TATION
OJECT

COORDINATION AND
INFORMATION CENTER

Operated by The CDM
Associates
Sponsored by the U. S. Agency
for International Development

1611 N. Kent Street, Room 1002
Arlington, Virginia 22209 USA

Telephone: (703) 243-8200
Telex No. WUI 64552
Cable Address WASHAID

TUNISIA

ASPECTS OF WELL DRILLING

RURAL POTABLE WATER PROJECT

WASH FIELD REPORT NO. 4

December 20-27, 1980

Contract No. AID/DSPE-C-0080

Project No. 931-1176

The WASH Project is managed by Camp Dresser & McKee Incorporated. Principal Cooperating Institutions and subcontractors are: International Science and Technology Institute; Research Triangle Institute; University of North Carolina at Chapel Hill; Georgia Institute of Technology—Engineering Experiment Station.

WATER AND SANITATION FOR HEALTH PROJECT

COORDINATION AND INFORMATION CENTER

Operated by The CDM Associates
Sponsored by the U. S. Agency for International Development

1611 N. Kent Street, Room 1002
Arlington, Virginia 22209 USA

Telephone: (703) 243-8200
Telex No. WUI 64552
Cable Address WASHAID

February 10, 1981

Mr. William Gelabert
Mission Director
U.S. Agency for International Development
Tunis, Tunisia

Dear Mr. Gelabert:

I have the honor to transmit to you herewith fifteen copies of a report on Aspects of Well Drilling of the Rural Potable Water Project, Central Tunisia. This report was prepared for WASH by Mr. Michael Glaze and is based on a visit to Tunisia during the period December 20 to 27, 1980.

If mission staff have any questions about this report, WASH will be glad to try to answer them.

Very truly yours,

James Arbuthnot
Project Director

JA:jml

The WASH Project is managed by Camp Dresser & McKee Incorporated. Principal Cooperating Institutions and subcontractors are: International Science and Technology Institute; Research Triangle Institute; University of North Carolina at Chapel Hill; Georgia Institute of Technology—Engineering Experiment Station.

TABLE OF CONTENTS

REPORT ON ASPECTS

OF WELL DRILLING - RURAL POTABLE WATER PROJECT

CENTRAL TUNISIA
12/20-12/27
1980

1. GENERAL

The purpose of this report is to elaborate on the draft report left with the AID Tunis mission on 27 December 1980. It will discuss mainly two topics:

1) The choice of a suitable water well drilling machine and a suitable adviser to assist in its operation.
2) The methodology used in previous and current (if any) installations of PVC casing and screen, what inherent problems occurred or are occurring,and to attempt to answer specific questions that Regie des Sondage and the U.S. AID mission have raised regarding PVC casing and screen.

The proposed project for which the drilling rig is to be supplied aims at drilling to a maximum depth of 200m (656 ft.) with hole diameter capability to accomodate up to 9 3/8"O.D. casing with gravel packed screens. One of the purposes of the project is to provide a low-cost technology for installing low yield, smaller diameter wells in more remote, less accessible areas of central Tunisia where obtaining potable water is difficult.

The meeting of 12/23/80 with Tunisian project managers of the C.T.D.A. ended with a statement on their part that they were

going to control and operate the new, proposed drilling rig. It is not clear at this time which governmental organization will be operating the proposed drilling machine. Both Regie des Sondage and C.T.D.A. expressed a desire to initiate a new drilling methodology; however, Regie is much better equipped to handle the new rig in terms of facilities, and technical knowhow.

A) Drilling Rig

In preparing the invitation for bid, the advisor recommends specifying a top head drive rotary drilling machine, preferably truck mounted, with the following characteristics:

Drill Rig Capability

1) Minimum depth capacity of 200M (656') drilling a nominal 12" (30,48cm) diameter hole.
2) All rig controls to be pneumatically operated.

Mast

1) Constructed of tubular steel.
2) Capable of handling up to 4½ inches diameter internal flush drill pipe in 20 ft. (6.1m) lengths.
3) Equipped with lights for night operation.
4) Hydraulically operated with dual hoist cylinders.
5) Derrick capacity of 40,000 lbs. (18,140 Kg.)

Rotary Drive

1) Rotational speed of 0-160 R.P.M.
2) Pull down minimum of 12 tons (10,900 Kg.)
3) Holdback minimum of 7 tons (6,350 Kg.)
4) Torque of 30,000 inch-lbs. (34,600cm-Kg.) minimum.
5) Retractable head for handling casing installation.

Water Swivel

1) Inside diameter equal to 2" (5.08 cm)

Stand Pipe

1) Inside diameter equal to 2½" (6.35cm)
2) Shut-off valves to be 2½" (6.35cm) and of quick-action type.

Sand Reel

1) Sand reel will be equipped with clutch.
2) Minimum 3/8' diameter cable and preferably holding 1,000 ft. (305m) of cable.
3) Cable fittings to be equipped with quick release.

Main Rig Drive

1) Rig to be driven via heavy-duty power take off from truck engine.

Compressor

1) Capacity of 100 cfm @ 125 psi(2.8ms/min. @ 8.8 Kg/cm^2)
2) Reciprocating type.

Mud Pump

1) Duplex type, cylinders approximately five inches diameter by six inch stroke.
2) 200 gpm @ 310 psi (757 liters/min. @ 21.8 Kg/cm^2)
3) Complete with 4" suction hose and strainer and 2½" discharge.

Optional Equipment - (priced separately)

1) Compressor - capacity of 625 cfm @ 125 psi (17.7 m^3/min. @8.8 Kg/cm^2).
2) Foam injection pump - capacity of 0-25 gpm (-95 litter/ min.).

3) 4 barrels of foam agent.

Truck Description

1) 18,000 lb. (8,160Kg.) front axle capacity.
2) 40,000 lb. (18,140Kg.) rear axle capacity.
3) Interlock on rear axles.
4) 13-speed transmission.
5) 150-gallon (570 liter) fuel tank capacity.
6) Flotation tires for front axle.
7) 10.00 x 20.00 12-ply mud/snow tube tires on rear axles.
8) Caterpillar-type engine or equivalent (engine block to be wet sleeved type).

Ancillary Equipment

1) Drill pipe - 4½ inches diameter internal flush, in lengths of 20 ft. (6.1m) lengths - 41 lengths total.
2) Necessary fishing tools, handling subs and drilling subs.
3) 12 - 6½" tri-cone bits for drilling sedimentary limestones and sandstones.
4) 15 - 12¼" tri-cone bits for drilling sedimentary limestones and sandstones.
5) 2 - 15" reamers with 4 sets of spare cutters.
6) 1 - stabilizer for 15" nominal hole.
7) 200 amp electric welder - diesel driven with necessary power outlets 220V and 115V. Include necessary cables minimum 25' length.
8) Hard-wheel grinder with spare wheels.
9) Oxy/acetylene welding outfit complete, less tanks.
10) 50 lbs.- 3/32" Stoodite hard surface welding rod.
11) 50 lbs.- 1/8" and 3/32" low hydrogen #7018 welding rod.
12) Necessary safety equipment for welding and cutting.
13) 5,000 watt electric generating plant - diesel driven, 220 volt.

14) Necessary filters, spare parts, repair kits and hand tools for operating in the field for one year.

Technical Assistance

Well Drilling Adviser's Requirements & Job Description

1) Speaking ability in French essential.
2) Prior extensive drilling experience, including at least 2 years working in a developing country.
3) A minimum of 5 years experience with operation and maintenance of top-head drive rotary drills.
4) Experience should include capability for formulating the logistical planning for operating a complete drilling program.
5) Job will involve complete on-the-job training of Tunisian drill crew(s) for estimated 6-month period in areas such as drilling, transportation, test pumping, preventive maintenance and trouble shooting.
6) Well drilling advisor will assist in accepting shipment delivery at Tunis and check listing for any damage or loss.
7) Prior to field drilling adviser will provide C.D.T.A./U.S. AID with:
   A) Proposed manpower and logistical requirements for field operation.
   B) Drill and ancillary equipment O&M manuals and schedule.
   C) Recommendations on drilling site scheduling, focusing on weather and site accessibility.
8) During operations, adviser will provide C T.D.A./U.S. AID with monthly progress reports on drilling conditions, completion times, well logs, pump test data, and difficulties incurred and remedial action(s) taken.
9) Prior to departure, adviser will provide a final summary report detailing levels of training in O&M procedures, recommendations and projected budget for continued operation.

II. P.V.C. CASING/SCREEN

A. General

In considering the use of P.V.C. casing and/or screen for the proposed drilling project, several facts in terms of recommended installation procedures, need to be set forth:

1) Non-metallic casing/screen can collapse due to bridging and subsequent collapse of the gravel pack, due to heat of hydration during cement grouting, and due to surging during development.
2) Performance may be adequate for several years and then collapse due to ground subsidence.
3) Direct setting of any pumping equipment against P.V.C. should be avoided by placement of a protective steel outer casing sleeved over the non-metallic (P.V.C,) casing and which is set slightly higher than the P.V.C. (see drawing). Centralizers must be used on all column pipe.

Addressing these facts, the collapse problem can be avoided by:

1) Drilling a straight, clean hole.
2) Placing of the gravel pack only through a tremie line mixing the gravel with water and fill in at a slow, even rate.
3) Add a little bentonite from (2-9%) or sand to the grout mixture and avoid using quick-drying cement.
4) While grout is setting up, cool casing by circulating water through it.
5) During air surging, control the rate of air injection so that excessive pressures do not develop and so that the hydrostatic collapse pressure rating of the pipe is not exceeded.
6) Obtaining a well yield that does not exceed the safe

yield beyond which subsidence occurs.

The advisor feels that the use of P.V.C. casing/screen as low cost new technology is suitable for the project based on the following:

1) P.V.C. casing and screen is suitable in almost the entire proposed project area.
2) P.V.C. screens are quite varied in types of construction and cost. The Robo screen (sample provided by the University of Maryland) has not been produced in diameters larger than 3" and no field testing is known to have been done at this time. Several other manufactures produce P.V.C. screen; however, their costs are considerably higher in comparison to the Robo screen with same diameters. The Robo screen is primarily designed for use with small diameter wells using hand pump installations. (In the opinion of the advisor, the wide spread use of hand pumps in the project area is not considered to be feasible due to excessive depths to water. 1978 Piezometric surface maps of the SBEITLA area indicate depth to water at 50 meters and greater).
3) Screen installation methods used by Regie des Sondage and Equipment Hydraulique are of the "Layne" and "California" methods. (See illustrations).

Neither Regie des Sondage nor Equipment Hydraulique use a tremie line for placement of the gravel pack nor do they use a screen seal as prescribed in the A.W.W.A. "Standard for Deep Wells". Regie des Sondage admitted to earlier damaging of pumps by pumping gravel caused by placement of suction intakes too close to the screen.

Gravel pack placed without a tremie is liable to sort itself by size as it falls and to provide an inferior or ineffective pack. Use of a screen seal would have prevented the pumping of gravel noted.

P.V.C. casing and screen of nominal diameters 6" and greater are adaptable to both construction methods shown above. A comparison chart of non-metallic casing parameters is furnished in Table 1. There is no comparable chart for nonmetallic screens included in this report due to lack of known availability of such a report.

Table 1

Comparison of Nonmetallic Well Casing Materials

Material	Specific Gravity	Tensile Strength psi	Tensile Modulus 10^5 psi	Impact Strength ft-lbs/in	Upper Temperature Limits °F	Thermal Expansion 10^6 in/in °F	Heat Transfer Btu-in/ hr-ft² °F	Water Absorption wt%/24 hrs	Corrosion Resistance	Scaling Resistance	Cost $/ft/in. diam.
ABS	1.04	4500	3.00	6.0	180	5.5	1.35	.30	Excellent	Excellent	1.03
PVC	1.40	8000	4.10	1.0	150	3.0	1.10	.05	Excellent	Excellent	.80
CPVC	1.55	8400	4.22	1.5	210	3.0	1.00	.05	Excellent	Excellent	1.90
Styrene rubber	1.06	3800	3.20	0.8	140	6.8	0.80	.15	Very good	Excellent	.39
Fiberglass epoxy	1.89	16750	23.00	20.0	300	8.5	2.30	.20	Excellent	Excellent	2.07
Fiberglass vinylester	1.53	8470	10.20	7.4	150	8.3	3.40	.20	Good	Excellent	1.75
Reinforced plastic mortar	1.95	20000	20.00	10.0	140	3.3	1.94	1.00	Good	Excellent	1.69
Laminated wood	1.25	9243	17.06	4.3	250	3.3	0.39	3.50	Good	Good	2.37
Asbestos cement	1.85	3000	30.00	1.0	250	1.7	0.56	2.00	Excellent	Very good	.30
Polymer concrete	2.26	1700	64.00	0.9	500	3.3	2.73	.06	Excellent	Very good	.30

B. Responses to Regie des Songage's Questions Re: P.V.C.

(Ref. cable 12/9/80 8:35 P.M.)

1) Is it possible to cement grout P.V.C.?

2) What are the results of performance tests on P.V.C, casing and screen as concerns tensile strength, tendency to collapse inwards, resistence to HCL?

Tensile strengths for P.V.C. and other non-metallic casing materials are included in Table 1. Insofar as collapse resistence, this is referred to as "hydrostatic collapse pressure" and is a function of the difference in water levels inside and outside the casing during

development and operating conditions. All plastic casings are now under the S.D.R. (Standard Dimension Ratio) rating system which is simply a ratio of outside diameter to wall thickness of the pipe. For example, a casing with an S.D.R. of 21 and a wall thickness of .316 inch has a hydrostatic collapse pressure of 111 psi. So, if the static water level were 60 feet from ground level in a deep well, the total draw-down upon pumping should not exceed 196 feet. In practice, pressures should be limited to approximately 2/3 of the hydrostatic collapse pressure to provide a margin of safety. HCL or muriatic acid is reported not to cause deleterious effects upon P.V.C. casing and screen on short term development procedures. Some degree of brittleness is reported with P.V.C. on prolonged contact with concentrated solutions of HCL.

3) Is it possible to remove cuttings, bentonite drilling mud, etc. and otherwise clean out a drilled well during development using the same technique applied to a steel cased well?
Following the guidelines referenced earlier in this report,P.V.C. cased and screened wells can be developed with the same methods normally used for steel cased and screened wells.

4) What is the smallest possible slot opening on P.V.C. screen? Is 1 mm possible?
Firstly, there are basically two methods of fabricating P.V.C. screen: sawing and continuous wrap. Using the former, P.V.C. can be slotted to slot sizes as small as .018 inch. However, this is the special extruded Robo screen and has only been done in diameters up to 3". Regularly sawed P.V.C. is limited to minimum slot sizes of about .050 inch. The Johnson type plastic screen is available in slot sizes less than .018 inch and in diameters up to 6" nominal size. A 1 mm slot opening is equivalent to a .039 inch opening.

Questions of U.S. AID Mission

1) What is the maximum depth to which P.V.C. casing and screen can be used and what are the relevant considerations?
   Depth in itself is not the sole limiting factor as mentioned earlier in the report. There are many considerations that have to be weighed before using P.V.C. casing and screen in a drilled hole. There is also no reason not to consider using P.V.C. casing with steel screen and vice versa.
2) Ref. (a), p.30 implies that P.V.C. should not be used for wells with yields in excess of 15 liters per second. (237 gpm). Is this the limit?
   The limitations on using P.V.C. as casing and/or screen are not a function of well yield, but rather a limitation based in this reference, on hydrostatic collapse pressure ratings which vary as to diameter and wall thickness of the P.V.C.
3) The same reference implies that gravel pack cannot be used with P.V.C. Please verify.
   This is an invalid implication and no further discussion is necessary (see above).
4) A request for a detailed chart comparing steel and P.V.C. casing and steel and P.V.C. screen stating their advantages, disadvantages, limitations, characteristics and their resistance to chemical action has not been included in this report. The chart in Table 1 is a comparison of current nonmetallic casings using different parameters. The detailed chart which was requested would require a great deal of time to prepare, if it could be prepared. There are numerous screen manufacturers in the U.S. and the rest of the world. Steel is not a specific term when applied to casing and/or screen as there are a number of different alloy combinations used in screen manufacturing for different water well conditions. This is not meant to be an evasive answer, but is hoped to

serve as an indication of the complex nature of the request and the amount of time and effort that would have to be expended trying to obtain the information.

III. CONCLUSIONS AND RECOMMENDATIONS

A. The tophead rotary type of drill that is recommended for use in the proposed AID project will require technical training of G.O.T. personnel by an individual who has a good deal of patience. The whole success of the program hinges on this individual being able to cope with adverse living and working conditions. C.D.T.A.'s willingness to cooperate in providing necessary support vehicles, manpower, etc. has not been tested for a drilling project. Regie des Sondage has expressed enthusiasm for acquiring the rig and it does, at least, have a bonafide track record in being able to handle operations of this nature. All things considered, Regie des Sondage appears to be the best G.O.T. agency to conduct the drilling program.

B. The level of previous education and training could be a very real problem with C.D.T.A. in that none of their personnel has been associated with operation and maintenance of heavy equipment--especially hydraulic equipment. Regie des Sondage has people with this capability and should be adaptable to the new equipment without lengthy, involved basic training.

Drilling conditions are quite varied throughout the proposed project area. Rock types are mainly alternating sandstones and limestones that have varying degrees of hardness. Karst conditions in the limestone are prevalent resulting in lost circulation zones. These type of conditions will permit the use of P.V.C. but will require knowledge and expertise that the drilling adviser must be able to convey to the G.O.T. drilling personnel.

This advisor recommends initiating the drilling program using

steel casing and screen. After some degree of familiarity is achieved with the rig operation(s),the project could attempt using P.V.C. in an area where the drilling is relatively uncomplicated and straight forward.

Schedule for Michael V. Glaze

Friday, December 19, 1980

3:15 p.m. - Arrive Tunis, met by Dorothy Young

4:00 p.m. - Discuss schedule and scope of work with Project Manager (Dorothy Young)

Saturday, December 20, 1980

7:45 a.m. - Depart Hotel Claridge

8:30 a.m. - Discussions at AID office

1:00 p.m. - Meeting with Mohamed BACHA, President, Director General of Regie des Sondage's Hydraulique. (This is the drilling branch of the Ministry of Agriculture and the organization responsible for preparing the IFB for the drill rig)

- discussions with Bacha
- visit the Regie yard - Mr. Jaffar
- arrange to visit drilling sites en route to Kasserine on Monday
- review the IFB specifications and the job descriptions for the hydrogeologist and the well driller
- discuss use of P.V.C. screen and casing.

Sunday, December 21, 1980

- Reviewed technical literature supplied by D. Young & C.D.M.

Monday, December 22, 1980

6:30 a.m. - Depart hotel for Kasserine with Dorothy Young. Visit drilling sites en route.

1:00 p.m. - Meeting with Tunisian project managers: Mohamed Salah Nenni and Moncef Huddein.
Review and discuss the IFB and the job descriptions.

2:00 p.m. - Field visit to Regie des Sondage Sbeitla drilling site (Failing 2500 rig) with CTDA and DRES representative Abdulaziz.

4:00 p.m. - Meeting with Mr. Rahouri, director of the regional office of DRES (Direction des Ressources en eau et en sol); this office is responsible for mapping the area and approving all drilling activities.

Tuesday, December 23, 1980

9:00 a.m. -

1:00 p.m. - Continue discussions with Nenni and Hussein on the IFB

3:00 p.m. -

4:30 p.m. - Meeting with CTDA - Planning Unit and Moncef Hussein

4:30 p.m. - Returned to Tunis

Wednesday, December 24, 1980

10:00 a.m. Equipment Hydralique, Mr. Hacmche

11:30 a.m. Mr. Trebelsi and Mr. Rahoui, Library of DRE (direction des Ressources en eau Consultation) on Maps

1:00 p.m. Societe d'Injection et Forage, Ms. Debora

3:00 p.m. Debriefing: U.S. AID director William Gelabert: Program Officer Edmund Auchter

3:00 p.m.

10:00 p.m. Work on specifications with D. Young.

Thursday, December 25, 1980

Report writing

Friday, December 26, 1980

Prepare report - Meeting with D. Young

Saturday, December 27, 1980

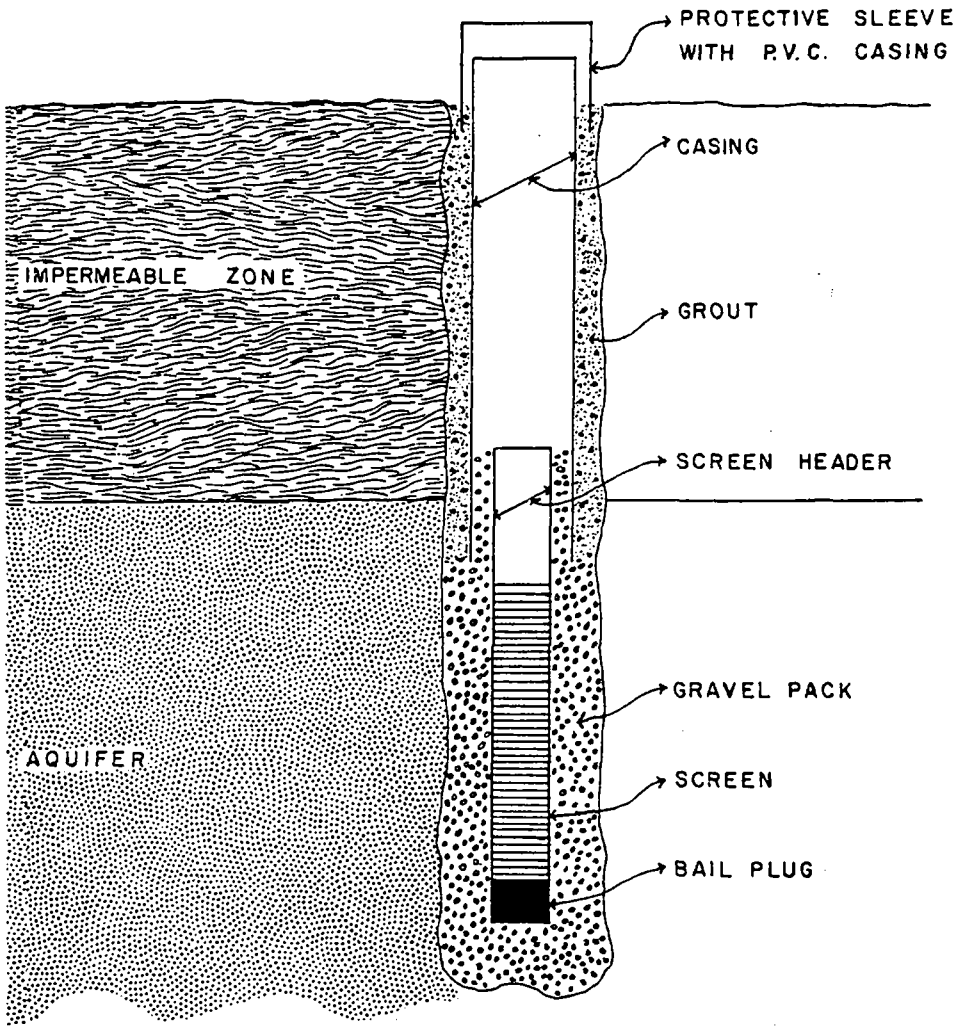
3:00 p.m. Depart Tunisia

LIST OF REFERENCES

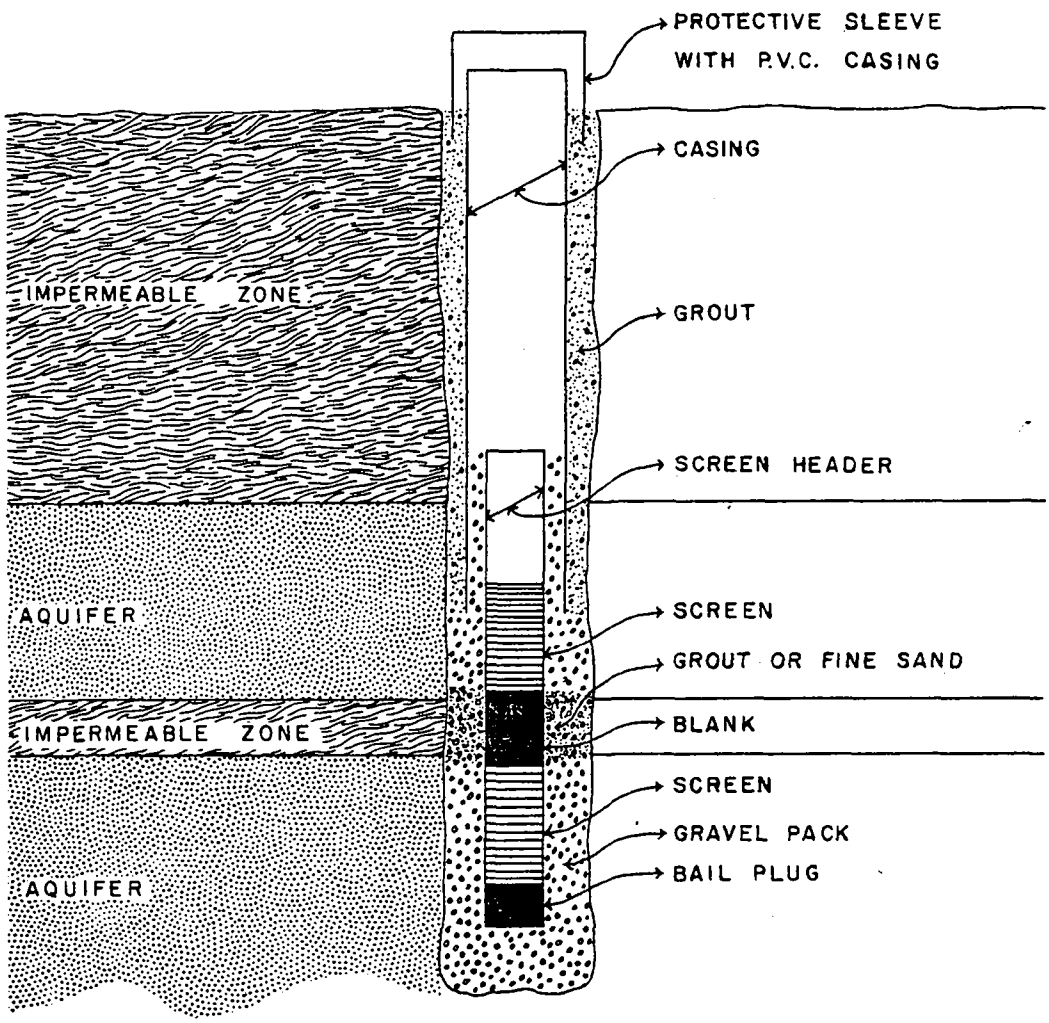
1) "Development Of P.V.C. Well Screens For Local Fabrication In Developing Countries" - P.U. Report No. Re 51., International Bank for Reconstruction and Development; International Development Association; Public Utilities Dept., Research Working Paper Series April 1978. Prepared by Yaron M. Sternberg and Robert Knight of International Rural Water Research and Development Laboratory; University of Maryland.

"Final Report On The Development Of The Broached Roboscreen"- August 1980; by Yaron M. Sternberg and Robert Knight of International Rural Water Research Development Laboratory; University of Maryland.

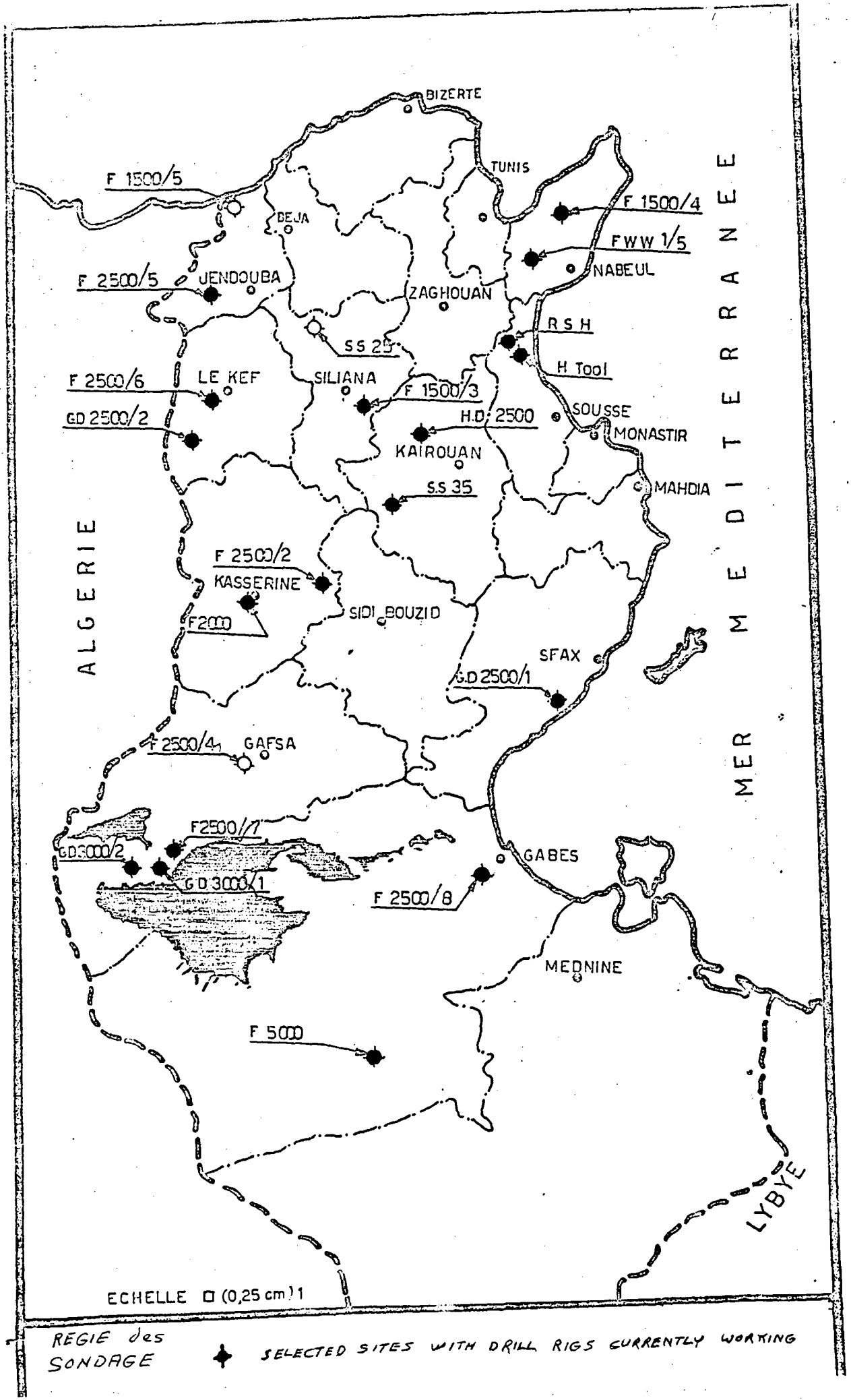
"Using Nonmetallic Casing For Geothermal Wells" - by Wayne Purdin, Research Associate; National Water Well Association; Water Well Journal, April 1980.
Personal Communication 12/17/80 Al Smith of Johnson Screen Company.



LAYNE METHOD



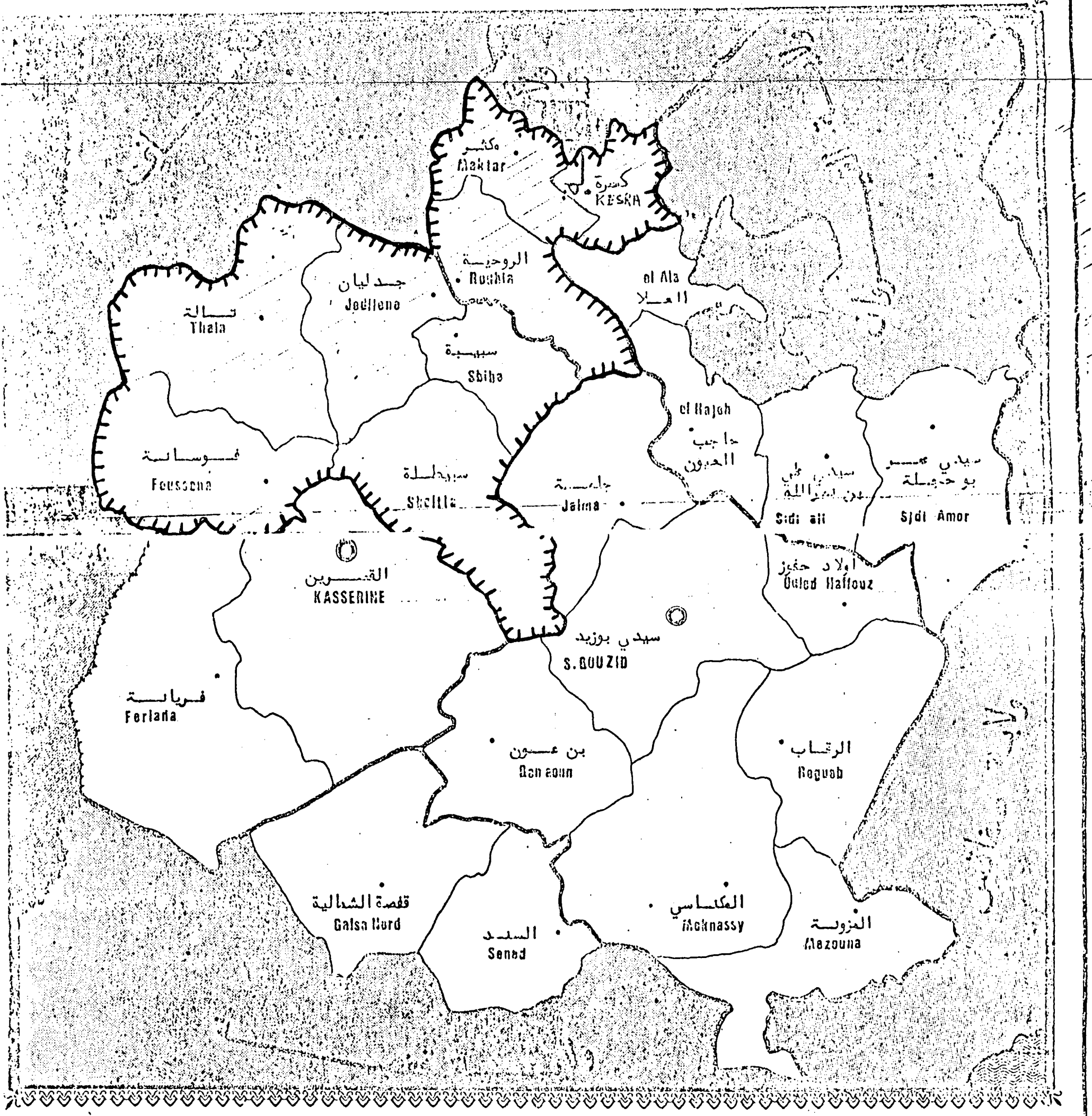
CALIFORNIA METHOD


BIZERTE
TUNIS
F 1500/5
F 1500/4
BEJA
FWW 1/5
NABEUL
F 2500/5
JENDOUBA
ZAGHOUAN
RSH
SS 25
H Tool
F 2500/6
LE KEF
SILIANA
F 1500/3
SOUSSE
GD 2500/2
H.D 2500
MONASTIR
KAIROUAN
SS 35
MAHDIA
ALGERIE
F 2500/2
KASSERINE
SIDI BOUZID
F2000
SFAX
GD 2500/1
F 2500/4
GAFSA
MER MEDITERRANEE
F2500/7
GD3000/2
GABES
GD 3000/1
F 2500/8
MEDNINE
F 5000
LYBYE
ECHELLE □ (0,25 cm) 1
REGIE des SONDAGE
SELECTED SITES WITH DRILL RIGS CURRENTLY WORKING

منطقة تدخل ديوان تنمية تونس الوسطى

ZONE D'INTERVENTION

DE L'OFFICE DE DEVELOPPEMENT DE LA TUNISIE CENTRALE



PROJECT AREA

LEGENDE

+++++ Limite du pays

Limite Gouvernorats

Limite Délégations