depth into the bedrock. Below a certain depth, it could no longer be worth drilling for water. This threshold depth must be defined by each drilling contractor.

The curve also indicates the fractures of erosive origin (see section 2.5) in the first 30 meters drilled in the bedrock.

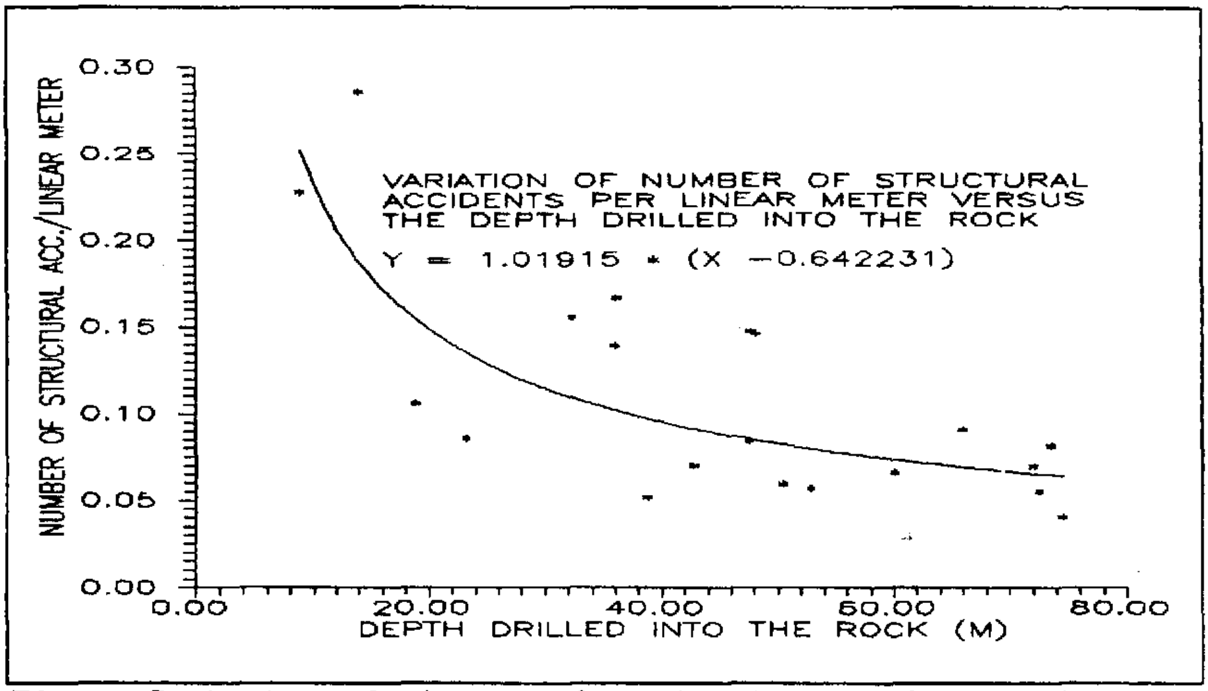

Figure 2 Number of structural accidents per linear meter as a function of depth in the bedrock

This graphic does not take into account the specific structures of the different geological formations traversed by the piezometers of the OMVS network. All the geological formations are considered here to be homogenous and uniformly fractured, which is evidently not the case.

In order to determine the specific structure of each geological formation drilled, an analysis of the number of accidents per geological formation associated with the linear meters drilled in the bedrock related to each geological formation was performed. Table #6 lists the results obtained. A code number is attributed to each geological formation (1 to 14) which will be used in later graphics (figures 2 and 3). The fracture rate specific to each geological formation was obtained by dividing the linear meters drilled in the bedrock related to each formation, by the number of corresponding structural accidents.

Table #6: Linear meters drilled and fracture rate per geological formation

PIEZO	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	total Lm drilled
		>---	---	---	---	Geological	Formations	---	---	---	---	---	---	---	--->	
MA000	1	-	-	-	-	-	-	-	1.25	7.55	-	-	-	-	-	8.80
MA000	2	-	-	-	-	-	-	-	3.35	21.75	7.86	5.77	-	-	-	38.73
MA000	3	-	-	-	-	-	-	-	22.50	13.20	-	7.05	-	-	-	42.75
MA000	4	-	-	-	-	-	-	22.85	51.68	-	-	-	-	-	-	74.53
MA000	5	0.80	-	42.90	-	4.40	-	-	-	-	-	-	-	-	-	48.10
MA000	6	-	65.93	-	-	-	-	-	-	-	-	-	-	-	-	65.93
MA000	7	-	50.36	-	-	-	-	-	-	-	-	-	-	-	-	50.36
MA000	8	-	60.00	-	-	-	-	-	-	-	-	-	-	-	-	60.00
MA000	9	-	-	-	-	-	-	-	-	24.00	-	12.00	-	-	-	36.00
MA00	10	-	-	-	-	-	-	4.60	28.20	14.80	-	-	-	-	-	47.60
MA00	11	-	-	-	-	-	-	12.55	25.90	17.10	-	18.00	-	-	-	73.55
MA00	12	-	-	-	-	-	-	16.00	16.25	-	-	-	-	-	-	32.25
MA00	13	-	-	-	-	-	-	18.86	-	-	-	-	-	-	-	18.86
MA00	14	-	-	-	-	-	-	19.00	53.48	-	-	-	-	-	-	72.48
MA00	15	-	-	-	-	-	-	23.25	-	-	-	-	-	-	-	23.25
MA00	16	-	-	-	-	-	-	-	-	-	-	-	-	5.05	8.95	14.00
MA00	17	-	-	-	-	-	-	-	-	5.62	-	30.43	-	-	-	36.05
MA00	18	-	-	-	-	-	-	-	49.80	-	3.00	-	-	-	-	52.80
MA00	19	-	-	-	-	-	-	-	47.50	-	-	-	-	-	-	47.50
MA00	20	-	-	-	-	-	-	-	57.30	-	8.70	6.00	-	-	-	72.00
total Lm/Fm		0.8	176.2	42.9	0	4.4	0	117.1	357.2	104.0	19.56	79.25	0	5.05	8.95	915.54
tot.mL drill%		0.09	19.26	4.69	0.00	0.48	0.00	12.79	39.02	11.36	2.14	8.66	0.00	0.55	0.98	100.00
num fract./Fm		1	13	4	0	2	0	11	22	10	0	16	0	0	4	83
fract. rate/Fm		1.25	0.07	0.09	N/A	0.45	N/A	0.09	0.06	0.10	0.00	0.20	N/A	0.00	0.45	0.09

Codes 1 to 14 in table #6 are listed in table #7 below. The reader will find, in annex #1, a complete and detailed description of the geologic codes used. These codes are related to the codification developed by Groupement de Manantali (see section 2.3.2). Some supplementary codes were added to accommodate the more specific analysis done by DNHE (codes 1, 5, 10, 13, 14). Table #7 associates with each code (1 to 14), a percentage which reflects the number of structural accidents related to that formation with respect to all the structural accidents (83).

Table #7: Distribution of structural accidents per geologic formation

GEOL.FM.	CODE #	NUMBER ACCIDENTS	% ACCIDENTS
UC-SHALE	1	1	1.20%
UC-SANDSTONE C	2	13	15.66%
UC_SANDSTONE B	3	4	4.82%
UC-SANDSTONE A	4	0	0.00%
UC-INDIF.	5	2	2.41%
LC-CLAYSTONE	6	0	0.00%
LC-SANDSTONE 0	7	11	13.25%
LC-SANDSTONE 1A	8	22	26.51%
LC-PELITE 1B	9	10	12.05%
LC-1A/1B	10	0	0.00%
LC-SANDSTONE 2	11	16	19.28%
LC-SHALE 3	12	0	0.00%
LC-INDIF.	13	0	0.00%
LC-DOLERITE	14	4	4.82%

Figures #3 and #4 indicate the respective distributions per geological formation of:

* linear meters drilled,
* fracture rate

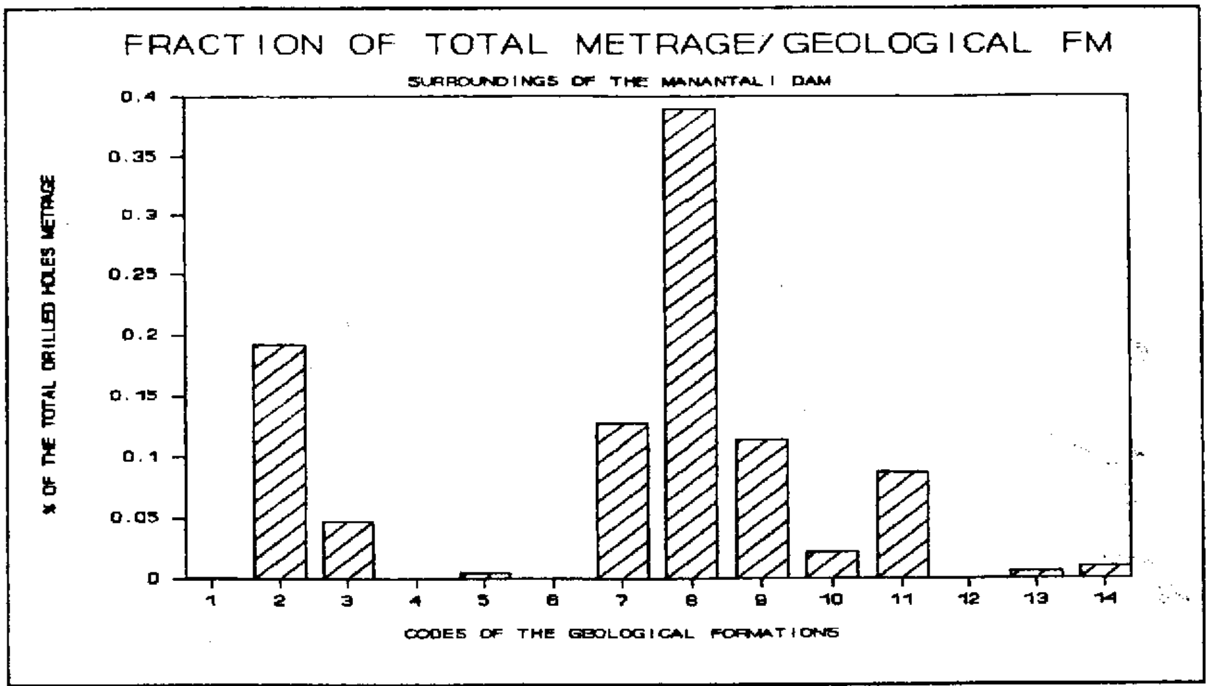

Figure 3 Percentage linear meters drilled per geological formation

From figure #3 we see that:

* the linear meters drilled through the geological formations coded (1=UC-SCH., 5=UC-INDIF., 10=LC-1A/1B, 13=LC-INDIF., and 14=LC-DOLER.) are not representative of all the coded geological formations. These formations correspond to supplementary codes added by the project and are not significant in the area of the dam.

* the geological formations coded (4=UC-SANDSTONE A, 6=C1-ARGIL. and 12=LC-SCH. 3) were not drilled.

* the Lower Complex (codes 6 to 14) was drilled through much more than the Upper Complex (codes 1 to 5).

Consequently, the fracture rates related to the geological formations which were drilled little, or not at all, will not be compared (see figure #3) though the rates are indicated in table #6. It would seem that these rates are over-estimated. A comment about the dolerite formation (code 14) in the Lower Complex is in order. This rock is intrusive and has filled the shear zones and fractures. Its nature and relative hardness with respect to the other formations of sedimentary origin make the fracture rate indicated in table #6 probable.

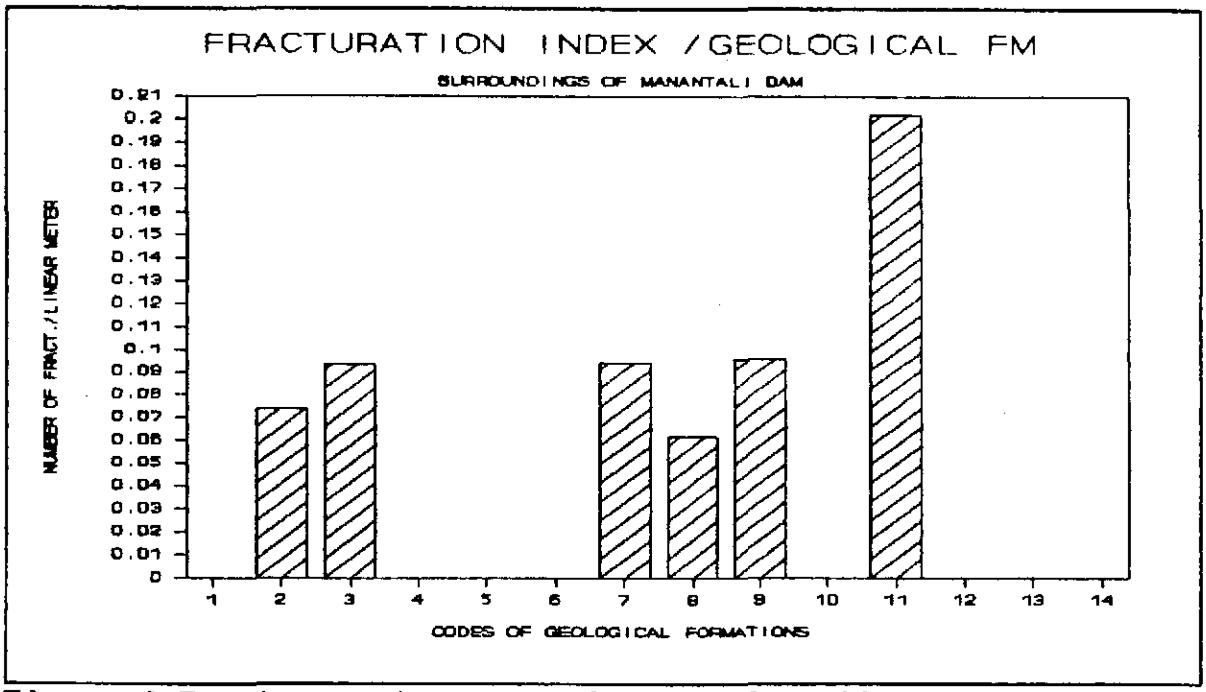

Figure 4 Fracture rate per geological formation

We see from figure #4 that:

* Sandstone 2 of the Lower Complex (code 11) has the highest fracture rate (0.20 structural accidents/linear meter) reflecting the quartzic nature of this sandstone (highly brittle) compared to the other geological formations (feldspathic sandstone, pelite and shale),

* the fracture rates of the other Upper and/or Lower Complex formations are comparable (between 0.06 and 0.1 structural accidents/linear meter),

* Sandstone 1A of the Lower Complex (code 8) has the lowest fracture rate (0.06 structural accidents/linear meter).

4 HYDROGEOLOGICAL DESCRIPTION

In an effort to establish the hydrogeological properties of the aquifers, the project determined hydraulic conductivity coefficients for all the piezometers constructed in the study zone (unconsolidated sedimentary terrain in the Senegal River valley and consolidated, fractured, sedimentary terrain in the Upper Basin of the Senegal River valley). Three methods were used to determine the hydraulic conductivity of the terrains:

* granulometric analysis
* hydraulic conductivity tests
* pumping tests

In the Manantali Dam region, the granulometric estimation of hydraulic conductivity is without interest. The KB1 and KB2 values in the GES table #3 are marked N/R (not realized).

4.1 Hydraulic conductivity tests - dropping level method (KK values in table)

Hvorslev[13] (1951) developed a theory for the interpretation of hydraulic conductivity tests with the dropping level method (slug test), which were systematically used by the project for the entire OMVS network covering the study zone (Senegal River Valley and Upper Basin).

This method was adapted for normalized application in *unconsolidated terrain* by the "SOCIETE D'ENERGIE DE LA BAIE JAMES". The field procedures, as defined in the inspector's manual[14], were adopted by the project. Although this test is not usually used in fractured bedrock, the project made the experiment.

The application of this method is not related to the geometry of the tapped aquifer. It may not be used in plastic clays (there are none in the surroundings of Manantali Dam) and it takes into consideration the geometry of the piezometer intake.

This method is applicable for transmissivity values less than 10^{-3} m^2/sec. When transmissivity values are close to or greater than this limit, the water level drops rapidly (often instantaneously) and in practice is unmeasurable. In this case, only a pumping test can be used to determine hydraulic conductivity.

The plot of the test data (t-log (lambda)) *MUST* make a straight line for proper interpretation of the result. Otherwise, interpretation is not possible.

In practice, the increase in the hydraulic charge would, ideally, be instantaneous. In reality, the field procedures and the sometimes large transmissivities rarely permit an instantaneous filling. The following difficulties are often encountered:

* a filling time (t) varying from several seconds to many minutes, and even, sometimes, the impossibility of filling the PVC tube,

* an inadequate method of filling the PVC tube, (pressurized injection of water).

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[13] Ref.: Freeze, 1979, p.339.

[14] Ref.: SEBJ, 1978.

These problems cause a deformation of the plot of t-vs-log(lambda) about an inflection point situated generally at t = 1, or more rarely, at t = 2 minutes. The air bubbles injected into the PVC tube during the filling necessary for the conductivity test, rise to the surface in a time t < 1 minute. This phenomenon creates an artificial drop in the water level which is not strictly related to the hydraulic parameters intrinsic to the tested aquifer. In this case, the test interpretation is made on the straight-line part of the t - vs - log(lambda) curve, after the inflection point.

The test interpretation is, in this case, a purely qualitative estimation of the hydraulic conductivity value (approximation).

The reader will find, in the GES tables, the codes:

* N/D : not determined (non-linear plot)
* N/R : not realizable (not doable)
* >1.0E^{-3} cm/sec (water level drop too rapid)

The consultation of all the conductivity tests performed (raw data and interpretation) is possible with the GES system. It is good, at this point, to underline the importance of the hydrogeologist's judgement in evaluating the intrinsic value of the field test.

The hydraulic conductivity values thus obtained must be used with caution since we know that values resulting from the such tests are only valid for the immediate area around the piezometer intake (radius of a few meters at most).

4.2 Pumping tests

As part of the effort to establish the hydrogeological characteristics of the formations tapped by the OMVS piezometers, 9 long duration pumping tests (varying from 24 hours to 72.5 hours) were performed without short duration tests

Interpretation of the test data was made according to the Jacob method by Mr. TOURE, chief of the Manantali Sector, even though the tests were made in fractured, consolidated, thus non-homogeneous formations.

The average transmissivity values (T descending + T ascending) and coefficients of storage (S) interpreted from these pumping tests are shown in table #8 on the next page. This table also lists the lithostratigraphic formation at the level of the piezometer intake and indicates whether it is part of the Upper or Lower Complex (see section 2.3.1).

The hydraulic conductivity value (KQ) was calculated with the following formula:

KQ = T/E
T = transmissivity (m^2/s)
E = well screen length (m)
KQ = hydraulic conductivity (m/s)

This hydraulic conductivity value (KQ) was compared to its counterpart calculated from the hydraulic conductivity test (KK).

Table #8: Results interpreted from pumping tests made in the area near Manantali Dam, Mali.

PIEZO #	---well screen--- base depth	top depth	intake m	----- Hydrodynamic Parameters---- T avg. m^2/sec	S dimensionless	KK cm/sec	KQ cm/sec	strat. intake	complex UC or LC
MA0001	13.90	9.32	3.01	N\R	N\R	2.90E-03	N\R	PELITE 1B	LC
MA0002	43.60	36.22	5.88	3.40E-03	7.00E-04	>1.0E-3	4.61E-02	SANDSTONE 2	LC
MA0003	45.93	41.16	3.04	3.00E-03	9.50E-04	1.40E-03	6.29E-02	SANDSTONE 2	LC
MA0004	28.84	24.49	2.61	3.00E-03	N/D	>1.0E-3	6.90E-02	SANDSTONE 0	LC
MA0005	45.54	40.99	3.01	N\R	N\R	>1.0E-3	N\R	SANDSTONE B	UC
MA0006	63.90	58.97	3.01	N\R	N\R	3.00E-03	N\R	SANDSTONE C	UC
MA0007	50.60	46.00	3.01	N\R	N\R	>1.0E-3	N\R	SANDSTONE C	UC
MA0008	54.60	48.96	3.01	N\R	N\R	>1.0E-3	N\R	SANDSTONE C	UC
MA0009	33.65	26.00	5.88	6.70E-03	1.20E-05	>1.0E-3	8.76E-02	SANDSTONE 2	LC
MA0010	50.37	45.96	3.04	2.00E-03	7.00E-03	5.10E-04	4.54E-02	SANDSTONE 2	LC
MA0011	67.32	59.96	5.88	N\R	N\R	8.40E-04	N\R	SANDSTONE 2	LC
MA0012	40.44	35.96	3.04	2.70E-04	1.00E-05	2.20E-04	6.03E-03	SANDSTONE 1A	LC
MA0013	25.00	20.79	0.00	N\R	N\R	>1.0E-3	N\R	SANDSTONE 0	LC
MA0014	78.74	71.12	5.88	8.10E-04	3.20E-04	1.50E-03	1.06E-02	SANDSTONE 1A	LC
MA0015	22.00	17.49	3.01	N\R	N\R	2.30E-03	N\R	SANDSTONE 0	LC
MA0016	16.36	12.15	3.01	N\R	N\R	2.70E-03	N\R	DOLERITE	LC
MA0017	40.90	36.34	3.01	4.90E-04	N/D	>1.0E-3	1.07E-02	SANDSTONE 2	LC
MA0018	58.28	53.99	3.01	N\R	N\R	>1.0E-3	N\R	SANDSTONE 1A	LC
MA0019	32.27	27.99	3.01	N\R	N\R	5.20E-04	N\R	SANDSTONE 1A	LC
MA0020	72.00	67.49	0.00	3.30E-04	N/D	3.10E-03	7.32E-03	SANDSTONE 2	LC

The (KQ) hydraulic conductivity values vary from 10^{-3} to 10^{-2} cm/sec and the (KK) from 10^{-4} to > 10^{-3} cm/sec. The values are comparable with those used by Groupement de Manantali for the dam site, $4*10^{-3}$ cm/sec (according to professor Hettfeld) and $5*10^{-4}$ cm/sec (according to the Lugeon tests)[15]. The methods used by the Groupement were different from those used by the project.

These hydraulic conductivity values are characteristic of metamorphic rock and/or sandstone[16]. The hydraulic conductivity values measured do not permit a hydraulic classification of the geologic formations (column "strat. intake") tested.

4.3 Hydraulic productivity per geologic formation

Table #9 on the next page lists the total air lift discharge per piezometer per geological formation traversed and the total measured air lift discharge from each of these formations (m^3/h). The specific hydraulic productivity of each formation is calculated by dividing the total air lift discharge from the formation by the number of inventoried fractures in the formation. From table #9 we note that certain formations (1=UC-SHALE, 5=UC-INDIF. and 13=LC-INDIF.), although fractured, have zero productivity (dry fractures).

Figure #5 indicates the distribution of productivity per formation. This figure shows that the Upper Complex formations are 2 to 3 times more productive than the Lower Complex formations and that sandstone B is by far the most productive. The Upper Complex formations constitute the walls of the Manantali Dam Reservoir.

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15 See section 2.5 of this report.

16 Ref.: Freeze, 1979, p. 29.

Table #9: Discharge (air lift) per geological formation

PIEZO	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Q (m3/h)
MA000	1	-	-	-	-	-	-	-	-	8.0	-	-	-	-	-	8.0
MA000	2	-	-	-	-	-	-	-	-	2.4	-	16.2	-	-	-	18.6
MA000	3	-	-	-	-	-	-	-	-	3.0	-	3.6	-	-	-	6.6
MA000	4	-	-	-	-	-	-	27.0	-	-	-	-	-	-	-	27.0
MA000	5	-	-	87.5	-	-	-	-	-	-	-	-	-	-	-	87.5
MA000	6	-	25.6	-	-	-	-	-	-	-	-	-	-	-	-	25.6
MA000	7	-	65.4	-	-	-	-	-	-	-	-	-	-	-	-	65.4
MA000	8	-	93.5	-	-	-	-	-	-	-	-	-	-	-	-	93.5
MA000	9	-	-	-	-	-	-	-	-	42.2	-	-	-	-	-	42.2
MA00	10	-	-	-	-	-	-	-	6.2	10.8	-	21.6	-	-	-	38.6
MA00	11	-	-	-	-	-	-	-	-	13.0	-	16.2	-	-	-	29.2
MA00	12	-	-	-	-	-	-	16.6	57.6	-	-	-	-	-	-	74.2
MA00	13	-	-	-	-	-	-	19.8	-	-	-	-	-	-	-	19.8
MA00	14	-	-	-	-	-	-	12.7	-	-	-	-	-	-	-	12.7
MA00	15	-	-	-	-	-	-	4.1	-	-	-	-	-	-	-	4.1
MA00	16	-	-	-	-	-	-	-	-	-	-	-	-	3.9	-	3.9
MA00	17	-	-	-	-	-	-	-	-	-	-	33.2	-	-	-	33.2
MA00	18	-	-	-	-	-	-	-	64.0	-	-	-	-	-	-	64.0
MA00	19	-	-	-	-	-	-	-	28.9	-	-	-	-	-	-	28.9
MA00	20	-	-	-	-	-	-	-	1.5	-	-	20.1	-	-	-	21.6
TOTAL Q (m3/h)		0.0	184.5	87.5	0.0	0.0	0.0	80.2	158.2	79.4	0.0	110.9	0.0	3.9	0.0	704.5
NUM. FRACT./FM		1	13	4	0	2	0	11	22	10	0	16	0	0	4	83
Q (m3/h)/FRACT		0.0	14.2	21.9	N/A	0.0	N/A	7.3	7.2	7.9	N/A	6.9	N/A	N/A	0.0	8.5

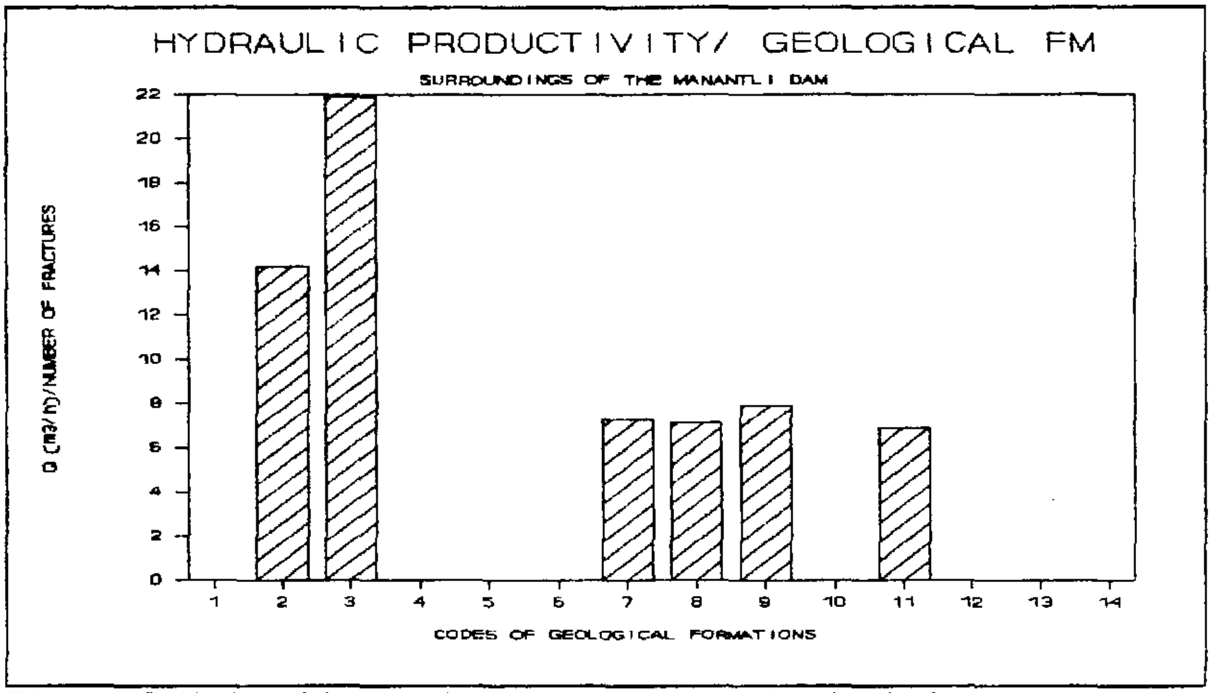

Figure 5 Hydraulic productivity per geological formation

4.4 Groundwater chemistry

After completion of the OMVS piezometer network, the DNHE, in February of 1989, took 20 groundwater samples (one per piezometer). These samples were analyzed to determine the contents of the major elements (anions and cations) in the DNHE laboratory in Bamako, Mali.

All the results (values in ppm and epm, calculated S.A.R. and the graphic representation of the analysis) are included in annex #3 of this report.

Table #10 summarizes the principal chemical characteristics of the samples (total dissolved solids - TDS, the sodium adsorption ratio - SAR, and the geohydrochemical facies). The results of the analysis are compared with the geological formations at the piezometer intake level and the distance of the piezometer from the nearest watercourse. In this table, the piezometers are classified according to the chrono-stratigraphic scale for the environs of Manantali Dam.

Table #10: Geohydrochemical facies, TDS and SAR per piezometer

Piezo #	Date Sampled	mg/l Solids	S.A.R.	Geohydrochemical Facies	Intake Strat.	Complex UC or LC	Distance BAFING	Intake m ASL
MA0008	04-Feb-89	366.0	0.1	CALCIUM-MAGNES. BICARBONATE	SANDSTONE C	UC	11.75	204.06
MA0007	04-Feb-89	315.0	0.1	CALCIUM-MAGNES. BICARBONATE	SANDSTONE C	UC	11.40	203.99
MA0006	04-Feb-89	61.0	0.0	CALCIUM-MAGNES. BICARBONATE	SANDSTONE C	UC	10.50	194.74
MA0005	05-Feb-89	772.0	0.2	(CA&MG) SULFATE & BICARBONATE	SANDSTONE B	UC	5.00	243.07
MA0004	06-Feb-89	1770.0	0.1	CALCIUM- MAGNES. CHLORIDE	SANDSTONE 0	LC	0.75	131.75
MA0013	06-Feb-89	211.0	0.2	CALCIUM SULFATE	SANDSTONE 0	LC	0.25	136.17
MA0015	05-Feb-89	323.0	0.3	CALCIUM-MAGNES. BICARBONATE	SANDSTONE 0	LC	1.50	130.37
MA0019	06-Feb-89	1905.0	1.7	HYPER CALC-MAGNES CHLORIDE	SANDSTONE 1A	LC	0.55	126.76
MA0012	06-Feb-89	9488.0	0.0	HYPER CALC-MAGNES CHLORIDE	SANDSTONE 1A	LC	0.25	120.85
MA0018	06-Feb-89	306.0	0.1	CALCIUM-MAGNES. BICARBONATE	SANDSTONE 1A	LC	0.75	103.97
MA0014	06-Feb-89	276.0	0.2	CALCIUM BICARBONATE	SANDSTONE 1A	LC	0.40	82.44
MA0001	06-Feb-89	2100.0	0.3	CALCIUM-MAGNES CHLORIDE	PELITE 1B	LC	0.65	147.25
MA0002	06-Feb-89	2190.0	0.2	CALCIUM-MAGNES CHLORIDE	SANDSTONE 2	LC	0.50	117.54
MA0020	06-Feb-89	3503.0	0.0	CALCIUM-MAGNES CHLORIDE	SANDSTONE 2	LC	0.15	87.17
MA0017	05-Feb-89	1366.0	0.2	HYPER CALCIUM-MAGNES SULFATE	SANDSTONE 2	LC	0.75	92.27
MA0010	06-Feb-89	343.0	0.1	CALCIUM-MAGNES. BICARBONATE	SANDSTONE 2	LC	0.40	111.66
MA0003	06-Feb-89	400.0	0.1	CALCIUM-MAGNES. BICARBONATE	SANDSTONE 2	LC	0.20	116.22
MA0009	06-Feb-89	764.0	0.1	(CA&MG) CHLORIDE & BICARBONATE	SANDSTONE 2	LC	0.40	127.49
MA0011	06-Feb-89	317.0	0.1	CALCIUM-MAGNES. BICARBONATE	SANDSTONE 2	LC	0.15	96.04
MA0016	05-Feb-89	281.0	0.1	CALCIUM BICARBONATE	DOLERITE	LC	0.75	113.59

There are three geohydrochemical facies of this groundwater:

* calcium and magnesium bicarbonates (10/20),
* calcium and magnesium chlorides (8/20),
* calcium sulfates and bicarbonates (2/20).

These varied geohydrochemical facies misrepresent the relatively homogenous, sometimes metamorphic, lithostratigraphic nature of these Bakoye Group formations (quartziferous and feldspathic sandstones and shales).

A classification of the groundwater based on Total Dissolved Solids content (mg/l), using the classification limits below[17] gives the following results.

limits	class	number of samples surface	groundwater
0 < TDS < 1,000	fresh	-	13/20
1,000 < TDS < 10,000	brackish	-	7/20
10,000 < TDS < 100,000	saline	-	0/20
100,000 < TDS	brine	-	0/20

This classification indicates the existence of fresh and brackish water.

A classification of the groundwater based on S.A.R. (Sodium Adsorption Ratio), using the classification limits below[18] gives the following results.

code	class limits	number of samples/per class surface	groundwater
S1	0 < SAR < 10	-	20/20
S2	10 < SAR < 18	-	0/20
S3	18 < SAR < 26	-	0/20
S4	SAR > 26	-	0/20

This classification indicates that all the analyzed water is in class S1. The range of measured S.A.R values varied from 0 to 0,7. These S.A.R. values, associated with measured electrical conductivity values (100 to 5000 µmhos/cm), indicate that this water can be considered "mediocre" to "excellent" for irrigation.

Relationships between Total Dissolved Solids and the following parameters were examined in the data presented in table #10:

1) the distance from the piezometers to the nearest watercourse,

2) the piezometer intake elevation,

3) the chemical composition (lithostratigraphic nature) of the tapped formation.

No clear relationships were found.

Table #11 on the following page lists the major anion and cation contents (mg/l) of the groundwater samples. The chlorine anions (Cl−) and the sulfate anions (SO_2 −−) which determine the geohydrochemical facies of the water vary a great deal. This table classifies the piezometers by geographic site, numbered 1 to 9. Several piezometers tapping distinct geological formations may be located at the same site. We note that for some sites where several piezometers are located, each tapping a different geological formation, many chemical facies are identified. This reflects the vertical compartmentalization of the groundwater. The geohydrochemical facies can even change within the same geological formation. Only the geographic site #4, located upstream of the dam and tapping the Upper Complex (sandstone C) has a homogeneous chemical facies.

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[17] Ref.: FREEZE, p. 84.

[18] Ref.: FREEZE, p. 84.

In consequence of these phenomena we must assume the existence of several juxtaposed or superposed fracture networks, vertically and horizontally non-communicating.

Table #11 : Results of the chemical analysis from the DNHE laboratory

PIEZO #	DATE SAMPLED	HCACO3 mg/l	CA++ mg/l	MG++ mg/l	NA+ mg/l	K+ mg/l	CL- mg/l	SO4-- mg/l	HCO3-- mg/l	CO3- mg/l	SOLIDS mg/l	GEOHYDROCHEMICAL FACIES	SITE
MA0001	06-Feb-89	217.0	172.0	72.0	21.0	11.0	825.0	218.0	264.0	0.0	2100.0	CALCIUM-MAGNES CHLORIDE	1
MA0002	06-Feb-89	223.0	202.0	63.0	10.0	12.0	890.0	243.0	271.0	0.0	2190.0	CALCIUM-MAGNES CHLORIDE	1
MA0003	06-Feb-89	281.0	64.0	45.0	5.0	5.0	16.0	17.0	343.0	0.0	400.0	CALCIUM-MAGNES. BICARBONATE	1
MA0004	06-Feb-89	192.0	226.0	137.0	5.0	6.0	745.0	183.0	235.0	0.0	1770.0	CALCIUM-MAGNES CHLORIDE	2
MA0005	05-Feb-89	212.0	103.0	20.0	10.0	4.0	48.0	325.0	257.0	0.0	772.0	(CA&MG) SULFATE & BICARBONATE	3
MA0006	04-Feb-89	40.0	8.0	9.0	0.0	2.0	0.0	0.0	49.0	0.0	61.0	CALCIUM-MAGNES. BICARBONATE	4
MA0007	04-Feb-89	244.0	50.0	27.0	2.0	4.0	0.0	7.0	297.0	0.0	315.0	CALCIUM-MAGNES. BICARBONATE	4
MA0008	04-Feb-89	277.0	64.0	25.0	5.0	2.0	1.0	27.0	339.0	0.0	366.0	CALCIUM-MAGNES. BICARBONATE	4
MA0009	06-Feb-89	240.0	57.0	56.0	5.0	6.0	215.0	63.0	294.0	0.0	764.0	(CA&MG) CHLORIDE & BICARBONATE	5
MA0010	06-Feb-89	259.0	74.0	9.0	2.0	3.0	4.0	12.0	317.0	0.0	343.0	CALCIUM-MAGNES. BICARBONATE	5
MA0011	06-Feb-89	246.0	56.0	24.0	5.0	3.0	4.0	11.0	301.0	0.0	317.0	CALCIUM-MAGNES. BICARBONATE	5
MA0012	06-Feb-89	150.0	459.0	337.0	2.0	38.0	3950.0	800.0	182.0	0.0	9488.0	HYPER CALC.-MAGNES. CHLORIDE	6
MA0013	06-Feb-89	74.0	47.0	6.0	5.0	2.0	9.0	27.0	90.0	0.0	211.0	CALCIUM SULFATE	6
MA0014	06-Feb-89	190.0	66.0	5.0	5.0	3.0	4.0	26.0	232.0	0.0	276.0	CALCIUM BICARBONATE	6
MA0015	05-Feb-89	293.0	47.0	20.0	10.0	2.0	9.0	45.0	232.0	0.0	323.0	CALCIUM-MAGNES. BICARBONATE	7
MA0016	05-Feb-89	219.0	47.0	0.0	2.0	0.0	2.0	2.0	266.0	0.0	281.0	CALCIUM BICARBONATE	8
MA0017	05-Feb-89	88.0	112.0	35.0	10.0	4.0	2.0	260.0	107.0	0.0	1366.0	HYPER CALC.-MAGNES. SULFATE	8
MA0018	06-Feb-89	171.0	33.0	29.0	2.0	1.0	19.0	34.0	209.0	0.0	306.0	CALCIUM-MAGNES. BICARBONATE	9
MA0019	06-Feb-89	142.0	177.0	47.0	100.0	6.0	765.0	380.0	172.0	0.0	1905.0	HYPER CALC.-MAGNES. CHLORIDE	9
MA0020	06-Feb-89	224.0	206.0	89.0	3.0	15.0	1500.0	600.0	272.0	0.0	3503.0	CALCIUM-MAGNES. CHLORIDE	9

The water's hardness ($CaCo_3$ = mg/l) is a natural characteristic[19] related to leaching of the terrains through which the water has drained and corresponds to the water's calcium and magnesium content. The measured hardness values are high and suggest the presence of calcareous and dolomitic rocks, rather than the chemical composition of the rocks constituting the Bakoye Group (sandstones and shales). Only the Nioro Group (see section 2.3.1 of this report) contains calcareous dolomites but the formations of this Group appear at the surface approximately 50 or 60 km to the N.E. of Manantali Dam. All the analyzed samples were classified as "moderately hard", with a hardness value > 75 mg/l of $CaCo_3$.

The concentrations of sulfate ions in the analyzed water was quite variable. The values are sometimes high, exceeding 300 mg/l, which suggests the presence of gypsum or time in contact with the surrounding rock. Sulfate concentrations greater than 300 mg/l can cause erosion of concrete and the corrosion of iron. Concentrations greater than 480 mg/l make the water unfit for agriculture[20].

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[19] Rodier, 1984, p. 1020.

[20] Rodier, 1984, p. 1094.

Table #12: Electrical conductivity and pH values: June and September 1989

PIEZO #	CO_06/89 µS/cm	CO_09/89 µS/cm	pH_06/89	pH_09/89
MA0001	1830	620	7.5	6.4
MA0002	2400	1210	7.5	6.5
MA0003	600	174	7.4	5.7
MA0004	1850	500	7.6	7.0
MA0005	1000	n/m	7.3	n/m
MA0006	85	70	6.2	5.5
MA0007	415	400	6.8	7.2
MA0008	460	470	7.0	8.0
MA0009	1300	1600	7.2	7.1
MA0010	490	400	7.7	7.0
MA0011	430	80	7.3	6.5
MA0012	2600	2100	7.9	7.3
MA0013	350	195	7.0	6.5
MA0014	240	250	6.3	6.7
MA0015	520	n/m	7.7	n/m
MA0016	400	n/m	8.2	n/m
MA0017	1820	n/m	6.2	n/m
MA0018	205	115	6.5	6.5
MA0019	2700	2580	7.0	7.0
MA0020	5000	4600	7.3	7.0
Number	20	16	20	16
Min	85	70	6.2	5.5
Max	5000	4600	8.2	8.0
Average	1235	960	7.2	6.7
Std. Dev.	1203	1194	0.5	0.6

The average electrical conductivity of the groundwater varies from 1235 µS/cm (dry season) to 960 µS/cm (rainy season). These waters are highly mineralized[21]. The origin, in the Bakoye Group (siliceous and feldspathic sandstones, shales), is probably to be found in the chemical alteration of the feldspathic portion of the aquifer.

The measured decrease in average electrical conductivity (960 µS/cm) after the rainy season indicates an effective recharge of the fracture network by the infiltration of rainwater, weakly mineralized.

The average pH of the groundwater varies from 7.2 (dry season) to 6.7 (rainy season). These average values are characteristics of siliceous rock. The change from a slightly basic water at the end of the dry season to a slightly acid water after the rainy season suggests a recharge of the fracture network by runoff water slightly acidified by organic matter.

[21] Rodier, 1984, p. 1015.

Tables #13 and #14 compare the groundwater concentrations of chlorine (Cl−) and nitrate (NO_3−−) anions for two different sampling dates. For nitrates, the American standard for drinking water is No_3 < 45 mg/l.

Table #13: Concentrations of Chlorine (mg/l) February and July 1989

PIEZO #	Sampling Date Feb-89	Jul-89	Strat. Intake	Complex UC_LC	Site #	Location from Dam		Water-course	Distance km
MA0001	825.0	244.0	PELITE 1B	LC	1	BELOW	RB	BAFING	0.65
MA0002	890.0	532.0	SANDSTONE 2	LC	1	BELOW	RB	BAFING	0.50
MA0003	16.0	352.0	SANDSTONE 2	LC	1	BELOW	RB	BAFING	0.20
MA0004	745.0	236.0	SANDSTONE 0	LC	2	BELOW	LB	BAFING	0.75
MA0005	48.0	222.0	SANDSTONE B	UC	3	BELOW	LB	BAFING	5.00
MA0006	0.0	168.0	SANDSTONE C	UC	4	ABOVE	RB	BAFING	10.50
MA0007	0.0	160.0	SANDSTONE C	UC	4	ABOVE	RB	BAFING	11.40
MA0008	1.0	376.0	SANDSTONE C	UC	4	ABOVE	RB	BAFING	11.75
MA0009	215.0	224.0	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.40
MA0010	4.0	400.0	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.40
MA0011	4.0	272.0	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.15
MA0012	3950.0	580.0	SANDSTONE 1A	LC	6	BELOW	LB	BAFING	0.25
MA0013	9.0	320.0	SANDSTONE 0	LC	6	BELOW	LB	BAFING	0.25
MA0014	4.0	144.0	SANDSTONE 1A	LC	6	BELOW	LB	BAFING	0.40
MA0015	9.0	222.0	SANDSTONE 0	LC	7	BELOW	LB	BAFING	1.50
MA0016	2.0	280.0	DOLERITE	LC	8	BELOW	LB	BAFING	0.75
MA0017	2.0	380.0	SANDSTONE 2	LC	8	BELOW	LB	BAFING	0.75
MA0018	19.0	78.0	SANDSTONE 1	LC	9	BELOW	RB	BAFING	0.75
MA0019	765.0	92.0	SANDSTONE 1A	LC	9	BELOW	RB	BAFING	0.55
MA0020	1500.0	484.0	SANDSTONE 2	LC	9	BELOW	RB	BAFING	0.15

Table #14: Concentrations of Nitrate (NO3−−mg/l) February and July 1989

PIEZO #	Sampling Date Feb-89	Jul-89	Strat. Intake	Complex UC_LC	Site #	Location from Dam		Water-course	Distance km
MA0001	0.2	1.3	PELITE 1B	LC	1	BELOW	RB	BAFING	0.65
MA0002	0.0	0.9	SANDSTONE 2	LC	1	BELOW	RB	BAFING	0.50
MA0003	0.8	0.9	SANDSTONE 2	LC	1	BELOW	RB	BAFING	0.20
MA0004	0.1	0.9	SANDSTONE 0	LC	2	BELOW	LB	BAFING	0.75
MA0005	0.2	0.4	SANDSTONE B	UC	3	BELOW	LB	BAFING	5.00
MA0006	0.4	4.4	SANDSTONE C	UC	4	ABOVE	RB	BAFING	10.50
MA0007	0.0	0.4	SANDSTONE C	UC	4	ABOVE	RB	BAFING	11.40
MA0008	0.1	0.4	SANDSTONE C	UC	4	ABOVE	RB	BAFING	11.75
MA0009	0.1	0.9	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.40
MA0010	0.0	0.4	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.40
MA0011	0.1	4.4	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.15
MA0012	0.2	0.9	SANDSTONE 1A	LC	6	BELOW	LB	BAFING	0.25
MA0013	0.0	4.4	SANDSTONE 0	LC	6	BELOW	LB	BAFING	0.25
MA0014	0.1	0.0	SANDSTONE 1A	LC	6	BELOW	LB	BAFING	0.40
MA0015	0.8	0.0	SANDSTONE 0	LC	7	BELOW	LB	BAFING	1.50
MA0016	0.1	0.4	DOLERITE	LC	8	BELOW	LB	BAFING	0.75
MA0017	0.4	0.0	SANDSTONE 2	LC	8	BELOW	LB	BAFING	0.75
MA0018	0.1	0.4	SANDSTONE 1A	LC	9	BELOW	RB	BAFING	0.75
MA0019	0.2	0.9	SANDSTONE 1A	LC	9	BELOW	RB	BAFING	0.55
MA0020	0.1	4.4	SANDSTONE 2	LC	9	BELOW	RB	BAFING	0.15

Tables #15 and #16 indicate the concentrations of iron (Fe^{++}) and Turbidity values. The American standards for drinking water are: Iron < 0.3 mg/l and turbidity (less than 5 J.T.U). The measured turbidities are quite high and indicate an effective recharge of the fracture network by surface water.

Table #15: February 1989 - Iron concentration (Fe^{++})

PIEZO #	Fe++ mg/l	Strat. Intake	Complex UC_LC	Site #	Location from Dam	Bank	Water-course	Dist. km
MA0001	0.0	PELITE 1B	LC	1	BELOW	RB	BAFING	0.65
MA0002	0.0	SANDSTONE 2	LC	1	BELOW	RB	BAFING	0.50
MA0003	0.1	SANDSTONE 2	LC	1	BELOW	RB	BAFING	0.20
MA0004	0.6	SANDSTONE 0	LC	2	BELOW	LB	BAFING	0.75
MA0005	2.2	SANDSTONE B	UC	3	BELOW	LB	BAFING	5.00
MA0006	0.1	SANDSTONE C	UC	4	ABOVE	RB	BAFING	10.50
MA0007	0.1	SANDSTONE C	UC	4	ABOVE	RB	BAFING	11.40
MA0008	0.1	SANDSTONE C	UC	4	ABOVE	RB	BAFING	11.75
MA0009	0.0	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.40
MA0010	0.0	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.40
MA0011	0.0	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.15
MA0012	0.0	SANDSTONE 1A	LC	6	BELOW	LB	BAFING	0.25
MA0013	0.1	SANDSTONE 0	LC	6	BELOW	LB	BAFING	0.25
MA0014	0.4	SANDSTONE 1A	LC	6	BELOW	LB	BAFING	0.40
MA0015	0.1	SANDSTONE 0	LC	7	BELOW	LB	BAFING	1.50
MA0016	0.8	DOLERITE	LC	8	BELOW	LB	BAFING	0.75
MA0017	1.6	SANDSTONE 2	LC	8	BELOW	LB	BAFING	0.75
MA0018	0.0	SANDSTONE 1A	LC	9	BELOW	RB	BAFING	0.75
MA0019	0.2	SANDSTONE 1A	LC	9	BELOW	RB	BAFING	0.55
MA0020	0.0	SANDSTONE 2	LC	9	BELOW	RB	BAFING	0.15

Table #16: February 1989 - Turbidity (Jackson Turbidity Unit - JTU)

PIEZO #	Turb. JTU	Strat. Intake	Complex UC_LC	Site #	Location from Dam	Bank	Water-course	Dist. km
MA0001	29.0	PELITE 1B	LC	1	BELOW	RB	BAFING	0.65
MA0002	5.0	SANDSTONE 2	LC	1	BELOW	RB	BAFING	0.50
MA0003	72.0	SANDSTONE 2	LC	1	BELOW	RB	BAFING	0.20
MA0004	10.0	SANDSTONE 0	LC	2	BELOW	LB	BAFING	0.75
MA0005	36.0	SANDSTONE B	UC	3	BELOW	LB	BAFING	5.00
MA0006	11.0	SANDSTONE C	UC	4	ABOVE	RB	BAFING	10.50
MA0007	10.0	SANDSTONE C	UC	4	ABOVE	RB	BAFING	11.40
MA0008	11.0	SANDSTONE C	UC	4	ABOVE	RB	BAFING	11.75
MA0009	38.0	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.40
MA0010	2.0	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.40
MA0011	9.0	SANDSTONE 2	LC	5	BELOW	RB	BAFING	0.15
MA0012	55.0	SANDSTONE 1A	LC	6	BELOW	LB	BAFING	0.25
MA0013	22.0	SANDSTONE 0	LC	6	BELOW	LB	BAFING	0.25
MA0014	16.0	SANDSTONE 1A	LC	6	BELOW	LB	BAFING	0.40
MA0015	8.0	SANDSTONE 0	LC	7	BELOW	LB	BAFING	1.50
MA0016	8.0	DOLERITE	LC	8	BELOW	LB	BAFING	0.75
MA0017	31.0	SANDSTONE 2	LC	8	BELOW	LB	BAFING	0.75
MA0018	24.0	SANDSTONE 1A	LC	9	BELOW	RB	BAFING	0.75
MA0019	52.0	SANDSTONE 1A	LC	9	BELOW	RB	BAFING	0.55
MA0020	12.0	SANDSTONE 2	LC	9	BELOW	RB	BAFING	0.15

5 ANNUAL FLUCTUATIONS

5.1 Manantali Dam Reservoir - Water level variations

The reservoir of Manantali Dam began to fill on July 18, 1987. Since that date, the gradual filling has continued, under the supervision of Groupement de Manantali, as a function of geotechnical preoccupations and the needs of water users throughout the Senegal River valley. The filling will be completed during the rainy season of 1990 when the water level in the reservoir reaches the designed use elevation (208 m ASL).

The stored water creates a great hydraulic surcharge in the physical surroundings of Manantali Dam as it rises over a few years from 154 m ASL to 208 m ASL, for an hydraulic charge equivalent to 54 meters of water.

Figure #6 indicates the water level variation of the Bafing River downstream of the dam for the year 1989.

Figure #7 indicates the rising water level in the reservoir from July 1987 until December 1989. Annex #5 documents the volumes of water stored in the Manantali Dam reservoir over time, monthly average discharges (m^3/sec) from the dam, made to regularize the Senegal River discharge, the cumulative volumes of water (m^3) stored by the dam per year, and the daily variations in dam discharge (m^3/sec).

Water level fluctuations in the Manantali Dam reservoir are highly related to the region's climatic cycle: a rainy season from May to October with maximum precipitation levels in August. Annex #6 presents, for the period 1986 - 1989, the principal climatic parameters (Tmin, Tmax, Taverage (celsius), relative humidity (%), wind speed (m/s), Piche evaporation (mm), precipitation (mm), days of rain, insolation (h/jr), potential evapotranspiration (Penman) (mm) and evaporation (Penman) (mm)) measured at the meteorological station at Mahina, a town located 90 km N.W. of the dam.

For the four year period 1986 - 1989: average annual precipitation[22] was 814 mm over 60 days of rain, average annual Piche evaporation was 2559 mm and average annual insolation was 2520 hours.

Schematically, Manantali Dam stocks precipitation runoff from July until October, then loses 2.5 meters as evaporation in addition to the volumes discharged to regularize the Senegal River.

[22] Ref.: annex #6 of this report, p.4.

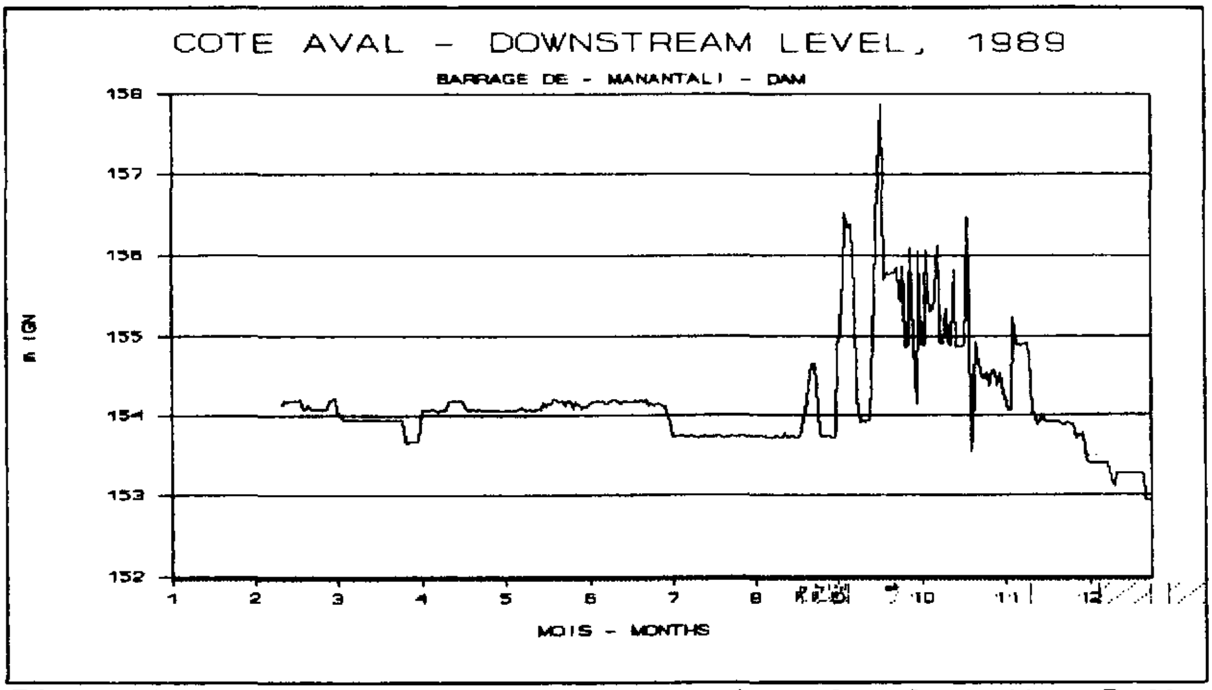

Figure 6 Year 1989: Variations in water level on the Bafing River downstream of Manantali Dam.

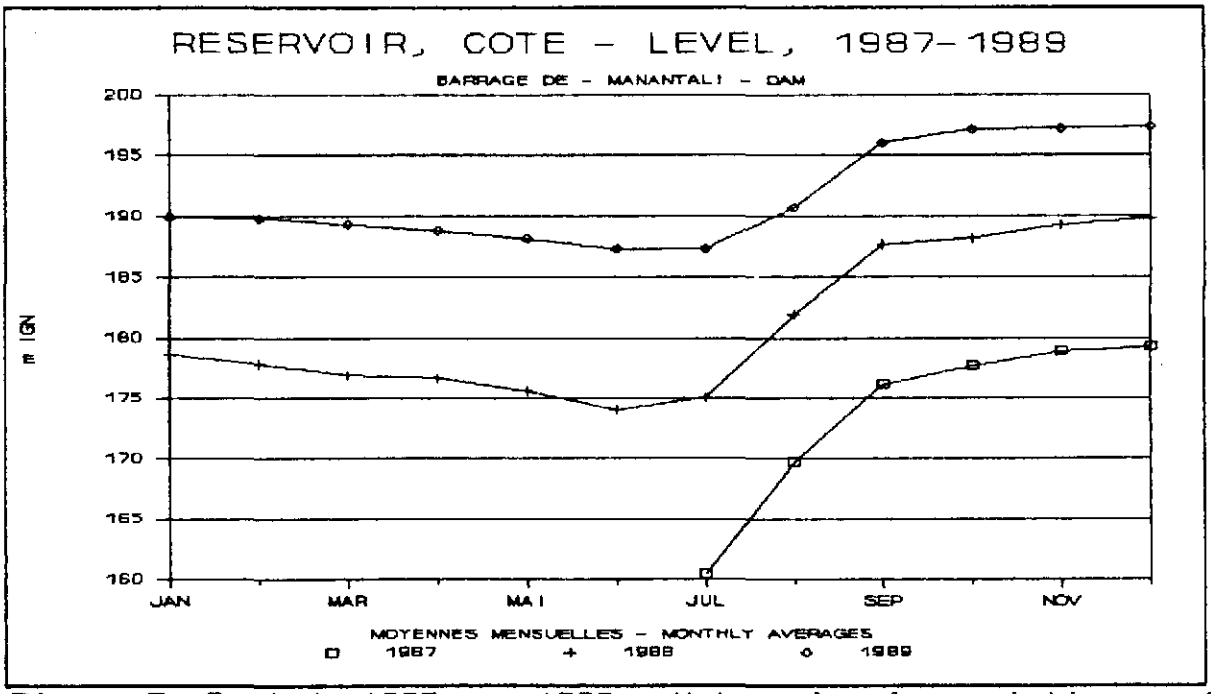

Figure 7 Period 1987 - 1989: Water level variations of Manantali Dam reservoir.

5.2 Piezometric fluctuations

The personnel of the Manantali sector periodically measure the depth of water in the piezometers with respect to points of known elevation: the top of the steel tube, which have been levelled. Measurements are made with a weekly or bi-monthly frequency.

The data collected in this periodic monitoring are sent to the central office in St. Louis where they are entered into the GES data base. The graphic function of the GES data base permits visualization of the piezometric fluctuations at any site over a given time period and the comparison of these with variations of water level in the Bafing River (upstream and/or downstream of the dam - by choice) and daily precipitation. Characteristic graphics for 9 geographic sites have been printed (see annex #4) for the period: 9/30/88 to 01/01/90. Depending on the geographic site in question, one or more isopiez curves are shown (one, two or three piezometers) on the same graphic.

Table #17 indicates, for each of the piezometers located in the area near Manantali Dam, the elevation ASL of the piezometer's concrete base (which corresponds to that of the topography around it), the water levels (isopiezes) for the months of June and September 1989 and the geological formation. From these basic data, the rise in water level (isopiezes September - June) and the depth of the water (September) from the ground surface, were calculated.

Table #17: Rise of piezometric levels between June and September 1989

Piezo #	Surface m ASL	Intake m ASL	06/89 m ASL	09/89 m ASL	Rise m	DS_09 depth	Strat. Intake	Complex UC_LC	Coordinates MTU-X	MTU-Y	Site #	Location from Dam	Bank	Water-course	Dist km
MA0001	161.15	151.83	157.63	160.08	2.45	1.07	PELITE 1B	LC	343.0	1459.6	1	BELOW	RB	BAFING	0.65
MA0002	161.14	124.92	158.36	160.05	1.69	1.09	SANDSTONE 2	LC	343.0	1459.6	1	BELOW	RB	BAFING	0.50
MA0003	162.15	120.99	158.64	160.55	1.91	1.59	SANDSTONE 2	LC	343.5	1459.7	1	BELOW	RB	BAFING	0.20
MA0004	160.59	136.10	156.87	157.95	1.08	2.64	SANDSTONE 0	LC	342.2	1458.4	2	BELOW	LB	BAFING	0.75
MA0005	288.61	247.62	288.22	N/A	N/A	N/A	SANDSTONE B	UC	341.4	1452.0	3	BELOW	LB	BAFING	5.00
MA0006	258.65	199.67	243.48	246.87	3.39	11.78	SANDSTONE C	UC	366.5	1455.5	4	ABOVE	RB	BAFING	4.00
MA0007	254.59	208.59	247.14	250.87	3.73	3.72	SANDSTONE C	UC	370.1	1458.2	4	ABOVE	RB	BAFING	5.00
MA0008	258.66	209.70	247.14	250.84	3.70	7.82	SANDSTONE C	UC	370.1	1458.4	4	ABOVE	RB	BAFING	5.00
MA0009	161.14	135.14	159.52	160.76	1.24	0.39	SANDSTONE 2	LC	343.9	1459.6	5	BELOW	RB	BAFING	0.40
MA0010	162.03	116.07	159.30	160.84	1.54	1.19	SANDSTONE 2	LC	343.9	1459.7	5	BELOW	RB	BAFING	0.40
MA0011	163.36	103.40	159.33	161.33	2.00	2.03	SANDSTONE 2	LC	343.9	1459.8	5	BELOW	RB	BAFING	0.15
MA0012	161.29	125.33	157.06	157.81	0.75	3.48	SANDSTONE 1A	LC	344.2	1459.1	6	BELOW	LB	BAFING	0.25
MA0013	161.17	140.38	156.44	159.93	3.49	1.24	SANDSTONE 0	LC	344.5	1458.9	6	BELOW	LB	BAFING	0.25
MA0014	161.18	90.06	156.46	159.93	3.47	1.24	SANDSTONE 1A	LC	344.2	1458.9	6	BELOW	LB	BAFING	0.40
MA0015	152.37	134.88	149.18	N/A	N/A	N/A	SANDSTONE 0	LC	324.6	1465.0	7	BELOW	LB	BAFING	1.50
MA0016	129.95	117.80	122.30	N/A	N/A	N/A	DOLERITE	LC	317.0	1464.2	8	BELOW	LB	BAFING	0.75
MA0017	133.17	96.83	118.37	N/A	N/A	N/A	SANDSTONE 2	LC	318.1	1464.2	8	BELOW	LB	BAFING	0.75
MA0018	162.25	108.26	156.34	161.15	4.81	1.10	SANDSTONE 1A	LC	338.2	1465.7	9	BELOW	RB	BAFING	0.75
MA0019	159.03	131.04	155.86	159.81	3.95	-0.78	SANDSTONE 1A	LC	338.1	1465.6	9	BELOW	RB	BAFING	0.55
MA0020	159.17	91.68	155.95	N/A	N/A	N/A	SANDSTONE 2	LC	338.0	1465.4	9	BELOW	RB	BAFING	0.15

All the elevations in this table are comparable with those in figures #6 and #7. From this table, and in general, we note that:

1) the piezometers, drilled in the Upper Complex lithostratigraphic series and located upstream and downstream of the dam, on both banks of the river, tap one or more water tables of which the surface are at elevations quite a bit higher than the water level in the reservoir,

2) all the other piezometers, drilled in the Lower Complex lithostratigraphic series and located downstream of the dam on the right

and left banks, tap one or more water tables of which the surfaces are at elevations (June '89) (118.37 to 159.52 m ASL) corresponding closely to that of the Bafing valley floor, with depths below the ground surface varying between -0.78 and 3.48 m.

3) the depths of the water table surfaces below the ground are slight, (depth from surface-DS less than 3.7 m), independent of topographic elevation of the piezometer. The piezometric surfaces seem to be controlled by the ground relief which suggests an effective vertical recharge.

5.2.1 Zone #1 - MA001, MA002 and MA003 - right bank of the Bafing downstream of the dam

Geographic zone #1 contains 3 piezometers having intakes in Pelite 1B (MA001) and Sandstone 2 (MA002 and MA003) of the Lower Complex.

The piezometric fluctuations are comparable from one piezometer to another and are independent of variations in the water level of the reservoir (dam is situated about 1 km from this zone).

Comparison of the periodic measurements of the piezometric levels reveals a constant difference in hydraulic pressure related to the hydraulic conditions of each tapped fracture network. We record a difference of hydraulic pressure Dh=1.01 m between the two aquifers which could create a vertical hydraulic gradient. However, the piezometric levels of the two tapped aquifers are greater than that of the Bafing downstream of the dam which confirms the constant recharge of the Bafing by the fracture networks.

The rise in piezometric level during the rainy season (May to September) is observable towards the end of July, that is, 2 months after the beginning of the rainy season (mid-May). The maximum amplitude (between 1.69 and 2.45 m depending on the piezometer in question) of this rise is seen near mid-September, 2.5 months later. The intensity of the precipitations is directly reflected in the piezometric profile which develops with a sawtooth pattern.

After the rise, we observe a decrease (during 2 months as for the rise) followed by a stabilization stage, corresponding to the dry season (observable from the beginning of November until the end of July).

Therefore, the recharge of the fracture network is related to infiltration of rainfall and inflows from the Bafing. Discharges from the network seem to be principally by evaporation.

5.2.2 Zone #2 - MA004 - left bank of the Bafing downstream of the dam

Geographic zone #2 contains only one piezometer with an intake in Sandstone 0 of the Lower Complex.

The piezometric fluctuations (MA004) are similar to those of zone #1. They are independent of variations of water level in the reservoir of the dam (dam situated 1 km from the zone).

The rise in piezometric level during the rainy season (May to September) is observable towards the end of July, that is, 2 months after the beginning of the rainy season (mid-May). The maximum amplitude (1.08 m) of this rise is seen near the beginning of October, 3months later. The intensity of the precipitations is directly reflected in the piezometric profile which develops with a sawtooth pattern.

After the rise, we observe a decrease (during 2 months as for the rise) followed by a stabilization stage, corresponding to the dry season (observable from the beginning of November until the end of July).

Therefore, the recharge of the fracture network is related to infiltration of rainfall. Discharges from the network seem to be principally by evaporation and drainage of the network towards the Bafing.

5.2.3 Zone #3 - MA005 - left bank of the Bafing downstream of the dam

Geographic zone #3 contains only one piezometer with an intake in Sandstone B of the Upper Complex.

This piezometer is, hydrographically, the only observation structure located in the watershed of the Balinn, juxtaposed to that of the Bafing. This structure is situated about 5 km from the dam. The intake is at an elevation of 247.62 m ASL, approximately 55 meters above the water level in the reservoir in 1989.

The measured piezometric level is very shallow (288.22 m ASL June '89) with respect to the topographic elevation of the piezometer (288.61 m ASL).

The piezometric fluctuations in this structure indicate two maximum values for the water level rise during the year of 1989. The first corresponds to the month of March (difficult to explain) and the second during the rainy season.

In August, this piezometer becomes artesian for the next four month period, reflecting an effective recharge of the fracture network, linked throughout the nearby high topography and draining toward the depressions.

The rise in water level which was measured during the dry season can, hypothetically, be explained by a halt in the pumping of wells in the village. No field observations were made in regards to this subject.

5.2.4 Zone #4 - MA006, MA007 and MA008 - right bank of the Bafing upstream of the dam

Geographic zone #4 contains 3 piezometers with intakes in Sandstone C of the Upper Complex.

The piezometric fluctuations of piezometers MA007 and MA008 are identical and are comparable to those of piezometer MA006. They are independent of the variations in the water level of the reservoir (187 to 197 m ASL) since the piezometric surface (243.48 to 247.14 m ASL) is higher.

Comparison of the periodic measurements of the water levels between the piezometers reveals a difference of hydraulic head (D_h = 3.6m) between piezometer MA006 (4.0 km from the reservoir) and the two other piezometers (5.0 km from the reservoir). This difference in pressure infers a verical hydraulic gradient between the different networks. However, the piezometric levels are greater than that of the Bafing downstream of the dam which confirms the constant recharge of the Bafing by the fracture networks.

The rise in water level during the rainy season (May to September) is observable towards the end of July, that is, 2 months after the beginning of the rainy season (mid-May). The maximum amplitude (about 3.7 m) of the rise is seen in mid September, 2.5 months later.

After the recharge of the fracture network by infiltration of rainfall, we observe a sustained and gradual decrease (during 10 months) throughout the dry season. This corresponds to the drainage phase of this fracture network.

Therefore, the recharge of the fracture network is related to infiltration of rainfall and its discharge to evaporation.

5.2.5 Zone #5 - MA009, MA010 and MA011 - right bank of the Bafing downstream of the dam

Geographic zone #5 contains 3 piezometers with intakes at different depths in Sandstone 2 of the Lower Complex.

The piezometric fluctuations of the three are identical and independent of reservoir water level variations (dam structure situated at 0.3 km from the zone).

Comparison of periodic measurements of the piezometric levels reveals a difference in hydraulic head D_h=0.60 m reflecting a vertical hydraulic gradient between the tapped aquifers. However, the piezometric levels are greater than that of the Bafing downstream of the dam which confirms the constant recharge of the Bafing by the fracture networks.

During a pumping test made on the MA009 structure (drawdown = 24 hours and recovery = 24 hours), we noted a stabilization of drawdown at t=950 minutes, indicating aquifer recharge. Previous to this, we had noted steepening of the time-drawdown curve at t=70 minutes and at t=650 minutes, indicating two imperious boundaries in the aquifer.

The rise in piezometric level during the rainy season (May to September) is observable towards the end of July, that is, 2 months after the beginning of the rainy season (mid-May). The maximum amplitude (between 1.24 m and 2.00 m depending on the piezometer in question) of this rise is seen near mid-September, 2.5 months later. The intensity of the precipitations is directly reflected in the piezometric profile which develops with a sawtooth pattern.

After the rise, we observe a decrease (during 2 months as for the rise) followed by a stabilization stage, corresponding to the dry season (observable from the beginning of November until the end of July).

Therefore, the Bafing constitutes a recharge zone for the fractured, anisotropic aquifer.

5.2.6 Zone #6 - MA012, MA013 and MA014 - left bank of the Bafing downstream of the dam

Geographic zone #6 contains 3 piezometers with intakes at different depths in Sandstone 1A (MA012 and MA014) and in Sandstone 0 (MA013) of the Lower Complex.

MA012

The piezometric fluctuations in the structure MA012 are identical to those measured on the right bank of the river in zone #5 (MA009, MA010 and MA011) and are independent of the reservoir water level variations (dam structure is situated 0.3 km from the zone).

The rise in piezometric level during the rainy season (May to September) is observable towards the end of July, that is, 2 months after the beginning of the rainy season (mid-May). The maximum amplitude (0.75 m) of this rise is seen near mid-September, 2.5 months later. The intensity of the precipitations is directly reflected in the piezometric profile which develops with a sawtooth pattern.

After the rise, we observe a decrease (during 2 months as for the rise) followed by a stabilization stage, corresponding to the dry season (observable from the beginning of November until the end of July).

During a pumping test made on MA012 (drawdown = 48 hours and recovery = 48 hours), we noted a stabilization of the drawdown at t=95 minutes which indicates a recharge to the aquifer.

MA013 and MA014

The piezometric fluctuations for MA013 and MA014 are comparable and their piezometric profiles are distinct from that of MA012.

The stabilization of the water table was not observed and the aquifer reaction to rainfall events was instantaneous.

The rise in piezometric level during the rainy season (May to September) is observable towards mid-June, that is, 1 month after the beginning of the rainy season (mid-May). The maximum amplitude (3.49 m) of this rise is seen near mid-August, 2.0 months later. The intensity of the precipitations is directly reflected in the piezometric profile which develops with a sawtooth pattern, although its profile is less accentuated than that of MA012.

After the recharge of the fracture network by infiltration of rainfall, we observe a sustained and gradual decrease (during 10 months) throughout the dry season. This corresponds to the drainage phase of this fracture network.

During a pumping test made on the MA012 structure (drawdown = 48 hours and recovery = 48 hours), the measured drawdowns for the piezometers MA013 and MA014 did not stabilize during the test.

Therefore, the piezometers of this zone tap two distinct aquifers. Recharge of the fracture zone is related to rainfall infiltration and its discharge to evaporation.

5.2.7 Zone #7 - MA0015 - left bank of the Bafing downstream of the dam

Geographic zone #7 contains the piezometer MA015 with an intake in Sandstone O of the Lower Complex.

The piezometric fluctuations in this structure are independent of the reservoir water level variations (dam structure at 16,4 km from the zone).

The measured piezometric level is shallow (149.18 m ASL June 89) with respect to the topographic elevation of the piezometer (152.37 m ASL).

The piezometric fluctuations in this structure reach their maximum value during the rainy season. In August, this piezometer becomes artesian for the next three months, reflecting an effective recharge of the fracture network, linked throughout the nearby high topography and draining toward the depressions.

The rise in water level (more than 3 meters) during the rainy season (May to September) is observable towards the beginning of July, that is, 1.5 months after the beginning of the rainy season (mid-May). In September, this piezometer becomes artesian for the next three month period, reflecting an effective recharge of the fracture network, linked throughout the nearby high topography and draining toward the depressions.

After the recharge of the fracture network by infiltration of rainfall, we observe a sustained and gradual decrease throughout the dry season. This corresponds to the drainage phase of this fracture network.

Therefore, the recharge of the fracture network is related to rainfall infiltration and its discharge to evaporation.

5.2.8 Zone #8 - MA016 and MA017 - left bank of the Bafing downstream of the dam

Geographic zone #8 contains 2 piezometers with intakes at different depths in Sandstone 2 (MA017) of the Lower Complex and in the intrusive dolerite rock (MA016). The piezometric fluctuations of the two structures are totally different and are independent of the reservoir water level variations (dam structure at 21.6 km and 23 km from the zone).

MA016

The annual precipitation influences the piezometer MA016 (Dolerite). The rise in water level during the rainy season (May to September) is observable towards the beginning of July, that is, 1.5 months after the beginning of the rainy season (mid-May). The maximum amplitude of the rise was not measured but would be on the order of 7.5 to 8 meters.

In August, this piezometer becomes artesian for the next two month period, reflecting an effective recharge of the fracture network, linked throughout the nearby high topography and draining toward the depressions.

During the dry season we note a continuous drop in the water level which indicates evaporation losses and drainage towards a connected fracture network.

MA017

During a pumping test (48 hours), the piezometer MA017 showed a response like that of a confined aquifer with transient flow. Annual precipitation does not influence this piezometer. Examination of the piezometric profile suggests a weak recharge from a connected fracture network. This recharge is effective well after the rainy season.

Therefore, the recharge of part of this fracture network (MA016) is related to the infiltration of rainfall and its discharge to evaporation and drainage to a connected fracture network. Recharge of the other part of the fracture network (MA017) is related to drainage from a connected fracture network and its discharge was not observed.

5.2.9 Zone #9 - MA018, MA019 and MA020 - right bank of the Bafing downstream of the dam

Geographic zone #9 contains 3 piezometers with intakes in Sandstone 1A (MA018 and MA019) and Sandstone 2 (MA020) of the Lower Complex.

The piezometric fluctuations of the three piezometers are comparable and are independent of the water level variations in the reservoir of the dam.

Comparison of periodic measurements of the water levels in the piezometers reveals a difference in hydraulic head (D_h = 0.5 m) between piezometers MA018 and MA019, reflecting a vertical hydraulic gradient between the tapped aquifers. However, the piezometric levels are greater than that of the Bafing downstream of the dam which confirms the constant recharge of the Bafing by the fracture networks.

During a pumping test (48 hours), the piezometer MA020 showed a response like that of a confined aquifer with transient flow.

The rise in piezometric level during the rainy season (May to September) is observable towards mid-June, that is, 1 month after the beginning of the rainy season (mid-May). The maximum amplitude (between about 3.95 m and about 5 m) of this rise is seen near mid-September, 3 months later.

In August, the piezometers (MA019 and MA020) become artesian for a one month period, reflecting an effective recharge of the fracture network, linked throughout the nearby high topography and draining toward the depressions.

After the recharge of the fracture network by infiltration of rainfall, we observe a sustained and gradual decrease throughout the dry season. This corresponds to the drainage phase of this fracture network.

6 CONCLUSIONS

The OMVS piezometric network (20 piezometers) is located in the Manantali Dam area, in 9 distinct geographic zones upstream and downstream of the dam structure. The reservoir created by the dam began to fill on July 18, 1987 (initial water level 154 m ASL) and since then the water level has steadily continued to rise. The maximum fill level (208 m ASL), should be reached during the rainy season 1990.

Through analysis of data from boreholes drilled during construction of the network, several fractured aquifers were identified, all belonging to the Bakoye Group lithostratigraphic series (siliceous and feldspathic sandstones and shales). This Group was subdivided according to the codification system proposed by the engineers of the Groupement de Manantali, into two Complexes, Lower and Upper. Schematically, the Lower Complex is linked to the Bafing River valley bottom and the Upper Complex is linked to the cliffs which border the reservoir created by Manantali Dam.

The relationship between the appearance (occurrence) frequency of structural accidents (number of fractures/linear meter) and the depth drilled into the bedrock was determined. This frequency, regardless of the geochemical composition of the surrounding rocks, diminishes with depth drilled in the bedrock. When geochemical composition is considered, it appears that Sandstone 2 of the Lower Complex is the most fractured (0.2 structural accidents/linear meter) and that the other formations (Lower and Upper Complex) are comparably fractured (0.06 to 0.1 structural accidents/linear meter).

Hydraulic productivity per lithostratigraphic formation [(Q air lift m^3/hour)/number structural accidents] was also established. The Upper Complex formations (cliffs bordering the reservoir) have a much greater hydraulic productivity (14 to 22 m^3/hour/structural accident) than those of the Lower Complex (about 7 m^3/hour/structural accident).

The chemical analysis of 20 groundwater samples indicates a great diversity of geohydrochemical facies, such as:

* calcium and magnesium bicarbonates (10/20),
* calcium and magnesium chlorides (8/20),
* calcium sulfates and bicarbonates (2/20).

The water is usually fresh and sometimes brackish. Their fitness for irrigation varies from "mediocre" to "excellent", depending on the degree of mineralization of the water.

The chemical analysis results suggest the existence of many juxtaposed or superposed and non-linked fracture networks. These different networks delimit many anisotropic aquifers.

Comparison of average physicochemical parameters (electrical conductivity and pH) between the end of the dry season and the beginning of the rainy season indicates a decrease (from the dry to the rainy season) which suggests a vertical recharge of the fracture networks by infiltration of weakly mineralized rainfall. The high turbidity values measured for the groundwater samples are theoretically characteristic of the surface waters, which tends to confirm the infiltration of rainfall.

The piezometric fluctuations of the network (cycle 88/89) were analyzed in relation to water level variations of the Manantali Dam reservoir and rainfall.

In general, for the whole OMVS network (20 piezometers), regardless of geographic position of the piezometers (upstream or downstream of the dam), we note that:

1) the principal recharge source of the aquifers is the infiltration of rainfall during the months of August and September (2 months per year),

2) the water losses are principally related to evaporation (10 months per year) and evapotranspiration, and probably to some extent, drainage from one fracture network to another,

3) the hydraulic head (proportional to a column of water 54 m high) induced by the filling of Manantali Dam reservoir does not influence the piezometry of the aquifers tapped by the OMVS network,

4) the depth of the water tables below the ground surface is shallow (DS < 3.7 m). The potentiometric surface seems to be controlled by the relief, which suggests an effective vertical recharge.

More specifically, except for zone #3 where MA005 is located outside of the Bafing watershed, the piezometric fluctuation curves are classified in three categories:

1) Rise - descent - stabilization period

This category contains most of the piezometers located downstream of the dam and at distances of approximately one kilometer from the Bafing River.

The measured piezometric levels are systematically greater than the water level of the Bafing River.

Therefore, the Bafing constitutes a zone of groundwater resurgence, fed by drainage of the various nearby fracture systems. The stabilization stage that was observed can be explained by the absence of piezometric fluctuations caused by the convergence of the flow lines toward the Bafing River bed.

2) Rise - gradual descent without stabilization period

This category contains all the piezometers located:

1) downstream of the dam and at more than one kilometer from the resurgence zone constituted by the Bafing River,

2) in the geographic zones situated upstream of the dam,

3) downstream of the dam, in the corridor generally recharged by the Bafing, in zones where the fracture network is not linked to the Bafing (zone #6).

The piezometric fluctuation curves of these sites do not indicate a stabilization period.

Therefore, the progressive drop without stabilization can be explained by a fracture network which is not linked with the Bafing.

3) Continuous slow rise

This category contains the piezometer MA017. This piezometer taps a fracture network which is hydraulically isolated from the Bafing River recharge zone. During the observation period, 1989, this fracture network seemed to be recharged by another connected fracture network.

Project measurements indicate that groundwater flow helps to maintain the discharge of the Bafing River, throughout the year. This observation which was true before July 1987 is still true after Manantali Dam has become operational. In fact, the potentiometric surface of the aquifers in the plateaus which border the dam's reservoir are clearly above the actual and planned operating level of the dam (208 m ASL).

However, this does not signify that the Manantali Dam reservoir does not influence the formations which are on its immediate borders (Upper Complex sandstone cliffs).

Before the reservoir began filling, there existed a heavily fractured but non-saturated zone in the Upper Complex sandstone cliffs. The artificial raising of the water level in the reservoir could induce recharge of this non saturated zone. This zone is delimited by the cliffs, the piezometric surface under natural conditions before the reservoir began filling, and a horizontal surface corresponding to the operating level of the reservoir. This volumetric definition supposes the existence of several interconnected fracture networks linked to the Manantali reservoir. This hypothesis is not confirmed by our piezometric observations.

If this was the case, as the water level rose in the reservoir, the non-saturated zone would be recharged and, as the water level dropped, the fracture network would return part of its stored water to the reservoir. This zone would be something of a secondary reservoir. Upon stabilization of the water level in the reservoir, at the operating level (208 m ASL), a new piezometric equilibrium would be established. The large differences between the piezometric levels at the observation points and the expected operating level indicates that the distance to which the reservoir will influence the aquifers will be small.

The number of observation points in the OMVS piezometric network does not permit one to answer this question.

The installation of one or more perpendicular piezometer lines on the plateau at the edges of the reservoir, and on sites which are judged structurally representative, would allow an answer to be developed to this question.

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INTRODUCTORY COMMENTS

A) GENERAL

The graphic representations of the geologic and technical sections in this annex, as well as the tables detailing the hydrogeological descriptions, were produced with GROUNDWATER software.

Files are identified as *.WLT and *.WLC.

The symbol * corresponds to the number of the piezometer concerned and the extensions:

WLT: contains all the geologic data for the piezometer concerned,

WLC: contains all the technical data for the piezometer concerned.

The reader will find, following this section, a complete listing of all the files dealt with in this annex, corresponding to the piezometers located within the limits of the topographic map 1/200,000 concerned.

All the piezometers, dealt with in this annex, are localized on the 1/200,000 map which accompanies this document.

The complete listing of the piezometers related to this map was produced with XTREE utility software..

Path: C:\GWDATA\27-1B
6 tagged files using 4,864 bytes

MA015	.WLC	1,152	.a..	9-25-89	11:06	am
MA016	.WLC	1,152	.a..	9-25-89	10:22	am
MA017	.WLC	1,152	.a..	9-25-89	4:01	am
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MA016	.WLT	384	.a..	4-13-90	11:28	am
MA017	.WLT	758	.a..	1-22-90	4:51	am

Path: C:\GWDATA\27-2A
22 tagged files using 17,792 bytes

MA001	.WLC	1,152	.a..	9-25-89	4:04	am
MA002	.WLC	1,152	.a..	9-25-89	4:06	am
MA003	.WLC	1,152	.a..	9-25-89	4:09	am
MA004	.WLC	1,152	.a..	9-25-89	4:50	pm
MA005	.WLC	1,152	.a..	9-25-89	4:15	am
MA009	.WLC	1,152	.a..	9-25-89	4:17	am
MA010	.WLC	1,152	.a..	9-25-89	4:20	am
MA011	.WLC	1,152	.a..	9-25-89	4:22	am
MA012	.WLC	1,152	.a..	9-25-89	4:25	am
MA013	.WLC	1,152	.a..	9-25-89	4:26	am
MA014	.WLC	1,152	.a..	9-25-89	4:28	am
MA001	.WLT	256	.a..	1-22-90	6:06	am
MA002	.WLT	512	.a..	9-27-89	10:20	am
MA003	.WLT	768	.a..	9-27-89	10:23	am
MA004	.WLT	384	.a..	9-27-89	8:16	pm
MA005	.WLT	768	.a..	9-27-89	10:28	am
MA009	.WLT	384	.a..	1-22-90	8:17	am
MA010	.WLT	324	.a..	9-27-89	4:38	pm
MA011	.WLT	512	.a..	9-27-89	10:31	am
MA012	.WLT	384	.a..	9-27-89	10:32	am
MA013	.WLT	384	.a..	3-05-90	3:36	pm
MA014	.WLT	384	.a..	9-27-89	10:36	am

Path: C:\GWDATA\27-2B
6 tagged files using 4,364 bytes

MA006	.WLC	1,152	.a..	9-25-89	4:30	am
MA007	.WLC	1,152	.a..	9-25-89	4:33	am
MA008	.WLC	1,152	.a..	9-25-89	4:34	am
MA006	.WLT	512	.a..	9-27-89	11:01	am
MA007	.WLT	512	.a..	9-27-89	10:39	am
MA008	.WLT	384	.a..	9-27-89	11:05	am

Path: C:\GWDATA\27-2C

6 tagged files using 4,992 bytes

MA018	.WLC	1,152	.a..	9-25-89	4:37	am
MA019	.WLC	1,152	.a..	9-25-89	4:38	am
MA020	.WLC	1,152	.a..	9-25-89	4:40	am
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MA019	.WLT	384	.a..	9-27-89	10:45	am
MA020	.WLT	512	.a..	9-27-89	10:47	am

Path: C:\GWDATA\27-1B
4 tagged files using 662 bytes

271B	.CHM	278	.a..	4-10-90	9:09	am
MA015	.CHM	128	.a..	9-27-89	4:26	am
MA016	.CHM	128	.a..	9-27-89	4:31	am
[illegible]	[illegible]	[illegible]	.a..	[illegible]	[illegible]	[illegible]

Path: C:\GWDATA\27-2A
11 tagged files using 1,408 bytes

MA001	.CHM	128	.a..	9-27-89	9:48	pm
MA002	.CHM	128	.a..	9-27-89	5:06	am
MA003	.CHM	128	.a..	9-27-89	5:02	am
MA004	.CHM	128	.a..	9-27-89	4:39	am
MA005	.CHM	128	.a..	9-27-89	4:36	am
MA009	.CHM	128	.a..	9-27-89	10:41	pm
MA010	.CHM	128	.a..	9-27-89	4:56	am
MA011	.CHM	128	.a..	9-27-89	4:59	am
MA012	.CHM	128	.a..	9-27-89	4:51	am
MA013	.CHM	128	.a..	9-27-89	4:44	am
MA014	.CHM	128	.a..	9-27-89	4:41	am

Path: C:\GWDATA\27-2B
3 tagged files using 384 bytes

MA006	.CHM	128	.a..	9-28-89	2:06	am
MA007	.CHM	128	.a..	9-28-89	2:18	am
MA008	.CHM	128	.a..	9-27-89	4:10	am

Path: C:\GWDATA\27-2C
3 tagged files using 384 bytes

MA018	.CHM	128	.a..	9-27-89	8:05	am
MA019	.CHM	128	.a..	9-27-89	8:02	am
MA020	.CHM	128	.a..	9-27-89	8:08	am

B) REMARKS CONCERNING THE COLUMN "GEOLOGIC COMMENTS"

Use of GROUNDWATER software imposes certain data entry constraints related to printing of the different reports:

* geologic sections
* summary tables

The space allocated to printing comments in the summary table is limited to 22 characters. This limit (22 characters) may be exceeded, however, when plotting the geologic sections.

Therefore, in order to ensure legibility in the summary tables and geologic sections, the following codification principles were adopted:

XXXX 22 characters XXXX free style

SEQ 1: limited to 4 characters.
SEQ 2: limited to 6 characters.
SEQ 3: limited to 10 characters.

DEFINITION OF SEQUENCES + CODES USED

SEQ 1: Geologic formation. The geologic codes used are those used in the GES data base.

SEQ 2 Color. The definition of colors uses the first two letters of the color concerned.
EX.: a brown sample would be coded BR; a brown grey sample would be coded BR/GR. (in French)

Note: 1) Sequence 1 is obligatory.

2) The order of these sequences must obligatorily be respected.

3) If information relative to one of the sequences is missing, continue with the next sequence.

4) After SEQ 2, the comments are in free style. These will only appear when printing the detailed geologic section.

LEXICON

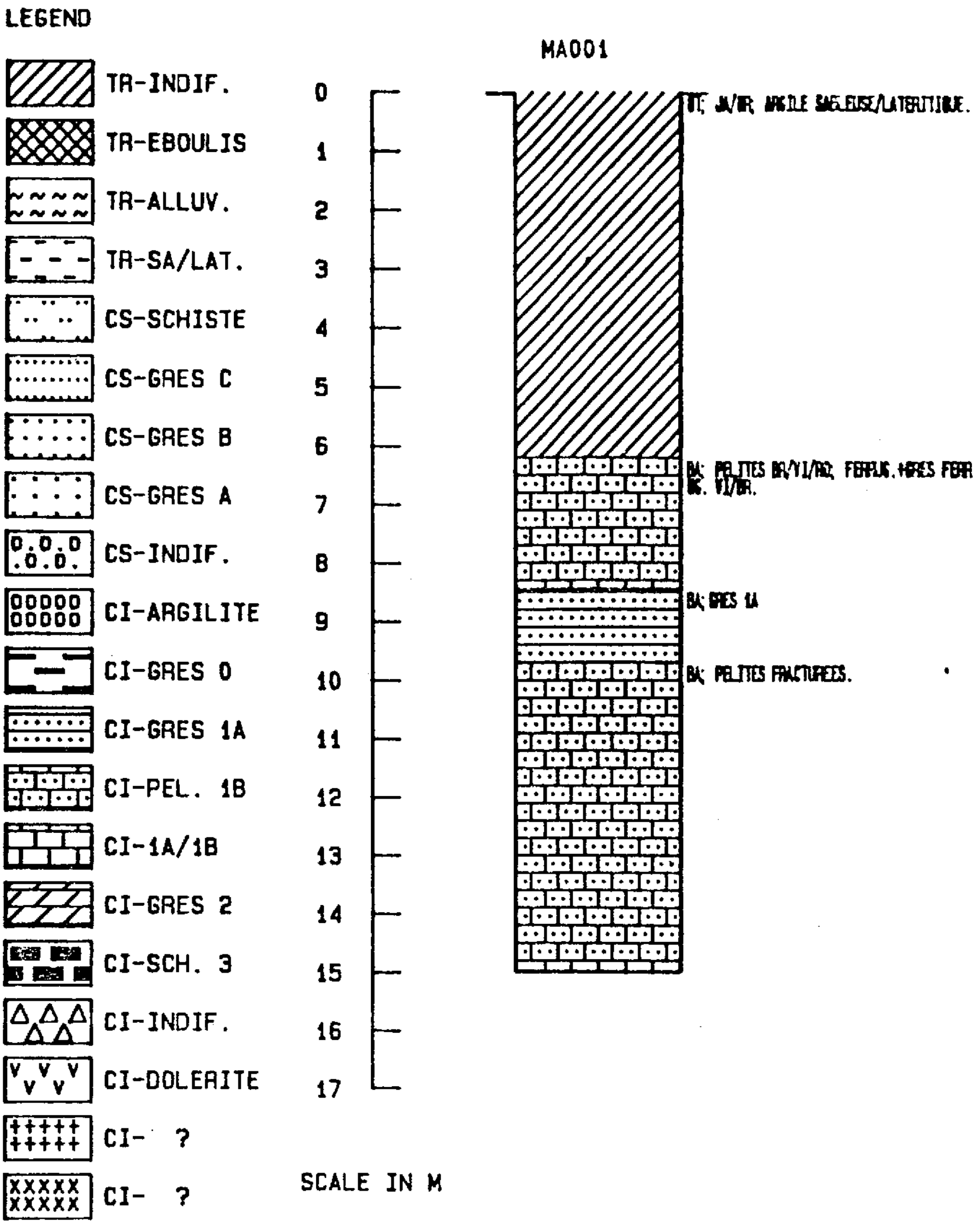
All the graphics and the tables characterizing the piezometers # ... , contained in annex # 1, were produced with GROUNDWATER/LITHOCON software. Since this software was written in English, it is useful here to clarify the translated terms. The translations are not rigorous and are adapted to the activities of this project.

LITHOLOGY	= DESCRIPTION LITHOSTRATIGRAPHIQUE
WELL CONSTRUCTION DETAILS	= COUPE TECHNIQUE DU PIEZOMETRE
WELL CAP	= COUVERCLE DE PROTECTION
CASING	= TUBE D'ACIER PEINT EN ROUGE
LINER	= TUBE PVC PLEIN
DRILLED HOLE	= TROU DE FORAGE
WELL SCREEN	= CREPINE EN PVC
PLUG	= BOUCHON DE FERMETURE A LA BASE DU PIEZOMETRE
GRAVEL PACK	= GRAVIER FILTRE
STATIC WATER LEVEL	= NIVEAU STATIQUE MESURE PAR RAPPORT AU SOL
SCALE	= ECHELLE
PROJECT	= PROJET
FILE	= FICHIER, CORRESPOND AU # DU PROJET
LOCATION	= LOCALISATION, CORRESPOND AU NOM DE LA CARTE 1/50.000
WELL NO	= NO DU PIEZOMETRE
DRILLER	= FOREUR, CORRESPONDANT AU NOM DE L'ENTREPRISE RESPONSABLE DES TRAVAUX DE FORAGE
ELEVATION (m)	= ELEVATION EXPRIMEE EN METRES PAR RAPPORT AU ZERO IGN
DATE DRILLED	= DATE D'EXECUTION DU FORAGE
TYPE OF RIG	= TECHNIQUE DE FORAGE
DEPTH	= PROFONDEUR
THICKNESS (m)	= EPAISSEUR EXPRIMEE EN METRES

GROUNDWATER - STRATIGRAPHIC DESCRIPTION CODES

CODES	LITHOLOGIC DESCRIPTIONS ABBREVIATED[23]	COMPLETE
	....	
F1	TR-INDIF.	unconsolidated, undifferentiated terrain,
F2	TR-EBOULIS	unconsolidated, debris terrain,
F3	TR- ALLUV	unconsolidated, alluvial terrain
F4	TR-SA/LAT.	unconsolidated, sand & laterrite terrain
F5	CS-SCHISTE	upper complex - shale
F6	CS-GRES C	upper complex - Sandstone C
F7	CS-GRES B	upper complex - Sandstone B
F8	CS-GREA	upper complex - Sandstone A
F9	CS-INDIF.	upper complex - undifferentiated
F10	CI-ARGILITE	lower complex - Argilite
SHIFT F1	CI-GRES 0	lower complex - Sandstone 0
SHIFT F2	CI-GRES 1A	lower complex - Sandstone 1A
SHIFT F3	CI-PEL. 1B	lower complex - Pelite 1B
SHIFT F4	CI-1A/1B	lower complex Sandstone 1A and/or Pelite 1B
SHIFT F5	CI-GRES 2	lower complex Sandstone 2
SHIFT F6	CI-SCH. 3	lower complex Shale 3
SHIFT F7	CI-INDIF.	lower complex undifferentiated
SHIFT F8	CI-DOLERITE	lower complex Dolerite
SHIFT F9	CI- ?	unused Code
SHIFT F10	CI- ?	unused Code

23 The abbreviated descriptions are limited by graphic representation constraints to a maximum of 11 characters.



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA001

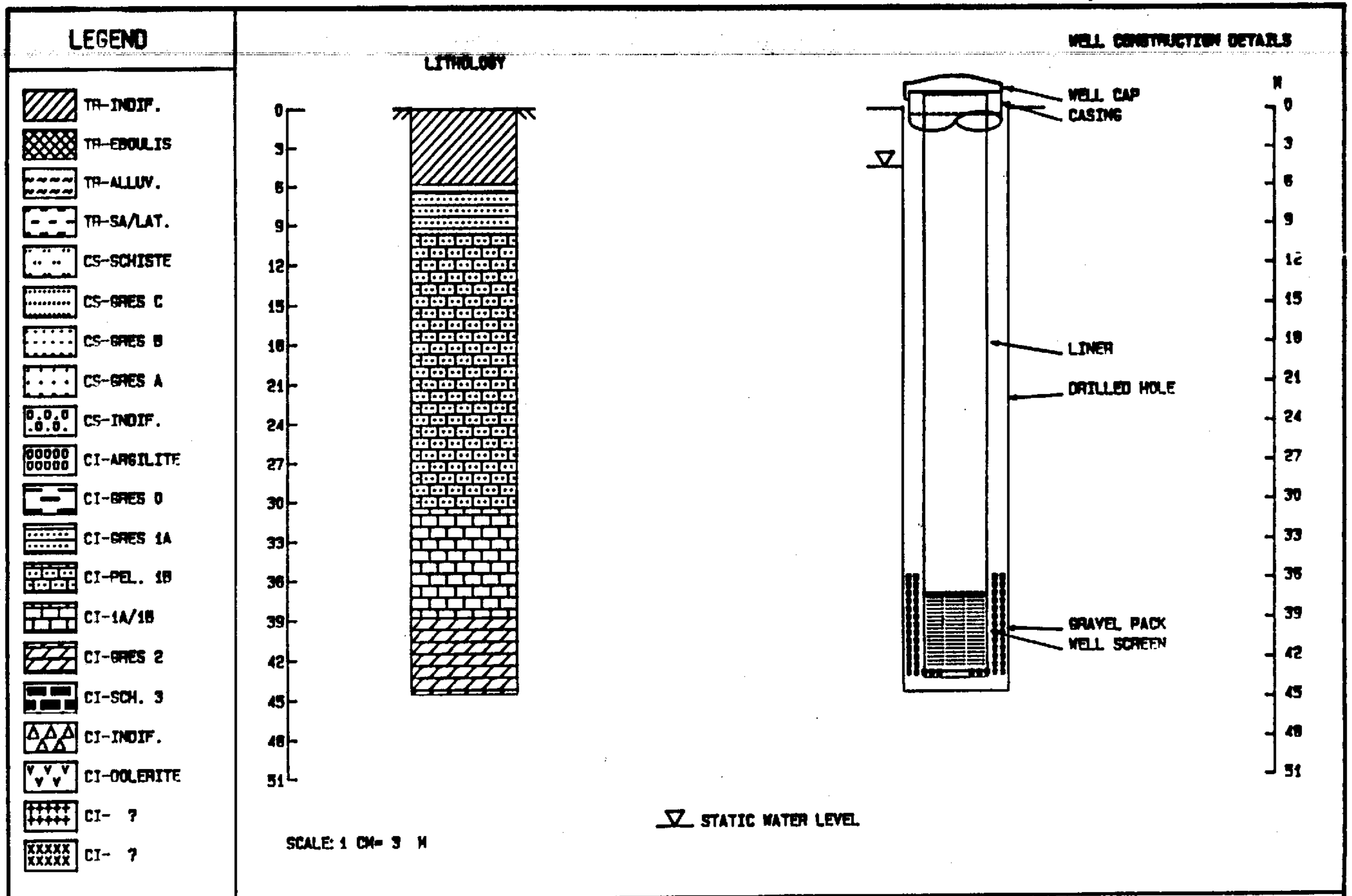
WELL LITHOLOGY

PROJECT: OMVS/USAID FILE NO.: 625-0958
LOCATION: BAFOULABE 2A

WELL # MA001 ELEVATION (m): 161.15

DEPTH (m) FROM	TO	THICKNESS (m)	LITHOLOGY
0.000	6.200	6.200	TR-INDIF.,GT: JA/OR; AR
6.200	8.450	2.250	CI-PEL. 1B,BA; PELITES
8.450	9.700	1.250	CI-GRES 1A,BA;GRES 1A
9.700	15.000	5.300	CI-PEL. 1B,BA; PELITES

USAID/DAKAR/SENEGAL

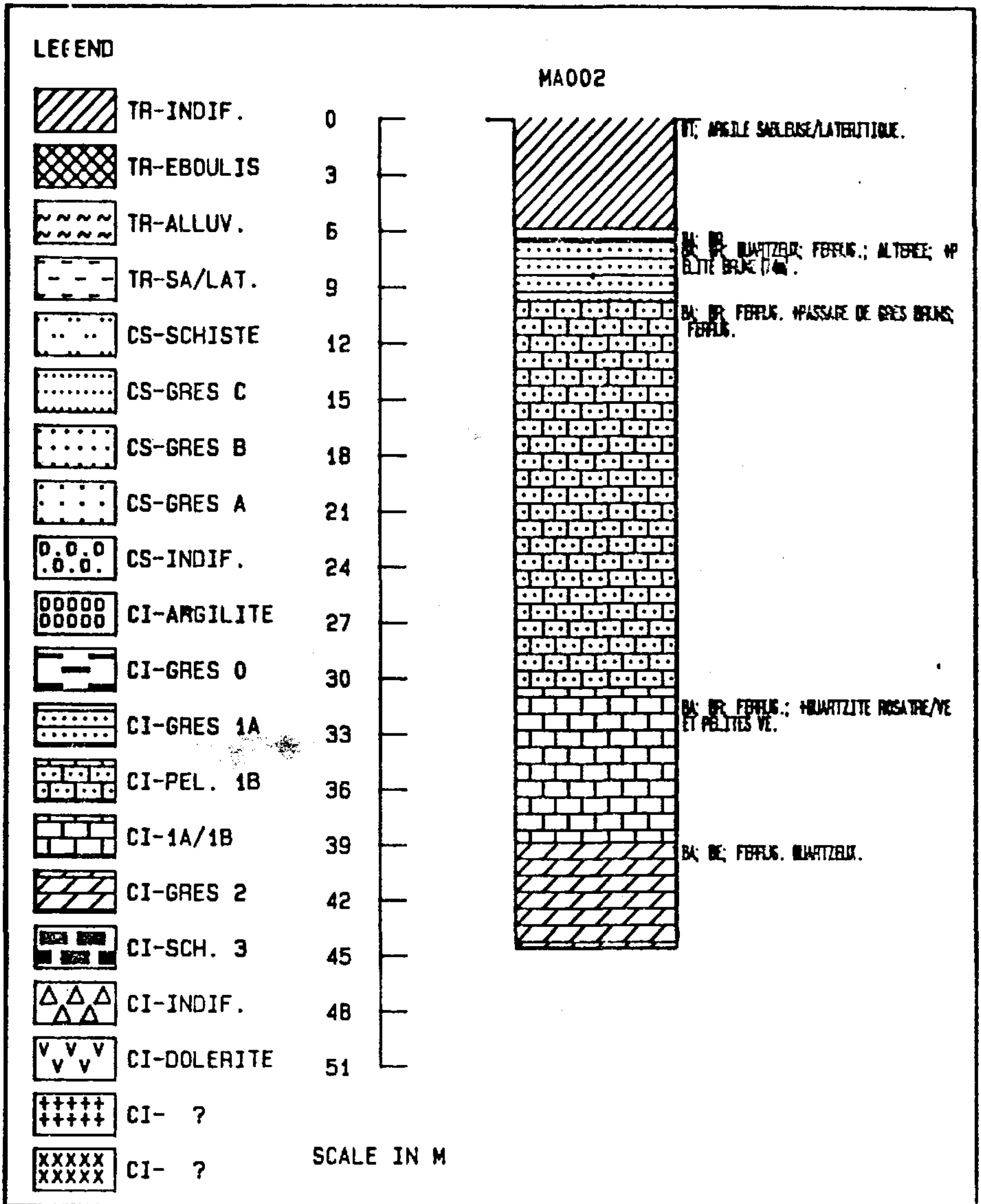


PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA002



PROJECT: OMVS/USAID
FILE: 625-0956
LOCATION: BAFOULABE 2A

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA002

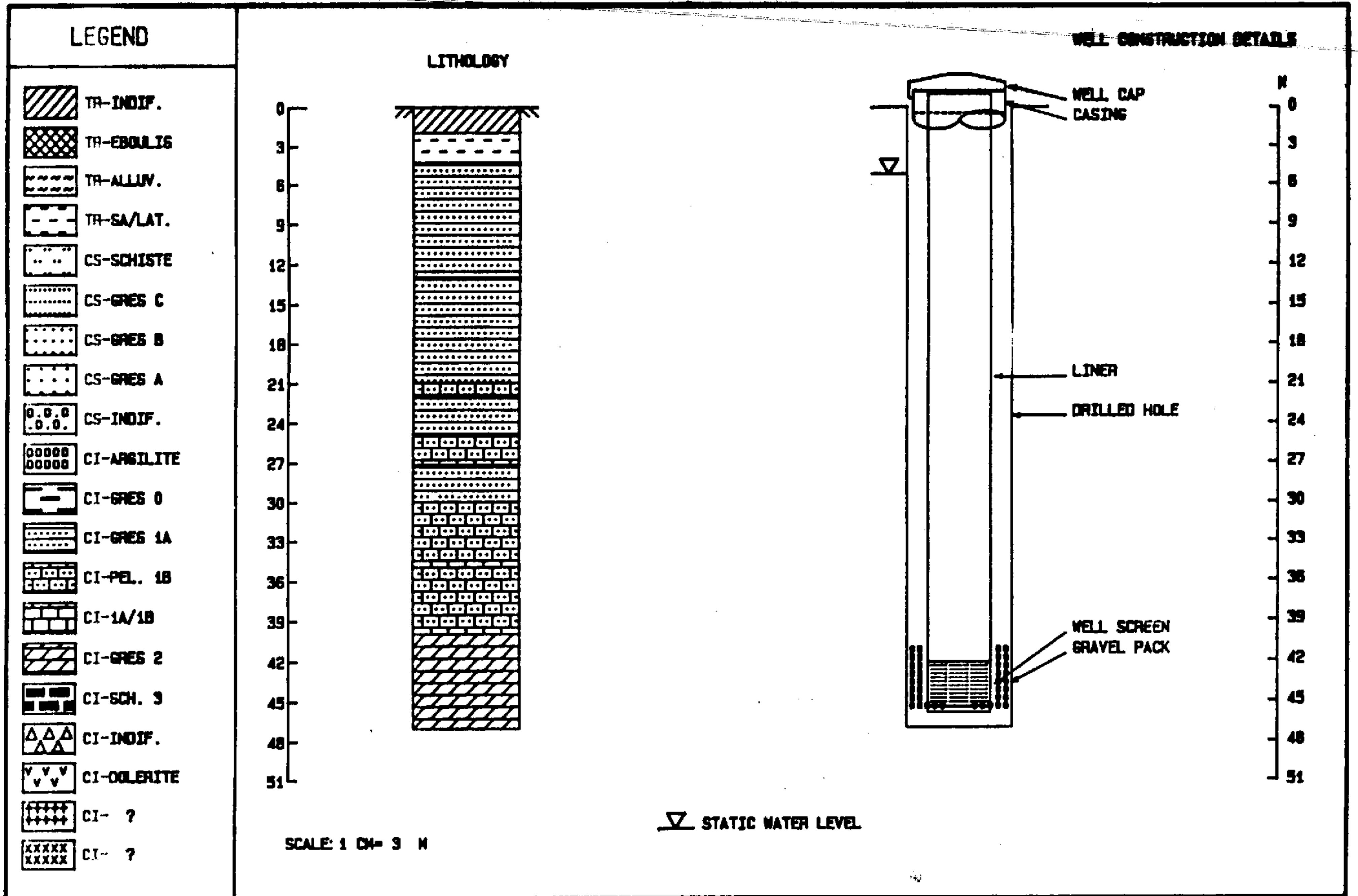
WELL LITHOLOGY

PROJECT: OMVS/USAID FILE NO.: 625-0958
LOCATION: BAFOULABE 2A

WELL # MA002 ELEVATION (m): 161.139

DEPTH (m)		THICKNESS (m)	LITHOLOGY
FROM	TO		
0.000	5.900	5.900	TR-INDIF.,QT; ARGILE SA
5.900	6.450	0.550	CI-PEL. 1B,BA; BR.
6.450	9.800	3.350	CI-GRES 1A,BA; GR; QUAR
9.800	31.000	21.200	CI-PEL. 1B,BA; BR; FERR
31.000	38.860	7.860	CI-1A/1B,BA; BR; FERRUG
38.860	44.630	5.770	CI-GRES 2,BA; BE; FERRU

USAID/DAKAR/SENEGAL

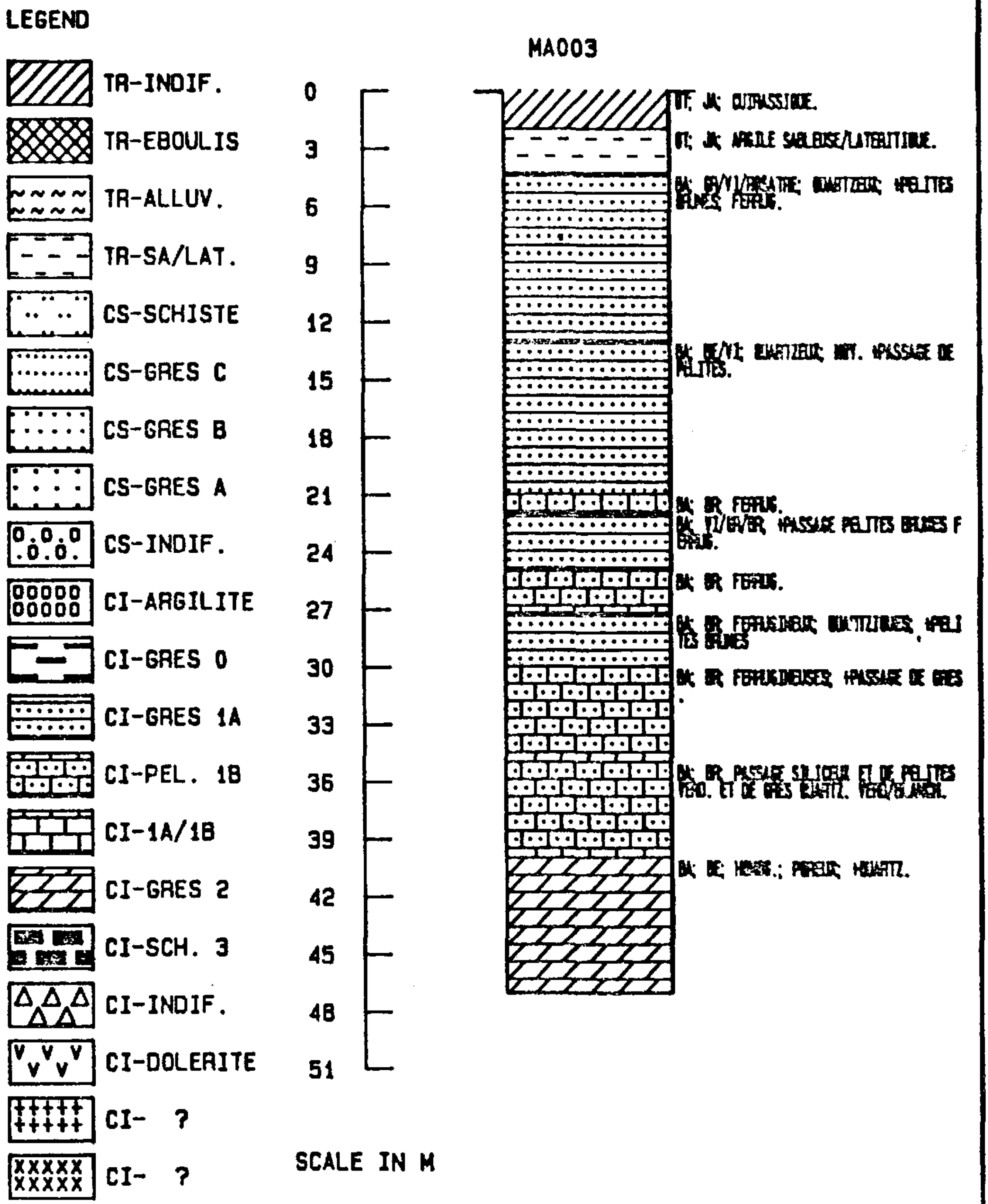


PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA003



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA003

WELL LITHOLOGY

PROJECT: OMVS/USAID
LOCATION: BAFOULABE 2A

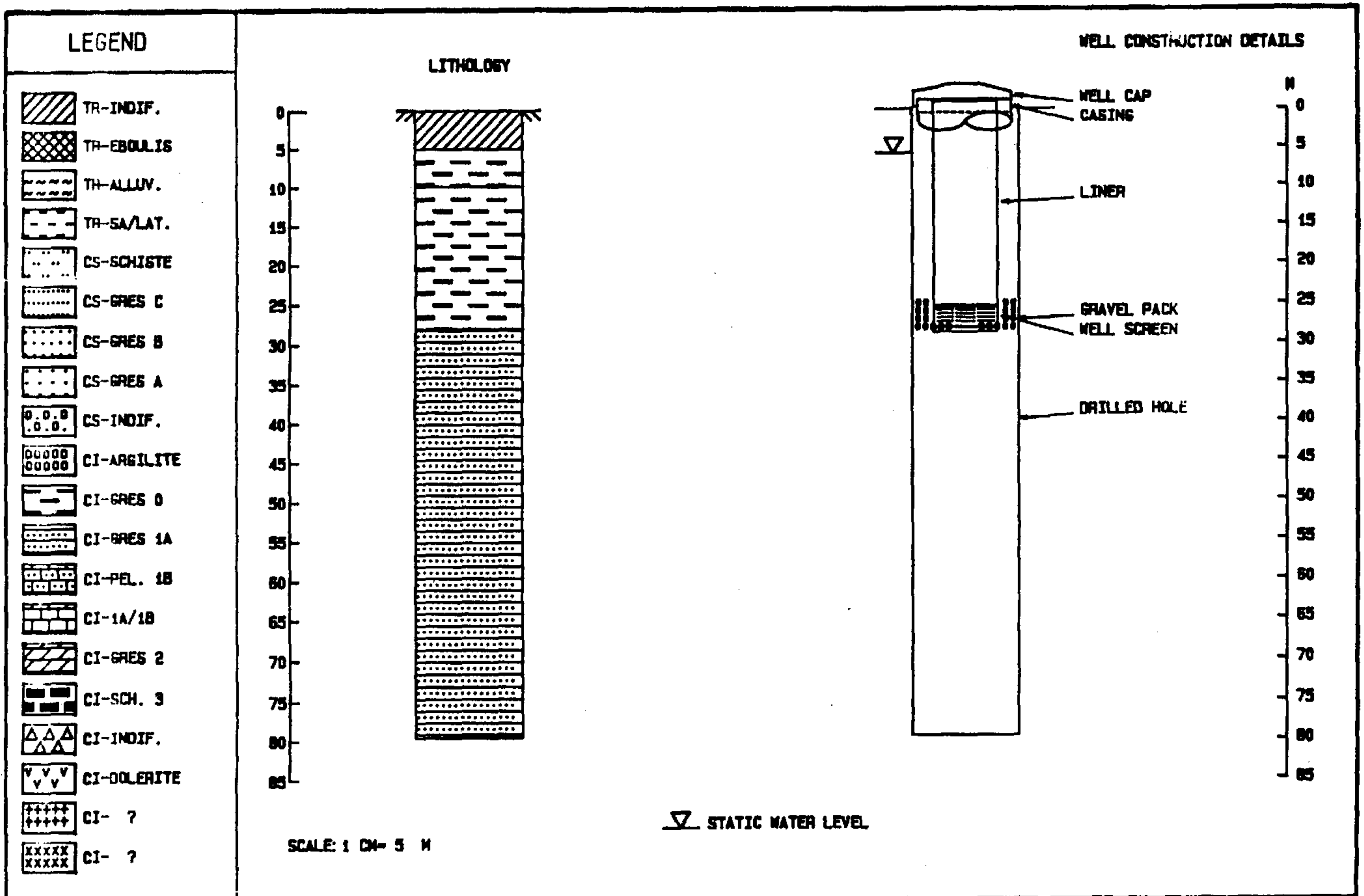
FILE NO.: 625-0958

WELL # MA003

ELEVATION (m): 162.146

DEPTH (m) FROM	TO	THICKNESS (m)	LITHOLOGY
0.000	2.000	2.000	TR-INDIF.,QT; JA; CUIRA
2.000	4.300	2.300	TR-SA/LAT.,QT; JA; ARGI
4.300	13.000	8.700	CI-GRES 1A,BA; GR/VI/RO
13.000	21.000	8.000	CI-GRES 1A,BA; BE/VI; Q
21.000	22.000	1.000	CI-PEL. 1B,BA; BR; FERR
22.000	25.000	3.000	CI-GRES 1A,BA; VI/GR/BR
25.000	27.200	2.200	CI-PEL. 1B,BA; BR; FERR
27.200	30.000	2.800	CI-GRES 1A,BA; BR; FERR
30.000	35.000	5.000	CI-PEL. 1B,BA; BR; FERR
35.000	40.000	5.000	CI-PEL. 1B,BA; BR; PASS
40.000	47.050	7.050	CI-GRES 2,BA; BE; HOMOG

USAID/DAKAR/SENEGAL

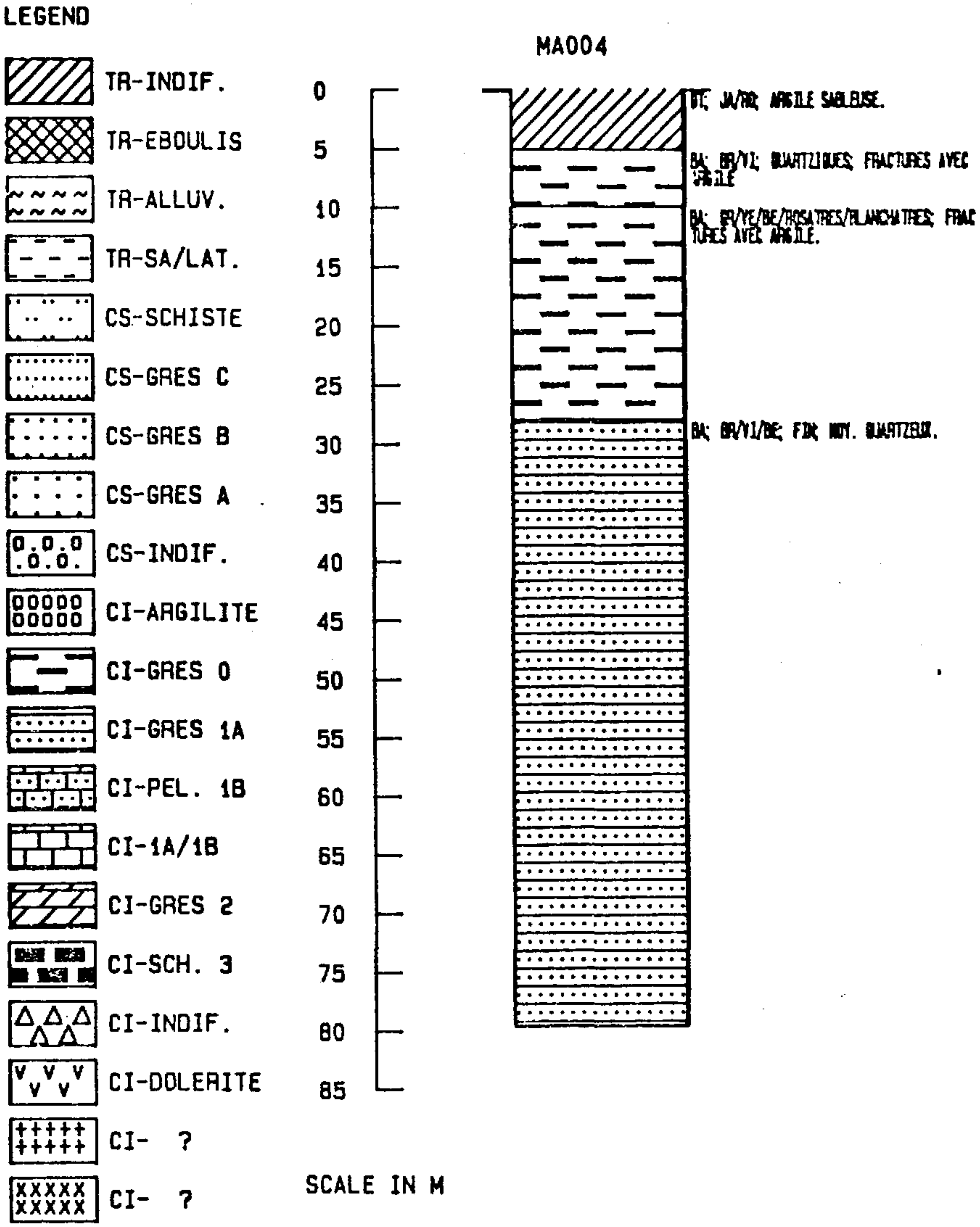


PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA004



PROJECT: OMVS/USIAD
FILE: 625-0958
LOCATION: BAFOULABE 2A

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA004

WELL LITHOLOGY:

PROJECT: OMVS/USAID
LOCATION: BAFOULABE 2A

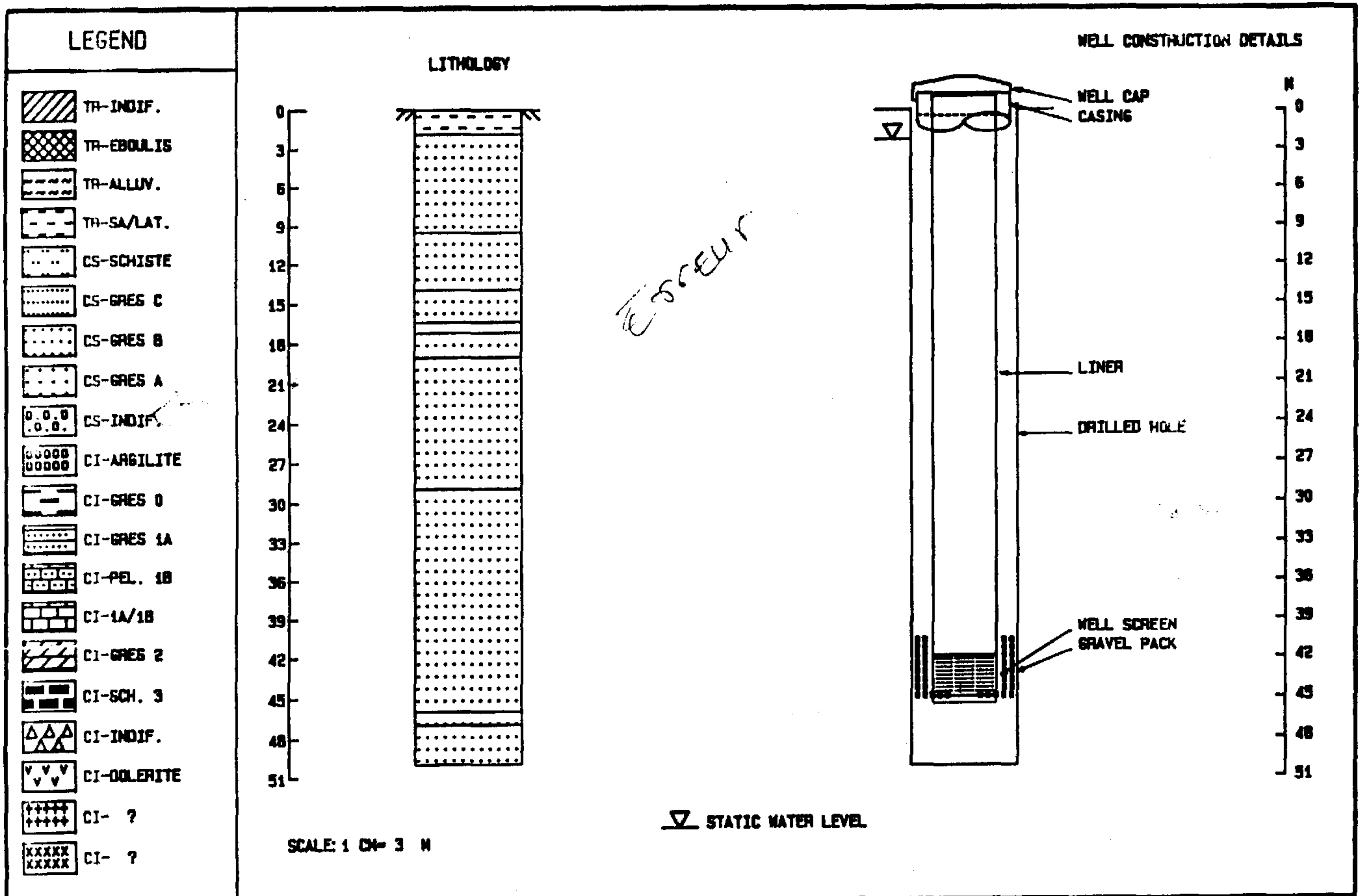
FILE NO.: 625-0958

WELL # MA004

ELEVATION (m): 160.593

DEPTH (m)		THICKNESS (m)	LITHOLOGY
FROM	TO		
0.000	5.150	5.150	TR-INDIF.,QT; JA/RO; AR
5.150	10.000	4.850	CI-GRES O,BA; BR/VI; QU
10.000	28.000	18.000	CI-GRES O,BA; GR/VE/BE/
28.000	79.680	51.680	CI-GRES 1A,BA; BR/VI/BE

USAID/DAKAR/SENEGAL

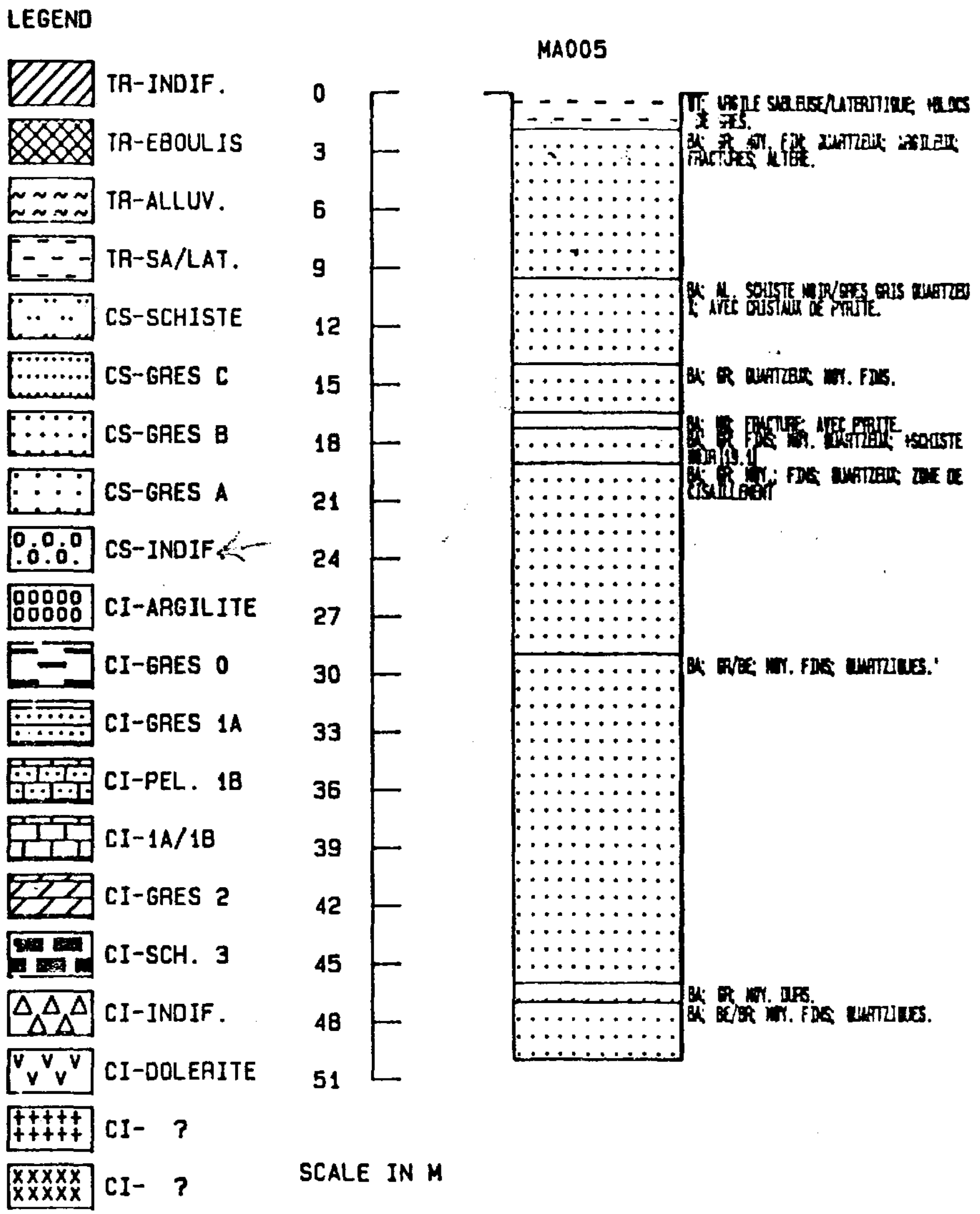


PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA005



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA005

WELL LITHOLOGY

PROJECT: OMVS/USAID
LOCATION: BAFOULABE 2A

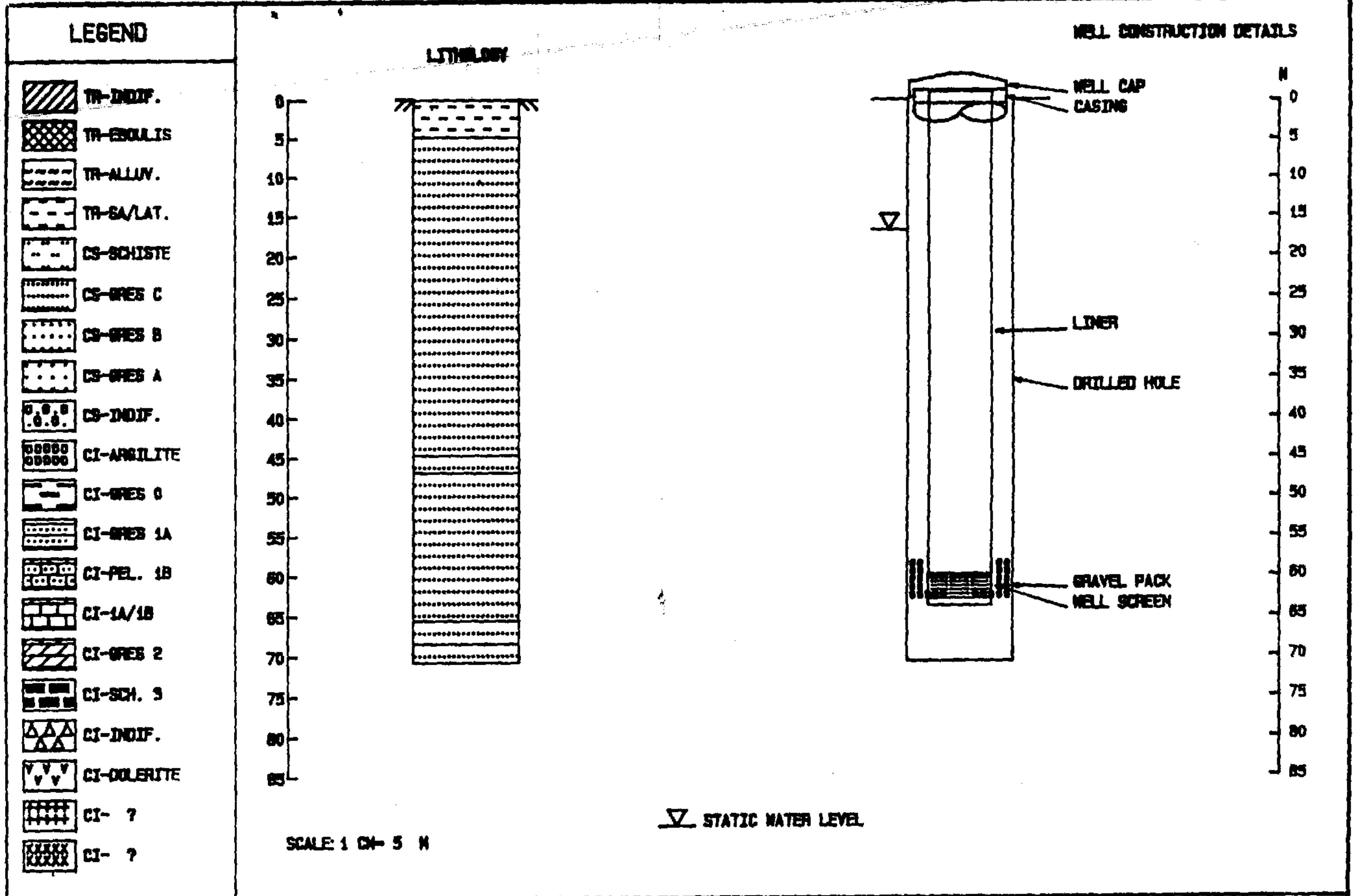
FILE NO.: 625-0958

WELL # MA005

ELEVATION (m): 288.608

DEPTH (m)		THICKNESS (m)	LITHOLOGY
FROM	TO		
0.000	1.900	1.900	TR-SA/LAT..ST; ARGILE S
1.900	9.600	7.700	CS-GRES B,BA; GR; MOY.
9.600	14.000	4.400	CS-GRES B,BA; AL. SCHIS
14.000	16.500	2.500	CS-GRES B,BA; GR; QUART
16.500	17.300	0.800	CS-SCHISTE,BA; NO; FRAC
17.300	19.100	1.800	CS-GRES B,BA; GR; FINS;
19.100	29.000	9.900	CS-GRES B,BA; GR; MOY.;
29.000	46.000	17.000	CS-GRES B,BA; GR/BE; MO
46.000	47.000	1.000	CS-GRES B,BA; GR; MOY.
47.000	50.000	3.000	CS-GRES B,BA; BE/BR; MO

USAID/DAKAR/SENEGAL

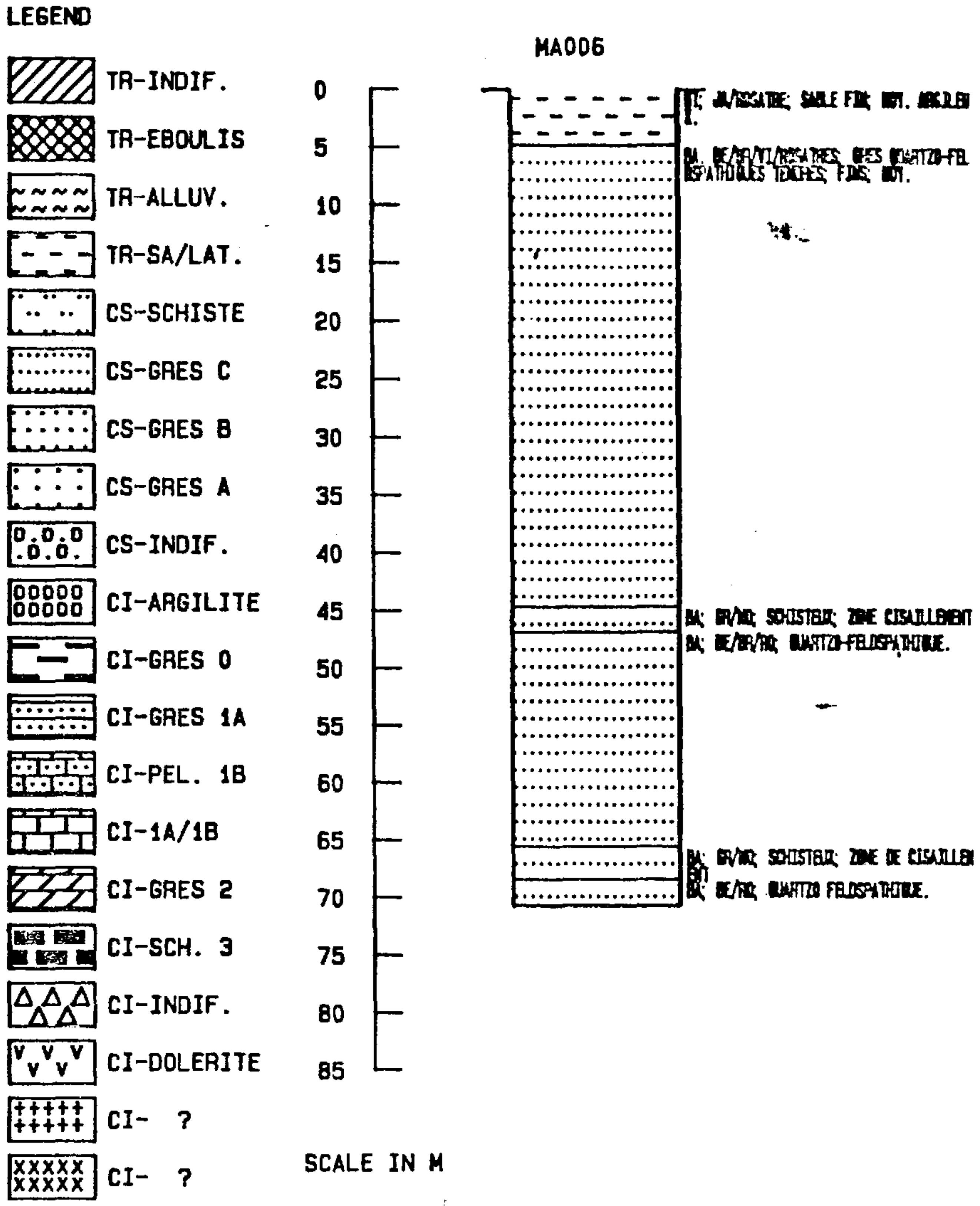


PROJECT: OMVS/USAID
FILE: 825-0958
LOCATION: BAFOULABE 2B

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA006



PROJECT:	OMVS/USAID	LITHOLOGY
FILE:	625-0958	
LOCATION:	BAFOULABE 2B	

USAID/DAKAR/SENEGAL

FIGURE MA006

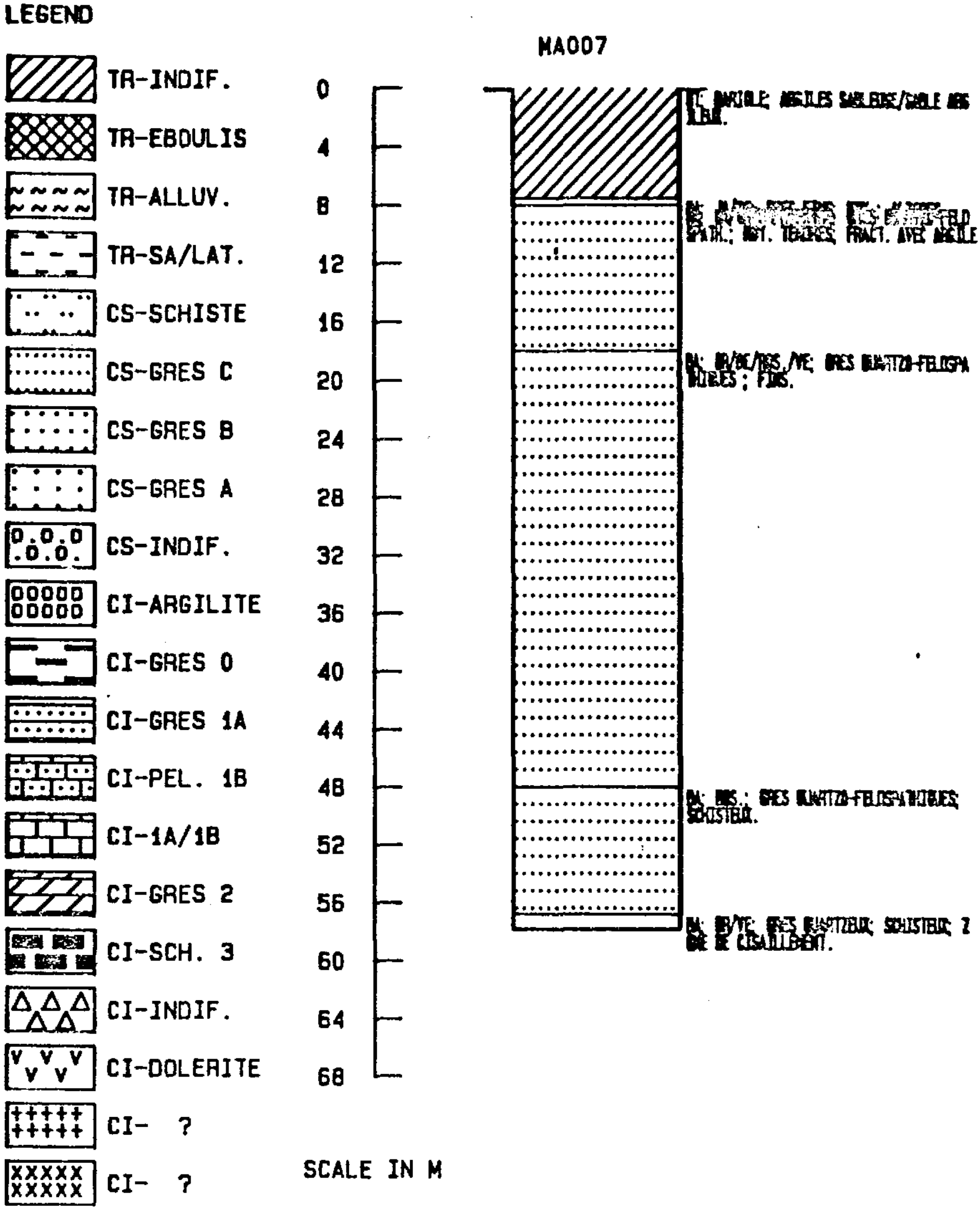
WELL LITHOLOGY

PROJECT: OMVS/USAID FILE NO.: 625-0958
LOCATION: BAFOULABE 2B

WELL # MA006 ELEVATION (m): 228.645

DEPTH (m)		THICKNESS (m)	LITHOLOGY
FROM	TO		
0.000	4.900	4.900	TR-SA/LAT.,QT; JA/ROSAT
4.900	44.800	39.900	CS-GRES C,BA. BE/BR/VI/
44.800	47.000	2.200	CS-GRES C,BA; GR/NO; SC
47.000	65.650	18.650	CS-GRES C,BA; BE/BR/RO;
65.650	68.480	2.830	CS-GRES C,BA; GR/NO; SC
68.480	70.830	2.350	CS-GRES C,BA; BE/RO; QU

USAID/DAKAR/SENEGAL



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2B

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA007

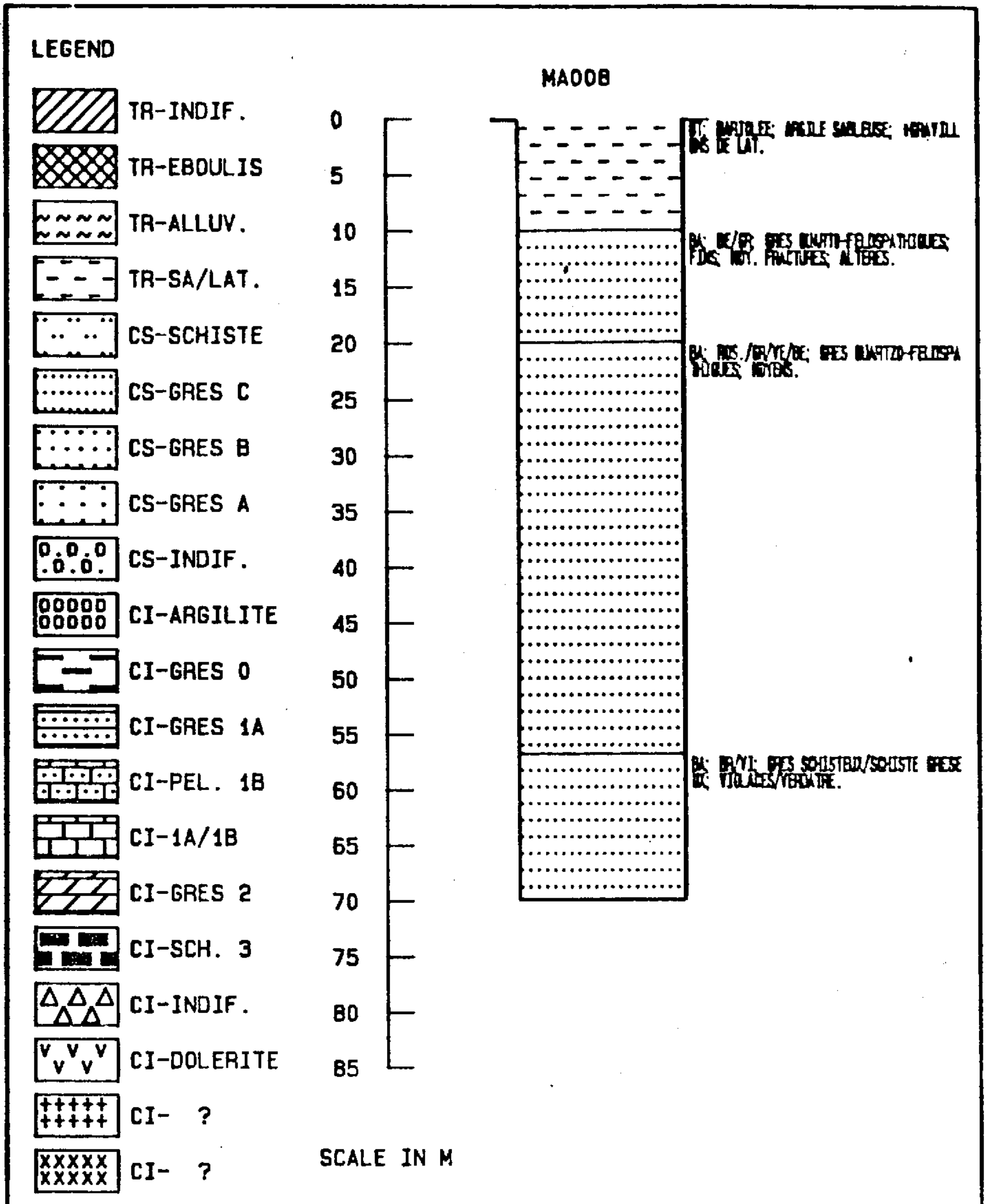
WELL LITHOLOGY

PROJECT: OMVS/USAID FILE NO.: 625-0958
LOCATION: BAFOULABE 2B

WELL # MA007 ELEVATION (m): 254.586

DEPTH (m) FROM	TO	THICKNESS (m)	LITHOLOGY
0.000	7.520	7.520	TR-INDIF.,QT; BARIOLE;
7.520	8.000	0.480	CS-GRES C,BA; JA/BE; GR
8.000	18.000	10.000	CS-GRES C,BA; JA/GR/BR/
18.000	48.000	30.000	CS-GRES C,BA; GR/BE/ROS
48.000	56.800	8.800	CS-GRES C,BA; ROS.; GRE
56.800	57.880	1.080	CS-GRES C,BA; BR/VE; GR

USAID/DAKAR/SENEGAL

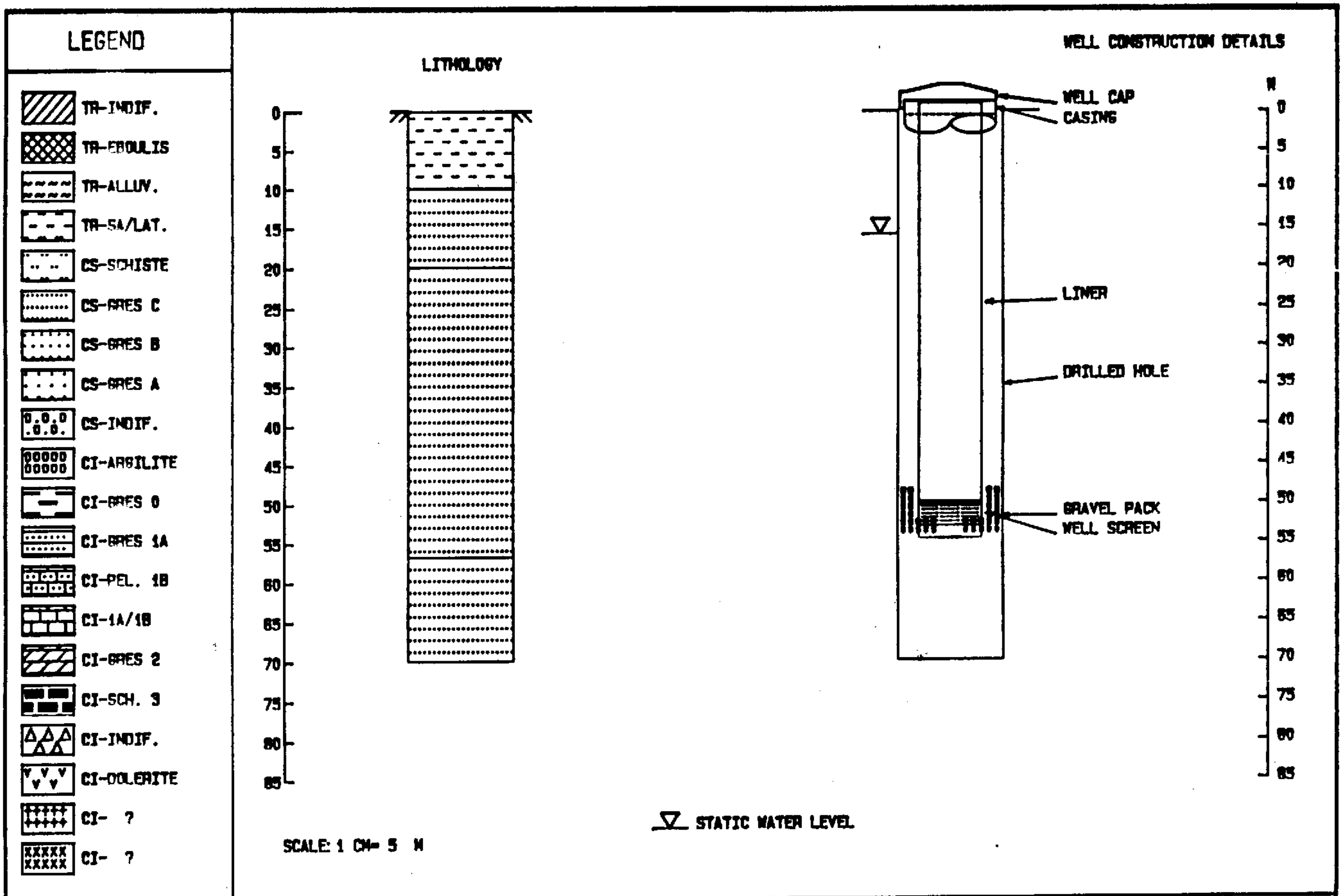


PROJECT: OMVS/USAID
FILE: 625-0956
LOCATION: BAFOULABE 2B

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA008



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2B

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA008

WELL LITHOLOGY

PROJECT: OMVS/USAID
LOCATION: BAFOULABE 2B

FILE NO.: 625-0958

WELL # MA008

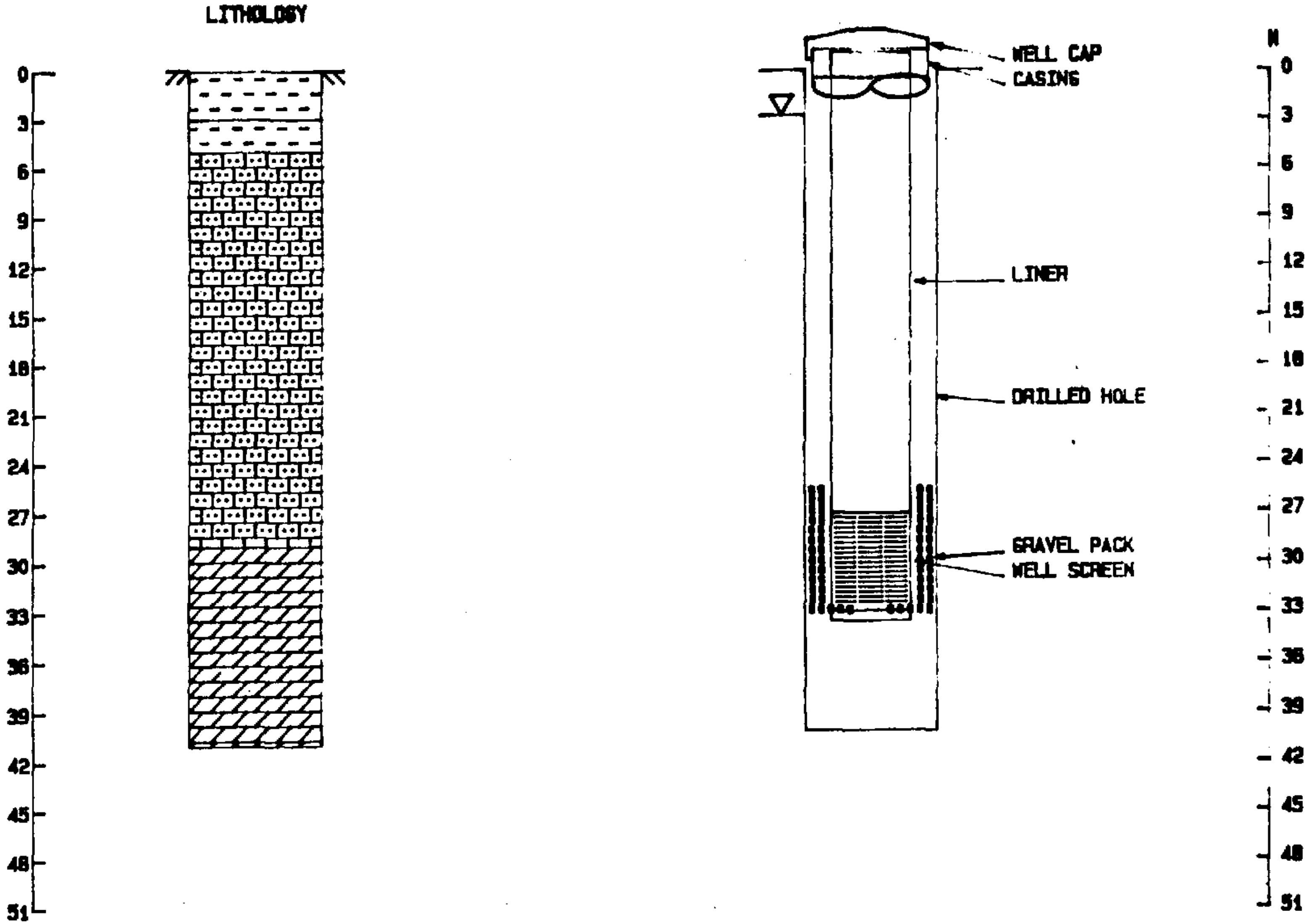
ELEVATION (m): 258.659

DEPTH (m)		THICKNESS (m)	LITHOLOGY
FROM	TO		
0.000	10.000	10.000	TR-SA/LAT.,QT; BARIOLEE
10.000	20.000	10.000	CS-GRES C,BA; BE/GR; GR
20.000	56.800	36.800	CS-GRES C,BA; ROS./GR/V
56.800	70.000	13.200	CS-GRES C,BA; BR/VI; GR

USAID/DAKAR/SENEGAL

LEGEND

- TR-INDIF.
- TR-EBOULIS
- TR-ALLUV.
- TR-SA/LAT.
- CS-SCHISTE
- CS-GRES C
- CS-GRES B
- CS-GRES A
- CS-INDIF.
- CI-ARGILITE
- CI-GRES 0
- CI-GRES 1A
- CI-PEL. 1B
- CI-1A/1B
- CI-GRES 2
- CI-SCH. 3
- CI-INDIF.
- CI-DOLERITE
- CI- ?
- CI- ?



SCALE: 1 CM= 3 M

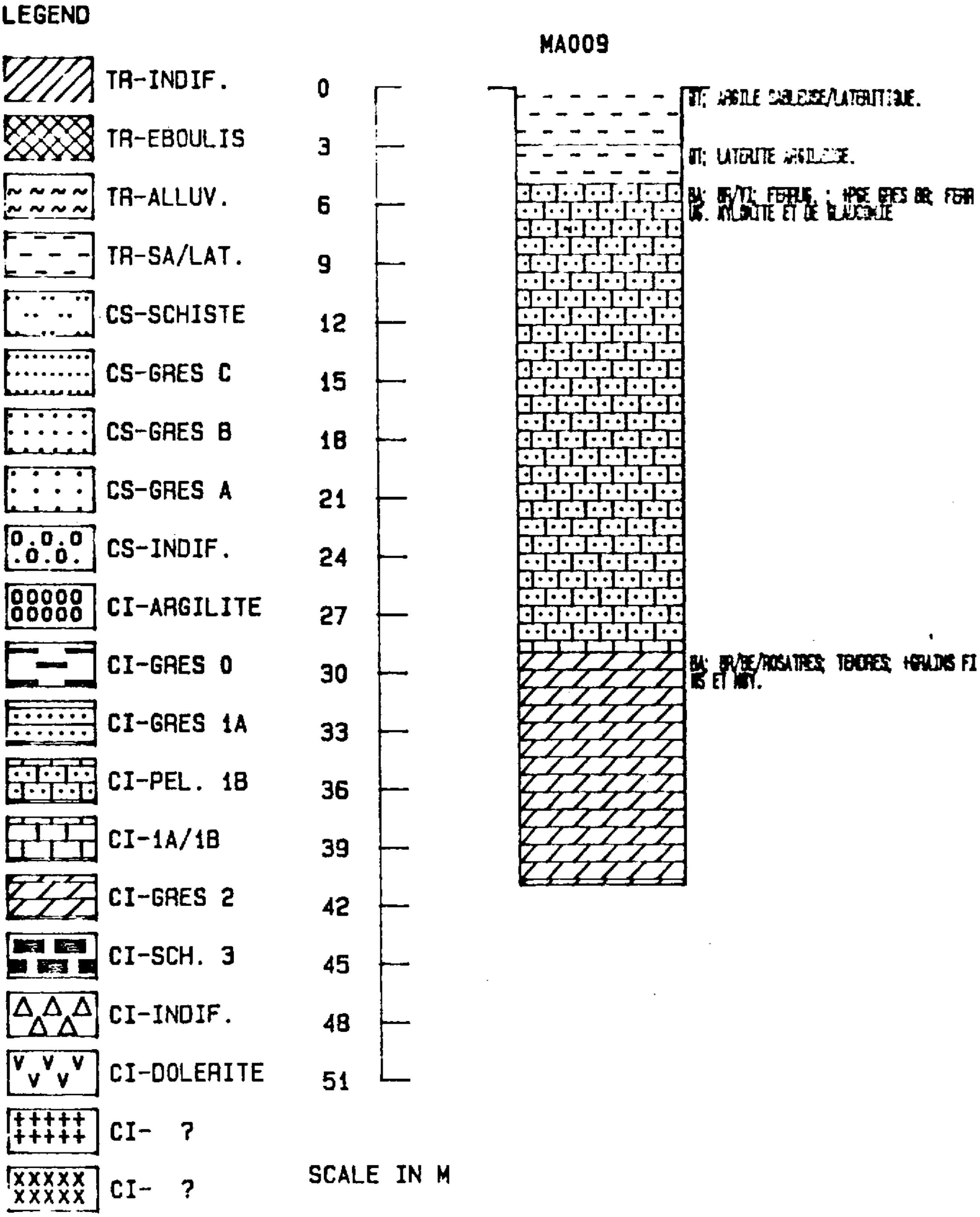
▽ STATIC WATER LEVEL

PROJECT: OMVS/USAID
FILE: 825-0958
LOCATION: BAFOULABE 2A

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA009



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA009

WELL LITHOLOGY

PROJECT:OMVS/USAID
LOCATION:BAFOULABE 2A
[illegible]
DRILLER:DNHE

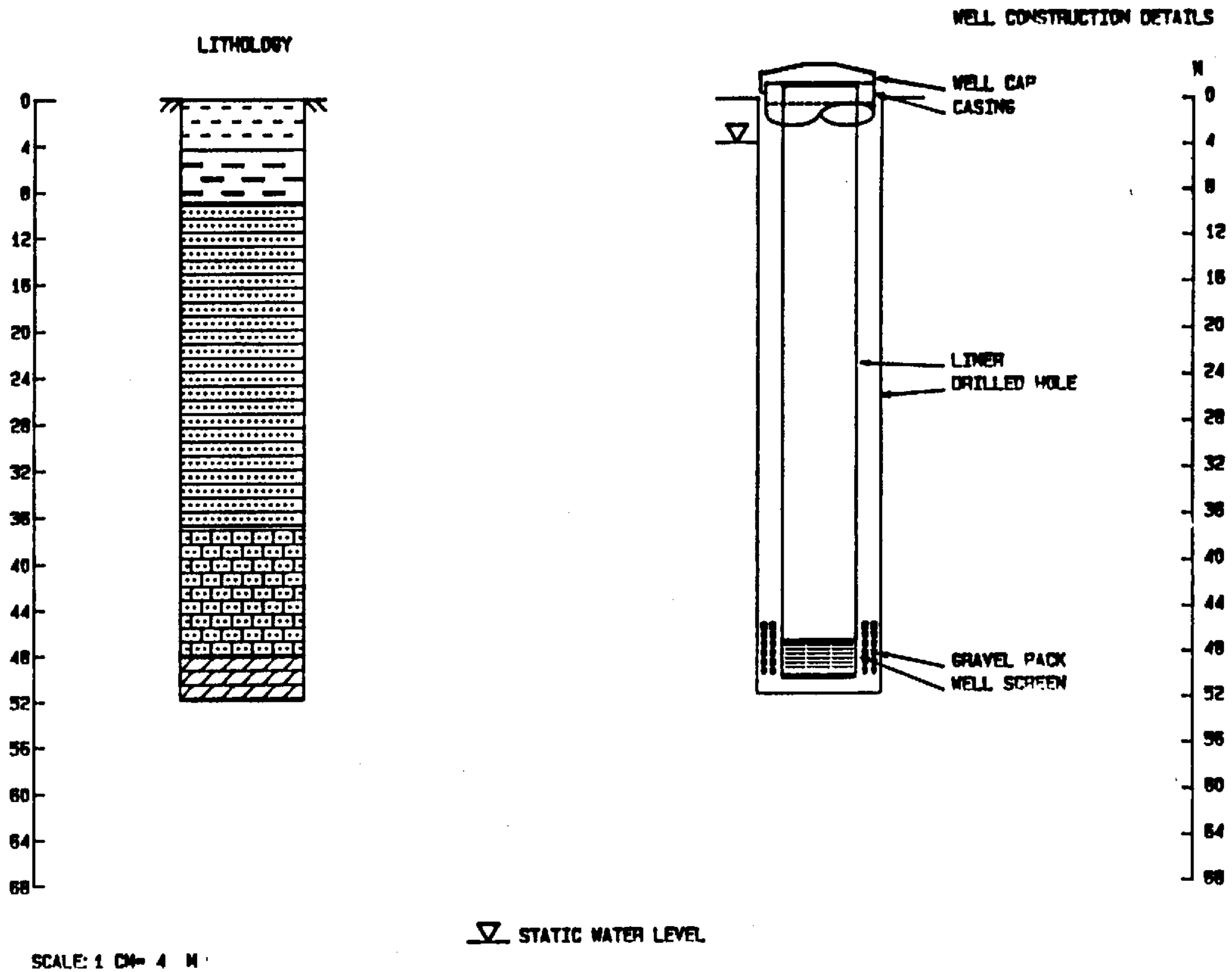
FILE NO.:625-0956
ELEVATION (M): 161.145
[illegible]
TYPE OF RIG:MARTEAU FOND DU TROU

DEPTH (M)		ELEVATION (M)		THICKNESS (M)	LITHOLOGY
FROM	TO	FROM	TO		
0.00	3.00	161.15	158.15	3.00	TR-SA/LAT.,QT; ARGILE S
3.00	5.00	158.15	156.15	2.00	TR-SA/LAT.,QT; LATERITE
5.00	29.00	156.15	132.15	24.00	CI-PEL. 1B,BA; BR/V1; F
29.00	41.00	132.15	120.15	12.00	CI-GRES 2,IA; BR/BE/ROS

USAID/DAKAR/SENEGAL

LEGEND

- TR-INDIF.
- TR-EBOULIS
- TR-ALLUV.
- TR-SA/LAT.
- CS-SCHISTE
- CS-GRES C
- CS-GRES B
- CS-GRES A
- CS-INDIF.
- CI-ARGILITE
- CI-GRES 0
- CI-GRES 1A
- CI-PEL. 1B
- CI-1A/1B
- CI-GRES 2
- CI-SCH. 3
- CI-INDIF.
- CI-DOLERITE
- CI- ?
- CI- ?

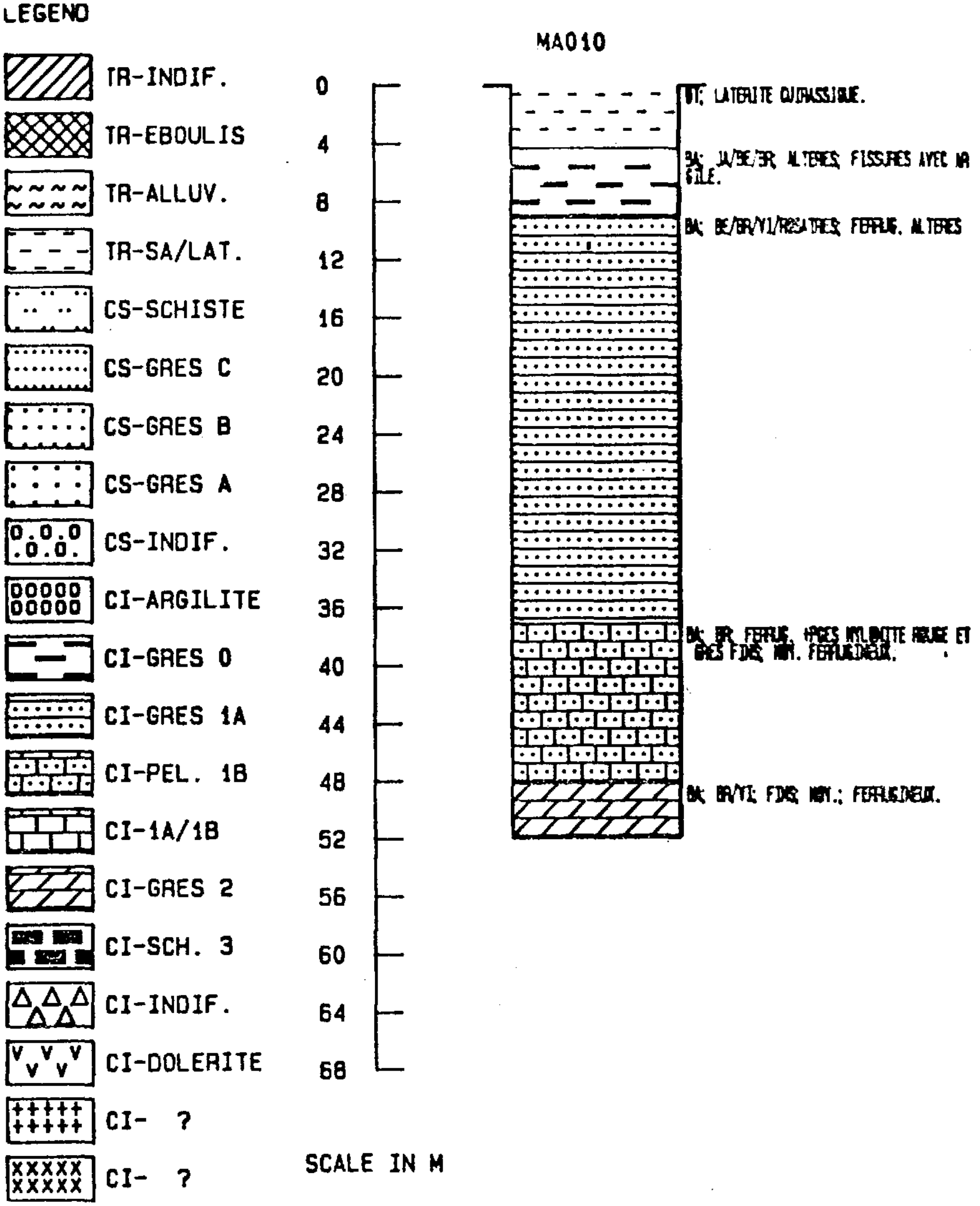


PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA010



PROJECT: OMVS//USAID FILE: 625-0958 LOCATION: BAFOULABE 2A	LITHOLOGY
USAID/DAKAR/SENEGAL	FIGURE MA010

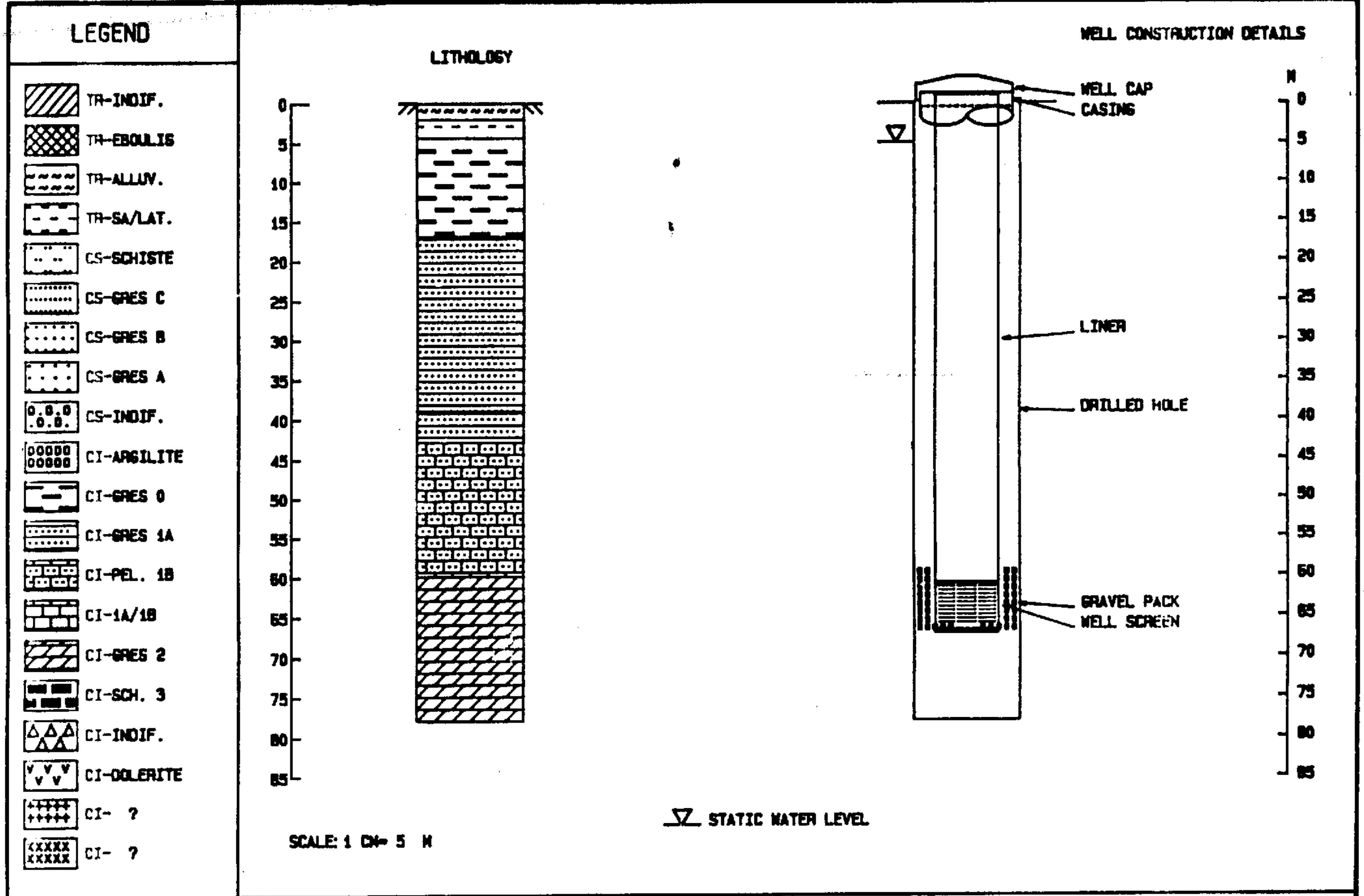
WELL LITHOLOGY

PROJECT:LAVS/USAID
LOCATION:BAFOULABE 2A
WELL NO.:MA010
DRILLER:[illegible]

FILE NO.:625-0958
ELEVATION (M): 162.03
DATE DRILLED:05/03/88
[illegible] RIG:[illegible]

DEPTH (M)		ELEVATION (M)		THICKNESS (M)	LITHOLOGY
FROM	TO	FROM	TO		
0.00	4.40	162.03	157.63	4.40	TR-SA/LAT.,QT; LATERITE
4.40	9.00	157.63	153.03	4.60	CI-GRES 0,BA; JA/BE/BR;
9.00	37.20	153.03	124.83	28.20	CI-GRES 1A,BA; BE/BR/VI
37.20	48.20	124.83	113.83	11.00	CI-PEL. 1B,BA; BR; FERR
48.20	52.00	113.83	110.03	3.80	CI-GRES 2,BA; BR/VI; FI

USAID/DAKAR/SENEGAL

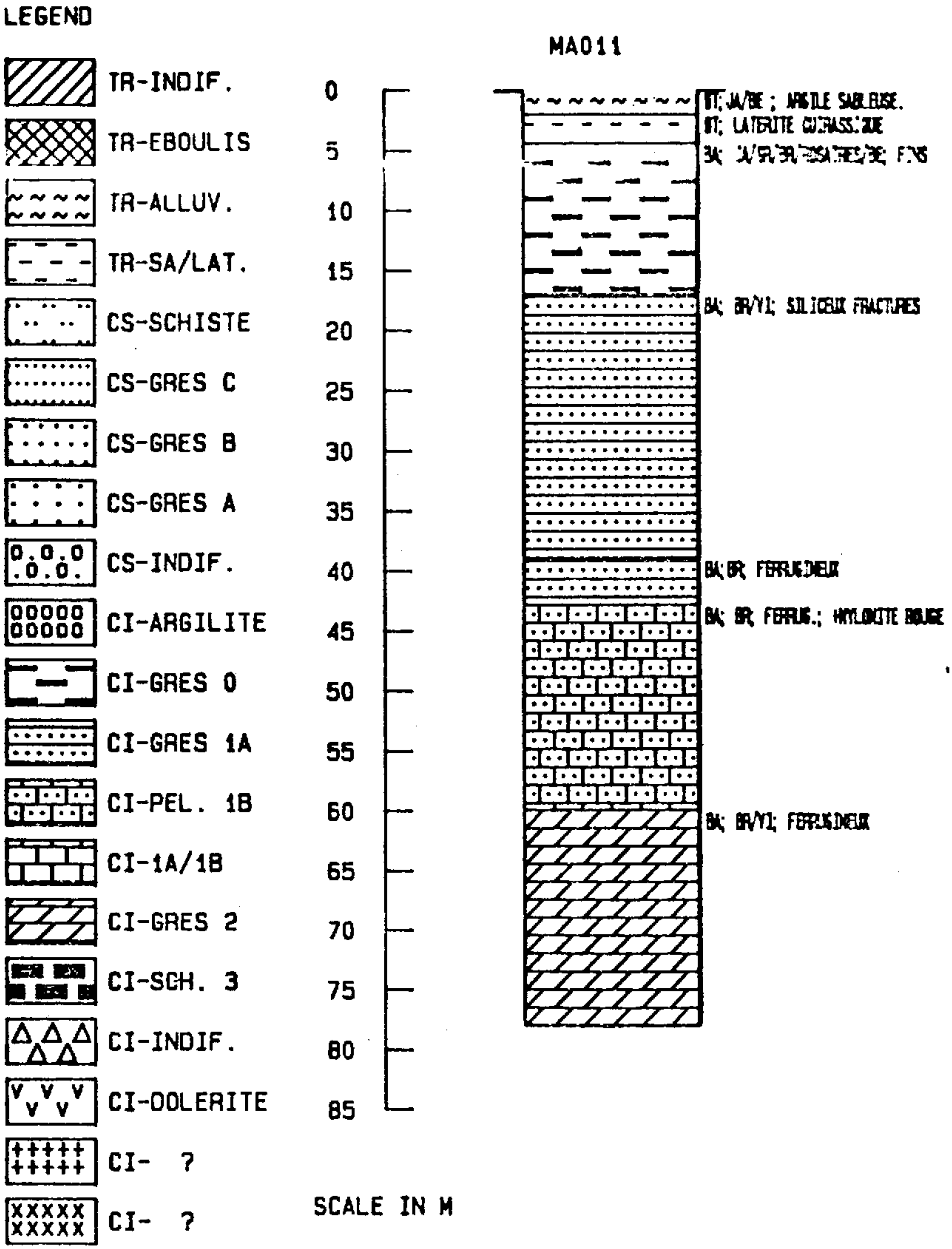


PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

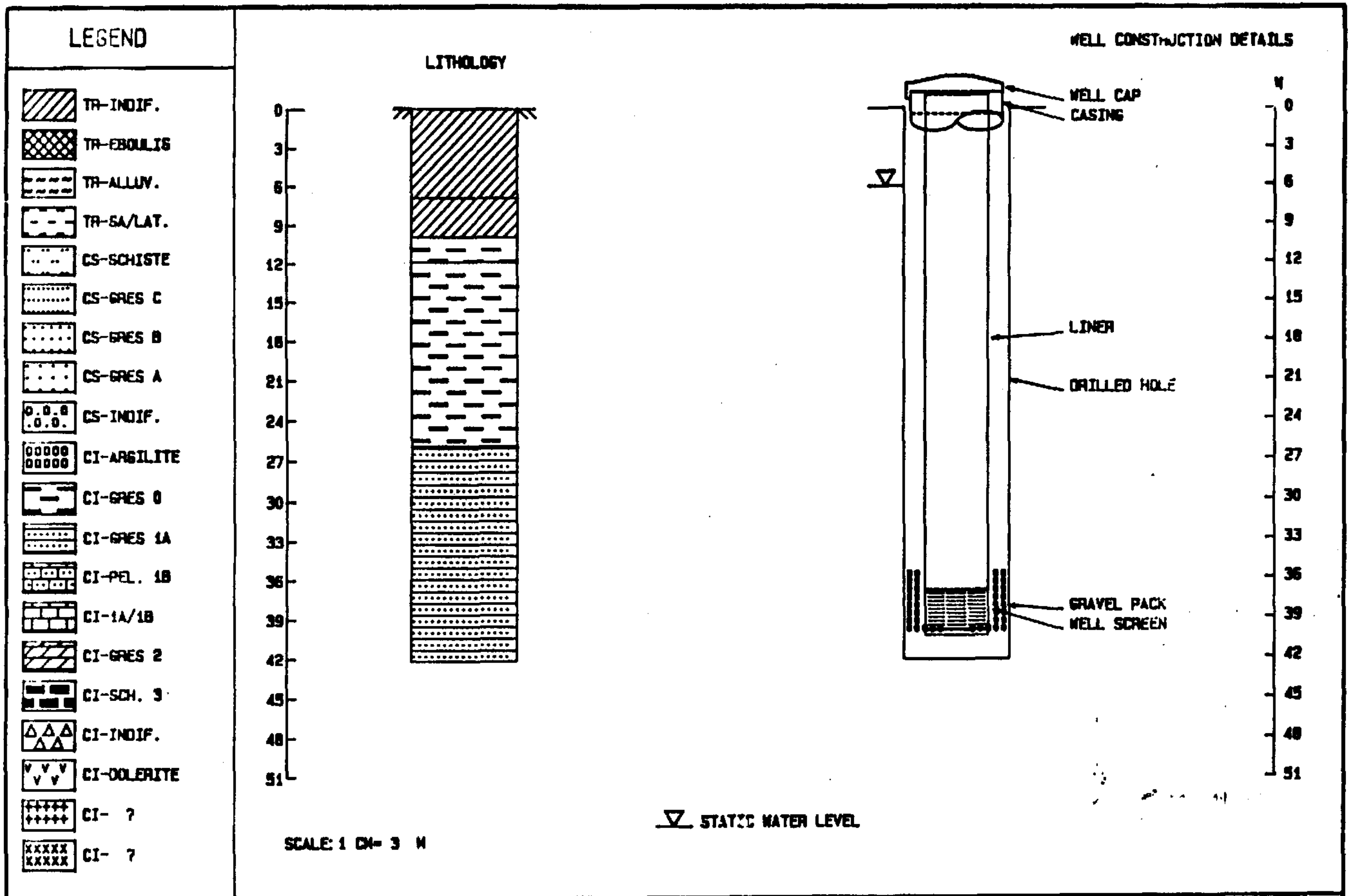
COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA011



PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 2A	LITHOLOGY
USAID/DAKAR/SENEGAL	FIGURE MA011

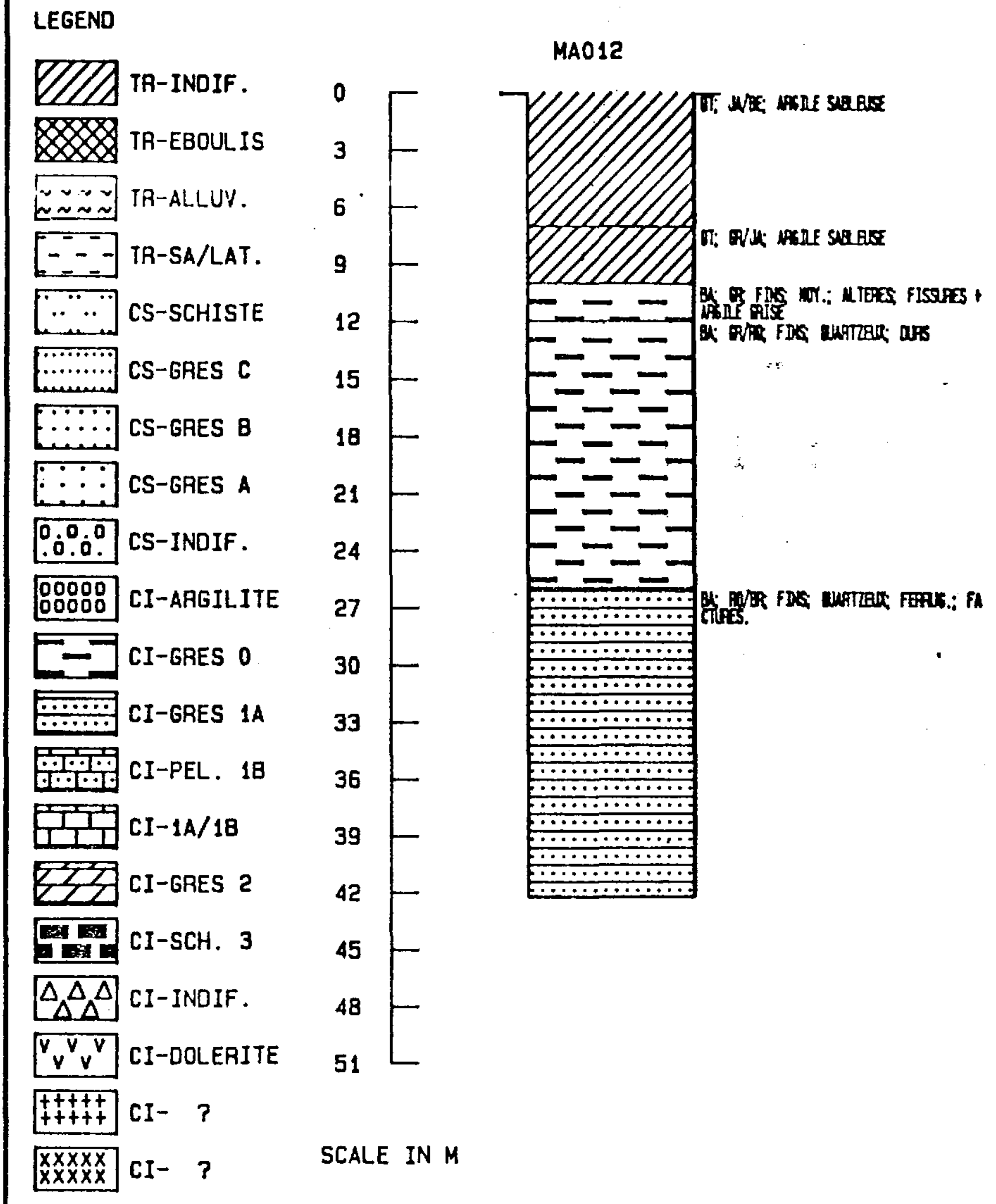


PROJECT: OMVS/USAID
FILE: 825-0958
LOCATION: BAFOULABE 2A

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA012



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA012

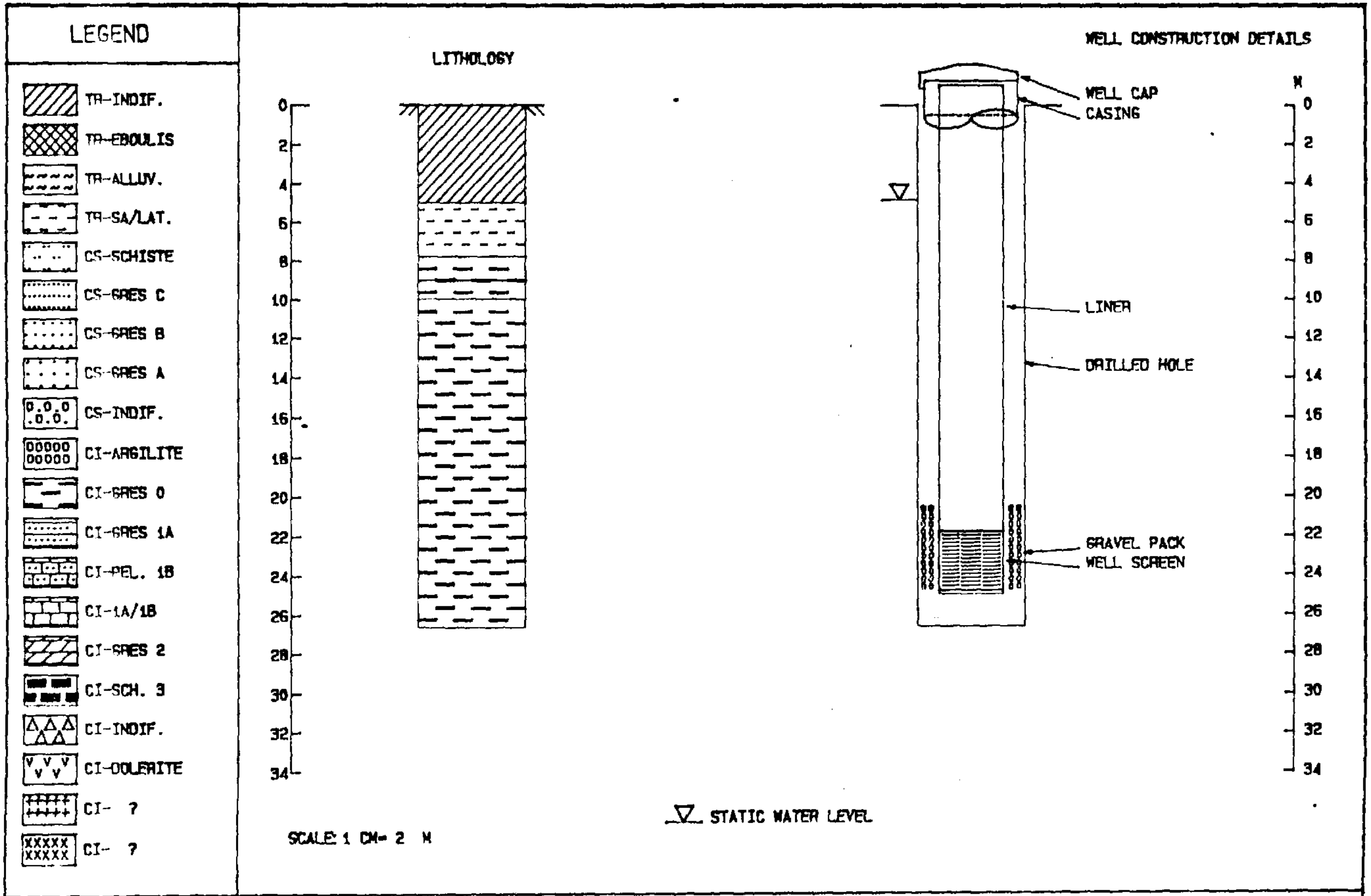
WELL LITHOLOGY

PROJECT: OMVS/USAID FILE NO.: 625-0958
LOCATION: BAFOULABE 2A

WELL # MA012 ELEVATION (m): 161.293

DEPTH (m)		THICKNESS (m)	LITHOLOGY
FROM	TO		
0.000	7.000	7.000	TR-INDIF.,QT; JA/BE; AR
7.000	10.000	3.000	TR-INDIF.,QT; GR/JA; AR
10.000	12.000	2.000	CI-GRES O,BA; GR; FINS;
12.000	26.000	14.000	CI-GRES O,BA; GR/RO; FI
26.000	42.250	16.250	CI-GRES 1A,BA; RO/BR; F

USAID/DAKAR/SENEGAL



PROJECT: ONVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA013

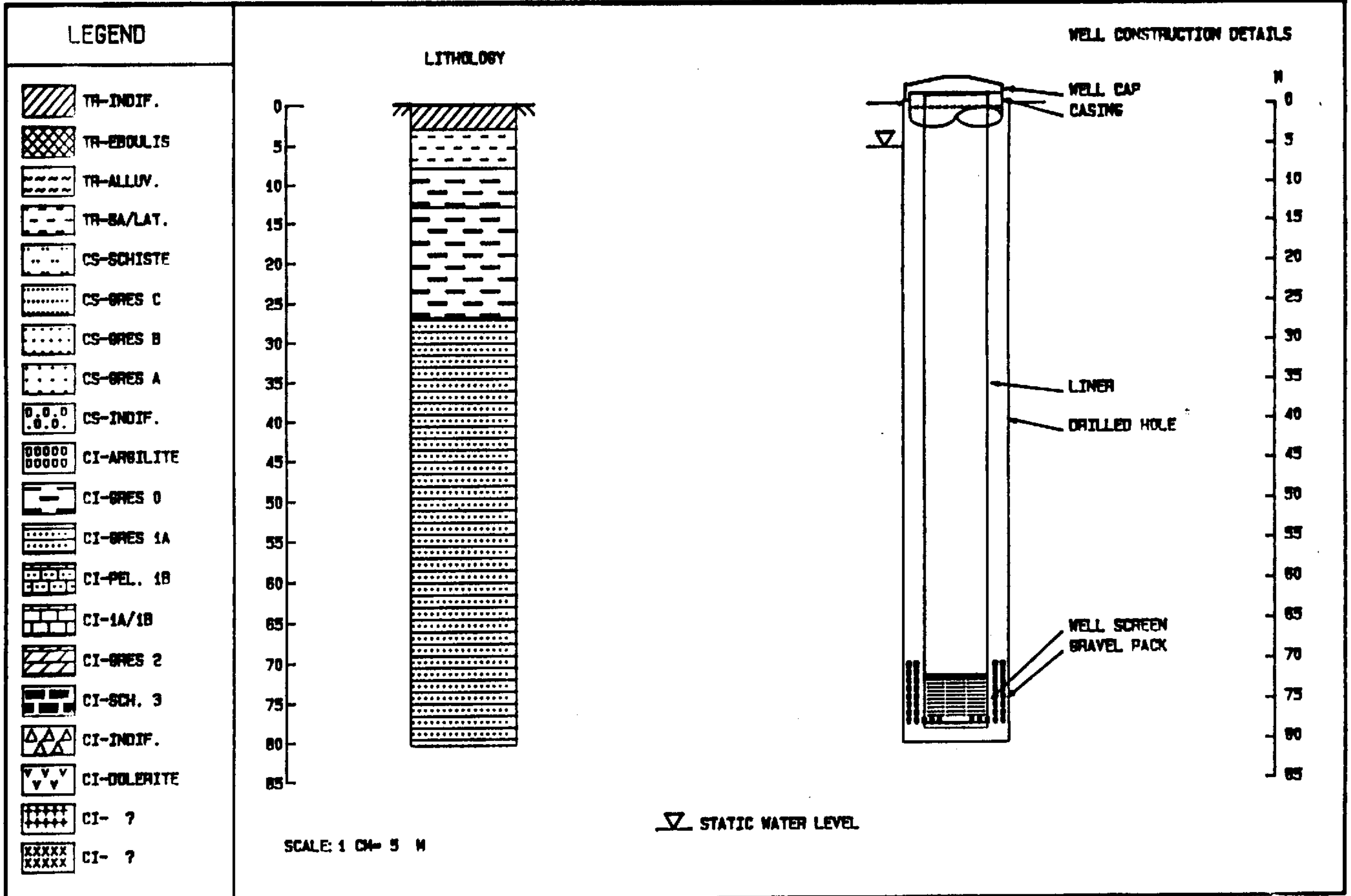
WELL LITHOLOGY

PROJECT:OMVS/USAID
LOCATION:BAFOULABE 3A
WELL NO.:MA013
DRILLER:DNHE

FILE NO.:625-0958
ELEVATION (M): 161.167
DATE DRILLED:07/04/88
TYPE OF RIG:MARTEAU FOND DU TROU

DEPTH (M)		ELEVATION (M)		THICKNESS (M)	LITHOLOGY
FROM	TO	FROM	TO		
0.00	5.00	161.17	156.17	5.00	TR-INDIF.,QT; JA/BLANCH
5.00	7.77	156.17	153.40	2.77	TR-SA/LAT.,QT; LATERITE
7.77	9.00	153.40	152.17	1.23	CI-GRES O,BA; QUARTZIOU
9.00	10.00	152.17	151.17	1.00	CI-GRES O,BA; GR; FINS;
10.00	26.63	151.17	134.54	16.63	CI-GRES O,BA; ROSATRES;

USAID/DAKAR/SENEGAL

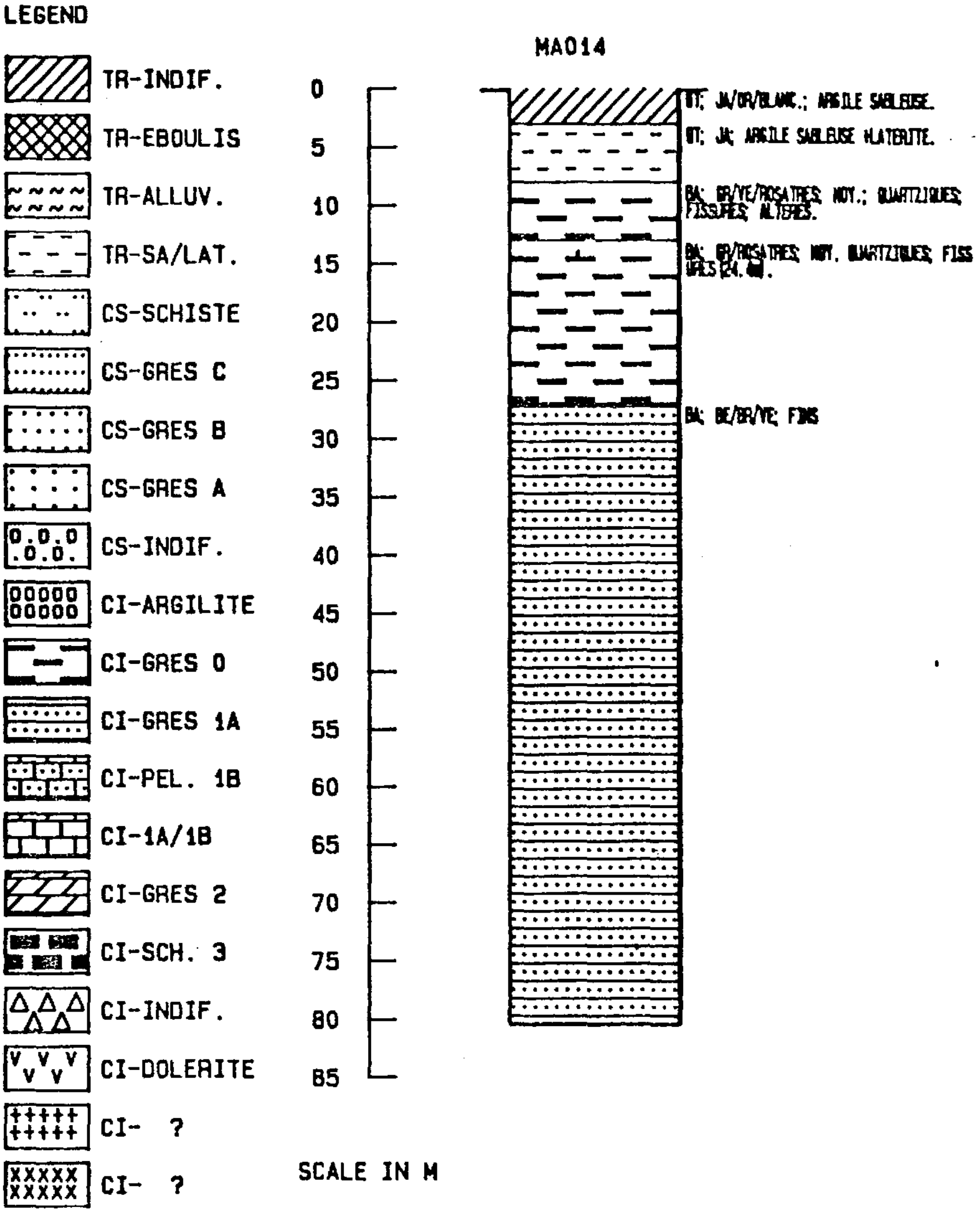


PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA014



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA014

WELL LITHOLOGY

PROJECT: OMVS/USAID
LOCATION: BAFOULABE 2A

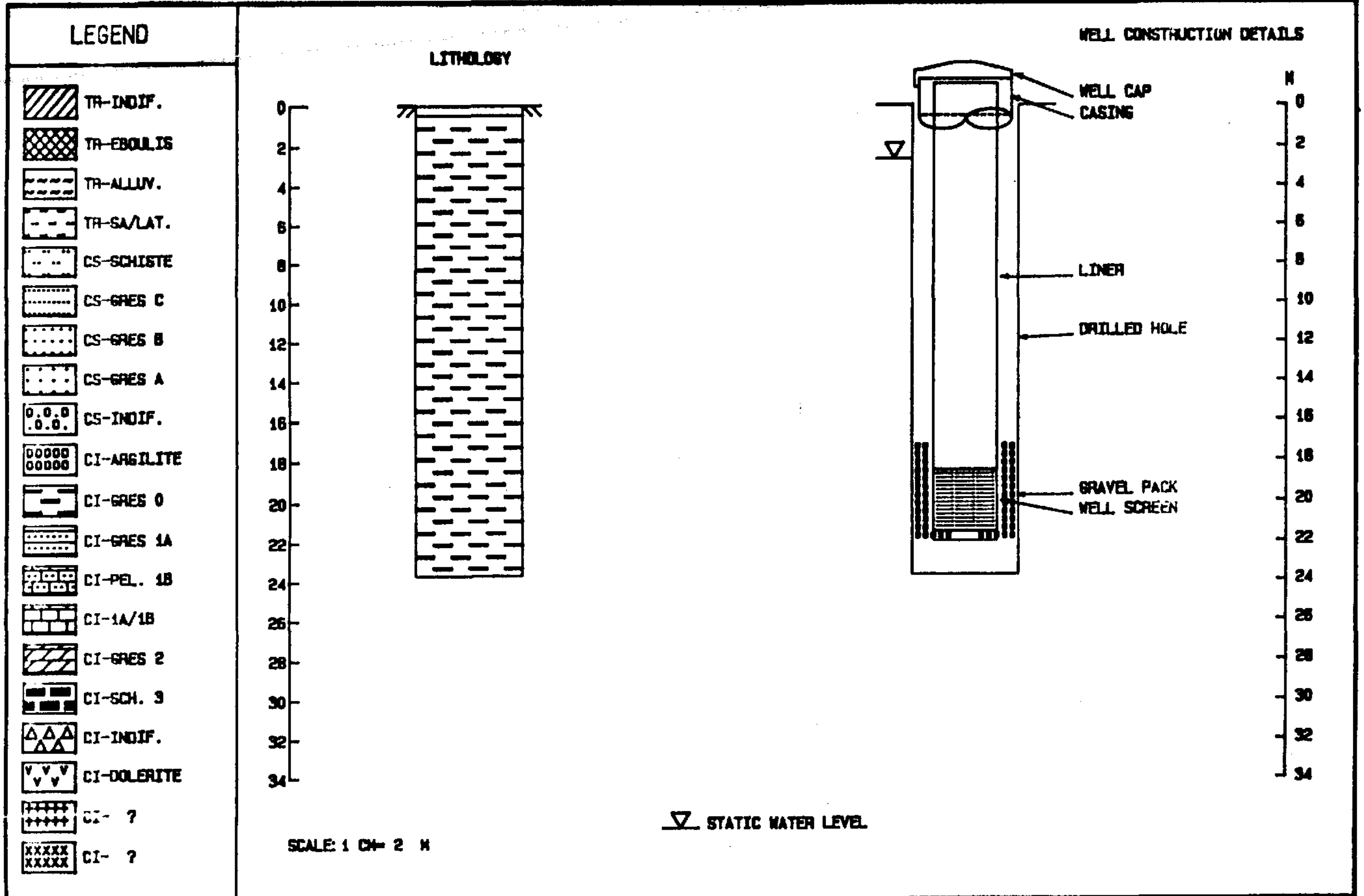
FILE NO.: 625-0958

WELL # MA014

ELEVATION (m): 161.178

DEPTH (m)		THICKNESS (m)	LITHOLOGY
FROM	TO		
0.000	3.000	3.000	TR-INDIF.,QT; JA/OR/BLA
3.000	8.000	5.000	TR-SA/LAT.,QT; JA; ARGI
8.000	13.000	5.000	CI-GRES 0,BA; GR/VE/ROS
13.000	27.000	14.000	CI-GRES 0,BA; GR/ROSATR
27.000	80.480	53.480	CI-GRES 1A,BA; BE/BR/VE

USAID/DAKAR/SENEGAL

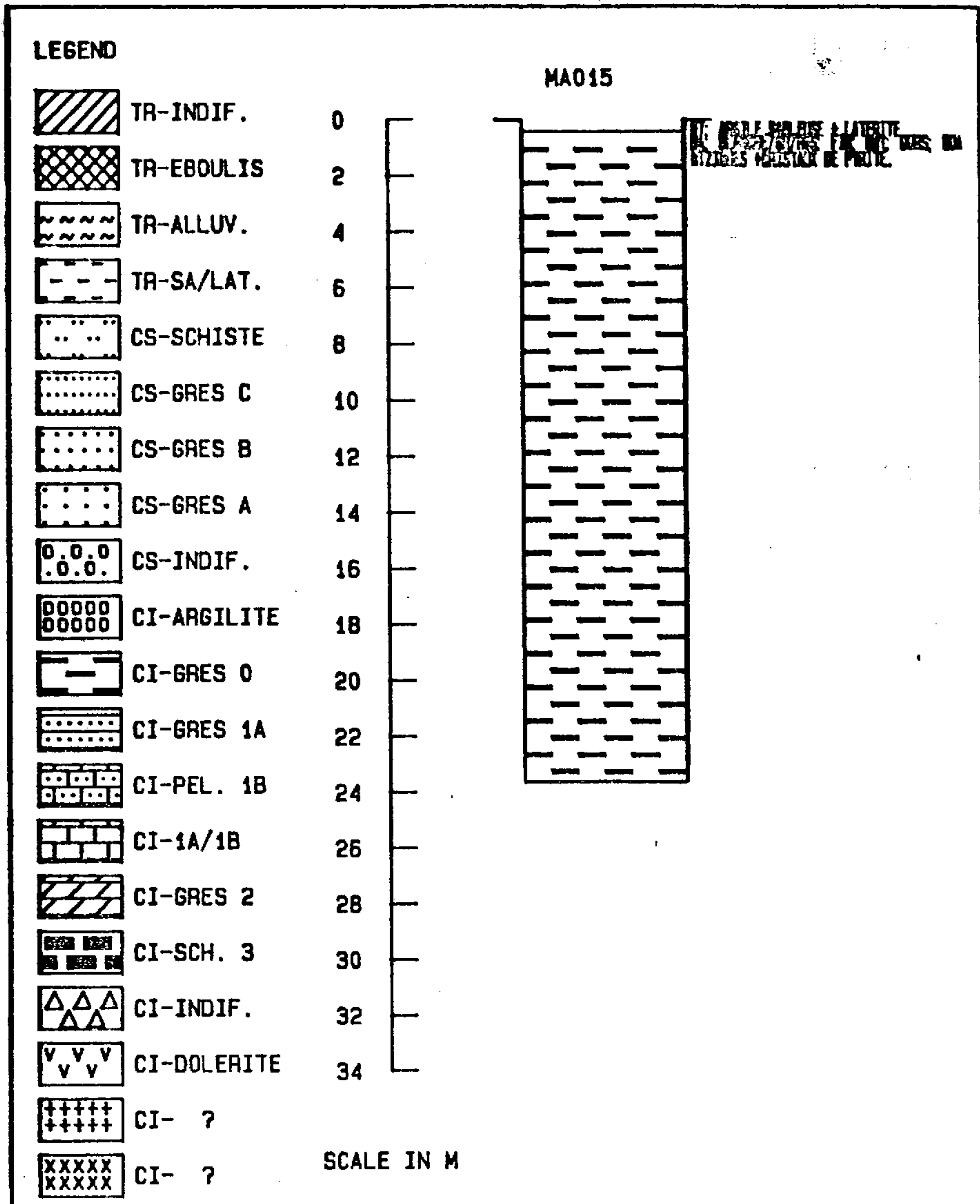


PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 1B

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA015



PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 1B	LITHOLOGY
USAID/DAKAR/SENEGAL	FIGURE MA015

WELL LITHOLOGY

PROJECT: OMVS/USAID
LOCATION: BAFOULABE 1B

FILE NO.: 325-0958

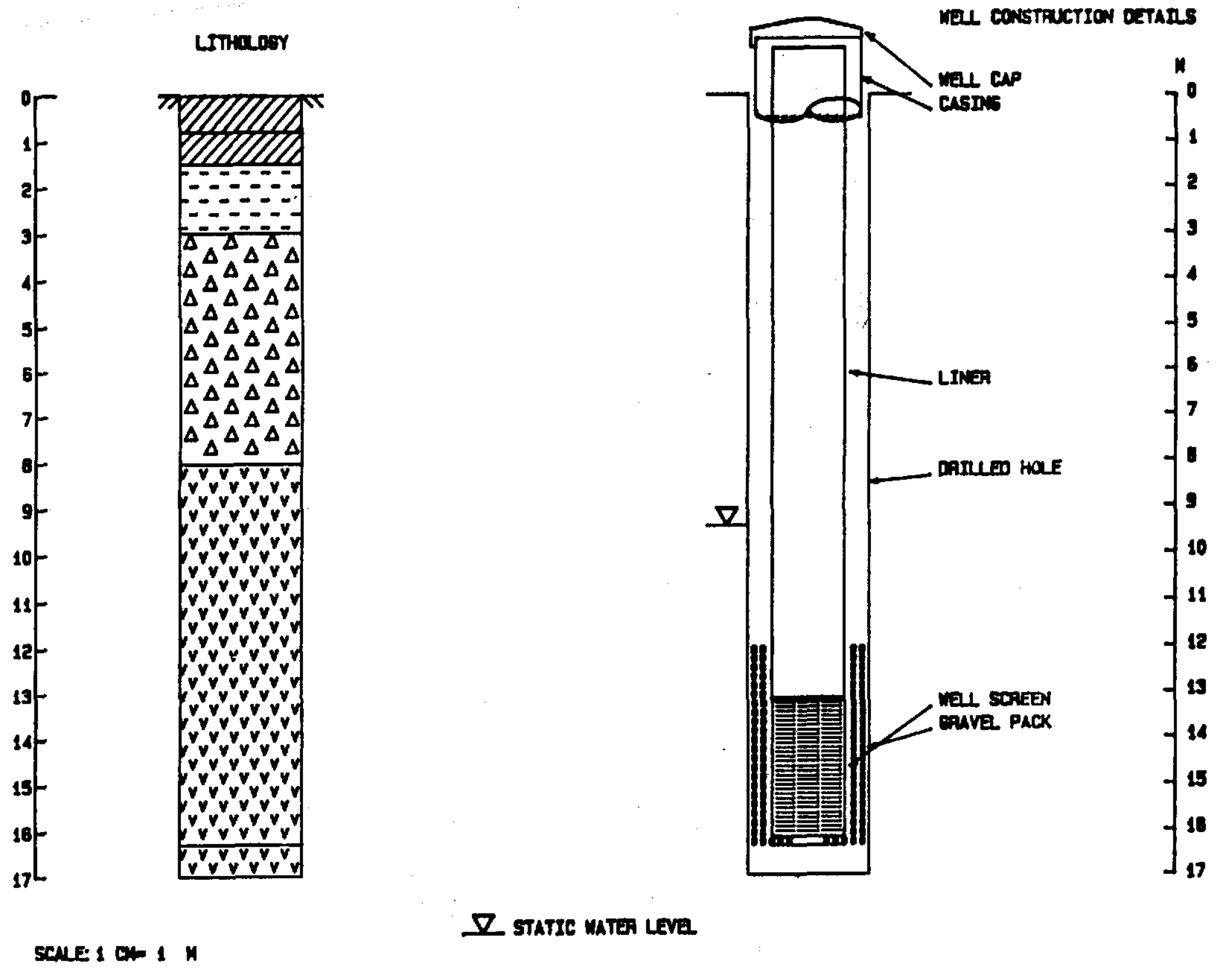
WELL # MA015

ELEVATION (m): 152.366

DEPTH (m)		THICKNESS (m)	LITHOLOGY
FROM	TO		
0.000	0.450	0.450	TR-SA/LAT.,GT; ARGILE S
0.450	23.700	23.250	01-GRES 0,3A; BLANCHE/G

LEGEND

- TR-INDIF.
- TR-EBOULIS
- TR-ALLUV.
- TR-SA/LAT.
- CS-SCHISTE
- CS-GRES C
- CS-GRES B
- CS-GRES A
- CS-INDIF.
- CI-ARGILITE
- CI-GRES 0
- CI-GRES 1A
- CI-PEL. 1B
- CI-1A/1B
- CI-GRES 2
- CI-SCH. 3
- CI-INDIF.
- CI-DOLERITE
- CI- ?
- CI- ?

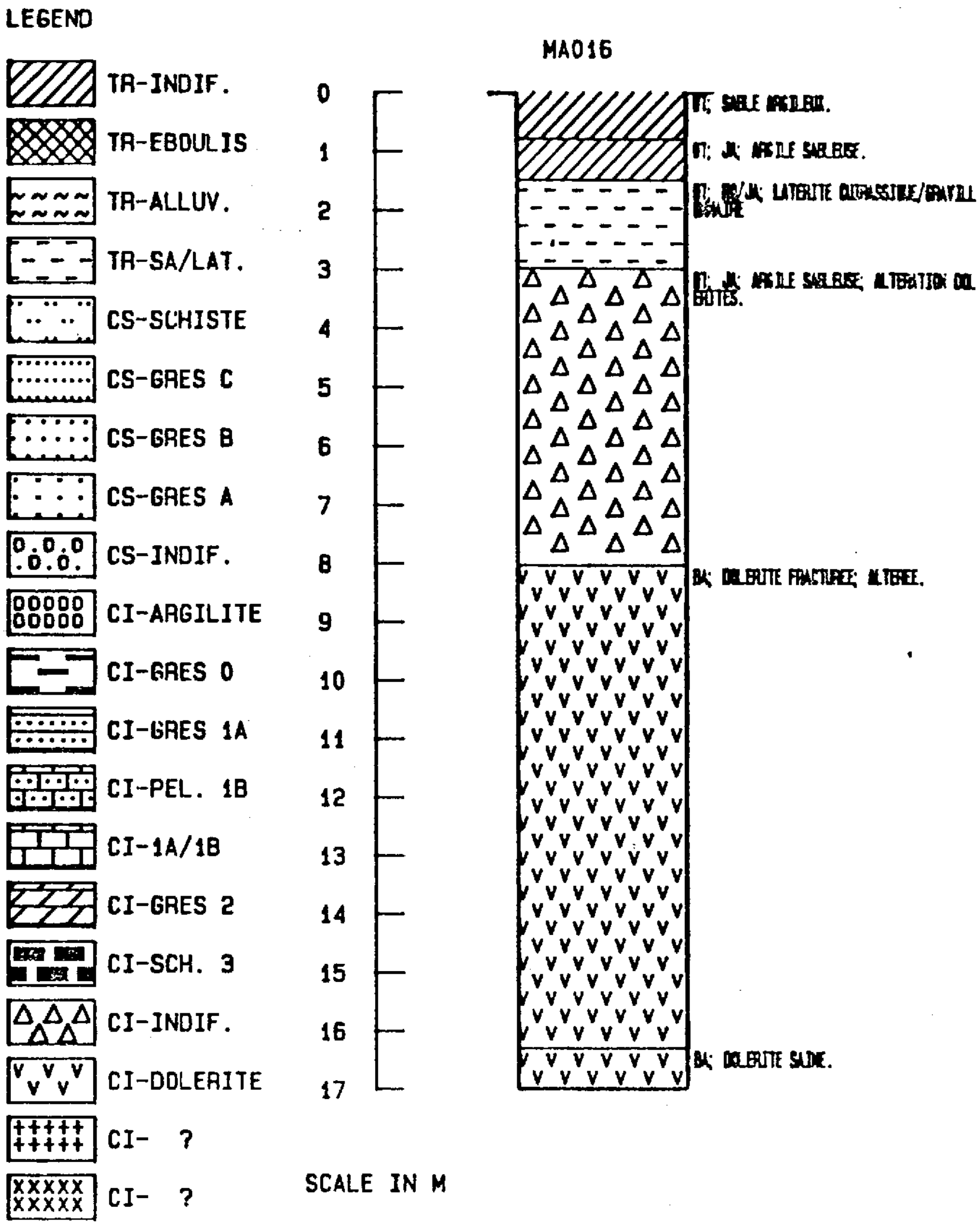


PROJECT: DNVS/USAID
FILE: 825-0958
LOCATION: BAFOULABE 18

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA016



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 1B

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA016

WELL LITHOLOGY

PROJECT: OMVS/USAID FILE NO.: 625-0958
LOCATION: BAFOULABE 1B

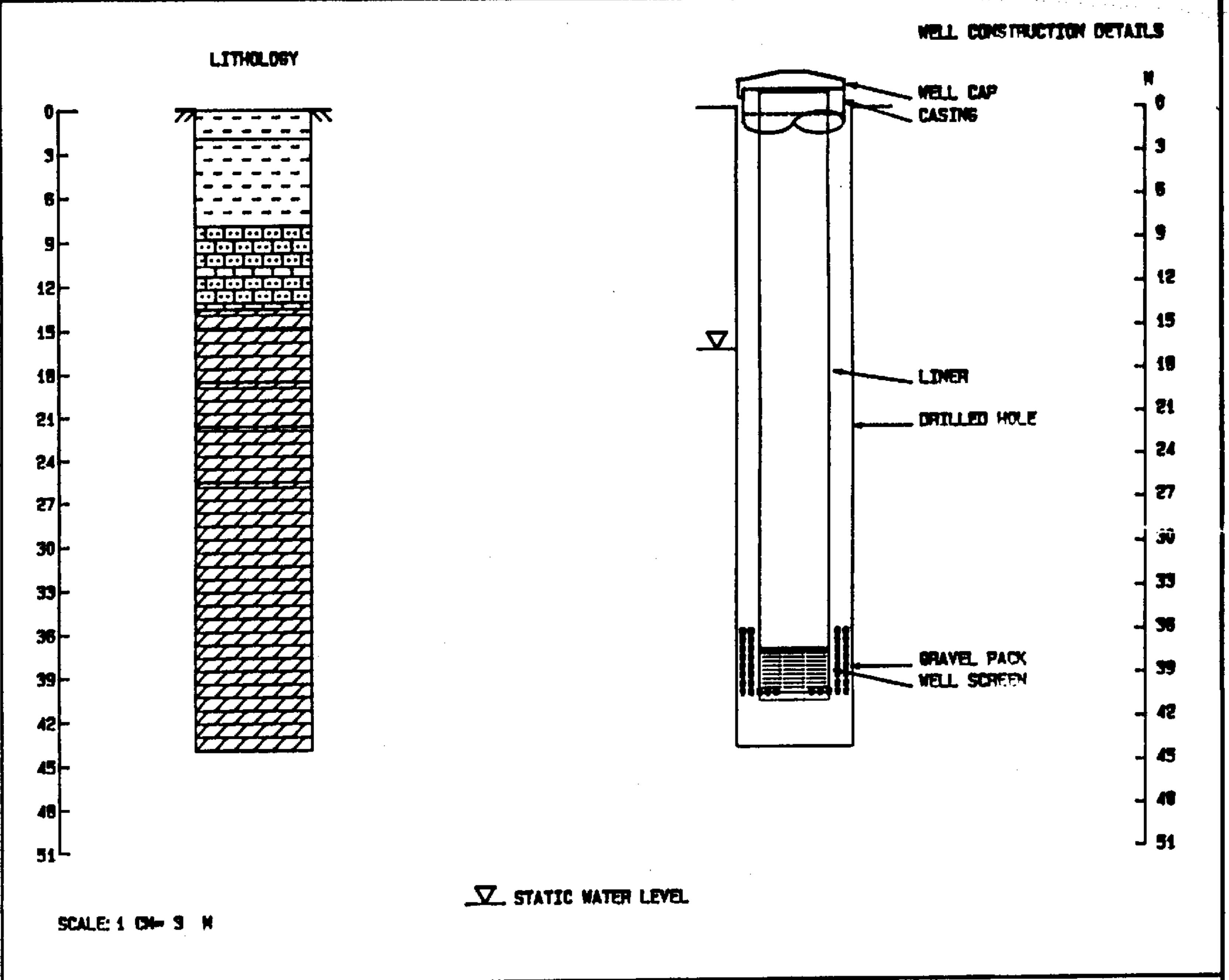
WELL # MA016 ELEVATION (m): [illegible]

DEPTH (m) FROM	DEPTH (m) TO	THICKNESS (m)	LITHOLOGY
0.000	0.800	0.800	TR-INDIF.,GT; SABLE ARG
0.800	1.500	0.700	TR-INDIF.,GT; JA; ARGIL
1.500	3.000	1.500	TR-SA/LAT.,CT; SO/JA; L
3.000	8.050	5.050	CI-INDIF.,CT; JA; ARGIL
8.050	16.300	8.250	CI-DOLERITE,BR; DOLERIT
16.300	17.000	0.700	CI-DOLERITE,BR; DOLERIT

USAID/DAKAR, SENEGAL

LEGEND

- TR-INDIF.
- TR-EBOULIS
- TR-ALLUV.
- TR-SA/LAT.
- CS-SCHISTE
- CS-GRES C
- CS-GRES B
- CS-GRES A
- CS-INDIF.
- CI-ARGILITE
- CI-GRES 0
- CI-GRES 1A
- CI-PEL. 1B
- CI-1A/1B
- CI-GRES 2
- CI-SCH. 3
- CI-INDIF.
- CI-DOLERITE
- CI- ?
- CI- ?

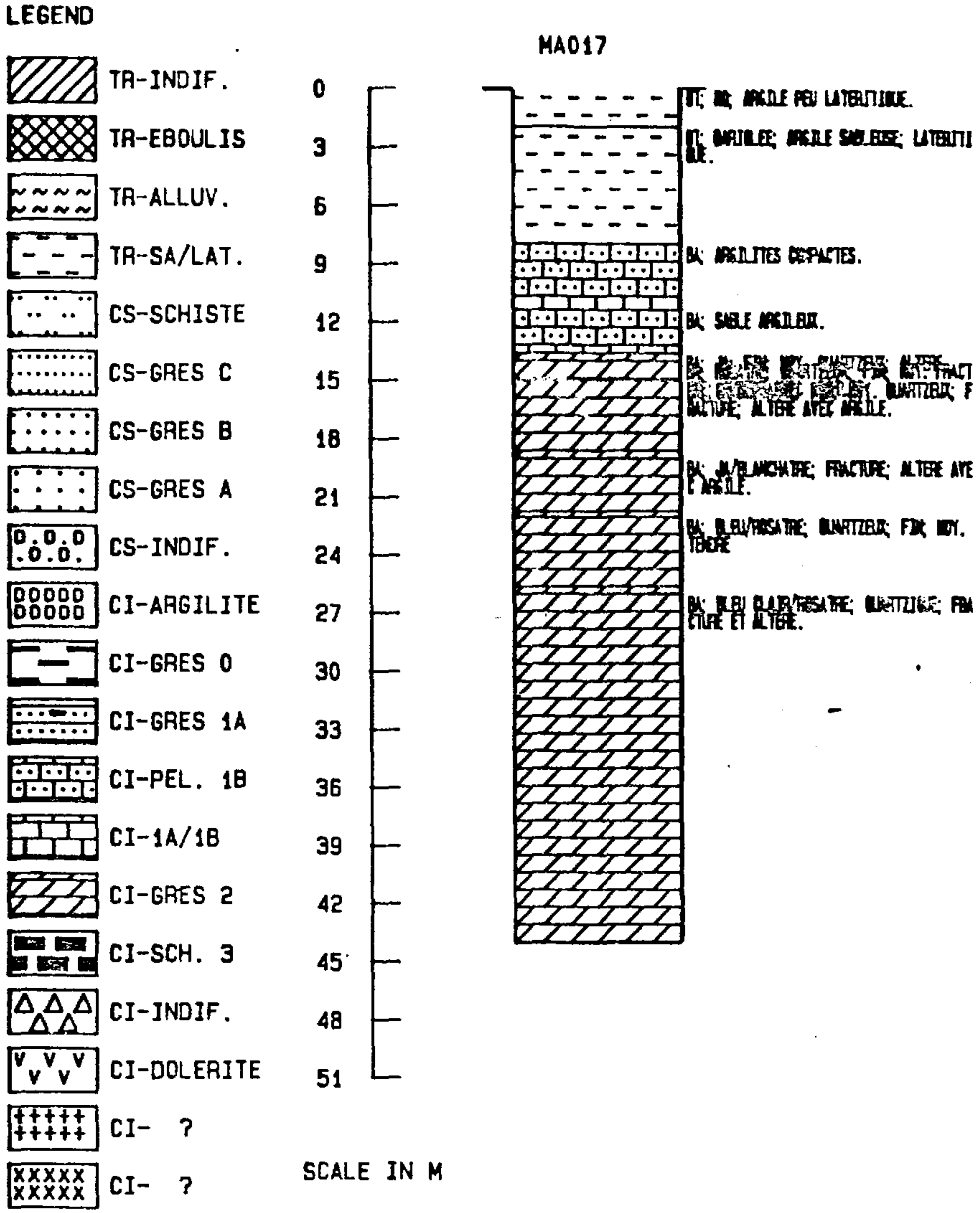


PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFC"LABE 1B

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA017



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 1B

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA017

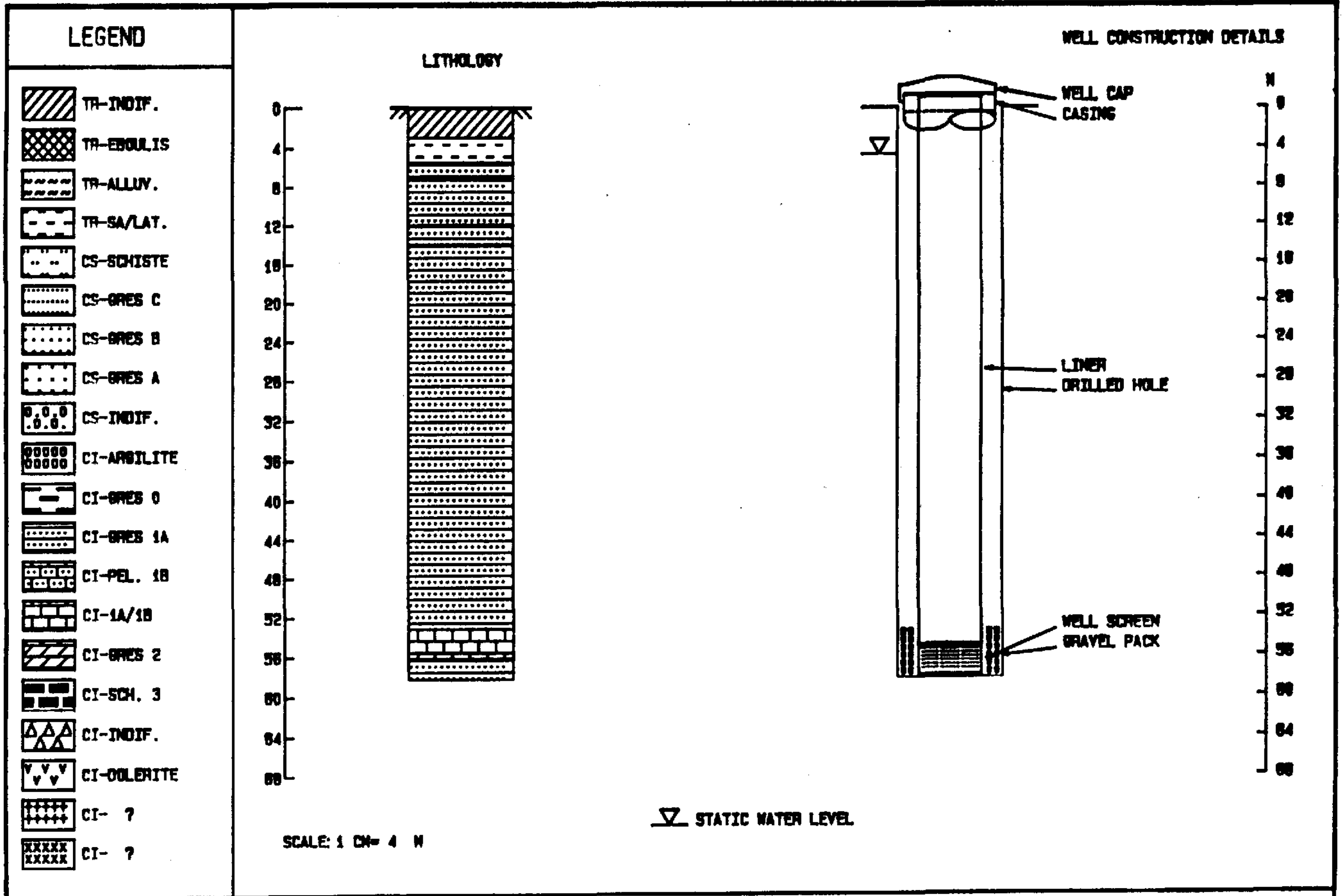
WELL LITHOLOGY

PROJECT: OMVS/USAID FILE NO.: 625-0958
LOCATION: BAFOULABE 1B

WELL # MA017 ELEVATION (m): 133.172

DEPTH (m) FROM	DEPTH (m) TO	THICKNESS (m)	LITHOLOGY
0.000	2.000	2.000	TR-SA/LAT.,QT; RO; ARGI
2.000	8.000	6.000	TR-SA/LAT.,QT; BARIOLEE
8.000	11.400	3.400	CI-PEL. 1B,BA; ARGILITE
11.400	13.620	2.220	CI-PEL. 1B,BA; SABLE AR
13.620	14.000	0.380	CI-GRES 2,BA; JA; FIN;
14.000	15.000	1.000	CI-GRES 2,BA; ROSATRE;
15.000	19.000	4.000	CI-GRES 2,BA; GR/BLEUAT
19.000	22.000	3.000	CI-GRES 2,BA; JA/BLANCH
22.000	26.000	4.000	CI-GRES 2,BA; BLEU/ROSA
26.000	44.050	18.050	CI-GRES 2,BA; BLEU CLAI

USAID/DAKAR/SENEGAL

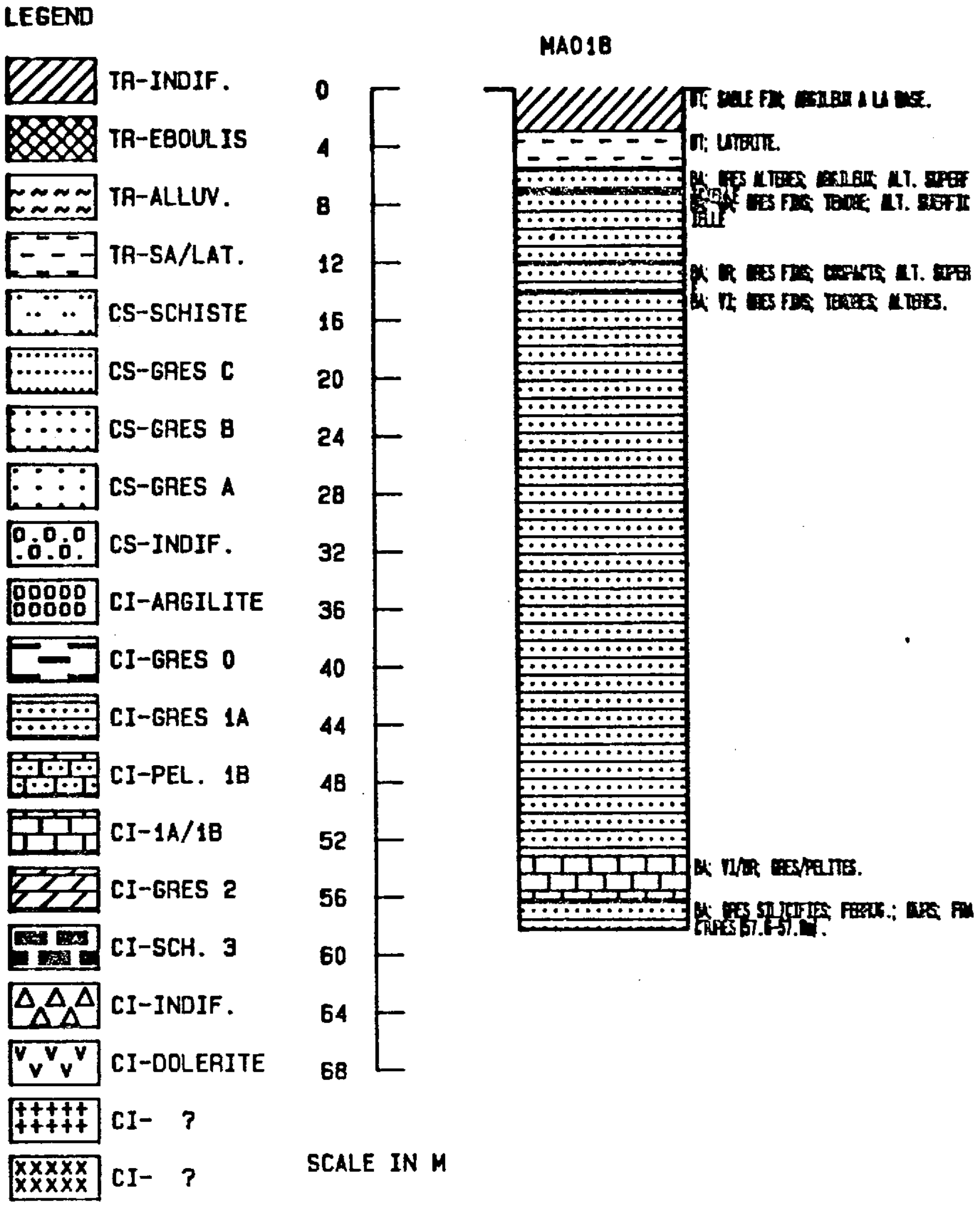


PROJECT: OMVS/USAID
FILE: 825-0958
LOCATION: BAFOULABE 2C

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA018

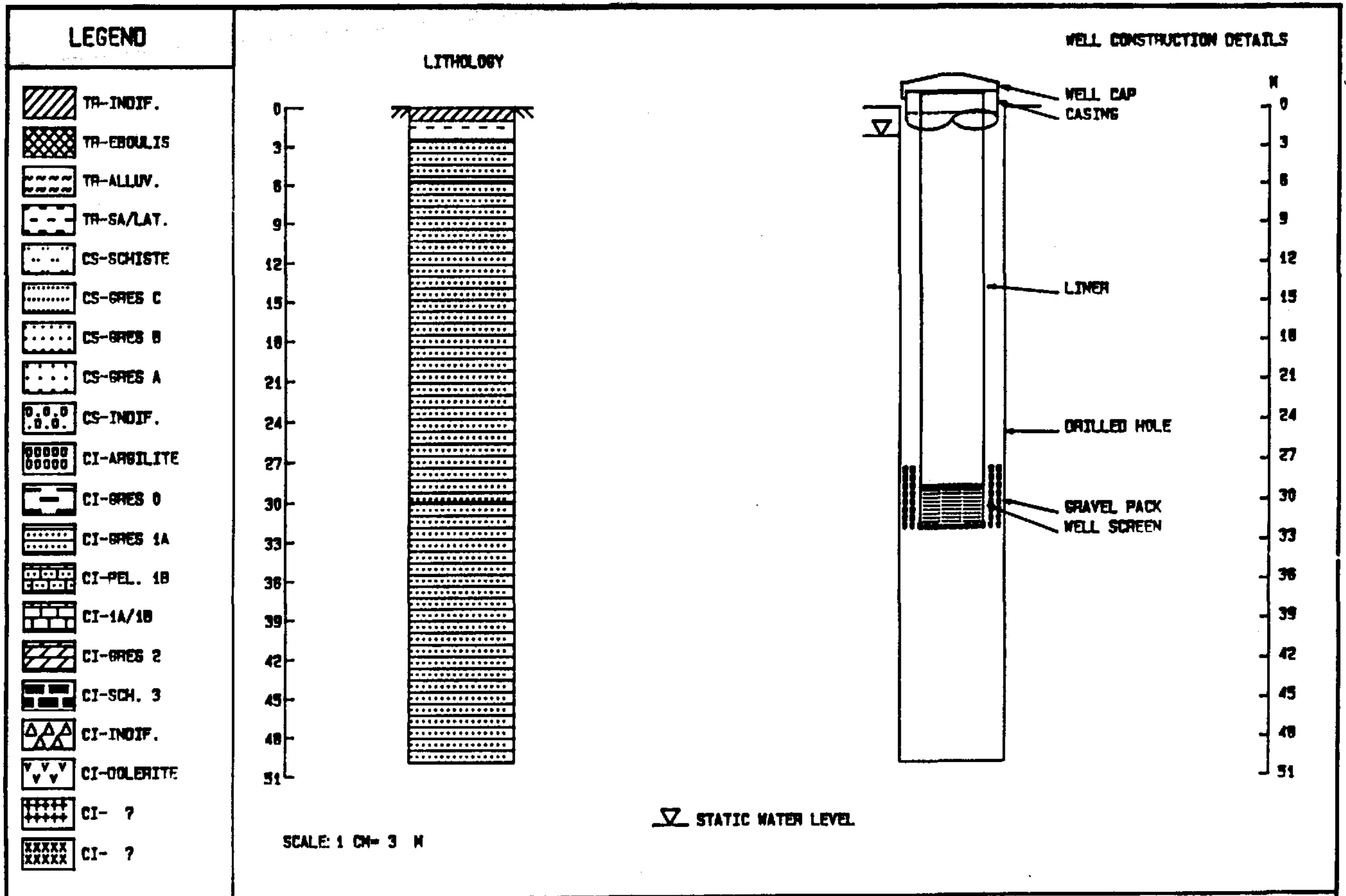


PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2C

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA01B

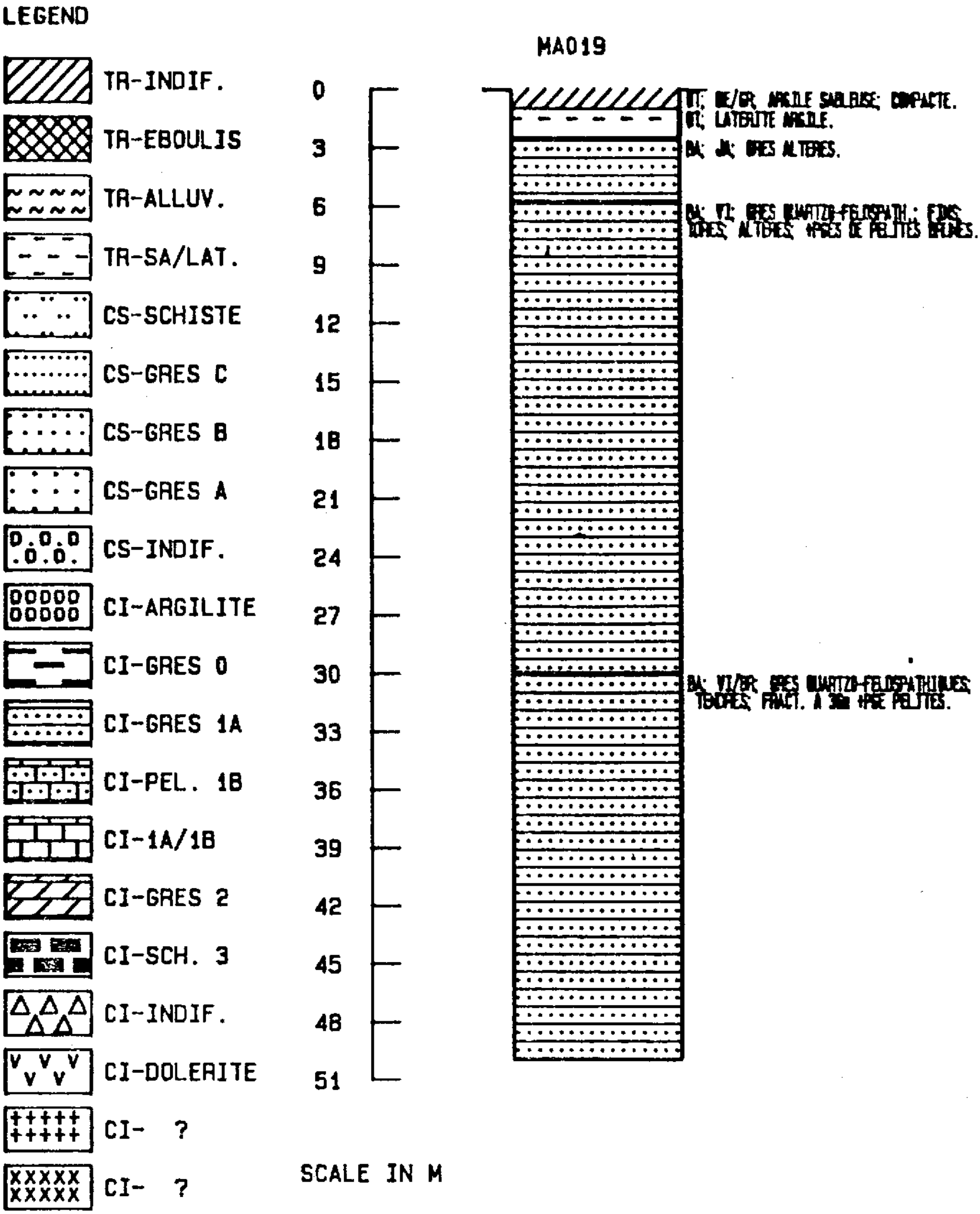


PROJECT: OMVS/USAID
FILE: 825-0958
LOCATION: BAFOULABE 2C

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA019



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2C

LITHOLOGY

USAID/DAKAR/SENEGAL

FIGURE MA019

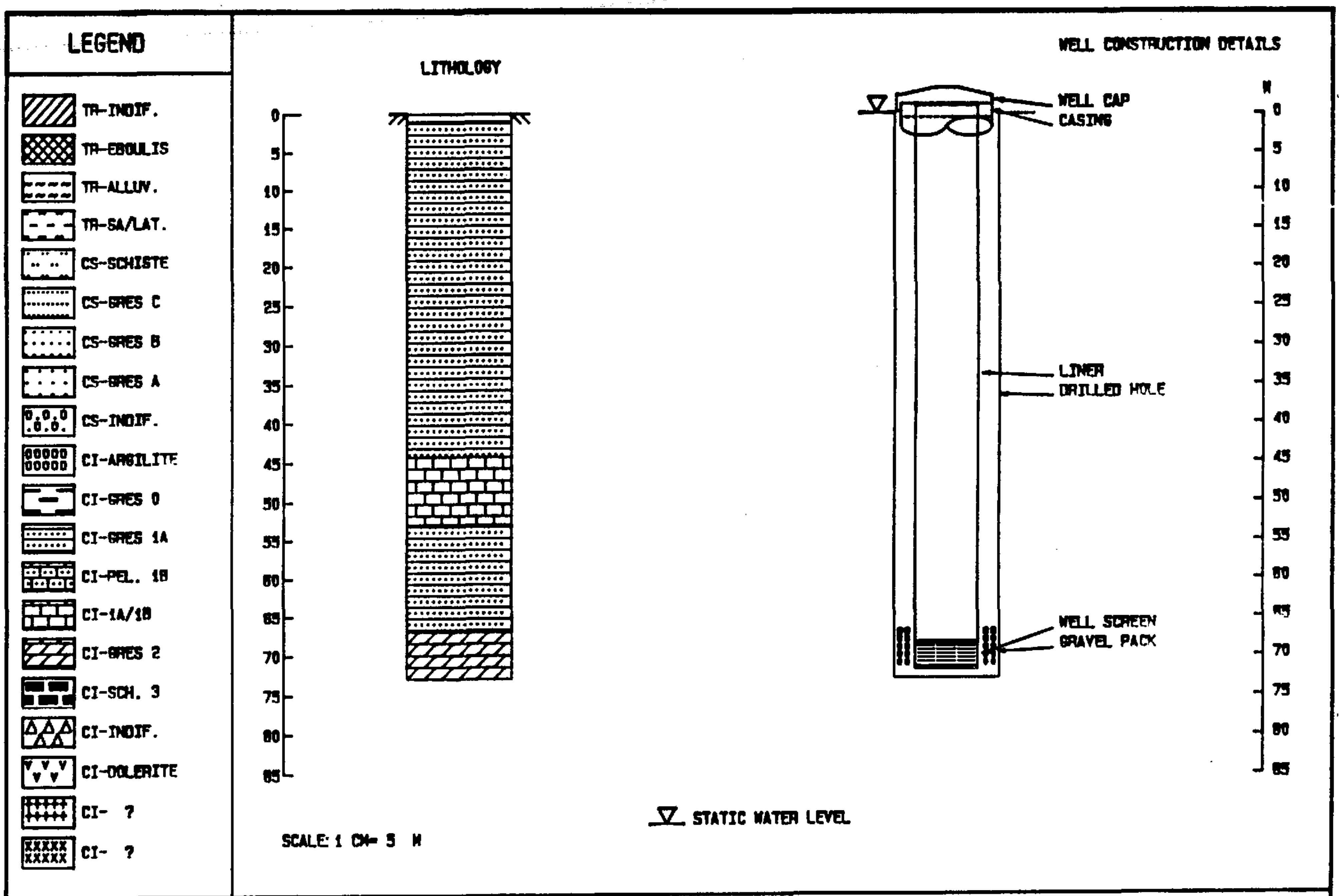
WELL LITHOLOGY

PROJECT: OMVS/USAID FILE NO.: 625-0958
LOCATION: BAFOULABE 2C

WELL # MA019 ELEVATION (m): 159.028

DEPTH (m)		THICKNESS (m)	LITHOLOGY
FROM	TO		
0.000	1.000	1.000	TR-INDIF.,QT; BE/GR; AR
1.000	2.500	1.500	TR-SA/LAT.,QT; LATERITE
2.500	5.750	3.250	CI-GRES 1A,BA; JA; GRES
5.750	30.000	24.250	CI-GRES 1A,BA; VI; GRES
30.000	50.000	20.000	CI-GRES 1A,BA; VI/BR; G

USAID/DAKAR/SENEGAL

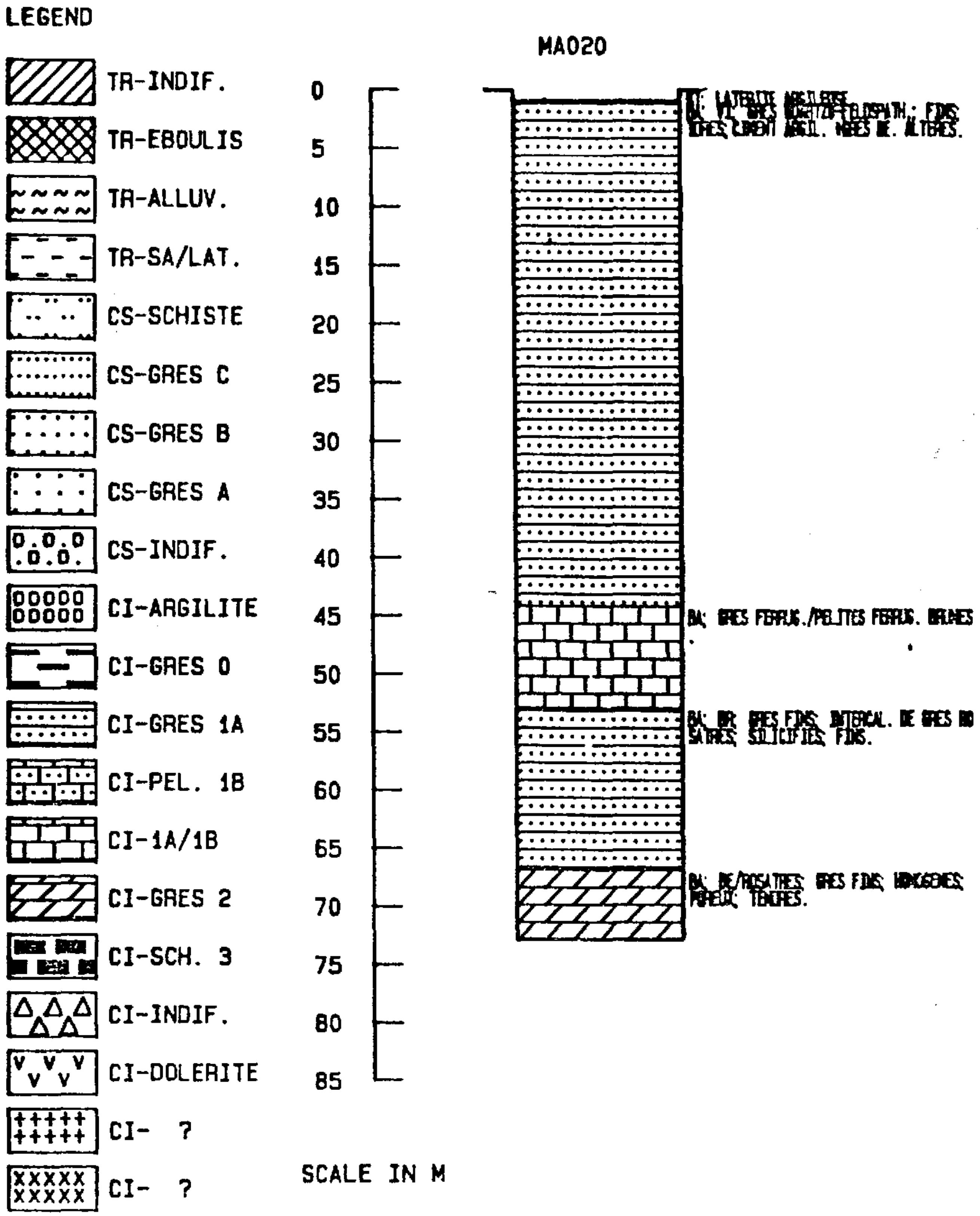


PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2C

COUPE GEOLOGIQUE ET TECHNIQUE

USAID/DAKAR/SENEGAL

FIGURE: MA020



PROJECT:	OMVS/USAID	LITHOLOGY
FILE:	625-0958	
LOCATION:	BAFOULABE 2C	

USAID/DAKAR/SENEGAL

FIGURE MA020

WELL LITHOLOGY

PROJECT: OMVS/USAID
LOCATION: BAFOULABE 2C

FILE NO.: 625-0958

WELL # MA020

ELEVATION (m): 159.175

DEPTH (m)		THICKNESS (m)	LITHOLOGY
FROM	TO		
0.000	1.000	1.000	TR-SA/LAT.,QT; LATERITE
1.000	44.300	43.300	CI-GRES 1A,BA; VI; GRES
44.300	53.000	8.700	CI-1A/1B,BA; GRES FERRU
53.000	67.000	14.000	CI-GRES 1A,BA; BR; GRES
67.000	73.000	6.000	CI-GRES 2,BA; BE/ROSATR

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GROUNDWATER MONITORING UNIT
OMVS/USAID PROJECT 625-0958

HYDROGEOLOGICAL REPERTOIRE

TOPOGRAPHIC MAP 1:200,000

27 BAFOULABE

ANNEX # 2

GEOLOGIC CROSS SECTIONS

COMMENTS ON THE GEOLOGIC CROSS SECTIONS

The following geologic cross sections were plotted with the GROUNDWATER/LITHOCON program. The following information was added to the geologic cross sections.

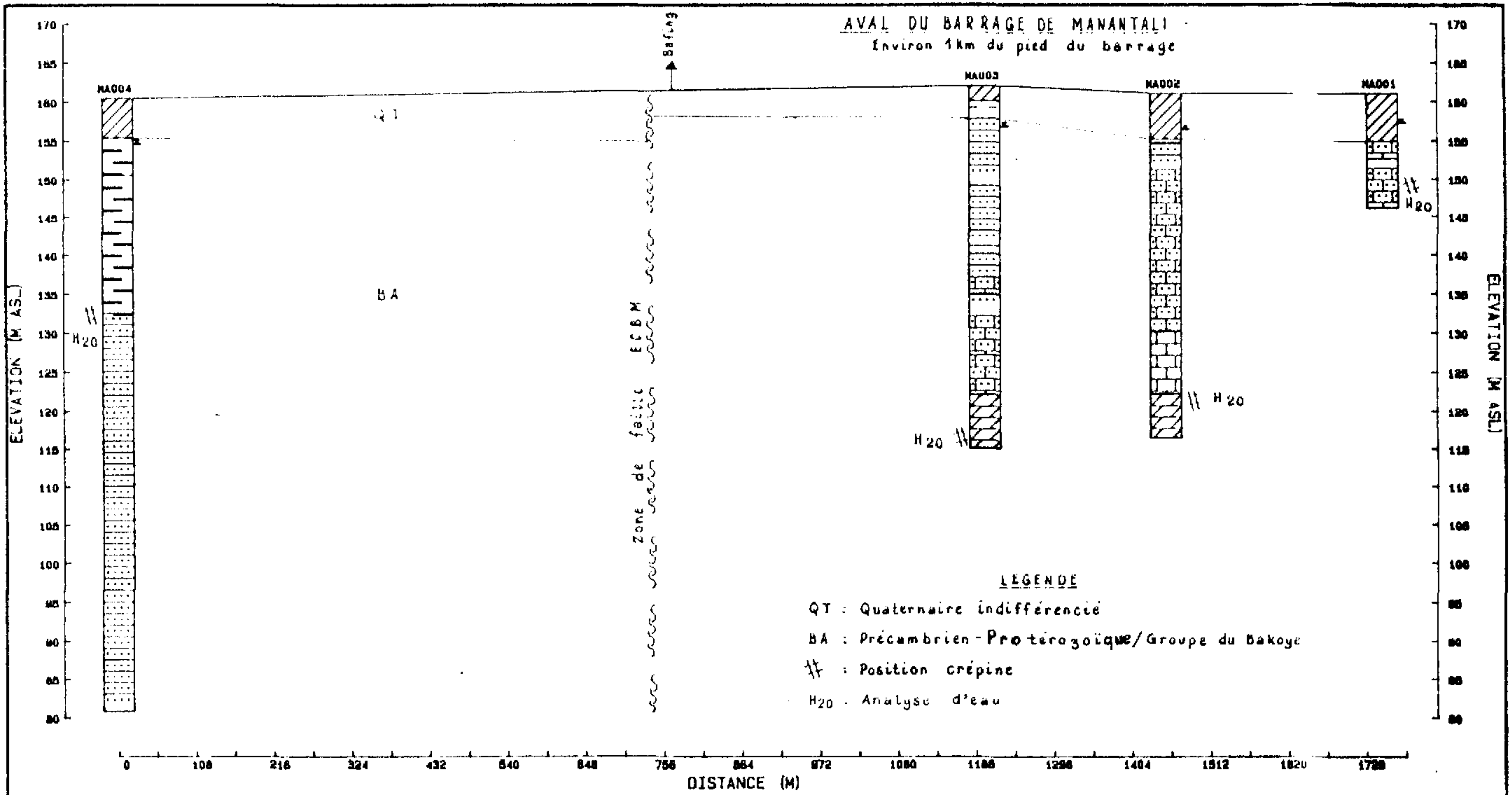
1) the geologic age of the different sediments crossed

2) the positions of multiple intakes at the same geographic site (double equipment)

3) water samples drawn, if any, corresponding to a chemical analysis identified by the number of the piezometer from which it was drawn (see annex #4)

4) the geologic correlation between the different formations crossed by each of the boreholes made at the site concerned.

All of this information was determined from analysis of data presented in the tables which are contained in the text of this documentary repertoire.



LEGEND | SWL : N.S. (Avril - Mai 1989)

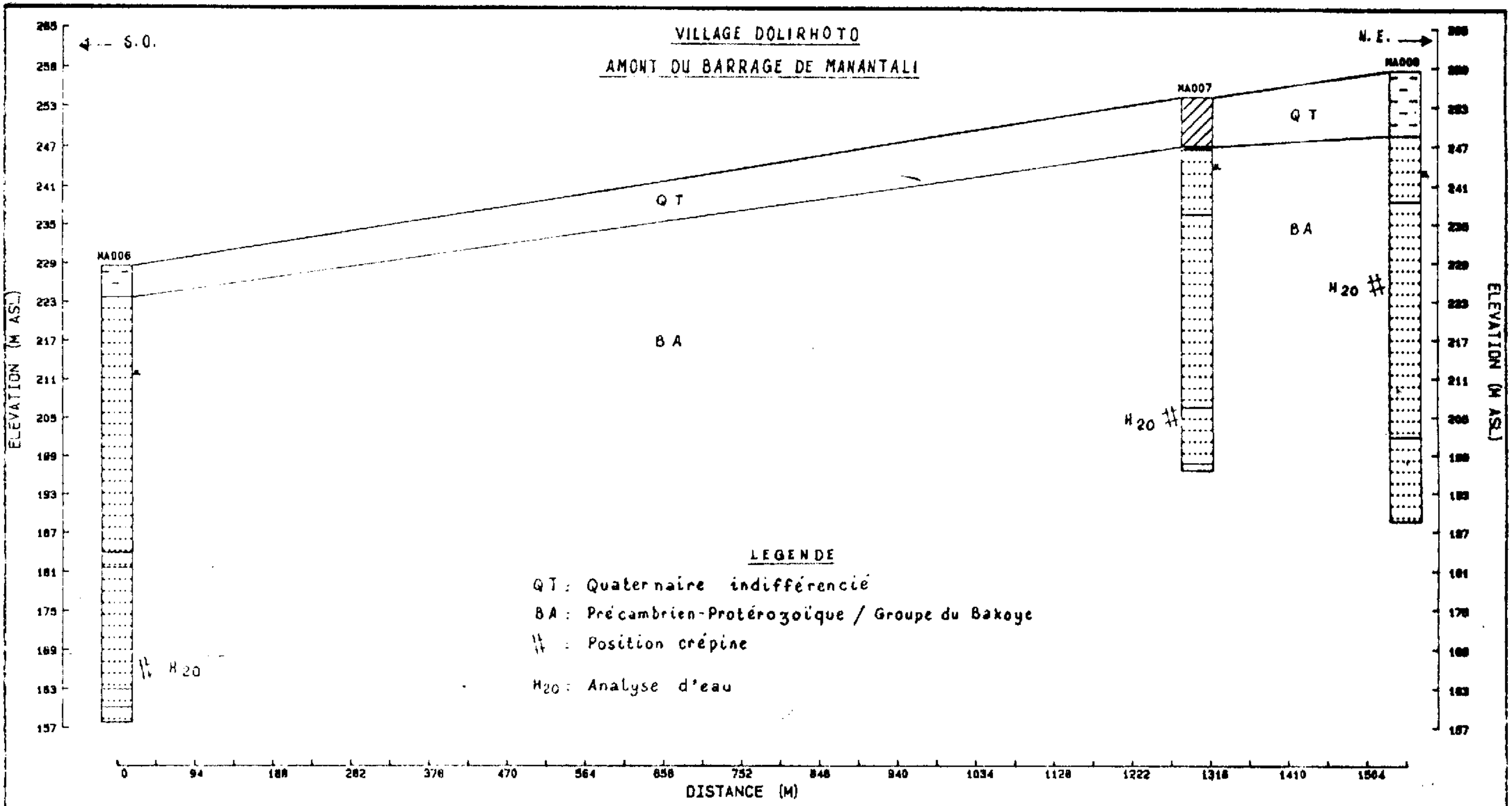
TH-INDIF.	CS-SCHISTE	CS-INDIF.	CI-PEL. 1B	CI-INDIF.
TH-EBOULIS	CS-GRES C	CI-ARGILITE	CI-1A/1B	CI-DOLERITE
TR-ALLUV.	CS-GRES B	CI-GRES 0	CI-GRES 2	CI- ?
TR-SA/LAT.	CS-GRES A	CI-GRES 1A	CI-SCH. 3	CI- ?

PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

FIGURE: 27BB2A

GEOLOGIC CROSS SECTION
SECTION GEOLOGIQUE

USAID/DAKAR/SENEGAL



LEGEND | SWL : N.S. (Juin - Juillet 1989)

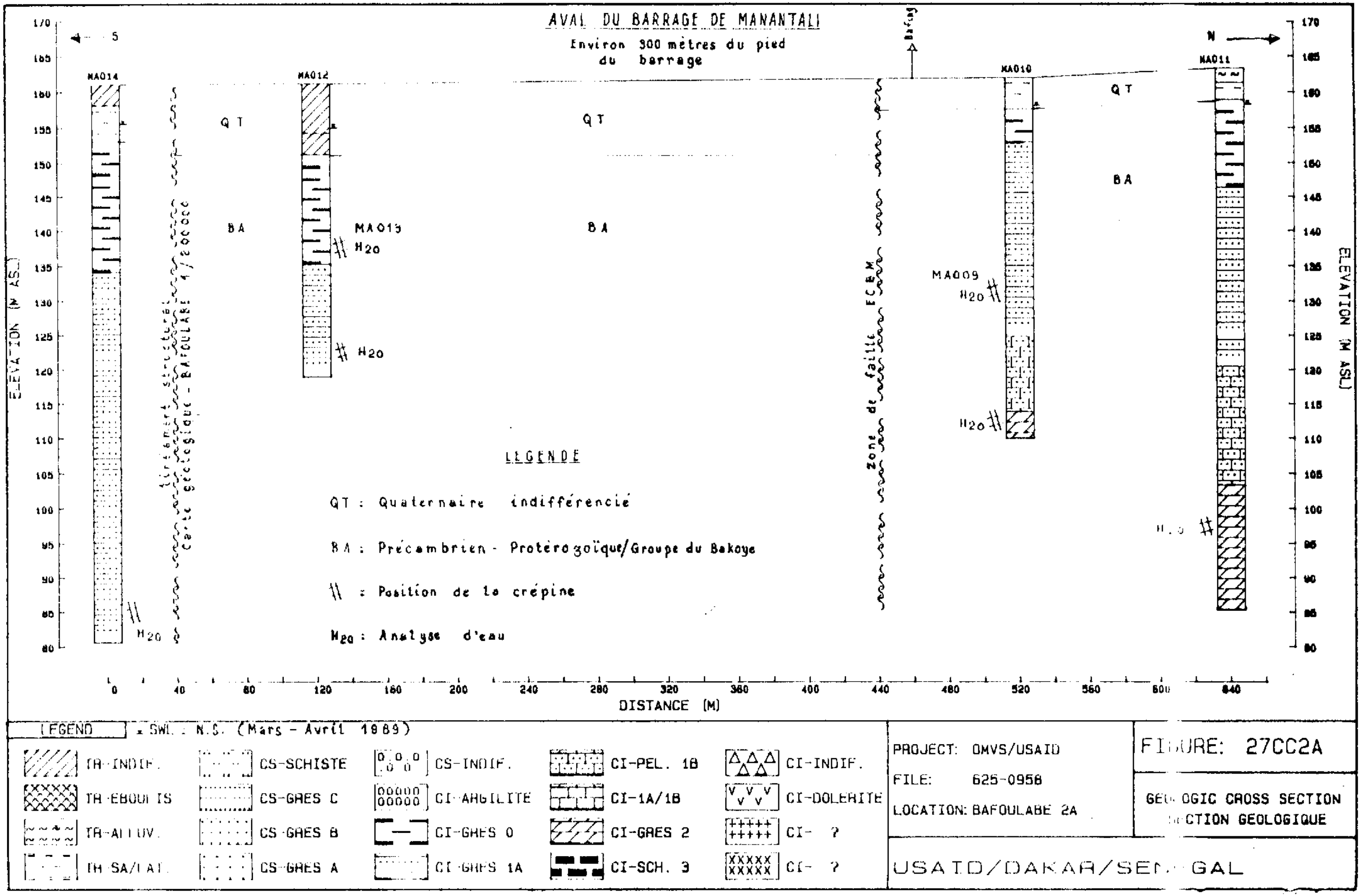
TR-INDIF.	CS-SCHISTE	CS-INDIF.	CI-PEL. 1B	CI-INDIF.
TR-EBOULIS	CS-GRES C	CI-ARGILITE	CI-1A/1B	CI-DOLERITE
TR-ALLUV.	CS-GRES B	CI-GRES 0	CI-GRES 2	CI- ?
TR-SA/LAT.	CS-GRES A	CI-GRES 1A	CI-SCH. 3	CI- ?

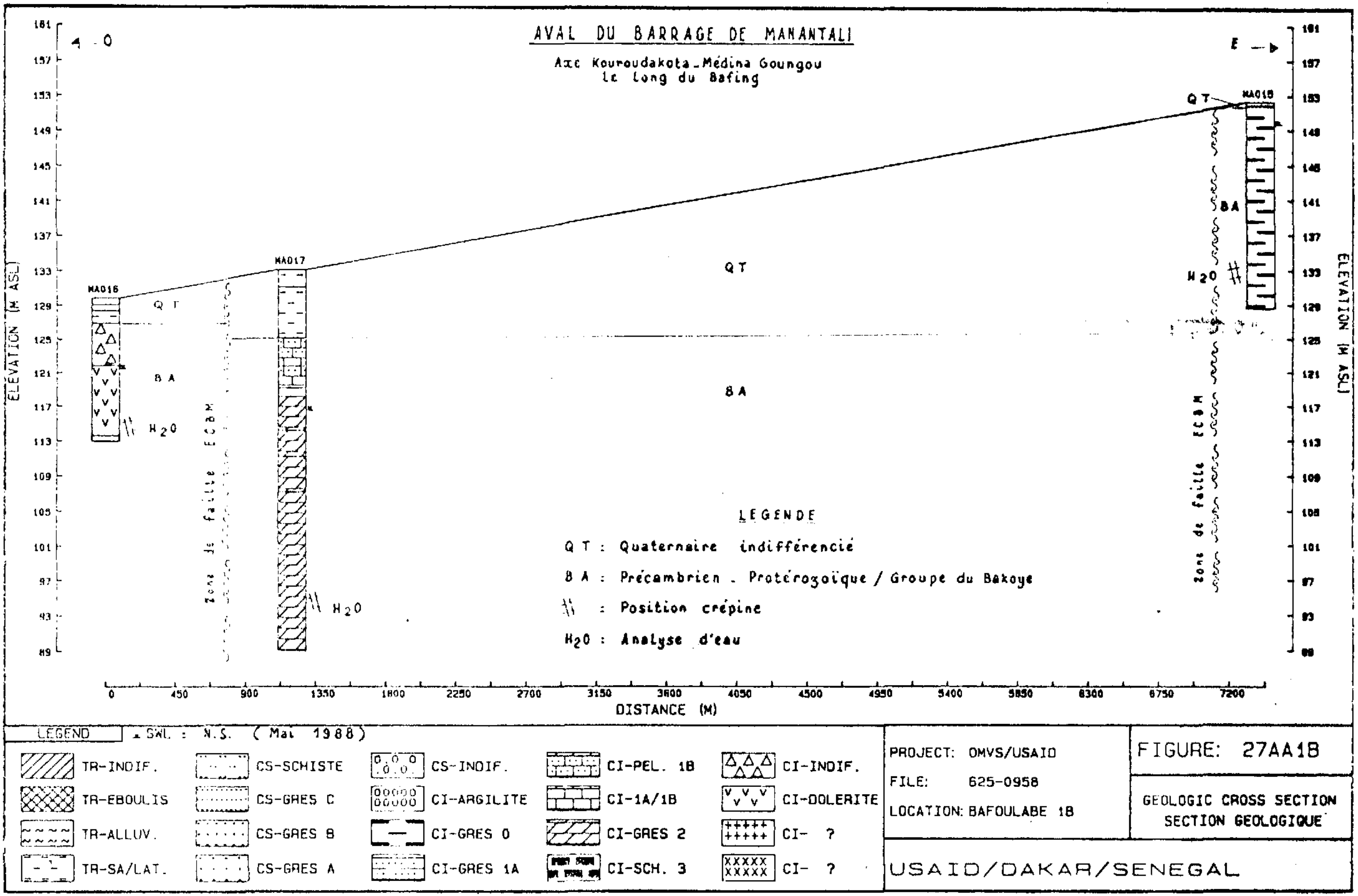
PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 28

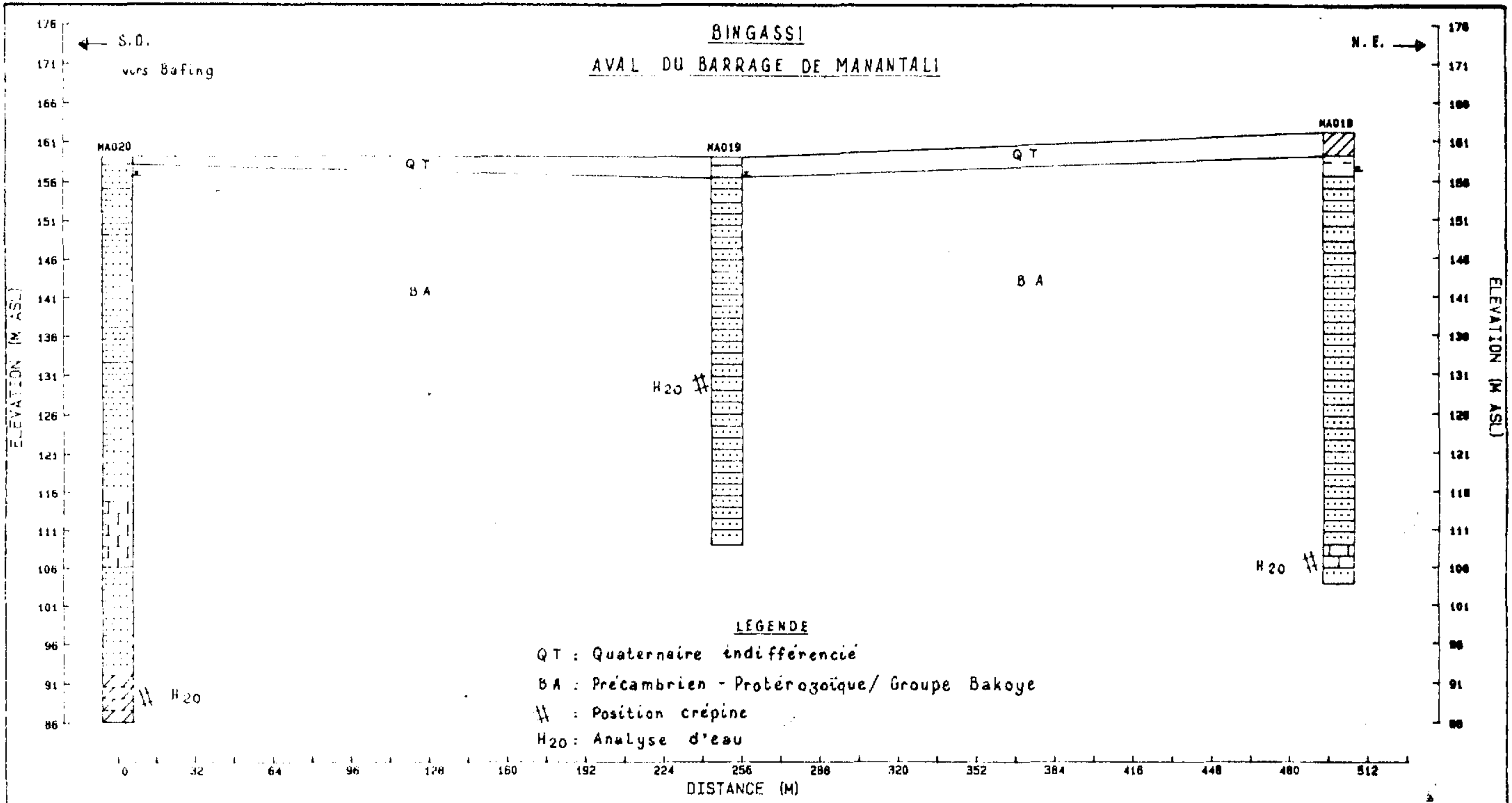
FIGURE: 27AA28

GEOLOGIC CROSS SECTION
SECTION GEOLOGIQUE

USAID/DAKAR/SENEGAL


AVAL DU BARRAGE DE MANANTALI
Environ 300 mètres du pied du barrage
S
N
Bafing
MA014
MA012
MA010
MA011
MA015
MA009
QT
BA
H2o
Linéament structural Carte géologique - BAFOULABE 1/200000
Zone de faille FCBM
LEGENDE
QT : Quaternaire indifférencié
BA : Précambrien - Protérozoïque/Groupe du Bakoye
\\ : Position de la crépine
H2o : Analyse d'eau
ELEVATION (M ASL)
DISTANCE (M)
LEGEND
x SWL : N.S. (Mars - Avril 1989)
TR-INDIF.
TR-EBOULIS
TR-ALLUV.
TR-SA/LAT.
CS-SCHISTE
CS-GRES C
CS-GRES B
CS-GRES A
CS-INDIF.
CI-ARGILITE
CI-GRES 0
CI-GRES 1A
CI-PEL. 1B
CI-1A/1B
CI-GRES 2
CI-SCH. 3
CI-INDIF.
CI-DOLERITE
CI- ?
CI- ?
PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A
FIGURE: 27CC2A
GEOLOGIC CROSS SECTION
SECTION GEOLOGIQUE
USAID/DAKAR/SENEGAL


AVAL DU BARRAGE DE MANANTALI
Axe Kouroudakota_Médina Goungou le long du Bafing
W — O
E →
MA016
MA017
MA018
Q T
B A
H 2 O
Zone de faille ECBM
ELEVATION (M ASL)
DISTANCE (M)
0
450
900
1350
1800
2250
2700
3150
3600
4050
4500
4950
5400
5850
6300
6750
7200
LEGENDE
Q T : Quaternaire indifférencié
B A : Précambrien . Protérozoïque / Groupe du Bakoye
: Position crépine
H2O : Analyse d'eau
LEGEND
SWL : N.S. (Mai 1988)
TR-INDIF.
TR-EBOULIS
TR-ALLUV.
TR-SA/LAT.
CS-SCHISTE
CS-GRES C
CS-GRES B
CS-GRES A
CS-INDIF.
CI-ARGILITE
CI-GRES 0
CI-GRES 1A
CI-PEL. 1B
CI-1A/1B
CI-GRES 2
CI-SCH. 3
CI-INDIF.
CI-DOLERITE
CI- ?
CI- ?
PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 1B
FIGURE: 27AA18
GEOLOGIC CROSS SECTION
SECTION GEOLOGIQUE
USAID/DAKAR/SENEGAL



LEGEND — SWL . N.S. (26 Novembre 1988)

TR-INDIF.	CS-SCHISTE	CS-INDIF.	CI-PEL. 1B	CI-INDIF.
TR-EBOULIS	CS-GRES C	CI-ARGILITE	CI-1A/1B	CI-DOLERITE
TR-ALLUV.	CS-GRES B	CI-GRES 0	CI-GRES 2	CI- ?
TR-SA/LAT.	CS-GRES A	CI-GRES 1A	CI-SCH. 3	CI- ?

PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2C

FIGURE: 27AA2C

GEOLOGIC CROSS SECTION
SECTION GEOLOGIQUE

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HYDROGEOLOGICAL REPERTOIRE

TOPOGRAPHIC MAP 1:200,000

27 BAFOULABE

ANNEX # 3

WATER ANALYSIS

* Practical comments
* Analysis results/tables
* Classification diagrams

GUIDE

All the classification diagrams indicating results of the chemical analysis of the groundwater and the tables of results were produced with the GROUNDWATER/CHEMISTRY program. In spite of its English language origins it was not necessary to develop a lexicon to read these graphics.

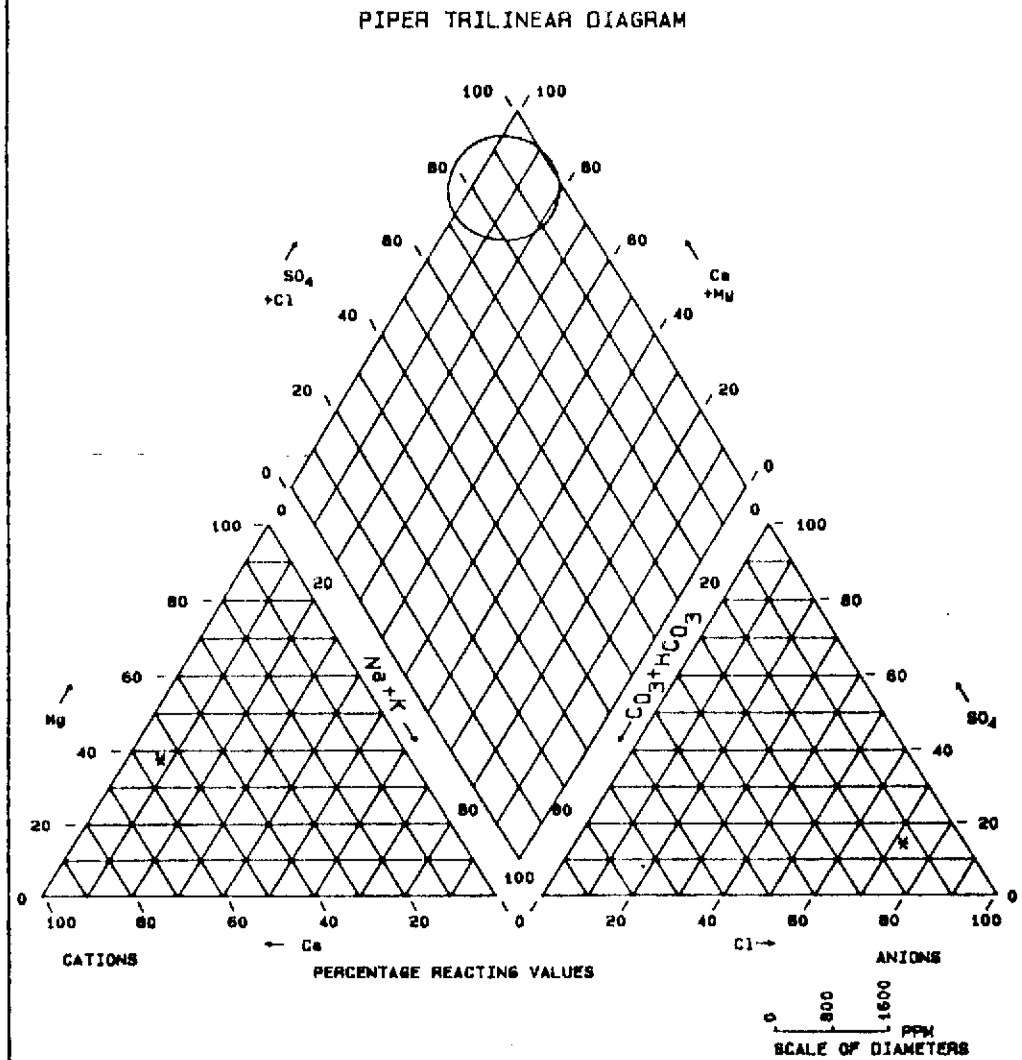
The GES data base can print out a summary table of water analysis results for any specific piezometer. These tables contain the complete analysis results including those not indicated in the diagrams.

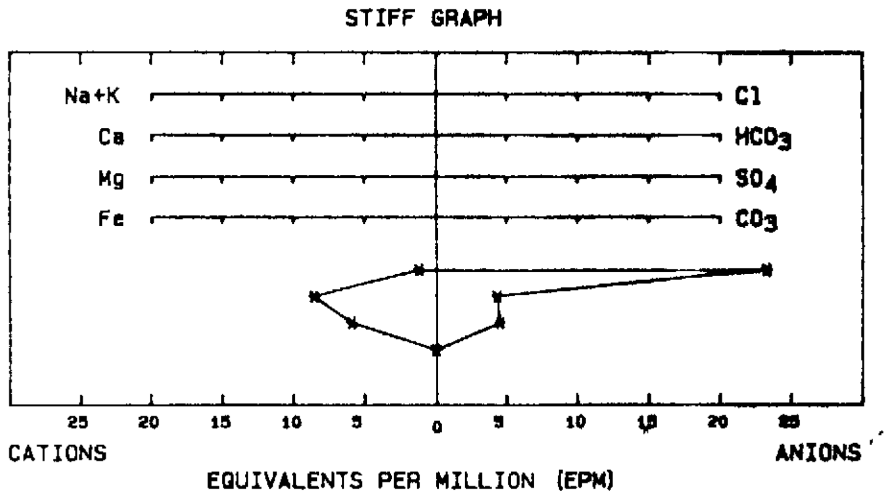
The reader will note that the number of the figure in the diagrams corresponds to the number of the piezometer from which the samples were drawn or near to where a surface water sample was taken.

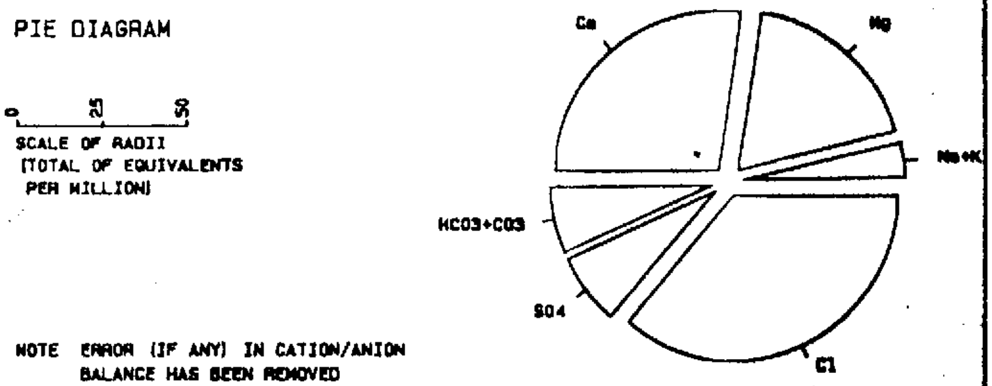
The reader will find, attached, the complete list of all the files dealt with in this annex, corresponding to the number of piezometers contained in the limits of the topographic map 1/200,000 concerned.

All the piezometers, dealt with in this annex are localized on the map 1/200,000 which accompanies this document.

The complete list of piezometers related to this map was produced with XTREE utility software.







PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

SAMPLE: MA001 08/02/89

CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL

FIGURE: MA001

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2A

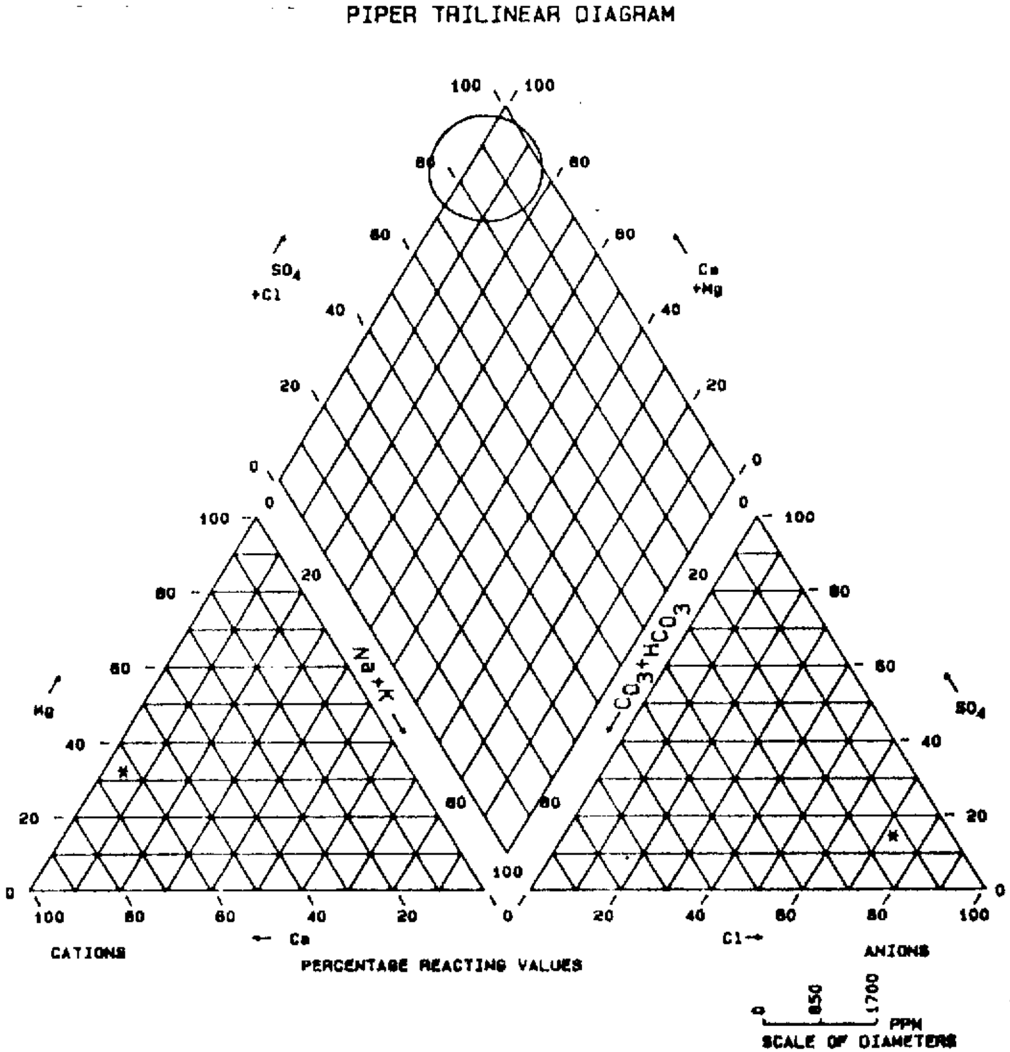
WELL NO.: MA001 08/02/89

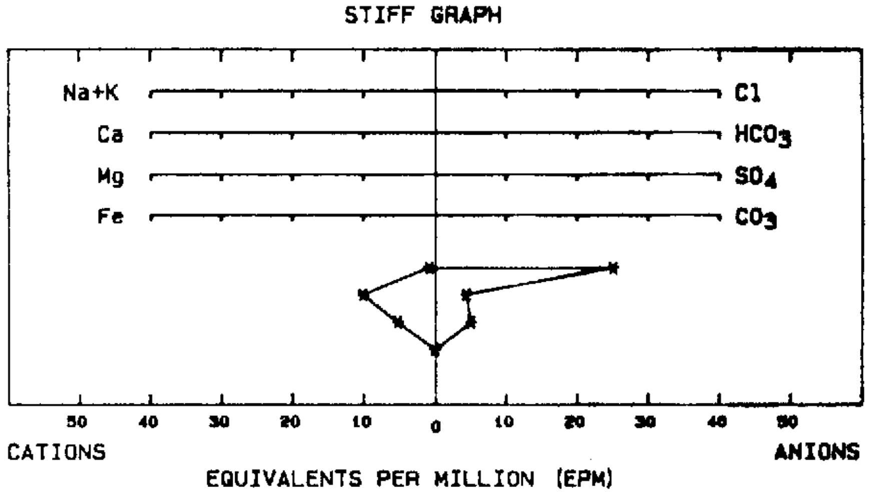
CATIONS	PPM	EPM	% EPM
Ca	172.30	8.60	54.82
Mg	71.58	5.89	37.53
Na+K	32.20	1.20	7.65

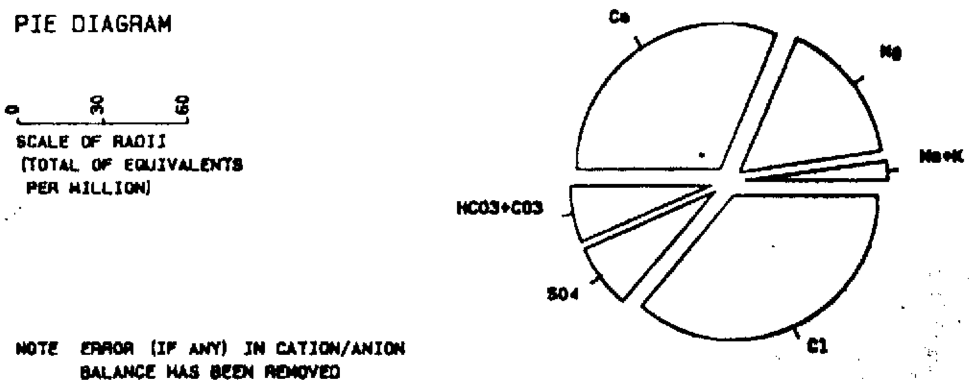
ANIONS	PPM	EPM	% EPM
HCO3+CO3	264.00	4.33	13.47
SO4	217.50	4.53	14.10
Cl	825.00	23.27	72.43

TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 34.39 %
SODIUM ABSORPTION RATION (S.A.R.): 0.34

USAID/DAKAR/SENEGAL







PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 2A	SAMPLE: MA002 08/02/89	CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL

FIGURE: MA002

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID
LOCATION: BAFOULABE 2A

FILE: 625-0958

WELL NO. : MA002 08/02/89

CATIONS	PPM	EPM	% EPM
Ca	202.00	10.08	63.02
Mg	63.04	5.18	32.42
Na+K	21.50	0.73	4.56

ANIONS	PPM	EPM	% EPM
HCO3+CO3	271.00	4.44	12.84
SO4	242.50	5.05	14.60
Cl	890.00	25.10	72.56

TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 36.76 %
SODIUM ABSORPTION RATION (S.A.R.): 0.16

USAID/DAKAR/SENEGAL

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2A

WELL NO. : MA003 08/02/89 .

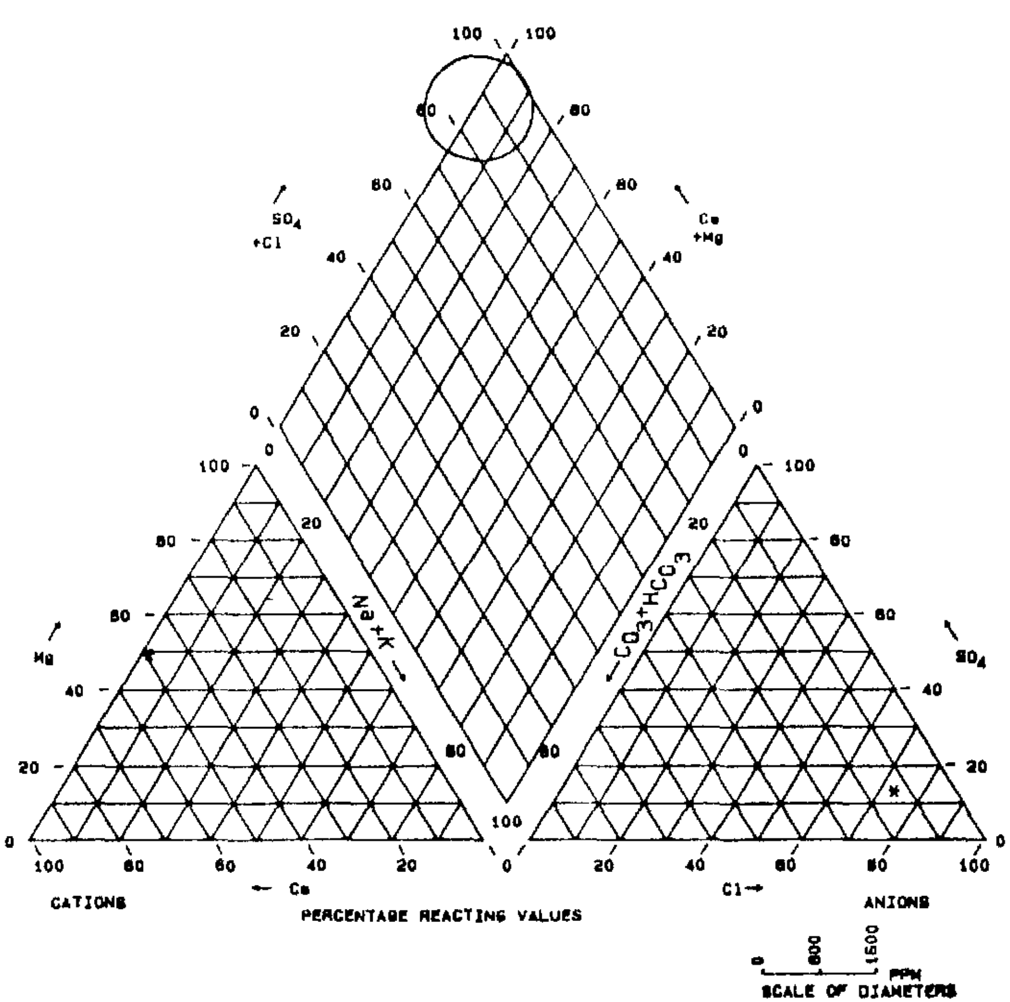
CATIONS	PPM	EPM	% EPM
Ca	64.10	3.20	44.55
Mg	44.54	3.66	51.02
Na+K	9.30	0.32	4.44

ANIONS	PPM	EPM	% EPM
HCO3+CO3	343.00	5.62	87.61
SO4	17.20	0.36	5.58
Cl	15.50	0.44	6.81

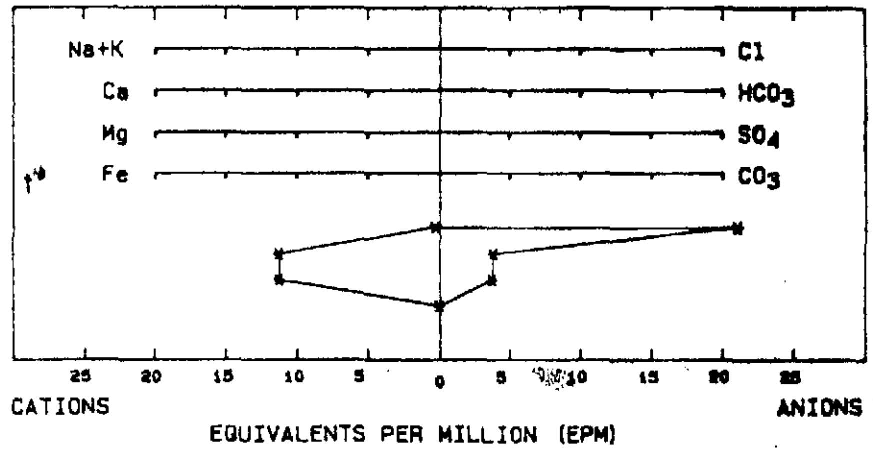
TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 5.54 %
SODIUM ABSORPTION RATION (S.A.R.): 0.11

USAID/DAKAR/SENEGAL

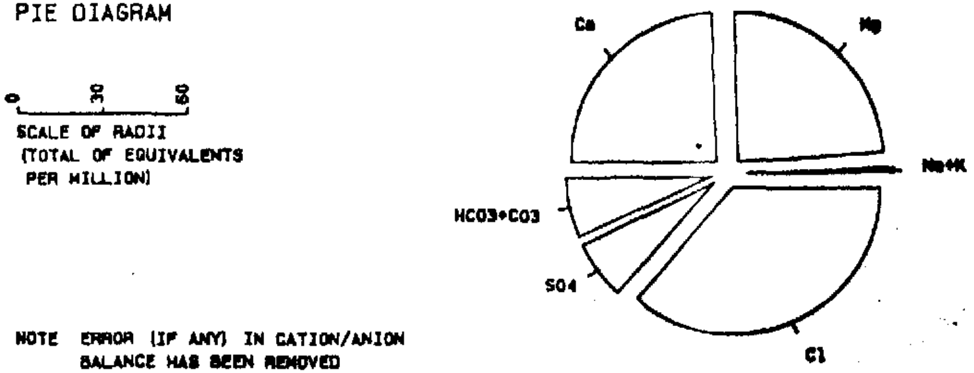
PIPER TRILINEAR DIAGRAM



STIFF GRAPH



PIE DIAGRAM



PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 2A	SAMPLE: MA004 08/02/89	CHEMICAL GRAPHS
USAID/DAKAR/SENEGAL		FIGURE: MA004

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2A

WELL NO.: MA004 08/02/89 .

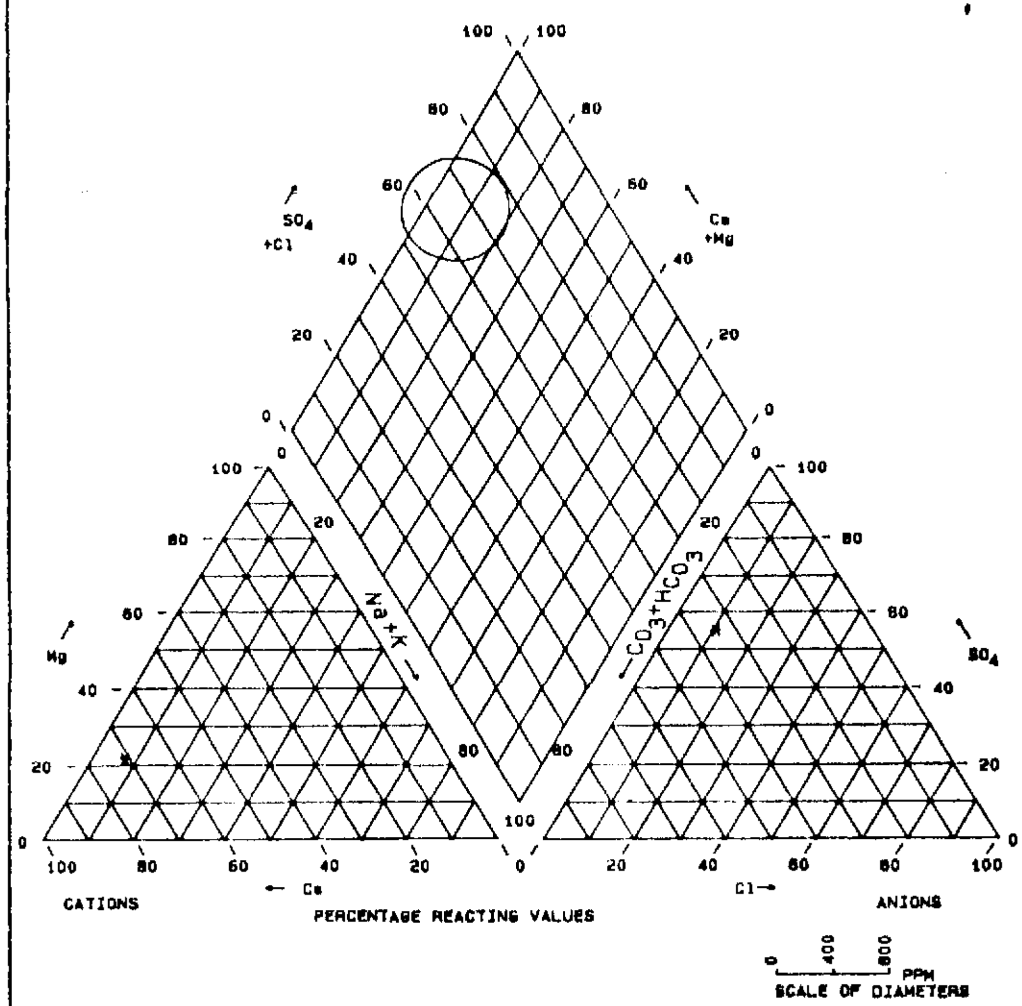
CATIONS	PPM	EPM	% EPM
Ca	226.00	11.28	49.24
Mg	137.04	11.27	49.21
Na+K	10.80	0.36	1.56

ANIONS	PPM	EPM	% EPM
HCO3+CO3	235.00	3.85	13.44
SO4	182.50	3.80	13.26
Cl	745.00	21.01	73.30

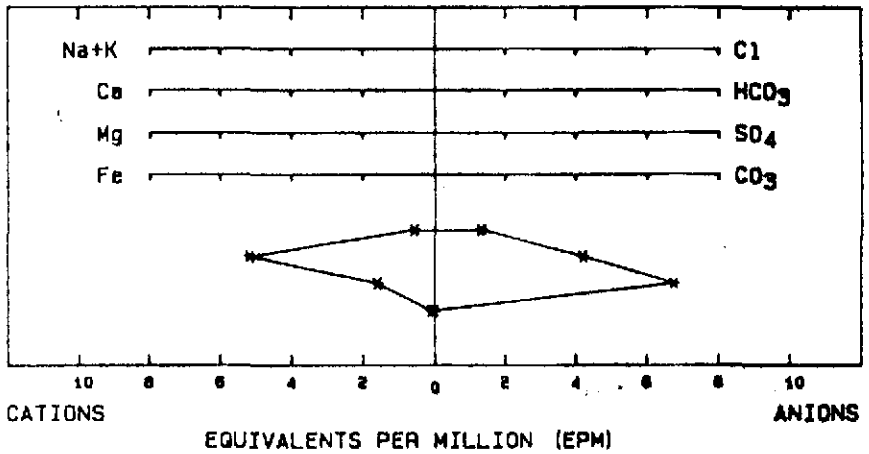
TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 11.12 %
SODIUM ABSORPTION RATION (S.A.R.): 0.06

USAID/DAKAR/SENEGAL

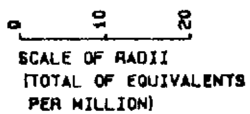
PIPER TRILINEAR DIAGRAM

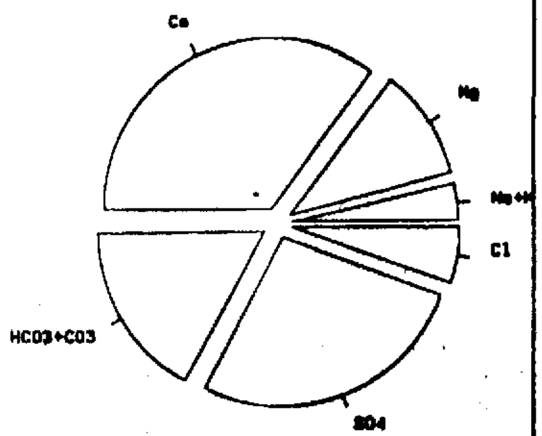


STIFF GRAPH



PIE DIAGRAM





NOTE ERROR (IF ANY) IN CATION/ANION BALANCE HAS BEEN REMOVED

PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 2A	SAMPLE: MA005 08/02/89	CHEMICAL GRAPHS
USAID/DAKAR/SENEGAL		FIGURE: MA005

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2A

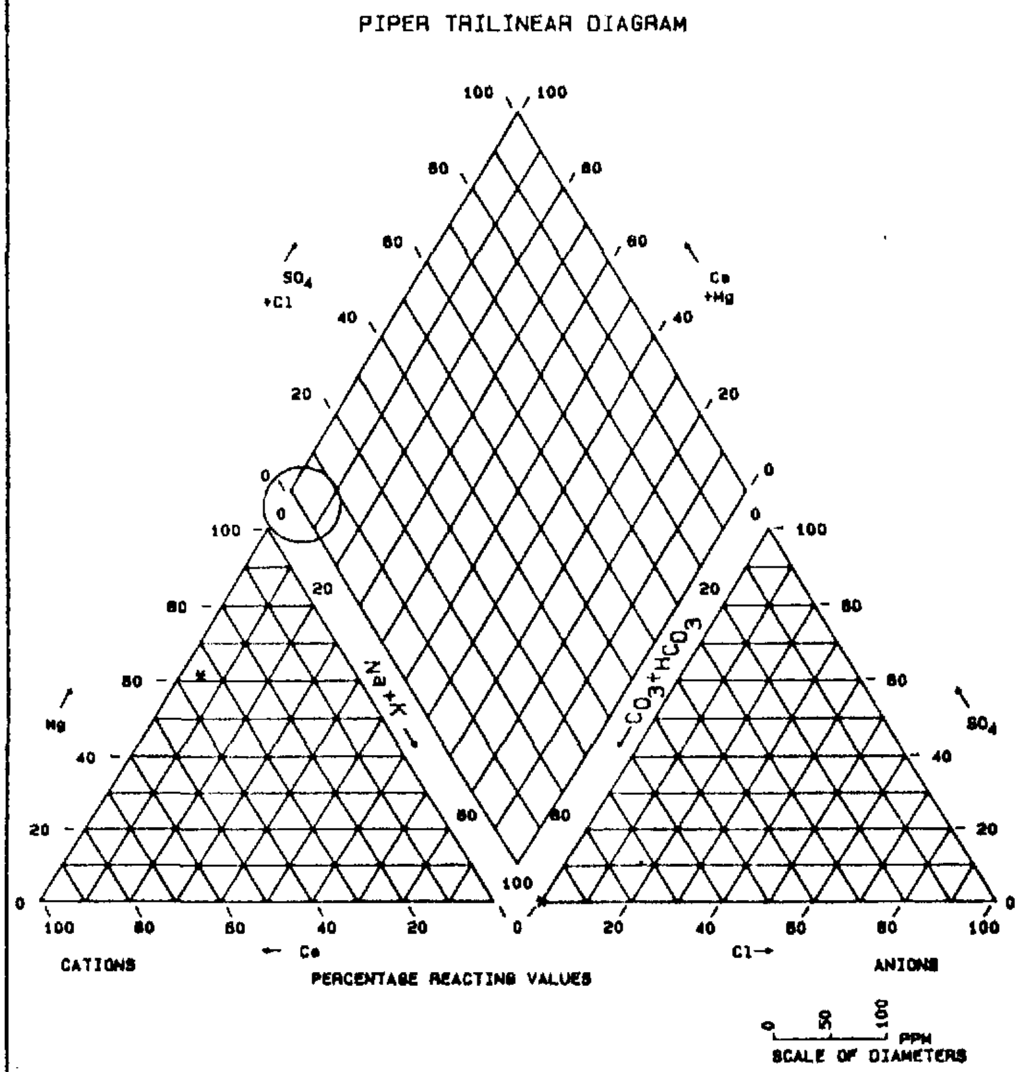
WELL NO.: MA005 08/02/89.

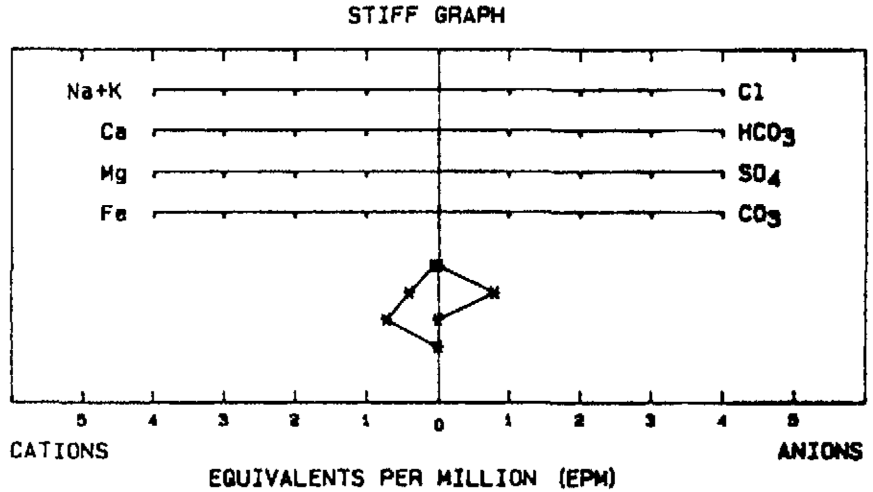
CATIONS	PPM	EPM	% EPM
Ca	103.40	5.16	70.89
Mg	19.14	1.57	21.63
Na+K	14.30	0.54	7.49

ANIONS	PPM	EPM	% EPM
HCO3+CO3	257.00	4.21	34.20
SO4	325.00	6.77	54.93
Cl	47.50	1.34	10.87

TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 25.22 %
SODIUM ABSORPTION RATION (S.A.R.): 0.24

USAID/DAKAR/SENEGAL





NOTE ERROR (IF ANY) IN CATION/ANION BALANCE HAS BEEN REMOVED

PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 2B	SAMPLE: MA006 08/02/89	CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL	FIGURE: MA006

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2B

WELL NO. : MA006 08/02/89

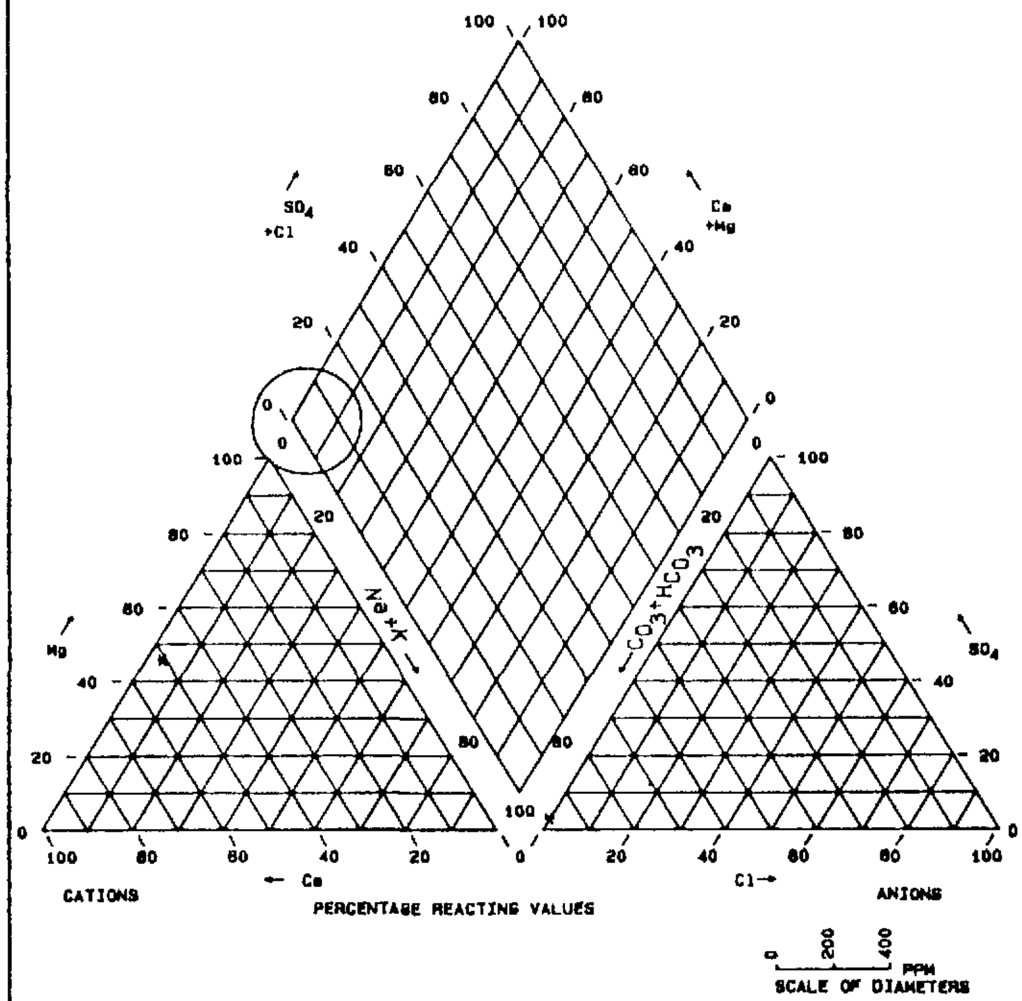
CATIONS	PPM	EPM	% EPM
Ca	8.00	0.40	34.05
Mg	8.75	0.72	61.37
Na+K	2.10	0.05	4.58

ANIONS	PPM	EPM	% EPM
HCO3+CO3	49.00	0.80	99.48
SO4	0.20	0.00	0.52
Cl	0.00	0.00	0.00

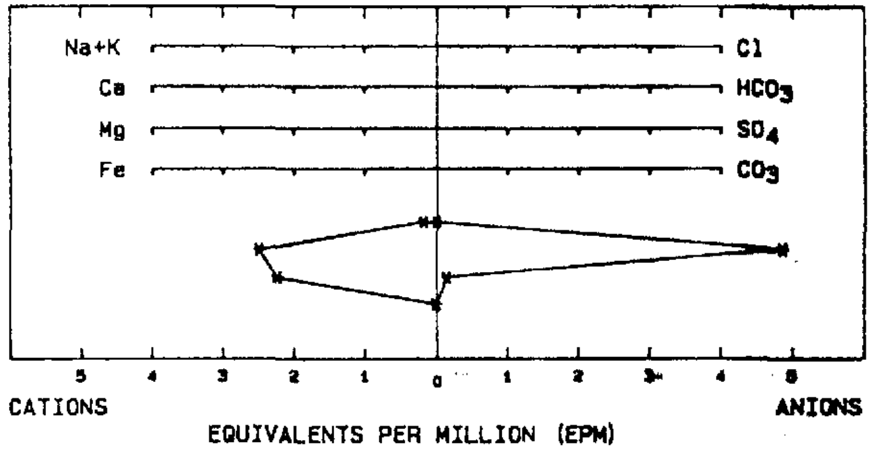
TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 18.26 %
SODIUM ABSORPTION RATION (S.A.R.): 0.00

USAID/DAKAR/SENEGAL

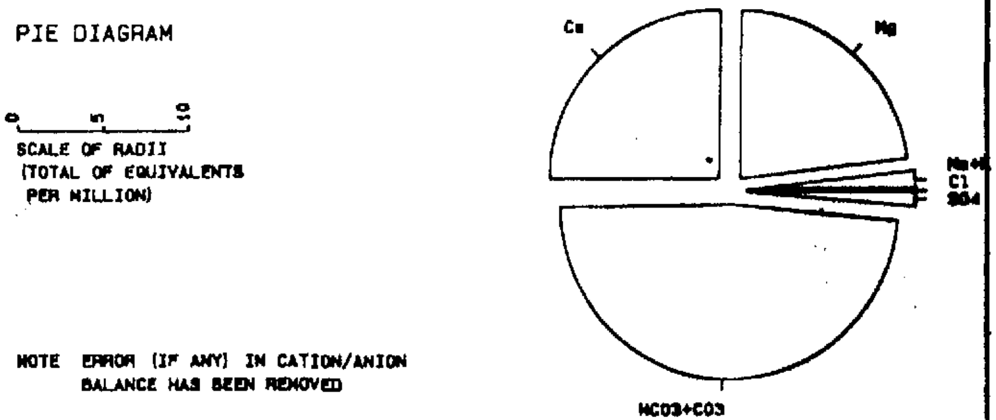
PIPER TRILINEAR DIAGRAM



STIFF GRAPH



PIE DIAGRAM



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2B

SAMPLE: MA007 08/02/89

CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL

FIGURE: MA007

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2B

WELL NO.: MA007 08/02/89

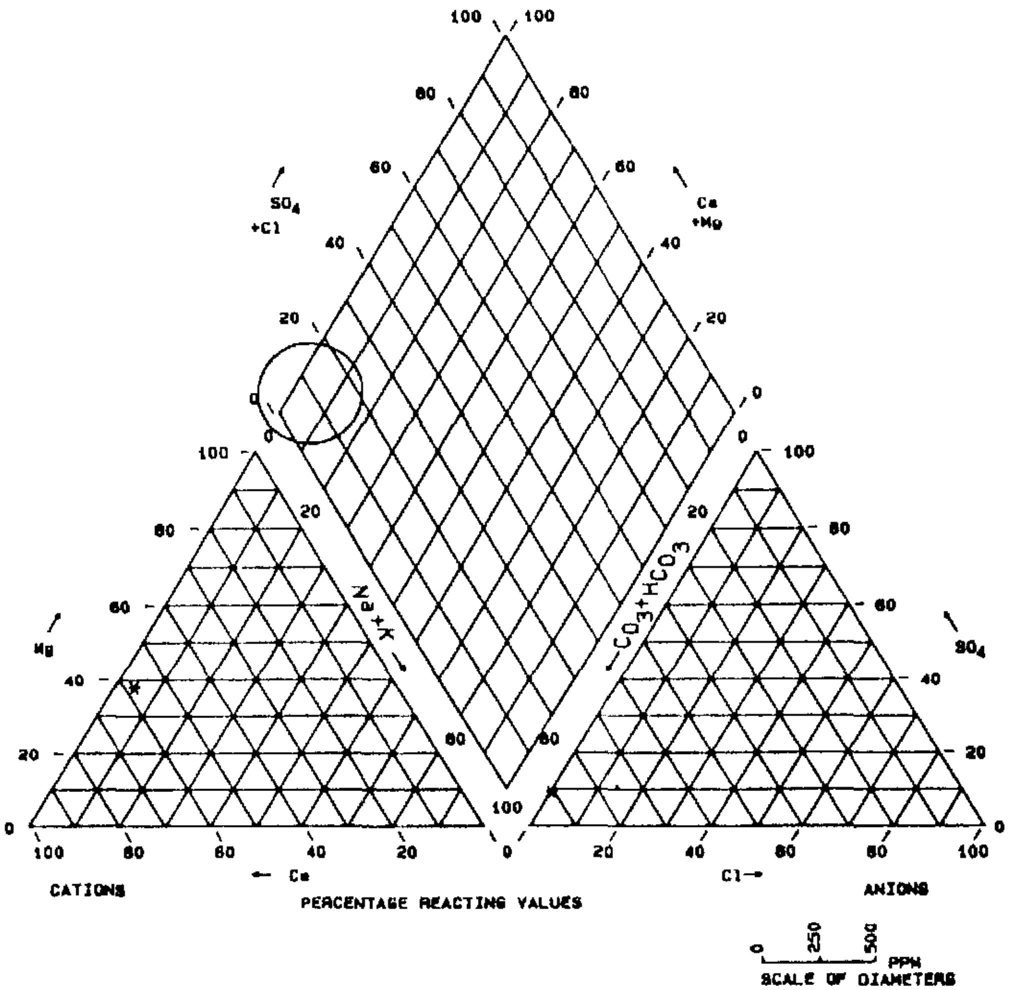
CATIONS	PPM	EPM	% EPM
Ca	49.70	2.48	50.66
Mg	27.17	2.23	45.64
Na+K	5.60	0.18	3.69

ANIONS	PPM	EPM	% EPM
HCO3+CO3	297.00	4.87	97.09
SO4	7.00	0.15	2.91
Cl	0.00	0.00	0.00

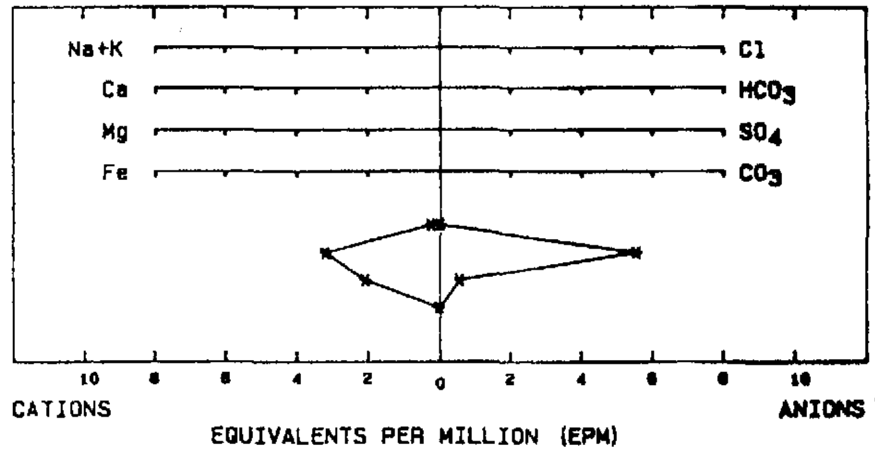
TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 1.15 %
SODIUM ABSORPTION RATION (S.A.R.): 0.06

USAID/DAKAR/SENEGAL

PIPER TRILINEAR DIAGRAM



STIFF GRAPH



PIE DIAGRAM

NOTE ERROR (IF ANY) IN CATION/ANION BALANCE HAS BEEN REMOVED

PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 2B	SAMPLE: MA008 08/02/89	CHEMICAL GRAPHS
USAID/DAKAR/SENEGAL		FIGURE: MA008

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2B

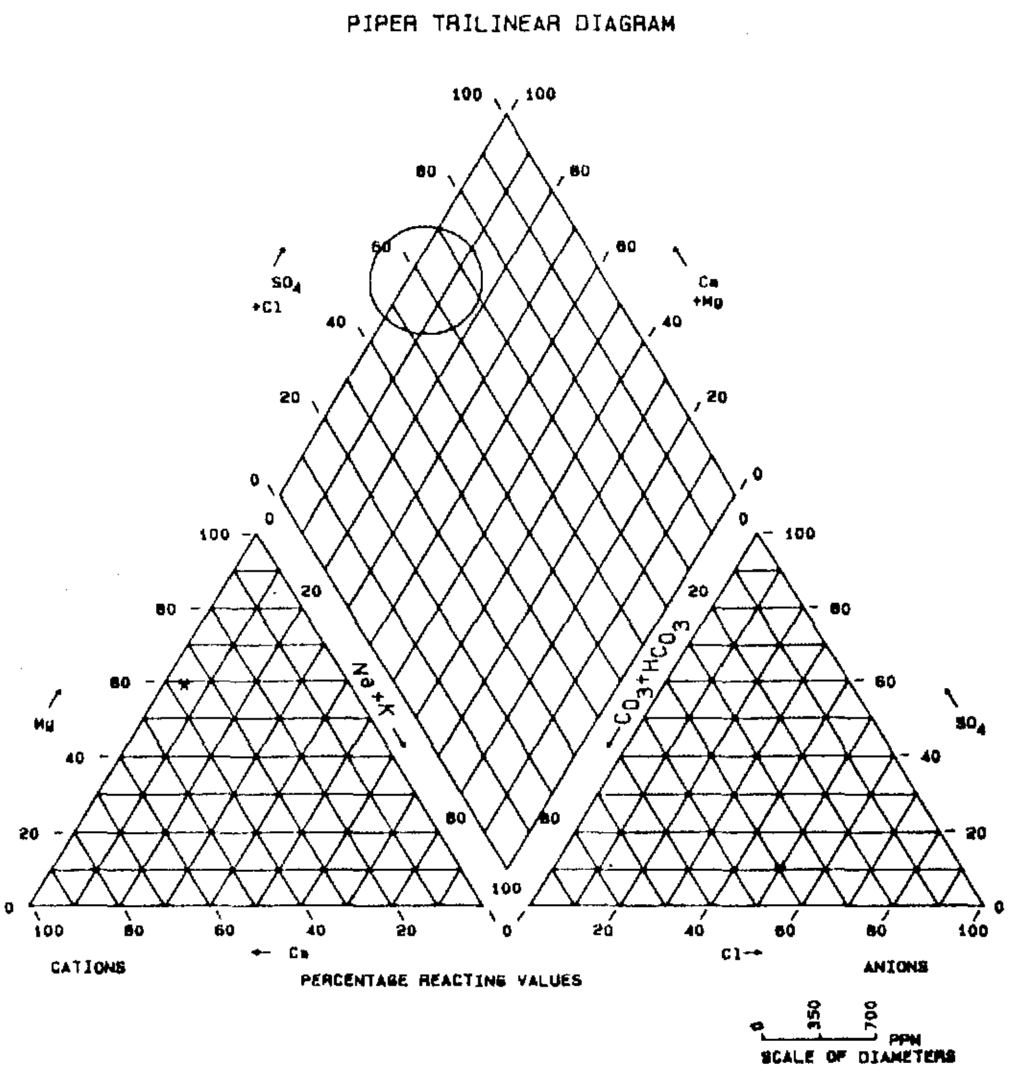
WELL NO.: MA008 08/02/89

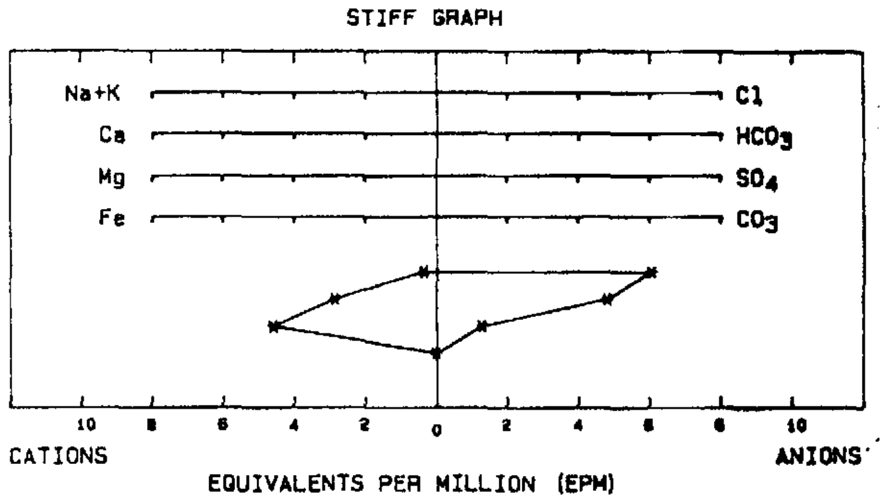
CATIONS	PPM	EPM	% EPM
Ca	64.10	3.20	57.85
Mg	25.24	2.08	37.54
Na+K	6.80	0.25	4.60

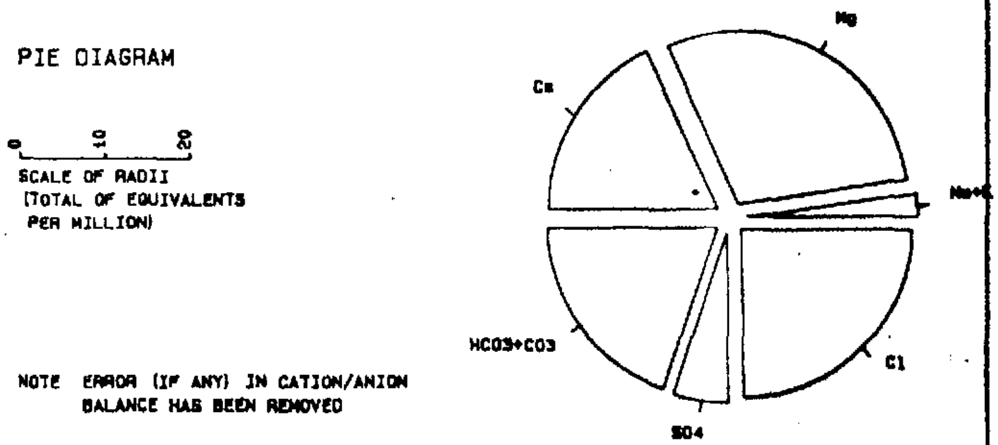
ANIONS	PPM	EPM	% EPM
HCO3+CO3	339.00	5.56	90.33
SO4	27.20	0.57	9.21
Cl	1.00	0.03	0.46

TOTAL DISSOLVED SOLIDS: 366
ERROR IN CATION/ANION BALANCE: 5.30 %
SODIUM ABSORPTION RATION (S.A.R.): 0.12

USAID/DAKAR/SENEGAL







PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

SAMPLE: MA009 08/02/89

CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL

FIGURE: MA009

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2A

WELL NO.: MA009 08/02/89.

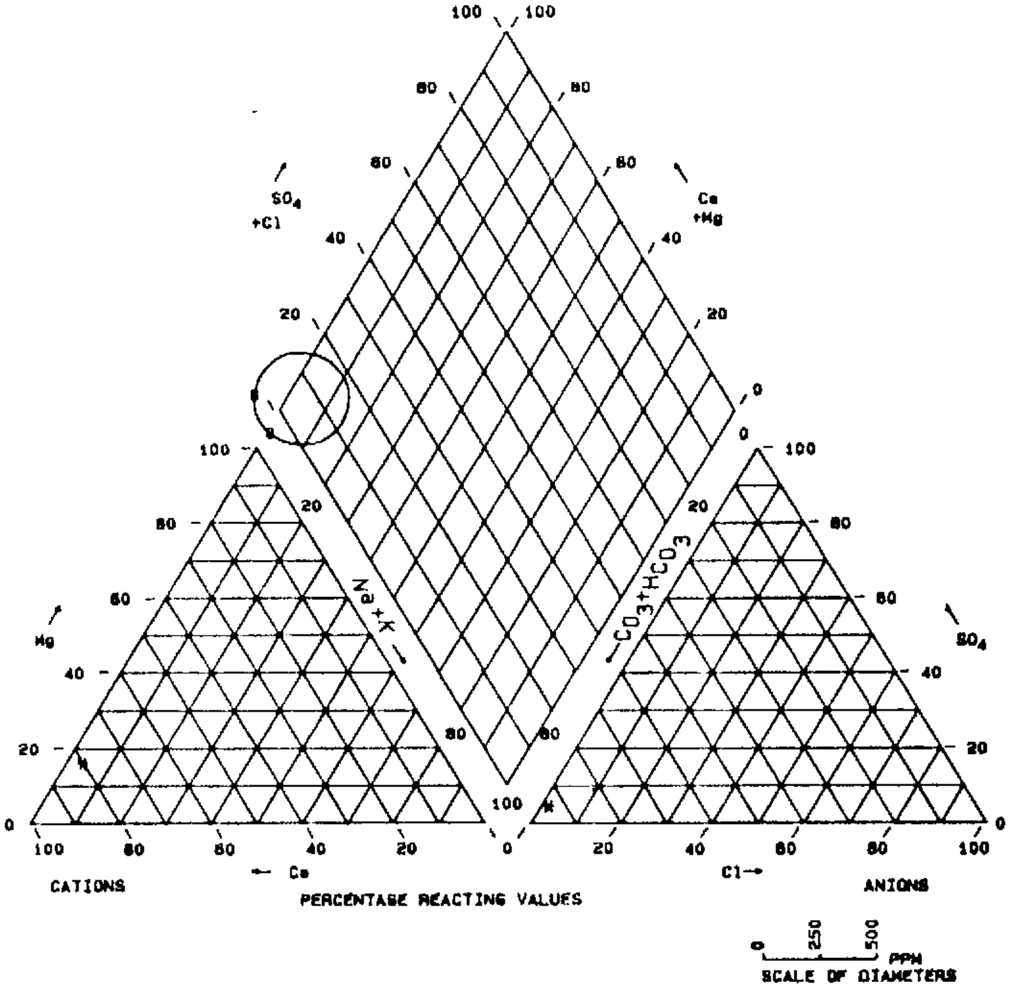
CATIONS	PPM	EPM	% EPM
Ca	56.90	2.84	36.48
Mg	55.83	4.59	59.00
Na+K	10.60	0.35	4.52

ANIONS	PPM	EPM	% EPM
HCO3+CO3	294.00	4.82	39.55
SO4	62.50	1.30	10.68
Cl	215.00	6.06	49.77

TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 22.05 %
SODIUM ABSORPTION RATION (S.A.R.): 0.10

USAID/DAKAR/SENEGAL

PIPER TRILINEAR DIAGRAM



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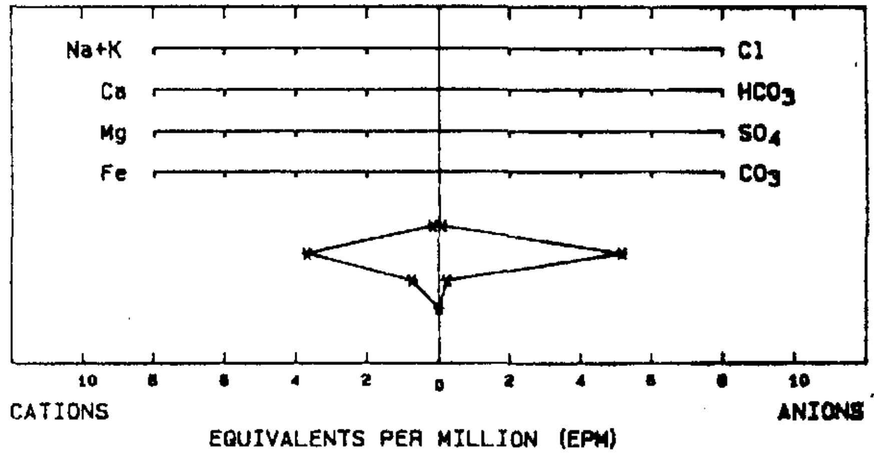


PIE DIAGRAM

NOTE ERROR (IF ANY) IN CATION/ANION BALANCE HAS BEEN REMOVED

PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

SAMPLE: MA010 08/02/89

CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL

FIGURE: MA010

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2A

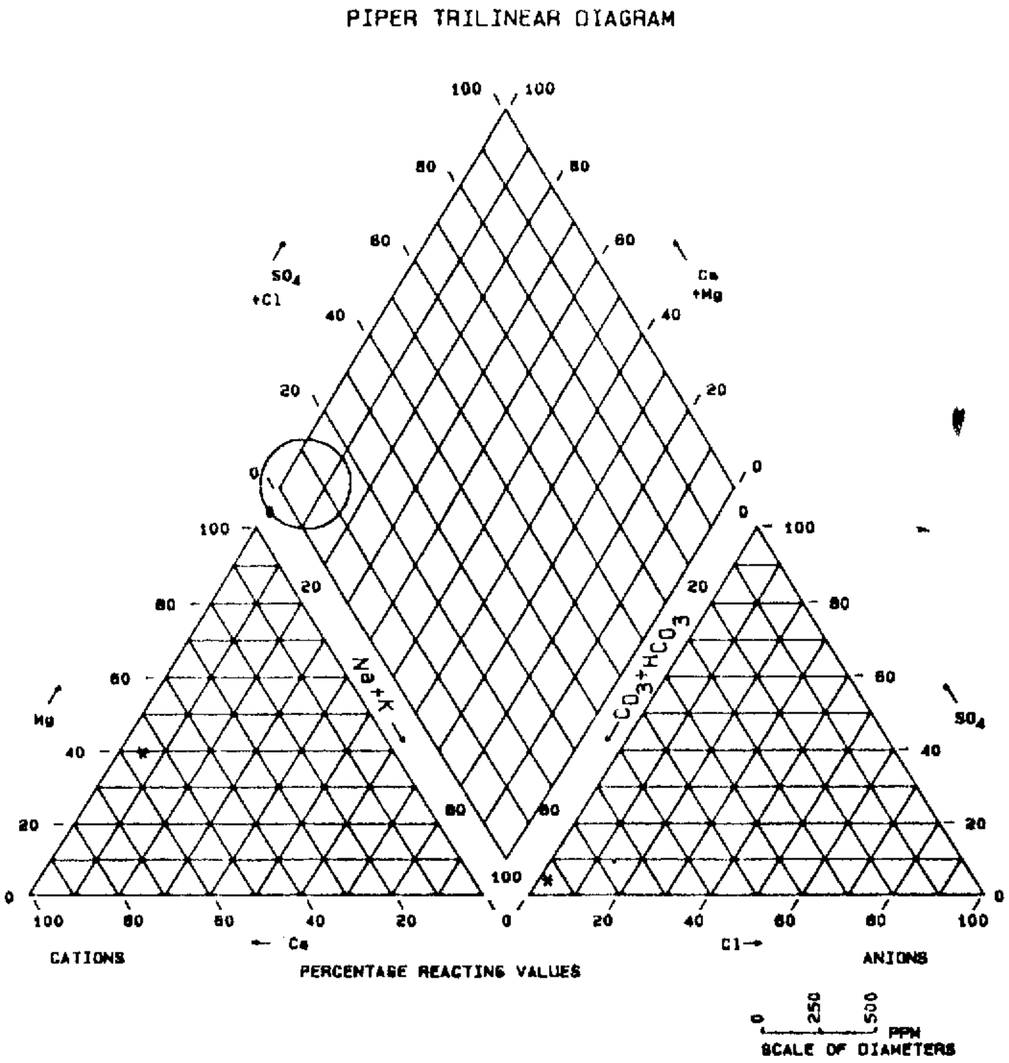
WELL NO.: MA010 08/02/89

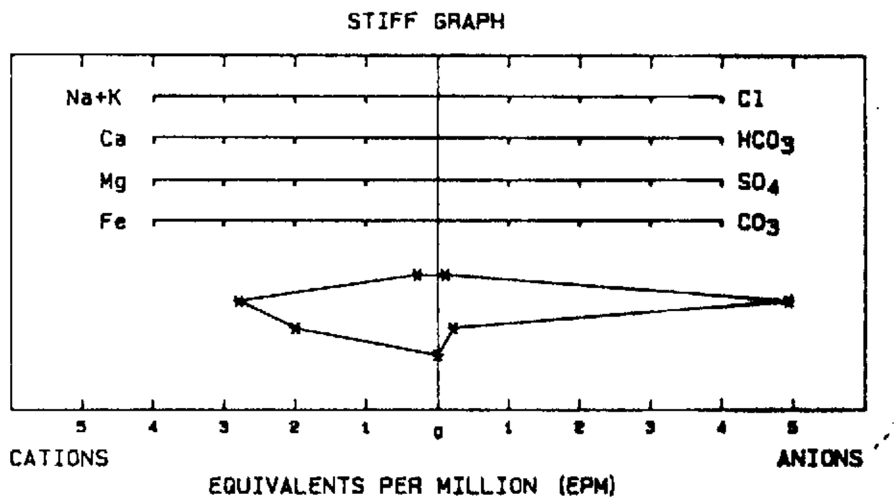
CATIONS	PPM	EPM	% EPM
Ca	73.70	3.68	80.28
Mg	8.91	0.73	16.00
Na+K	5.20	0.17	3.73

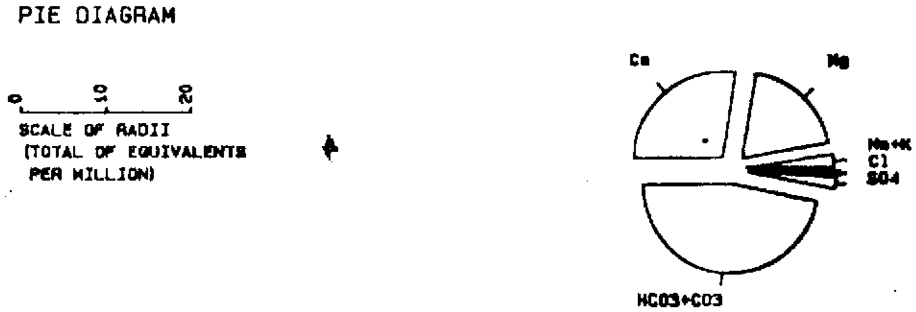
ANIONS	PPM	EPM	% EPM
HCO3+CO3	317.00	5.20	93.64
SO4	12.20	0.25	4.58
Cl	3.50	0.10	1.78

TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 9.55 %
SODIUM ABSORPTION RATION (S.A.R.): 0.06

USAID/DAKAR/SENEGAL







NOTE ERROR (IF ANY) IN CATION/ANION BALANCE HAS BEEN REMOVED

PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 2A	SAMPLE: MA011 08/02/89	CHEMICAL GRAPHS
USAID/DAKAR/SENEGAL		FIGURE: MA011

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2A

WELL NO.: MA011 08/02/89

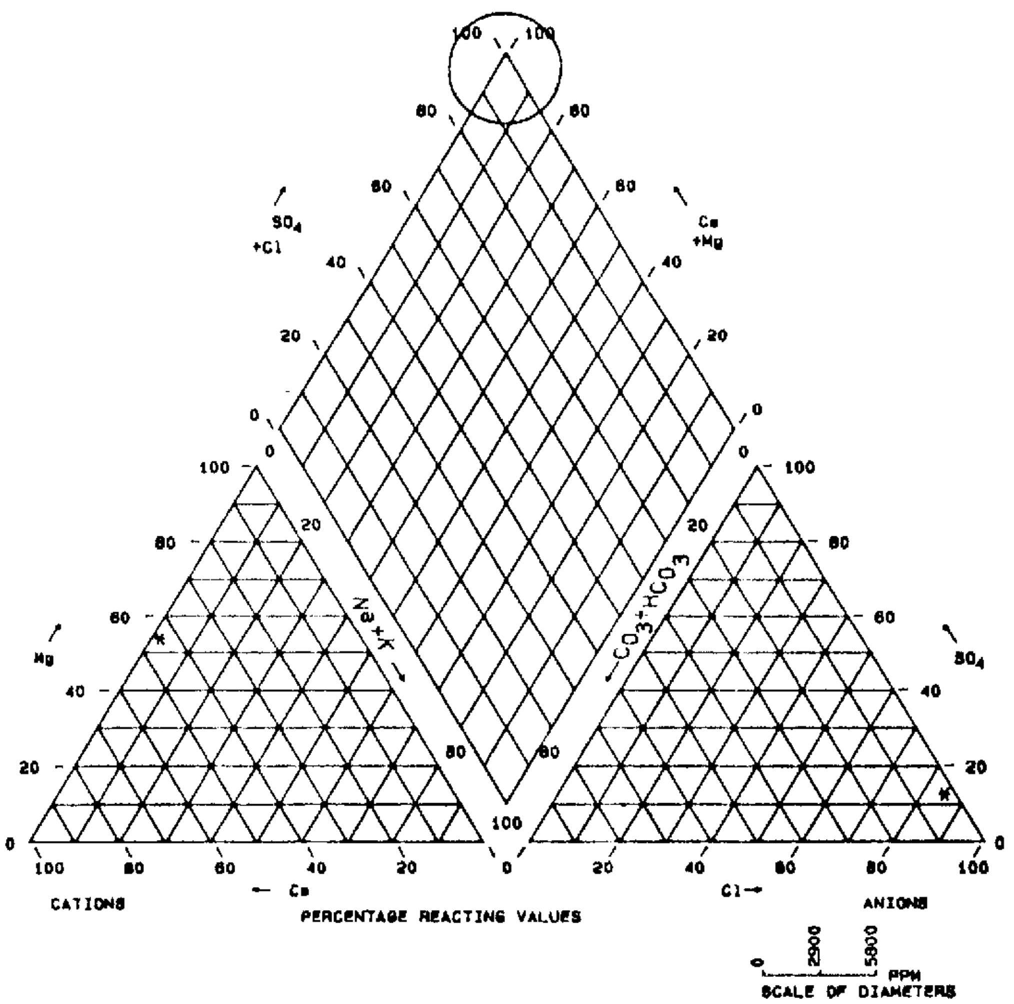
CATIONS	PPM	EPM	% EPM
Ca	56.10	2.80	55.19
Mg	24.26	2.00	39.34
Na+K	7.70	0.28	5.47

ANIONS	PPM	EPM	% EPM
HCO3+CO3	301.00	4.93	93.71
SO4	10.50	0.22	4.15
Cl	4.00	0.11	2.14

TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 1.88 %
SODIUM ABSORPTION RATION (S.A.R.): 0.13

USAID/DAKAR/SENEGAL

PIPER TRILINEAR DIAGRAM



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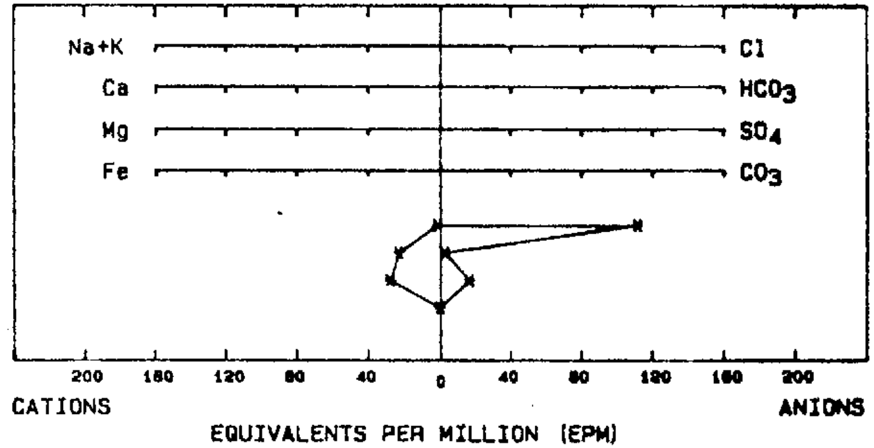
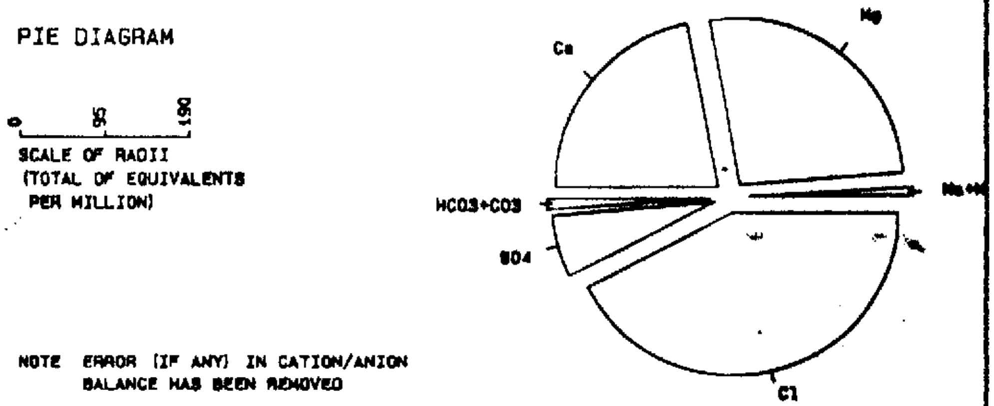




PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2A

SAMPLE: MA012 08/02/89

CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL

FIGURE: MA012

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2A

WELL NO.: MA012 08/02/89.

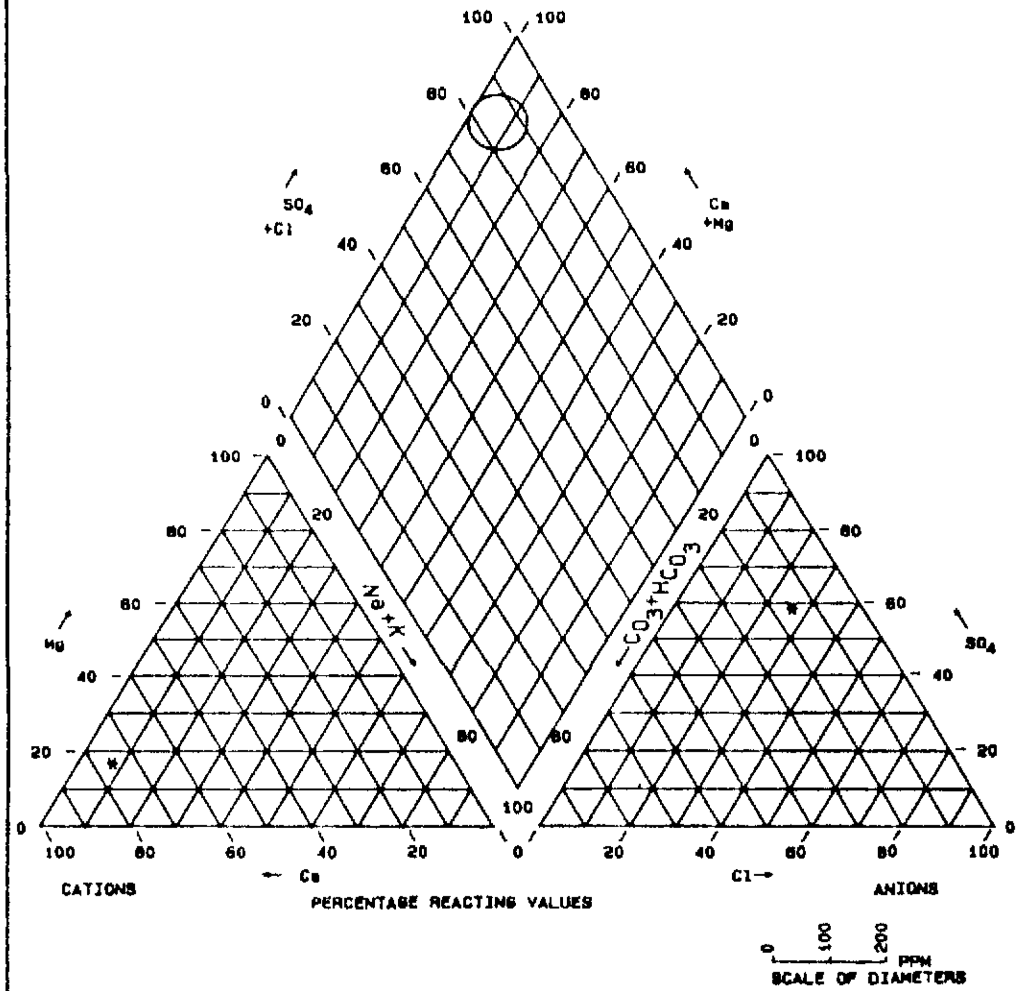
CATIONS	PPM	EPM	% EPM
Ca	458.50	22.88	44.30
Mg	336.84	27.70	53.64
Na+K	40.10	1.06	2.06

ANIONS	PPM	EPM	% EPM
HCO3+CO3	182.00	2.98	2.28
SO4	800.00	16.66	12.71
Cl	3950.00	111.39	85.01

TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 43.46 %
SODIUM ABSORPTION RATION (S.A.R.): 0.02

USAID/DAKAR/SENEGAL

PIPER TRILINEAR DIAGRAM



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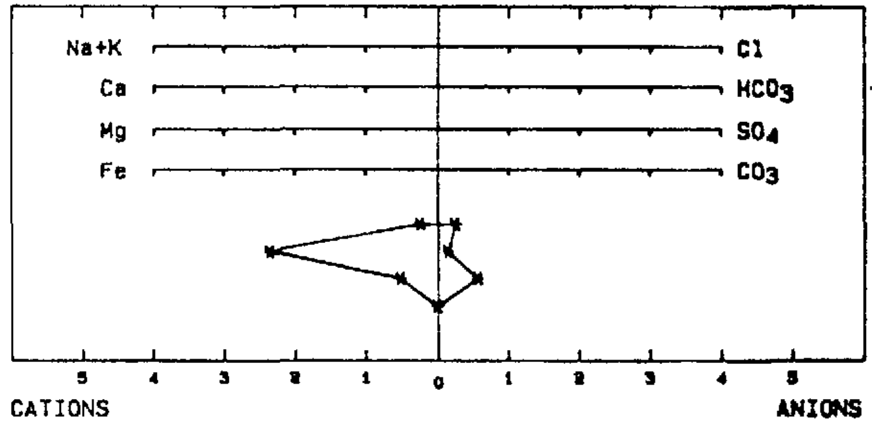


PIE DIAGRAM

SCALE OF RADII
(TOTAL OF EQUIVALENTS
PER MILLION)

NOTE ERROR (IF ANY) IN CATION/ANION
BALANCE HAS BEEN REMOVED

PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 2A	SAMPLE: MA013 08/02/89	CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL — FIGURE: MA013

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2A

WELL NO.: MA013 08/02/89

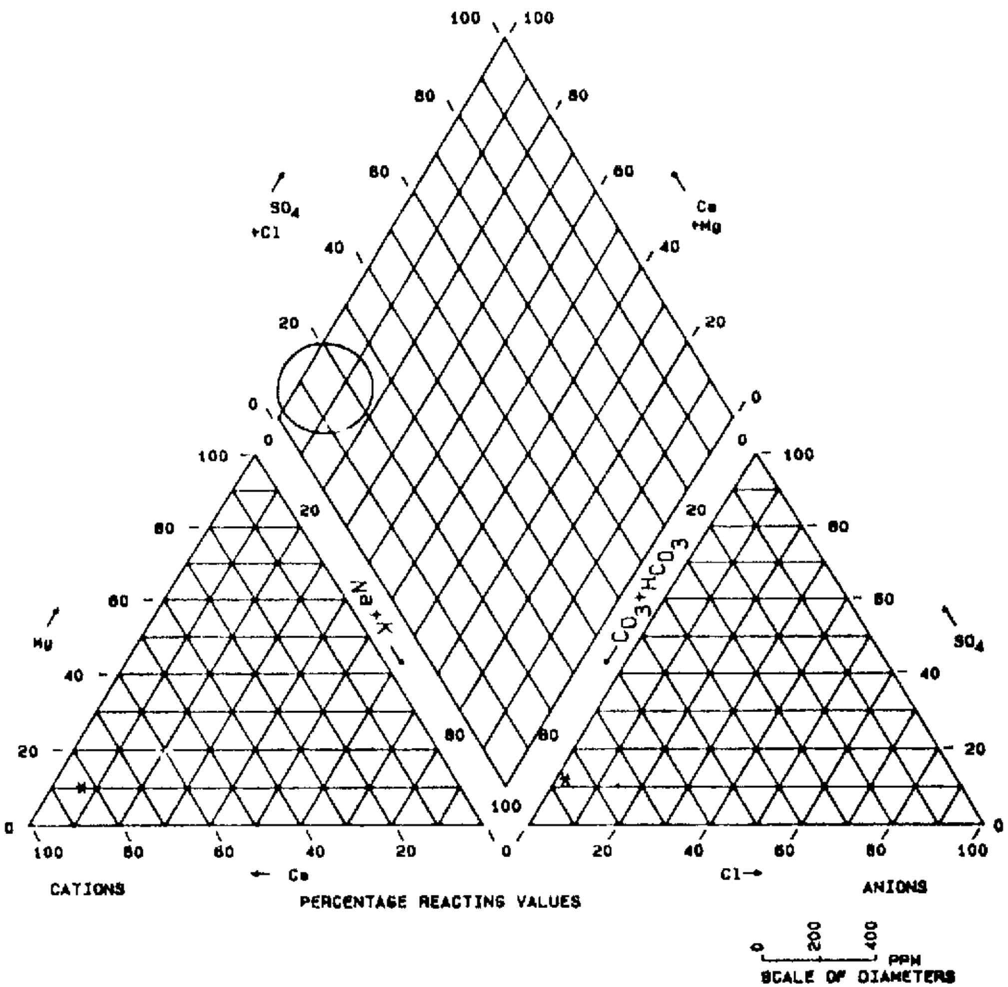
CATIONS	PPM	EPM	% EPM
Ca	47.30	2.36	75.87
Mg	6.28	0.52	16.60
Na+K	6.00	0.23	7.53

ANIONS	PPM	EPM	% EPM
HCO3+CO3	[illegible]	[illegible]	15.31
SO4	27.00	0.56	58.35
Cl	9.00	0.25	26.34

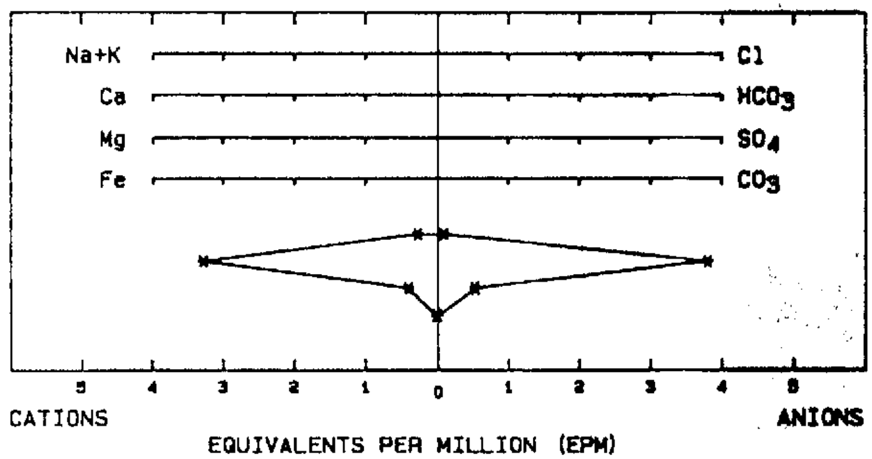
TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 53.75 %
SODIUM ABSORPTION RATION (S.A.R.): 0.16

USAID/DAKAR/SENEGAL

PIPER TRILINEAR DIAGRAM

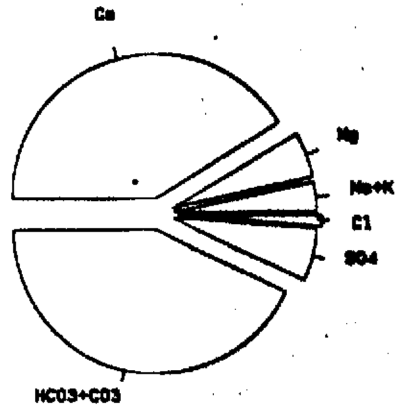


STIFF GRAPH



PIE DIAGRAM

0 5 10
SCALE OF RADII
(TOTAL OF EQUIVALENTS
PER MILLION)



NOTE ERROR (IF ANY) IN CATION/ANION BALANCE HAS BEEN REMOVED

PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 2A	SAMPLE: MA014 08/02/89	CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL — FIGURE: MA014

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2A

WELL NO.: MA014 08/02/89

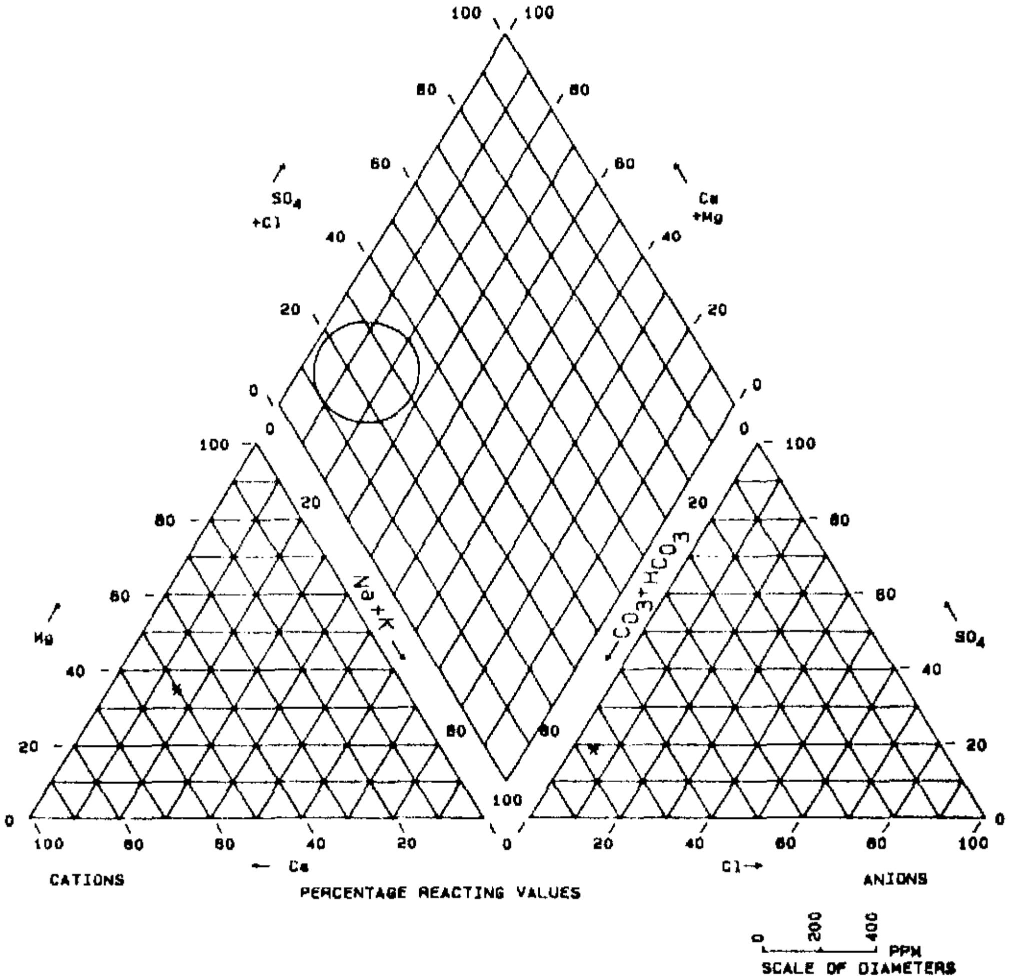
CATIONS	PPM	EPM	% EPM
Ca	65.70	3.28	83.07
Mg	4.84	0.40	10.09
Na+K	7.40	0.27	6.84

ANIONS	PPM	EPM	% EPM
HCO3+CO3	232.00	3.80	85.71
SO4	25.70	0.54	12.06
Cl	3.50	0.10	2.22

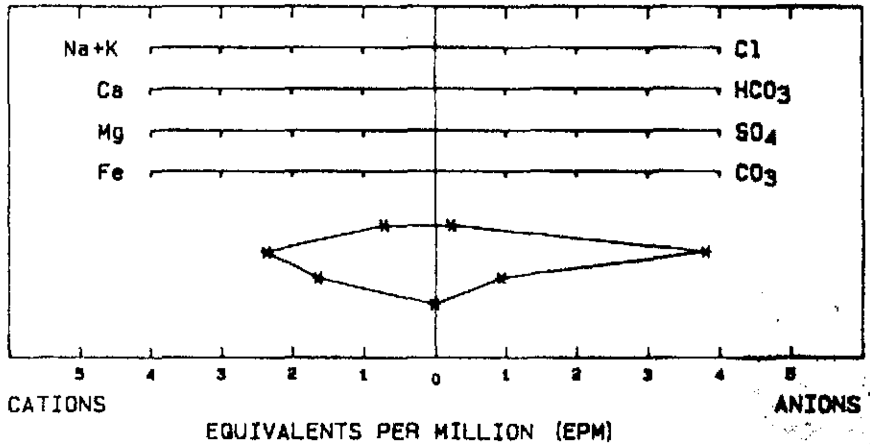
TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 5.67 %
SODIUM ABSORPTION RATION (S.A.R.): 0.14

USAID/DAKAR/SENEGAL

PIPER TRILINEAR DIAGRAM

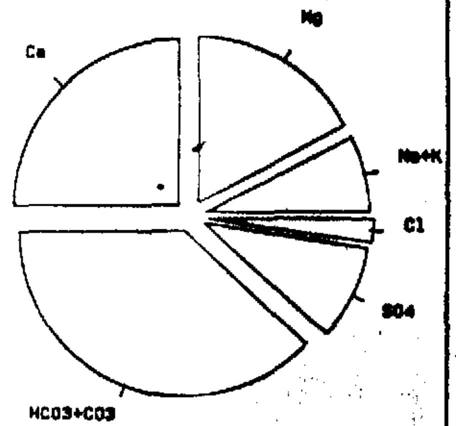


STIFF GRAPH



PIE DIAGRAM

0 5 10
SCALE OF RADII
(TOTAL OF EQUIVALENTS PER MILLION)



NOTE ERROR (IF ANY) IN CATION/ANION BALANCE HAS BEEN REMOVED

PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 1B

SAMPLE: MA015 08/02/89

CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL

FIGURE: MA015

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 1B

WELL NO.: MA015 08/02/89

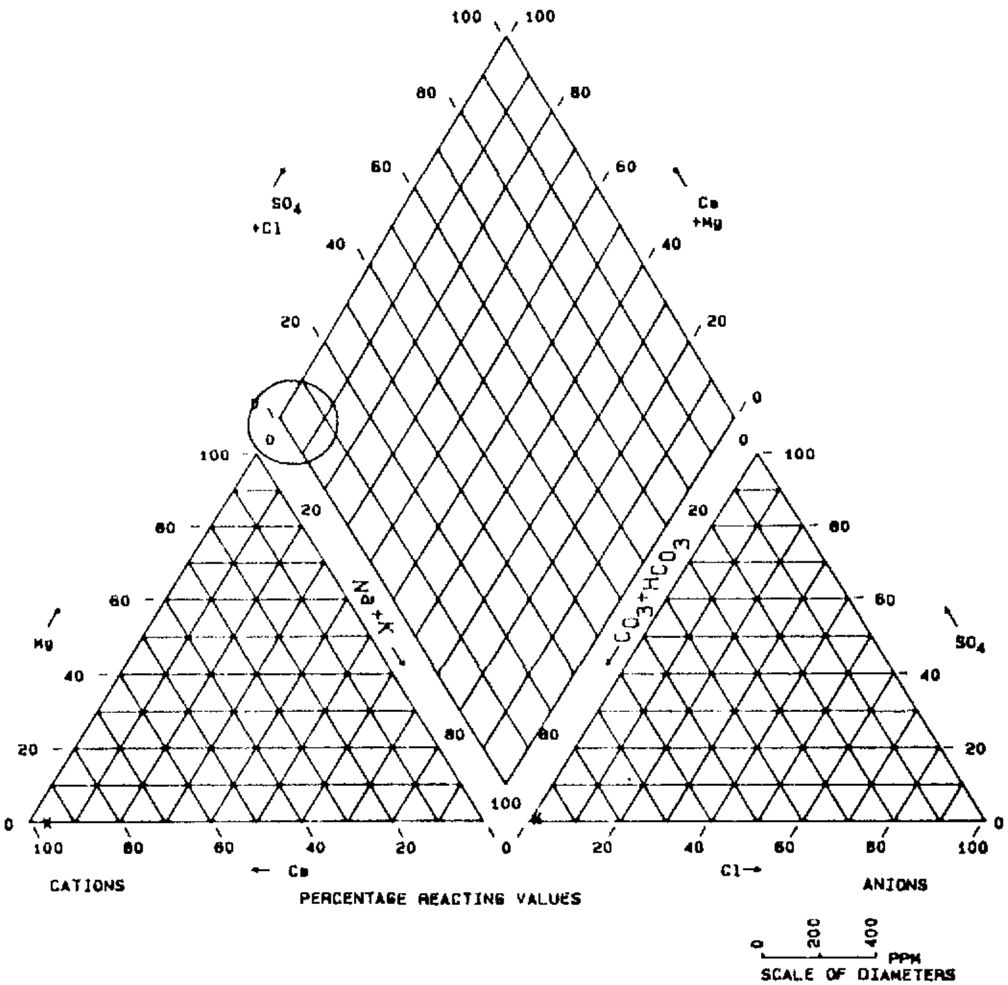
CATIONS	PPM	EPM	% EPM
Ca	47.30	2.36	50.15
Mg	19.88	1.63	34.74
Na+K	20.80	0.71	15.11

ANIONS	PPM	EPM	% EPM
HCO3+CO3	232.00	3.80	76.37
SO4	45.00	0.94	18.82
Cl	8.50	0.24	4.61

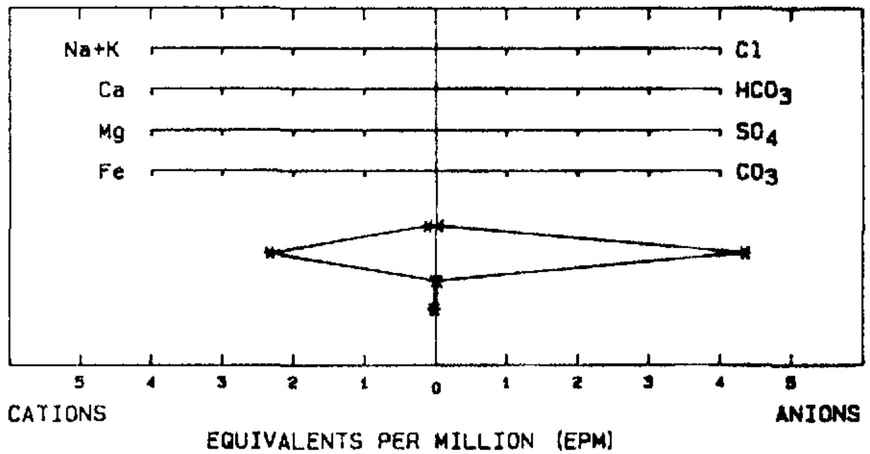
TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 2.92 %
SODIUM ABSORPTION RATION (S.A.R.): 0.31

USAID/DAKAR/SENEGAL

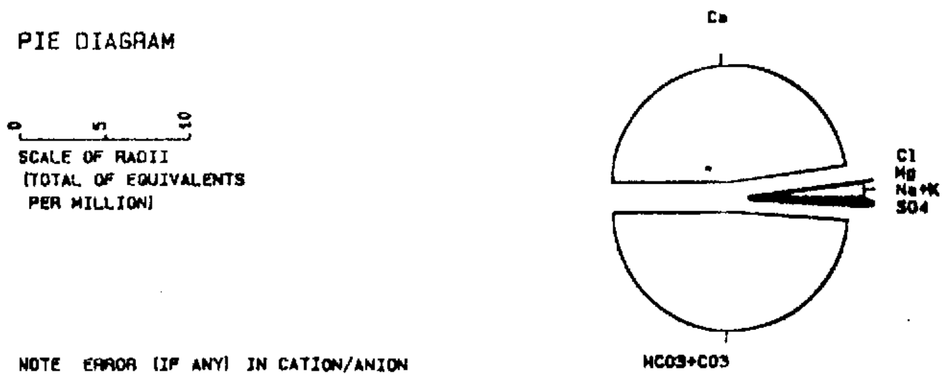
PIPER TRILINEAR DIAGRAM



STIFF GRAPH



PIE DIAGRAM



NOTE ERROR (IF ANY) IN CATION/ANION BALANCE HAS BEEN REMOVED

PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 1B	SAMPLE: MA016 08/02/89	CHEMICAL GRAPHS
USAID/DAKAR/SENEGAL		FIGURE: MA016

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 1B

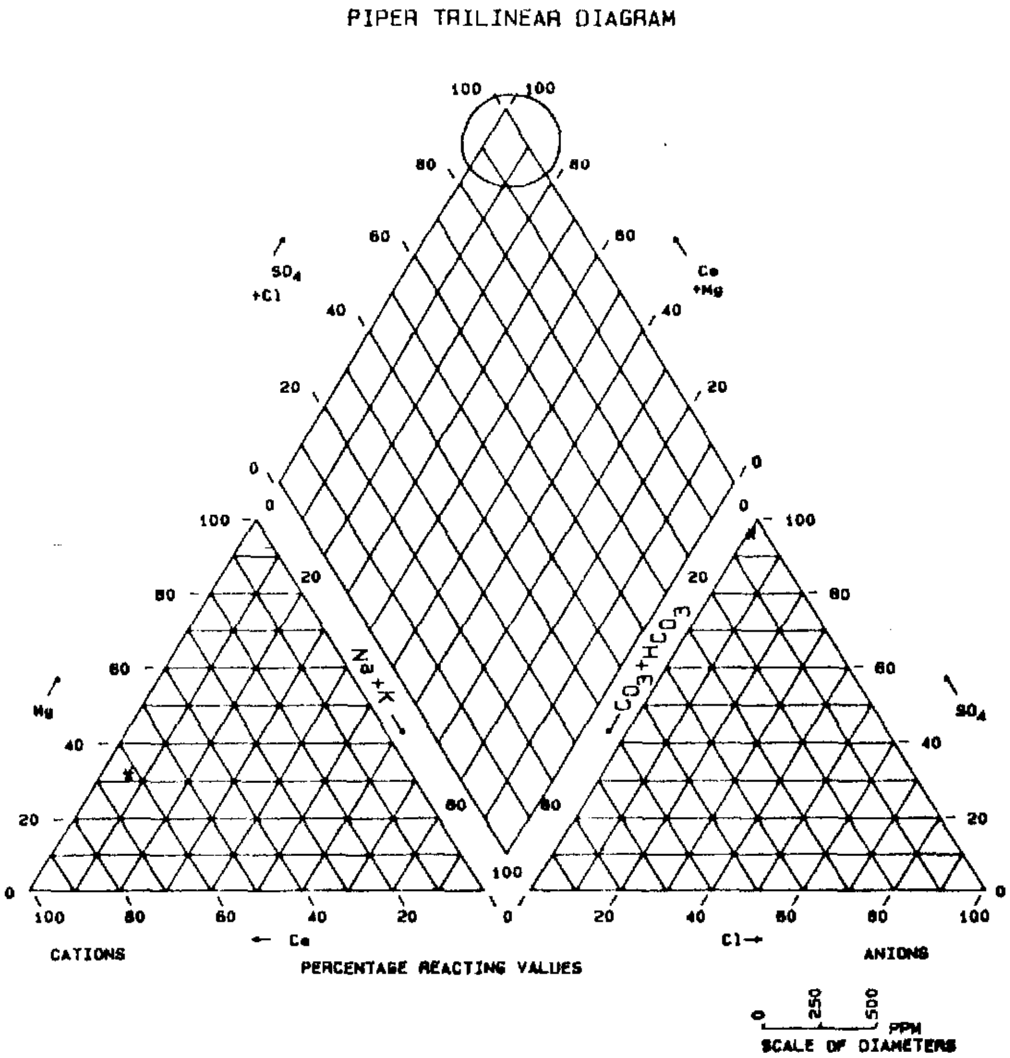
WELL NO.: MA016 08/02/89

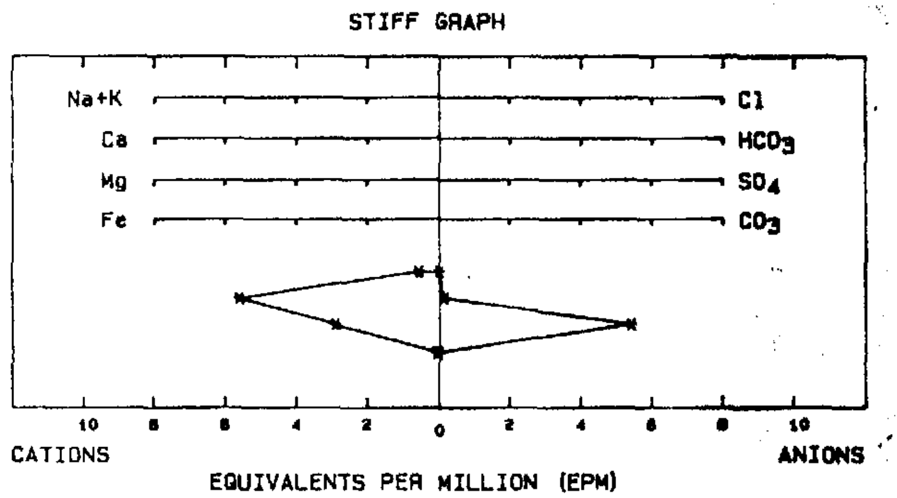
CATIONS	PPM	EPM	% EPM
Ca	46.50	2.32	95.84
Mg	0.02	0.00	0.07
Na+K	2.40	0.10	4.09

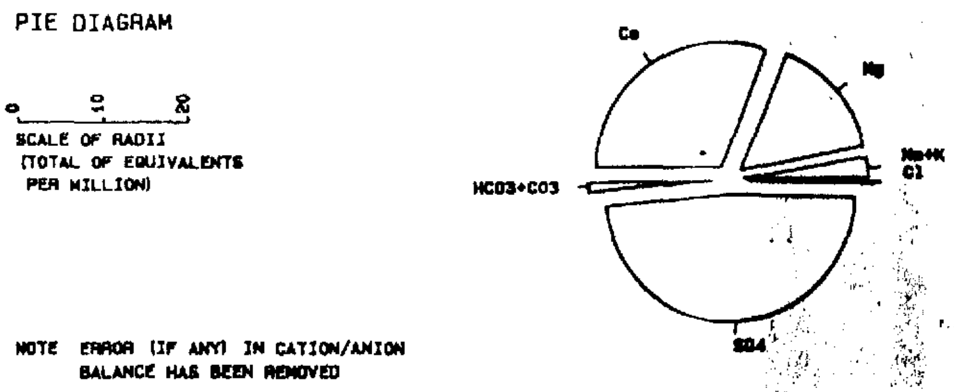
ANIONS	PPM	EPM	% EPM
HCO3+CO3	266.00	4.36	97.80
SO4	2.00	0.04	0.93
Cl	2.00	0.06	1.27

TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 29.06 %
SODIUM ABSORPTION RATION (S.A.R.): 0.08

USAID/DAKAR/SENEGAL







PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 1B

SAMPLE: MA017 08/02/89

CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL

FIGURE: MA017

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 1B

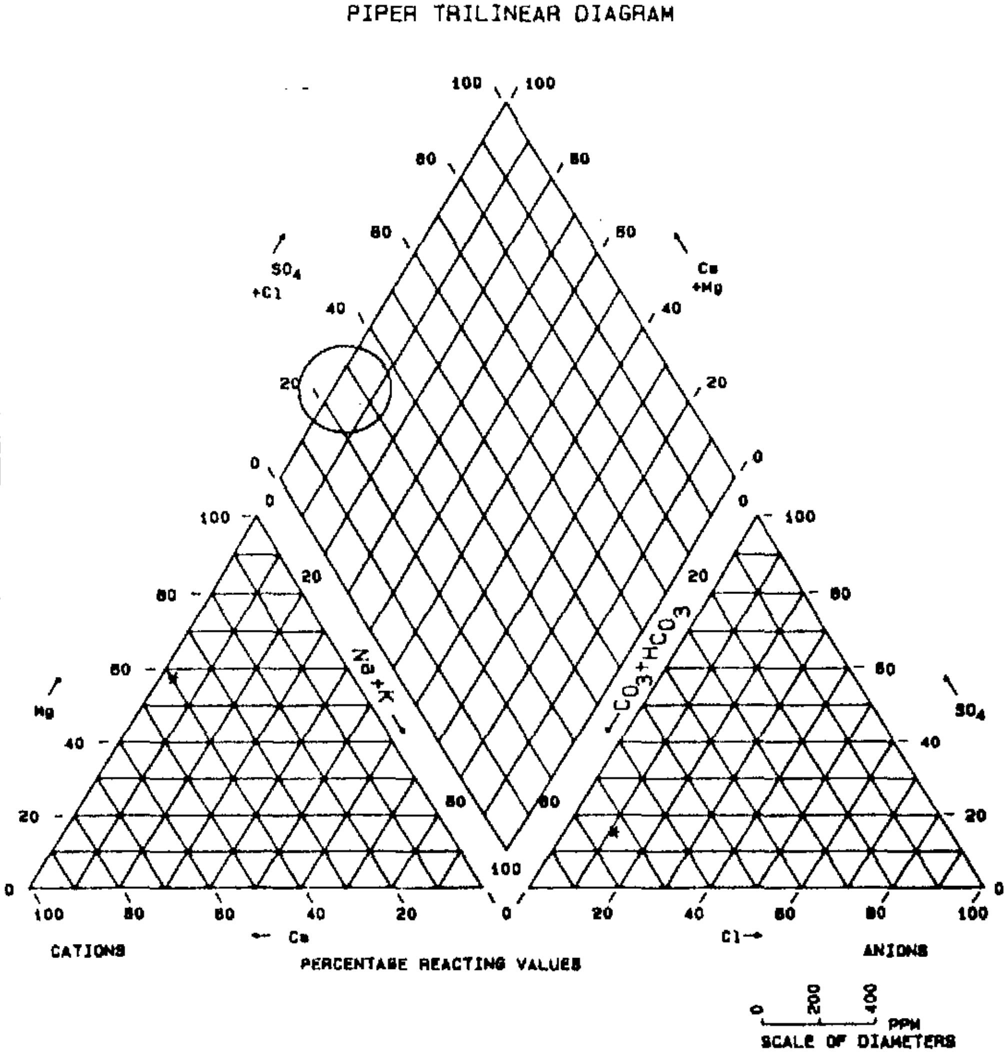
WELL NO.: MA017 08/02/89

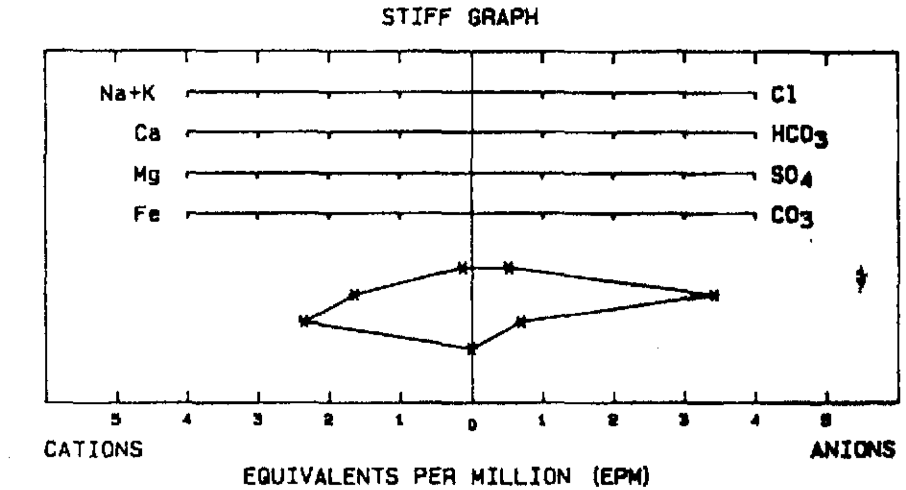
CATIONS	PPM	EPM	% EPM
Ca	112.20	5.60	62.10
Mg	35.05	2.88	31.97
Na+K	13.90	0.53	5.93

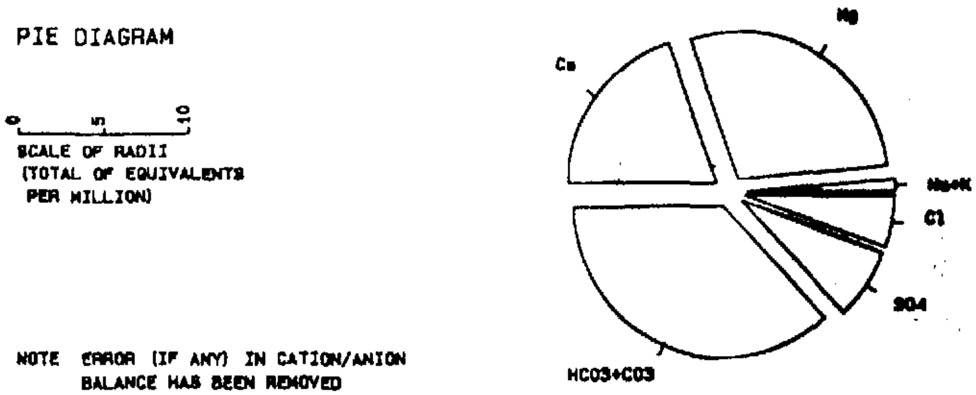
ANIONS	PPM	EPM	% EPM
HCO3+CO3	10.70	0.18	3.11
SO4	260.00	5.41	96.13
Cl	1.50	0.04	0.75

TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 23.35 %
SODIUM ABSORPTION RATION (S.A.R.): 0.21

USAID/DAKAR/SENEGAL







PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2C

SAMPLE: MA018 08/02/89

CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL

FIGURE: MA018

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2C

WELL NO.: MA018 08/02/89

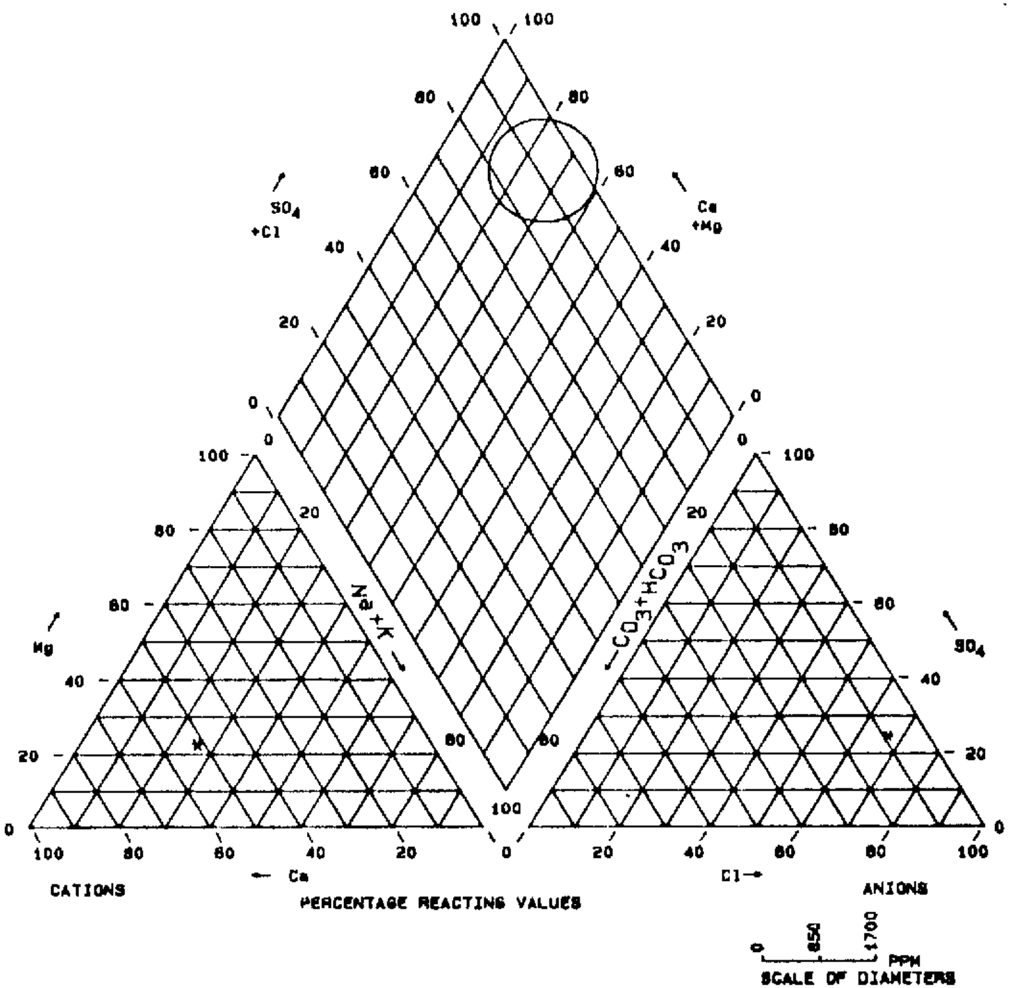
CATIONS	PPM	EPM	% EPM
Ca	32.80	1.64	39.73
Mg	28.68	2.36	57.25
Na+K	3.40	0.12	3.02

ANIONS	PPM	EPM	% EPM
HCO3+CO3	209.00	3.43	73.69
SO4	33.70	0.70	15.09
Cl	18.50	0.52	11.22

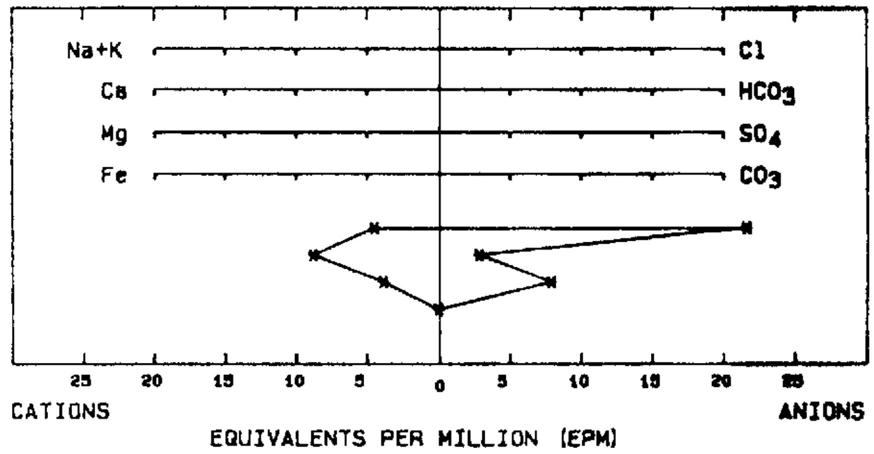
TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 6.05 %
SODIUM ABSORPTION RATION (S.A.R.): 0.06

USAID/DAKAR/SENEGAL

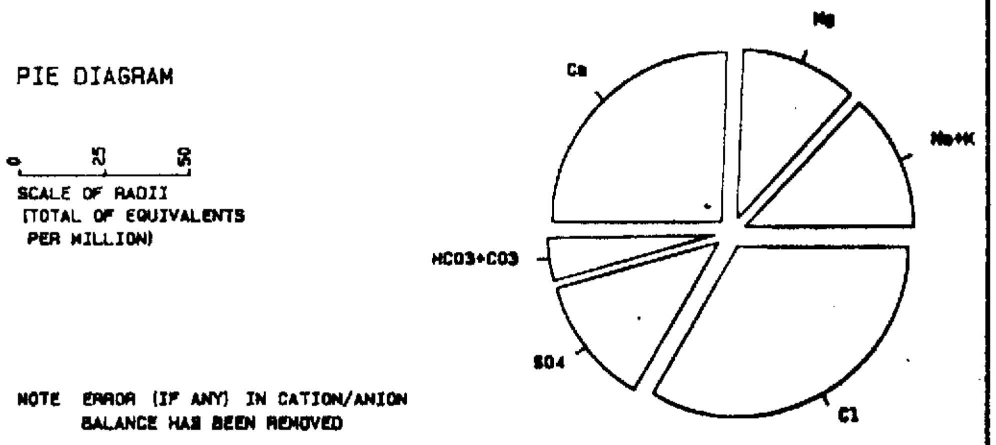
PIPER TRILINEAR DIAGRAM



STIFF GRAPH



PIE DIAGRAM



NOTE ERROR (IF ANY) IN CATION/ANION BALANCE HAS BEEN REMOVED

PROJECT: OMVS/USAID FILE: 625-0958 LOCATION: BAFOULABE 2C	SAMPLE: MA019 08/02/89	CHEMICAL GRAPHS
USAID/DAKAR/SENEGAL		FIGURE: MA019

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2C

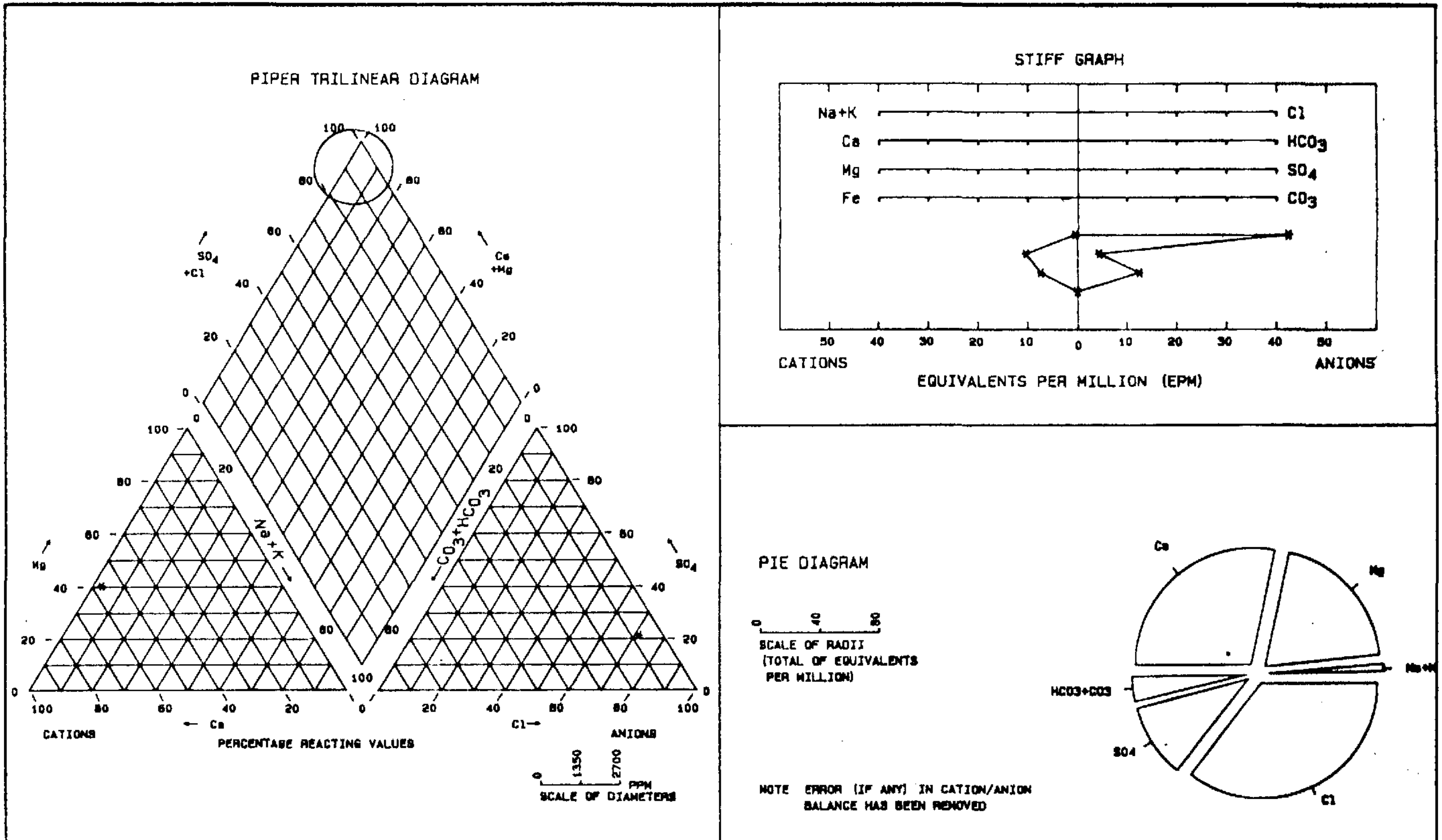
WELL NO.: MA019 08/02/89

CATIONS	PPM	EPM	% EPM
Ca	177.10	8.84	51.38
Mg	47.06	3.87	22.50
Na+K	105.50	4.49	26.11

ANIONS	PPM	EPM	% EPM
HCO3+CO3	172.00	2.82	8.73
SO4	380.00	7.91	24.49
Cl	765.00	21.57	66.78

TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 30.50 %
SODIUM ABSORPTION RATION (S.A.R.): 1.73

USAID/DAKAR/SENEGAL



PROJECT: OMVS/USAID
FILE: 625-0958
LOCATION: BAFOULABE 2C

SAMPLE: MA020 08/02/89

CHEMICAL GRAPHS

USAID/DAKAR/SENEGAL

FIGURE: MA020

CHEMISTRY ANALYSIS

PROJECT: OMVS/USAID FILE: 625-0958
LOCATION: BAFOULABE 2C

WELL NO.: MA020 08/02/89

CATIONS	PPM	EPM	% EPM
Ca	206.00	10.28	56.85
Mg	88.78	7.30	40.38
Na+K	17.50	0.50	2.77

ANIONS	PPM	EPM	% EPM
HCO3+CO3	272.00	4.46	7.52
SO4	600.00	12.49	21.08
Cl	1500.00	42.30	71.39

TOTAL DISSOLVED SOLIDS:
ERROR IN CATION/ANION BALANCE: 53.24 %
SODIUM ABSORPTION RATION (S.A.R.): 0.04

USAID/DAKAR/SENEGAL

ORGANISATION POUR LA MISE EN VALEUR DU FLEUVE SENEGAL OMVS
DEPARTEMENT DES INFRASTRUCTURES REGIONALES DIR
GROUNDWATER MONITORING UNIT
OMVS/USAID PROJECT 625-0958

HYDROGEOLOGICAL REPERTOIRE

TOPOGRAPHIC MAP 1:200,000

27 BAFOULABE

ANNEX #4

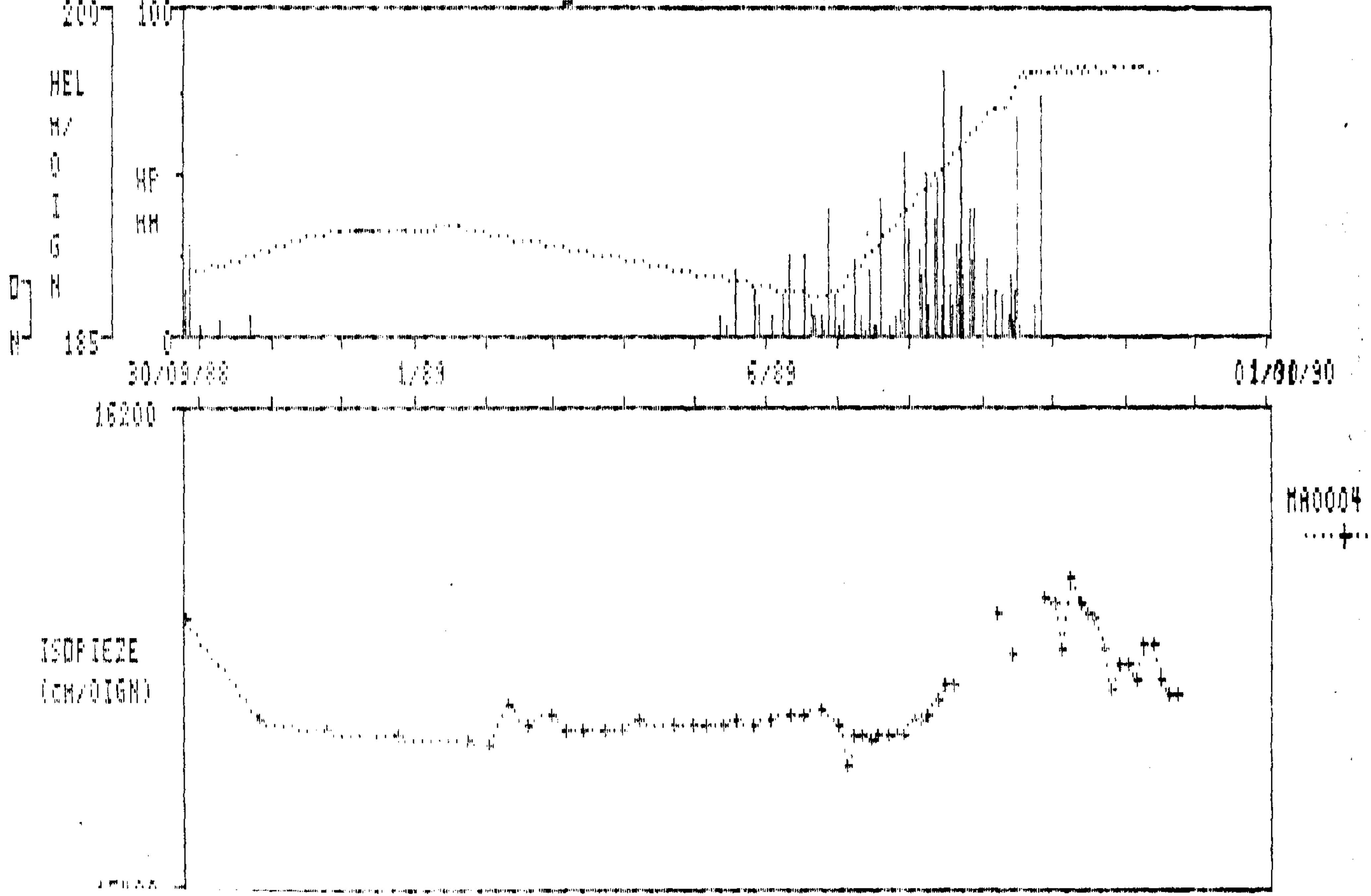
GES - GRAPHICS

PIEZOMETRIC VARIATIONS
AS A FUNCTION
OF TIME

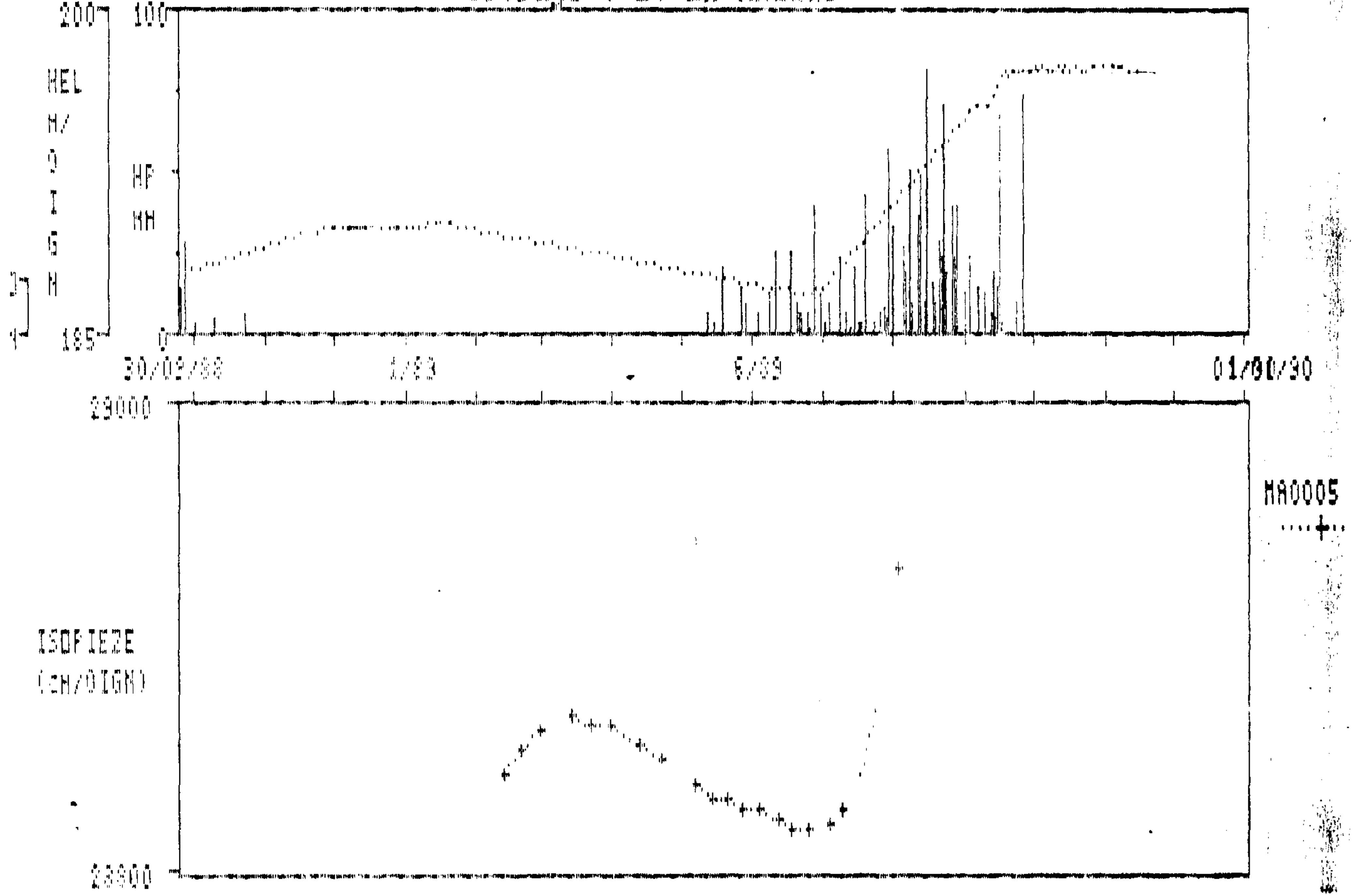
OBSERVATION PERIOD

9/30/88 to 01/01/90

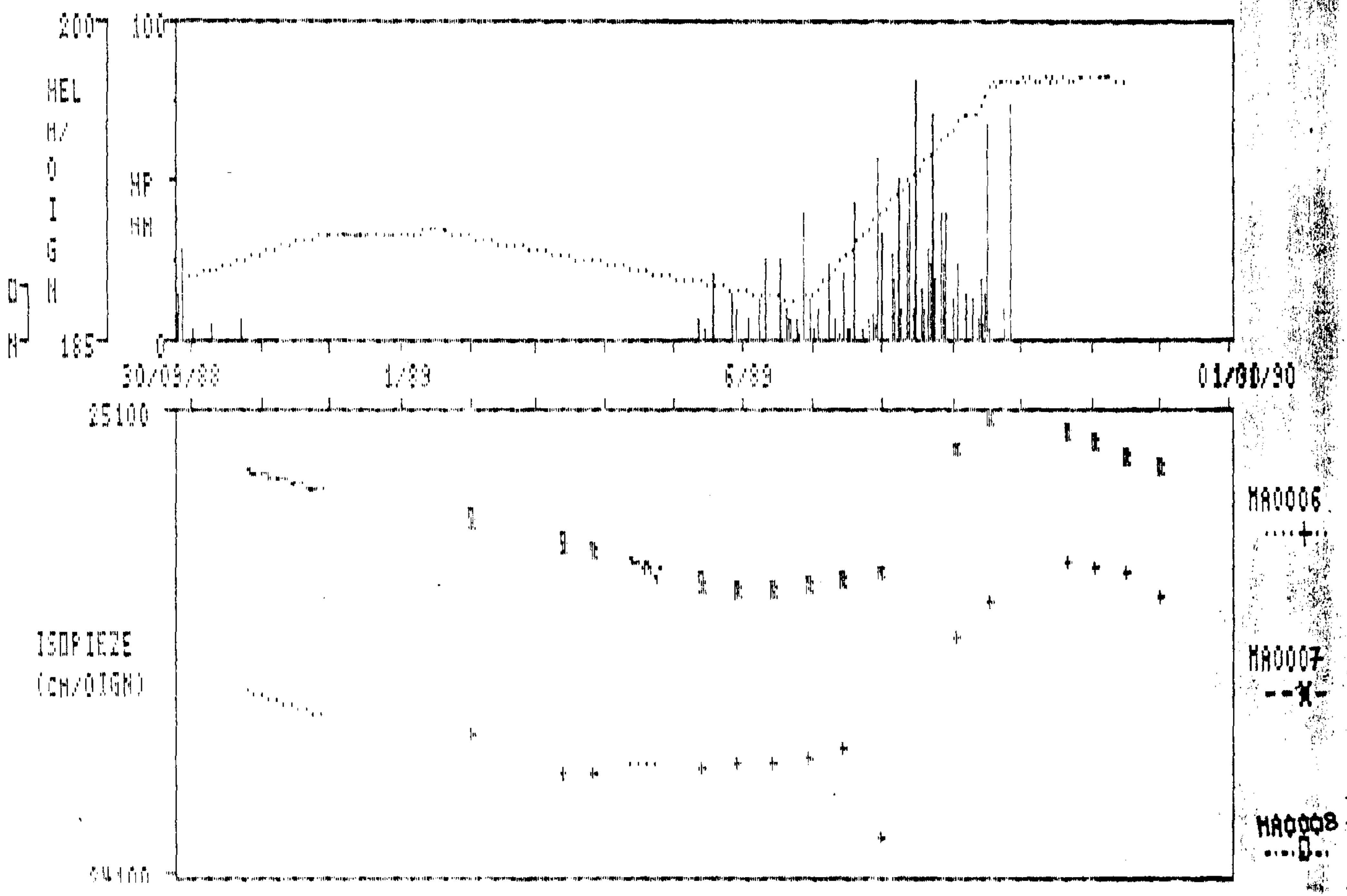
Graphique Piézométrie-fct-Temps
Ouvrage : 27-2A-MA0004-



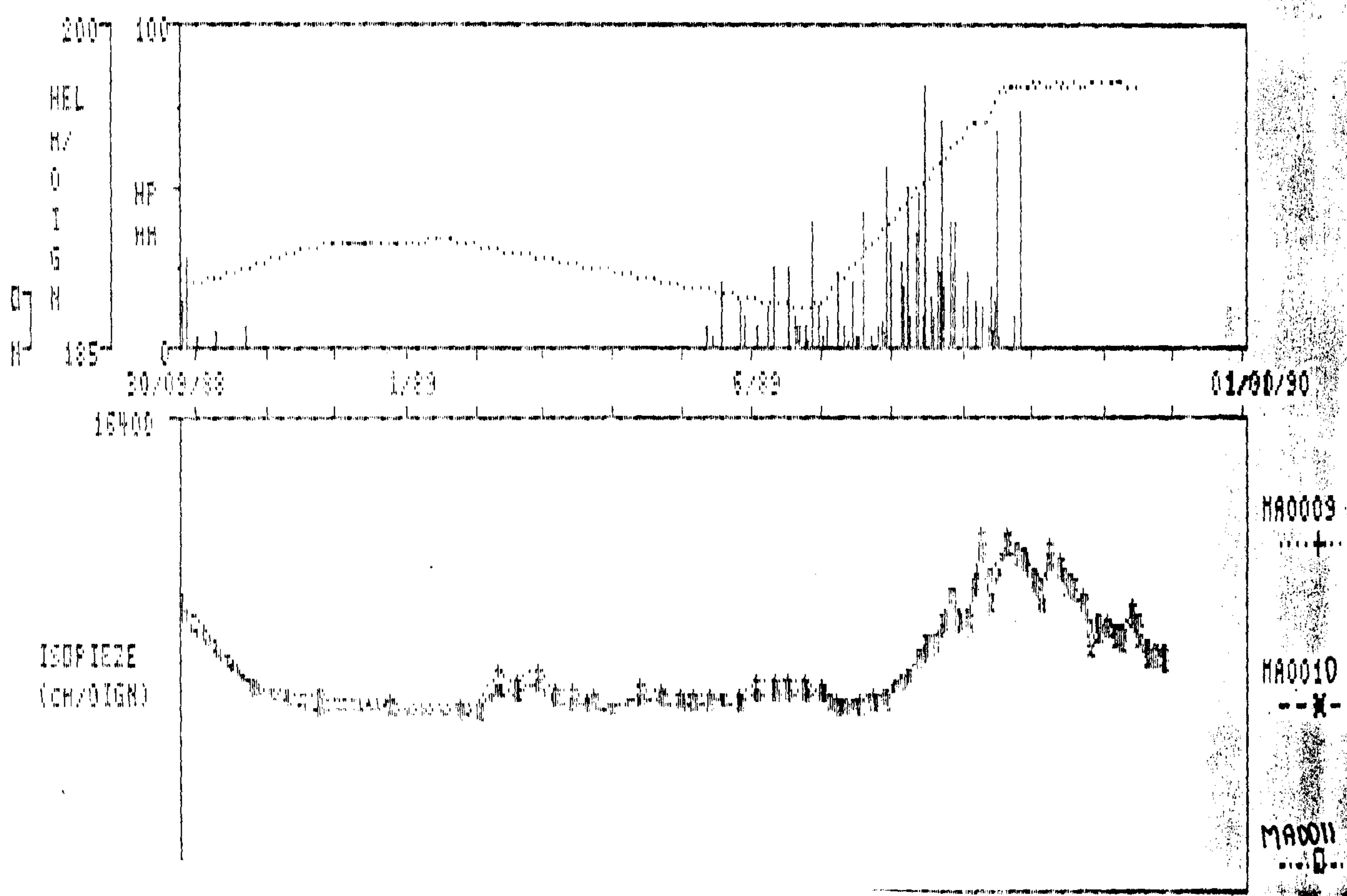
Graphique Piézométrie-fct-Temps
Ouvrage : 27-2A-MA0005-



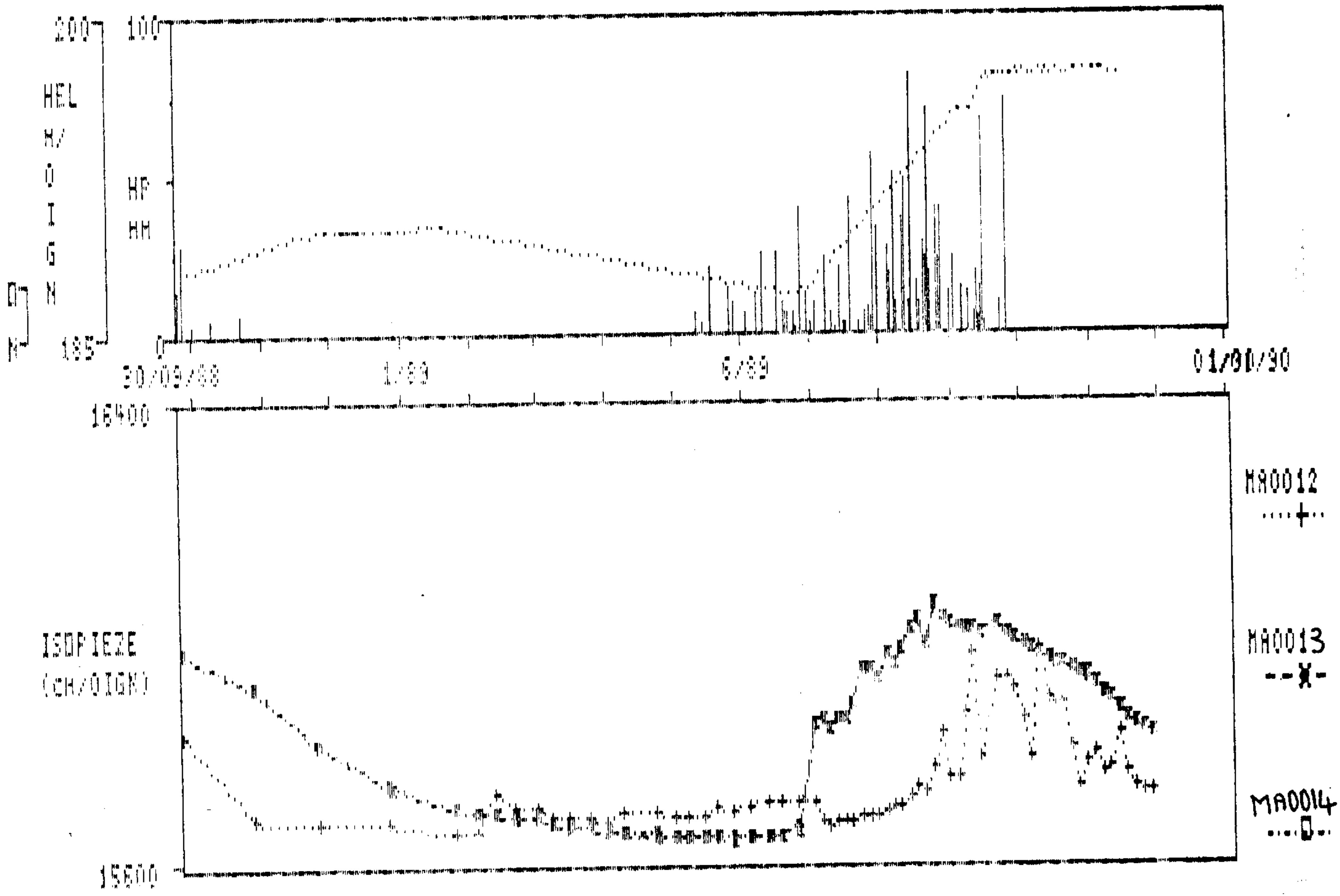
Graphique Piézométrie-fct-Temps



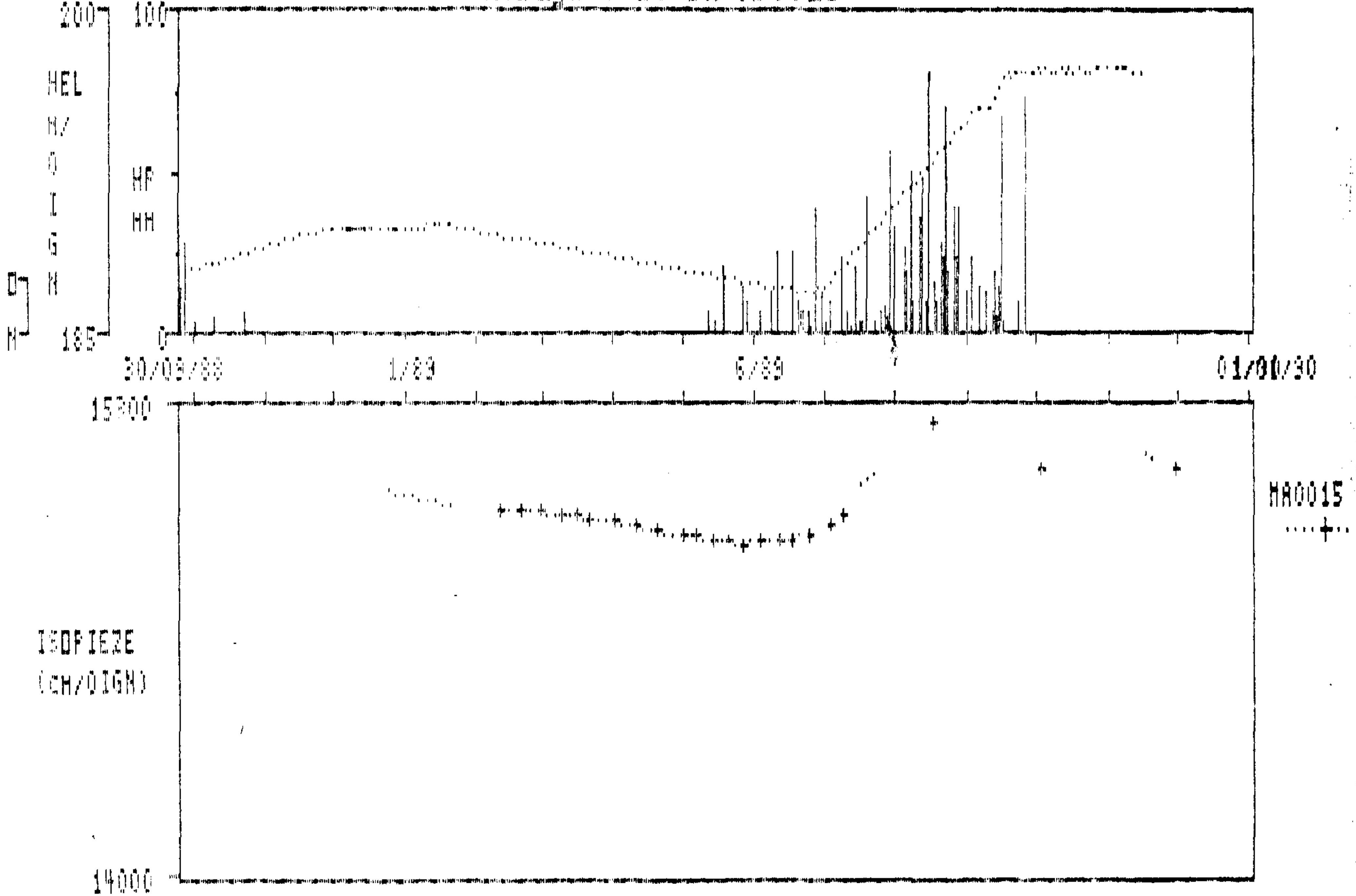
Graphique Piézométrie-fct-Temps



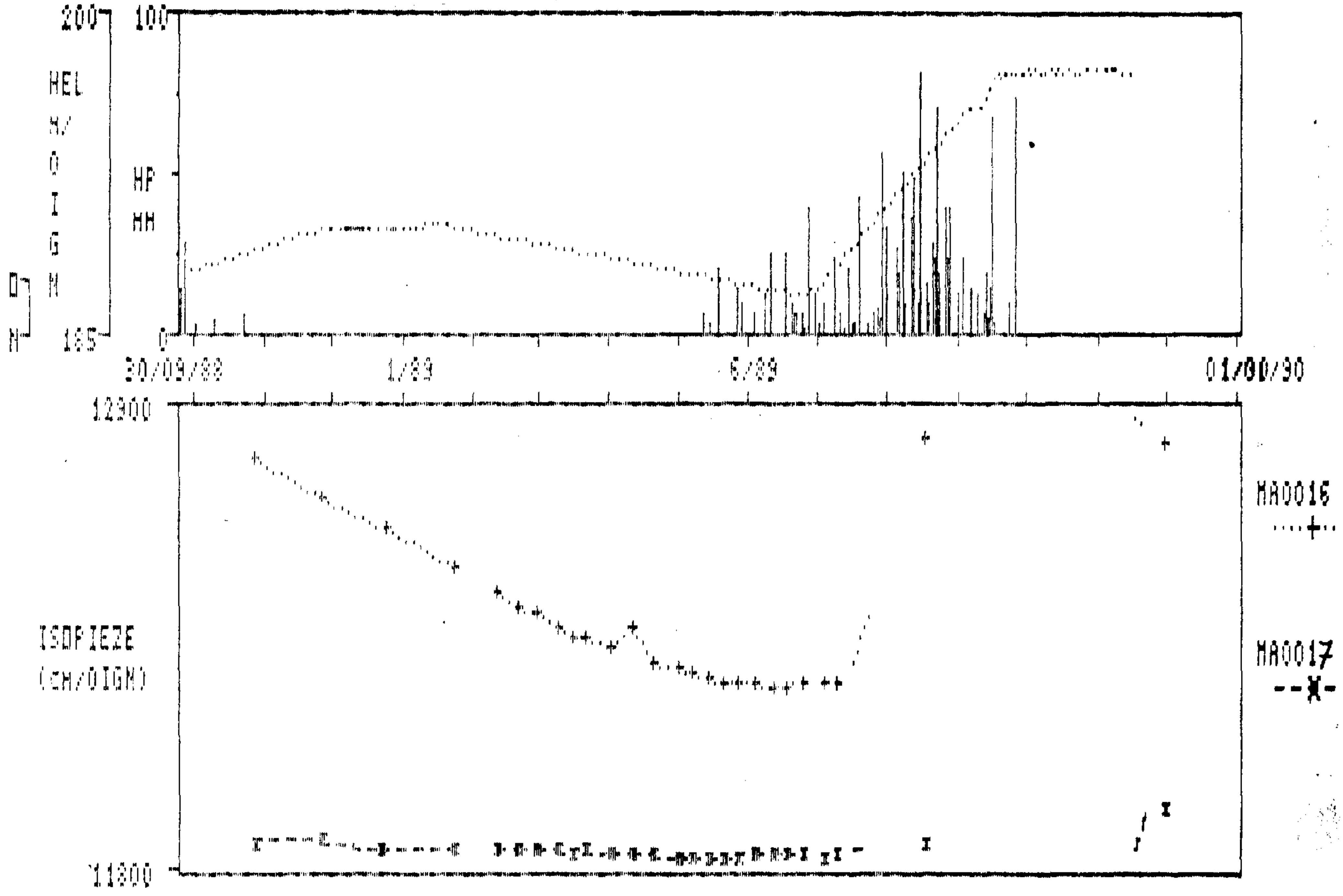
Graphique Piézométrie-fct-Temps



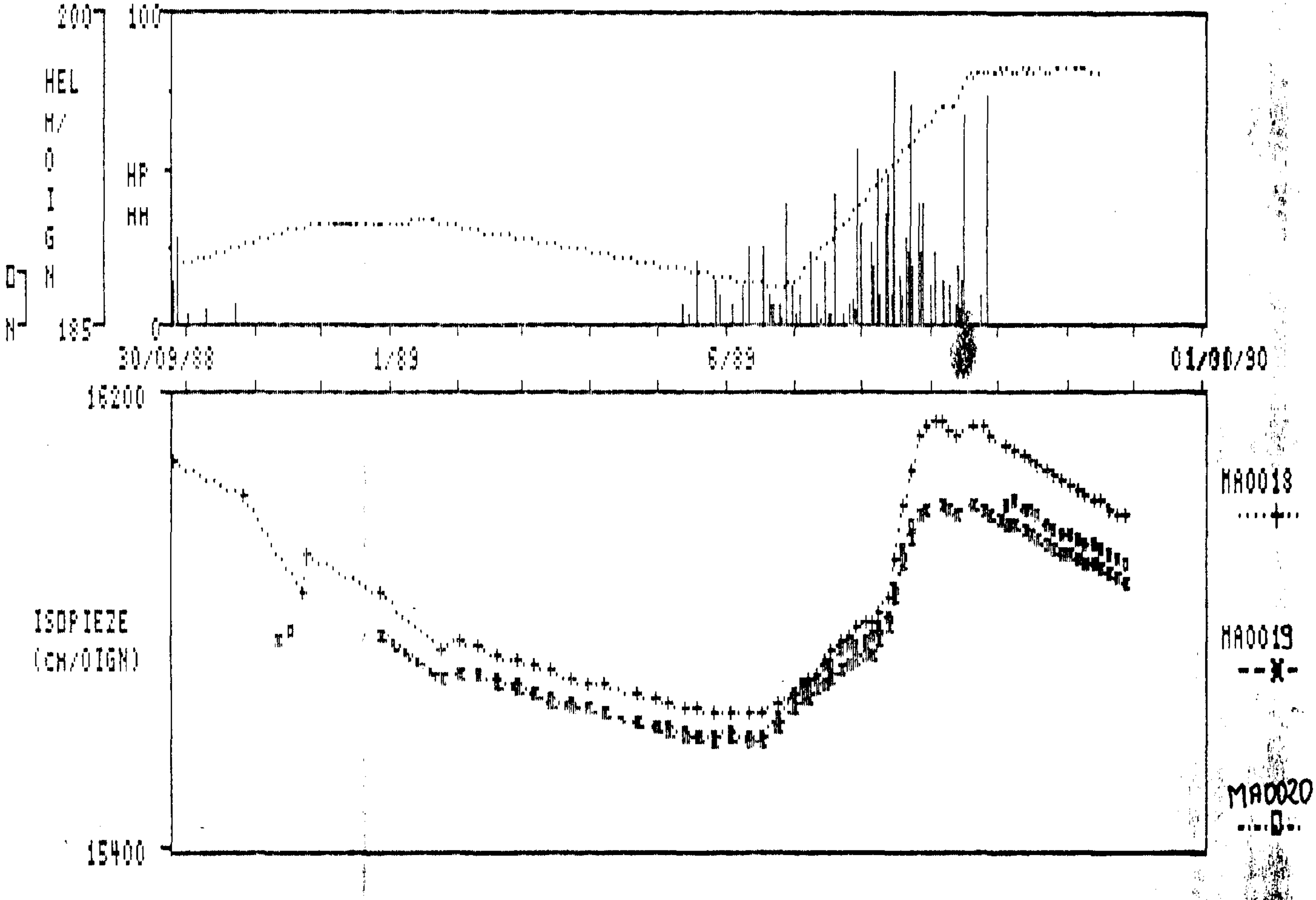
Graphique Piézométrie-fct-Temps
Ouvrage : 27-2A-MA0015-



Graphique Piézométrie-fct-Temps



Graphique Piézométrie-fct-Temps



ORGANISATION POUR LA MISE EN VALEUR DU FLEUVE SENEGAL OMVS
DEPARTEMENT DES INFRASTRUCTURES REGIONALES DIR
GROUNDWATER MONITORING UNIT
OMVS/USAID PROJECT 625-0958

HYDROGEOLOGICAL REPERTOIRE

TOPOGRAPHIC MAP 1:200,000

27 BAFOULABE

ANNEX 5

HYDROLOGICAL PARAMETERS

OF

MANANTALI DAM

OBSERVATION PERIOD

1987-1989

TABLE OF CONTENTS

1 Data

In this report, hydrological data are presented and analyzed for the period from July 1987 to December 1989.

OMVS personnel at Manantali Dam record the water levels in the reservoir of the dam and in the stilling basin at the foot of the dam on a daily basis. They calculate the daily discharge from the dam as a function of the gate opening and the level of water in the reservoir. The volume of water in the reservoir, corresponding to its level, is read from a graph or table. These data have been recorded since July 18, 1987 except for the level in the stilling basin which has been recorded since May 1, 1988. The daily data which are analyzed here are annexed to this report. The monthly average values of the aforementioned data are presented in the following table.

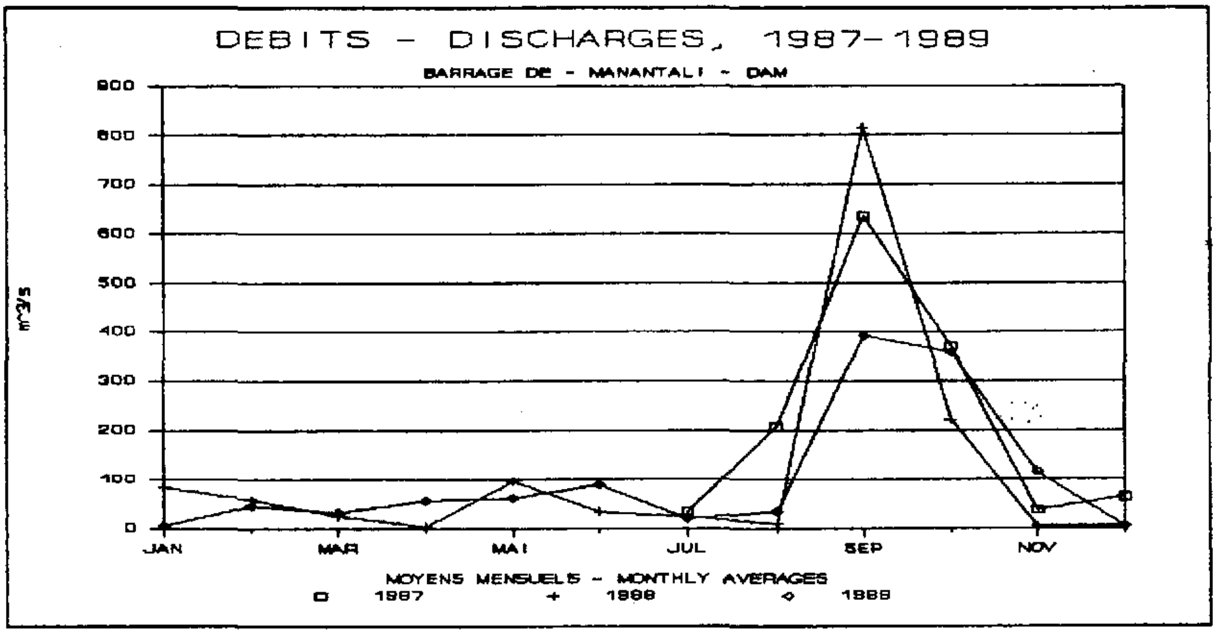
DONNEES HYDROLOGIQUES DU BARRAGE ET RESERVOIR DE MANANTALI
MANANTALI DAM AND RESERVOIR HYDROLOGICAL DATA
SOURCE: OMVS, BARRAGE DE MANANTALI

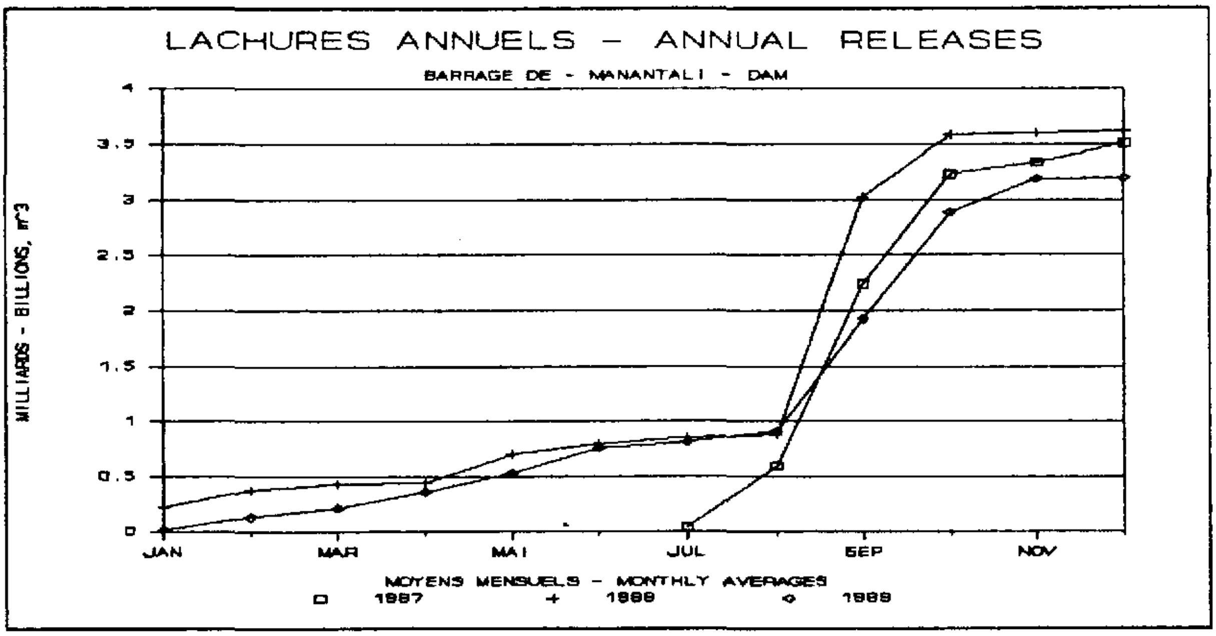
MOYENS MENSUELS - MONTHLY AVERAGES	<---RESERVOIR--->				VOLUME LACHE
	COTE LEVEL	VOLUME	COTE AVAL DOWNSTREAM LEVEL	DEBIT DU BARRAGE DISCHARGE	CUMULATIF RELEASED CUMULATIVE
MOIS	(m IGN)	(m^3 E9)	(m IGN)	(m^3/s)	(m^3 E9)
Jul-87	160.47	0.045	NA	34.6	0.042
Aug-87	169.74	0.532	NA	206.1	0.594
Sep-87	176.10	1.498	NA	635.4	2.241
Oct-87	177.68	1.782	NA	370.0	3.232
Nov-87	178.87	1.996	NA	38.8	3.332
Dec-87	179.27	2.068	NA	64.5	3.505
Jan-88	178.66	1.958	NA	84.0	0.225
Feb-88	177.84	1.810	NA	59.7	0.375
Mar-88	176.91	1.643	NA	21.5	0.432
Apr-88	176.67	1.601	NA	4.2	0.443
May-88	175.61	1.410	154.35	98.3	0.707
Jun-88	174.03	1.125	154.18	34.1	0.795
Jul-88	175.06	1.310	153.91	23.2	0.857
Aug-88	181.92	2.556	153.68	9.3	0.882
Sep-88	187.70	3.802	156.73	825.0	3.020
Oct-88	188.20	3.931	154.61	211.4	3.587
Nov-88	189.30	4.217	NA	5.3	3.600
Dec-88	189.82	4.354	NA	6.0	3.616
Jan-89	189.92	4.380	NA	5.7	0.015
Feb-89	189.83	4.356	154.13	46.7	0.128
Mar-89	189.34	4.227	153.96	32.2	0.215
Apr-89	188.83	4.096	154.05	56.8	0.362
May-89	188.14	3.917	154.08	62.0	0.528
Jun-89	187.33	3.706	154.16	90.2	0.761
Jul-89	187.36	3.714	153.76	19.6	0.814
Aug-89	190.71	4.658	153.85	34.6	0.907
Sep-89	196.07	6.387	155.18	392.5	1.924
Oct-89	197.19	6.788	155.05	358.5	2.884
Nov-89	197.27	6.816	154.29	115.6	3.184
Dec-89	197.42	6.873	153.36	4.6	3.196

The water level downstream of the dam was not read from November 2, 1988 to February 11, 1989 because the energy dissipation basin at the foot of the dam was being repaired.

3 Discharges from the dam

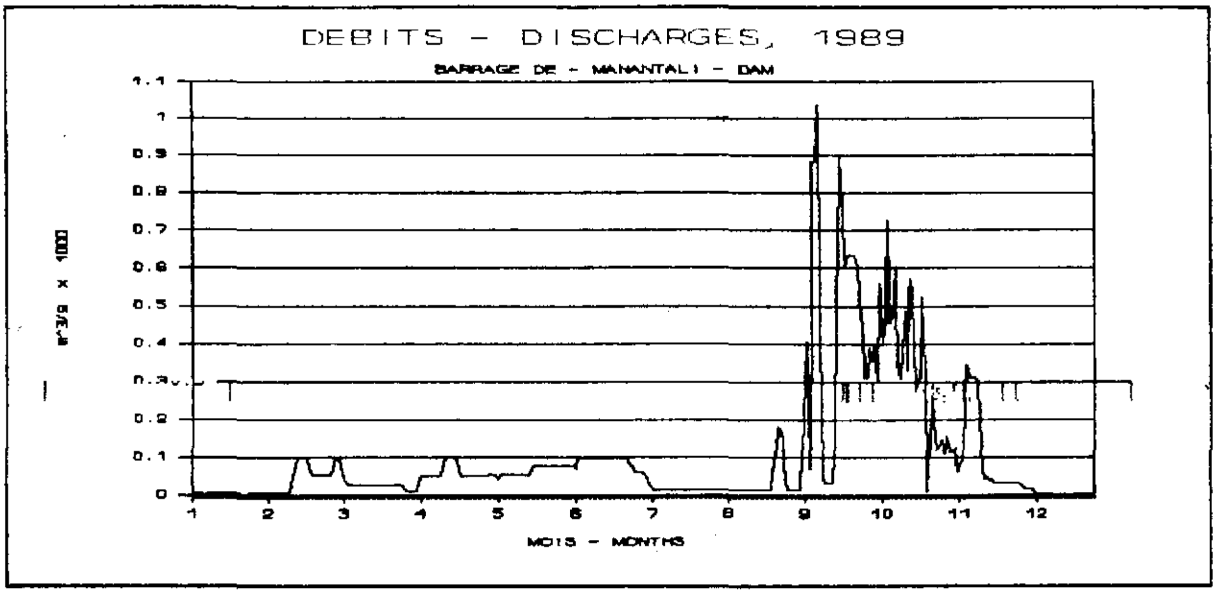
The high discharges from the dam, in September and October, were made in response to the rate with which the water level was rising in the reservoir. The water level in the reservoir dropped gradually from January to June because of evaporation and maintenance discharges. Filling of the reservoir should be complete, to 208 m ASL, during the rainy season of 1990 or 1991. The following figures indicate the discharges and volumes released during the period.



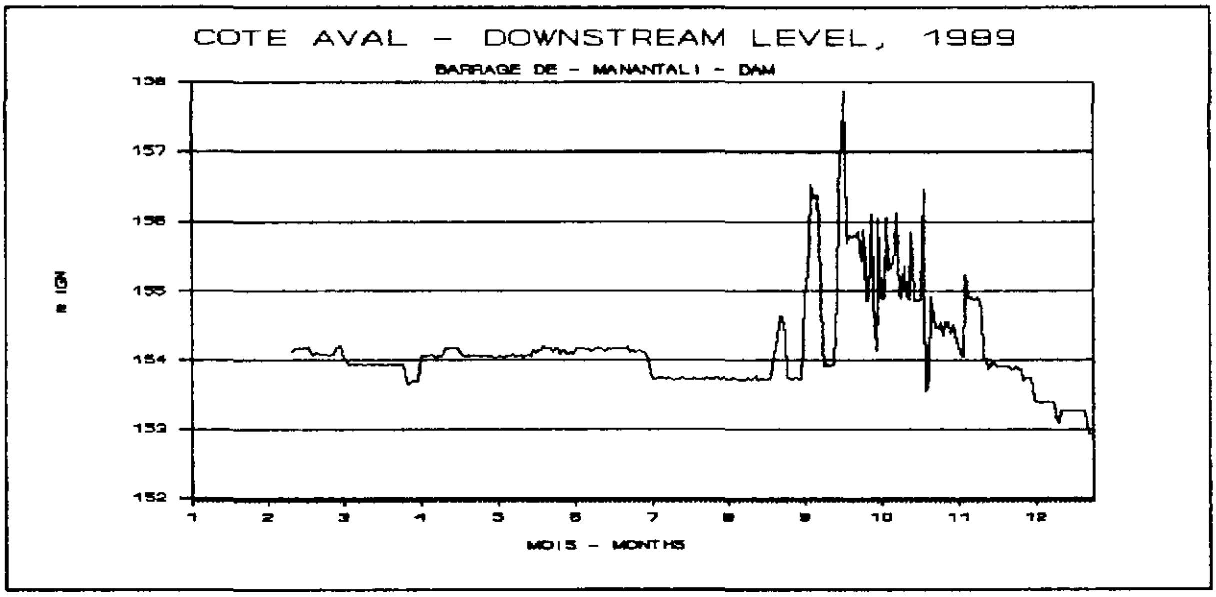


4 Water levels downstream of the dam

All the water released from the dam has been discharged through the bottom gates since the upper gates will only serve when the reservoir is full. The discharge has been highly controlled. We see from the figure below that the discharge could change from one day to the next from 40 m^3/s to 1000 m^3/s.



The water level downstream of the dam is read in the energy dissipation basin at the foot of the dam. As we can remark in the figure below, the water level in the basin is very sensitive to the dam's discharge. It would be more significative if the water level were read on a scale located several kilometers downstream where the peaks would be laminated.



Annex - Daily data

DATE	RESERVOIR LEVEL (m IGN)	RESERVOIR (milliards m^3) (billions m^3)	COTE AVAL LEVEL (m IGN)	DEBITS DU DISCHARGE (m^3/s)
01-Jul-87				
02-Jul-87				
03-Jul-87				
04-Jul-87				
05-Jul-87				
06-Jul-87	DONNEES DISPONIBLES A PARTIR DU 18 JUILLET 1987			
07-Jul-87	DATA AVAILABLE FROM JULY 18, 1987			
08-Jul-87				
09-Jul-87	COTE AVAL DISPONIBLE A PARTIR DU 1 MAI 1988			
10-Jul-87	WATER LEVEL DOWNSTREAM AVAILABLE FROM MAY 1, 1988			
11-Jul-87				
12-Jul-87				
13-Jul-87				
14-Jul-87				
15-Jul-87				
16-Jul-87				
17-Jul-87				
18-Jul-87	156.87	0.004		22.8
19-Jul-87	157.57	0.007		26.8
20-Jul-87	157.78	0.008		19.9
21-Jul-87	158.27	0.011		15.1
22-Jul-87	158.78	0.015		16.3
23-Jul-87	159.27	0.019		17.3
24-Jul-87	159.80	0.024		18.4
25-Jul-87	160.50	0.036		19.7
26-Jul-87	161.31	0.052		21.1
27-Jul-87	162.17	0.069		18.0
28-Jul-87	162.75	0.081		18.7
29-Jul-87	163.33	0.092		19.4
30-Jul-87	163.87	0.103		20.0
31-Jul-87	164.28	0.111		230.7
01-Aug-87	164.28	0.111		307.0
02-Aug-87	164.34	0.112		308.0
03-Aug-87	164.50	0.115		465.9
04-Aug-87	164.40	0.113		20.6
05-Aug-87	164.83	0.122		21.1
06-Aug-87	165.61	0.158		18.5
07-Aug-87	166.35	0.198		19.1
08-Aug-87	166.98	0.232		19.7
09-Aug-87	167.66	0.269		20.3
10-Aug-87	168.29	0.303		20.8
11-Aug-87	168.98	0.340		21.3
12-Aug-87	169.56	0.371		21.8
13-Aug-87	170.00	0.395		145.4
14-Aug-87	170.30	0.449		266.2
15-Aug-87	170.63	0.509		457.7
16-Aug-87	170.62	0.507		476.0
17-Aug-87	170.75	0.531		476.0
18-Aug-87	170.77	0.534		476.0
19-Aug-87	170.82	0.543		476.0
20-Aug-87	171.01	0.578		549.5
21-Aug-87	171.04	0.583		549.5
22-Aug-87	171.10	0.594		259.8
23-Aug-87	171.57	0.679		88.0
24-Aug-87	172.03	0.762		88.0
25-Aug-87	172.45	0.838		90.0
26-Aug-87	172.85	0.911		90.0
27-Aug-87	173.25	0.983		90.0
28-Aug-87	173.60	1.047		92.0
29-Aug-87	173.99	1.117		93.0
30-Aug-87	174.46	1.202		94.0
31-Aug-87	174.94	1.299		267.8
01-Sep-87	175.28	1.350		580.5
02-Sep-87	175.40	[illegible]		766.0
03-Sep-87	175.39	1.370		834.0
04-Sep-87	175.36	1.365		834.0
05-Sep-87	175.32	1.358		834.0
06-Sep-87	175.29	1.352		834.0
07-Sep-87	175.30	1.354		834.0
08-Sep-87	175.30	1.354		486.5
[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
11-Sep-87	175.70	1.415		252.[illegible]

BARRAGE DE MANANTALI DAM

DATE	<-------RESERVOIR-------> COTE LEVEL (m IGN)	VOLUME (milliards m^3) (billions m^3)	COTE AVAL DOWNSTREAM LEVEL (m IGN)	DEBITS DU BARRAGE DISCHARGE (m^3/s)
12-Sep-87	175.62	1.412		428.0
13-Sep-87	175.85	1.453		288.0
14-Sep-87	176.10	1.498		204.0
15-Sep-87	176.37	1.547		248.0
16-Sep-87	176.52	1.574		538.5
17-Sep-87	176.48	1.566		858.0
18-Sep-87	176.37	1.547		694.8
19-Sep-87	176.37	1.547		588.0
20-Sep-87	176.37	1.547		588.0
21-Sep-87	176.42	1.556		594.0
22-Sep-87	176.51	1.572		597.0
23-Sep-87	176.64	1.595		666.0
24-Sep-87	176.70	1.606		1062.0
25-Sep-87	176.51	1.572		1152.0
26-Sep-87	176.58	1.584		348.0
27-Sep-87	176.94	1.649		209.3
28-Sep-87	176.99	1.658		768.8
29-Sep-87	176.99	1.658		600.0
30-Sep-87	177.03	1.665		391.9
01-Oct-87	177.29	1.712		162.5
02-Oct-87	177.47	1.745		524.0
03-Oct-87	177.50	1.750		592.0
04-Oct-87	177.51	1.752		592.0
05-Oct-87	177.49	1.748		592.0
06-Oct-87	177.45	1.741		554.5
07-Oct-87	177.44	1.739		450.0
08-Oct-87	177.45	1.741		418.8
09-Oct-87	177.46	1.743		350.0
10-Oct-87	177.47	1.745		291.7
11-Oct-87	177.52	1.754		250.0
12-Oct-87	177.57	1.763		250.0
13-Oct-87	177.66	1.779		255.0
14-Oct-87	177.71	1.788		290.4
15-Oct-87	177.77	1.799		365.0
16-Oct-87	177.78	1.800		455.0
17-Oct-87	177.78	1.800		455.0
18-Oct-87	177.80	1.804		460.0
19-Oct-87	177.80	1.804		460.0
20-Oct-87	177.80	1.804		460.0
21-Oct-87	177.80	1.804		460.0
22-Oct-87	177.78	1.800		460.0
23-Oct-87	177.75	1.795		390.0
24-Oct-87	177.75	1.795		365.0
25-Oct-87	177.76	1.796		365.0
26-Oct-87	177.77	1.799		325.6
27-Oct-87	177.83	1.809		275.0
28-Oct-87	177.85	1.813		275.0
29-Oct-87	177.89	1.820		136.0
30-Oct-87	177.98	1.836		95.0
31-Oct-87	178.05	1.849		95.0
01-Nov-87	178.10	1.858		85.7
02-Nov-87	178.18	1.872		77.8
03-Nov-87	178.27	1.889		52.0
04-Nov-87	178.35	1.903		52.0
05-Nov-87	178.43	1.917		52.0
06-Nov-87	178.49	1.928		52.0
07-Nov-87	178.55	1.939		52.0
08-Nov-87	178.61	1.950		52.0
09-Nov-87	178.66	1.959		52.0
10-Nov-87	178.70	1.966		52.0
11-Nov-87	178.74	1.973		52.0
12-Nov-87	178.78	1.980		52.0
13-Nov-87	178.82	1.988		37.9
14-Nov-87	178.86	1.995		26.0
15-Nov-87	178.90	2.002		26.0
16-Nov-87	178.94	2.009		26.0
17-Nov-87	178.98	2.016		26.0
18-Nov-87	179.01	2.022		26.0
19-Nov-87	179.05	2.029		26.0
20-Nov-87	179.09	2.036		26.0
[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
23-Nov-87	179.19	2.054		26.0

DATE	RESERVOIR COTE LEVEL (m IGN)	RESERVOIR VOLUME (milliards m^3) (billions m^3)	COTE AVAL DOWNSTREAM LEVEL (m IGN)	DEBITS DU BARRAGE DISCHARGE (m^3/s)
24-Nov-87	179.21	2.058		26.0
25-Nov-87	179.24	2.063		26.0
26-Nov-87	179.27	2.069		26.0
27-Nov-87	179.30	2.074		26.0
28-Nov-87	179.32	2.078		26.0
29-Nov-87	179.34	2.081		26.0
30-Nov-87	179.36	2.085		26.0
01-Dec-87	179.38	2.088		43.3
02-Dec-87	179.39	2.090		65.8
03-Dec-87	179.39	2.090		85.5
04-Dec-87	179.37	2.087		94.0
05-Dec-87	179.36	2.085		90.1
06-Dec-87	179.34	2.081		90.1
07-Dec-87	179.32	2.078		90.1
08-Dec-87	179.30	2.074		60.0
09-Dec-87	179.29	2.072		60.0
10-Dec-87	179.30	2.074		60.0
11-Dec-87	179.31	2.076		60.0
12-Dec-87	179.32	2.078		60.0
13-Dec-87	179.32	2.078		60.0
14-Dec-87	179.31	2.076		60.0
15-Dec-87	179.31	2.076		60.0
16-Dec-87	179.30	2.074		60.0
17-Dec-87	179.30	2.074		60.0
18-Dec-87	179.28	2.070		60.0
19-Dec-87	179.27	2.069		60.0
20-Dec-87	179.26	2.067		60.0
21-Dec-87	179.25	2.065		60.0
22-Dec-87	179.25	2.065		60.0
23-Dec-87	179.23	2.061		60.0
24-Dec-87	179.21	2.058		60.0
25-Dec-87	179.19	2.054		60.0
26-Dec-87	179.17	2.051		60.0
27-Dec-87	179.15	2.047		60.0
28-Dec-87	179.13	2.043		60.0
29-Dec-87	179.11	2.040		60.0
30-Dec-87	179.09	2.036		60.0
31-Dec-87	179.07	2.033		60.0
01-Jan-88	179.05	2.029		60.0
02-Jan-88	179.03	2.025		60.0
03-Jan-88	179.01	2.022		60.0
04-Jan-88	179.01	2.022		60.0
05-Jan-88	178.98	2.016		60.0
06-Jan-88	178.98	2.016		60.0
07-Jan-88	178.97	2.015		90.0
08-Jan-88	178.97	2.015		90.0
09-Jan-88	178.96	2.013		100.0
10-Jan-88	178.95	2.011		110.0
11-Jan-88	178.94	2.009		110.0
12-Jan-88	178.90	2.002		92.5
13-Jan-88	178.80	1.984		120.0
14-Jan-88	178.75	1.975		141.7
15-Jan-88	178.70	1.966		57.0
16-Jan-88	178.67	1.961		80.4
17-Jan-88	178.63	1.953		110.0
18-Jan-88	178.60	1.948		110.0
19-Jan-88	178.56	1.941		110.0
20-Jan-88	178.52	1.934		110.0
21-Jan-88	178.48	1.926		60.2
22-Jan-88	178.44	1.919		62.0
23-Jan-88	178.41	1.914		27.1
24-Jan-88	178.38	1.908		84.0
25-Jan-88	178.35	1.903		84.0
26-Jan-88	178.31	1.896		84.0
27-Jan-88	178.28	1.890		84.0
28-Jan-88	178.25	1.885		84.0
29-Jan-88	178.19	1.874		8[illegible]
30-Jan-88	178.15	1.867		82.0
31-Jan-88	178.13	1.863		82.[illegible]
01-Feb-88	178.10	1.858		55.0
[illegible]-Feb-88	178.[illegible]	1.848		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
[illegible]-Feb-88	[illegible]	[illegible]		[illegible]

DATE	<------RESERVOIR------> COTE LEVEL (m IGN)	VOLUME (milliards m^3) (billions m^3)	COTE AVAL LEVEL (m IGN)	DEBITS DU DISCHARGE (m^3/s)
05-Feb-88	177.98	1.836		20.0
06-Feb-88	178.01	1.842		8.2
07-Feb-88	178.01	1.842		10.0
08-Feb-88	178.01	1.842		10.5
09-Feb-88	178.00	1.840		39.1
10-Feb-88	178.00	1.840		57.3
11-Feb-88	177.96	1.833		50.6
12-Feb-88	177.93	1.827		45.8
13-Feb-88	177.96	1.833		9.8
14-Feb-88	177.90	1.822		5.0
15-Feb-88	177.89	1.820		76.3
16-Feb-88	177.88	1.818		31.9
17-Feb-88	177.88	1.818		7.6
18-Feb-88	177.89	1.820		62.4
19-Feb-88	177.83	1.809		100.0
20-Feb-88	177.81	1.806		100.0
21-Feb-88	177.75	1.795		100.0
22-Feb-88	177.66	1.779		100.0
23-Feb-88	177.61	1.770		100.0
24-Feb-88	177.55	1.759		100.0
25-Feb-88	177.51	1.752		100.0
26-Feb-88	177.45	1.741		100.0
27-Feb-88	177.41	1.734		100.0
28-Feb-88	177.34	1.721		100.0
29-Feb-88	177.28	1.710		100.0
01-Mar-88	177.22	1.700		100.0
02-Mar-88	177.17	1.691		100.0
03-Mar-88	177.10	1.678		100.0
04-Mar-88	177.05	1.669		100.0
05-Mar-88	176.98	1.656		54.8
06-Mar-88	176.95	1.651		30.0
07-Mar-88	176.93	1.647		24.2
08-Mar-88	176.93	1.647		10.0
09-Mar-88	176.93	1.647		10.0
10-Mar-88	176.92	1.646		10.0
11-Mar-88	176.91	1.644		10.0
12-Mar-88	176.89	1.640		10.0
13-Mar-88	176.88	1.638		10.0
14-Mar-88	176.87	1.637		10.0
15-Mar-88	176.86	1.635		10.0
16-Mar-88	176.85	1.633		10.0
17-Mar-88	176.84	1.631		8.0
18-Mar-88	176.83	1.629		5.0
19-Mar-88	176.83	1.629		5.0
20-Mar-88	176.82	1.628		5.0
21-Mar-88	176.82	1.628		4.0
22-Mar-88	176.82	1.628		4.2
23-Mar-88	176.82	1.628		4.2
24-Mar-88	176.82	1.628		4.2
25-Mar-88	176.82	1.628		4.2
26-Mar-88	176.82	1.628		4.2
27-Mar-88	176.81	1.626		4.2
28-Mar-88	176.80	1.624		4.2
29-Mar-88	176.79	1.622		4.2
30-Mar-88	176.77	1.619		4.2
31-Mar-88	176.77	1.619		4.2
01-Apr-88	176.77	1.619		4.2
02-Apr-88	176.76	1.617		4.2
03-Apr-88	176.76	1.617		4.2
04-Apr-88	176.75	1.615		4.2
05-Apr-88	176.74	1.613		4.2
06-Apr-88	176.73	1.611		4.2
07-Apr-88	176.73	1.611		4.2
08-Apr-88	176.72	1.610		4.2
09-Apr-88	176.72	1.610		4.2
10-Apr-88	176.71	1.608		4.2
11-Apr-88	176.70	1.606		4.2
12-Apr-88	176.70	1.606		4.2
13-Apr-88	176.69	1.604		4.2
14-Apr-88	176.68	1.602		4.2
15-Apr-88	176.67	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
17-Apr-88	176.65	1.597		4.2

DATE	<------RESERVOIR------> COTE LEVEL (m IGN)	VOLUME (milliards m^3) (billions m^3)	COTE AVAL LEVEL (m IGN)	DEBITS DU DISCHARGE (m^3/s)
18-Apr-88	176.65	1.597		4.2
19-Apr-88	176.64	1.595		4.2
20-Apr-88	176.63	1.593		4.2
21-Apr-88	176.63	1.593		4.2
22-Apr-88	176.62	1.592		4.2
23-Apr-88	176.61	1.590		4.2
24-Apr-88	176.60	1.588		4.2
25-Apr-88	176.59	1.586		4.2
26-Apr-88	176.58	1.584		4.2
27-Apr-88	176.57	1.583		4.2
28-Apr-88	176.56	1.581		4.2
29-Apr-88	176.56	1.581		4.2
30-Apr-88	176.56	1.581		4.2
01-May-88	176.56	1.581	153.50	4.2
02-May-88	176.55	1.579	153.50	4.2
03-May-88	176.54	1.577	153.50	4.2
04-May-88	176.54	1.577	153.50	4.2
05-May-88	176.53	1.575	153.50	4.2
06-May-88	176.52	1.574	153.50	4.2
07-May-88	176.51	1.572	153.50	4.2
08-May-88	176.50	1.570	153.50	8.1
09-May-88	176.49	1.568	154.23	118.9
10-May-88	176.37	1.547	155.00	210.0
11-May-88	176.22	1.520	155.00	210.0
12-May-88	176.08	1.494	155.05	210.0
13-May-88	175.94	1.469	155.04	210.0
14-May-88	175.77	1.439	155.05	266.7
15-May-88	175.64	1.415	155.30	315.0
16-May-88	175.36	1.365	155.30	206.2
17-May-88	175.26	1.347	154.75	140.0
18-May-88	175.16	1.329	154.75	140.0
19-May-88	175.07	1.313	154.75	140.0
20-May-88	174.98	1.296	154.75	97.7
21-May-88	174.91	1.284	154.36	70.0
22-May-88	174.84	1.271	154.36	70.0
23-May-88	174.78	1.260	154.36	70.0
24-May-88	174.75	1.255	154.36	70.0
25-May-88	174.71	1.248	154.36	70.0
26-May-88	174.67	1.240	154.36	52.3
27-May-88	174.62	1.231	154.36	70.0
28-May-88	174.57	1.222	154.36	70.0
29-May-88	174.52	1.213	154.36	70.0
30-May-88	174.48	1.206	154.36	70.0
31-May-88	174.43	1.197	154.36	63.2
01-Jun-88	174.38	1.188	154.36	50.0
02-Jun-88	174.35	1.182	154.24	50.0
03-Jun-88	174.32	1.177	154.24	50.0
04-Jun-88	174.28	1.170	154.24	50.0
05-Jun-88	174.24	1.162	154.24	50.0
06-Jun-88	174.19	1.153	154.24	50.0
07-Jun-88	174.14	1.144	154.24	50.0
08-Jun-88	174.10	1.137	154.24	50.0
09-Jun-88	174.07	1.132	154.25	50.0
10-Jun-88	174.03	1.124	154.26	50.0
11-Jun-88	174.01	1.121	154.27	50.0
12-Jun-88	173.97	1.114	154.28	50.0
13-Jun-88	173.93	1.106	154.30	39.6
14-Jun-88	173.91	1.103	154.94	22.5
15-Jun-88	173.92	1.105	154.94	22.5
16-Jun-88	173.91	1.103	154.94	22.5
17-Jun-88	173.90	1.101	153.93	21.5
18-Jun-88	173.87	1.095	153.90	22.5
19-Jun-88	173.89	1.099	153.91	22.5
20-Jun-88	[illegible]	1.101	153.91	[illegible]
21-Jun-88	173.91	1.103	153.91	22.5
22-Jun-88	173.91	1.10[illegible]	153.90	[illegible]
23-Jun-88	173.90	1.101	153.90	22.5
24-Jun-88	173.93	1.106	153.91	22.5
25-Jun-88	173.93	1.106	153.90	22.5
26-Jun-88	173.93	1.106	153.90	22.5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29-Jun-88	173.94	1.108	153.90	22.5

DATE	<------RESERVOIR------> COTE LEVEL (m IGN)	VOLUME (milliards m^3) (billions m^3)	COTE AVAL [illegible] LEVEL (m IGN)	DEBITS DU [illegible] DISCHARGE (m^3/s)
30-Jun-88	173.94	1.108	153.90	22.5
01-Jul-88	173.94	1.108	153.90	22.5
02-Jul-88	173.96	1.112	153.90	22.5
03-Jul-88	173.96	1.112	153.90	22.5
04-Jul-88	173.97	1.114	153.90	22.5
05-Jul-88	173.98	1.115	153.90	22.5
06-Jul-88	173.99	1.117	153.90	22.5
07-Jul-88	174.04	1.126	153.91	22.5
08-Jul-88	174.05	1.128	153.91	22.5
09-Jul-88	174.09	1.135	153.91	22.5
10-Jul-88	174.12	1.141	153.91	22.5
11-Jul-88	174.17	1.150	153.91	22.5
12-Jul-88	174.19	1.153	153.91	22.5
13-Jul-88	174.26	1.166	153.91	22.5
14-Jul-88	174.28	1.170	153.92	22.5
15-Jul-88	174.34	1.181	153.92	22.5
16-Jul-88	174.43	1.197	153.92	23.0
17-Jul-88	174.65	1.237	153.92	24.0
18-Jul-88	174.91	1.284	153.92	24.0
19-Jul-88	175.18	1.332	153.92	24.0
20-Jul-88	175.39	1.370	153.92	24.0
21-Jul-88	175.60	1.408	153.92	24.0
22-Jul-88	175.93	1.467	153.92	24.0
23-Jul-88	176.31	1.536	153.92	24.0
24-Jul-88	176.52	1.574	153.92	24.0
25-Jul-88	176.74	1.613	153.92	24.0
26-Jul-88	176.90	1.642	153.91	24.0
27-Jul-88	177.05	1.669	153.91	24.0
28-Jul-88	177.18	1.692	153.91	24.0
29-Jul-88	177.31	1.716	153.92	24.0
30-Jul-88	177.50	1.750	153.92	24.0
31-Jul-88	177.67	1.781	153.92	24.0
01-Aug-88	177.88	1.818	153.92	24.0
02-Aug-88	178.11	1.860	153.92	16.0
03-Aug-88	178.41	1.914	153.92	8.0
04-Aug-88	178.76	1.977	153.61	8.0
05-Aug-88	179.09	2.036	153.61	8.0
06-Aug-88	179.43	2.097	153.61	8.0
07-Aug-88	179.67	2.141	153.62	8.0
08-Aug-88	179.99	2.198	153.61	8.0
09-Aug-88	180.22	2.240	153.61	8.0
10-Aug-88	180.52	2.294	153.66	8.0
11-Aug-88	180.79	2.342	153.66	8.0
12-Aug-88	181.08	2.394	153.64	8.0
13-Aug-88	181.33	2.439	153.63	8.0
14-Aug-88	181.56	2.481	153.64	8.0
15-Aug-88	181.79	2.522	153.64	8.0
16-Aug-88	182.00	2.560	153.64	8.0
17-Aug-88	182.25	2.605	153.64	8.0
18-Aug-88	182.46	2.643	153.64	8.0
19-Aug-88	182.86	2.715	153.64	8.0
20-Aug-88	183.28	2.790	153.64	8.0
21-Aug-88	183.66	2.859	153.68	8.0
22-Aug-88	183.98	2.916	153.68	8.0
23-Aug-88	184.21	2.958	153.67	8.0
24-Aug-88	184.52	3.014	153.68	8.0
25-Aug-88	184.85	3.073	153.68	8.0
26-Aug-88	185.15	3.139	153.67	8.0
27-Aug-88	185.50	3.230	153.67	8.0
28-Aug-88	185.94	3.318	153.69	8.0
29-Aug-88	186.15	3.399	153.68	9.0
30-Aug-88	186.45	3.477	153.69	9.0
31-Aug-88	186.70	3.542	153.69	21.1
01-Sep-88	187.10	3.644	154.09	94.6
02-Sep-88	187.40	3.724	154.76	449.4
03-Sep-88	187.56	3.771	155.00	1090.5
04-Sep-88	187.63	3.784	157.40	916.8
05-Sep-88	187.51	3.753	158.73	994.1
06-Sep-88	187.56	3.766	157.20	964.0
07-Sep-88	187.70	3.802	157.28	1195.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10-Sep-88	187.[illegible]4	3.8[illegible]4	15[illegible]	[illegible]

DATE	<------RESERVOIR------> COTE LEVEL (m IGN)	VOLUME (milliards m^3) (billions m^3)	COTE AVAL DOWNSTREAM LEVEL (m IGN)	DEBITS DU BARRAGE DISCHARGE (m^3/s)
11-Sep-88	187.91	3.857	158.03	1360.0
12-Sep-88	187.84	3.838	157.93	1298.0
13-Sep-88	187.77	3.820	157.53	1107.3
14-Sep-88	187.79	3.825	156.96	974.0
15-Sep-88	187.79	3.825	156.94	1014.1
16-Sep-88	187.75	3.815	157.32	895.7
17-Sep-88	187.77	3.820	157.54	784.0
18-Sep-88	187.80	3.828	157.58	784.0
19-Sep-88	187.77	3.820	157.54	784.0
20-Sep-88	187.75	3.815	156.58	678.9
21-Sep-88	187.78	3.823	156.00	606.0
22-Sep-88	187.79	3.825	155.92	606.0
23-Sep-88	187.81	3.831	155.93	606.0
24-Sep-88	187.80	3.828	155.95	606.0
25-Sep-88	187.81	3.831	155.96	606.0
26-Sep-88	187.80	3.828	155.93	558.6
27-Sep-88	187.80	3.828	155.64	518.0
28-Sep-88	187.78	3.823	155.68	449.4
29-Sep-88	187.82	3.833	155.30	434.0
30-Sep-88	187.85	3.841	155.30	306.5
01-Oct-88	187.95	3.867	154.71	228.4
02-Oct-88	188.06	3.896	154.98	266.0
03-Oct-88	188.13	3.914	154.98	611.0
04-Oct-88	188.11	3.909	156.40	535.0
05-Oct-88	188.07	3.898	156.42	531.5
06-Oct-88	188.05	3.893	155.56	434.0
07-Oct-88	188.04	3.890	155.60	434.0
08-Oct-88	188.04	3.890	155.57	434.0
09-Oct-88	188.03	3.888	155.54	434.0
10-Oct-88	188.02	3.885	155.54	383.0
11-Oct-88	188.02	3.885	155.30	167.7
12-Oct-88	188.05	3.893	155.36	102.6
13-Oct-88	188.10	3.906	154.70	216.0
14-Oct-88	188.11	3.909	154.94	276.4
15-Oct-88	188.11	3.909	154.93	276.4
16-Oct-88	188.11	3.909	154.94	276.4
17-Oct-88	188.11	3.909	154.94	276.4
18-Oct-88	188.10	3.906	154.93	276.4
19-Oct-88	188.09	3.903	154.94	269.5
20-Oct-88	188.13	3.914	154.05	27.1
21-Oct-88	188.20	3.932	154.02	27.1
22-Oct-88	188.28	3.953	154.02	27.1
23-Oct-88	188.34	3.968	154.03	27.1
24-Oct-88	188.42	3.989	154.03	0.0
25-Oct-88	188.48	4.005	153.32	0.0
26-Oct-88	188.53	4.018	152.00	0.0
27-Oct-88	188.56	4.026	152.00	0.0
28-Oct-88	188.58	4.031	152.80	3.2
29-Oct-88	188.68	4.057	153.50	5.3
30-Oct-88	188.74	4.072	153.50	5.3
31-Oct-88	188.77	4.080	153.50	3.5
01-Nov-88	188.84	4.098	153.50	5.3
02-Nov-88	188.90	4.114	153.50	5.3
03-Nov-88	188.92	4.119		5.3
04-Nov-88	188.99	4.137		5.3
05-Nov-88	189.00	4.140	BASSIN A SEC	5.3
06-Nov-88	189.01	4.143	OU EN	5.3
07-Nov-88	189.05	4.153	REPARATION	5.3
08-Nov-88	189.08	4.161	DU 2 NOV 88	5.3
09-Nov-88	189.12	4.171	AU 11 FEV 89	5.3
10-Nov-88	189.15	4.179		5.3
11-Nov-88	189.20	4.192		5.3
12-Nov-88	189.25	4.205	DISCHARGE	5.3
13-Nov-88	189.29	4.215	BASIN DRY	5.3
14-Nov-88	189.34	4.228	OR UNDER	5.3
15-Nov-88	189.37	4.236	REPAIR	5.3
16-Nov-88	189.38	4.239	FROM	5.3
17-Nov-88	189.43	4.252	NOV 2, 88	5.3
18-Nov-88	189.45	4.257	UNTIL	5.3
19-Nov-88	189.50	4.270	FEB 11, 89	5.3
[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
22-Nov-88	189.54	4.280		5.3

DATE	RESERVOIR LEVEL (m IGN)	RESERVOIR (milliards m^3) (billions m^3)	COTE AVAL LEVEL (m IGN)	DEBITS DU DISCHARGE (m^3/s)
23-Nov-88	189.55	4.283		5.3
24-Nov-88	189.56	4.286		5.3
25-Nov-88	189.57	4.288		5.3
26-Nov-88	189.60	4.296		5.3
27-Nov-88	189.62	4.301		5.3
28-Nov-88	189.66	4.312		5.3
29-Nov-88	189.68	4.317		5.3
30-Nov-88	189.69	4.319		5.3
01-Dec-88	189.70	4.322		5.3
02-Dec-88	189.71	4.325		5.3
03-Dec-88	189.72	4.327		5.3
04-Dec-88	189.74	4.332		5.3
05-Dec-88	189.76	4.338		5.3
06-Dec-88	189.77	4.340		5.3
07-Dec-88	189.78	4.343		5.3
08-Dec-88	189.79	4.345		5.3
09-Dec-88	189.81	4.351		6.0
10-Dec-88	189.82	4.353		6.0
11-Dec-88	189.82	4.353		6.0
12-Dec-88	189.83	4.356		6.0
13-Dec-88	189.83	4.356		6.0
14-Dec-88	189.84	4.358		6.0
15-Dec-88	189.84	4.358		6.1
16-Dec-88	189.85	4.361		6.1
17-Dec-88	189.85	4.361		6.1
18-Dec-88	189.85	4.361		6.1
19-Dec-88	189.86	4.364		6.1
20-Dec-88	189.87	4.366		6.1
21-Dec-88	189.87	4.366		6.5
22-Dec-88	189.88	4.369		6.5
23-Dec-88	189.88	4.369		6.5
24-Dec-88	189.88	4.369		6.5
25-Dec-88	189.88	4.369		6.5
26-Dec-88	189.88	4.369		6.5
27-Dec-88	189.88	4.369		6.5
28-Dec-88	189.88	4.369		6.5
29-Dec-88	189.88	4.369		6.5
30-Dec-88	189.88	4.369		6.5
31-Dec-88	189.89	4.371		6.5
01-Jan-89	189.89	4.371		6.5
02-Jan-89	189.90	4.374		6.5
03-Jan-89	189.90	4.374		6.5
04-Jan-89	189.90	4.374		6.5
05-Jan-89	189.90	4.374		6.5
06-Jan-89	189.90	4.374		3.6
07-Jan-89	189.90	4.374		3.3
08-Jan-89	189.90	4.374		6.5
09-Jan-89	189.90	4.374		6.5
10-Jan-89	189.91	4.377		6.5
11-Jan-89	189.92	4.379		6.5
12-Jan-89	189.92	4.379		6.5
13-Jan-89	189.92	4.379		6.5
14-Jan-89	189.92	4.379		6.5
15-Jan-89	189.93	4.382		6.5
16-Jan-89	189.93	4.382		6.5
17-Jan-89	189.93	4.382		6.5
18-Jan-89	189.93	4.382		6.5
19-Jan-89	189.93	4.382		6.5
20-Jan-89	189.94	4.384		6.5
21-Jan-89	189.94	4.384		3.3
22-Jan-89	189.94	4.384		0.0
23-Jan-89	189.94	4.384		0.0
24-Jan-89	189.94	4.384		4.1
25-Jan-89	189.95	4.387		[illegible]
26-Jan-89	189.95	4.387		6.5
27-Jan-89	189.95	4.387		6.5
28-Jan-89	189.95	4.387		6.5
29-Jan-89	189.95	4.387		6.5
30-Jan-89	189.95	4.387		5.5
31-Jan-89	189.95	4.387		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
03-Feb-89	189.95	4.387		6.5

DATE	<------RESERVOIR------> COTE LEVEL (m IGN)	VOLUME (milliards m^3) (billions m^3)	COTE AVAL DOWNSTREAM LEVEL (m IGN)	DEBITS DU BARRAGE DISCHARGE (m^3/s)
04-Feb-89	189.95	4.387		6.5
05-Feb-89	189.95	4.387		6.5
06-Feb-89	189.95	4.387		6.5
07-Feb-89	189.95	4.387		6.5
08-Feb-89	189.95	4.387		6.5
09-Feb-89	189.95	4.387		6.5
10-Feb-89	189.95	4.387		6.5
11-Feb-89	189.95	4.387	154.13	46.4
12-Feb-89	189.94	4.384	154.18	81.2
13-Feb-89	189.92	4.379	154.17	94.2
14-Feb-89	189.89	4.371	154.19	101.4
15-Feb-89	189.86	4.361	154.18	101.3
16-Feb-89	189.84	4.358	154.19	101.3
17-Feb-89	189.80	4.348	154.18	101.2
18-Feb-89	189.77	4.340	154.20	74.9
19-Feb-89	189.75	4.335	154.08	51.3
20-Feb-89	189.73	4.330	154.09	51.3
21-Feb-89	189.72	4.327	154.13	51.3
22-Feb-89	189.70	4.322	154.08	51.3
23-Feb-89	189.68	4.317	154.08	51.3
24-Feb-89	189.66	4.312	154.08	51.3
25-Feb-89	189.64	4.306	154.08	51.2
26-Feb-89	189.62	4.301	154.07	51.2
27-Feb-89	189.60	4.296	154.08	51.2
28-Feb-89	189.58	4.291	154.08	80.1
01-Mar-89	189.56	4.286	154.18	100.9
02-Mar-89	189.52	4.280	154.20	100.8
03-Mar-89	189.49	4.267	154.22	76.8
04-Mar-89	189.47	4.262	154.03	40.9
05-Mar-89	189.45	4.257	154.02	32.8
06-Mar-89	189.45	4.257	153.95	27.3
07-Mar-89	189.44	4.254	153.96	27.3
08-Mar-89	189.43	4.252	153.96	27.3
09-Mar-89	189.42	4.249	153.96	27.2
10-Mar-89	189.41	4.247	153.96	27.2
11-Mar-89	189.40	4.244	153.96	27.2
12-Mar-89	189.39	4.241	153.95	27.2
13-Mar-89	189.37	4.236	153.96	27.2
14-Mar-89	189.36	4.234	153.96	27.2
15-Mar-89	189.35	4.231	153.95	27.2
16-Mar-89	189.34	4.228	153.96	27.2
17-Mar-89	189.33	4.226	153.96	27.2
18-Mar-89	189.32	4.223	153.95	27.2
19-Mar-89	189.30	4.218	153.96	27.2
20-Mar-89	189.29	4.215	153.95	27.2
21-Mar-89	189.28	4.213	153.95	27.2
22-Mar-89	189.27	4.210	153.96	27.2
23-Mar-89	189.25	4.205	153.96	27.2
24-Mar-89	189.24	4.202	153.95	27.2
25-Mar-89	189.22	4.197	153.96	27.2
26-Mar-89	189.20	4.192	153.95	27.2
27-Mar-89	189.19	4.189	153.96	27.2
28-Mar-89	189.18	4.187	153.95	16.7
29-Mar-89	189.17	4.184	153.70	10.3
30-Mar-89	189.16	4.182	153.65	10.3
31-Mar-89	189.15	4.179	153.69	10.3
01-Apr-89	189.14	4.176	153.69	10.3
02-Apr-89	189.13	4.174	153.69	10.3
03-Apr-89	189.13	4.174	153.69	32.6
04-Apr-89	189.12	4.171	154.06	50.9
05-Apr-89	189.09	4.163	154.06	50.8
06-Apr-89	189.07	4.158	154.06	50.8
07-Apr-89	189.05	4.153	154.07	50.8
08-Apr-89	189.04	4.150	154.08	50.8
09-Apr-89	189.02	4.145	154.07	50.8
10-Apr-89	188.99	4.137	154.04	50.8
11-Apr-89	188.97	4.132	154.07	50.8
12-Apr-89	188.95	4.127	154.06	50.7
13-Apr-89	188.93	4.122	154.06	58.9
14-Apr-89	188.89	4.111	154.17	99.9
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
17-Apr-89	188.78	4.083	154.18	99.7

DATE	<------RESERVOIR------> COTE LEVEL (m IGN)	VOLUME (milliards m^3) (billions m^3)	COTE AVAL DOWNSTREAM LEVEL (m IGN)	DEBITS DU BARRAGE DISCHARGE (m^3/s)
18-Apr-89	188.75	4.075	154.18	99.7
19-Apr-89	188.71	4.065	154.18	69.9
20-Apr-89	188.69	4.059	154.12	50.5
21-Apr-89	188.67	4.054	154.07	50.5
22-Apr-89	188.65	4.049	154.07	50.5
23-Apr-89	188.63	4.044	154.09	50.5
24-Apr-89	188.61	4.039	154.06	50.5
25-Apr-89	188.59	4.033	154.08	50.5
26-Apr-89	188.56	4.026	154.07	50.4
27-Apr-89	188.55	4.023	154.07	50.4
28-Apr-89	188.53	4.018	154.06	50.4
29-Apr-89	188.50	4.010	154.07	50.4
30-Apr-89	188.48	4.005	154.07	50.4
01-May-89	188.46	4.000	154.06	51.2
02-May-89	188.43	3.992	154.06	51.2
03-May-89	188.42	3.989	154.05	51.2
04-May-89	188.39	3.981	154.05	51.2
05-May-89	188.37	3.976	154.06	41.1
06-May-89	188.35	3.971	154.06	51.1
07-May-89	188.34	3.968	154.05	51.1
08-May-89	188.32	3.963	154.06	51.1
09-May-89	188.29	3.955	154.07	51.1
10-May-89	188.27	3.950	154.08	51.1
11-May-89	188.26	3.948	154.10	51.1
12-May-89	188.23	3.940	154.06	51.0
13-May-89	188.22	3.937	154.07	51.0
14-May-89	188.19	3.929	154.08	51.0
15-May-89	188.18	3.927	154.05	51.0
16-May-89	188.16	3.922	154.07	51.0
17-May-89	188.14	3.916	154.08	51.0
18-May-89	188.11	3.909	154.06	67.5
19-May-89	188.07	3.898	154.16	76.7
20-May-89	188.06	3.896	154.11	76.7
21-May-89	188.03	3.888	154.15	76.7
22-May-89	188.01	3.883	154.14	76.7
23-May-89	187.99	3.877	154.21	76.6
24-May-89	187.97	3.872	154.18	76.6
25-May-89	187.95	3.867	154.17	76.6
26-May-89	187.93	3.862	154.19	76.6
27-May-89	187.90	3.854	154.12	76.5
28-May-89	187.87	3.846	154.19	76.5
29-May-89	187.84	3.838	154.19	76.5
30-May-89	187.82	3.833	154.09	76.4
31-May-89	187.80	3.828	154.16	76.4
01-Jun-89	187.77	3.820	154.14	76.3
02-Jun-89	187.75	3.815	154.09	76.3
03-Jun-89	187.73	3.810	154.12	76.3
04-Jun-89	187.69	3.799	154.10	76.2
05-Jun-89	187.67	3.794	154.15	69.5
06-Jun-89	187.65	3.789	154.17	98.8
07-Jun-89	187.60	3.776	154.17	98.7
08-Jun-89	187.58	3.771	154.19	98.7
09-Jun-89	187.53	3.758	154.16	98.6
10-Jun-89	187.50	3.750	154.18	98.6
11-Jun-89	187.46	3.740	154.14	98.5
12-Jun-89	187.42	3.729	154.15	98.5
13-Jun-89	187.40	3.724	154.18	98.4
14-Jun-89	187.37	3.716	154.20	98.4
15-Jun-89	187.34	3.708	154.18	98.3
16-Jun-89	187.30	3.698	154.16	98.3
17-Jun-89	187.27	3.690	154.14	98.2
18-Jun-89	187.23	3.680	154.18	98.2
19-Jun-89	187.21	3.675	154.16	98.1
20-Jun-89	187.17	3.664	154.17	98.1
21-Jun-89	187.14	3.656	154.17	98.0
22-Jun-89	187.11	3.649	154.18	98.0
23-Jun-89	187.08	3.641	154.17	98.0
24-Jun-89	187.05	3.633	154.18	97.9
25-Jun-89	187.02	3.625	154.17	97.9
26-Jun-89	186.99	3.620	154.20	92.5
27-Jun-89	186.98	3.615	154.12	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29-Jun-89	186.95	3.610	154.12	59.3

DATE	<------RESERVOIR------> COTE LEVEL (m IGN)	VOLUME (milliards m^3) (billions m^3)	COTE AVAL DOWNSTREAM LEVEL (m IGN)	DEBITS DU BARRAGE DISCHARGE (m^3/s)
30-Jun-89	186.95	3.607	154.14	59.8
01-Jul-89	186.95	3.607	154.15	59.8
02-Jul-89	186.95	3.607	154.12	59.8
03-Jul-89	186.95	3.607	154.12	54.6
04-Jul-89	186.96	3.610	154.03	40.6
05-Jul-89	186.98	3.615	153.93	27.2
06-Jul-89	187.00	3.620	153.73	14.1
07-Jul-89	187.02	3.625	153.73	14.1
08-Jul-89	187.04	3.630	153.74	14.1
09-Jul-89	187.05	3.633	153.74	14.1
10-Jul-89	187.06	3.636	153.74	14.1
11-Jul-89	187.08	3.641	153.73	14.1
12-Jul-89	187.15	3.659	153.73	14.1
13-Jul-89	187.18	3.667	153.74	14.1
14-Jul-89	187.24	3.682	153.73	14.1
15-Jul-89	187.27	3.690	153.72	14.1
16-Jul-89	187.34	3.708	153.73	14.1
17-Jul-89	187.36	3.714	153.73	14.1
18-Jul-89	187.41	3.727	153.74	14.2
19-Jul-89	187.43	3.732	153.73	12.8
20-Jul-89	187.46	3.740	153.73	14.2
21-Jul-89	187.50	3.750	153.73	14.2
22-Jul-89	187.57	3.768	153.73	14.2
23-Jul-89	187.62	3.781	153.74	14.2
24-Jul-89	187.67	3.794	153.73	14.2
25-Jul-89	187.71	3.805	153.72	14.2
26-Jul-89	187.77	3.820	153.73	14.2
27-Jul-89	187.80	3.828	153.72	14.2
28-Jul-89	187.85	3.841	153.74	14.2
29-Jul-89	187.89	3.851	153.73	14.3
30-Jul-89	187.92	3.859	153.73	14.3
31-Jul-89	187.97	3.872	153.73	14.3
01-Aug-89	188.06	3.896	153.75	14.3
02-Aug-89	188.14	3.916	153.74	14.3
03-Aug-89	188.29	3.955	153.72	14.3
04-Aug-89	188.44	3.994	153.74	14.4
05-Aug-89	188.57	4.028	153.73	14.4
06-Aug-89	188.63	4.059	153.73	14.4
07-Aug-89	188.82	4.093	153.73	14.4
08-Aug-89	189.00	4.140	153.74	14.5
09-Aug-89	189.19	4.189	153.73	14.5
10-Aug-89	189.32	4.223	153.72	14.5
11-Aug-89	189.47	4.262	153.72	14.7
12-Aug-89	189.61	4.299	153.72	14.7
13-Aug-89	189.75	4.335	153.72	14.7
14-Aug-89	190.01	4.403	153.74	14.8
15-Aug-89	190.22	4.470	153.72	14.8
16-Aug-89	190.41	4.531	153.72	14.9
17-Aug-89	190.61	4.595	153.77	14.9
18-Aug-89	190.82	4.662	153.72	14.9
19-Aug-89	191.06	4.739	153.73	15.0
20-Aug-89	191.26	4.803	153.73	15.0
21-Aug-89	191.50	4.880	153.72	15.1
22-Aug-89	191.78	4.970	153.73	15.1
23-Aug-89	192.10	5.072	153.73	15.2
24-Aug-89	192.48	5.194	153.97	56.3
25-Aug-89	192.80	5.296	154.17	114.5
26-Aug-89	193.09	5.389	154.36	182.4
27-Aug-89	193.35	5.472	154.64	169.1
28-Aug-89	193.58	5.546	154.64	146.6
29-Aug-89	193.75	5.600	154.39	36.3
30-Aug-89	193.92	5.654	153.76	15,6
31-Aug-89	194.13	5.722	153.73	15.6
01-Sep-89	194.35	5.795	153.73	15.5
02-Sep-89	194.57	5.862	153.74	15.7
03-Sep-89	194.77	5.926	153.73	15.7
04-Sep-89	194.97	5.990	153.72	15.7
05-Sep-89	195.18	6.065	153.73	109.8
06-Sep-89	195.29	6.104	154.90	306.6
07-Sep-89	195.37	6.133	155.05	406.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10-Sep-89	195.35	6.125	156.34	282.8

DATE	(-------RESERVOIR-------) LEVEL (m IGN)	(milliards m^3) (billions m^3)	COTE AVAL LEVEL (m IGN)	DEBITS DU DISCHARGE (m^3/s)
11-Sep-89	195.34	6.122	156.38	1039.0
12-Sep-89	195.33	6.119	155.95	424.2
13-Sep-89	195.50	6.180	154.23	46.9
14-Sep-89	195.74	6.266	153.92	31.0
15-Sep-89	195.98	6.353	153.94	31.1
16-Sep-89	196.24	6.446	153.92	31.2
17-Sep-89	196.48	6.533	153.94	31.2
18-Sep-89	196.71	6.616	153.93	111.8
19-Sep-89	196.92	6.691	155.01	625.0
20-Sep-89	196.99	6.716	156.27	899.0
21-Sep-89	196.94	6.698	157.02	762.1
22-Sep-89	196.98	6.713	157.87	602.2
23-Sep-89	196.98	6.713	155.70	634.2
24-Sep-89	196.99	6.716	155.79	634.3
25-Sep-89	197.05	6.738	155.77	634.7
26-Sep-89	197.04	6.734	155.79	636.0
27-Sep-89	197.03	6.731	155.78	606.0
28-Sep-89	197.04	6.734	155.86	515.6
29-Sep-89	197.08	6.749	155.44	445.7
30-Sep-89	197.12	6.763	155.88	312.4
01-Oct-89	197.12	6.763	154.87	312.4
02-Oct-89	197.19	6.785	154.89	389.5
03-Oct-89	197.15	6.774	156.10	355.2
04-Oct-89	197.18	6.785	154.93	396.1
05-Oct-89	197.19	6.788	154.14	304.1
06-Oct-89	197.19	6.788	156.06	561.4
07-Oct-89	197.17	6.781	154.90	407.0
08-Oct-89	197.19	6.788	154.89	457.0
09-Oct-89	197.19	6.788	156.07	728.0
10-Oct-89	197.14	6.770	155.31	455.8
11-Oct-89	197.18	6.785	155.34	472.9
12-Oct-89	197.20	6.792	155.57	607.0
13-Oct-89	197.15	6.774	156.13	345.6
14-Oct-89	197.13	6.767	154.93	309.5
15-Oct-89	197.19	6.788	154.91	389.4
16-Oct-89	197.18	6.785	155.36	487.9
17-Oct-89	197.18	6.785	154.94	331.9
18-Oct-89	197.20	6.792	154.89	572.4
19-Oct-89	197.21	6.796	155.84	533.8
20-Oct-89	197.18	6.785	154.88	277.3
21-Oct-89	197.20	6.792	154.88	297.9
22-Oct-89	197.20	6.792	154.88	312.8
23-Oct-89	197.21	6.796	154.89	526.8
24-Oct-89	197.11	6.756	156.47	319.9
25-Oct-89	197.17	6.781	153.55	10.8
26-Oct-89	197.22	6.799	153.75	134.0
27-Oct-89	197.23	6.803	154.93	260.4
28-Oct-89	197.23	6.803	154.65	145.9
29-Oct-89	197.25	6.810	154.48	121.4
30-Oct-89	197.28	6.821	154.46	135.1
31-Oct-89	197.30	6.828	154.55	146.0
01-Nov-89	197.31	6.832	154.36	109.8
02-Nov-89	197.32	6.835	154.57	154.6
03-Nov-89	197.33	6.839	154.57	114.8
04-Nov-89	197.37	6.853	154.38	117.9
05-Nov-89	197.37	6.853	154.53	124.1
06-Nov-89	197.38	6.857	154.28	62.1
07-Nov-89	197.40	6.864	154.23	80.4
08-Nov-89	197.40	6.864	154.06	91.5
09-Nov-89	197.42	6.871	154.06	265.3
10-Nov-89	197.35	6.846	155.24	347.0
11-Nov-89	197.31	6.832	154.90	313.1
12-Nov-89	197.27	6.817	154.90	313.0
13-Nov-89	[illegible]	[illegible]	154.89	[illegible]
14-Nov-89	197.19	6.788	154.91	301.5
15-Nov-89	197.17	6.767	154.92	302.8
16-Nov-89	[illegible]	6.767	154.75	[illegible]
17-Nov-89	197.14	6.770	154.02	[illegible]
18-Nov-89	197.15	6.774	[illegible]	[illegible]
19-Nov-89	197.16	6.778	153.89	39.1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

DATE	RESERVOIR LEVEL (m IGN)	RESERVOIR (milliards m^3) (billions m^3)	COTE AVAL LEVEL (m IGN)	DEBITS DU DISCHARGE (m^3/s)
23-Nov-89	197.22	6.799	153.92	31.5
24-Nov-89	197.23	6.803	153.92	31.5
25-Nov-89	197.24	6.806	153.92	31.5
26-Nov-89	197.25	6.810	153.92	31.5
27-Nov-89	197.26	6.814	153.92	31.5
28-Nov-89	197.28	6.821	153.88	31.5
29-Nov-89	197.29	6.824	153.87	31.5
30-Nov-89	197.30	6.828	153.91	31.5
01-Dec-89	197.31	6.832	153.88	31.6
02-Dec-89	197.31	6.832	153.88	22.9
03-Dec-89	197.32	6.835	153.70	16.3
04-Dec-89	197.33	6.839	153.74	16.3
05-Dec-89	197.34	6.842	153.74	16.3
06-Dec-89	197.34	6.842	153.76	16.2
07-Dec-89	197.36	6.850	153.43	1.0
08-Dec-89	197.37	6.853	153.39	1.0
09-Dec-89	197.38	6.857	153.39	1.0
10-Dec-89	197.39	6.860	153.39	1.0
11-Dec-89	197.40	6.864	153.39	1.0
12-Dec-89	197.41	6.867	153.39	1.0
13-Dec-89	197.42	6.871	153.39	1.0
14-Dec-89	197.43	6.875	153.39	1.0
15-Dec-89	197.43	6.875	153.39	0.4
16-Dec-89	197.44	6.878	153.20	0.3
17-Dec-89	197.46	6.886	153.10	1.0
18-Dec-89	197.47	6.889	153.26	0.7
19-Dec-89	197.47	6.889	153.26	1.0
20-Dec-89	197.47	6.889	153.26	0.6
21-Dec-89	197.47	6.889	153.26	1.0
22-Dec-89	197.47	6.889	153.26	0.3
23-Dec-89	197.47	6.889	153.26	1.0
24-Dec-89	197.47	6.889	153.26	1.0
25-Dec-89	197.48	6.893	153.26	1.0
26-Dec-89	197.48	6.893	153.26	1.0
27-Dec-89	197.49	6.896	153.26	1.0
28-Dec-89	197.49	6.896	153.26	1.0
29-Dec-89	197.49	6.896	152.95	1.0
30-Dec-89	197.50	6.900	152.94	1.0
31-Dec-89	197.50	6.900	152.94	1.0

ORGANISATION POUR LA MISE EN VALEUR DU FLEUVE SENEGAL OMVS
DEPARTEMENT DES INFRASTRUCTURES REGIONALES DIR
GROUNDWATER MONITORING UNIT
OMVS/USAID PROJECT 625-0958

HYDROGEOLOGICAL REPERTOIRE

TOPOGRAPHIC MAP 1:200,000

27 BAFOULABE

ANNEX 6

CLIMATIC PARAMETERS

METEOROLOGICAL STATION
AT
MAHINA

OBSERVATION PERIOD

1986-1989

TABLE OF CONTENTS

Note:

This annex is an extract of the first two chapters of the report "Paramètres climatiques de la vallée du fleuve Sénégal observés sur la période 1986-1989", prepared for USAID/OMVS, Groundwater Project, by Thomas Piekutowski, May, 1990.

1 *INTRODUCTION*

1.1 Data

1.1.1 Meteorological stations

In this report, climatic parameters are presented and analyzed for the period from January 1986 to December 1989 for the following meteorological stations:

- the upper basin:
  - Mahina, Mali (Direction du Service Météorologique du Mali)
- the valley from Bakel to Podor:
  - Bakel, Senegal (ASECNA, Dir. de l'exploitation météorologique)
  - Matam, Senegal "
  - Podor, Senegal
- the delta:
  - Richard Toll, Senegal (Compagnie Sucrière Sénégalaise)
  - St. Louis, Senegal (ASECNA)

The stations are operated by the organizations indicated in parentheses.

1.1.2 Parameters analyzed

The following parameters are analyzed in this report:

- temperature
- relative humidity
- wind speed
- insolation
- rainfall
- evaporation and evapotranspiration (calculated with the Penman equation)
- evaporation measured with the Piche evaporometer and "Class A" pan

1.1.3 Data collection

Most of the data were collected by the personnel of the Groundwater Project. Missing data, for the period from January 1986 to December 1989, were collected by the author in collaboration with ASECNA and the CSS. The author noticed some questionable data among those collected by the project. These questionable values were replaced with average values when it was not possible to verify them.

The data which were collected and analyzed are the monthly averages recorded at each station. All the analyzed values are attached to this report.

The text of this report contains tables of the average monthly climatic parameters for the 48 month period 1986-1989, as well as graphics developed from these values.

1.2 Evaporation - Evapotranspiration

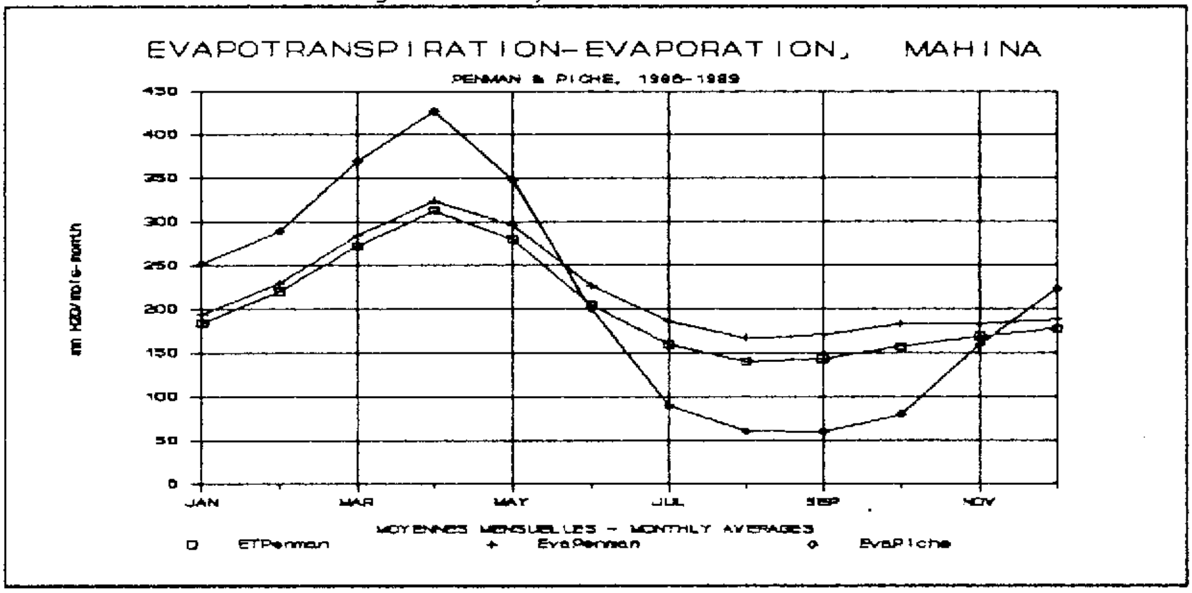
1.2.1 Penman equation

The equation used here to estimate the rates of evaporation from an open water surface and potential evapotranspiration (reference crop: grass) is that developed by Penman, as recommended by the FAO[1]. The coefficients used to estimate global radiation are in accordance with those determined for various stations in the valley of the Senegal River[2].

For the interested reader, the calculation tables attached to this report indicate all the coefficients values used for each month. The tables also indicate the relative importance of the energy and aerodynamic terms in the total evapotranspiration rates.

1.2.2 Piche evaporometer

All the meteorological stations, except for the one at Richard Toll, are equipped with Piche evaporometers. The monthly evaporation measured with these instruments is indicated in the following table but no analysis is made because the correlation between these values and the real evaporation rate is too poor. The Piche evaporometer is insensitive to insolation since it is installed in a ventilated shelter. It is especially sensitive to relative humidity of the air, thus not very significant in this region where the evaporation caused by radiation is high. The figure below indicates the evaporation measured with the Piche instrument at Mahina with respect to the calculated rate for the same place: it is overestimated during the dry season and under estimated during the rainy season.



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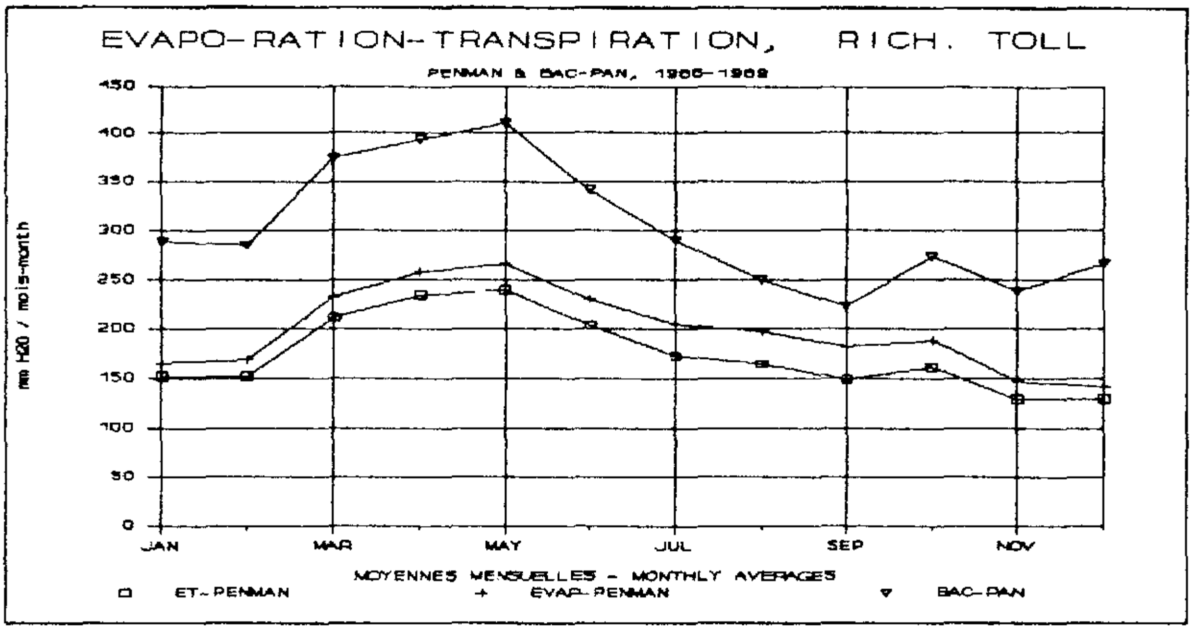
[1] Frère, M. et Popov, G.F., Surveillance agrométéorologique pour la prévision des récoltes, Etude FAO: production végétale et protection des plantes, #17, Rome 1979.

[2] Rijks, D.A., 1976. Agrométéorologie. AGP:SF/REG 114, Rapport technique 2. FAO, Rome.

1.2.3 Class A evaporation pan

Evaporation pans are not used in all the meteorological stations in the valley. Data for the entire period exist for the station at Richard Toll only. Data exist for part of the period for the stations at St. Louis, Podor and Bakel. Therefore, no analysis of these data was made. The figure below indicates the correlation between the evaporation rate measured with the pan at Richard Toll and the calculated rate for the same place (calculated = 0.6 x measured).



2 THE UPPER BASIN

The Malian Meteorological Service (Direction du Service Météorologique du Mali) provided the monthly average climatic data measured at Mahina (600 kilometers from the sea) during the period from January 1986 to December 1989. The table below indicates the average monthly values for the period.

METEO: MAHINA
LAT: 13.7°

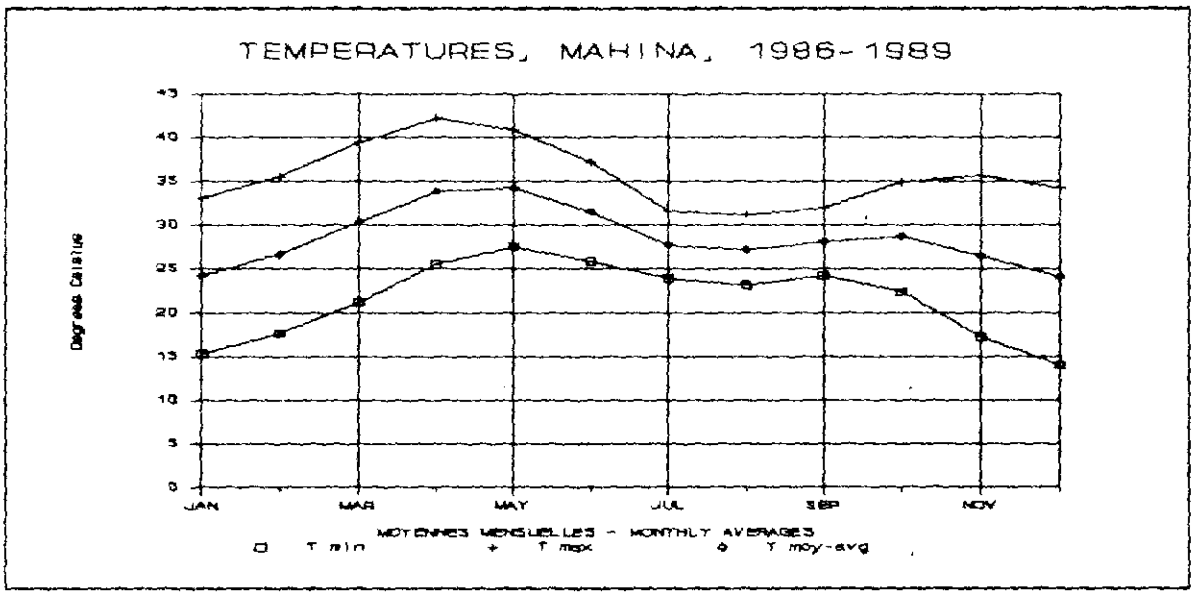
SOURCE: DIRECTION DU SERVICE METEOROLOGIQUE, MALI
ALT: 100 METERS

ESTIMATED

MOIS/AN MON/YR	T MIN moyen average Cels.	T MAX moyen average Cels.	T MOY T AVG moyen average Cels.	T MAX- T MIN moyen average Cels.	HUM.REL. REL.HUM. moyen average %	VENT WIND moyen average m/s	EVAP'N Evapo-rometre PICHE mm	EVAP'N BAC "A" Class A Pan mm	PLUIE totale RAIN FALL mm	JOURS de pluie DAYS of rain jrs/days	INSOLA-TION totale heures hours	INSOLA-TION hres/jr hours/da	EVAPOTRANS-PIRATION PENMAN totale mm	EVAPO-RATION PENMAN totale mm
JAN	15.3	33.1	24.2	17.8	32.8	2.8	252.6	*	0.0	0.0	230.0	7.4	183.7	193.7
FEB	17.7	35.6	26.6	17.9	25.0	3.2	289.5	*	0.0	0.0	210.6	7.5	220.4	229.7
MAR	21.2	39.4	30.3	18.2	20.5	3.0	370.2	*	0.0	0.0	250.6	8.1	272.3	284.9
APR	25.5	42.2	33.9	16.7	21.7	3.4	427.1	*	2.7	1.0	221.0	7.4	312.8	324.4
MAY	27.5	40.9	34.2	13.4	36.5	3.9	348.3	*	28.5	4.3	212.8	6.9	280.0	296.4
JUN	25.8	37.2	31.5	11.3	55.3	3.7	199.8	*	137.7	8.8	199.2	6.6	204.6	226.3
JUL	23.9	31.5	27.7	7.7	72.5	3.2	89.1	*	170.7	13.3	189.6	6.1	159.1	186.0
AUG	23.2	31.2	27.2	8.0	79.0	2.7	60.3	*	256.4	16.0	162.7	5.2	139.4	166.5
SEP	24.2	32.0	28.1	7.8	76.3	2.6	60.0	*	171.9	12.0	186.3	6.2	142.9	170.0
OCT	22.4	35.0	28.7	12.5	68.1	2.4	79.7	*	46.0	5.0	222.4	7.2	156.7	182.4
NOV	17.3	35.6	26.4	18.4	46.8	2.3	159.6	*	0.0	0.0	213.8	7.1	168.2	182.8
DEC	14.0	34.2	24.1	20.2	38.9	2.6	223.0	*	0.0	0.0	221.4	7.1	177.3	188.0
TOTAL							2559		814	60	2520		2418	2631

2.1 Air temperature

The figure below indicates the average minimum, average maximum and average (Tmin+Tmax)/2, temperatures at Mahina for the period. We note that April and May are the warmest months of the year and December the coolest month. We note also that the difference between the average minimum and the average maximum temperatures is large from October to June. The difference is reduced during the rainy season when the relative humidity of the air increases.



METEO: MAHINA
LAT: 13.7°

SOURCE: DIRECTION DU SERVICE METEOROLOGIQUE, MALI
ALT: 100 METRES

MOIS/AN MON/YR	T MIN moyen average Cels.	T MAX moyen average Cels.	T MOY T AVG moyen average Cels.	T MAX-T MIN moyen average Cels.	HUM.REL. REL.HUM. moyen average %	VENT WIND moyen average m/s	EVAP'N Evaporometre PICHE mm	EVAP'N BAC "A" Class A Pan mm	PLUIE totale RAIN FALL mm	JOURS de pluie DAYS of rain jrs/days	INSOLATION totale heures hours	INSOLATION hres/jr hours/da	ESTIMEE ESTIMATED EVAPOTRANSPIRATION PENMAN totale mm	EVAPORATION PENMAN totale mm
Jan-86	13.5	31.2	22.4	17.7	29	3.2	266.2	*	0.0	0	247.3	8.0	207.7	217.7
Feb-86	16.3	34.7	25.5	18.4	25	2.7	287.8	*	0.0	0	253.4	9.1	197.6	210.1
Mar-86	20.2	38.7	29.5	18.5	17	3.3	392.4	*	0.0	0	284.0	9.2	289.7	303.8
Apr-86	25.8	41.9	33.9	16.1	22	3.7	439.4	*	3.8	2	239.4	8.0	328.5	341.8
May-86	26.5	38.1	32.3	11.6	44	3.8	299.5	*	72.5	7	194.9	6.3	231.4	249.3
Jun-86	25.3	38.0	31.7	12.7	53	3.6	234.7	*	81.0	6	223.0	7.4	216.6	239.4
Jul-86	23.6	32.2	27.9	8.6	71	2.8	101.5	*	245.1	11	199.3	6.4	159.0	186.3
Aug-86	22.9	31.9	27.4	9.0	75	2.4	76.0	*	172.9	15	186.4	6.0	146.0	173.7
Sep-86	22.6	30.2	26.4	7.6	78	2.6	52.7	*	235.6	18	178.7	6.0	132.8	159.5
Oct-86	23.3	34.2	28.8	10.9	68	2.1	40.5	*	67.8	5	229.7	7.4	149.8	176.1
Nov-86	16.8	34.7	25.8	17.9	43	1.8	185.6	*	0.0	0	201.8	6.7	153.8	166.3
Dec-86	13.0	33.3	23.2	20.3	41	2.6	229.9	*	0.0	0	201.7	6.5	169.7	179.7
Jan-87	13.8	35.3	24.6	21.5	41	1.9	238.8	*	0.0	0	231.9	7.5	155.4	168.3
Feb-87	17.1	37.7	27.4	20.6	30	2.7	273.4	*	0.0	0	219.9	7.9	201.7	213.2
Mar-87	20.2	39.5	29.9	19.3	20	2.5	385.3	*	0.0	0	260.7	8.4	248.0	261.2
Apr-87	24.5	42.2	33.4	17.7	22	3.3	406.6	*	0.0	0	202.3	6.7	304.1	314.3
May-87	29.0	41.4	35.2	12.4	38	4.4	336.0	*	15.4	3	154.9	5.0	281.2	293.1
Jun-87	26.4	37.3	31.9	10.9	55	3.6	194.6	*	115.9	7	186.3	6.2	200.9	221.5
Jul-87	24.8	33.3	29.1	8.5	68	3.9	111.6	*	140.5	11	205.1	6.6	181.9	208.7
Aug-87	23.7	31.8	27.8	8.1	77	3.1	68.4	*	137.3	13	155.9	5.0	146.3	172.3
Sep-87	28.8	34.1	31.5	5.3	71	2.8	84.9	*	76.0	6	204.5	6.8	168.6	196.2
Oct-87	22.7	36.1	29.4	13.4	65	2.6	118.4	*	56.6	6	203.2	6.6	167.5	190.7
Nov-87	17.3	37.5	27.4	20.2	43	2.7	192.0	*	0.0	0	227.9	7.6	192.1	206.5
Dec-87	16.5	35.1	25.8	18.6	33	3.1	263.9	*	0.0	0	218.2	7.0	212.4	220.8
Jan-88	21.1	31.6	26.4	10.5	33	3.7	248.4	*	0.0	0	208.1	6.7	184.2	192.8
Feb-88	20.3	34.9	27.6	14.6	22	4.2	326.4	*	0.0	0	168.8	5.8	258.2	263.1
Mar-88	24.2	40.0	32.1	15.8	23	3.4	334.1	*	0.0	0	208.4	6.7	289.9	299.7
Apr-88	26.2	42.5	34.4	16.3	21	3.2	435.4	*	4.2	1	221.2	7.4	305.7	317.1
May-88	27.5	42.5	35.0	15.0	30	3.8	392.6	*	18.1	2	252.6	8.1	310.8	328.1
Jun-88	26.2	36.0	31.1	9.8	59	3.8	156.3	*	188.4	8	186.7	6.2	195.4	217.4
Jul-88	23.6	30.5	27.1	6.9	75	3.1	74.3	*	238.2	16	148.2	4.8	145.0	169.4
Aug-88	23.1	30.4	26.8	7.3	82	2.6	41.6	*	345.5	18	140.6	4.5	129.5	155.7
Sep-88	22.9	31.7	27.3	8.8	78	2.2	49.0	*	197.9	13	178.0	5.9	133.0	159.9
Oct-88	21.7	35.3	28.5	13.6	68	2.3	85.9	*	18.4	3	236.4	7.6	159.7	186.4
Nov-88	16.2	35.3	25.8	19.1	49	2.0	131.7	*	0.0	0	227.8	7.6	155.1	171.4
Dec-88	12.6	32.9	22.8	20.3	33	2.1	209.2	*	0.0	0	244.9	7.9	158.6	168.8
Jan-89	12.9	34.4	23.7	21.5	28	2.5	256.9	*	0.0	0	232.7	7.5	187.3	196.1
Feb-89	17.0	35.1	26.1	18.1	23	3.2	270.2	*	0.0	0	200.4	7.2	224.3	232.2
Mar-89	20.3	39.3	29.8	19.0	22	2.8	369.0	*	0.0	0	249.4	8.0	261.9	275.0
Apr-89	*	*	*	*	*	*	*	*	*	*	*	*	*	*
May-89	27.0	41.6	34.3	14.6	34	3.7	365.2	*	8.0	5	248.6	8.0	296.7	315.3
Jun-89	25.4	37.3	31.4	11.9	54	3.8	213.7	*	165.4	14	200.7	6.7	205.6	227.0
Jul-89	23.5	30.1	26.8	6.6	76	2.9	69.1	*	59.1	15	205.6	6.6	150.4	179.6
Aug-89	23.0	30.7	26.9	7.7	82	2.8	55.3	*	369.9	18	167.9	5.4	136.0	164.5
Sep-89	22.5	31.8	27.2	9.3	78	2.7	53.3	*	177.9	11	184.0	6.1	137.2	164.5
Oct-89	22.0	34.2	28.1	12.2	71	2.4	73.8	*	41.2	6	220.2	7.1	149.9	176.4
Nov-89	18.7	35.0	26.9	16.3	52	2.6	129.1	*	0.0	0	197.6	6.6	171.7	187.0
Dec-89	13.9	35.4	24.7	21.5	49	2.7	189.0	*	0.0	0	220.8	7.1	168.7	182.4
MIN	12.6	30.1	22.4	5.3	17	1.8	40.5	*	0.0	0	140.6	4.5	129.5	155.7
MOY/AVG	21.4	35.5	28.5	14.1	48	3.0	208.7	*	69.2	5	209.8	6.9	199.1	217.0
MAX	29.0	42.5	35.2	21.5	82	4.4	439.4	*	369.9	18	284.0	9.2	328.5	341.8

--------MOYENS ANNUELS - YEARLY AVERAGES------------- ----------------TOTAUX ANNUELS - YEARLY TOTALS--------------

1986	20.8	34.9	27.9	14.1	47.2	2.9	2606	*	879	64	2640	*	2383	2604
1987	22.1	36.8	29.4	14.7	46.9	3.1	2674	*	542	46	2471	*	2460	2667
1988	22.1	35.3	28.7	13.2	47.8	3.0	2485	*	1011	61	2422	*	2425	2630
1989	*	*	*	*	*	*	*	*	(822)	(69)	*	*	*	*

MAHINA PARA-METRE	PSYCHO-METRIQUE CONST.	RAY.SOL. MAX SOLAR RAD'N	INS.ASTR. MAX INSOL'N	RATIO INSOL'N	RAD'N RECU REC'D	CORPS NOIR BLACK BODY RAD'N	VAP.SAT. SAT'D VAP TENS.-PRES.	VAP.ACT. ACTUAL VAP TENS.-PRES.	RAD'N EMISE EMITTED	RAD'N NETTE NET	COEFF. VENT WIND	AERODY-NAMIQUE NAMIC	EVAPOTRANS PIRATION POTENT'L	EVAPO-RATION eau libre free water
STATUT STATUS	Saisie Measured	Saisie Measured	Saisie Measured	Calcul Calcul'd	Calcul Calcul'd	Calcul Calcul'd	Saisie Measured	Calcul Calcul'd	Calcul Calcul'd	Calcul Calcul'd	Saisie Measured	Calcul Calcul'd	Calcul Calcul'd	Calcul Calcul'd
SYMBOLES	DeltaGamma	RA	N	n/N	RA	sTk4	Ea	Ed	Ed,n/N	RA,n/N,Ed		Ea,Ed,U	Et	Et
UNITE	sans/none	mm H20	hres/hours	sans/none	mm H20	mm H20	millibars	millibars	mm H20	mm H20	sans	mm H20	mm H20	mm H20
Jan-86	2.48	12.41	11.3	0.71	3.89	15.10	26.93	7.81	2.69	1.21	0.89	5.49	6.70	7.02
Feb-86	2.94	13.62	11.6	0.78	4.71	15.76	32.64	8.16	3.15	1.55	0.89	5.50	7.06	7.50
Mar-86	3.58	14.89	12.0	0.76	5.33	16.61	41.01	6.97	3.59	1.74	0.89	7.60	9.34	9.80
Apr-86	4.44	15.65	12.5	0.64	5.35	17.60	52.62	11.58	2.82	2.53	0.89	8.42	10.95	11.39
May-86	4.13	15.83	12.8	0.49	4.74	17.24	48.38	21.29	1.47	3.27	0.54	4.19	7.46	8.04
Jun-86	3.99	15.70	13.0	0.57	4.99	17.10	46.50	24.65	1.41	3.58	0.61	3.64	7.22	7.98
Jul-86	3.32	15.72	12.9	0.50	4.53	16.27	37.59	26.69	1.04	3.48	0.54	1.65	5.13	6.01
Aug-86	3.22	15.65	12.6	0.48	4.39	16.16	36.30	27.22	0.97	3.43	0.54	1.28	4.71	5.60
Sep-86	3.07	15.14	12.2	0.49	4.24	15.95	34.43	26.85	0.98	3.26	0.54	1.16	4.43	5.32
Oct-86	3.46	14.12	11.8	0.63	4.55	16.45	39.38	26.78	1.28	3.27	0.54	1.57	4.83	5.68
Nov-86	2.97	12.84	11.4	0.59	3.87	15.81	33.03	14.20	1.96	1.92	0.89	3.21	5.13	5.54
Dec-86	2.59	12.02	11.2	0.58	3.47	15.27	28.26	11.59	2.00	1.48	0.89	4.00	5.47	5.80
Jan-87	2.79	12.41	11.3	0.66	3.89	15.56	30.75	12.61	2.23	1.66	0.89	3.35	5.01	5.43
Feb-87	3.24	13.62	11.6	0.68	4.48	16.16	36.51	10.95	2.62	1.87	0.89	5.34	7.20	7.61
Mar-87	3.65	14.89	12.0	0.70	5.12	16.70	41.96	8.39	3.17	1.95	0.89	6.05	8.00	8.43
Apr-87	4.33	15.65	12.5	0.54	4.93	17.48	51.18	11.26	2.45	2.47	0.89	7.66	10.14	10.48
May-87	4.71	15.83	12.8	0.39	4.45	17.91	56.84	21.60	1.29	3.16	0.61	5.91	9.07	9.45
Jun-87	4.03	15.70	13.0	0.48	4.63	17.14	47.03	25.86	1.15	3.48	0.54	3.22	6.70	7.38
Jul-87	3.51	15.72	12.9	0.51	4.64	16.52	40.06	27.24	1.07	3.57	0.54	2.30	5.87	6.73
Aug-87	3.29	15.65	12.6	0.40	4.12	16.24	37.16	28.61	0.79	3.33	0.54	1.39	4.72	5.56
Sep-87	3.96	15.14	12.2	0.56	4.76	17.05	45.98	32.64	0.89	3.86	0.54	1.76	5.62	6.54
Oct-87	3.58	14.12	11.8	0.56	4.33	16.60	41.01	26.66	1.18	3.15	0.68	2.25	5.40	6.15
Nov-87	3.24	12.84	11.4	0.67	4.19	16.16	36.51	15.70	2.13	2.06	0.89	4.34	6.40	6.88
Dec-87	2.98	12.02	11.2	0.63	3.74	15.82	33.22	10.96	2.35	1.39	0.89	5.47	6.85	7.12
Jan-88	3.06	12.41	11.3	0.59	3.78	15.94	34.22	11.29	2.24	1.54	0.54	4.40	5.94	6.22
Feb-88	3.27	13.62	11.6	0.50	3.92	16.21	36.94	8.13	2.29	1.63	0.75	7.28	8.90	9.07
Mar-88	4.09	14.89	12.0	0.56	4.71	17.20	47.83	11.00	2.49	2.23	0.82	7.13	9.35	9.67
Apr-88	4.55	15.65	12.5	0.59	5.17	17.71	54.11	11.36	2.69	2.48	0.89	7.71	10.19	10.57
May-88	4.71	15.83	12.8	0.64	5.46	17.86	56.24	16.87	2.33	3.12	0.75	6.90	10.03	10.58
Jun-88	3.90	15.70	13.0	0.48	4.60	16.97	45.19	26.66	1.09	3.51	0.54	3.00	6.51	7.25
Jul-88	3.17	15.72	12.9	0.37	3.99	16.09	35.65	26.74	0.80	3.19	0.54	1.49	4.68	5.46
Aug-88	3.12	15.65	12.6	0.36	3.92	16.02	35.04	28.73	0.70	3.22	0.54	0.96	4.18	5.02
Sep-88	3.22	15.14	12.2	0.49	4.28	16.14	36.30	28.31	0.92	3.36	0.54	1.08	4.43	5.33
Oct-88	3.42	14.12	11.8	0.65	4.60	16.40	38.93	26.47	1.33	3.27	0.68	1.88	5.15	6.01
Nov-88	2.97	12.84	11.4	0.67	4.10	15.81	33.03	16.18	2.00	2.10	0.89	3.07	5.17	5.71
Dec-88	2.54	12.02	11.2	0.71	3.79	15.18	27.59	9.11	2.57	1.22	0.89	3.90	5.11	5.45
Jan-89	2.66	12.41	11.3	0.66	3.85	15.37	29.13	8.16	2.61	1.24	0.89	4.80	6.04	6.33
Feb-89	3.01	13.62	11.6	0.62	4.21	15.87	33.61	7.73	2.66	1.55	0.89	6.46	8.01	8.29
Mar-89	3.65	14.89	12.0	0.67	5.01	16.69	41.96	9.23	2.95	2.06	0.89	6.38	8.45	8.87
Apr-89	!	15.65	12.5	!	!	!	!	!	!	!	!	!	!	!
May-89	4.55	15.83	12.8	0.63	5.38	17.70	54.11	18.40	2.13	3.25	0.75	6.32	9.57	10.17
Jun-89	3.94	15.70	13.0	0.51	4.75	17.03	45.72	24.69	1.28	3.47	0.54	3.38	6.85	7.57
Jul-89	3.14	15.72	12.9	0.51	4.52	16.03	35.24	26.78	1.03	3.49	0.54	1.36	4.85	5.79
Aug-89	3.14	15.65	12.6	0.43	4.19	16.04	35.24	28.90	0.80	3.39	0.54	1.00	4.39	5.31
Sep-89	3.19	15.14	12.2	0.50	4.33	16.11	35.87	27.97	0.96	3.37	0.54	1.20	4.57	5.48
Oct-89	3.36	14.12	11.8	0.60	4.43	16.31	38.03	27.11	1.20	3.23	0.61	1.60	4.83	5.69
Nov-89	3.14	12.84	11.4	0.58	3.89	16.04	35.24	18.43	1.67	2.22	0.89	3.50	5.72	6.23
Dec-89	2.80	12.02	11.2	0.64	3.70	15.58	30.93	15.03	1.96	1.74	0.89	3.70	5.44	5.89
MIN	2.48	12.02	11.20	0.36	3.47	15.10	26.93	6.97	0.70	1.21	0.54	0.96	4.18	5.02
MOY/AVG	3.45	14.44	12.10	0.57	4.42	16.40	39.39	18.71	1.82	2.61	0.72	3.94	6.55	7.14
MAX	4.71	15.83	13.00	0.78	5.46	17.91	56.84	32.64	3.59	3.86	0.89	8.42	10.95	11.39

CONSTANTES ET COEFFICIENTS UTILISEES - CONSTANTS AND COEFFICIENTS USED

Albedo = 0.25 (evapotranspiration), 0.050 (evaporation)
Coefficient "a" = 0.29 : radiation terme: (a + b*n/N)
Coefficient "b" = 0.42 : radiation terme: (a + b*n/N)
Coefficient du Vent - Wind = Tire de (read from) Table, P.40, Para.2.3, FAO 1979
Ra = Tire de (read from) Table 1, P. 44 , FAO 1979
N = Tire de (read from) Table 2, P. 46, FAO 1979
Ea = Tire de (read from) Table 7, P. 53, FAO 1979
Ed = Calcul: Ea * %Hum., FAO 1979, P. 42, Par; 5, Note #2
sTk4 = Calcul: 11.71E-8 * (Tc + 273)^4
DeltaGamma = Tire de (read from) Table 10, P.58, FAO 1979