VOL. II CHAPTER 1
INTRODUCTION

CHAPTER 1 INTRODUCTION

1. Study Sites

Under the Master Plan described in Volume 1, the following 7 sites were selected for micro-hydropower development. Of these, 3 sites considered to be at the highest level of maturity for early implementation were selected for pre-feasibility study.

	Site	Cercle	Commune R.	River	Facility output (kW)	No. of villages
*	Adardour	Amizmiz	Anougal	Amizmiz	26	1
	Inzaine	Amizmiz	Anougal	Amizmiz	62	8
*	Arg	Asni	Asni	Rheraya	30	3
	Ait Oumzri	Asni	Talat N Yacoub	N'fis	10	1
	Id Ssiar	Asni	Ijoukak	N'fis	16	1
	Anfli	Ourika	Tahanaout	Ourika	20	2
*	Tidsi	Ait Ouir	Tighouine	Zat	16	2

* sites subject to pre-feasibility study

2. Field Survey

Under the pre-feasibility study, the following field survey was carried out and the obtained data applied to pre-feasibility planning and design.

(1) Topo-survey

Topo-survey was carried out for the 3 sites totaling 45,900 m². On this basis, 1:500 topomapping was prepared. In addition, river cross-sectional survey was done at 26 locations.

(2) Geological Survey

Reconnaissance was carried out for the 3 sites, and 1:500 geological mapping prepared as a basis for geological evaluation. Rock at the sites is basically hard and compact. Although weathering is seen in some portions with resultant weak surface layer, no problems are envisioned for civil works. At the same time, a preliminary survey was carried out for the other 4 sites not designated for pre-feasibility study in order to facilitate future study works towards the implementation of these sites, and the results of this are contained as well in this Report.

(3) Meteo-hydrology

As discussed in Volume 1, there are 5 gauging stations in the downstream area of the Project sites. However, these are located at considerable distance from the said sites, were catchment area size is significantly bigger. Accordingly, gauging stations (water level markers) were established proximate to the sites, and discharge and water level observations carried out to cross-check data from the existing stations downstream. However, due to the fact that observation period was a limited 9 months with resultant insufficient data for full evaluation, discharge at the scheme sites was computed on the safe side on the basis of specific discharge conversion.

(4) Environmental Impact Assessment

Reconnaissance was carried out for the 3 scheme sites, and evaluation made of the impact of scheme construction and operation on the environment. The said assessment examined both direct and indirect impacts on the immediate project area and adjacent environs. As a result, it is concluded that no significant impacts to the natural and social environment will result from scheme implementation. However, coordination of discharge use for hydropower and irrigation purposes, where such applies, will be necessary among the parties concerned.

3. Formulation of Optimum Development Plan

Run-of-river type development is the optimum approach for the subject schemes. In the interest of cost effectiveness, existing irrigation canal is to be widened and used jointly for hydropower and irrigation purposes. As a result, there are constraints on selection of canal route. With consideration of topographical and geological factors, every effort has been made to minimize canal length while achieving maximum head.

Location of major scheme structures is likewise subject to constraints; however, intake and tailrace facilities for hydropower have been selected to minimize impact on irrigation practices.

4. Pre-feasibility Level Design

(1) Civil Works

Due to the similarity of river discharge, river gradient, topography and other site conditions, uniform basic design criteria have been applied to all sites.

A reverse "T" type, reinforced concrete structure is adopted for the intake. The downstream side of the intake is to be reinforced with masonry, and the upstream side with cobble. The resultant structure is anticipated to be able to withstand a considerable overflow volume.

Canal capacity is to be enough to pass discharge for both hydropower and irrigation.. Canal is to be open canal constructed of masonry with mortar lining. Penstock is to be of steel pipe, for the most part embedded below ground surface.

(2) Generating Equipment

Turbine is to be the crossflow type, with non-separating guide vanes due to the small scale. Accordingly, a small scale, reverse flow pump unit is to be supplemented in the case of the Adardour and Tidsi schemes to prevent shut-down due to drop in efficiency at times of low discharge.

Generator is to be of the synchronous type, and the dummy load system adopted for control in order to eliminate the need for a governor and thereby reduce cost.

5. Implementation Plan

As discussed in Volume 1, the 3 subject schemes are to be implemented during the phase I. The 3 schemes would be constructed simultaneously over a 16 month period.

6. Project Cost Estimate

Total project cost estimate for the 3 schemes is US$ 2,489,000. Breakdown is US$ 853,000 for Adardour, US$ 958,000 for Arg and US$ 678,000 for Tidsi. Of the total, foreign currency portion is US$ 567,000 and local currency portion is US$ 1,922,000.

7. Financial Evaluation

Evaluation of micro-hydropower is as set out in Volume 1. In Volume 2, more detailed financial evaluation of the selected 3 schemes has been carried out. Financial evaluation for household monthly payment excluding operating costs yielded US$1.4/household for Adardour, US$ 1.0/household for Arg and US$ 1.8/household for Tidsi in the case of an initial investment recovery rate of 0%. In the case of inclusion of operating cost, this would comprise an additional charge of US$ 2/household (US$ 1 each for CDER and user association costs).

VOL.II CHAPTER 2
TOPOGRAPHIC SURVEY

CHAPTER 2 TOPOGRAPHICAL SURVEY

2.1 Survey Sites

Topographic survey was carried out for 3 micro-hydropower sites which were selected as the promising candidate sites to be targeted in the Pre-feasibility Study. Those sites are shown in Table 2-1.

Table 2.1-1 Survey Sites

Site	District		River	
	Commune R.	Cercle	Tributary	River
Adardour	Anougal	Amizmiz	Anougal	Amizmiz
Arg	Asni	Asni	Imenane	Rheraya
Tidsi	Tighdouine	Ait Ourir	Afouughal	Zat

2.2 Scope of Topographic Survey

This survey consists of 2 categories, one is topographic survey for mapping and another is river cross section survey. The former covers intake site, waterway route and power house site (total area is 45,900m^2), the latter covers between 200 m upstream of the intake site and 200 m down stream of the power house site along the river. The scope for each of the 3 sites is shown in Table 2.2-1. Results of topographical survey were applied to geological survey and to prefeasibility design of the schemes.

Table 2.2-1 Scope of the Survey

Survey Item	Adardour	Arg	Tidsi
Topographic Survey			
>Survey area (total)	14,600m^2	17,000m^2	14,300m^2
>>Intake site	2,100m^2 (30m x 70m)	3,000m^2 (30m x 100m)	1,800m^2 (30m x 60m)
>>Waterway route	8,000m^2 (10m x 800m)	8,000m^2 (10m x 800m)	8,000m^2 (10m x 800m)
>>Penstock and power house sites	4,500m^2 (30m x 150m)	6,000m^2 (30m x 200m)	4,500m^2 (30m x 150m)
River Cross Section Survey			
>Nos of Cross Section	6 sections	10 sections	7 sections
>Cross section points	>200m upstream of intake site > Intake site - interval of 200 - >Power house site >200m sownstrea of power house site		
Other section points	---------	Foot path bridge of village (2 sections)	200m upstream of intake for branch stream

2.3 Bench Mark

At each of the 3 sites, new bench marks were set up near the proposed intake site and these bench marks were designated as BM-1 throughout this topographic survey. The coordinates and height of BM-1 was elicited from existing 1/50,000 topographic mapping, and fixed by the Study Team.

Table 2.3-1 Coordinates and Height of BM-1

	Adardour	Arg	Tidsi
Latitude	56.750 31°04'51"	67.950 31°10'50"	85.050 31°20'41"
Longitude	225.000 08°16'51"	259.900 07°55'05"	305.900 07°26'25"
Elevation	1,770m	1,575m	1,725m

2.4 North Direction

The study team applied "*magnetically north direction*" for this topographic survey.

2.5 Survey Result

2.5.1 Topographic Survey

At each of the 3 sites, another bench mark (BM-2) was set up near the proposed power house site. The coordinates and height of BM-2 was surveyed by traversing and leveling survey in the field. These figures are shown in Table 2-5-1.

Table 2.5-1 Coordinates and Height of BM-2

	Adardour	Arg	Tidsi
Latitude	57.008	67.616	84.714
Longitude	225.633	260.838	306.259
Elevation	1,719.8m	1,531.9m	1,726.2m

The specification of the original topographic map is as follows;

Scale	: 1/500
Interval of contour line	: 1 m
Paper size	: A1 size

2.5.2 River Cross Section Survey

The basic interval of the cross section was fixed as 200 m between the intake site and power house site, and 200 m upstream of the intake site and 200 m downstream of the power house site were included. Drawing scale of the section (both vertical and horizontal) is 1/200.

2.5.3 Other Information

Survey Period	15 October 1996 to 15 December 1996
Contractor in Morocco	Maghreb Projets S.A. / Rabat
(Sub-contractor)	Promo Conseil / Marrakech
	Bureau d'Evaluations (B.E.E.) / Marrakech
	Cabinet Topographique Embarch Abdella / Marrakech

Evaluation of contractors:

Technical level of contractors were enough for this survey scope and specification, however there were quite few staff who could understand English among the 3 sub-contractors, making it sometimes difficult to discuss about detailed matters smoothly and efficiently.

VOL.II CHAPTER 3
GEOLOGICAL SURVEY

CHAPTER 3 GEOLOGICAL SURVEY

3.1 Regional Geology

The geology in and around the Study area comprises strata generated over a wide period ranging from Pre-Cambrian to recent. The distribution of these layers is strongly governed by tectonic geology, and can be broadly classified into 2 groups.

These are (i) the Meseta Central extending to the south of Marrakech city, and the Atlas range which runs southwest~northeast. The Atlas range in turn can be divided into the Haut Atlas to the north and the Anti Atlas to the south.

The Meseta Central comprises mainly sedimentary rock (sandstone, mudstone, limestone and conglomerate) and volcanics (lavas and pyroclastics) of the Mesozoic and Cenozoic. Due to a predominance of continental sediments, rock color tends to be reddish brown.

The Atlas range comprises primarily sedimentary rocks, volcanics and granitic rocks of the Pre-Cambrian~Palaeozoic. However, in many cases original rock is not clearly known due to composition of crystalline schist, quartzite, gneiss and other metamorphic rocks which have been subjected to strong dynamometamorphosis due to Hersinian tectonic movement and Alpine orogenese occurring in the formation of the Atlas range.

In the case of the 7 sites selected under the Master Plan as candidates for micro-hydropower development, all are located on the northwest slope of the Haut Atlas. The 2 sites at Arg and Anfli are situated in granitic rock zone, while the remaining 5 sites are in metamorphic rock zone. Lithologic character of the sites is basically hard, well compacted rock; however, the fact that the Study area is located in steep mountain terrain with little vegetal cover, and is subject to intense sunlight during the dry season (summer) and freezing as a result of low temperatures in the rainy season (winter), surface layer is heavily weathered and comprises fragile rock.

A regional geological map of the Study area is given in Figure 3.1-1, and an interpretation (legend) of the same in Figure 3.1-2.

3.2 Geology of Micro-hydropower Sites Selected for Pre-feasibility Study

Of the 7 promising candidate sites selected identified under the Master Plan Study, geological reconnaissance was carried out and 1/500 scale geological mapping prepared for the 3 sites designated for Prefeasibility Study.

3.2.1 Adardour

The geology at this site comprises greenish gray metamorphic rock, talus deposits and recent river deposits. Metamorphic rock consists mainly of green schist intercalated with thin layers of crystalline limestone (marble) and tuff breccia, pierced by porphyrite dyke and quartz veins (see Figure 3.2-1 and 3.2-2).

(1) Lithology

1) Green Schist (Chlorite Schist)

This is the most widely distributed rock in the site area. It is generally deep green in color and massive, showing little schistocity. Component minerals are quartz, feldspar, chlorite, muscovite, etc. Schistocity exhibits predominately NS~NE-SW strike with a steep dip and fissures generally run NE-SW, being concordant with the axis of extension of the Atlas range. As this rock is massive, it exhibits little weathering and in terms of rock engineering belongs to the category of hard rock.

2) Limestone

Limestone exhibits lenticularity ranging several meters to several tens of meters, and is intercalated with green schist. Rock is white ~ white gray in color and exhibits recrystallized, massive tendency as a result of dynamometamorphosis. Strike and dip of bedding are parallel to the schistocity of the green schist.

3) Tuff Breccia

Small outcrops were observed near the intake site, however, the surrounding area is covered by talus deposits preventing a detailed identification of rock structure. Strike is roughly NS, and rock overall exhibits a yellowish gray color. Tuff breccia comprises cobbles 10~15 cm in diameter, of andesitic breccia and volcanic ash. As small faults pass through the area, it is assumed that some argillization has occurred and that rock is soft.

4) Porphyrite Dyke

This is compact rock, dark greenish gray in color, with strike of N 50° and dip to the east. It appears as small dykes 2~3 m in width. Differentiation from massive green schist is difficult due to the effects of dynamometamorphosis.

5) Quartz Vein

At the power station site, quartz veins are observed with thickness ranging from several millimeters to several meters. Strike is roughly EW, with steep dip.

6) Talus Deposits

Due to steep topography, talus deposits are heavily present at the river bed and on mountain slope. These deposits comprise rock fragments of irregular size, and soil. In many cases, the erosion of these has been prevented by construction of rock walls, and the deposits are utilized for cultivation of upland crops.

7) Recent River Deposits

River deposits comprise either gravel of metamorphic rock, or sub-rounded gravel, sand and clay. However, distribution and thickness of these are limited due to narrow river width and steep ravine slopes.

(2) Engineering Geology for Micro-hydropower Structures

1) Intake Site (Figure 3.2-3)

The site is located at a point where slopes are relatively gentle, and talus deposits are distributed on both banks. Outcrops of green schist are seen at the site, leading to the conclusion that the said talus deposits are around 1 m in thickness and pose no problem from an engineering standpoint for intake facility construction.

2) Headrace Alignment

Total headrace length is 685 m. Talus deposits are distributed along the first 350 m from the intake site. Due to the fact that the an existing canal is present along the said design headrace route, new headrace canal construction will be facilitated. However, due to the high permeability of the talus deposits, it will be necessary to consider measures to prevent water seepage from the canal and to protect the structure from rock fall (covered canal).

Along the canal segment 350~500 m from the intake site, there are continuous outcrops of green schist and limestone forming cliffs. As lithology is massive, hard rock, it is anticipated that some minor difficulty in canal construction may be encountered. Particularly along the segment 450~500 m from the intake site, heavy cracking is seen which will require safety measures during construction.

From the 500 m point onward to the envisioned penstock site, slope talus deposits with scattered outcrops of green schist and limestone are distributed which are not anticipated to pose any particular problems as far as canal construction is concerned.

3) Powerhouse Site (Figure 3.2-4)

In the case of the segment along the design penstock site to the powerhouse site, scattered, small outcrops of green schist are seen, with the penstock alignment being covered by a thin layer of talus deposits. An open area used for agricultural purposes (roughly 10 m × 15 m) is located approximately midway along the penstock alignment; however, this is not seen as posing any special problems with regards to construction of the bearing foundation for the said penstock. The schistocity of the green schist at the site dips sharply roughly parallel to the penstock alignment axis, and as a result there is no danger of bedding plane slip.

The powerhouse site corresponds to the crown of the talus deposit formation, and is presently small cultivated field. Outcrops of bedrock are observed nearby, indicated a thin talus deposit layer and an advantageous site for powerhouse construction.

3.2.2 Arg

Geology at the site comprises Pre-Cambrian gneiss and granite covered with talus and recent river deposits (see Figure 3.2-5 to 3.2-7).

(1) Geology

1) Gneiss

This rock is the most widely distributed at the site. It is generally dark greenish gray in color and massive, and composed of fine grained quartz, feldspar, chlorite, etc. The gneiss exhibits an irregular lithofacie due to the effects of dynamometamorphosis and hydrothermal alteration. It is assumed that original rock is andesitic volcanics; however, some portions are migmatite retaining granitic structure.

Overall, due to hydrothermal alteration caused by granitic intrusion, gneiss contains a large amount of fine grained pyrite which at some locations gives a yellowish color to the rock due to alteration to limonite as a result of oxidation in the surface layer.

In terms of rock engineering, fresh main rock is hard; however, in actuality the greater part of the formation is not so hard (with the exception of a portion in the river bottom) due to progressive weathering.

2) Granite

This is distributed at the intake site in the south and the powerhouse site in the extreme north of the overall scheme area. It comprises granite and granodiorite consisting of quartz, feldspar and biotite. The closer the proximity to gneiss, the more the content of dark greenish gray xenolith. The boundary with gneiss formation is covered with talus deposits at the southern outcrop; however, the northern outcrop exhibits irregularity. In general, the rock shows only slight weathering and is hard.

3) Talus Deposits

These are distributed at various locations on mountain slopes, but not to an extensive degree. They are comprised of rock fragments of granite and gneiss, and soil. Rock retaining walls have been constructed to contain these deposits which are utilized as upland field and orchard.

4) Recent River Deposits

These are distributed to a small scale in low areas along ravines. They are comprised of rounded to sub-rounded gravel, sand and clay. Areas of distribution are utilized as upland field and for livestock grazing; however, erosion of these deposits often occur during flooding.

(2) Engineering Geology for Micro-hydropower Structures

1) Intake Site (Figure 3.2-8)

Geology at the intake site comprises granite, talus deposits and recent river deposits. As seen in the cross-sectional diagram in Figure 3.2-8., granite outcrops occur on the right bank at the site with river deposits being distributed on the left bank. The granite is estimated to be hard and the river deposits thin, thereby posing no problems in terms of bearing foundation for weir and other intake facility construction.

2) Headrace Alignment

Total headrace length is 1,175 m, most of which passes through area distributed with talus deposits and gneiss. The entire design alignment will utilize existing canal. At roughly the 200 m mark from the intake site, the canal passes a valley opening to the northwest from which a large inflow of eroded soil occurs, and at this point the existing canal is buried for about a 40 m segment under such erosion deposits. It will be necessary along this segment to consider covered canal structure to protect the canal from the inflow of eroded rock and soil.

Outcrops of gneiss occur along the segment 350~600 m from the intake site, with some portions exhibiting hard rock as a result of silicification and pyritization. Also, it is considered difficult to widen the canal at those locations where it is supported by masonry wall. After the 600 m mark from the intake site, talus deposits and outcrops of gneiss repeatedly occur. The gneiss exhibits numerous small cracks and progressive weathering, leading to the conclusion that there would not be any geological problem in widening the canal at this point.

3) Power House Site (Figure 3.2-9)

Talus deposits are seen along most of the distance from the penstock alignment to the envisioned power house site, and have been converted into terraced fields by masonry retaining wall. Rock outcrops are seen around the fields, based on which it is estimated that the thickness of the talus deposits is 1~2 m. No particularly problems are anticipated in bearing foundation construction for the penstock.

However, a mountain stream runs roughly parallel (EW) to the penstock alignment axis roughly 10 m to the south of the penstock route, posing concern about the generation of eroded rock and soil during heavy, concentrated rainfall. Consideration must be given to the impact of this on the penstock and other power generating facilities.

3.2.3 Tidsi

Geology of the site area comprises sandy~lutaceous, green schist with intrusion of dolerite, talus deposits, recent river deposits, etc. (see Figure 3.2-10 and 3.2-11).

(1) Geology

1) Green Schist (chlorite schist)

This is the dominant rock distributed in the site area. According to the regional geological map, this is interpreted as sedimentary rock of the Palaeozoic Cambrian; however, sedimentary structure is clear due to overall weak metamorphosis (with the exception of strong chloritization). The green schist comprises alternating greenish~gray, sandy layers, and bluish~green, lutaceous~silty layers. Bedding plane strike and dip are generally constant at NS~NNE-SSW and around 30° to the east. Overall, weathering is progressive and rock weak particularly in the mudstone were heavy presence of fine, spherical cracking is seen. Rockfall is observed along bedding planes where sloping is to the east.

2) Dolerite

Sheeted dyke with thickness of 10~15 m is observed in and around the penstock alignment site, and exhibits dark green color and hard, uneven lithofacie. A large amount of chloritized mafic minerals is present, with oxidation occurring in the surface layer resulting in a reddish brown color. Strike and dip are parallel to that of green schist.

3) Talus Deposits

These consist of fine rock fragments and soil, and are distributed on a small scale at some locations.

4) Recent River Deposits

These comprise 30 cm diameter rounded and sub-rounded gravels, sand and clay. In addition to being distributed in the form of river terrace on both banks at the intake site and at the power house site, they are also found at locations on a small scale in the river bed.

(2) Engineering Geology for Micro-hydropower Structures

1) Intake Site (Figure 3.2-12)

The intake site is located roughly 50 m below the confluence of 2 mountain streams. The right bank consists of sandy and massive, green schist; and the left bank is river deposits forming terrace including boulders of 4~5 m diameter. A concrete bridge is located at the site which serves as access to the village of Tidsi. A small intake weir for irrigation diversion is located directly below the bridge. River width at this point is under 10 m, and is a favorable site for intake facility construction.

2) Headrace Alignment

Total headrace length is roughly 750 m, the greater part of which runs through area distributed with sandy~lutaceous green schist. The green schist of the area shows progressive weathering and belongs to the medium hard ~ soft rock category. Lithology is considered relatively favorable for headrace construction. Several small faults with cracky zones are observed along the route; however, these will not impact on the headrace structure.

Talus deposits are distributed at the point roughly 700 m upstream of the envisioned penstock alignment site, and it will accordingly be necessary to consider seepage prevention measures and a covered canal structure at this location.

3) Power House Site (Figure 3.2-13)

At the downstream terminus of the headrace canal route, distribution of dolerite (10 m thickness) is observed with NS strike and dip of 30°E. To the west of this, and extending to the power house site, green schist is widely distributed on the opposite stream bank. These rock formations exhibit progressive weathering, and no problem is envisioned in facility construction by means of manual labor.

At the power house site itself, flat land (about 20 m wide) atop thick river terrace is utilized for cultivation. Elevation from the river bed is 5 m, and no problems are envisioned with regards to scheme construction.

3.3 Geology of Micro-hydropower Sites Not Selected for Pre-feasibility Study

In the case of the 4 sites which were identified as promising under the Master Plan Study but were ultimately excluded from consideration under the Prefeasibility Study, a detailed geological survey was carried out for Alla Oumzri and a preliminary geological survey for Inzaine, and the results of these are described below.

3.3.1 Alla Oumzri

Geology at the site comprises metamorphic rocks, including chlorite quartz schist, limestone, phyllite, etc., and talus and recent river deposits.

(1) Geology

1) Chlorite Quartz Schist

From a point roughly 50 m to the southeast of the penstock alignment and extending to the intake site, green-mudstone quartz schist if the predominant rock distribution. It is comprised almost totally of quartz and chlorite, and exhibits a dark greenish~gray, tightly compacted lithofacie. Schistocity structure is weak, in some portions is N65E, 85 NW.

2) Limestone

In the north-central part of the site area, limestone with thickness of over 40 m forming cliffs is found within the chlorite quartz schist. Rock is white ~ grayish white in color, and recrystallized as result of the effects of dynamometamorphosis. An almost vertical fault with orientation of N65E forms the northern boundary with the chlorite quartz schist; while the southern boundary is unclear due to being covered with talus deposits.

3) Phyllite

This is distributed along the ridge extending from the penstock alignment to the power house site. It is yellow-green in color, lutaceous and exhibits progressive schistocity. Due to weathering, rock has a tendency to break into fine fragments. Strike and dip of schistocity are roughly N40E and 40NW.

4) Talus Deposits

These are distributed along the stream and on gentle mountain slopes. They comprise unrounded gravels of green schist, quartz, rock fragments and soil, and in all cases distribution is small in scale.

5) Recent River Deposits

These are distributed in small amounts in the river bed at the intake site. They comprise various rounded ~ sub-rounded gravels, sand and clay.

(2) Engineering Geology for Micro-hydropower Structures

1) Intake Site

Geology at the intake site comprises massive and tightly compacted green schist, small scale talus deposits and river deposits. Ravine width is narrow at the site, and outcrops of hard basement rock are seen. The site is advantageous for intake facility construction.

2) Headrace Alignment

Total headrace length is roughly 300 m. For the first 100 m segment from the intake site, green schist is primarily distributed and due to massive and hard lithological characteristics, some minor difficulty in canal construction is envisioned. It is necessary to consider a canal structure of stone masonry, which utilizes the abandoned, old canal as bearing foundation. Along the canal segment 100~200 m from the intake site, the area is distributed primarily with talus deposits and no problems in canal construction are foreseen. However, the segment 200~250 m from the intake site is along cliff of hard green schist, and this represents the portion of greatest difficulty in canal construction. Along this segment, it will be necessary to adopt a stone masonry canal structure utilize the old canal remnants as bearing foundation. The NE oriented faulting at this location is not anticipated to pose any particular problem.

3) Power House Site

Lutaceous phyllite is distributed in the area from the downstream terminus of the headrace canal to the power house site. The phyllite exhibits progressive weathering and is soft rock. Penstock and power house facility construction are envisioned to be facilitated by this geology.

3.3.2 Inzaine

The geology of the Anougal left and right banks vary greatly. Specifically, the right bank comprises metamorphic rocks including green schist of the Cambrian ~ lower Palaeozoic; while the right bank comprises red sandstone and white sandstone assumed to be of the Mesozoic Cretaceous. This fact can be concluded on the basis of the considerable upward thrusting of the right bank along the NS oriented fault running roughly parallel to the Anougal river. In addition, the area is covered by talus and recent river deposits.

(1) Geology

1) Green Schist

This is distributed throughout the right bank of the Anougal river, which is to serve as the alignment site for headrace construction. Mainly, this comprises chlorite schist and chlorite quartz schist, and progressive weathering of the surface layer has resulted in a tendency for fine fragmentization and susceptibility to rock fall. Schistocity is roughly parallel to that of the Atlas range as a whole with NE-SW orientation and steep dip. Original rock is estimated to be either sandstone or sandy tuff.

2) Dacite

This appears within the green schist as sheeted dyke with thickness ranging several meters to 10~15 meters. It is light reddish~pink in color, massive and tightly compacted. 2~3 mm diameter quartz phenocrysts are clearly visible within the ground mass of fine grained quartz and feldspar. Structure parallels that of green schist, although it is not clear whether this is dacite lava or dyke.

3) Red Sandstone

This is distributed from the Anougal river bed up to mountain slopes on the left bank. At the river bed, it comprises red gravels; while at higher elevations on mountain slope it consists of reddish-brown, hard~lutaceous sediments, with bedding structure showing waving fold. These are considered to be continental sediments.

4) White Sandstone

Red sandstone on the left bank of the Anougal river is covered with white sandstone. It is fine~medium grained, white sandstone ~ silt rock with well defined bedding planes. Structure is essentially horizontal. The Imi-n-Tala spring emits from this formation.

5) Talus Deposits

These comprise various gravels, rock fragments and soil, and are distributed on mountain slope. Near the village, these are in many cases utilized for cultivation.

6) Recent River Deposits

These are distributed at the river bed along the Anougal river and its tributaries. They comprise gravel, sand and clay, and are utilized for upland crop and orchard cultivation.

(2) Engineering Geology for Micro-hydropower Structures

1) Intake Site

Red sandstone is distributed on the left bank, and green schist on the right bank. River is wide, and it is necessary to confirm the thickness of river deposits.

2) Headrace Alignment

The headrace alignment runs through area distributed with green schist, dacite and talus deposits. Green schist and dacite exhibit progressive weathering and are fragile rock. Now problems in canal construction are envisioned from a geological standpoint. However, since portions of the headrace on both steep slope and through talus deposits will run close to a motorable road passing above the canal, some difficulty in canal construction will be encountered along these segments.

3) Power House Site

Green schist is distributed along the penstock alignment, and no particular problems in construction are envisioned. However, in the case of the power house site which is located on river deposits utilized as upland field, careful attention must be given to the effects of flooding on the power house facility.

3.3.3 Id Ssior, Anfli

A geological reconnaissance in-situ could not be done for these 2 sites under the Study to date. However, on the basis of existing data, geology at the subject sites is roughly estimated as follows.

(1) Id Ssiar

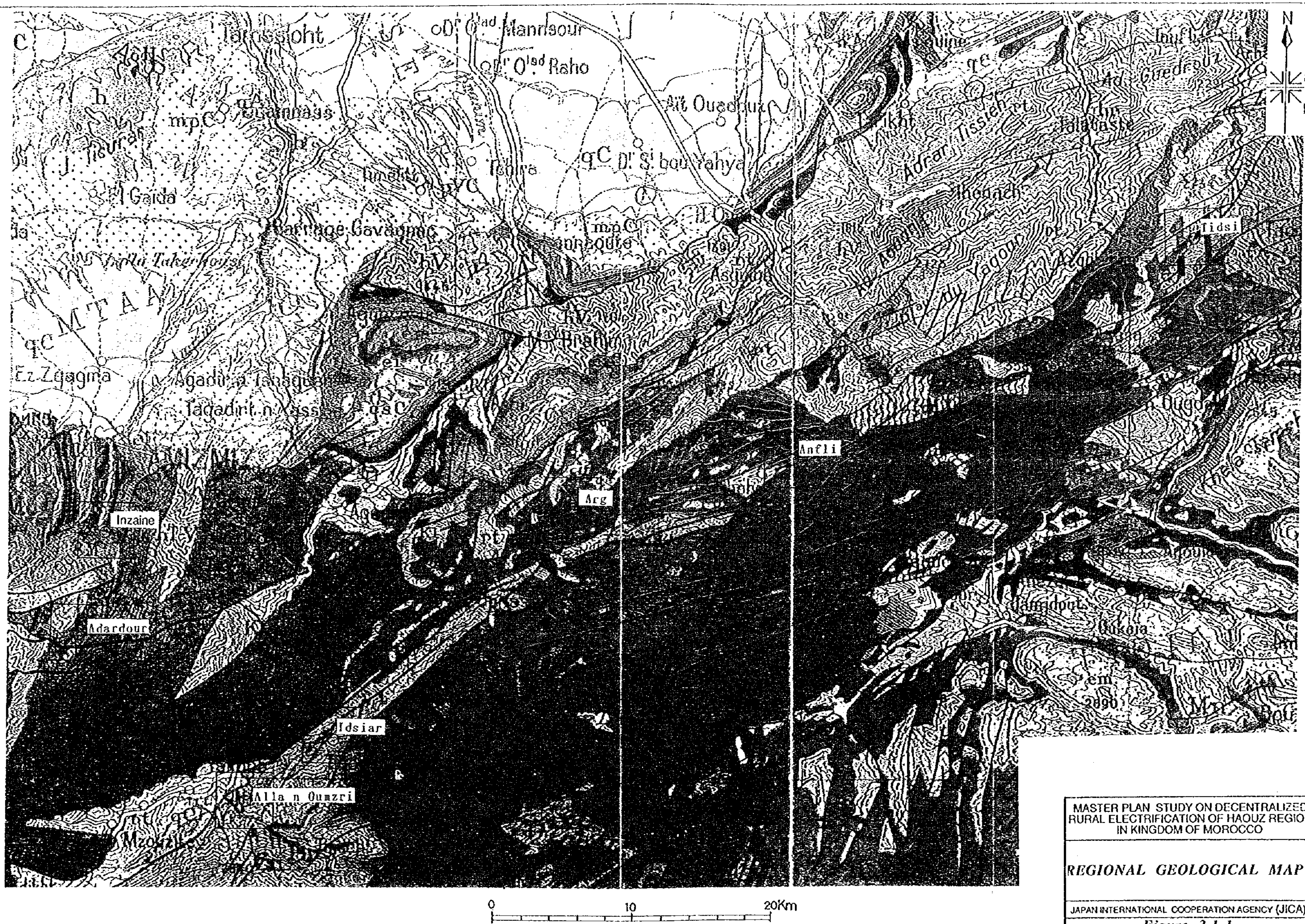
This site is located roughly 8km to the northeast of Alla Oumzri, and although the river system varies geological structure is essentially uniform. Geology consists primarily of Palaeozoic metamorphic rocks (schist, quartzite, limestone) assumed to have NE-SW strike and steep dip.

The siliceous metamorphic rock at the lower portion of the Palaeozoic formation is assumed to be partially massive, tightly compacted hard rock and the surface layer well weathered, with no major problem envisioned from a geological standpoint for the construction of micro-hydropower facilities.

(2) Anfli

This site is located roughly 15 km to the east of Arg. Geology is mainly Pre-Cambrian granites and gneisses, located in stable block. Granites observed at Arg are generally only slightly weathered, hard rock; however, gneisses exhibit progressive weathering and well developed fine cracking in the surface layer.

On the basis of study of 1/50,000 scale topomapping, relief at the micro-hydropower scheme site is relatively gentle with estimated distribution of talus and recent river deposits over a wide area. As a result, not problems in facility construction are envisioned; however, it may be necessary to give attention to measures to protect facilities during flooding.



MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO

REGIONAL GEOLOGICAL MAP

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Figure 3.1-1

TERRAINS SÉDIMENTAIRES

A — Formations modernes et Quaternaire récent (alluvions, limons alluvionnaires, limons rouges superficiels)

D — Dunes vives et sables récents partiellement fixés

qMD — Quaternaire marin et dunaire consolidé

qC, qCr, qA, qCl — qC Quaternaire moyen et ancien (regs, dépôts encroûtés etc...); qA Terrasses; qCr Arènes granitiques; qCl Calcaires lacustres; qT Travertins; VC Terrasses anciennes

pVC, pVCl — pVC Villafranchien (et Pliocène continental p.p.) conglomérats, cailloutis, formations rouges; pVCl Calcaires lacustres

pVD — Villafranchien dunaire; Surfaces plio-villafranchiennes

pq — Calabrien (Moghrebien); Surfaces anciennes anté-villafranchiennes

mpC, mс-p — Mio-Pliocène continental (Pontico?-Pliocène); (ms-p) (Mio)-Pliocène marin (Marnes d'Agadir); a Conglomérat blanc (Sous)

oCl — Oligocène (?): calcaires lacustres

esC, em, ei — esC Eocène supérieur continental; em Eocène moyen; eC Eocène continl. non subdivisé; ei Eocène infr.; Ph faciès phosphaté

osM — Maestrichtien

os, osC — os Sénonien; C faciès continental

cT — Turonien

cM, ci — cM Cénomanien; c Crétacé non subdivisé; ci Crétacé inférieur marin; C Infracénomanien et Cénomanien continental p.p.

jC — Jurassique lagunaire d'Imi n'Tanout

js-c — Berriasien (et Portlandien p.p.)

js3 — Kimmeridgien et Portlandien

js2 — Lusitanien

js1 — Callovo-Oxfordien (et Argovien)

js Jurassique non subdivisé de l'O. Tensift

jmL — Jurassique moyen lagunaire

ji — Liasnon subdivisé

rt — Permo-Trias continental

hr — Stéphano-Autunien continental

hS — Stéphanien (Série de Merkala)

hW — Westphalien probable

hN — Namurien (Série du Jebel Réouina)

hV — Viséen; hVs Calcaire de l'Outarkziz

hT-V — Tournaisien supr.- Viséen

hT — Tournaisien

dh — Strunien

Grès du Tazout

h Carbonifère non subdivisé ou probable

ds — Dévonien supérieur

dm — Dévonien moyen

di — Dévonien inférieur

ss-di — Séries d'âge indéterminé: Dévonien ou Gothlandien

d Dévonien non subdivisé

ss — Gothlandien

Caradoc; Llandeilo supr. — Quartzites du Bani

Ordovicien infr. (Trémadoc - Llandeilo), schistes des feijas externes

si-ss Silurien

si Ordovicien

Cambro-Ordovicien

ks — Grès et quartzites à Lingules; Schistes à Paradoxides avec à la base la zone à Myopsolenus (la brèche à Micmacca)

ks Acadien

ki4 — Schistes et grès terminaux passant aux cendres volcaniques remaniées

ki3 — Calcaires à Archaeocyathidés; série schisto-calcaire, calcaires supérieurs

ki2 — Schistes et grès violacés (série lie de vin) passant aux calcaires à l'Ouest

ki1 — Calcaires inférieurs et série de base; ki1a: ki2 conglomérats de base

ki Géorgien

a Conglomérats

Infracambrien (Adoudounien)

Primaire indéterminé

x3 — Précambrien III: conglomérats, brèches et localt. congl. de base de l'Infracambrien ou du Géorgien kx3; Calcaires à Collenia

Schistes et grès (série d'Anezi), pélites, etc...

x2 — Précambrien II: schistes, séricitoschistes, etc...

x2c — Conglomérats, grès, eventuelt. tillites

x2q — Quartzites

x2b — Calcaires

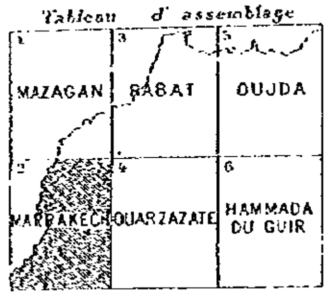
x2a — Conglomérats

x2 Précambrien II

x1 — Précambrien I: micaschistes (et migmatites)

Fe	Fer	Pb	Plomb	Be	Béryl
Mo	Molybdène	Zn	Zinc	G	Graphite
W	Wolfram (Scheelite)	Ag	Argent	Ap	Bitume
U	Uranium	Mn	Manganèse		Gypse
Cu	Cuivre	Ba	Barytine		Sel

Tableau d'assemblage



ROCHES ÉRUPTIVES ET MÉTAMORPHIQUES

ωMP Complexe phonolitique du Siroua

Basaltes doléritiques du Trias

Rhyolites stéphano-autuniennes

Orogénie hercynienne

Microgranites, microsyénites, microdiorites

Granites à biotite post-tectoniques (Azegour, Jebilet)

Granites et granodiorites syntectoniques (Tichka, Ramram)

δH Gabbros, δ1H diorites, δ2H dolérites

Métamorphisme de contact; a cipolins

Phyllades, séricitoschistes, chloritoschistes; a cipolins

MH Migmatites; ωMH migmatites amphiboliques

Complexe de granodiorites et de migmatites du Tichka

αK Andésites; βK basaltes (spilites), etc... du Géorgien terminal; α CK tufs

Andésites de l'Infracambrien (Adoudounien)

Précambrien III

Rhyolites, dacites etc... coulées, ignimbrites, dykes, necks etc...

αX3 Andésites; βX3 basaltes etc... coulées, filons

Tufs, brèches, conglomérats volcaniques

Complexe de microdiorites et de filons d'andésite du lac d'Ifni; δ2X3 filons d'andésite ou de dolérite

Microgranites

Granite d'Imorhsane; granite rose du Haut Atlas

Dernière orogénie précambrienne (P.II)

Laves (andésites) du Précambrien II

δX2 Gabbros; δ1X2 diorites; δ2X2 dolérites

Microgranites

γ1X2 Granites et granodiorites; γ1X2 granite alcalin de Tafraout — post-tectoniques

γX2 Granites à biotite et granodiorites et leurs faciès leucocrates γaX2 — syntectoniques

μ Schistes à andalousite, schistes micacés; μa adinoles (Ida ou Zekri)

Migmatites

Diorites injectées par du granite

Avant-dernière orogénie précambrienne (P.I)

Granites leucocrates ...

Granites à biotite et granodiorites

Migmatites

Gneiss d'injection

Granites précambriens d'âge indéterminé (Ifni)

Carte dressée par M. G. Choubert, Ingénieur Géologue, Chef du Service de la Carte Géologique.

Documents consultés: Levés géologiques de MM. R. Ambroggi, J. Bartboux, J. Boncart, M. Bourgeois, R. Bourgin, A. Brives (†), W. Chazan, G. Choubert, G. Colo, J. Dresch, J. Fabre, Mlle A. Faure Muret, MM. E. Fauvelet, L. Gentil (†), G. Greber, J. Hindermeyer, H. Hollard, P. Jacquemont, G. de Koning, P. Kuntz, R. Lavocat, G. Lecointre, L. Moret, R. Moussu, L. Neltner, F. Permingeat, F. Proust, E. Roch, B. Salvan, H. & G. Termier, G. Thuille, F. von der Weid, V. Ziegler.

Certains levés de détail ou observations de MM. J. Abadie, J. Agard, Ch. Bizard, B. Blanzy, J. Bondon, J. Bouladon, H. Carpentier, L. Clariond, L. Commanay, P. Gevin, N. Gouskov, A. Guilcher, O. Horon, P. Hupé, E. Joly, G. Jouravsky, W. van Leckwijck, N. Menchikoff, P. Rampont (†), J. Regnier, A. Robaux, P. Russo, E. Segaud (†), G. Suter, P. Taltasse, H. Tournoud et B. Yovanovitch (†).

Obs.ns récentes de MM. E. Cochet, F. Dufaud, O. Issenmann et F. Rivier.

Travaux pédologiques de MM. R. Jaminet, J. Soldini et S. Toujan.

Pour la zone d'IFNI, interprétation du fond topographique au 100.000e (I.G.N. 1940) d'après les travaux de MM. E. & F. Hernandez Pacheco et les descriptions pétrographiques de MM. M. San Miguel de la Camara et J. Marcet-Riba; pour le SAHARA espagnol, adaptation des levés de M. M. Alia Medina à la carte espagnole au 500.000e (édition 1952).

Travaux graphiques exécutés par M. D. Keguith.

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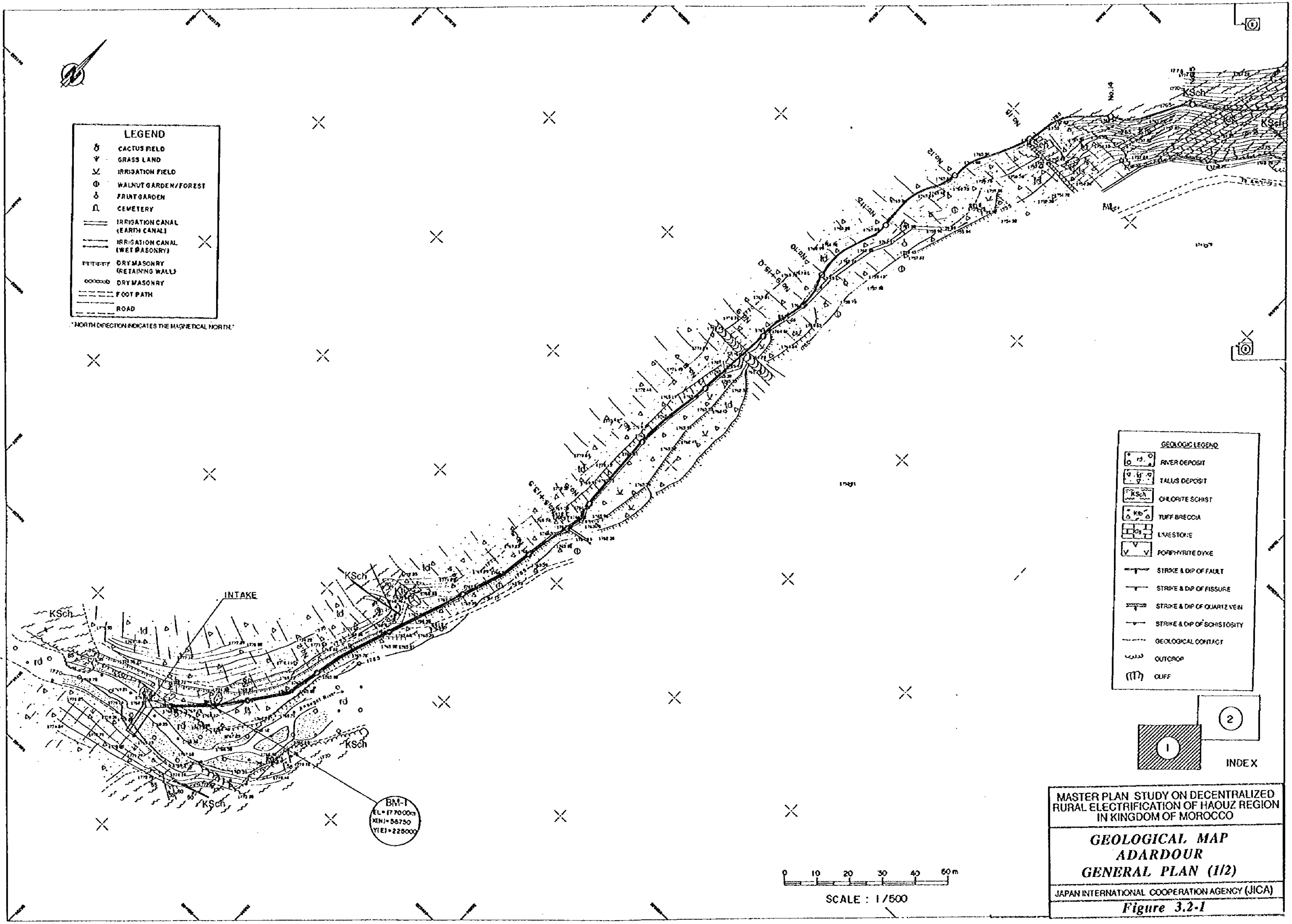
LEGEND FOR THE REGIONAL GEOLOGICAL MAP

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Figure 3.1-2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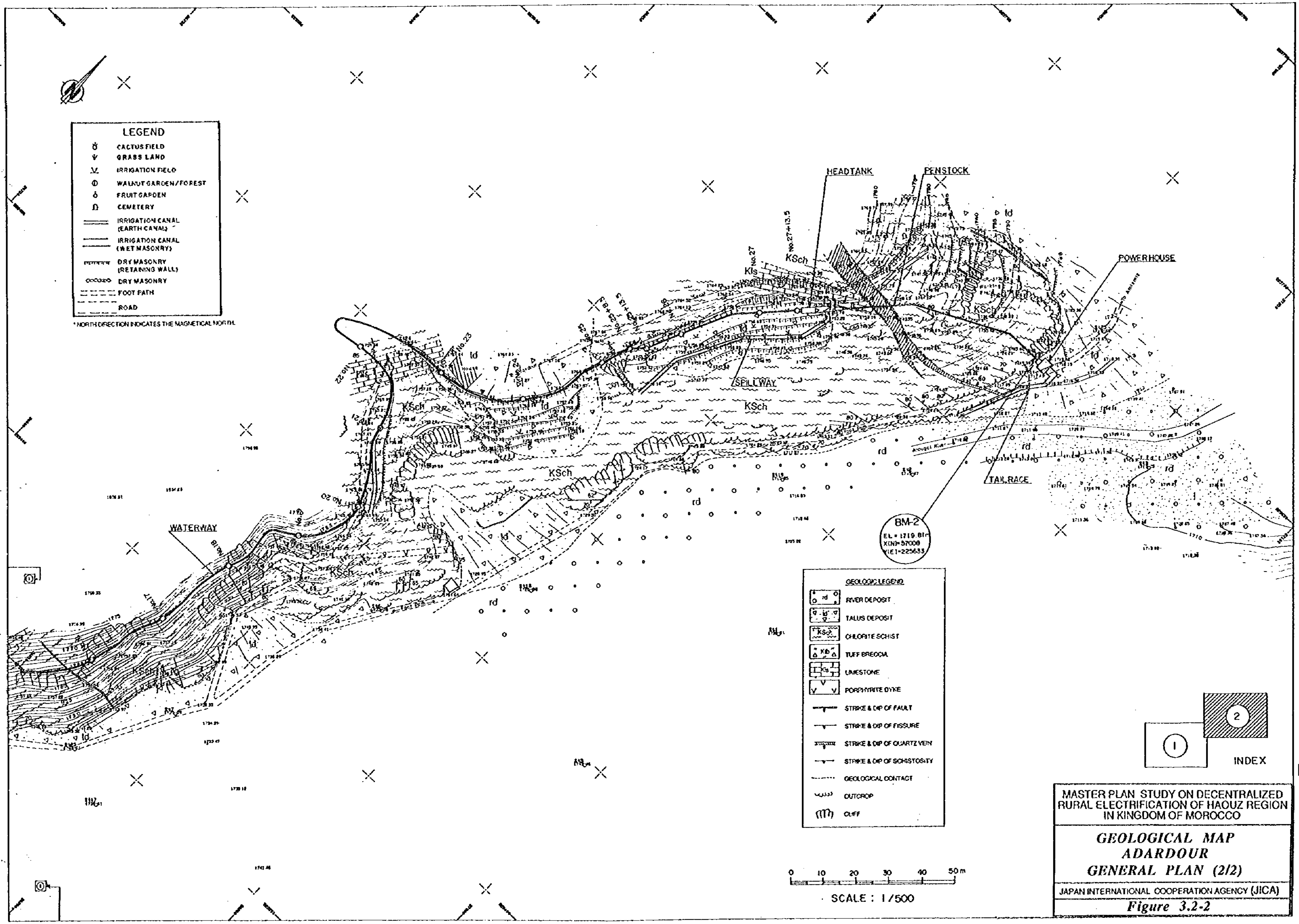
GRASS LAND
IRRIGATION FIELD
WALNUT GARDEN/FOREST
FRUIT GARDEN
CEMETERY
IRRIGATION CANAL (EARTH CANAL)
IRRIGATION CANAL (WET MASONRY)
DRY MASONRY (RETAINING WALL)
DRY MASONRY
FOOT PATH
ROAD
" NORTH DIRECTION INDICATES THE MAGNETICAL NORTH."
GEOLOGIC LEGEND
RIVER DEPOSIT
TALUS DEPOSIT
CHLORITE SCHIST
TUFF BRECCIA
LIMESTONE
PORPHYRITE DYKE
STRIKE & DIP OF FAULT
STRIKE & DIP OF FISSURE
STRIKE & DIP OF QUARTZ VEIN
STRIKE & DIP OF SCHISTOSITY
GEOLOGICAL CONTACT
OUTCROP
CLIFF
INTAKE
KSch
rd
td
No.12
No.13
No.14
BM-1
INDEX
SCALE : 1/500
0 10 20 30 40 50 m
MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO
GEOLOGICAL MAP
ADARDOUR
GENERAL PLAN (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
Figure 3.2-1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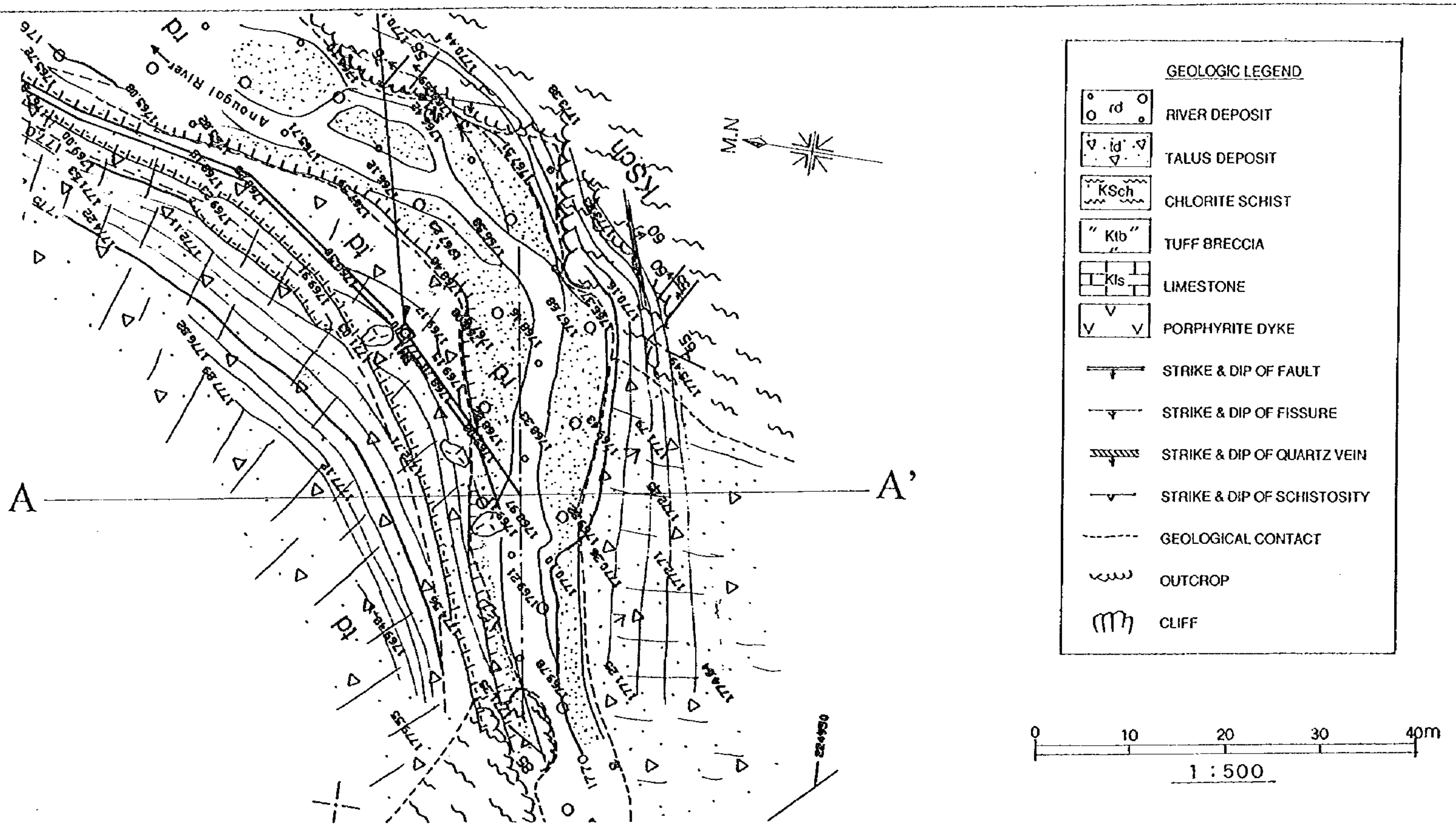
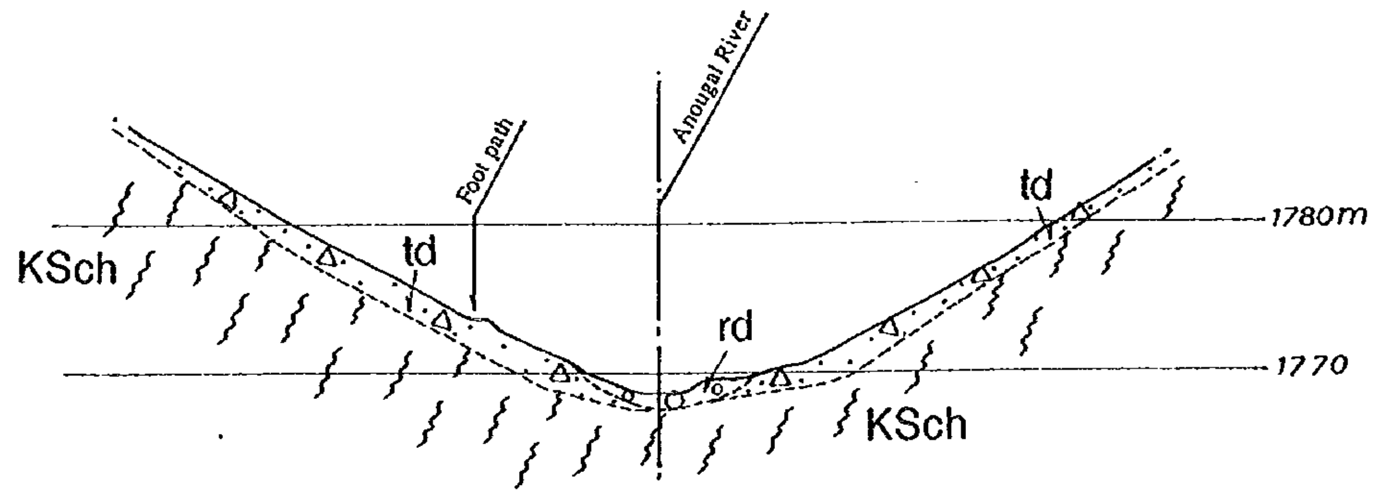
FRUIT GARDEN
CEMETERY
IRRIGATION CANAL (EARTH CANAL)
IRRIGATION CANAL (WET MASONRY)
DRY MASONRY (RETAINING WALL)
DRY MASONRY
FOOT PATH
ROAD
* NORTH DIRECTION INDICATES THE MAGNETICAL NORTH.
HEADTANK
PENSTOCK
POWERHOUSE
SPILLWAY
TAILRACE
WATERWAY
BM-2
EL = 1719.81m
X(N)=57008
Y(E)=225633
GEOLOGIC LEGEND
RIVER DEPOSIT
TALUS DEPOSIT
CHLORITE SCHIST
TUFF BRECCIA
LIMESTONE
PORPHYRITE DYKE
STRIKE & DIP OF FAULT
STRIKE & DIP OF FISSURE
STRIKE & DIP OF QUARTZ VEIN
STRIKE & DIP OF SCHISTOSITY
GEOLOGICAL CONTACT
OUTCROP
CLIFF
INDEX
SCALE : 1/500
MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO
GEOLOGICAL MAP
ADARDOUR
GENERAL PLAN (2/2)
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Figure 3.2-2



Section A~A'



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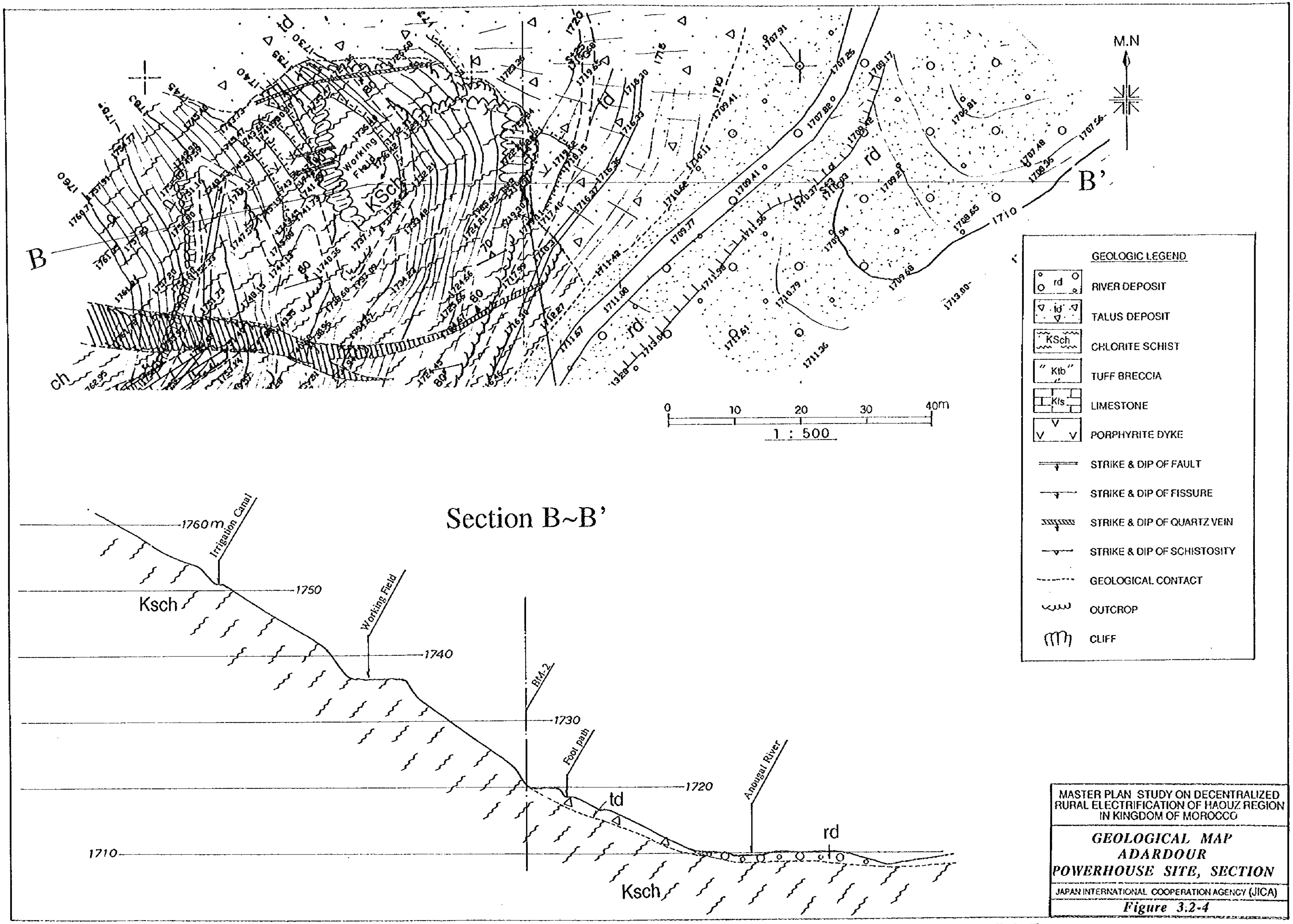
GEOLOGICAL MAP ADARDOUR INTAKE SITE, SECTION

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Figure 3.2-3

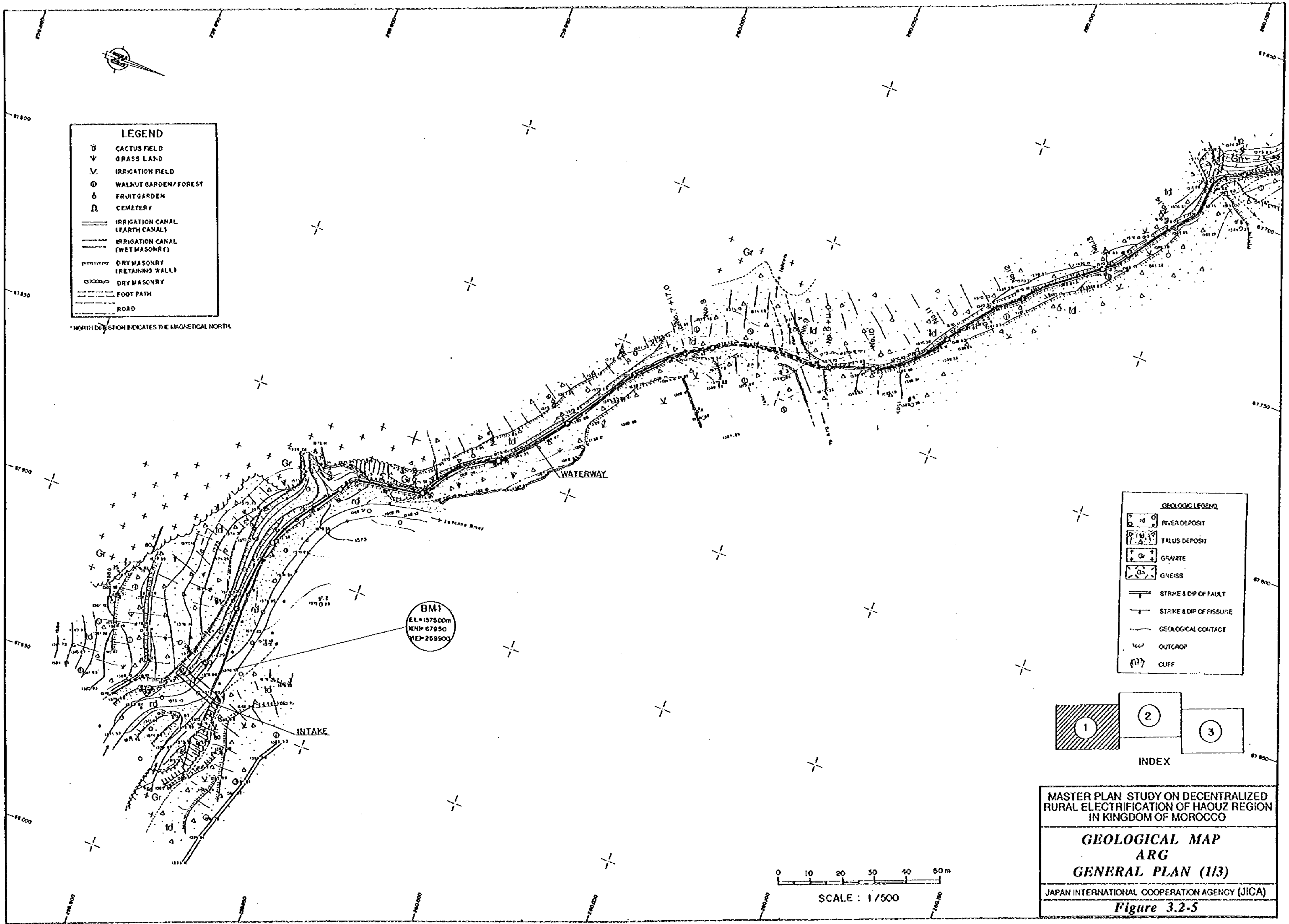


MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO

GEOLOGICAL MAP ADARDOUR POWERHOUSE SITE, SECTION

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Figure 3.2-4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CACTUS FIELD
GRASS LAND
IRRIGATION FIELD
WALNUT GARDEN/ FOREST
FRUIT GARDEN
CEMETERY
IRRIGATION CANAL (EARTH CANAL)
IRRIGATION CANAL (WET MASONRY)
DRY MASONRY (RETAINING WALL)
DRY MASONRY
FOOT PATH
ROAD
* NORTH DIRECTION INDICATES THE MAGNETICAL NORTH.
WATERWAY
INTAKE
BM-1
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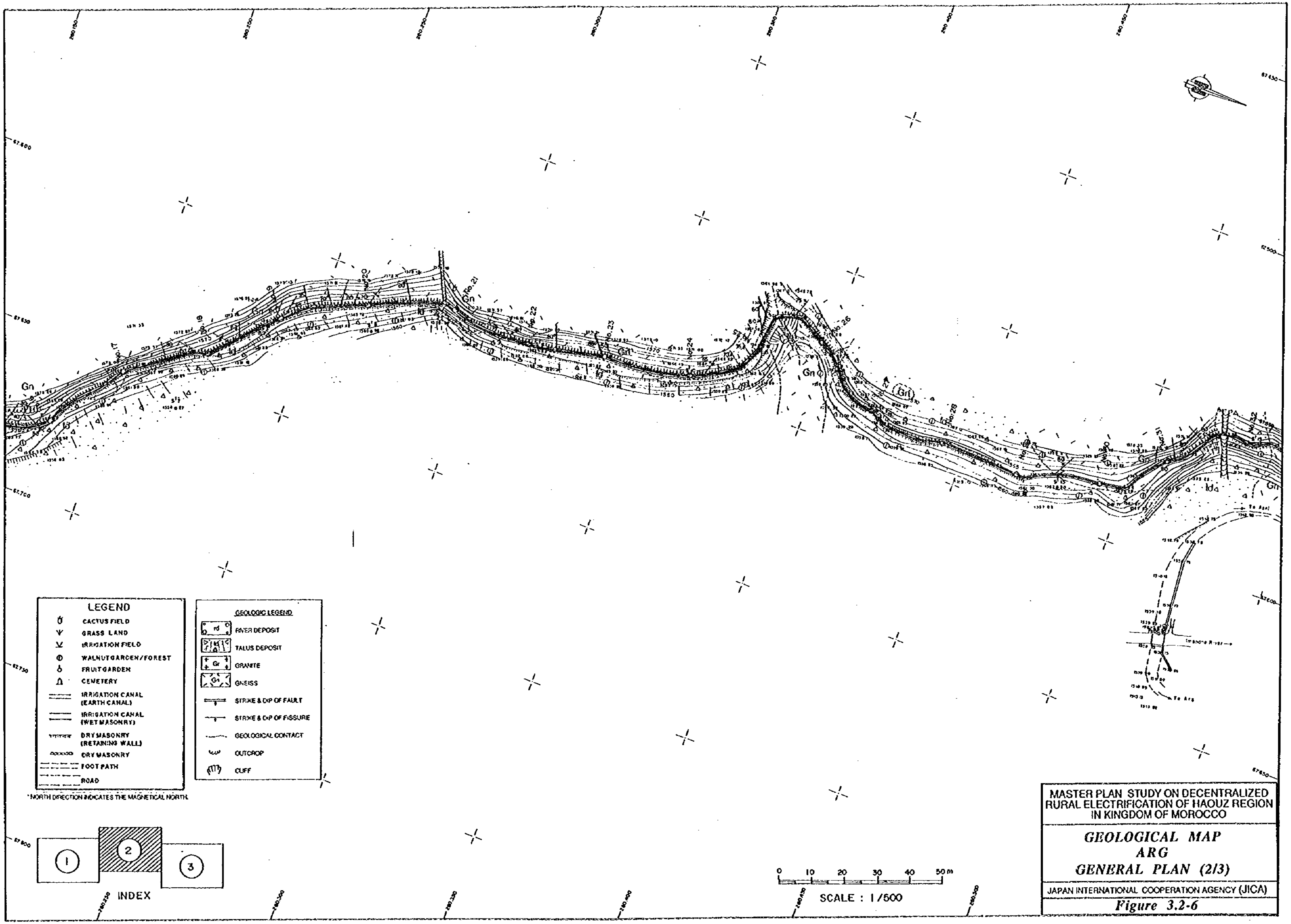
(X)=67950
(Y)=259500
GEOLOGIC LEGEND
RIVER DEPOSIT
TALUS DEPOSIT
GRANITE
GNEISS
STRIKE & DIP OF FAULT
STRIKE & DIP OF FISSURE
GEOLOGICAL CONTACT
OUTCROP
CLIFF
INDEX
SCALE : 1/500
0 10 20 30 40 50m
MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO
GEOLOGICAL MAP
ARG
GENERAL PLAN (1/3)
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
Figure 3.2-5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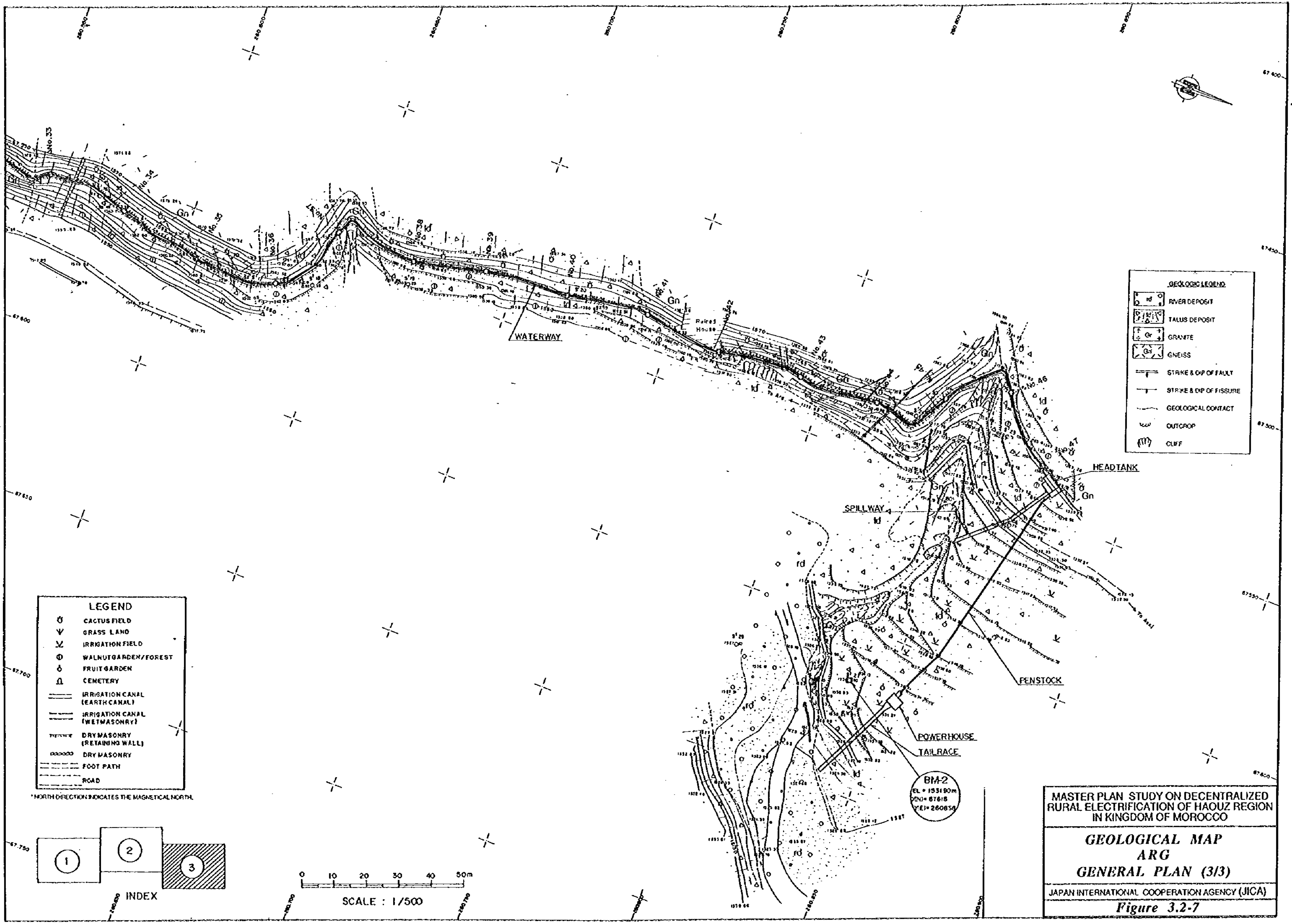
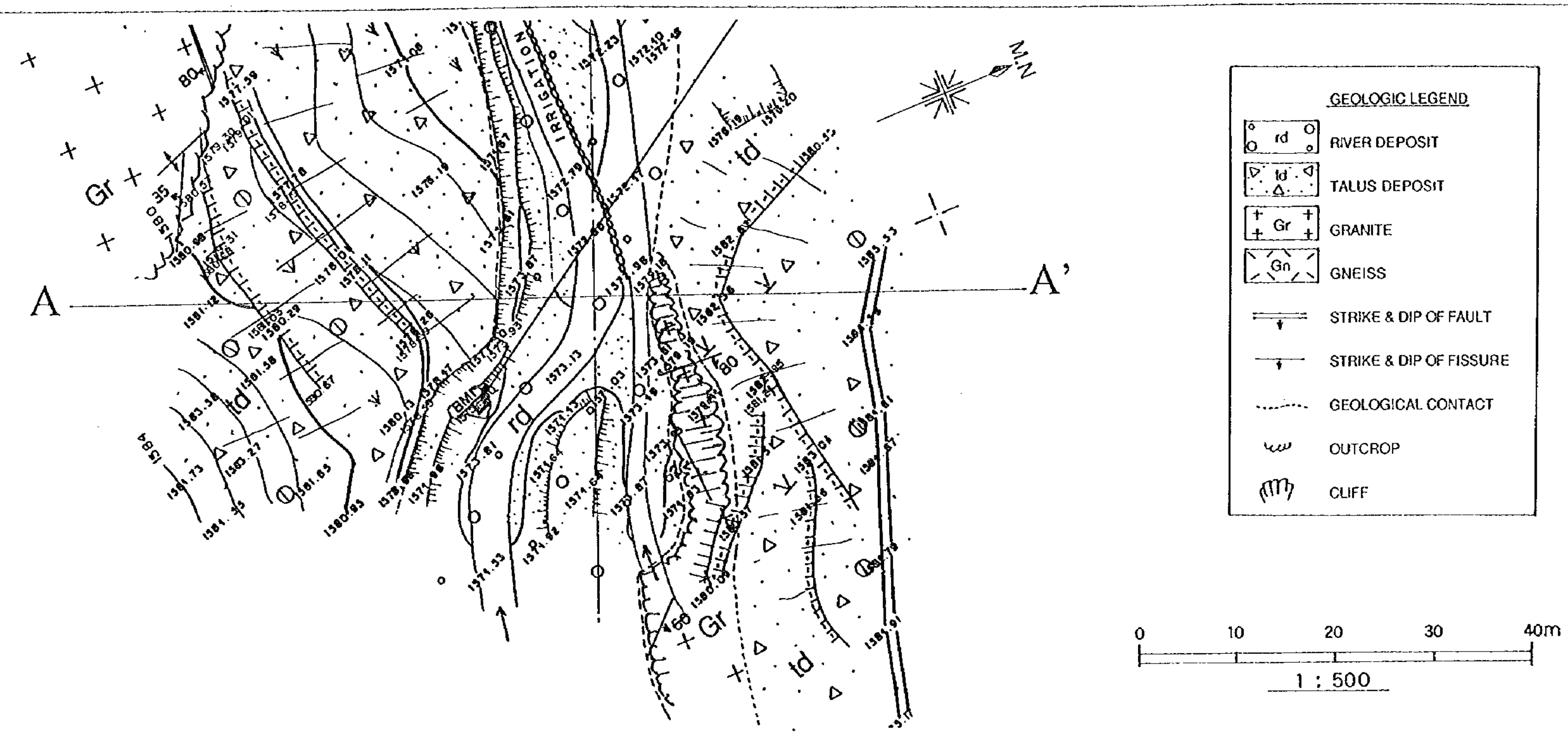
GRASS LAND
IRRIGATION FIELD
WALNUT GARDEN/FOREST
FRUIT GARDEN
CEMETERY
IRRIGATION CANAL (EARTH CANAL)
IRRIGATION CANAL (WET MASONRY)
DRY MASONRY (RETAINING WALL)
DRY MASONRY
FOOT PATH
ROAD
* NORTH DIRECTION INDICATES THE MAGNETICAL NORTH.
GEOLOGIC LEGEND
RIVER DEPOSIT
TALUS DEPOSIT
GRANITE
GNEISS
STRIKE & DIP OF FAULT
STRIKE & DIP OF FISSURE
GEOLOGICAL CONTACT
OUTCROP
CLIFF
INDEX
1
2
3
SCALE : 1/500
0 10 20 30 40 50 m
MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO
GEOLOGICAL MAP
ARG
GENERAL PLAN (2/3)
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
Figure 3.2-6


WATERWAY
SPILLWAY
HEADTANK
PENSTOCK
POWERHOUSE
TAILRACE
BM-2
GEOLOGIC LEGEND
RIVER DEPOSIT
TALUS DEPOSIT
GRANITE
GNEISS
STRIKE & DIP OF FAULT
STRIKE & DIP OF FISSURE
GEOLOGICAL CONTACT
OUTCROP
CLIFF
LEGEND
CACTUS FIELD
GRASS LAND
IRRIGATION FIELD
WALNUT GARDEN / FOREST
FRUIT GARDEN
CEMETERY
IRRIGATION CANAL (EARTH CANAL)
IRRIGATION CANAL (WET MASONRY)
DRY MASONRY (RETAINING WALL)
DRY MASONRY
FOOT PATH
ROAD
*NORTH DIRECTION INDICATES THE MAGNETICAL NORTH
INDEX
0 10 20 30 40 50m
SCALE : 1/500
MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO
GEOLOGICAL MAP
ARG
GENERAL PLAN (3/3)
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
Figure 3.2-7



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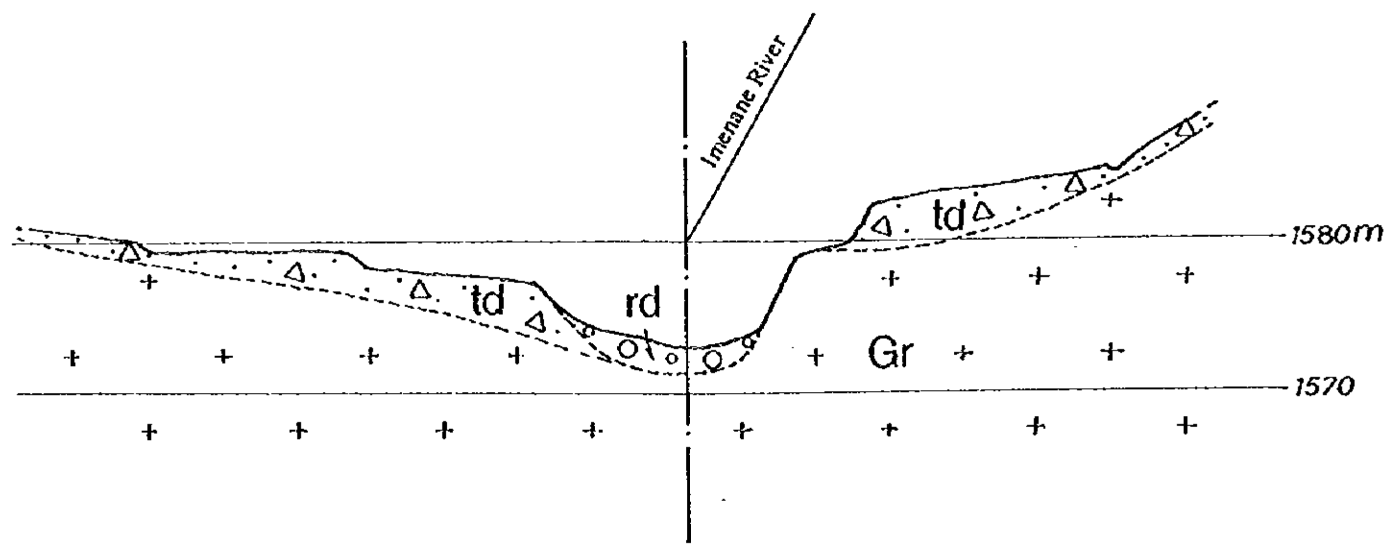
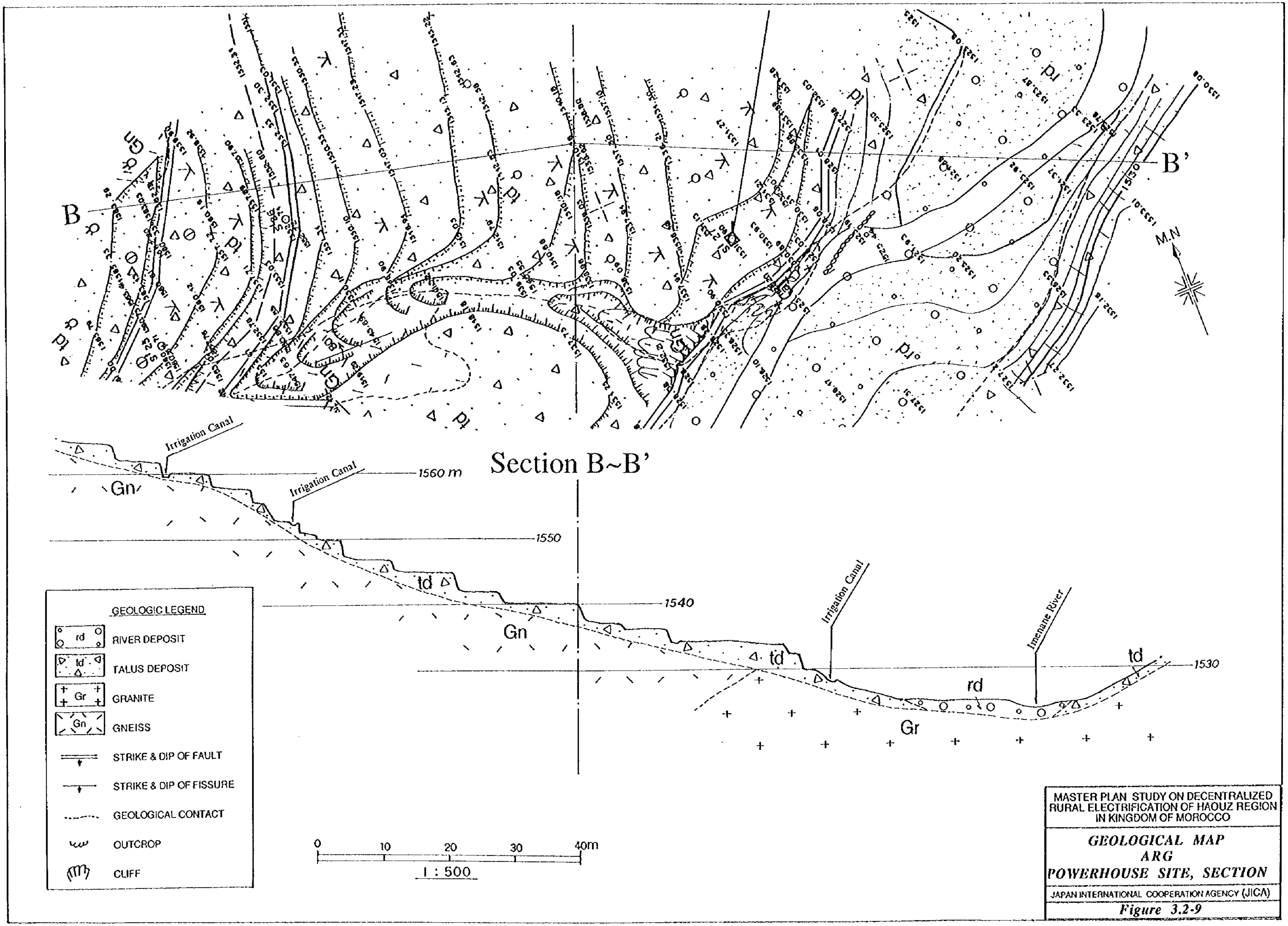


MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO

GEOLOGICAL MAP
ARG
INTAKE SITE, SECTION

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Figure 3.2-8



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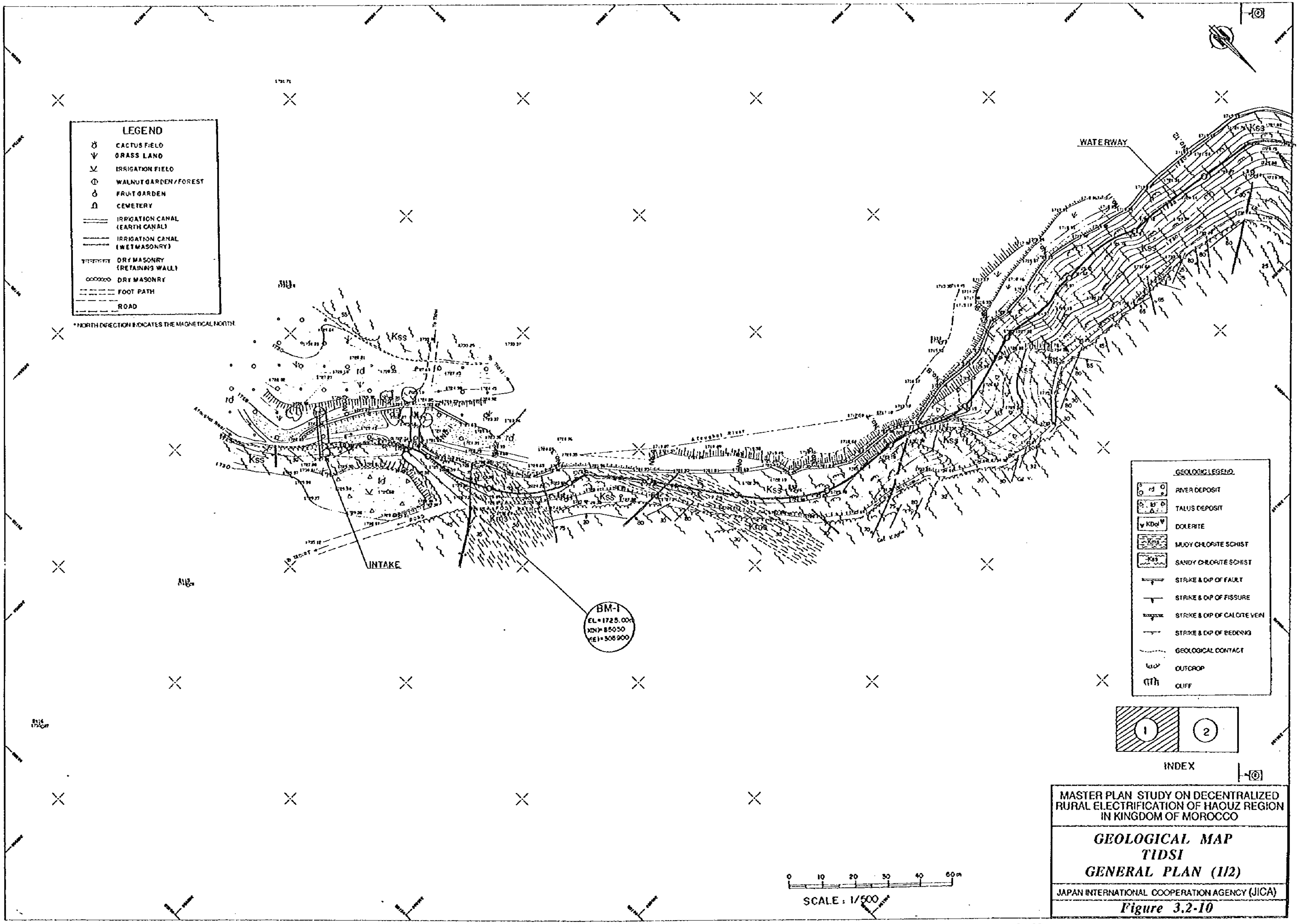
GEOLOGICAL MAP ARG POWERHOUSE SITE, SECTION

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Figure 3.2-9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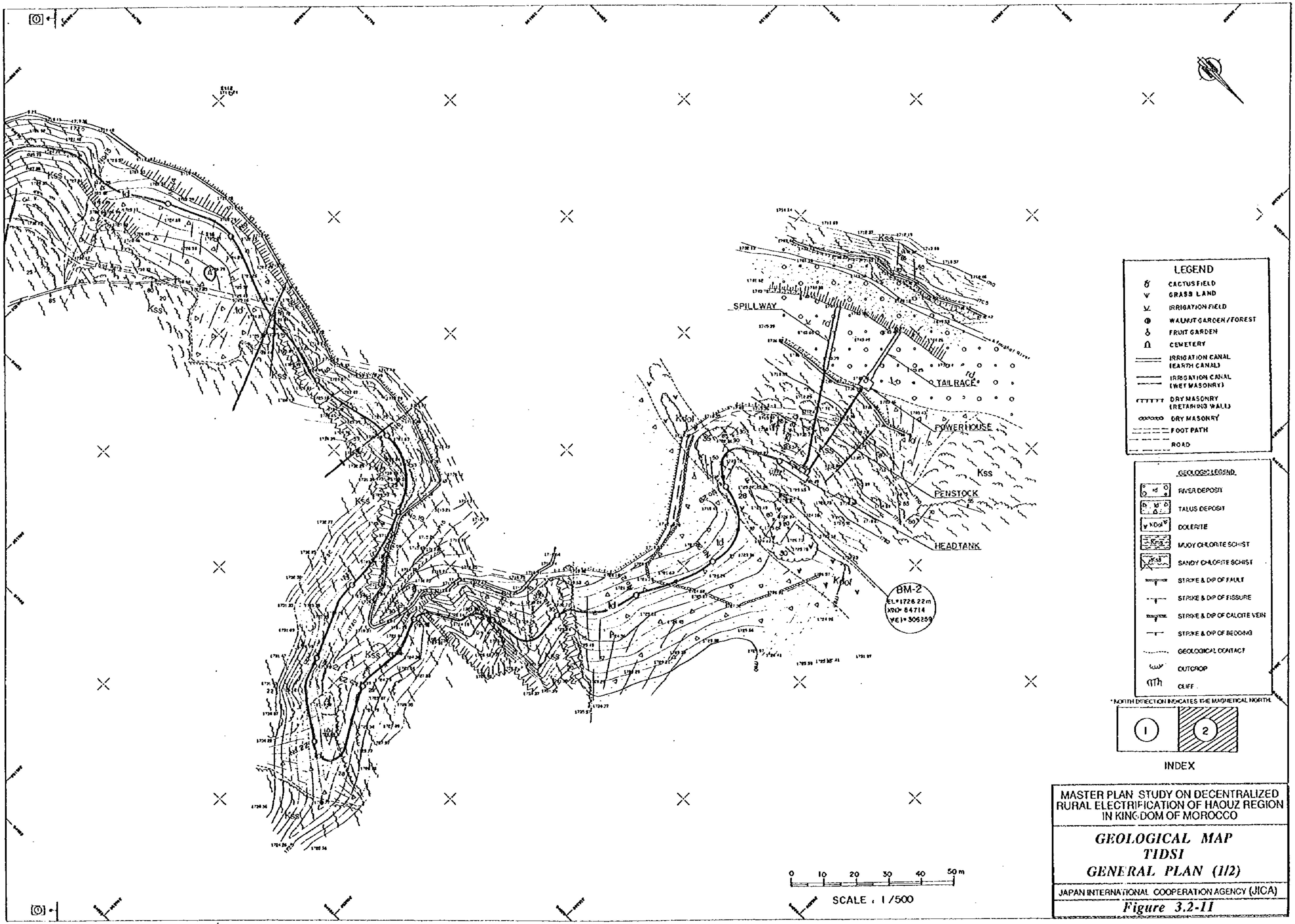
GRASS LAND
IRRIGATION FIELD
WALNUT GARDEN / FOREST
FRUIT GARDEN
CEMETERY
IRRIGATION CANAL (EARTH CANAL)
IRRIGATION CANAL (WET MASONRY)
DRY MASONRY (RETAINING WALL)
DRY MASONRY
FOOT PATH
ROAD
* NORTH DIRECTION INDICATES THE MAGNETICAL NORTH
WATERWAY
INTAKE
BM-1
EL=1725.00m
X(N)=85050
Y(E)=305900
Kss
rd
td
GEOLOGIC LEGEND
RIVER DEPOSIT
TALUS DEPOSIT
DOLERITE
MUDY CHLORITE SCHIST
SANDY CHLORITE SCHIST
STRIKE & DIP OF FAULT
STRIKE & DIP OF FISSURE
STRIKE & DIP OF CALCITE VEIN
STRIKE & DIP OF BEDDING
GEOLOGICAL CONTACT
OUTCROP
CLIFF
1
2
INDEX
0 10 20 30 40 50m
SCALE : 1/500
MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO
GEOLOGICAL MAP
TIDSI
GENERAL PLAN (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
Figure 3.2-10


SPILLWAY
TAILRACE
POWERHOUSE
PENSTOCK
HEADTANK
BM-2
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LEGEND
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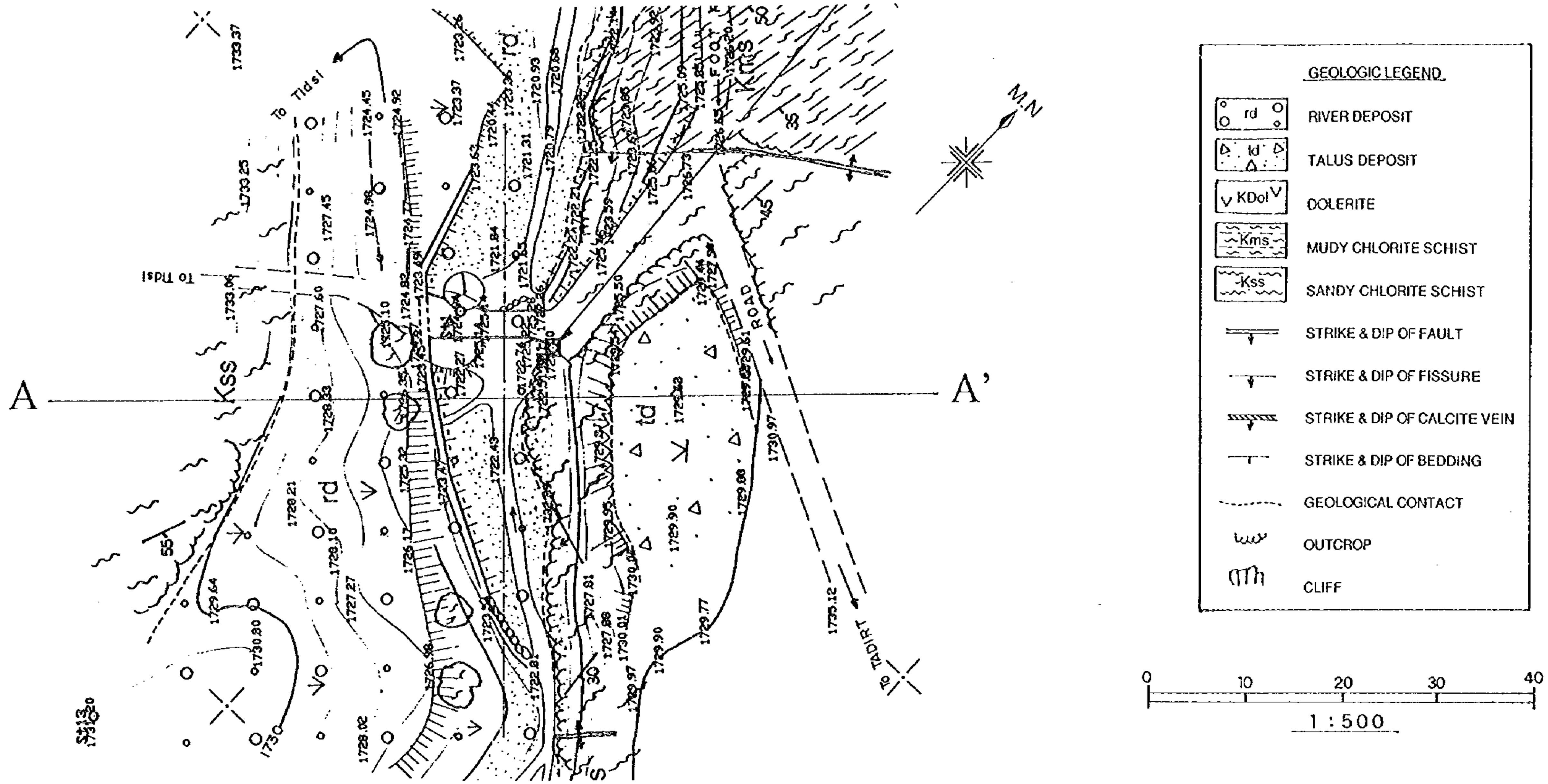
GRASS LAND
IRRIGATION FIELD
WALNUT GARDEN / FOREST
FRUIT GARDEN
CEMETERY
IRRIGATION CANAL (EARTH CANAL)
IRRIGATION CANAL (WET MASONRY)
DRY MASONRY (RETAINING WALL)
DRY MASONRY
FOOT PATH
ROAD
GEOLOGIC LEGEND
RIVER DEPOSIT
TALUS DEPOSIT
DOLERITE
MUDY CHLORITE SCHIST
SANDY CHLORITE SCHIST
STRIKE & DIP OF FAULT
STRIKE & DIP OF FISSURE
STRIKE & DIP OF CALCITE VEIN
STRIKE & DIP OF BEDDING
GEOLOGICAL CONTACT
OUTCROP
CLIFF
* NORTH DIRECTION INDICATES THE MAGNETICAL NORTH.
1
2
INDEX
0 10 20 30 40 50 m
SCALE : 1/500
MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO
GEOLOGICAL MAP
TIDSI
GENERAL PLAN (1/2)
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
Figure 3.2-11



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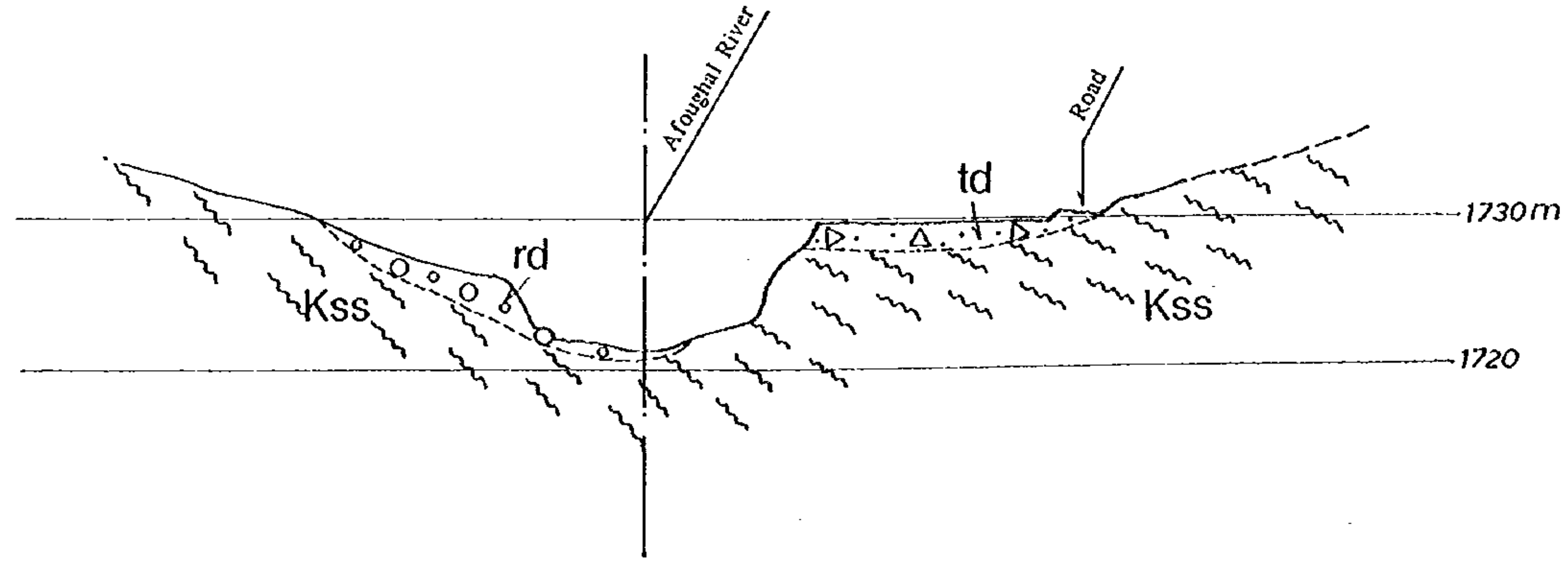


GEOLOGIC LEGEND

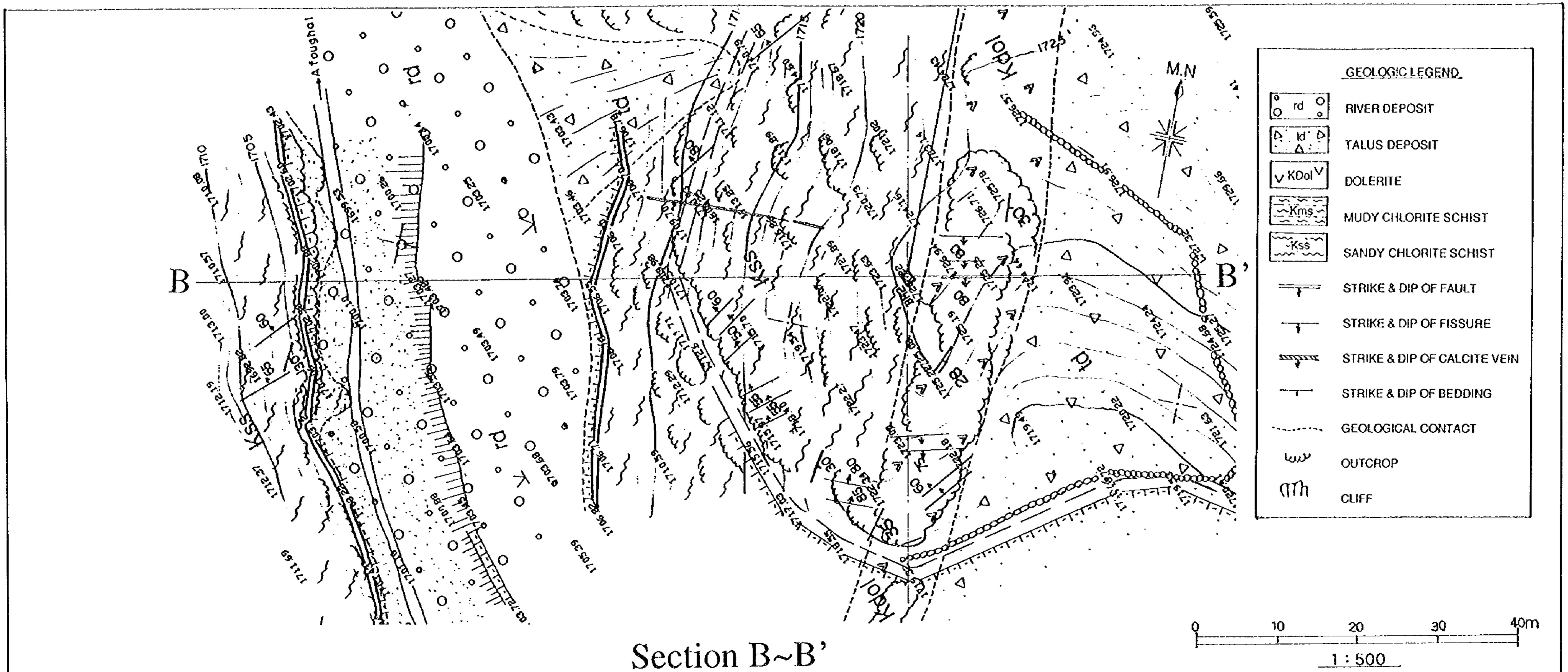
- rd — RIVER DEPOSIT
- td — TALUS DEPOSIT
- KDol — DOLERITE
- Kms — MUDY CHLORITE SCHIST
- Kss — SANDY CHLORITE SCHIST
- STRIKE & DIP OF FAULT
- STRIKE & DIP OF FISSURE
- STRIKE & DIP OF CALCITE VEIN
- STRIKE & DIP OF BEDDING
- GEOLOGICAL CONTACT
- OUTCROP
- CLIFF

MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO

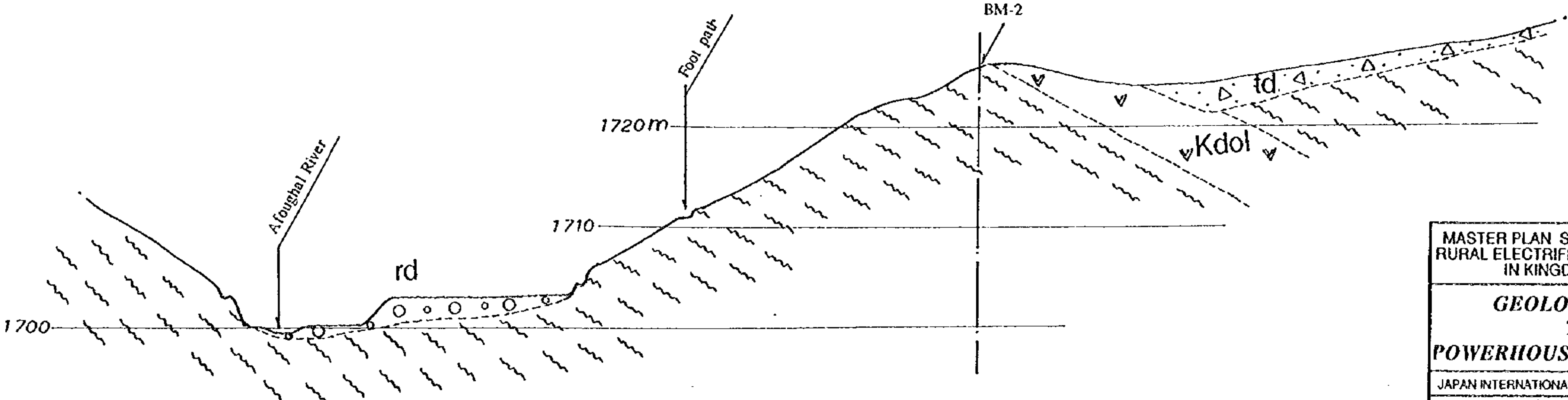
GEOLOGICAL MAP
TIDSI
INTAKE SITE, SECTION

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Figure 3.2-12



Section B~B'



MASTER PLAN STUDY ON DECENTRALIZED RURAL ELECTRIFICATION OF HAOUZ REGION IN KINGDOM OF MOROCCO

GEOLOGICAL MAP
TIDSI
POWERHOUSE SITE, SECTION

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Figure 3.2-13