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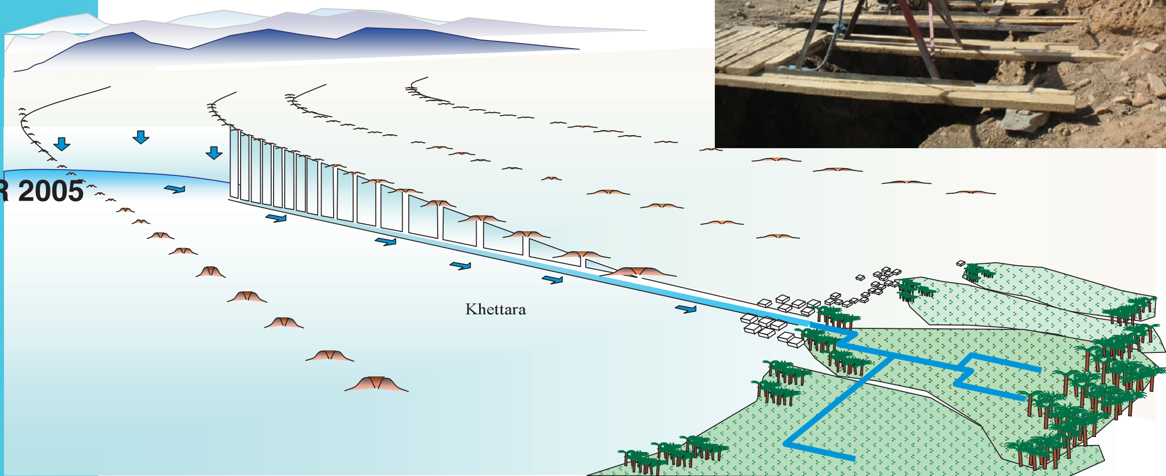
NO.

MINISTRY OF AGRICULTURE, RURAL DEVELOPMENT AND SEA FISHERIES
REGIONAL AGENCY FOR RURAL DEVELOPMENT OF THE TAFILALET
THE KINGDOM OF MOROCCO

THE DEVELOPMENT STUDY ON RURAL COMMUNITY DEVELOPMENT PROJECT IN SEMI-ARID EAST ATLAS REGIONS WITH KHETTARA REHABILITATION IN THE KINGDOM OF MOROCCO

MANUAL FOR KHETTARA REHABILITATION AND MAINTENANCE WORKS



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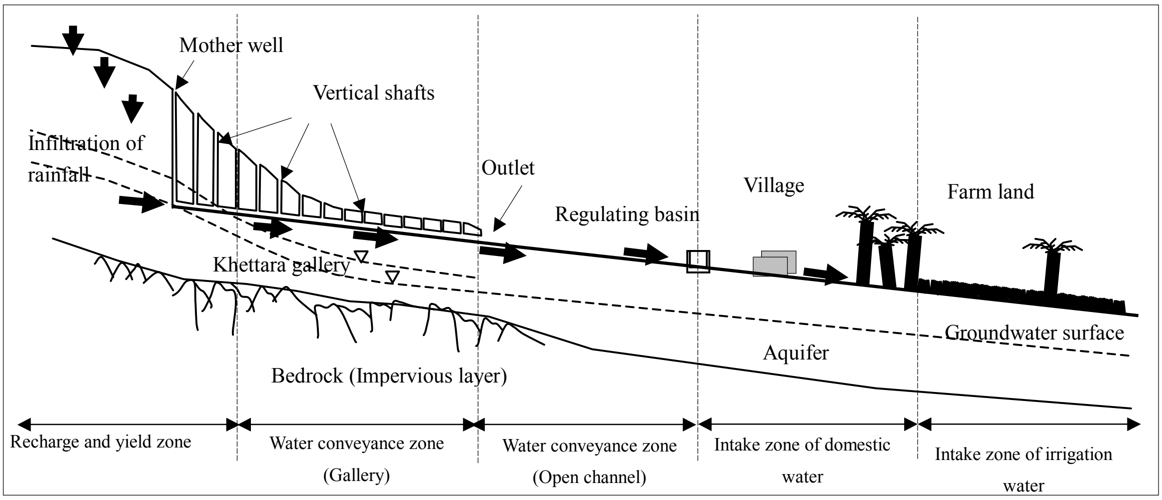


Definition

Definitions	Descriptions
Mother well	Shaft which yields groundwater located at most upstream of a khettara in general.
Vertical shaft	Shaft to remove excavated materials and to provide ventilation and access for maintenance works.
Khettara gallery	Tunnel portion of a khettara, which transports water from groundwater yield portion to the surface.
Outlet	Downstream end of gallery tunnel
Regulating basin	Water storage basin to control water delivery to the command area. It is constructed of concrete and located at immediately downstream of a khettara in general.
Recharge and yield zone	Zone located at upstream of khettara at where rainfall or stream flow infiltrates into aquifers to replenish them.
Water conveyance zone (Gallery)	Gallery (or tunnel) portion to convey water to downstream, at where infiltration loss may observed.
Water conveyance zone (Open canal)	Open channel portion to convey water to downstream.
Intake zone of domestic water	Located at immediately upstream of regulating basin at where inhabitant takes water for potable, domestic and livestock use.
Intake zone of irrigation water	Located at downstream of regulating basin to transport irrigation water to the command area.
Aquifer	Aquifers are rock or sediment that act as storage reservoirs for groundwater and are typically characterized by high porosity and permeability.
Settling basin	Basin for accumulating flow materials such as earth materials along the khettara gallery.

Degradation	Digging down of gallery base to settle gallery base under the groundwater level aiming at increase of khettara discharge.

Definitions	Descriptions
Open canal or open channel	Canal structure open to the sky
Culvert	A transverse waterway by means of enclosed channel
Frame structure	All members are connected in rigid joint.
Flume structure	Member is composed of base slab and side walls
PVC pipe	Plyvinyl chloride pipe
FRP pipe	Fiber-reinforced plastics pipe
Hydraulic gradient	The decrease in hydraulic head per unit distance in the direction of flow
Leakage, seepage	Uncontrolled loss of water from artificial hydraulic structure due to hydrostatic pressure
Climatic year	A continuous twelve-month during which occurs a complete annual climatic cycle
Wadi	A ravine or valley, dry except in the wet season

1. General Description

1.1 Objectives of the Manual

This manual defines the general and basic technical terms relating to the planning, standard design, construction or rehabilitation, as well as maintenance works of the khettaras in the Tafilalet regions in Morocco. Therefore for the design and construction of individual khettara in different conditions, technical and economic criteria shall be considered according to the principals set out in the manual, taking account of field conditions such as topography, hydro-geological condition, etc.

In addition, inspection and maintenance procedures are introduced in the manual giving a reference for further rehabilitation works.

1.2 Scope of Manual

The manual is applied to the planning, design and construction of the khettaras as detailed below:

1) Investigation

2) Design

3) Construction and supervisory works

4) Maintenance

1.3 Basic Consideration in Investigations

Investigations are required to collect the necessary basic data and information for determination of khettaras alignment, selection of rehabilitation types such as concrete culvert, concrete flume, pipe installation, as well as construction methods and maintenance activities from the technical, economical and social points of views. Investigations are therefore conducted and controlled systematically from the commencement by an experienced engineer with sufficient knowledge in planning, design, construction, operation and maintenance.

1.4 Basic Consideration in Design

The design for the khettara rehabilitation work shall be carried out in consideration of rehabilitation purposes, efficiency for a budget distribution, minimizing construction costs as well as operation and maintenance costs.

In designing khettara rehabilitation section, accurate information shall be collected as follows:

(1) Information necessary for design

(a) Discharge

Discharge data (including seasonal fluctuation), water use (domestic water use, etc.)

(b) Present conditions of command area of khettara

Extent of command area, topography, geology, climate, hydrology, land use, farm management

(water distribution, cropping pattern, etc.)

(c) Present conditions of khettara routes

Topography, geology, land use and other rights along the khettara routes, location of aquifers, drainage conditions, etc.

(d) Operation and maintenance

Organization (traditional khettara users' groups, etc.) and maintenance cost after completion of the rehabilitation works.

(2) Basic considerations in design of khettaras

The design of the khettara shall be made to fulfill their functions for minimizing water leakage and laborious works for maintenance with effective use of allocated budget for the khettara rehabilitation works. In this respect, it is basically considered in design to keep 1) appropriate selection of standard section of a gallery so as to maximize project benefits, 2) extent for rehabilitation works[1], 3) easiness of maintenance activities, etc.

1.5 Basic Consideration of Material Supply Plan

The grain size distribution is most important factor to maintain a concrete quality, especially compressive strength. Coarse aggregate is supplied from the crushing plant, while fine aggregate is produced bt a wire sieve in most cases. Standardization of aggregates is explained in the manual. In addition conduits (PVC pipe, prefabricated concrete products) are introduced in the manual.

1.6 Basic Consideration of Reconstruction Plan for Decrepit Structures

Khettara has its function of 1) structural function, 2) hydraulic function, 3) water use function, etc. Deterioration is categorized into physical deterioration caused by aging, and economical deterioration, for example increase of maintenance cost due to collapse of gallery wall, as well. It is necessary to survey the cause of such deterioration when decrepit structure is a subject for rehabilitation. Deterioration related to structural and hydraulic condition is discussed, and proper countermeasures are proposed in the manual.

1.7 Basic Consideration of Construction Planning

To achieve appropriate construction works of the khettara rehabilitation works, it is important to properly supervise the construction works as well as design work. The following are the points found during the rehabilitation works.

1) Earth work (Open excavation and tunnel works)

2) Dewatering

---

1 Master plan report indicates that 30 % of total length of each khettara shall be rehabilitated considering cost - benefit analysis. In this respect, rehabilitation shall be conducted at where higher benefit is expected.

3) Construction machinery and equipment

4) Prefabricated concrete

The manual indicates necessary points for the supervisory works.

1.8 Basic Consideration of Maintenance

It is conceivable that serious damages in the gallery by floods and spontaneous collapse of gallery wall cause a decline of the khettara flow. In the manual, periodical inspection method and maintenance work are discussed to make necessary countermeasures before some damages occur.

2. Investigation

2.1 Plan of Investigations

2.1.1 General Items

Proper investigation plan in terms of investigation scope, methods, precision and other conditions shall be made in order to collect the data necessary for the khettara rehabilitation works.

Investigations for the khettara rehabilitation works may include those necessary for 1) planning, 2) design, 3) construction and 4) operation and maintenance. In addition, methods of investigations may include 1) data collection, 2) reconnaissance, 3) field investigations, 4) topographic survey, 5) field and laboratory tests, 6) trial construction and observation during and after construction works.

In this manual, these investigations are divided into these for 1) preliminary design, 2) basic design, 3) detailed design and 4) supplementary investigation during and after construction works.

2.1.2 Stages of Investigation

(1) Investigation for preliminary design

The objectives of the investigations are to broadly evaluate available data on meteoro-hydrology, topography, topography, geology and site conditions, also to reconnoiter a site and other necessary studies with a view to establishing a basic plan of the khettara rehabilitation. Usually, several alternatives in terms of rehabilitation section, routes are proposed during a preliminary design stage.

(2) Investigation for basic design

The investigations provide basic data used for determining rehabilitation section, extent of rehabilitation length, temporary work plan, e.g. drainage and dewatering plan, as well as estimates for a rehabilitation cost. The investigation consists of data collection, topographic survey, cost estimates, etc.

(3) Investigation for detailed design

The investigations provide necessary data for a detailed design. Additional field tests such as soil tests and supplementary topographic survey shall be conducted as required. In addition, necessary data for construction planning including construction schedule, temporary work planning are collected.

(4) Supplementary investigation

The investigation ate to obtain supplementary data during a construction stage.

The outline of these investigation stages is shown on Fig. 2.1.1.

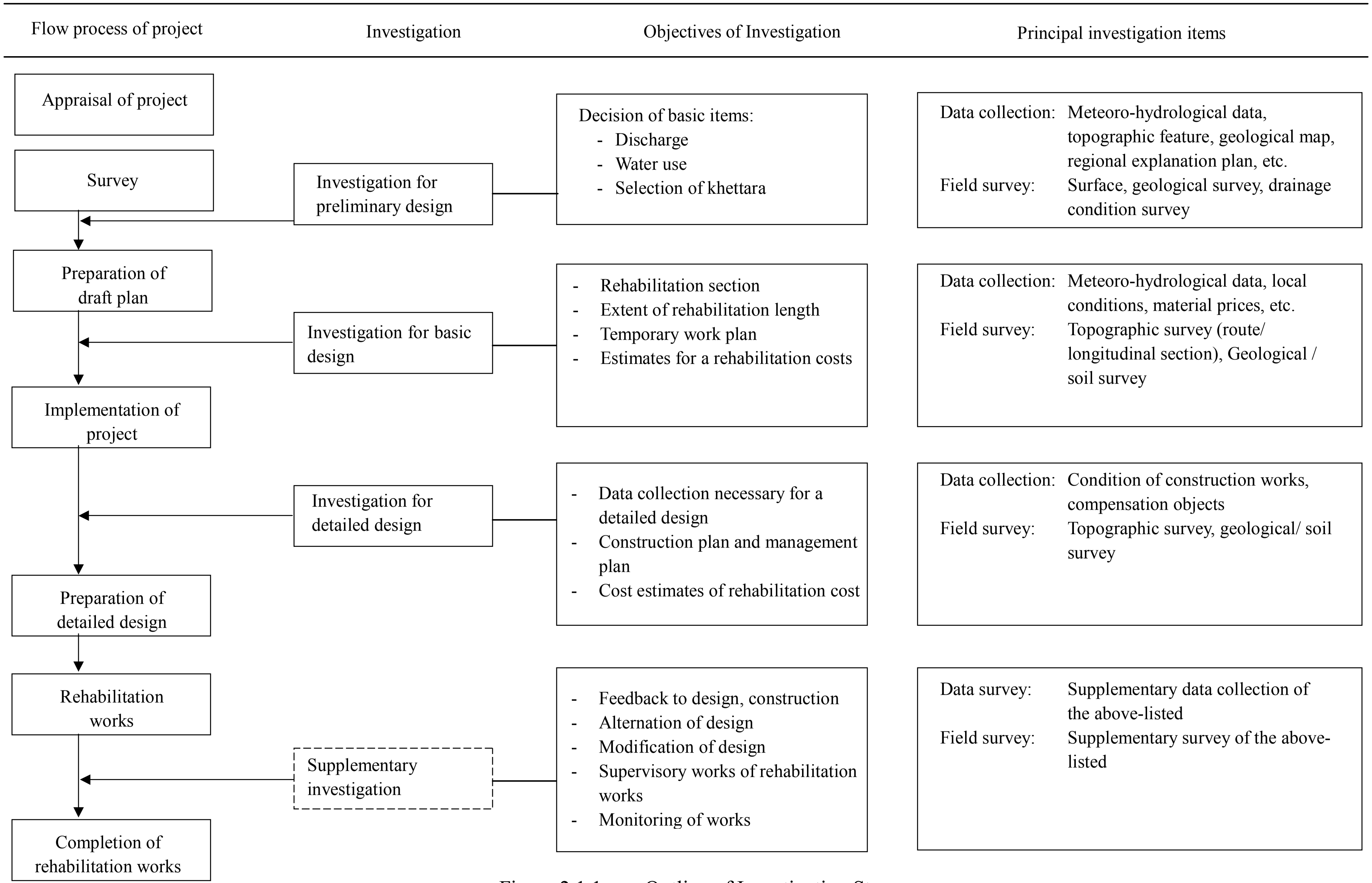


Figure 2.1.1 Outline of Investigation Stages

2.2 Items for Investigations

Investigation items shall be properly determined in accordance with the rehabilitation purposes, local conditions and other factors so as to rationally and effectively complete investigations.

Survey items necessary for a rehabilitation of the khettaras are selected from the list in Tables 2.2.1 to 2.2.3 in each implementation stage.

Table 2.2.1 Investigation Items for Preliminary Design

	Survey items	Remarks
1.	Project area	Name of ksar: Name of commune rural:
2.	Present condition of khettara	Discharge, total length of khettara, rehabilitation records (materials, completion date, etc.), section of gallery, structural information, water use, land use, existing water use facilities (canals, pipelines, etc.)
3.	Social information	Population, water users' associations, organizations of farmers
4.	Agricultural information	Farmland area, irrigable area, cropping pattern, water rights, other irrigation source (flood irrigation, pump stations, etc.)
5.	Natural conditions	River conditions (drainage, flood)
6.	Local development plan	Relation with other projects, water resources development plan

Table 2.2.2 Survey Items for Designs and Construction

	Survey items	Remarks
1.	Topography	Topographic survey
2.	Geological condition	(including engineering soil properties)
3.	Meteorology, hydrology	Temperature, precipitation, khettara discharge, river condition (drainage, flood),
4.	Site conditions	Social conditions, construction conditions, environmental conditions, road condition

Table 2.2.3 Investigation Items for Maintenance

	Survey items	Remarks
1.	Local conditions	Activities of water users' associations
2.	Water distribution system	Water rights, activities of water users' associations
3.	Others	Compensatory investigation, environmental investigations

2.3 Investigations

2.3.1 Topographical Investigations and Surveys

Topographical investigations and survey include preparation of topographical maps along the proposed khettara routes.

(1) GIS map

GIS maps (satellite images) of their resolution of 2.5 m pixel and 5.0 m pixel are available for a preparation of topographical maps.

(2) Route survey

Route survey is conducted based on available maps and aerial photographs as well as satellite images. The ground survey is the actual survey in the field to obtain data for the basic and detailed design. The satellite images and aerial photographs are available as shown on Figures 2.3.1 and Figure 2.3.2.

(3) Center line survey

This is the survey to locate the center line of the khettaras on the ground. Center stakes are driven from the starting point at specified intervals and precision. Additional stakes such as intersection point (IP) (point of intersection; PI) are placed at where necessary.

(4) Longitudinal survey

Longitudinal survey provides stake level, ground and gallery bed elevation in order to plot a longitudinal section along the center line of the khettara gallery. Bench marks (BM) used for reference are placed at specified intervals along the routes.

(5) Cross section survey

Cross sections are plotted for a center stake positions. These sections are filled in with the sections of excavation and embankment, and are used in khettara rehabilitation design.

(6) Land survey

Land survey is carried out for land compensation when required.

Table 2.3.1 Survey Maps

Survey map	Method of survey	Scope of survey	Scale	Survey station interval	Necessity
Topographic map	Aerial/satellite images	Along route	1/5,000 -1/2,500	---	△
Plane map Profile map Section map	Route survey Centerline survey Longitudinal and cross section survey	One side of route Approx. 30-100m	1/1,000-1/200 1/500-1/100 1/200-1/100	Approx. 50-100m	○ ○ △
Cadastral map	---	---	---	---	△

○: compulsory △: optional

2.3.2 Soil and Geological Investigations

Soil and geological investigations including the collection of geological data reconnaissance, are conducted along the proposed khettara gallery to survey the physical properties of the soil, groundwater level and other conditions.

2.3.3 Meteorological and Hydrological Investigations

Items to be investigated in meteoro-hydrological data are temperature, precipitation, discharge of khettara, water level, and flood records in case khettara is located along or near the river and drainage ditch. Discharge and water level data are inevitable for the construction planning, especially drainage and dewatering planning. Interviews or other means are applicable to get past data, such as flood records.

2.3.4 Investigations of Site Conditions

For the rehabilitation of the khettaras, since social and environmental conditions are important, these conditions are investigated as required.

(1) Investigation on social conditions

- (a) Land use, irrigation and drainage systems
- (b) River structures and water rights
- (c) Construction conditions

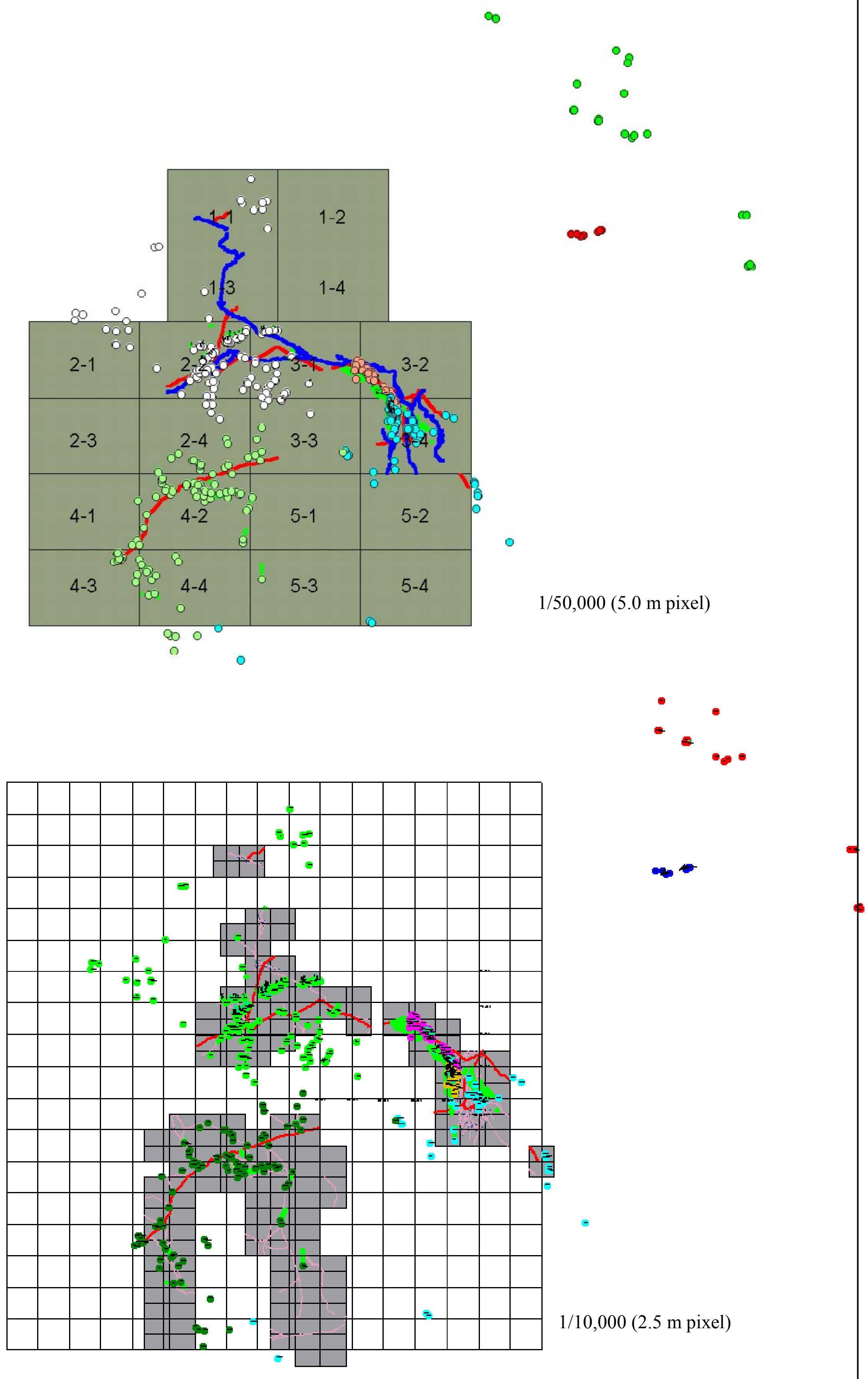


Figure 2.3.1 Location of Satellite Images

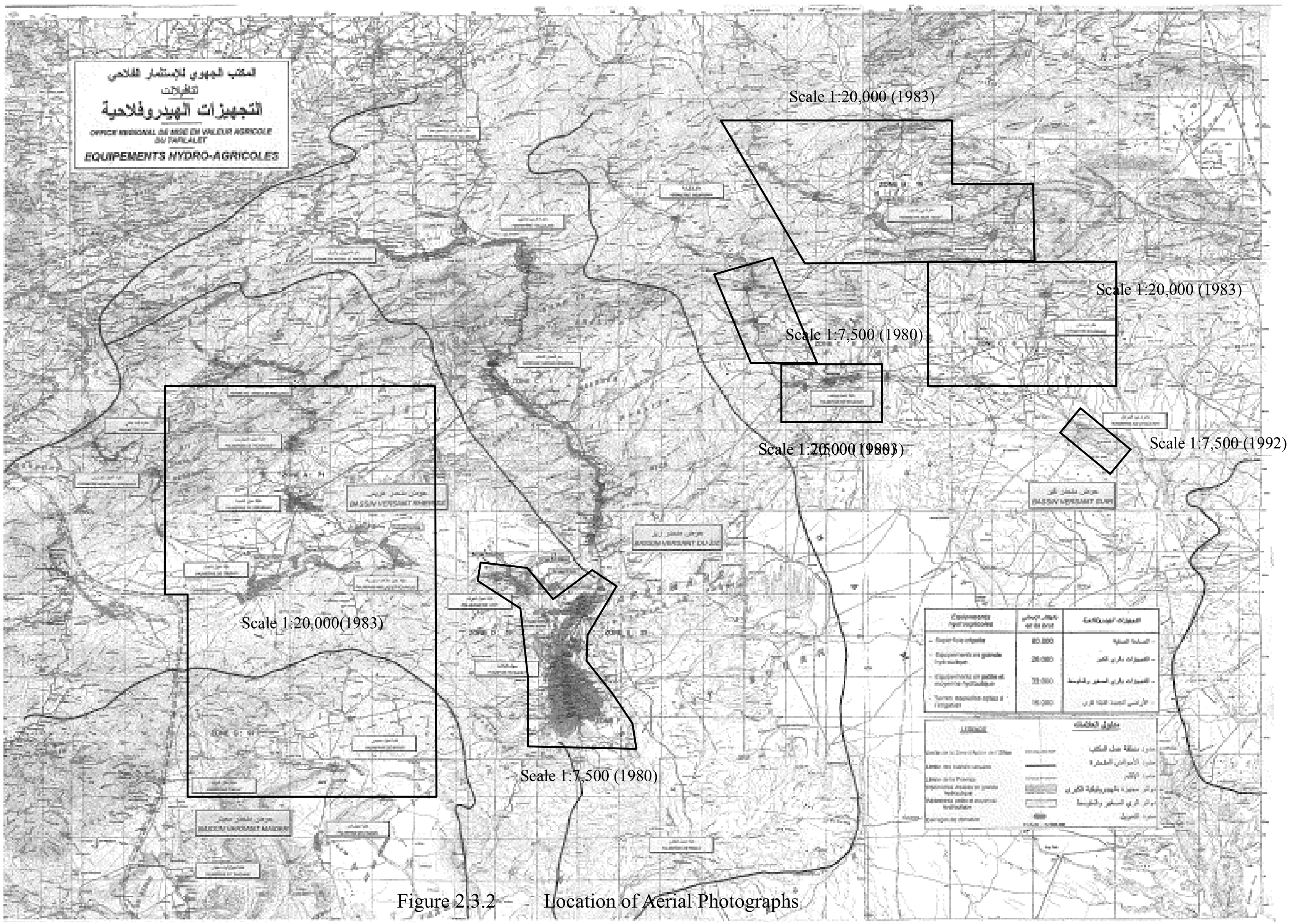


Figure 2.3.2 Location of Aerial Photographs

3. Basic Design Concepts

3.1 General

3.1.1 General Concepts

Proper khettara rehabilitation works shall be proposed taking account of economy and safety, proper water management, reduction of maintenance laborious works, etc.

3.1.2 Procedure of Design

The procedures of the overall design are shown on Figure 3.1.1.

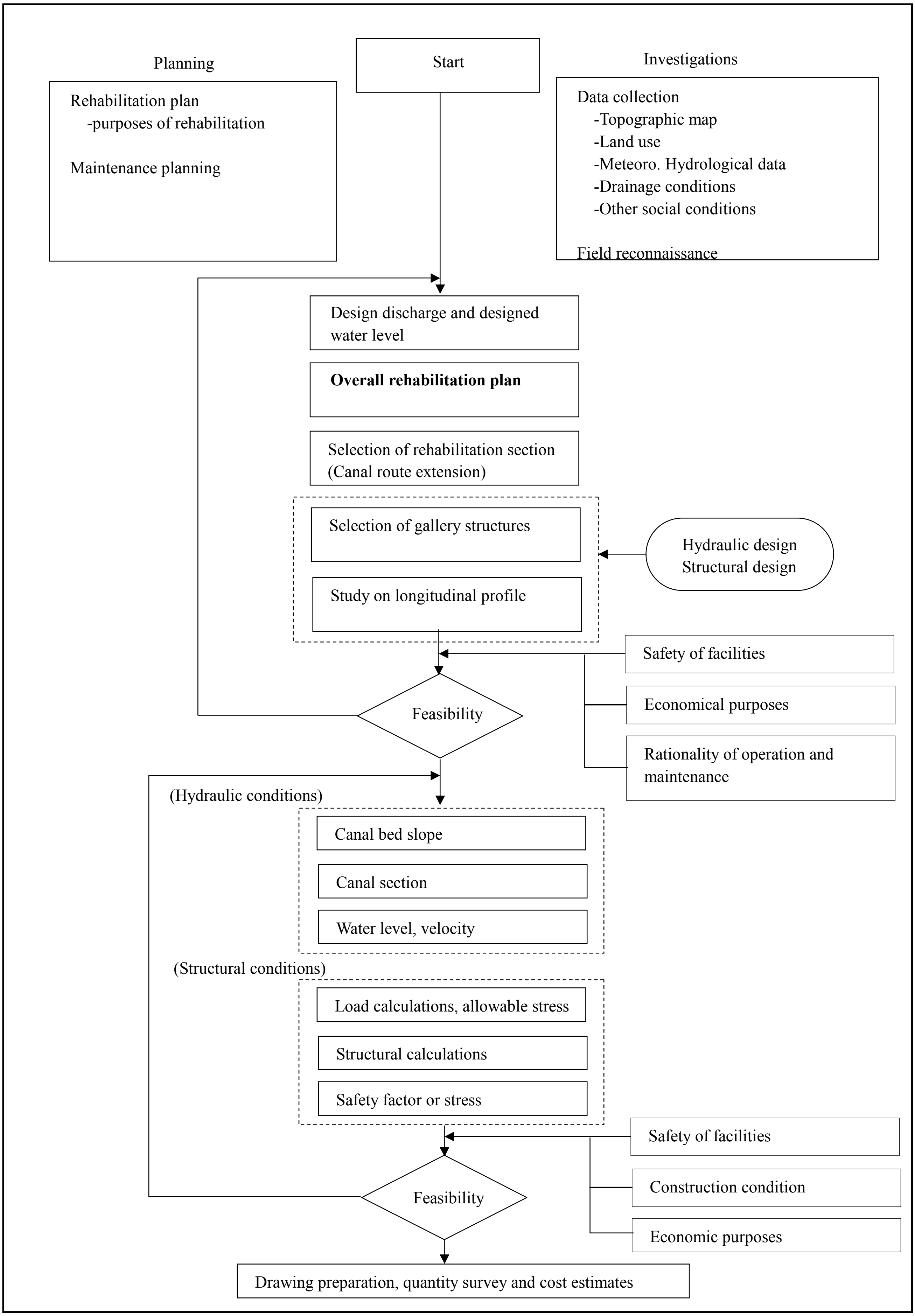


Figure 3.1.1 Overall design Flow Chart

3.1.3 Design Discharge and Designed Water Level

(1) Design discharge

Discharge of the khettara varies by 1) seasonal fluctuation of rainfall, 2) consecutive drought, 3) flood occurrence, in addition hydraulic condition of the yield section of the khettara, e.g., canal bed elevation, extension of gallery and influence by excessive pumpage surrounding to the khettara. With due consideration of these factors, design discharge shall be properly determined to estimate canal dimensions, canal bed slope taking account of an economical aspect.

(2) Design water level

The design water level is an important value to determine canal section and function of the facilities. As shown on schematic diagram in the opening page, there exist regulating basins at the most downstream of the khettara galleries aiming at water storage for irrigation. In the case the khettara gallery is situated in gentle slope, water level controlled in the regulating basin affects the water level in the gallery, i.e. "back water". Design water level is determined in consideration of the back water effect from the operation and maintenance points of views.

3.1.4 Selection of Canal Type

The selection of the canal type significantly affects the rehabilitation costs of the khettara. It is therefore necessary to consider the rehabilitation cost and future maintenance cost in the selection of the canal type. Types of canal are classified into two types, i.e. open flow type (gravity flow) and pipe flow type (pressure flow). The former consists of culvert, flume structures and conduits, and the latter is generally composed of conduits, etc. Open flow type is selected in general taking account of the cleaning of the canal itself. The following shows characteristic points of each type. The selection of most appropriate water conveyance facilities must take into account the canal type to maintain all functions of entire system.

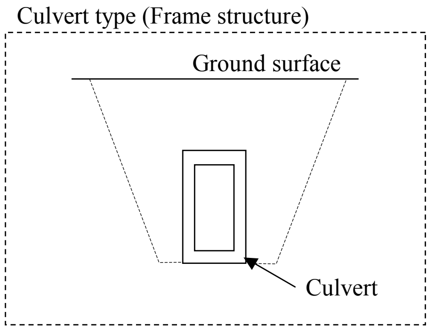
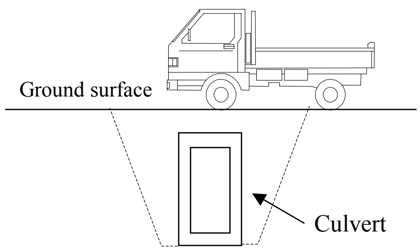
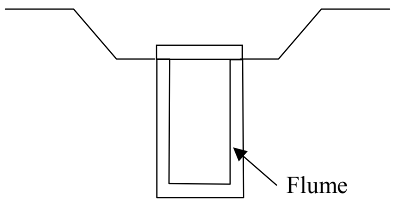
Table 3.1.1 Flow Type

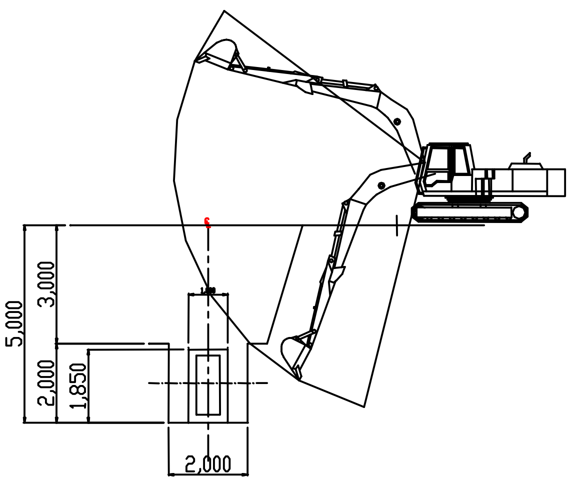
Canal type	General descriptions	Special considerations
Open channel (Open flow)	- Open channel type generally has higher flexibility in flow capacity than pipe flow type.	- When conduits are used, fluctuation of the discharge causes both open and pipe flow conditions.
Pipeline (Pipe flow)	- Pipeline is generally requires lower cost. - Deposits in a pipe cause reduction of its conveyance capacity. Settling basin is necessary to prevent intrusion of floating materials	- Since pipe materials are standardized, especially their length, pipe installation along serpentine gallery is unfavorable when pipe diameter is equal 200 mm or larger.

3.1.5 Canal Structural Selection for Open Excavation

When gallery is rehabilitated with open excavation method, culvert type by rigid frame structure or by flume structure is applied to the section. Rigid structure is selected when external load such as soil pressure is considerably large. The following table indicates comparison of both structures:

Table 3.1.2 Canal Structural Selection for Open Channel Type

No.	Descriptions	Figure
1.	Culvert type section (frame structure) is proposed to attain firm structure against larger soil pressure, especially when the gallery is constructed with open excavation. When the gallery is considerably deep from the ground surface, cost for earth works is excessively high. Culvert type have been applied at where open excavation was carried out.	
2.	As described above, culvert type has firm structure against load. In this regard, culver type (frame structure) is applicable to road bridge, etc.	
3.	Small load with shallow embedded condition allows flume type structure. Concrete cover is effective to prevent surface soil deposit in the canal. This type is proposed at where canal top is embedded less than 1m or less.	



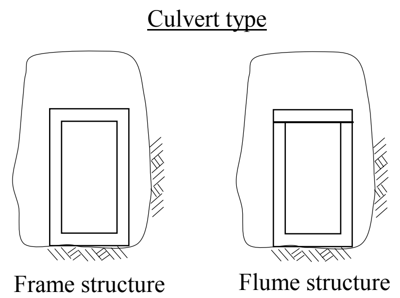
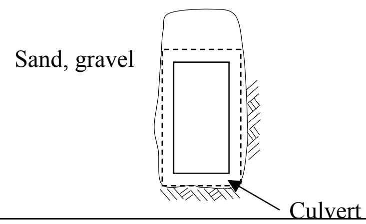
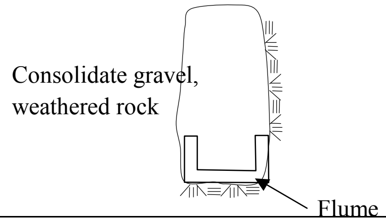
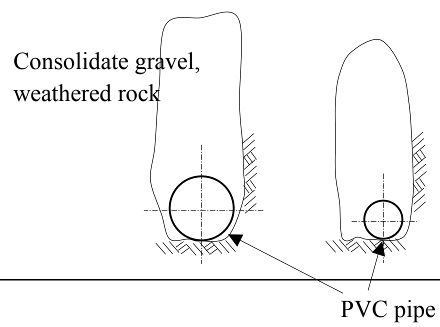
3.1.6 Canal Structural Selection for Tunnel Type

In the case the gallery is installed about 5 m deep from the ground surface or more, gallery construction is carried out in the tunnel (Tunnel work). Culvert type (or open channel with concrete cover) is selected to prevent collapsed material accumulated in the gallery canal when gallery was constructed along unconsolidated gravel/sand layers which are susceptible to collapse. Contrary to this, concrete flume canal is applied when the gallery wall is composed of rock or consolidated layer and not easily failures.

It is necessary to install drainage devices such as pumping and dewatering by pipe in the tunnel because continuous flow shall be diverted to the irrigation use at the downstream of the khettara, otherwise relocation of existing galley is proposed.

Several sections are proposed as below:

Table 3.1.3 Canal Structural Selection for Tunnel Work

No.	Descriptions	Figure
1.	Culvert type section is applicable to install in the existing tunnel section. With respect to the structure, flume structure needs less reinforcing bar due to small load of soil pressure. In case large load acts on the gallery section, frame structure is selected. Concrete cover is effective to prevent wall materials fall into the gallery canal. Open space is necessary at the top of gallery for installation/ removal of form and reinforcing bar, placing top slab concrete, etc. Winding route of existing khettara accompanies severe laborious works for earth works and concrete form installation.	
2.	To minimize earth work volume, wall concrete is directly placed at where soil is relatively hard. Soil support is necessary to prevent wall collapse due to soil saturation or repetition of dry and wet.	
3.	Open channel type is applied to mitigate water leakage from the foundation of the gallery. Less collapse of gallery wall does not require concrete cover of the canal.	
4.	PVC pipe economizes rehabilitation cost. As PVC pipe is manufactured in 6 m length in conformity to the pertinent of standards, a rectilinear portion costs less amount, however higher cost goes into meandering portion, especially for the earth work and joint work. Several opening shall be useful to remove sediment in the pipe.	

3.1.7 Particulars to be considered in Selection of Canal Route and Structure

The following are considered during route selection:

1) Minimum radius of canal curvature

2) Limits of canal slope

3) Minimum earth coverage

(1) Minimum radius of canal curvature

Minimum carve radius (canal center) of more than 30 m are recommended in the case steel form are to be used for a open channel. The requirement is disregarded where they are not maintained due to topographic or other field conditions.

(2) Longitudinal slope

A open channel type must be designed so as to hydraulically stable. Excessively low velocity is not appropriate for canal since sand sedimentation or growths of aquatic plants may occur.

(3) Minimum earth coverage

The minimum earth coverage is as follows:

1)	Farm land	:	deeper than 0.6 m
2)	Public road	:	deeper than 1.2 m (determined through discussion with road administrative agencies)
3)	River	:	deeper than 2.0 m (determined through discussion with administrative agencies concerned)

When the minimum coverage specified above is reduced or no earth cover is provided, specific loads such as live loads or other acting on the structure shall be considered during the structural calculation.

3.2 Hydraulic Design

3.2.1 Flow Velocity

(a) Minimum velocity

In general, it is recognized that sand deposits are not accumulated at a mean velocity of 0.45 m/sec in a canal. Table 3.2.1 shows calculation of tractive force. Tractive force is estimated by the following equations:

- $u^2 = g R I$

u : Friction velocity (cm/sec)
R : Hydraulic radius (cm)
I : Channel slope

- Critical tractive force

u_{*c} : Critical friction velocity (cm/sec)
d : Average grain size (cm)
I : Channel slope

Grain size			Eqautions
	d>	0.3030 cm	$u_{*c}^2 = 80.0\,d$
0.1180	<d<	0.3030 cm	$134.6\,d^{31/22}$
0.0565	<d<	0.1180 cm	$55.0\,d$
0.0065	<d<	0.0565 cm	$8.41\,d^{11/32}$
	d<	0.0065 cm	$226\,d$

Source: Equation of "Iwasaki, Japan"

Flow velocity of more than 0.15 m/sec moves small particle of silt, 0.30 m/sec moves silt, 0.50 m/sec moves fine sand of 0.2 mm or smaller grain. It is recommended to secure large velocity with a steeper channel slope to eliminate sediment deposition in the gallery, however velocity is limited to at most 0.2 m/sec due to present gentle slope of the khettaras. In this sense, minimum flow velocity may not be included in the design conditions.

Table 3.2.1 Grain Size

Grain size 0.074mm 0.42mm 2mm 5mm 20mm 75mm 30cm

Colloid	Silt	Fine sand	Coarse sand	Fine gravel	Fine - coarse gravel	Coarse gravel	Cobble	Boulder
		Sand		Gravel				

Source: Unified soil classification system, Japan

Table 3.2.2 Calculation of Tractive Force

Calculation of Tractive Force

1. Calculation

-Tractive force

$u^2 = g \cdot R \cdot I$

u: Friction velocity (m/sec)

R: Hydraulic radius (m)

I: Channel slope

-Critical tractive force

	d≧0.303cm (1)	0.118<d <0.303cm (2)	0.0565<d <0.118cm (3)	0.0065<d <0.0565cm (4)	d<0.0065cm (5)
u_{*c}^2=	$80.9d$	$134.6d^{31/22}$	$55.0d$	$8.41d^{11/32}$	$226d$

u_{*c}: Critical friction velocity

d: Average grain size (cm)

2-1 Calculation of tractive force and results (Canal width: 0.60 m, Bed slope: 1/5,000, Velocity: 0.17 m/sec)

(1) Condition of calculation

	(1)	(2)	(3)	(4)	(5)
R (m):	0.075	0.075	0.075	0.075	0.075
I:	1/5000	1/5000	1/5000	1/5000	1/5000
d (cm):	0.303	0.21	0.087	0.032	0.0065
	Fine sand			Silt	

(2) Calcultaion of tractive force

$u^2 = g \cdot R \cdot I$

= 9.8 * 0.075 * 1/5000

= 0.00015 m^2/sec^2

(3) Calcultaion of critical tractive force

u_*^2=	80.9d	$134.6d^{31/22}$	$55.0d$	$8.41d^{11/32}$	$226d$
=	80.9 * 0.303	134.6 * 0.210^31/22	55.0 * 0.087	8.41 * 0.032^11/32	226 * 0.007
=(cm^2/sec^2)	24.5	14.9	4.8	2.6	1.5
=(m^2/sec^2)	0.00245	0.00149	0.00048	0.00026	0.00015

(4) Calculation result of tractive force

u_*^2(m^2/sec^2)=	0.00245	0.00149	0.00048	0.00026	0.00015
u^2(m^2/sec^2)=	0.00015	0.00015	0.00015	0.00015	0.00015
Movement	not move	not move	not move	not move	move

2-2 Calculation of tractive force and results (Canal width: 0.60 m, Bed slope: 1/2,000, Velocity: 0.23 m/sec)

(1) Condition of calculation

	(1)	(2)	(3)	(4)	(5)
R (m):	0.059	0.059	0.059	0.059	0.059
I:	1/2000	1/2000	1/2000	1/2000	1/2000
d (cm):	0.303	0.21	0.087	0.032	0.0065
	Fine sand			Silt	

(2) Calcultaion of tractive force

$u^2 = g \cdot R \cdot I$

= 9.8 * 0.059 * 1/2000

= 0.00029 m^2/sec^2

(3) Calcultaion of critical tractive force

u_*^2=	0.00245	$134.6d^{31/22}$	$55.0d$	$8.41d^{11/32}$	$226d$
=	80.9 * 0.303	134.6 * 0.210^31/22	55.0 * 0.087	8.41 * 0.032^11/32	226 * 0.007
=(cm^2/sec^2)	24.5	14.9	4.8	2.6	1.5
=(m^2/sec^2)	0.00245	0.00149	0.00048	0.00026	0.00015

(4) Calculation result of tractive force

u_*^2(m^2/sec^2)=	0.00245	0.00149	0.00048	0.00026	0.00015
u^2(m^2/sec^2)=	0.00029	0.00029	0.00029	0.00029	0.00029
Movement	not move	not move	not move	move	move

2-3 Calculation of tractive force and results (Canal width: 0.60 m, Bed slope: 1/1,000, Velocity: 0.28 m/sec)

(1) Condition of calculation

	(1)	(2)	(3)	(4)	(5)
R (m):	0.049	0.049	0.049	0.049	0.049
I:	1/1000	1/1000	1/1000	1/1000	1/1000
d (cm):	0.303	0.21	0.087	0.032	0.0065
	Fine sand			Silt	

(2) Calcultaion of tractive force

$u^2 = g \cdot R \cdot I$ = 9.8 * 0.049 * 1/1000= 0.00048 m^2/sec^2

(3) Calcultaion of critical tractive force

u_*^2=	0.00245	$134.6d^{31/22}$	$55.0d$	$8.41d^{11/32}$	$226d$
=	80.9 * 0.303	134.6 * 0.210^31/22	55.0 * 0.087	8.41 * 0.032^11/32	226 * 0.007
=(cm^2/sec^2)	24.5	14.9	4.8	2.6	1.5
=(m^2/sec^2)	0.00245	0.00149	0.00048	0.00026	0.00015

(4) Calculation result of tractive force

u_*^2(m^2/sec^2)=	0.00245	0.00149	0.00048	0.00026	0.00015
u^2(m^2/sec^2)=	0.00048	0.00048	0.00048	0.00048	0.00048
Movement	not move	not move	move	move	move

2-4 Calculation of tractive force and results (Canal width: 0.60 m, Bed slope: 1/500, Velocity: 0.35 m/sec)

(1) Condition of calculation

	(1)	(2)	(3)	(4)	(5)
R (m):	0.041	0.041	0.041	0.041	0.041
I:	1/500	1/500	1/500	1/500	1/500
d (cm):	0.303	0.21	0.087	0.032	0.0065
	Fine sand			Silt	

(2) Calcultaion of tractive force

$u^2 = g \cdot R \cdot I$ = 9.8 * 0.041 * 1/500= 0.00080 m^2/sec^2

(3) Calcultaion of critical tractive force

u_*^2=	0.00245	$134.6d^{31/22}$	$55.0d$	$8.41d^{11/32}$	$226d$
=	80.9 * 0.303	134.6 * 0.210^31/22	55.0 * 0.087	8.41 * 0.032^11/32	226 * 0.007
=(cm^2/sec^2)	24.5	14.9	4.8	2.6	1.5
=(m^2/sec^2)	0.00245	0.00149	0.00048	0.00026	0.00015

(4) Calculation result of tractive force

u_*^2(m^2/sec^2)=	0.00245	0.00149	0.00048	0.00026	0.00015
u^2(m^2/sec^2)=	0.00080	0.00080	0.00080	0.00080	0.00080
Movement	not move	not move	move	move	move

2-5 Calculation of tractive force and results (Canal width: 0.60 m, Bed slope: 1/200, Velocity: 0.47 m/sec)

(1) Condition of calculation

	(1)	(2)	(3)	(4)	(5)
R (m):	0.032	0.032	0.032	0.032	0.032
I:	1/200	1/200	1/200	1/200	1/200
d (cm):	0.303	0.21	0.087	0.032	0.0065
	Fine sand			Silt	

(2) Calcultaion of tractive force

$u^2 = g \cdot R \cdot I$ = 9.8 * 0.032 * 1/200= 0.00157 m^2/sec^2

(3) Calcultaion of critical tractive force

u_*^2=	0.00245	$134.6d^{31/22}$	$55.0d$	$8.41d^{11/32}$	$226d$
=	80.9 * 0.303	134.6 * 0.210^31/22	55.0 * 0.087	8.41 * 0.032^11/32	226 * 0.007
=(cm^2/sec^2)	24.5	14.9	4.8	2.6	1.5
=(m^2/sec^2)	0.00245	0.00149	0.00048	0.00026	0.00015

(4) Calculation result of tractive force

u_*^2(m^2/sec^2)=	0.00245	0.00149	0.00048	0.00026	0.00015
u^2(m^2/sec^2)=	0.00157	0.00157	0.00157	0.00157	0.00157
Movement	not move	move	move	move	move

(b) Maximum allowable velocity

Limited velocities found to be applicable to different types of materials are enumerated in Table 3.2.3.

Table 3.2.3 Maximum Allowable Velocity

Types	Velocity (m/sec)
Sandy soil	0.45
Clayey soil	1.00
Sandy clay	1.20
Soft rock	2.00
Semi-hard rock	2.50
Hard rock	3.00

3.2.2 Flow Formula

The Manning and Hazen-Williams formula are used for determined of mean flow velocity of hydraulic gradient in uniform flow of open channel and pipe flow, respectively.

(a) Manning formula

$$Q = A \times V$$

$$V = (1/n) \times R^{2/3} \times I^{1/2}$$

where,
- Q : Design discharge (m^3/sec)
- V : Mean water velocity (m/sec)
- n : Roughness coefficient of Manning formula
- R : Hydraulic radius (m) A/P
- A : Flow area (m^2)
- P : Wet perimeter (m)
- I : Hydraulic gradient of canal

The following roughness coefficients are recommended for respective canal conditions.

Table 3.2.4 Roughness Coefficient

Canal Condition	Manning's "n" = 1/K
(a) Earthen/unlined canals	
Less than 10 m^3/s	0.028
1.0 - 5.0 m^3/s	0.025
5.0 - 10.0 m^3/s	0.235
10.0 and over	0.022
(b) Lined canal /structure	
- Concrete	0.015
- Masonry	0.0167
- Steel	0.0125

(2) Hazen-Williams formula

$$V = 0.35464 \cdot C \cdot D^{0.63} \cdot I^{0.54}$$

$$Q = 0.27853 \cdot C \cdot D^{2.63} \cdot I^{0.54}$$

$$D = 1.6258 \cdot C^{-0.38} \cdot Q^{0.38} \cdot I^{0.54}$$

$$I = \frac{h_f}{L} = 10.666 \cdot C^{-1.85} \cdot D^{-4.87} \cdot Q^{1.85}$$

where,
- Q : Design discharge (m^3/sec)
- C : Velocity coefficient
- D : Pipe diameter (m)
- h_f : Friction head loss (m)
- I : Hydraulic gradient of canal
- L : Pipe length (m)

The following coefficients are recommended for design.

Table 3.2.5 Velocity Coefficient (C)

Canal Condition	Velocity Coefficient		
	Maximum	Minimum	Normal
1) Cast iron pipe (with paint)	150	80	100
2) Steel pipe (without paint)	150	90	100
3) Concrete pipe	140	120	130
4) Pre-stressed concrete pipe	140	120	130
5) PVC pipe (1)	160	140	150
6) Polyethylene pipe (1)	170	130	150
7) Fiber reinforced plastics pipe (1)	160	---	150

(1): C=140 for pipe diameter 150mm or less

Following sheet is reference to calculate a uniform flow depth of conduits:

Calculation of Uniform flow

Uniform flow depth is estimated by following steps using discharge (Q), radius (r), bed slope (I), roughness coefficient (n).

1) Calculate $\dfrac{Q \cdot n}{I^{1/2} \cdot r^{8/3}}$

2) Calculate value of *d/r*

3) Uniform flow depth = $(d/r) \times r = d$

Example:

Radius r=0.4m, bed slope I=1/500, discharge Q=0.02 m^3/sec, PVC pipe n=0.012

$$\frac{Q \cdot n}{I^{1/2} \cdot r^{8/3}} = \frac{0.02 \times 0.012}{(1/2000)^{1/2} \cdot 0.2^{8/3}} = 0.7846$$

$\dfrac{d}{r}$	$\dfrac{Q \cdot n}{I^{1/2} \cdot r^{8/3}}$
0.840	0.7288
0.840 + x	0.7846
0.880	0.7921

(0.88-0.84):x=(0.7921-0.7288):(0.7846-0.7288)

x = 0.0353

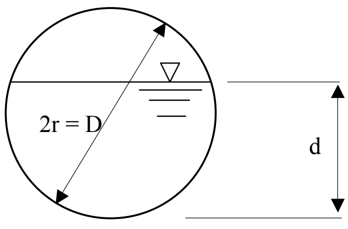
d/r = 0.875

$d = 0.2 \times 0.875 = 0.175\text{m}$

$A/r^2 = 1.322$

$A = 1.322 \times 0.2^2 = 0.053\text{m}^2$

V = Q/A = 0.02 / 0.053 = 0.377 m/sec



d/r	*a=A/r²*	*ab^{2/3}=Qn/I^{1/2}r^{8/3}*
2.000	3.1416	1.9791
1.960	3.1266	2.0913
1.920	3.0994	2.1203
1.880	3.0646	2.1289
1.840	3.0239	2.1241
1.800	2.9781	2.1093
1.760	2.9281	2.0863
1.720	2.8743	2.0565
1.680	2.8171	2.0208
1.640	2.7571	1.9799
1.600	2.6943	1.9345
1.560	2.6291	1.8851
1.520	2.5618	1.8323
1.480	2.4925	1.7764
1.440	2.4215	1.7178
1.400	2.3489	1.6570
1.360	2.2749	1.5942
1.320	2.1997	1.5297
1.280	2.1234	1.4640
1.240	2.0462	1.3972
1.200	1.9681	1.3296
1.160	1.8894	1.2616
1.120	1.8102	1.1933
1.080	1.7306	1.1251
1.040	1.6508	1.0571
1.000	1.5708	0.9895
0.960	1.4908	0.9227
0.920	1.4110	0.8569
0.880	1.3314	0.7921
0.840	1.2522	0.7288
0.800	1.1735	0.6669
0.760	1.0954	0.6068
0.720	1.0182	0.5487
0.680	0.9419	0.4926
0.640	0.8667	0.4389
0.600	0.7927	0.3876
0.560	0.7201	0.3389
0.520	0.6491	0.2930
0.480	0.5798	0.2500
0.440	0.5125	0.2100
0.400	0.4473	0.1733
0.360	0.3845	0.1399
0.320	0.3245	0.1099
0.280	0.2673	0.0834
0.240	0.2135	0.0605
0.200	0.1635	0.0413
0.160	0.1177	0.0258
0.120	0.0770	0.0140
0.080	0.0422	0.0059
0.040	0.0150	0.0013
0.000	0.000	0.0000

3.3 Structural Design

3.3.1 General

In the structural design of a canal, the type of the structure, design conditions and the details of the structures are determined in consideration of the site conditions and economic in compliance with the load applied to the structures, mechanical properties of the soil and metrological conditions.

3.3.2 Load

The following loads shall be considered during structural design taking into account of an importance of the structures, types, materials to be used, site conditions, etc.

Table 3.3.1 Load Selection

1	Dead load	2	Water pressure	3	Up-lift
4	Earth pressure	5	Wheel load	6	Impact load
7	Crowed load	8	Seismic load	9	Wind load
10	Construction load	11	Temperature stress	12	Creep stress of concrete

(1) Dead weight

Table 3.3.2 shows unit weight of materials. It is however used actual unit weight obtained from experimentation or specified unit weight when available.

Table 3.3.2 Unit Weight of Materials

Materials	Unit weight (kN/m^3)	Materials	Unit weight (kN/m^3)
Steel, cast steel	77.0	Pre-stressed concrete	24.5
Cast iron	71.0	Granite	27.0
Aluminum alloy	27.5	Sand stone	26.0
Reinforced concrete	24.5	Soil (dry)	16.0
Plain concrete	23.0	Soil (wet)	18.0
Mortar	21.0	Soil (saturated)	20.0
Asphalt concrete pavement	22.5	Soil (sub	10.0
Concrete block (wet)	22.5	Water	10.0
Concrete block (dry)	19.5		

(2) Buoyancy and up-lift

Buoyancy or up-lift shall be considered during stability calculation in terms of overturning and sliding, but neglected for bearing capacity (stress) calculation of the foundation.

(3) Soil pressure

Earth pressure is generally classified into horizontal and vertical pressures. Horizontal pressure acting against the canal wall is calculated by Rankin's and Coulomb's formulas. Vertical pressure acting to backfilled structures is calculated by Marton's and the Vertical Earth Pressure formula. Horizontal pressure acting against backfilled structures is calculated by earth pressure at rest, Rankin's and Spanglar's formulas.

Table 3.3.3 Load Conditions

		Ordinary	Earth quake	Angle of wall friction
1	Box culvert type (w/o movement, w/o transformation)	Earth pressure at rest	neglect	neglect
2	Flume canal type (w/o movement, w/ transformation)	Rankin's formula Coulomb's formula	Coulomb's formula	count
3	Retaining wall (w/ movement, w/ transformation)			count

(4) Load applied to the canal

Loads to be considered in structural design of the canal are, in general, dead loads, water pressure (internal and external), buoyancy/ up-lift, earth pressure, live loads including impact load and ground reaction.

(5) Soil constant

For the earth pressure calculation, the soil constant such as soil unit weight, internal friction angle, cohesion and others shall be estimated though an investigation such as soil test, etc. However it requires labor and time to carry out these investigation and tests, and also requires sufficient experience and high technique to decide the proper soil constant. Therefore a standard value shown in Table below is used for the design.

Table 3.3.4 Soil Constant

		Saturated unit weight	Wet unit weight	Internal friction angle
1	Gravel or coarse sand having little fine- graded materials of less than 5%) (GP, GW, SP, SW)	20 kN/m^3	18 kN/m^3	30
2	Gravel or soil having fine- grained materials of 5 - 15 %) (GC, GM, SC, SM)	20 kN/m^3	18 kN/m^3	25
3	Silty fine sand or gravel having clay of 15 - 50%) (SM, GL)	20 kN/m^3	18 kN/m^3	20

3.3.3 Plain Concrete and Reinforced Concrete

Table 3.3.5 Allowable Stress of Plain Concrete

(Unit: N/mm^2)

28-day strength / Allowable stress	18	21	24
Compressive	4.5	5.0	5.4
Bending tensile	0.25	0.29	0.29
Bearing	5.4	5.9	5.9

Table 3.3.6 Allowable Stress of Reinforced Concrete

(Unit: N/mm^2)

28-day strength / Allowable stress			18	21	24	30	40 or more
Bending compressive			7	8	9	11	14
Shear	Calculation for diagonal tension bars omitted	Beams	0.4	0.42	0.45	0.5	0.55
		Slabs	0.8	0.85	0.9	1.0	1.1
	Calculation for diagonal tension bars made	Shear force only	1.8	1.9	2.0	2.2	2.4
Bond	Round bars		0.7	0.75	0.8	0.9	1.0
	Deformed bars		1.4	1.5	1.6	1.8	2.0
Bearing			5.4	6.3	7.2	9.0	12.0

Table 3.3.7 Classification of Concrete

(Unit: N/mm^2)

Design strength	Descriptions
Plain concrete σck=18	Lean concrete for foundation Plain concrete such as base concrete
Reinforced concrete σck=21	Canal structures such as flume, culvert, siphon
Reinforced concrete σck=24	Structures which require higher wear In case the concrete is costly effective with use of high tension steel bar

Table 3.3.8 Allowable Stress of Steel Bar

(Unit: N/mm^2)

Steel bar	Allowable Tensile Stress			
	Ordinary	Fatigue failure	Facing water	Direct load of wheel loads
Ordinary	176	157	157	137
Earthquake	264	264	264	264

(Reference)

The following are design standard on allowable stress on concrete in Morocco.

Compressive Stress of Concrete

Classifications	Allowable Compressive Stress in bars	
	Compression in test σ'n 28	Tensile stress due to bending $\sigma' n28 = \frac{3.6M}{a3}$
CLASS B1 High quality concrete, such as high-strength concrete, pre-tension concrete, etc.	300	24.0
CLASS B2 Concrete for ordinal concrete structures for reinforcing concrete (Large load)	270	20 in minimum 22.0
CLASS B3 Concrete for ordinal concrete structures for reinforcing concrete (Normal load)	230	not available
CLASS B4 Concrete for plain concrete structures (Low load)	180	not available
CLASS B5 Concrete for lean concrete structures	130	not available
CLASS B4 and B5 Concrete class B4 and B5 of low permeability	130 à 180	not available

Source: NORME MAROCAINE, BETONS DE CIMENTS USUELS (10-03-F-009)

Allowable Stress of Reinforced Concrete (Shearing stress)

Dosage (kg/m^3)	Compression bars et (kg/cm^2)	Traction bars et (kg/cm^2)
250	54 (55)	5,3 (5,4)
300	69 (70)	6,2 (6,3)
350	81 (83)	7,0 (7,1)
400	90 (92)	7,5 (7,7)

Allowable Stress of Reinforced Concrete (Adhesive stress)

Compressive Stress of Concrete bars, (N/mm^2)	Allowable Adhesive Stress bars, (N/mm^2)	
	Round bars	Deformed bars
250 (25)	11 (1,1)	24 (2,4)
300 (30)	13 (1,3)	28 (2,8)
350 (35)	14 (1,4)	32 (3,2)
400 (40)	16 (1,6)	36 (3,6)

Source: REGLES TECHNIQUES de CONCEPTION ET DE CALCUL DES OUVRAGES ET CONSTRUCTIONS EN BETON ARME (July, 1985)

Allowable Tensile Stress of Reinforcing Bar

Type	Classification	Yield strength (bars)	Allowable tensile stress $\overline{\sigma}_a$ and $\overline{\sigma}_a$ (bars)	
			Normal load (First category)	Seismic load (Second category)
Round bar	Fe E 22	2 160 (2 200 kgf/cm^2)	1 440 (1 465kgf/cm^2)	2 160 (2 200kgf/cm^2)
	Fe E 24	2 350 (2 400 kgf/cm^2)	1 565 (1 600kgf/cm^2)	2 350 (2 400kgf/cm^2)
	Fe E 34	3 340 (3 400 kgf/cm^2)	2 220 (2 270kgf/cm^2)	3 335 (3 400kgf/cm^2)
Deformed bar	Fe E 40A	pour ϕ<=20 mm 4 120 (4 200 kgf/cm^2)	2 745 (2 800kgf/cm^2)	4 120 (4 200kgf/cm^2)
	Fe E 40B	pour ϕ>20 mm 3 920 (4 000 kgf/cm^2)	2 610 (2 665kgf/cm^2)	3 920 (4 000kgf/cm^2)
	Fe E 45	4 410 (4 500 kgf/cm^2)	2 940 (3 000kgf/cm^2)	4 410 (4 500kgf/cm^2)
	Fe E 50	4 900 (5 000 kgf/cm^2)	3 260 (3 333kgf/cm^2)	4 900 (5 000kgf/cm^2)

Allowable tensil stress is given as follow:

$\overline{\sigma} = \rho_{a \cdot \sigma_{en}}$

ρ_a =2/3 when normal load (First category)

ρ_a =1 when seismic load is considered (Second category)

Design load is estimated with combination of following loads: (The following shows sample combination of load. Proper combination shall be proposed in each project.)

- (G) Live loads,
- (P) Additional unexpected load,
- (V) Load under normal climatic condition,
- (W) Load under severe climatic condition,
- (T) Loads by temperature and concrete contraction,
- (SI) Seismic load.

Normal condition (First category):

(S_1)=(G) + 1,2(P) + (T)

(S'_1)=(G) + (P) + (V) + (T)

Seismic condition (Second category):

(S_2)=(G) + 1,5(P) + 1,5(W) + (T)

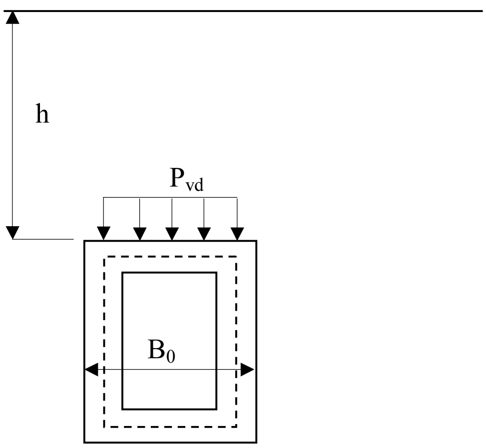
(S'_2)=(G) + (P) + (T) + (SI)

3.4 Load Design

(1) Death load

(a) Vertical load

$P_{vd} = \alpha \cdot \gamma \cdot h$ ....(1.1.1)



P_{vd}	:	Vertical load (kN/m^2)
α	:	Coefficient of vertical soil pressure
γ	:	Unit weight of soil (kN/m^3)
h	:	Depth of filling soil (m)

(b) Horizontal load

$P_{hd} = K_0 \cdot \gamma \cdot z$ ....(1.1.2)

P_{hd}	:	Horizontal load (kN/m^2)
K_0	:	Coefficient of static soil pressure coefficient (K_0=0.5 in general)
γ	:	Unit weight of Soil (kN/m^3)
z	:	Soil depth from ground surface to calculation point (m)

(2) Live load

$$P_{li} = \frac{2 \times \text{Wheel} \cdot \text{load}}{\text{Vehicl} \cdot \text{width}} \times (1 + \text{Impact} \cdot \text{coefficient})$$

Rear wheel : $P_{l1} = \frac{2 \times 40}{2.75} \times (1 + \text{Impact} \cdot \text{coefficient})$ ....(1.2.1)

Front wheel : $P_{l2} = \frac{2 \times 10}{2.75} \times (1 + \text{Impact} \cdot \text{coefficient})$ ....(1.2.2)

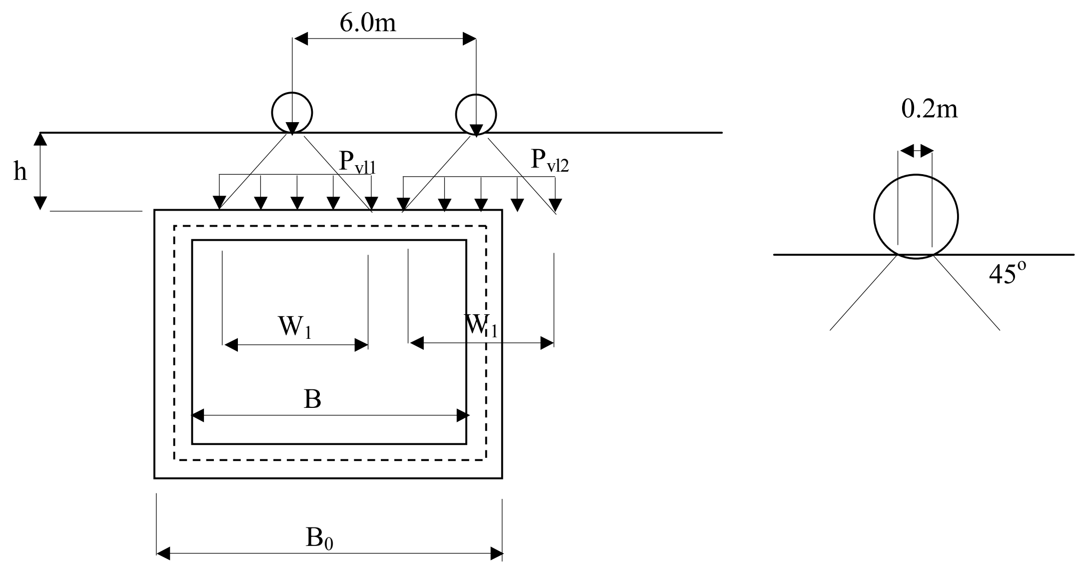
i : Impact coefficient, (when h<4.0m then i=0.3, when h>=4.0m then i=0.0)

Strength of a live load of rear and front wheels are as follows:

$$P_{vl1} = \frac{P_{l1} \cdot \beta}{W_1} = \frac{P_{l1} \cdot \beta}{2h + 0.2}$$
$$P_{vl2} = \frac{P_{l2} \cdot \beta}{W_1} = \frac{P_{l2} \cdot \beta}{2h + 0.2}$$
....(1.2.3)

β : Earth coverage depth (m), corresponding to inner width and height of a culvert.

H<=1m and B>=4m	Other than the left
β=1.0	β=0.9

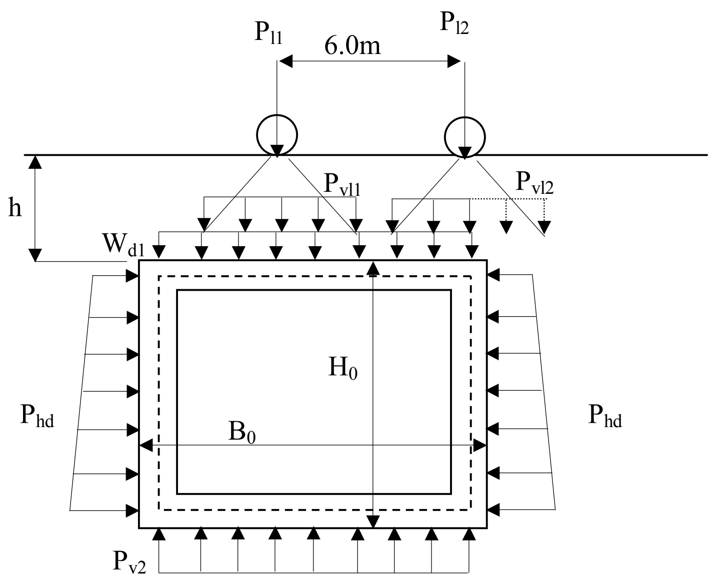


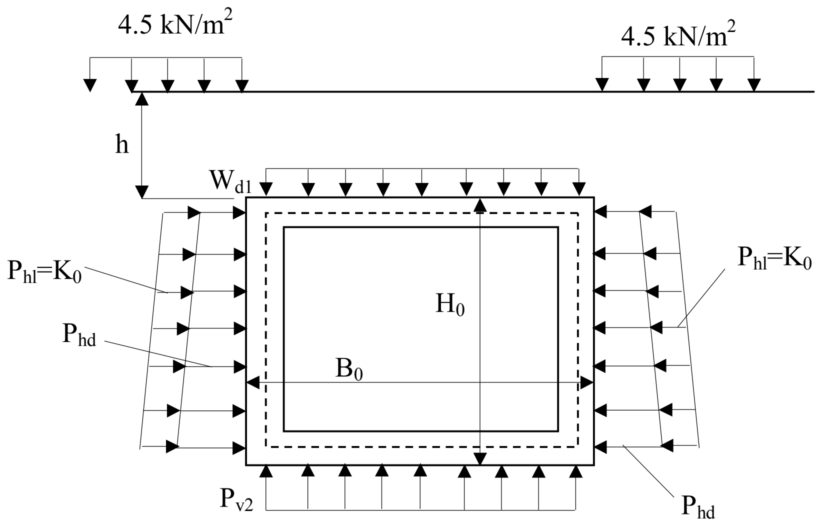
Equation (1.2.3) is applicable when an earth coverage depth is less than 4.0 m. In the case an earth coverage depth is higher than or equal to 4.0 m, 4.5 kN/m^2 is applicable.

(3) Load Combination

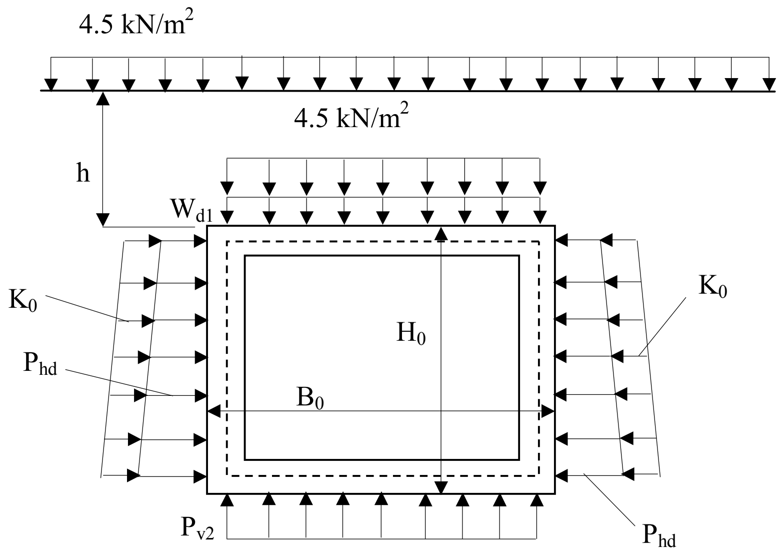
Culvert type structure in in-situ reinforced concrete shall be in accordance with the combination shown below:

(Earth coverage depth h < 4.0 m)





(Earth coverage depth h >= 4.0 m)



(4) Unit Weight

Materials	Unit Weight (kN/m^3)	Materials	Unit Weight (kN/m^3)
Reinforced concrete	24.5	Sand and gravel	20.0
Plain concrete	23.0	Sandy soil	19.0
Stone masonry	(Variable)	Clayey soil	18.0
Water	9.8		
Steel	78.5		

(5) Allowable Strength of Materials

Reinforced concrete	Allowable Strength
Compression stress	8.0 (N/mm^2)
Shearing stress	0.42 (N/mm^2)
Bond stress bar	1.5 (N/mm^2)
Steel bar	
Tensile stress (σ_{sa})	180 (N/mm^2)
Tensile stress (σ_{sa1})	160 (N/mm^2)

(6) Shearing Stress

Additional allowable stress is applicable to the concrete member in accordance with the following equation:

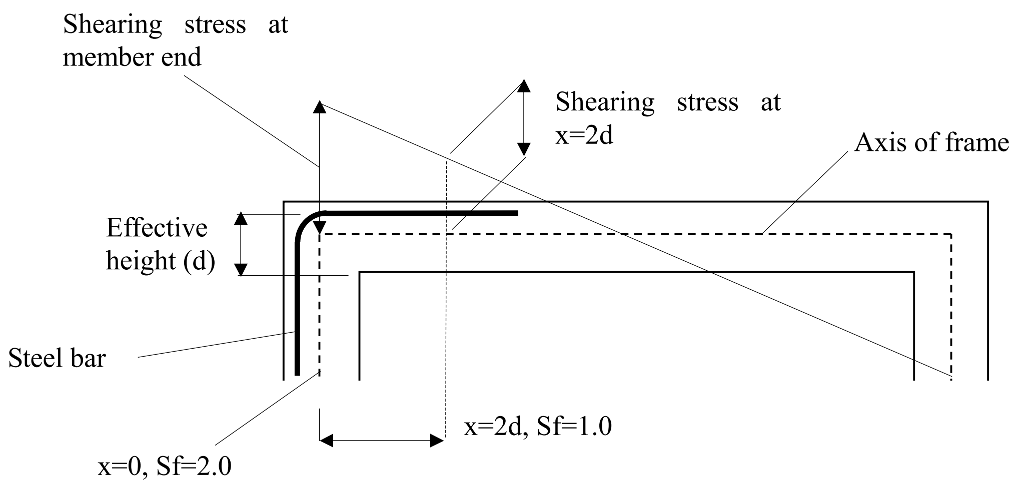
$$\alpha = 2 - \frac{x}{2d}$$

$$(1 \leq \alpha \leq 2)$$

where, a : Additional allowable stress

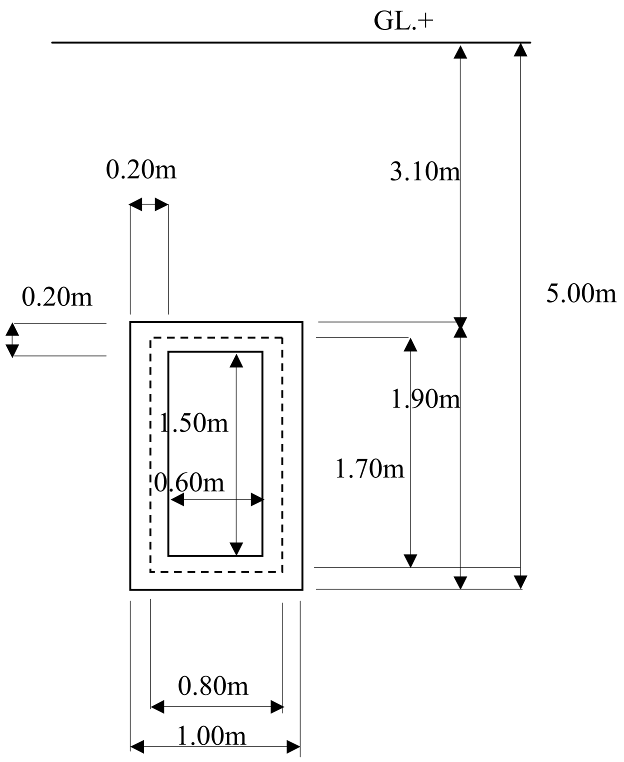
x : Distance between axis of frame member and calculation section (cm)

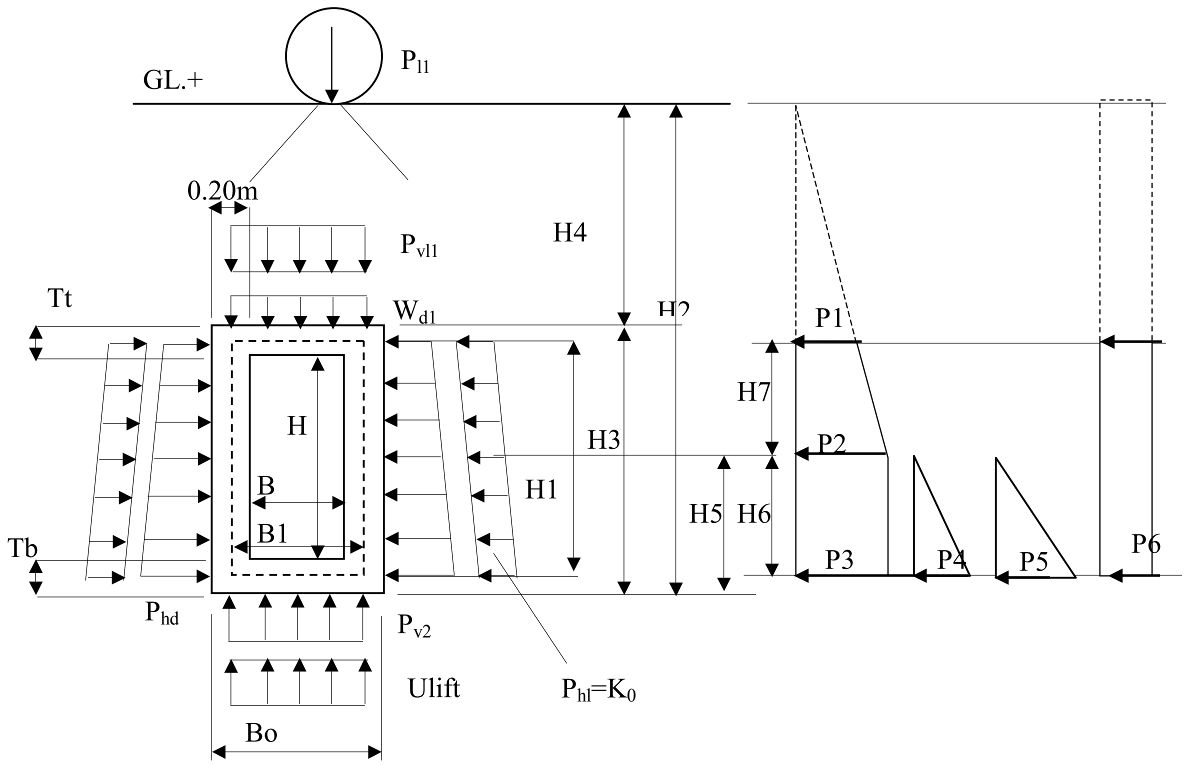
d : Effective height of member (cm)



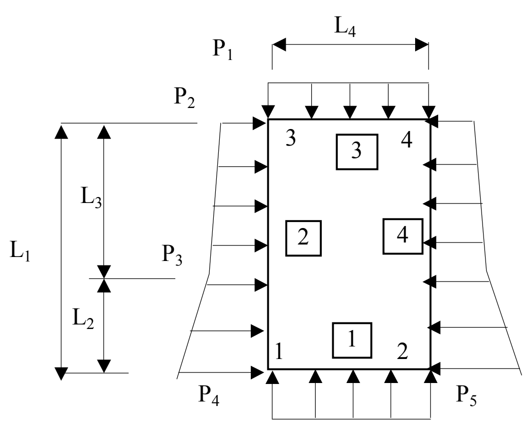
3.5 Case Study

(1) Gallery section with slab thickness 20 cm (H=5.00m)





					Case- 1		Case- 2	
H	1.5	m	Top slab					
H1	1.675	m		P_{V11}	0.582	tf/m^2	0.000	tf/m^2
H2	5	m		W_{d1}	5.670	tf/m^2	5.670	tf/m^2
H3	1.85	m		W_{slab}	0.469	tf/m^2	0.469	tf/m^2
H4	3.15	m						
H5	1	m		Total	6.721	tf/m^2	6.139	tf/m^2
H6	0.9	m						
H7	0.775	m	Base slab					
				P_{hd}	9.221	tf/m^2	9.221	tf/m^2
B	0.6	m		U_{lift}	1.250	tf/m^2	1.250	tf/m^2
Tt	0.15	m						
Tb	0.2	m		Total	10.471	tf/m^2	10.471	tf/m^2
B1	0.8	m						
B0	1	m	Side wall	P1	2.903	tf/m^2	2.903	tf/m^2
Ww	1	tf/m^3		P2	3.600	tf/m^2	3.600	tf/m^2
Wc	2.5	tf/m^3		P3	3.600	tf/m^2	3.600	tf/m^2
Wt	1.8	tf/m^3		P4	0.450	tf/m^2	0.450	tf/m^2
Ww	2	tf/m^3		P5	0.900	tf/m^2	0.900	tf/m^2
Ws	1	tf/m^3		P6	0.000	tf/m^2	0.225	tf/m^2
Rear wheel	4	tf	Input data	P_1	6.721	tf/m^2	6.139	tf/m^2
Front wheel	1	tf		P_2	2.903	tf/m^2	3.128	tf/m^2
Liveload	0.45	tf/m^2		P_3	3.600	tf/m^2	3.825	tf/m^2
Impact	0.3			P_4	4.950	tf/m^2	5.175	tf/m^2
β	1			P_5	10.471	tf/m^2	10.471	tf/m^2
Pressure coe.	0.5			L_1	1.675	m	1.675	m
				L_2	0.900	m	0.900	m
				L_3	0.775	m	0.775	m
				L_4	0.800	m	0.800	m



(Materials)

Material No.	Elasticity modules (tf/m2)	Area (m2)	Geometrical moment of inertia (m4)
1	2.55000E+06	.20000	.0006670
2	2.55000E+06	.15000	.0002810

(Joint data)

Joint No.	X-value (m)	Y-value (m)	Joint X	Y	θ
1	.000	1.675	1	1	0
2	.800	1.675	0	1	0
3	.000	.000	0	0	0
4	.800	.000	0	0	0

(Member data)

Member No. I J	MAterial No.	Length (m)
1 - 3	1	1.675
2 - 4	1	1.675
1 - 2	1	.800
3 - 4	2	.800

(Load data)

Load No.	Load Type	Load Title	Member I J	Direction	Load Parameter P1	P2	P3	P4
1	TP1	Uniformly verying load	1 - 2	Y	.000	.000	-10.470	-10.470
	TP1	Uniformly verying lo	3 - 4	Y	.000	.000	6.721	6.721
	TP1	Uniformly verying load	1 - 3	Y	.000	.900	4.950	3.600
	TP1	Uniformly verying load	1 - 3	Y	.900	.775	3.600	2.903
	TP1	Uniformly verying load	2 - 4	Y	.000	.900	-4.950	-3.600
	TP1	Uniformly verying load	2 - 4	Y	.900	.775	-3.600	-2.903

(Intersectional force)

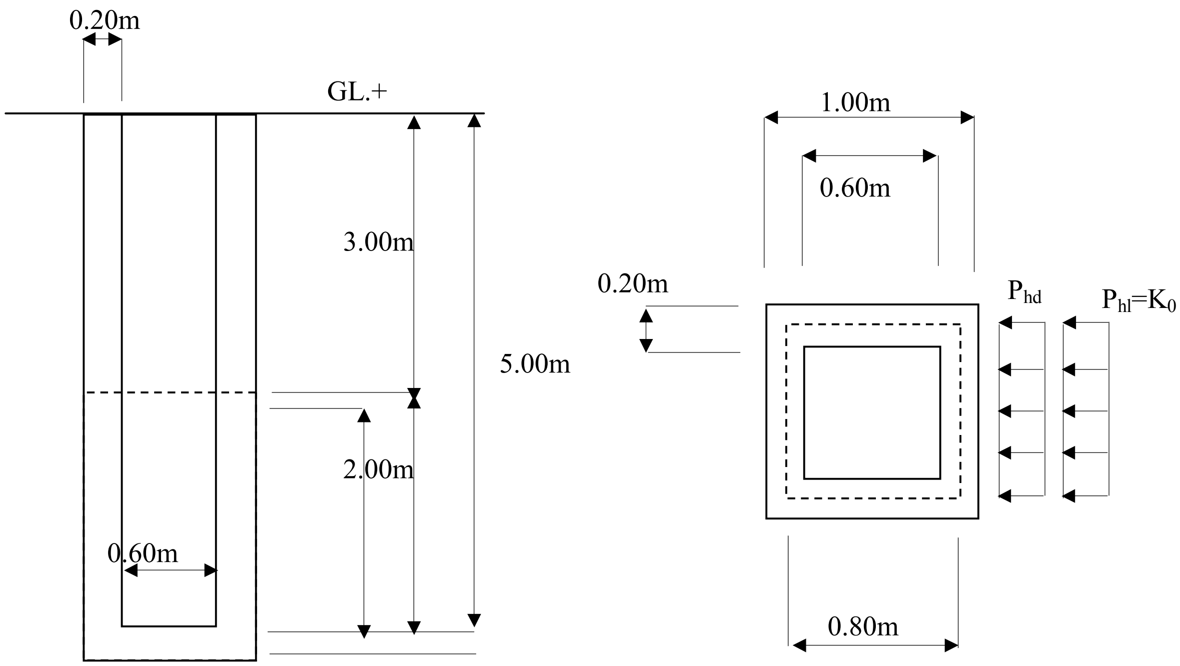
Member I J	Length (m)	Bend moment (tf·m)	Shearing force (tf)	Axial force (tf)
1 - 3	.000	-.858	3.657	2.688
	.280	-.023	2.330	2.688
	.419	.258	1.715	2.688
	.838	.616	.036	2.688
	1.256	.322	-1.415	2.688
	1.395	.094	-1.862	2.688
	1.675	-.548	-2.710	2.688
2 - 4	.000	.858	-3.657	2.688
	.280	.023	-2.330	2.688
	.419	-.258	-1.715	2.688
	.838	-.616	-.036	2.688
	1.256	-.322	1.415	2.688
	1.395	-.094	1.862	2.688
	1.675	.548	2.710	2.688
1 - 2	.000	.858	-4.188	3.657
	.280	.096	-1.256	3.657
	.400	.020	.000	3.657
	.520	.096	1.256	3.657
	.800	.858	4.188	3.657

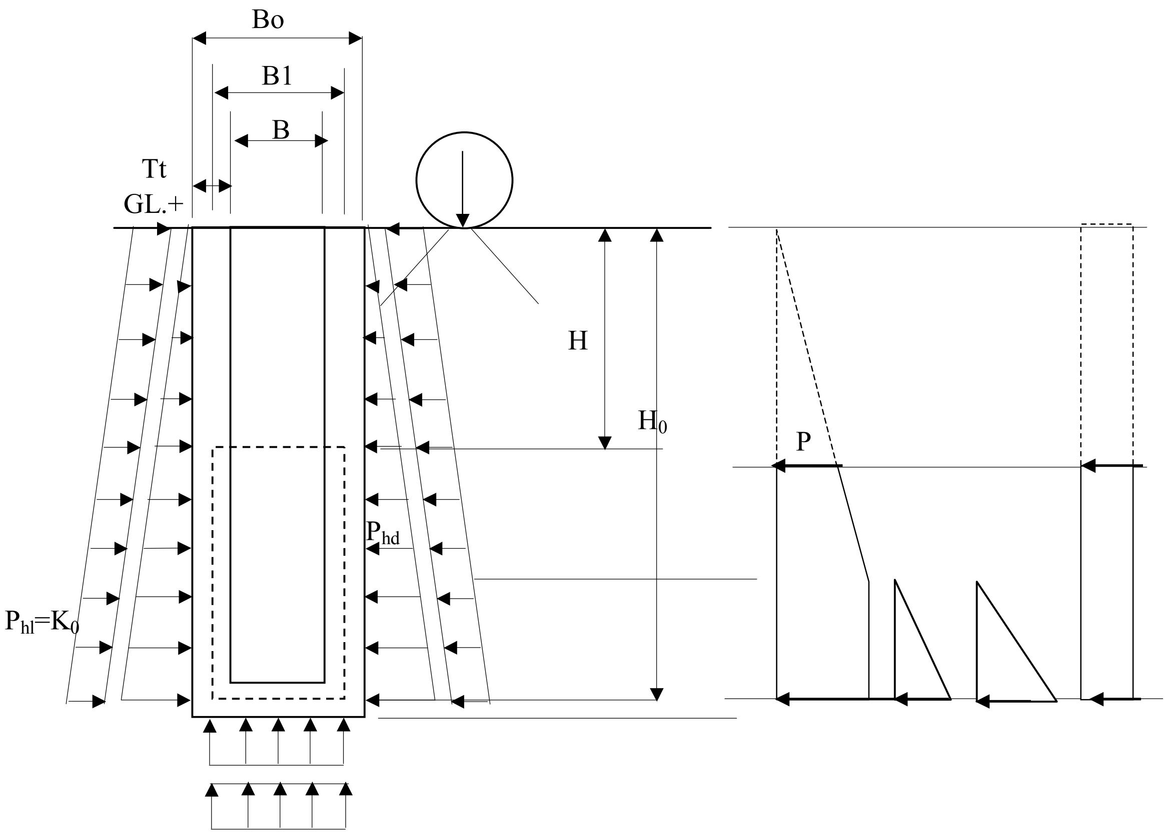
3 - 4 .000	-.548	2.688	2.710
.180	-.172	1.479	2.710
.400	-.010	.000	2.710
.620	-.172	-1.479	2.710
.800	-.548	-2.688	2.710

σca	8.0	N/mm2
σsa	140	N/mm2
τa	0.42	N/mm2
τoa	1.5	N/mm2
n	15.0	

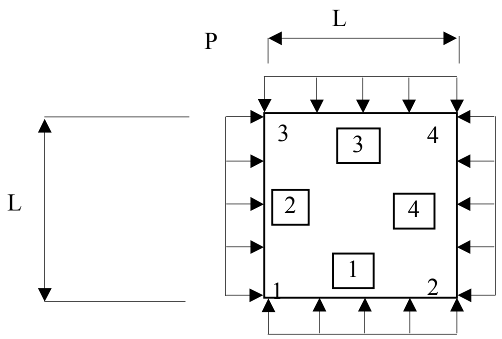
			Member	1-3			1-2			3-4		
			x=	0	2d	Center	0	2d	Center	0	2d	Center
Moment		M	kN・m	8.580	0.230	6.160	8.580	0.960	0.200	5.480	1.720	0.100
Shearing force		S	kN	36.570	23.300	0.360	41.880	12.560	0.000	26.880	14.790	0.000
Axial force		N	kN	26.880	26.880	26.880	36.570	36.570	36.570	27.100	27.100	27.100
Allowable stress	Tensil stress of bar	σsa	N/mm2	140	140	140	140	140	140	140	140	140
	Compressive stress	σca	N/mm2	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
	Shearing stress	τa	N/mm2	0.84	0.42	0.42	0.84	0.42	0.42	0.84	0.42	0.42
	Adhesive stress	τoa	N/mm2	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
		n		15	15	15	15	15	15	15	15	15
		k		0.462	0.462	0.462	0.462	0.462	0.462	0.462	0.462	0.462
		j		0.846	0.846	0.846	0.846	0.846	0.846	0.846	0.846	0.846
		p		0.004	0.004	0.004	0.004	0.004	0.004	0.006	0.006	0.006
		k'		0.283	0.283	0.283	0.283	0.283	0.283	0.339	0.339	0.339
		j'		0.906	0.906	0.906	0.906	0.906	0.906	0.887	0.887	0.887
Member width		d	cm	20	20	20	20	20	20	15	15	15
Cover thickness of bar		d1	cm	6	6	6	6	6	6	6	6	6
Area of reinforcement	Area required	Asm=	cm2	5.17	0.14	3.71	5.17	0.58	0.12	5.14	1.61	0.09
	Area installed	As=	cm2	5.23	5.23	5.23	5.23	5.23	5.23	5.23	5.23	5.23
		Diameter	mm	D10	D10	D10	D10	D10	D10	D10	D10	D10
		Interval@	mm	150	150	150	150	150	150	150	150	150
		Diameter	mm									
		Interval@	mm									
Calculation of stress	Compressive stress	σc	N/mm2	3.41	0.09	2.45	3.41	0.38	0.08	4.50	1.41	0.08
	Tensile stress	σs	N/mm2	129	3	93	129	14	3	131	41	2
	Shearing stress	τ	N/mm2	0.29	0.18	0.00	0.33	0.10	0.00	0.34	0.19	0.00
	Adhesive stress	τo	N/mm2	1.20	0.77	0.01	1.38	0.41	0.00	1.40	0.77	0.00
	Examination (Concrete)			OK	OK	OK	OK	OK	OK	OK	OK	OK
	Exmination (Reinf. Bar)			OK	OK	OK	OK	OK	OK	OK	OK	OK

(2) Vertical shafts with slab thickness 15 cm (H=5.00m)





H	3	m				
B	0.9	m		P_{hd}	2.700	tf/m^2
Tt	0.15	m		P_{hl}	0.225	tf/m^2
B1	1.05	m				
B0	1.2	m		Total	2.925	tf/m^2
Ww	1	tf/m^3	Input data	P	3.343	tf/m^2
Wc	2.5	tf/m^3		L	1.050	m
Wt	1.8	tf/m^3				
Ww	2	tf/m^3				
Ws	1	tf/m^3				
Liveload	0.45	tf/m^2				
Pressure coe.	0.5					



(Materials)

Material No.	Elasticity modules (tf/m2)	Area (m2)	Geometrical moment of inertia (m4)
1	2.55000E+06	.15000	.0002810
2	2.55000E+06	.15000	.0002810

(Joint data)

Joint No.	X-value (m)	Y-value (m)	Joint X	Y	θ
1	.000	1.050	1	1	0
2	1.050	1.050	0	1	0
3	.000	.000	0	0	0
4	1.050	.000	0	0	0

(Member data)

Member No. I - J	Material No.	Length (m)
1 - 3	1	1.050
2 - 4	1	1.050
1 - 2	1	1.050
3 - 4	2	1.050

(Load data)

Load No.	Load Type	Load Title	Member I J	Direction	P1	P2	P3	P4
1	TP1	Uniformly verying load	1 - 2	Y	.000	.000	-3.343	-3.343
1	TP1	Uniformly verying load	3 - 4	Y	.000	.000	3.343	3.343
1	TP1	Uniformly verying load	1 - 3	Y	.000	.000	3.343	3.343
1	TP1	Uniformly verying load	2 - 4	Y	.000	.000	-3.343	-3.343

(Intersectional force)

Member I J	Length (m)	Bend moment (tf·m)	Shearing force (tf)	Axial force (tf)
1 - 3	.000	-.307	1.755	1.755
	.180	-.045	1.153	1.755
	.525	.154	.000	1.755
	.870	-.045	-1.153	1.755
	1.050	-.307	-1.755	1.755
2 - 4	.000	.307	-1.755	1.755
	.180	.045	-1.153	1.755
	.525	-.154	.000	1.755
	.870	.045	1.153	1.755
	1.050	.307	1.755	1.755
1 - 2	.000	.307	-1.755	1.755
	.180	.045	-1.153	1.755
	.525	-.154	.000	1.755
	.870	.045	1.153	1.755
	1.050	.307	1.755	1.755
3 - 4	.000	-.307	1.755	1.755
	.180	-.045	1.153	1.755
	.525	.154	.000	1.755
	.870	-.045	-1.153	1.755
	1.050	-.307	-1.755	1.755

Calculation of allowable stress : D10 （Double reinforcing bar）

σca	8.0	N/mm2
σsa	140	N/mm2
τa	0.42	N/mm2
τoa	1.5	N/mm2
n	15.0	

			Member	1-3		
			x=	0	2d	Center
Moment		M	kN・m	3.070	0.450	1.540
Shearing force		S	kN	17.550	11.530	0.620
Axial force		N	kN	17.550	17.550	17.550
Allowable stress	Tensil stress of bar	σsa	N/mm2	140	140	140
	Compressive stress	σca	N/mm2	8.0	8.0	8.0
	Shearing stress	τa	N/mm2	0.84	0.42	0.42
	Adhesive stress	τoa	N/mm2	1.5	1.5	1.5
		n		15	15	15
		k		0.462	0.462	0.462
		j		0.846	0.846	0.846
		p		0.006	0.006	0.006
		k'		0.351	0.351	0.351
		j'		0.883	0.883	0.883
Member width		d	cm	15	15	15
Cover thickness of bar		d1	cm	6	6	6
Area of reinforcement	Area required	Asm=	cm2	2.88	0.42	1.44
	Area installed	As=	cm2	5.68	5.68	5.68
		Diameter	mm	D10	D10	D10
		Interval@	mm	125	125	125
		Diameter	mm			
		Interval@	mm			
Calculation of stress	Compressive stress	σc	N/mm2	2.45	0.36	1.23
	Tensile stress	σs	N/mm2	68	10	34
	Shearing stress	τ	N/mm2	0.22	0.15	0.01
	Adhesive stress	τo	N/mm2	0.87	0.57	0.03
	Examination (Concrete)			OK	OK	OK
	Exmination (Reinf. Bar)			OK	OK	OK

Calculation of allowable stress : D10（Single reinforcing bar）

σca	8.0	N/mm2
σsa	140	N/mm2
τa	0.42	N/mm2
τoa	1.5	N/mm2
n	15.0	

			Member	1-3		
			x=	0	2d	Center
Moment		M	kN・m	3.070	0.450	1.540
Shearing force		S	kN	17.550	11.530	0.620
Axial force		N	kN	17.550	17.550	17.550
Allowable stress	Tensil stress of bar	σsa	N/mm2	140	140	140
	Compressive stress	σca	N/mm2	8.0	8.0	8.0
	Shearing stress	τa	N/mm2	0.84	0.42	0.42
	Adhesive stress	τoa	N/mm2	1.5	1.5	1.5
		n		15	15	15
		k		0.462	0.462	0.462
		j		0.846	0.846	0.846
		p		0.008	0.008	0.008
		k'		0.376	0.376	0.376
		j'		0.875	0.875	0.875
Member width		d	cm	15	15	15
Cover thickness of bar		d1	cm	7.5	7.5	7.5
Area of reinforcement	Area required	Asm=	cm2	3.46	0.51	1.73
	Area installed	As=	cm2	5.68	5.68	5.68
		Diameter	mm	D10	D10	D10
		Interval@	mm	125	125	125
		Diameter	mm			
		Interval@	mm			
Calculation of stress	Compressive stress	σc	N/mm2	3.32	0.49	1.66
	Tensile stress	σs	N/mm2	82	12	41
	Shearing stress	τ	N/mm2	0.27	0.18	0.01
	Adhesive stress	τo	N/mm2	1.06	0.69	0.04
	Examination (Concrete)			OK	OK	OK
	Exmination (Reinf. Bar)			OK	OK	OK

3.6 Structural Design of Conduits (Flexible Conduits)

(1) Earth load

Earth loads or rigid underground conduits and structures are determined by means of Marston formula. Earth load computations, based on the construction methods that influence the loads, are classified into three conditions, i.e., trench condition, projection condition and imperfect trench condition

(2) Earth load formula

Following equations are applied based on construction methods:

Table 3.6.1 Applicable Formula for Conduits Calculation

Loads	Conditions	Formulas
Vertical soil pressure	Trench fill loads	$W_w = C_d \cdot w \cdot \frac{B^2}{D_c}$ (Marstone formula)
	Projection fill loads	$W_v = Cc \cdot w \cdot D_c$ (Marstone formula)
Horizontal pressure		$P_h = K \cdot w \cdot h$ (Rankin formula)

W_v: Vertical load on conduit (kgf/cm^2)

P_h: Horizontal load at "h" m depth from ground (or embankment) surface (kgf/cm^2)

B: Horizontal width of trench at top of conduit (cm)

D_c: Outside width of conduit (cm)

w: Design unit weight of backfill materials (kgf/cm^3)

C_d: Load coefficient for trench condition

$$C_d = \frac{1 - e^{-2K\cdot\mu'(H/B)}}{2K\cdot\mu'}$$

C_c: Load coefficient for projecting (or negative projecting) condition

H<He (positive projecting condition)

$$C_C = \frac{e^{2K\cdot\mu(H/D_c)} - 1}{2K\cdot\mu}$$

H>He (negative projecting condition)

$$C_C = \frac{e^{2K\cdot\mu(H/D_c)} - 1}{2K\cdot\mu} + \left(\frac{H}{D_c} - \frac{H_e}{D_c}\right)\cdot e^{2K\cdot\mu(H_e/D_c)}$$

$$\frac{e^{2K\cdot\mu(H_e/D_c)} - 1}{2K\cdot\mu}\left\{\frac{1}{2K\cdot\mu} + \left(\frac{H}{D_c} - \frac{H_e}{D_c}\right) + \frac{\gamma_{sd}\cdot P}{3}\right\} + \frac{1}{2}\left(\frac{H_c}{D_c}\right)^2 + \frac{\gamma_{sd}\cdot P}{3}\left(\frac{H}{D_c} - \frac{H_e}{D_c}\right)\cdot e^{2K\cdot\mu(H_e/D_c)}$$
$$- \frac{1}{2K\cdot\mu}\cdot\frac{H_e}{D_c} - \frac{H}{D_c}\cdot\frac{H_e}{D_c} = \gamma_{sd}\cdot P\cdot\frac{H}{D_c}$$

H: Height of fill above top of conduit to ground surface or embankment (cm)

H_e: Height of fill above top of conduit to settlement surface (cm)

K: Soil pressure coefficient of Rankin, $K = \dfrac{1-\sin\phi}{1+\sin\phi}$

μ: Coefficient of internal friction of fill material. $\mu = \tan\phi$

μ': Coefficient of internal friction between fill material and sides of trench $\mu' = \tan\phi'$ $(=\mu)$

ϕ: Internal friction of fill material

ϕ': Internal friction of fill material and sides of trench

P: Positive projection ratio, $P = x/D_c$ (generally P = 1.0)

x: Vertical distance between top of conduit and adjacent existing ground (cm)

γ_{sd}: Settlement ratio

Soil pressure coefficient under trench condition is theoretically smaller than that under projecting condition by calculation of Marston formula. In case width of trench at top of conduit is relatively wider, coefficient under projecting condition gives smaller value, accordingly smaller coefficient among those under trench condition and projecting condition shall selected for the structural calculation.

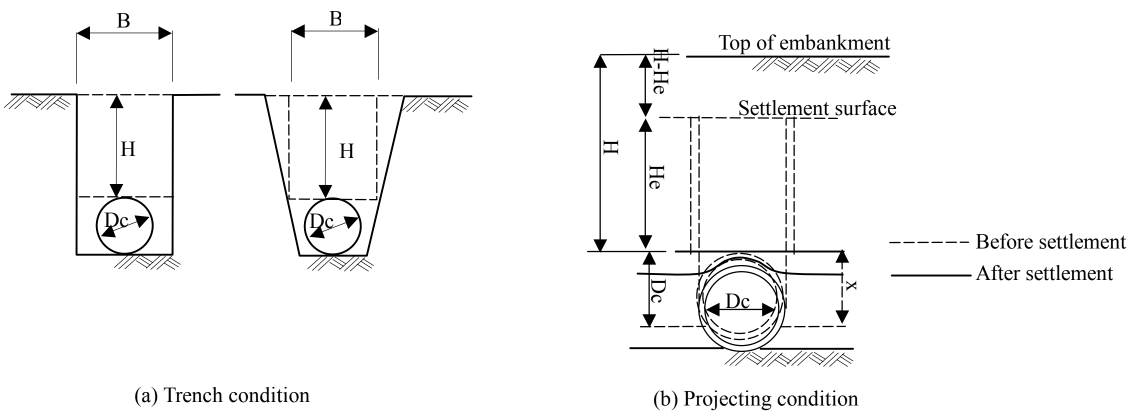
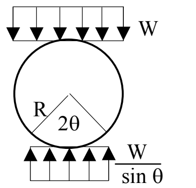
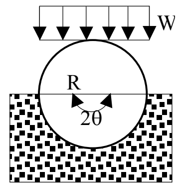
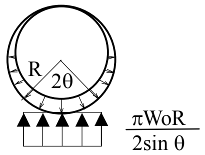
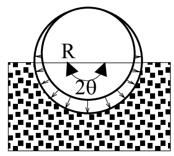
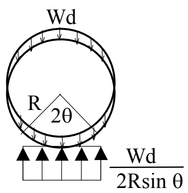
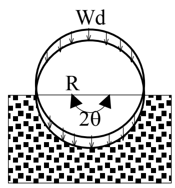
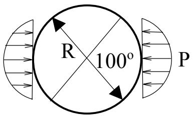
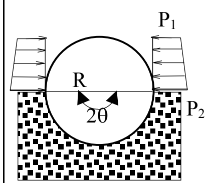


Figure 3.6.1 Varying Condition of Conduits

Table 3.6.2 Moment under Various Load Conditions

Loads	Support angle (2θ°)	Non-fixed support		Fixed support	
		Maximum moment	Load condition	Maximum moment	Load condition
Vertical load (uniform load)	60	$0.377\ WR^2$		---	
	90	$0.314\ WR^2$		---	
	120	$0.275\ WR^2$		---	
	180	(*) $0.250\ WR^2$		$0.220\ WR^2$	
Load of water	60	$0.420\ w_0R^3$		---	
	90	$0.321\ w_0R^3$		---	
	120	$0.260\ w_0R^3$		---	
	180	(*) $0.220\ w_0R^3$		$0.055\ w_0R^3$	
Load of pipe	60	$0.134\ W_dR$		---	
	90	$0.102\ W_dR$		---	
	120	$0.083\ W_dR$		---	
	180	(*) $0.070\ W_dR$		(*) $0.017\ W_dR$	
Horizontal load	60	$-0.166\ PR^2$		---	
	90	$-0.166\ PR^2$		---	
	120	$-0.166\ PR^2$		---	
	180	(*) $-0.166\ PR^2$		$-(0.047P_1+0.060P_2)R^2$	

W: Vertical loads act to conduit (kgf/cm^2)

W = Vertical soil load + Live loads and others

w_o: Unit weight of water (0.001 kgf/cm^3)

W_d: Weight of conduit per cm (kgf/cm)

P_1: Horizontal loads act at top of conduit (kgf/cm^2)

P_2: Horizontal loads act at bottom of conduit (kgf/cm^2)

R: Radius of conduit (center of conduit) (cm)

P: Horizontal loads act at center of side wall of conduit (kgf/cm^2)

P = Horizontal soil load + Weight of conduit and water inside + Horizontal live loads and others

Design support angle

(1) Soil foundation

Table 3.6.3 Design Support Angles of Compacted Soil Foundation (unit : °)

	Conduits	Flexible conduits		Rigid conduits
	Construction / Soil classification	larger than 120	larger than 180	360
Gravel	G, GS	90	90	120
	GF	90	90	90
Sandy soil	SW, SW-G, SGW in S, SG	90	120	120
	SP, SP-G, SGP in S, SG	90	90	90
	Other soil classified in S, SG, SF	60	60	90

Notes: Design support angles of soil layer classified into ML, CL are 30° for rigid conduit and 60° for flexible conduit, respectively on condition that gravel or sandy soil materials are constructed as al foundation of conduits.

(1) Calculation of conduit thickness determined from internal/external loads

$$t \geq \frac{0.5D \cdot h + \sqrt{(0.5D \cdot h)^2 + 24\alpha \cdot \sigma_a \cdot M +}}{2\sigma_a}$$ --(Equation (a)

t: Thickness of conduit 8cm)

D: Inside diameter fo conduit (cm)

h: Design water pressure (kgf/cm^2)

M: Maximum moment by external loads (kgf cm/cm)

α: Tension stress / bend stress

PVC pipe: 0.55

Polyethylene pipe: 0.75

σa: Allowable tensile stress (kgf/cm^2)

PVC pipe: 170 kgf/cm^2 (safety factor = 3)

Polyethylene pipe: 65 kgf/cm^2 (safety factor = 3)

(2) Equation to estimate necessary pipe thickness by flexure ratio

Following equation is applicable to estimate necessary pipe thickness:

$$\frac{\Delta X}{2R} \times 100 = \frac{F_1\left(K \cdot W_v + K_0 \cdot w_0 \cdot R + K_p \cdot W_p\right) + F_2 \cdot K \cdot W_w}{\frac{E \cdot I}{R^3} + 0.061e'} \times 100(\%)$$

ΔX: Flexure length in horizontal direction (cm)

ΔX_1: Flexure length by dead loads (cm)

ΔX_2: Flexure length by live loads (cm)

R: Radius of conduit (center of conduit) (cm)

$W_{v:}$ Vertical loads of soil pressure, etc. (kfg/cm^2)

$W_{w:}$ Vertical loads of live loads (kfg/cm^2)

$w_{0:}$ Unit weight of water (0.001 kgf/cm^3)

$W_{p:}$ Weight of conduit per cm (kgf/cm^2)

PVC pipe: 1.43
Polyethylene pipe: 0.96
Fiber reinforced pipe: 2.00

K, K_0, K_p: Coefficient determined by support angle of foundation

Standard of K values

Support angle of base	0°	30°	60°	90°	120°	180°
K	0.110	0.108	0.103	0.096	0.089	0.083
K_0	0.107	0.104	0.096	0.085	0.075	0.065
K_p	0.215	0.208	0.191	0.169	0.149	0.131

F_1: Delay coefficient of deflection by dead loads

Delay Coefficient of Deform by Dead Loads

Materials of base / Materials of original layer	Sandy materials	Gravelly soil
Gravelly soil	1.0	1.0
Sandy soil	1.1	1.0
Cohesive soil	1.3	1.2
Others	1.5 or more	1.5

Note: F_1=1.0 is applied to the conduit of diameter 300mm or smaller.

F_2: Delay coefficient of deflection by live loads (F_2=1.0 in general)

E: Modulus of elasticity: E (x10^{10} kgf/m^2)

Conduits	E
PVC pipe	0.03
Polyethylene pipe	0.01
Fiber reinforced pipe	0.15

I: Geometrical moment of inertia of conduit wall (cm^4/cm)

e': Coefficient of subgrade reaction (kgf/cm^2)

Coefficient of Subgrade Reaction

Materials of base / Materials of original layer	Sandy materials	Gravelly soil (including rock)
Gravelly soil	45	60
Sandy soil	40	55
Cohesive soil	30	40
Others	15	20

Note: Others include organic soil or soft ground.

Giving construction condition of the conduit, and flexure length in horizontal direction (refer to table below), geometrical moment of inertia of conduit wall is estimated.

$$I = \frac{R^3}{E} \cdot \left\{ \frac{F_1 \left(K \cdot W_v + K_0 \cdot w_0 \cdot R + K_p \cdot W_p \right) + F_2 \cdot K \cdot W_w}{\frac{\Delta X}{2R}} - 0.061e' \right\}$$

As geometrical moment of inertia is given as $b \cdot t^3 / 12$, thus, when b=1.0 cm, and necessary conduit thickness is given as $t \geq \sqrt[3]{12 \cdot I}$. --Equation (b)

Flexure length in horizontal direction (ΔX) is below:

Flexure Length in Horizontal Direction

Compaction	**D value 90% (General)**	D value 95% (Specifically)
Allowable deflection ratio (%)	**5**	5
Dispersion of deflection ratio (%)	**2 (1)**	1
Design deflection ratio (%)	**3 (4)**	4

Notes: Value in ( ) is applied to base of gravelly soil.

Conduit thickness which satisfies both "Equation (a) and (b)" is applied to the conduit.

(Example)

Necessary conduit thickness is estimated as follows:

Design conditions:

Conduit: PVC pipe. diameter 400 mm

Depth: 5 m from the ground surface (trench condition, 120 °)

Water depth in conduit is negligible.

1) Equation (a)

D (cm)	40	
R (cm)	20	
h (kgf/cm^2)	0	
H (cm)	500	
α	0.55	
σa (kgf/cm^2)	170	
M (kgf cm/cm)	$0.275WR^2 - 0.166PR^2$ $= 0.275 \cdot C_d \cdot w \cdot \frac{B^2}{D_c} \cdot R^2 - 0.166 \cdot PR^2$ $= 0.275 \times 1.606 \times 0.0018 \times \frac{200^2}{40} \times 20^2 - 0.166 \times 0.300 \times 20^2 = 298.068$	$C_d = \frac{1 - e^{-2K \cdot \mu'(H/B)}}{2K \cdot \mu'}$ $= \frac{1 - e^{-2 \times 0.333 \times 0.577 \times 500 \div 200}}{2 \times 0.333 \times 0.577} = 1.606$ $P_h = K \cdot w \cdot H = 0.333 \times 0.0018 \times 500 = 0.300$
t (cm)	$t \geq \frac{0.5D \cdot h + \sqrt{(0.5D \cdot h)^2 + 24\alpha \cdot \sigma_a \cdot M}}{2\sigma_a}$ $= \frac{0.5 \times 20 \times 0.0 + \sqrt{(0.5 \times 20 \times 0.0)^2 + 24 \times 0.55 \times 170 \times 298.068}}{2 \times 170}$ $= 2.41$	

2) Equation (b)

Symbols	Equations / values	Remarks
R (cm)	20	
E	$0.03x10^{10}$ (kgf/m^2) = $0.03x10^6$ (kgf/cm^2)	
F_1	1.0	
F_2	1.0	
K	0.089	
K_0	0.075	
K_p	0.149	

W_v	$W_v = C_d \cdot w \cdot \frac{B^2}{D_c} = 1.606 \times 0.0018 \times \frac{200^2}{40} = 2.891$	$C_d = \frac{1 - e^{-2K \cdot \mu'(H/B)}}{2K \cdot \mu'}$ $= \frac{1 - e^{-2\times 0.333\times 0.577\times 500\div 200}}{2 \times 0.333 \times 0.577} = 1.606$
w_0 (kgf/cm^2)	0.001	
W_p (kgf/cm^2)	$0.00143 \times 1.2 = 0.0017$	
W_w (kgf/cm^2)	0.000	
$\frac{\Delta X}{2R}$	$\frac{\Delta X}{2R} \times 100(\%) = 4$ $\frac{\Delta X}{2R} = 4 \times 100 = 400$	
I	$I = \frac{R^3}{E} \cdot \left\{ \frac{F_1(K \cdot W_v + K_0 \cdot w_0 \cdot R + K_p \cdot W_p) + F_2 \cdot K \cdot W_w}{\frac{\Delta X}{2R}} - 0.061e' \right\}$ $= \frac{20^3}{0.03 \times 10^6} \cdot \left\{ \frac{1.0 \times (0.089 \times 2.891 + 0.075 \times 0.001 \times 20 + 0.149 \times 0.0017) + 1.0 \times 0.089 \times 0.000}{0.04} - 0.061 \times 60 \right\}$ $= 0.751$	
t (cm)	$t \geq \sqrt[3]{12 \cdot I} = \sqrt[3]{12 \times 0.751} = 2.08$	

Minimum requirement of PVC pipe thickness is calculated at 2.41 cm by equation (a) and 2.08 cm by equation (b), accordingly larger thickness of 2.41 cm is requirement for the PVC pipe.

3.7 Bed Slope of Gallery

When re-profiling the gallery base, two of alternatives are proposed, one is setting slope in certain slope and the other is setting slope horizontally. Deliberative points on gallery slope setting are discussed below considering present condition of the khettara.

The following table explains advantage and disadvantage of both ideas:

Table 3.7.1 Re-profiling of Galley

Descriptions	with slope	level
1) As groundwater level has remarkably declined due to consecutive drought year, excavation of khettara gallery bed is necessary to penetrate gallery foundation into the ground below the groundwater level. Canal bed elevation shall be set up as lower as possible for water conveyance over the whole line. As galleries are rehabilitated with concrete for permanent use, their elevations shall be established at lower elevation starting from exit of gallery as topographic or physical condition permitting.	x	○
2) Certain canal bed slope, which is equal to the gradient of friction loss generally achieves lower construction cost in a measure by unified section, minimizing earth work volume, etc. There is few difference in quantities between khettaras with and without slope as explained below.	○	x
3) A certain bed slope may accelerate movement of sediment in the gallery. It is therefore effective to give a bed slope as topographical conditions permitting. However, most of khettaras have a gentle slope, an incline of 1 in thousands, thus giving slope may be ineffectual for this purpose.	△ Effective for khettaras located in hilly area.	x Periodical maintenance is necessary.

Assuming various flow velocity (or water depth), hydraulic loss (hydraulic gradient) is estimated as shown on Table 3.5.1 on condition below:

Calculation condition: Discharge 0.01 m^3/sec

Canal width 0.6 m (Standard width of khettara)

Roughness coefficient : 0.015 (Concrete)

As is evidence from Table 3.7.2, hydraulic gradient is estimated at about 1/5,000 to 1/100,000 in the velocity range of 0.16 to 0.06 m/sec. This fact indicates that re-profiling of the gallery bed corresponding to the hydraulic gradient is not so economically reduce construction amount, accordingly re-profiling with horizontal shape is preferable to hold gallery base in lower elevation assuming further decline of the groundwater level.

Table 3.7.2 Hydraulic Loss Calculation

	Water depth in average (m)			
	0.1	0.15	0.2	0.3
Discharge (m^3/sec)	0.01			
Canal width (m)	0.60			
Roughness coefficient (n)	0.015			
Hydraulic radius (m)	0.075	0.100	0.120	0.150
Velocity	0.167	0.111	0.083	0.056
$\frac{n^2 \cdot V^2}{R^{4/3}}$	0.00020	0.00006	0.00003	0.00001
Head loss when L=1000m (m)	0.20	0.06	0.03	0.01
Hydraulic gradient	1/5,000	1/17,000	1/33,000	1/100,000

Note: Head loss by friction is as follows:

$$h_f = \frac{n^2 \cdot V^2}{R^{4/3}} \times L$$

where,

h_f	:	Head loss by friction (m)
n	:	Roughness coefficient of Manning formula
V	:	Mean water velocity (m/sec)
R	:	Hydraulic radius (m)
L	:	Canal length (m)

4. Material Supply Plan

4.1 Concrete works

Concrete shall be composed of cement, fine aggregate, coarse aggregate, water and admixtures, all well mixed and brought to the proper consistency.

(1) Maximum size of aggregates and mixing proportions

The maximum size of aggregates and minimum compressive strength at 28 days shall be satisfied with the specifications shown on Table 4.1.1 in principle. Practical specifications should be, however, determined at site based on the test results.

Mixing proportions, such as the amount of cement, water-cement ratio, coarse aggregate, fine aggregate and admixtures per unit volume of concrete, shall be determined on the basis of those which produce the most economic concrete having suitable workability, density, impermeability, durability and strength required for the various types of structures in which the concrete is placed.

The amount of water to be used in concrete shall be regulated as required to produce concrete of the proper consistency and shall be adjusted for any variation in the moisture content or grading of the aggregates.

(2) Tests

The Contractor shall make all necessary tests for determining the mixing proportions of each type of concrete, including tests of aggregates, so as to produce the concrete specified in this clause.

In order to control the quality of concrete to be placed, the Contractor shall perform the field tests as specified in Table 4.1.2.

Table 4.1.1 Standard Mix Proportion for Concrete

Class (Category)	Max.Aggregate size (mm)	Compression (kg/cm^2,bar)	Utilization
B4E (31.5/150)	31.5	127 (130)	Lean concrete
B4 (63/250)	63	176 (180)	Plain concrete
B3 (31.5/300)	31.5	225 (230)	Reinforcing concrete
B2 (31.5/350)	31.5	265 (270)	Frame works
B1 (16/400)	16	294 (300)	Specified structures

Note: 1.0 bar = 0.98 kg/cm^2

Table 4.1.2 Field Tests for Quality Control of Concrete

Test	No. of tests	Sampling site	Method of test
Gradation test of coarse aggregate	once a month or as required	aggregate stockpile	ASTM C136
Gradation test of fine aggregate	once a month or as required	aggregate stockpile	ASTM C136
Test for compressive strength	Every 50 m^3 concrete placing (6 test specimens for each time)	mixing plant or placing site directed by the Consultant	ASTM C172 ASTM C31
Slump test	more than 2 times a day	mixing plant and/or placing site directed by the Consultant	ASTM C143
Test of air content in fresh concrete	more than 2 times a day	mixing plant or placing site as directed by the Consultant	ASTM C233
Measurement of Temperature	more than 2 times a day	mixing plant or placing site as directed by the Consultant	

(3) Cement

The cement shall conform to the requirements of Portland cement. The cement shall be stored in a suitable weather-tight storage bin or warehouse that will protect the cement from absorbing moisture.

(4) Water

Water for mixing concrete and mortar shall be free from objectionable quantities of silt, organic matter, oil, alkali, acid, salt or other impurities. A turbidity of more than 2,000 ppm shall be considered objectionable. Allowable content of chloride ion shall be limited to 0.3 kg/m^3 in concrete.

4.2 Concrete Aggregates

(1) Coarse Aggregate

Coarse aggregate is either natural gravel or manufactured coarse aggregate. The following are the tests for the coarse aggregate.

1) Resistance to abrasion by the Los Angeles Machine (ASTM C131) .... The loss shall not exceed 40% by weight.

2) Soundness by sodium sulfate (ASTM C88) .... The weighted average loss, after 5 cycles, shall be less than 12% by weight.

3) Specific gravity (ASTM C127) .... The specific gravity shall not be less than 2.60 in saturated surface dry condition.

The coarse aggregate shall be separated into two classifications as follows:

Table 4.2.1 Coarse Aggregate Classifications

Smallest dimension of element (cm)	Index	Max. grain size Class of concrete B1-B2-B3 Sharp (mm)	B1-B2-B3 Round (mm)	B4-B5-B4E-B5E Sharp (mm)	B4-B5-B4E-B5E Round (mm)
5 - 11	1	8 - 20	10 - 25	12.5 - 25	16 - 31.5
11 - 22	2	12.5 - 25	16 - 31.5	25 - 50	31.5 - 63
22 - 44	3	20 - 50	25 - 63	50	63
44 - 88	4	50	63	50 - 100	63 - 120

(2) Fine Aggregate

Fine aggregate shall be either natural sand or manufactured sand. The fine aggregate shall conform to the following requirements.

1) Material passing No. 200 (75 micron) sieve, tested as delivered to the mixer in accordance with ASTM C117, shall not exceed 5.0 % by weight for manufactured sand and 3 % for river sand.
2) Injurious organic compounds in natural sand shall be tested in accordance with ASTM C40. The color of the supernatant liquid above the sand shall be lighter than the standard color.
3) The weighted average loss of fine aggregate, after 5 cycles of sodium sulfate test for soundness provided in ASTM C88, shall be less than 10% by weight.

The fine aggregate as batched shall be well graded, and when tested shall conform to the following limits:

Table 4.2.2 Grading of Fine Aggregate

Screen Round (mm)	Screen Sharp (mm)	Percentage Passing by Weight Minimum	Percentage Passing by Weight Maximum
6.3	5	95	---
3.15	2.5	70	90
1.6	1.25	45	80
0.8	0.63	28	55
0.4	0.315	10	35
0.2	0.16	2	17
0.1	0.08	0	12

4.3 Reinforcing Bar

1) Materials

The reinforcing bars used for concrete structures shall be deformed bars grade Fe E 40 and dimensions, tensile strength, yield point, elongation and other properties, shall conform to the following:

Table 4.3.1 Specification of Fe E 40

Items	Unit	Specifications
Maximum diameter (d)	mm	25
Limited elastic tensile stress	kgf/cm^2	d<=20: 4,200
		d>20: 4,000
	bar	d<=20: 4,120
		d>20: 3,920
Braking tensile stress	kgf/cm^2	4,850
	bar	4,760

2) Fabrication and placing of reinforcing bar

(a) Spacing

The clear distance between parallel bars in beams shall be not less than the nominal diameter of the bar or 4/3 times and maximum size of coarse aggregate not less than 2.0 cm. The clear distance between vertical bars in columns shall be not less than 1.5 times the nominal diameter of the bar of 4/3 times the maximum size of coarse aggregate, not less than 4 cm.

(b) Hooks

Hooks shall be provided at the ends of tensile reinforcing bars which are anchored in the fixed end of members, footings and free ends of cantilevers. For anchorage other than that specified above, hooks are not required to be provided at the ends of reinforcing bars.

(c) Splices

Where required, reinforcing bars shall be joined by splicing. Splicing of reinforcing bars at points of maximum stress and concentration of splices in the same sections shall be avoided.

Length of overlapping for splices shall be more than the value shown on Table 4.1.6, unless otherwise shown in the drawings or directed by the Consultant.

Table 4.3.2 Length of Overlapping

Diameter of Reinforcing Bar (mm)	10	12	14	16	(18)	20	(22)	25
Length of Overlapping for a Splice (cm)	30	36	42	48	54	60	66	75

Note: Reinforcing bars of diameters 18 and 22 mm is not available in Morocco.

(d) Coverage

The coverage of reinforcing bars shall be as shown in Table 4.3.3.

Table 4.3.3 Coverage of Reinforcing Bars

Location	Depth of Coverage (cm)	
	D<=18 mm	D>20 mm
Surface in contact with earth	9.0	10.0
Surface in contact with water	6.0	7.0

4.4 Other Conduits Materials

(1) Reinforced concrete pipe

Reinforced concrete pipe shall be installed for the conduits. Concrete pipes to be used are as follows:

Table 4.4.1 Specification of Reinforced Concrete Pipe

Diameter	Series 60 A		Series 90 A		Series 135 A	
	Thickness (mm)	B.P. (kN/m)	Thickness (mm)	B.P. (kN/m)	Thickness (mm)	B.P. (kN/m)
300	37	38	37	38	37	41
400	43	38	43	38	45	54
500	50	40	50	45	53	68
600	56	43	58	54	62	81
700	62	46	66	63	70	95
800	68	49	74	72	80	100
1,000	80	60	90	90	100	135
1,100	86	66	97	99	110	147
1,200	92	72	105	108	120	162
1,300	98	78	112	117	130	174
1,500	113	90	128	135	148	203
1,800	130	108	150	162	170	243
2,000	140	120	160	180	180	270

(2) Reinforced half concrete pipes

Reinforced half concrete pipe is available for the gallery. The following are the specification of the Reinforced half concrete pipe.

Table 4.4.2 Specification of Reinforced Half Concrete Pipe

Diameter (mm)	Thickness (mm)	Length (mm)	Diameter (mm)	Thickness (mm)	Length (mm)
300	33	6,810	1,100	58	6,810
400	35	6,810	1,300	75	6,810
500	37	6,810	1,500	85	6,810
600	39	6,810	1,550	76	6,810
700	42	6,810	1,800	80	4,080
800	46	6,810	1,850	88	6,810
950	52	6,810	2,000	120	4,080
1,000	54	6,810			

(3) PVC Pipe

PVC pipe can be used in water conveyance system. Pipe and fittings are joined by gaskets or solvent cementing. PVC pipes have outside diameters that correspond to the outside diameter of either steel pipe or cast iron pipe.

PVC pipe and fittings are pressure rated at 6.0 bars at minimum to resist earth and live loads from the outside. Proper protection shall be taken for prolonged exposure to sunlight.

5. Reconstruction Plan for Decrepit Structures

5.1 General

Khettara rehabilitation works by concrete and masonry materials have been commenced since 1956 by the financial assistance of the local government according to the hearing from the water users groups. Since some khettara galleries have been rehabilitated 40 to 50 years before, functional disorder has been actualized caused by concrete deterioration, in addition narrower gallery section has hindered to easily repair gallery concrete.

5.2 Results of Investigations

Survey results of twelve (12) khettaras are shown on Table 5.1.1, and principal observation of these khettaras are notified as follows:

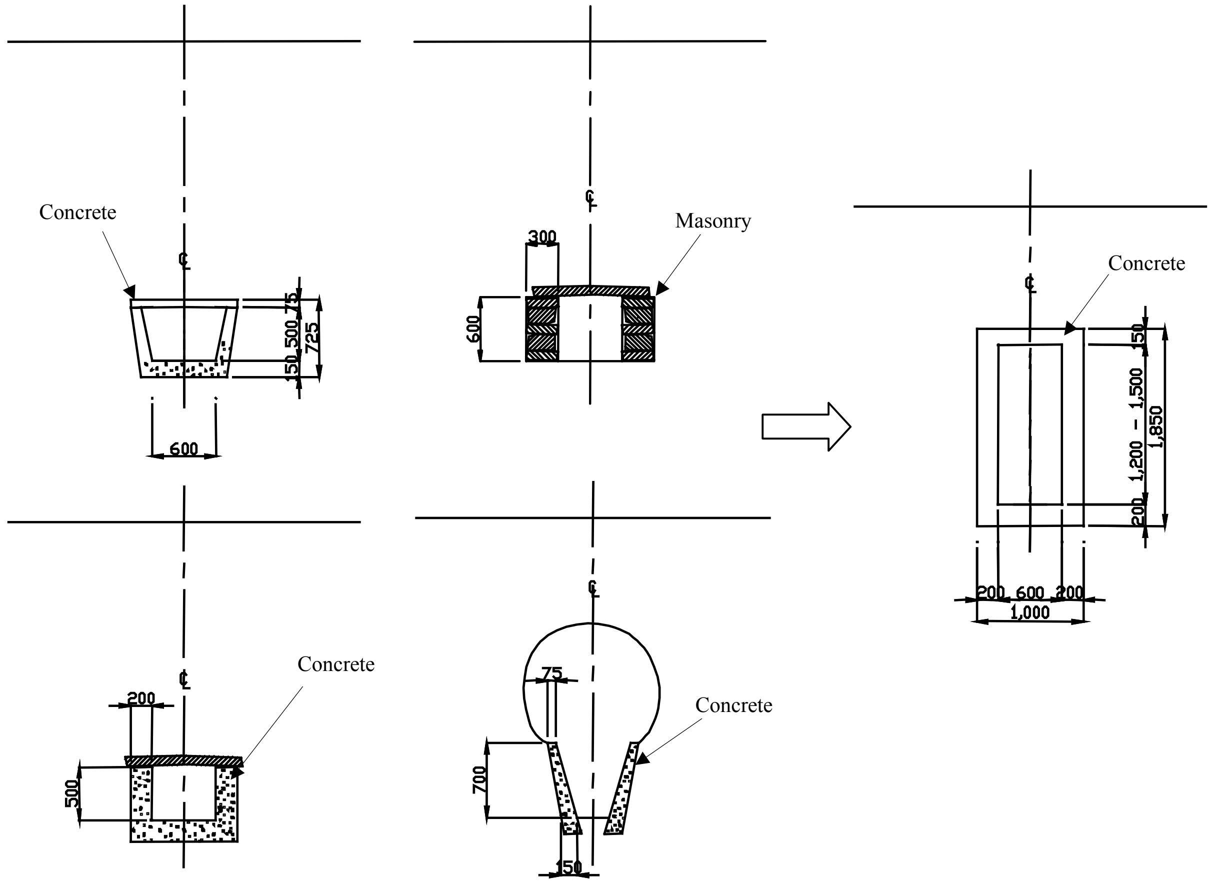
1) Narrow gallery section hinders periodical maintenance work, accordingly poor dredging work allows accumulation of the deposit and causes decrease of the khettara flow,
2) Sand dune has covered vertical shafts, and it is interfering with labors going into the khettara gallery,
3) Aged deterioration is found on the concrete surface, in addition reinforcing bar has rusted from moisture and saline water of khettara,
4) Siphon sections have been damaged by several floods,
5) Degrading of gallery bed is required to interpenetrate the upstream section of the khettara under the groundwater level since groundwater level has been depressing, especially recent two decades. In some cases, concrete base hinders digging down of the gallery, furthermore elevated concrete base prevents from water flowing towards downstream.

Taking account of the problems above, proper rehabilitation is proposed as below.

5.3 Rehabilitation Plan

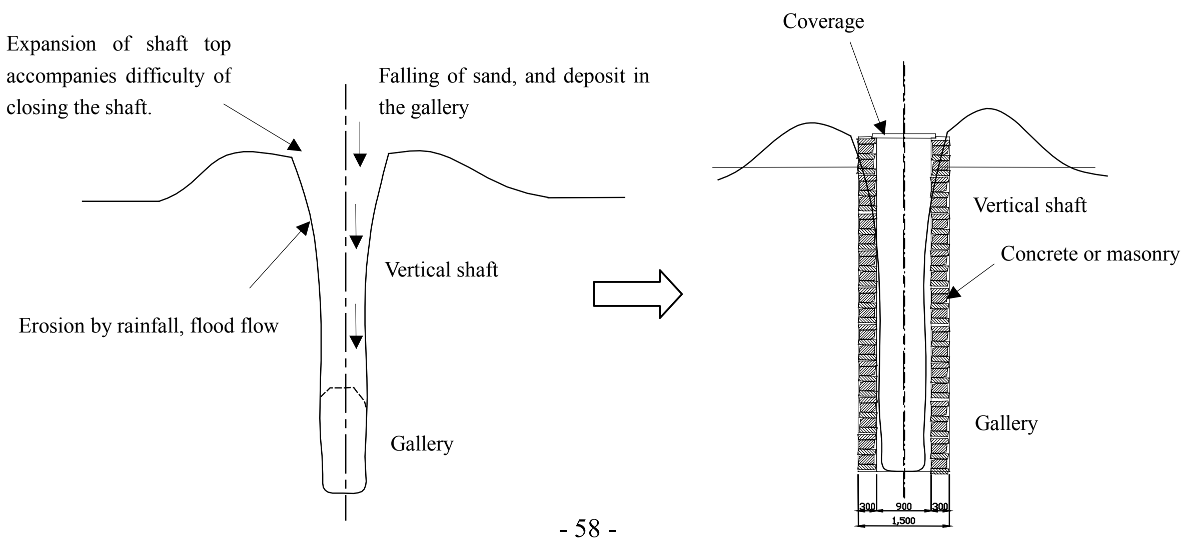
(1) Enlargement of gallery

Gallery section shall ensure at least 1.2 m high and 0.6 m wide at inside. Through the Verification study, 1.5 m high is recommended to lighten the work for the maintenance in the gallery.



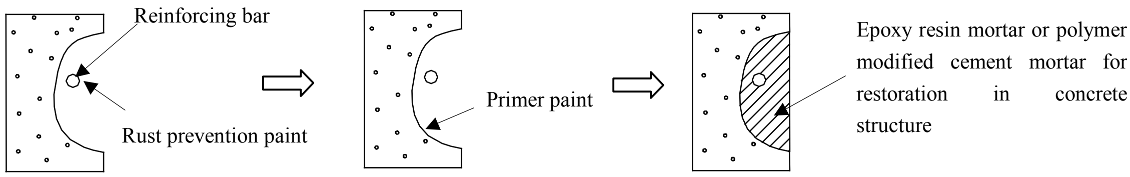
(2) Protection of vertical shaft

Extension of the vertical shaft on the existing concrete is effective to secure entering into the gallery and to protect the shaft wall itself from collapse and gully erosion. Concrete or masonry work is applicable to the rehabilitation work.

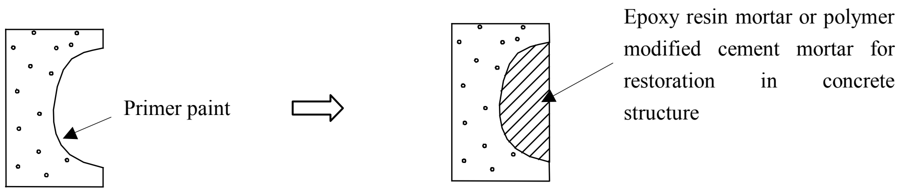


(3) Deterioration of concrete quality due to long use

Replacement with concrete canal or culvert is highly recommendable after demolition of the decrepit structures. Reinforcing bar shall be covered with mortar to protect its surface from a corrosion after concrete chipping and filing off rust as much as possible.



In case reinforcing bar is exposed



In case reinforcing bar is not exposed

(4) Rehabilitation of siphon

Siphon structure was introduced to collect riverbed flow. Since gallery section was too narrow to carried out maintenance work, siphon shall be replaced with large section of concrete, masonry as well as conduits such as concrete pipe, PVC pipe and FRP pipe (fiber reinforced plastics pipe). Filter material shall be placed around the structure to prevent from clogging of surroundings.

(5) Degrading of gallery base

It is suggested to degrading gallery base with following two methods:

Alternative 1: break concrete base and replace with concrete canal (tunnel work), and

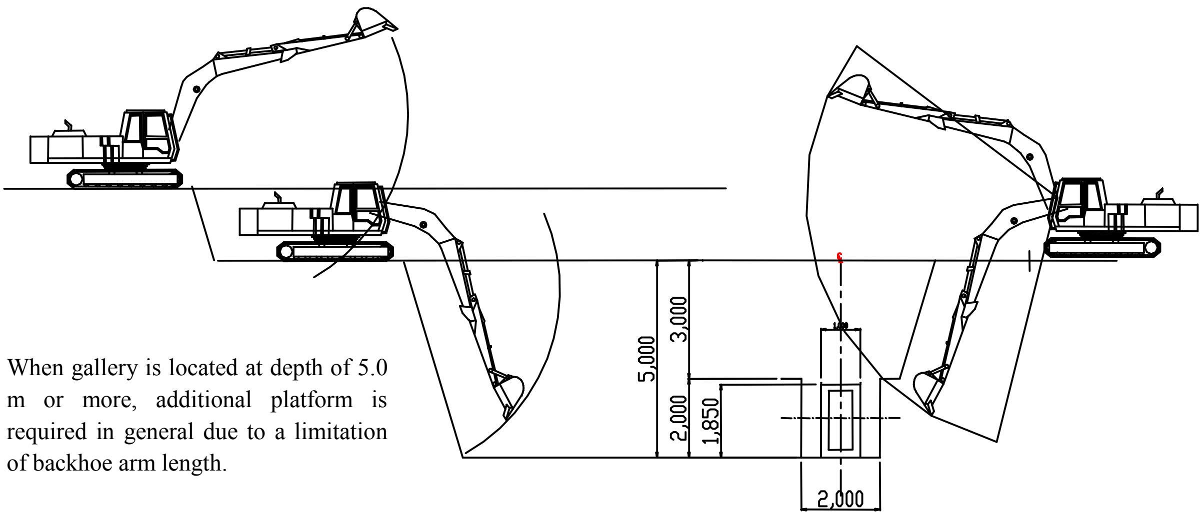
Alternative 2: newly construct gallery adjacent to the existing gallery (open excavation work)

Alternative 1 is quite useful as the rehabilitation method as long as its rehabilitation cost is reasonable. Alternative 2 may selected when gallery exists in shallow depth and cost for earth work is not so high. Slope of the galley base is determined considering a uniform flow depth (or hydraulic gradient). It has however higher precedence to settle the slope with a gentle slope when groundwater level is continuously depressing, especially at most upstream of the khettara.

6. Construction Planning

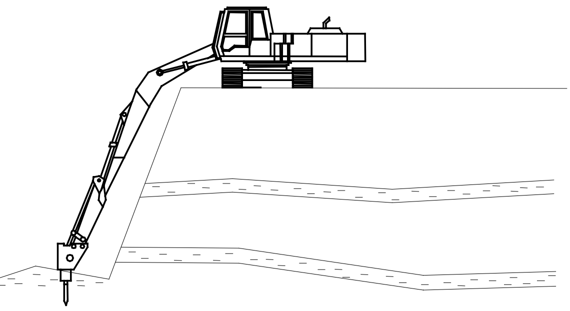
(1) Open excavation

In the case gallery is located in shallow depth, e.g. less than 5 m, an open excavation method is first recommended to secure the safety of labor, ease of construction, dewatering, etc.



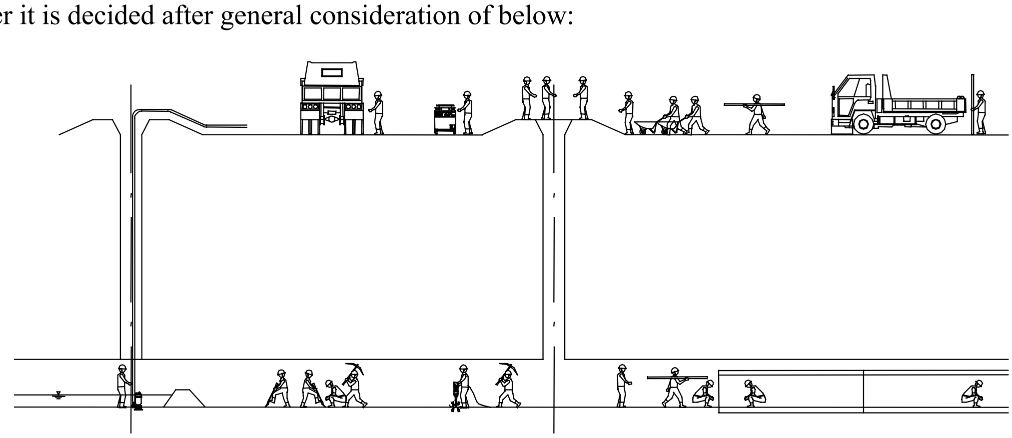
When gallery is located at depth of 5.0 m or more, additional platform is required in general due to a limitation of backhoe arm length.

When rock layers exist, first backhoe with breaker attachment shall be used to remove them. Explosives can not efficiently remove the rock, except outcrop of the rock according to the achievement during the Verification study.
Limestone layers and conglomerate are shown in Jorf area, and heavily cracked andesite is shown in Alnif and southern area of Tinejdad.

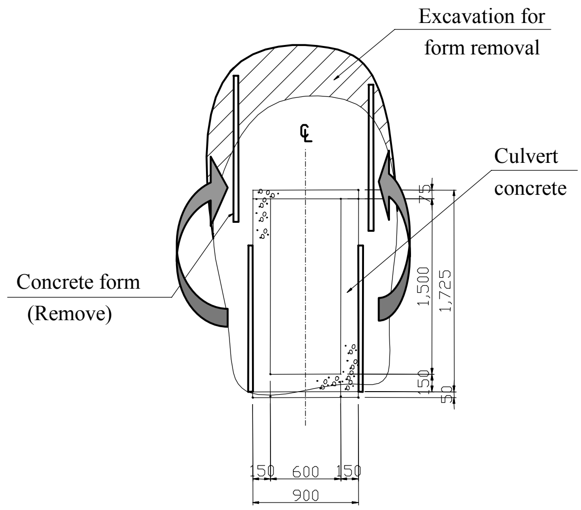


(2) Tunnel work

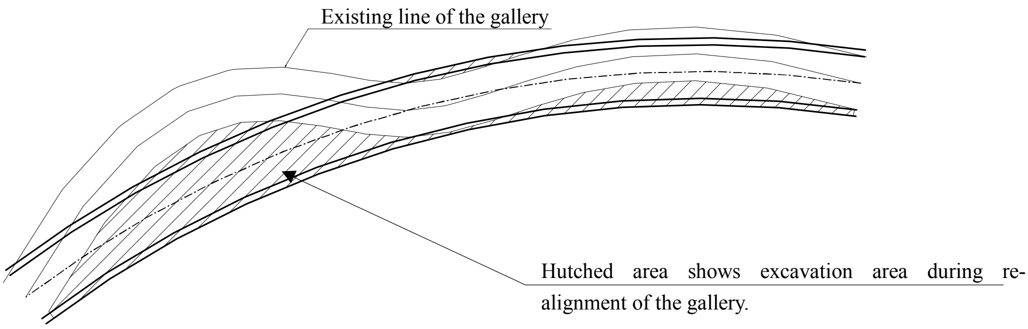
It becomes expensive to excavate more than 5 m in depth when ordinal backhoe (arem length 5 m) is used for the earth work. In this fact, tunnel work is reasonable when a gallery is located at 5 m deep or more. However it is decided after general consideration of below:



1) A barrel length of 12 m is generally applied to the gallery. In the case alignment of the existing gallery is indented and meandering complicatedly, excessive earth work may occur.



2) A certain open space is required for dewatering, mobilization of construction materials, installation/removal of concrete form, etc. When existing gallery section is small, especially upper part of the gallery, excessive earth work may occur.



(3) Dewatering

A by-path method is first recommended for dewatering. In the case dewatering by gravity or pumpage cannot be avoided during the construction for the reasons below, proper dewatering measures shall be adopted considering the water right at the downstream farmlands in the limits of the possible.

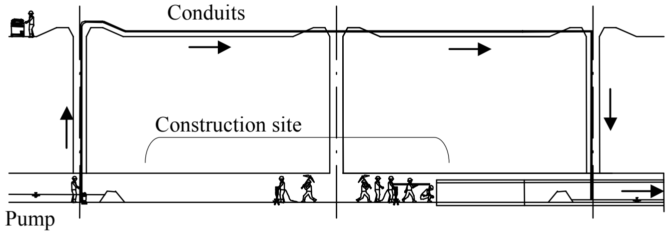
1) a possessory title to land (land owner does not allow relocation of the khettara)

2) topographical condition (plural khettaras are adjacent each other)

3) economical reasons (a by-path construction becomes more costly)

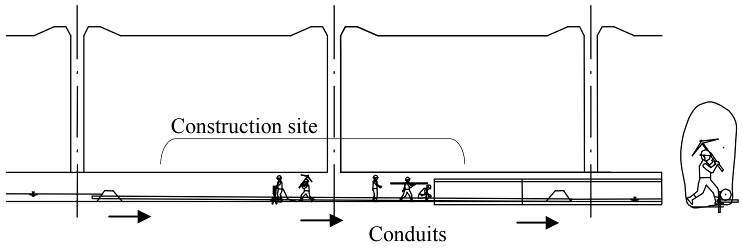
Dewatering by pump

Pump shall be continuously operated for 24 hours a day, otherwise muddy flow may stagnant on the construction site.



Dewatering by gravity

In the case water head between up and downstream is not so high, plural conduits are required to secure flow capacity.

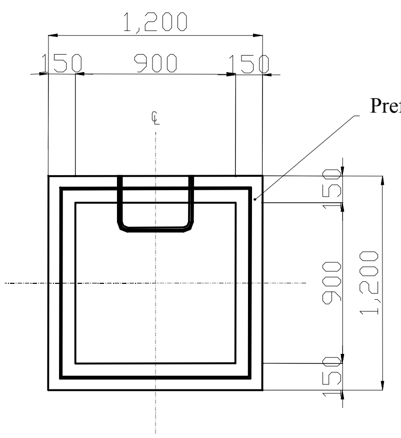


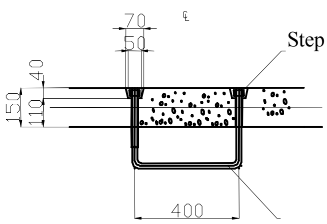
(4) Construction machinery and equipment

Availability of the construction machinery and equipment is most critical factor for construction scheduling, especially excavators such as bulldozer, backhoe, rock breaker include manual operation, etc. It is necessary to establish a proper construction schedule taking availability of backhoe into account in Errachidia.

(5) Pre-fabricated concrete

Pre-fabricated concrete shall be used for the vertical shaft because of its advantages of quality (compressive strength), shortening of the construction schedule. Applying pre-fabricated concrete contributes to standardization of gallery and shaft section for further rehabilitation works.





Prefabricate concrete used at khettara Oustania

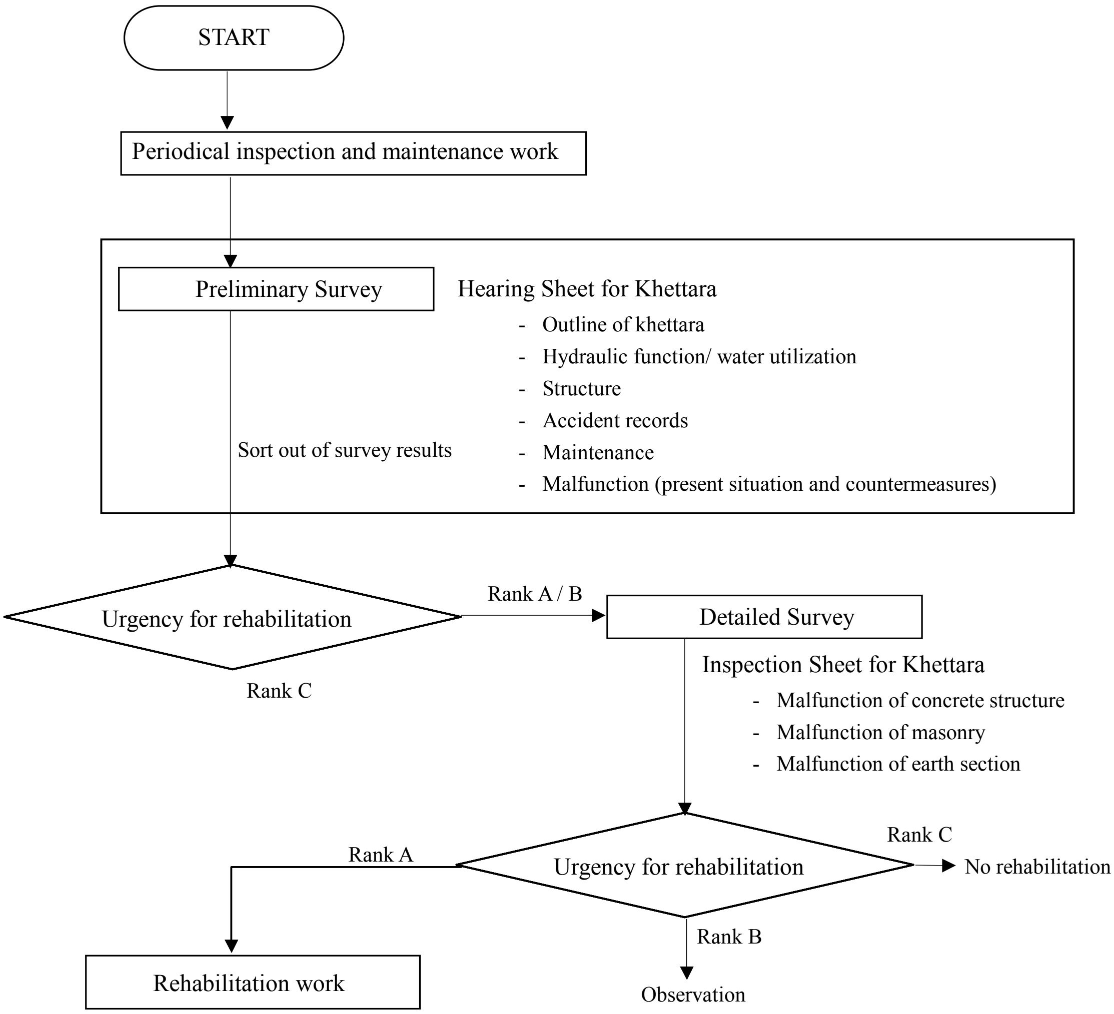
7. Maintenance of Khettaras

7.1 General

As described in Sub-chapter 1.8, daily and periodical inspections are effective to prevent some damages. Inspection is carried out to prevent a deterioration of the khettara in terms of physical and hydraulic problems before irrevocable damage occurs. Inspection is categorized into daily, periodically inspections and that taken upon any failure.

A daily inspection is carried out by a round on foot to find some collapse and sediment accumulation along the gallery. A periodical inspection is carried out once a year to find deterioration of whole khettara extent. Inspection upon failure is carried out base on the inspection method of daily and periodical inspections after some floods, as well.

It is recommended to prepare inspection sheet to store basic data which are effectively used for the prospective rehabilitation planning for a long term future.



Ranking: Necessity of urgent rehabilitation is judged by opinion of engineer and technician of the ORMVA/TF and scoring of inspection shown on Table 7.2.4 to 7.2.6.

Figure 7.1.1 Flow of Inspection and Rehabilitation Works

7.2 Rehabilitation of Khettaras

7.2.1 Preliminary Survey

Hearing records form khettara water user groups are collected and sorted out to determine a necessity of a detailed survey. The following are itemized for the preliminary study:

Table 7.2.1 Preliminary Survey Items

Items	Descriptions
1) Rehabilitation records	- Data collection (Drawings, discharge, geological profile, rehabilitation year) - Other information which may obstruct structural stability
2) Obstruction defined at present	- Obstruction in terms of water use, structural requirement (concrete crack, leakage, yield, uneven settlement, etc.) - Obstruction that a safety is extremely harmed.
3) Accident records	- Accident records (cause of accident, injury accident, site condition, etc.)
4) Task analysis on maintenance	- Current problem of maintenance - Necessity of urgent rehabilitation work

Sample hearing sheet is shown on Table 7.2.2.

Hearing results are sorted in sheet (Table 7.2.3) for further investigation. In case preliminary survey results in Rank "A" or "B", detailed survey shall be conducted to accurately judge a necessity of a rehabilitation work.

Table 7.2.2 Hearing Sheet for Khettara (1/2)

Items	Descriptions
1. Outline	
1) Khettara name	
2) Ksar, Commune rural	
3) Rehabilitation year	
4) Khettara length	Total length: m Open channel: m (Earth Concrete Masonry) Tunnel channel: m (Earth Concrete Masonry)
5) Observation	-Soil （ ） -Weathering
2. Hydraulic function/ water utilization	
1) Sediment (gravel, sand)	☐ Heavy (A) ☐ A few (B) ☐ not observed (C) ■Factor of sediment accumulation ( )
	Necessity to solve the problem (☐ Much necessary ☐Less necessary ☐ Not necessary)
2) Deterioration of water quality	☐ Heavy (A) ☐ A few (B) ☐ not observed (C) ■Factor of deterioration ( )
	Necessity to solve the problem (☐ Much necessary ☐Less necessary ☐ Not necessary)
3. Structure	
1) Collapse of gallery	☐ Heavy (A) ☐ A few (B) ☐ not observed (C) ■Factor of collapse ( )
2) Serious crack	☐ Heavy (A) ☐ A few (B) ☐ not observed (C) ■Factor of crack ( )
	Necessity to solve the problem (☐ Much necessary ☐Less necessary ☐ Not necessary)
3) Exposure of bar	☐ Heavy (A) ☐ A few (B) ☐ not observed (C) ■Factor of exposure of bar ( )
	Necessity to solve the problem (☐ Much necessary ☐Less necessary ☐ Not necessary)
4) Leakage	☐ Heavy (A) ☐ A few (B) ☐ not observed (C) ■Leakage part and factor of leakage ( )
	Necessity to solve the problem (☐ Much necessary ☐Less necessary ☐ Not necessary)

Table 7.2.2 Hearing Sheet for Khettara (2/2)

Items	Descriptions
4. Accident records	
1) Accident/ disaster	- Occurrence: (DD/MM/YY) Description of accident ( )
5. Maintenance	
1) Problem on maintenance	☐ Yes ☐ No If yes, matter of problem ( )
2) Cost for maintenance	■Maintenance cost (MM/YY) DH (MM/YY) DH (MM/YY) DH ■Factor when cost increased every year ( )
	Necessity to solve the problem (☐ Much necessary ☐Less necessary ☐ Not necessary)
7. Malfunction (present situation and countermeasures)	
1) Situation of malfunction	☐ Serious ☐ not serious ☐ not observed ■Factor of malfunction ( )
2) Cause of malfunction	Cause of malfunction is: ☐ obviously identified. ☐ not obvious identified, but there is doubtful factor. ☐ unaccountable. ■Factor of malfunction ( )
3) Necessity of field investigation	☐ necessary ☐ not necessary ■Reasons ( )
4) Urgency for rehabilitation	☐ urgently necessary (A) ☐ necessary within 5 years (B) ☐ necessary within 10 years(C) ☐ not urgently necessary(C) ■Reasons ( )
8. Inclusive observation	

Table 7.2.3 Summery Sheet of Preliminary Survey

	1.General			2. Water use		3. Structure				8. Urgency for rehabilitation
No.	1) Khettara	2)Ksar/ Commune rural	3)Khettara length (m)	1) Sediment	2) Water quality	1)Collapse of gallery	2) Serious crack	3) Exposure of bar	4) Leakage	
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										

Rank	Rehabilitation	Ranking rule	Others
A	Highly necessary	A>1 mark or B>4 marks	
B	Investigation required	between A and B	
C	Observation for the time being	A=0 mark and B<3 marks	

7.2.2 Detailed Survey

(1) Scope of survey

Survey method and scope of survey are determined in accordance with the results of the preliminary survey. Survey items are as follows:

Rank A: Whole line is surveyed with survey unit of 10 m to 100 m.

Rank B: At least 20 % of the whole line shall be surveyed. (Sampling is 2 sites in 100m long)

Survey sheets are shown on Table 7.2.6 to 7.2.8 according to a structural type of the khettara. Survey items and methods are tabulated below:

Table 7.2.4 Survey Items and Methods for Detailed Survey

Survey Items	Survey Methods
Crack on concrete and masonry	Crack width and length are measured and recorded.
Settlement	External appearances are checked by a visual observation
Separation of concrete	Shape and area of concrete separation are measured and observed.
Damage / scouring	Scale of damages and scouring depth are measured
Joint damages	Opening of joints and leakage amount are measured by scale and current meter.
Collapse of wall materials	Frequency of sediment removal is one of the effective indicator to judge a present condition of the gallery and shaft walls.
Others	Geological investigation is also effective to evaluate a susceptibility of collapse.

(2) Evaluation

Evaluation is conducted by survey unit. In the manual, survey unit is defined as follows:

Survey unit : 100 m

Table 7.2.4 to 7.2.6 indicate "score", and necessity of rehabilitation work is determined according to this score. The following are proposed standard for the evaluation, however conclusion by engineers has higher preference to the evaluation:

Table 7.2.5 Evaluation Standard (Survey Unit basis)

Necessity of rehabilitation	Score	Rank	Evaluation
Necessary	Equal to 11 or more	A	As deterioration such as scouring, deformation has proceeded, rehabilitation works is urgently required.
Observation	3 to 10 score	B	Khettara structure is not so disturbed, however there found initial deterioration. Rehabilitation is not urgently required.
Not necessary	Equal to 2 or less	C	No rehabilitation work is required at present.

Table 7.2.6 Inspection Sheet on Concrete (Detailed Survey)

Commune Rural/Ksar	Name of Khettara (ID No.)

Total Length	Inspection Length	Station No.	Completion year

Date of Inspection	Name of Inspector

Survey Items	Indicators	Rank of Deterioration					
		Rank A		Rank B		Rank C	
		Descriptions	Evaluation	Descriptions	Evaluation	Descriptions	Evaluation
1. Concrete crack							
Reinf. concrete (below water level)	Rehabilitation is necessary if crack width is more than 0.2 mm	1.0 mm < Crack	4	0.2mm < Crack <1.0 mm	2	Crack < 0.2 mm	0
Reinf. concrete (above water level)	Rehabilitation is necessary if crack width is more than 0.6 mm and length is more than 1.0 m	0.6 mm < Crack and 1.0 m < Length 5.0 mm < Crack max	2	0.6 mm < Crack and 1.0 m < Length Crack max < 5.0 mm	1	Crack < 0.6 mm	0
Plain concrete	Rehabilitation is necessary if crack width is more than 3.0 mm	5.0 mm < Crack	2	3.0 mm < Crack <5.0 mm	1	Crack < 3.0 mm	0
2. Settlement	Degree	Inclined or uneven settlement	4	Partially uneven settlement	2	No deformation	0
3. Deformation							
Separation of concrete surface with bar exposure	Separate portion in a barrel (9 to 12 m long)	2 portions or more	2	Less than 2 portions	1	not found	0
Separation of concrete surface without bar exposure	Separate portion in a barrel (9 to 12 m long)	2 portions or more	4	Less than 2 portions	2	not found	0
Damage / scouring	Depth and area	member thickness < Depth	2	Depth < member thickness	1	not found	0
Deterioration	Exposure of aggregates in a barrel (9 to 12 m long)	2 portions or more	2	Less than 2 portions	1	not found	0
4. Concrete joint							
Joint materials	Separation, gaps (rate of damage)	more than 10 %	2	5 - 9 %	1	less than 4 %	0
Joint	Leakage, etc.	more than 5 %	2	2 - 4 %	1	less than 1 %	0
Sub-Total							
Total							

Table 7.2.7 Inspection Sheet on Masonry (Detailed Survey)

Commune Rural/Ksar	Name of Khettara (ID No.)	Total Length	Inspection Length	Station No.	Completion year	Date of Inspection	Name of Inspector

Survey Items	Indicators	Rank of Deterioration								
		Rank A			Rank B			Rank C		
		Descriptions	Evaluation		Descriptions	Evaluation		Descriptions	Evaluation	
1. Crack of masonry										
Wet masonry	Rehabilitation is necessary if crack width is more than 5 mm	5.0 mm < Crack	4		2.0 mm < Crack <5.0 mm	2		Crack < 2.0 mm	0	
2. Crack of concrete										
Top slab concrete	Rehabilitation is necessary if crack width is more than 0.6 mm and length is more than 1.0 m	0.6 mm < Crack and 1.0 m < Length 5.0 mm < Crack max	2		0.6 mm < Crack and 1.0 m < Length Crack max < 5.0 mm	1		Crack < 0.6 mm	0	
Base concrete	Rehabilitation is necessary if crack width is more than 3.0 mm	5.0 mm < Crack	2		3.0 mm < Crack <5.0 mm	1		Crack < 3.0 mm	0	
3. Settlement	Degree	Inclined or uneven settlement	4		Partially uneven settlement	2		No deformation	0	
4. Deformation (Masonry)										
Damage / scouring	Depth and area	Member thickness < Depth	2		Depth < Member thickness	1		not found	0	
Deterioration	Damage of filling mortar	more than 10 %	2		5 - 9 %	1		less than 4 %	0	
5. Deformation (Concrete)										
Separation of concrete surface with bar exposure	Separate portion in a barrel (9 to 12 m long)	2 portions or more	2		Less than 2 portions	1		not found	0	
Separation of concrete surface without bar exposure	Separate portion in a barrel (9 to 12 m long)	2 portions or more	4		Less than 2 portions	2		not found	0	
Damage / scouring	Depth and area	member thickness < Depth	2		Depth < member thickness	1		not found	0	
Deterioration	Exposure of aggregates in a barrel (9 to 12 m long)	2 portions or more	2		Less than 2 portions	1		not found	0	
Sub-Total										
Total										

Table 7.2.8 Inspection Sheet on Earth Section (Detailed Survey)

Commune Rurale/Ksar	Name of Khettara (ID No.)

Total Length	Inspection Length	Station No.	Completion year

Date of Inspection	Name of Inspector

Length:	Sta. No. - Sta. No.

(Present sheet) of (total sheet)

Survey Items	Indicators	Rank of Deterioration								
		Rank A			Rank B			Rank C		
		Descriptions	Evaluation		Descriptions	Evaluation		Descriptions	Evaluation	
1. Collapse of gallery										
Wall condition	Rehabilitation is necessary if collapse occurs frequently.	Every month	2		Once in two to three months	1		Once in a half year	0	
2. Collapse of shaft										
Wall condition	Rehabilitation is necessary if collapse occurs frequently.	Every month	2		Once in two to three months	1		Once in a half year	0	
Collar of shaft entrance	Rehabilitation is necessary if collapse occurs frequently.	Every month	2		Once in two to three months	1		Once in a half year	0	
3. Scouring	Depth and area	5 cm depth or more a year	2		less than 5 cm a year	1		not found	0	
4. Water leakage	Amount of leakage	5 lit/sec or more per km	2		2 - 5 lit/sec per km	1		less than 2 lit/sec per km	0	
5. Entering to gallery										
Vertical shat	Interval of shafts (kept open)	More than 500 m in max.	2		100 - 500 m in max	1		less than 100 m in max	0	
Gallery	Section les than 1.2 m high	More than 500 m in max.	2		100 - 500 m in max	1		less than 100 m in max		
Sub-Total										
Total										

Note: Inspection sheet is filled up in gallery length of 1.0 km or less.

Table 7.2.9 Summary Sheet of Detailed Survey

Commune / Ksar	Name of khettara (ID No.)	Total length (m)	Inspection length (m)	Date:
				Inspector:

A: Urgently rehabilitation is necessary.
B: Rehabilitation is necessary in the near future.
C: No problem at present

Inspection sheet No.	Category	Structure	Section, etc.	Length (m)	Accumulated length (m)	Rank	Rank of deterioration			Remarks
							Rank A	Rank B	Rank C	
	(Example)									
1-1	*Gallery*	*Unlined*	*Gravel*	*750*	*750*	*A*	*750*			*Additional survey required*
1-2	*-do-*	*Unlined*	*Clayey silt*	*1,000*	*1,750*	*C*			*1,000*	
1-3	*-do-*	*Reinforced concrete*	*B0.6m x H1.2m*	*300*	*2,050*	*B*		*300*		
1-4	*-do-*	*Masonry*	*B0.6m x H1.2m*	*100*	*2,150*	*A*	*100*			
1-5	*Open channel*	*Plain concrete*	*B0.6m x H1.2m*	*50*	*2,200*	*C*			*50*	*Continue observation*
1-6	*Regulating basin*	*Reinforced concrete*	*B15.0m x W12.0m x H1.0m*	*---*						
Total				*2,200*			*850*	*300*	*1,050*	
Ratio in total length							*39%*	*14%*	*48%*	
Evaluation			*(Overall) B*	*Most upstream portion requires rehabilitation in urgent. Removal of sediment may effective for the work.*						

7.2.3 Periodical Inspection and Maintenance

Many khettaras have suffered damages from natural phenomena such as heavy rainfall, floods, movement of sand dune and collapse of gallery wall due to a repeated phenomena accompanied by dryness and moisture in the gallery. Amongst these various causes, flood inflow heavily damages the galleries and vertical shafts, especially the khettaras located adjacent to the rivers. In this fact, periodical inspection and maintenance work are indispensable to keep damages in minimum. The work shall be carried out paying attention of the points below:

(1) Work plan

- (a) Object of inspection (vertical shaft, gallery, embankment around shaft, water-route of the river, river dike, protection of shaft, etc.)
- (b) Maintenance method (material selection, budget preparation, etc.)
- (c) Inspection and maintenance schedule (prior to the season of heavy rain, and immediately after floods pass by)
- (d) Responsibility (Chief of khettara, engineer and technician of the ORMVA/TF and local government staff)

(2) Recording of the work

Recording form is shown in Table 7.2.10.

Inspection items

1. Structure	2. Water use	3. Accident records
Deformation, settlement, concrete and mortar cracking, exposure of bar, concrete joint damages, etc.	Leakage from concrete crack and foundation	Flood damage (natural river, artificial drainage canal, canal network for flood irrigation systems, etc.)

⇩ ⇩ ⇩

Maintenance items

Permanent and temporary repair	Mortar plastering on surface crack	Construction of flood protection dike
Partial repair of gallery wall	Concrete placing on the foundation	Extension of shaft entrance
Protection of shaft	Re-profiling of gallery	Construction of drainage canal
Dredging work of gallery		

Table 7.2.10 Recording Form for Periodical Inspection and Maintenance Works

	Date:	Inspector:
Commune/Ksar Name:		
Khettara Name:		
Chief of khettara:		

Inspection items	Remarkable points
1. Structure	Permanent and temporary repair:
2. Water use	Removal of sediment Leakage from concrete crack and foundation:
3. Accident record	Flood damage (natural river, artificial drainage canal, canal network for flood irrigation systems, etc.):
4. Opinion of Chief of khettara	
5. Opinion of Inspector	

Maintenance items	Work items and quantity
1. Structure	Removal of sediment Permanent and temporary repair: (Work items) (Work quantity)
2. Water use	Leakage from concrete crack and foundation: (Work items) (Work quantity)

8. Rehabilitation Records of Khettaras

8.1 Rehabilitation Records

Table F.8.2 shows khettara discharge, gallery length and rehabilitated quantity of 191 productive khettaras, which are functioning at present. The following are remarks of the table:

1) Total length: Total length of khettaras based on the inventory survey and detailed survey for 37 selected khettaras.

2) Rehabilitated length: Total length of khettaras rehabilitated by concrete or masonry, based on the inventory survey and detailed survey for 37 selected khettaras. Accordingly rehabilitation length includes excessively narrow section and superannuated structures.

3) Irrigation canal length:

   Total length of primary irrigation canal, composed of earth, concrete and masonry materials based on the inventory survey and detailed survey for 37 selected khettaras.

4) Rehabilitation work by ORMVA/TF

   Rehabilitation works under the PDRT project from 1992 to 2002. Rehabilitation works were categorized into a) dredging and re-profiling of gallery, b) extension of gallery, c) protection, d) construction of gallery, e) coverage of gallery with concrete slab, f) revetment (extension of side wall of gallery), g) shaft protection and h) regulating basin construction.

5) Small scale grant / verification study

   Rehabilitation works under the Japanese technical and financial assistances, i.e. small scale grant aid program and the Verification study by the JICA. Rehabilitation works are broadly categorized into re-profiling of gallery and construction of gallery section by concrete.

8.2 Analysis of Rehabilitation History

Rehabilitation works are summarized below:

Rehabilitation rate is estimated at average 10.2 % in 191 khettaras as shown on Table 8.2.1. Rehabilitation rate of each zone has a certain dispersion. Columns g and i in the table show rehabilitation rate in length and discharge rate against total khettara discharge, respectively. Higher rehabilitation rate is shown in Zones F and G, while khettara discharge is smaller in these zones. In this fact, it is concluded that rehabilitation work has provided to these areas taking a serious view of their severe weather condition.

It is expected further rehabilitation is carried out taking these rehabilitation records into account.

Table 8.2.1 Rehabilitation Rate by Zone

Zone	Khettara Length (m)	Number of khettaras	Construction by ORMVA/TF (m)	Construction by Japanese assistance (m)	Total Rehabilitation Length (m)	Rehabilitation Length per khettara (m)	**Rehabilitation rates (%)**	Total khettara discharge by zone (lit/sec)	**Khettara discharge rate by zone (%)**
	a	b	c	d	e	f	**g**	h	**i**
A	129,415	80	13,926	2,260	16,186	202	**12.5**	392	**30.7**
B	25,763	20	450	45	495	25	**1.9**	226	**17.7**
C	41,829	8	3,945	0	3,945	493	**9.4**	105	**8.2**
D	133,470	21	6,107	1,690	7,797	371	**5.8**	318	**24.9**
E	90,084	14	3,557	500	4,057	290	**4.5**	119	**9.3**
F	42,775	11	8,228	500	8,728	793	**20.4**	28	**2.2**
G	76,663	37	12,105	1,750	13,855	375	**18.1**	89	**6.7**
Total	539,999	191	48,318	6,745	55,063	288	**10.2**	1,277	**100.0**

Table 8.2.2 Khettara Rehabilitation Records (191 Khettaras)

: Detaied survey (37 khettaras)

Zone No.*[3]	Khettara	Ksar	Discharge (lit/sec)	Khettara length (m)		Irrigation Canal Length (m)				Rehabilitation Work by ORMVA/TF (1992 to 2002) *[2]								Small scale grant / Verification study	
			(Observed discharge in 2005 multiplies 1.3)	Total Length	Rehabilitated Length *[1]	Total Length	Earth	Concrete	Masonry	Re-profiling (m)	Exten-sion (m)	Protec-tion (m)	Const-ruction (m)	Cover (m)	Revet-ment (m)	Puits (no.)	Basin (no.)	Re-profiling (m)	Const-ruction (m)
A - 1	Taoutoutoute	Taoutoutoute	2.30	700		600	600												
A - 2	Iminkine	Iminkine	1.10	700		600	600												
A - 3	Ait oulhou	Ait oulhou	2.30	750		400	400												
A - 4	Toufaghantaste	Ait khlifa	3.40	350		500	500												
A - 5	Akkerouz	Akkerouz	1.70	630		1,100	1,100			1,300									
A - 6	Amgane	Amgane	2.30	1,600		1,000	1,000												
A - 7	Tighramt	Tighramt	1.70	250		1,000	1,000												
A - 8	**Ighrane**	**lghrane**	**7.30**	**1,286**	**1,118**	**2,056**	**1,845**	**211**					**800**						
A - 9	lkachrane	lkachrane	1.70	300		700	700												
A - 10	Ouine Oufroukh	Ouine Oufroukh	1.80	32		500	500												
A - 11	**Ouinigui**	**Ouinigui**	**3.60**	**754**	**638**	**1,317**	**439**	**878**		**500**			**680**						
A - 12	**Oukhite**	**Oukhite**	**10.10**	**1,656**	**981**	**6,431**	**5,700**	**710**	**21**	**8,700**			**70**				**1**		
A - 13	Ami Ali	El Galta	1.00	1,350		794	434	360											
A - 14	**Tiguida**	**Tiguida**	**3.10**	**1,010**		**1,678**	**1,196**	**482**											
A - 15	**Aghroud**	**Aghroud**	**10.60**	**2,927**	**859**	**1,150**	**800**	**350**		**300**			**660**			**12**			
A - 23	Ami Ahmed	Ami Ahmed	0.50	1,299		360		360									1		
A - 25	Darte Dghouvaues		6.80	1,120		6,000	2,000	4,000											
A - 31	Bou ouguiss		1.60	60		1,000	1,000												
A - 41	Bakassia	Tizagaghine	22.30	3,021	100	700	460	240					100						300
A - 42	Maamrya	Tizagaghine	10.00	3,500		2,900	1,300	1,600					180						
A - 43	Ami Hassan	Tizagaghine	7.60	5,310		50		50											
A - 44	**Lakbira**	**Tizagaghine**	**7.70**	**2,250**	**78**	**2,243**	**2,225**	**18**											
A - 45	El Mehdia	Tizagaghine	2.30	3,000		800	800												
A - 46	Atti Kida	Tizagaghine	6.80	3,500	1,040	5,000	1,000	4,000											
A - 47	Regaga	Ait Ba Maati	4.50	3,100		2,500	2,500												
A - 48	Mouyjna	Ait Ba Maati	8.20	4,000		1,500	300	1,200											
A - 49	**Ait My Mamoun**	**Ait My Mamoun**	**5.20**	**1,529**	**461**	**790**	**652**	**138**		**450**			**950**				**1**		
A - 50	Litama	Litama	8.50	3,000	2,088	6,000	5,500	500					2,018						

Zone No.*[3]	Khettara	Ksar	Discharge (lit/sec) (Observed discharge in 2005 multiplies 1.3)	Khettara length (m)		Irrigation Canal Length (m)				Rehabilitation Work by ORMVA/TF (1992 to 2002) *[2]								Small scale grant / Verification study	
				Total Length	Rehabilitated Length *[1]	Total Length	Earth	Concrete	Masonry	Re-profiling (m)	Exten-sion (m)	Protec-tion (m)	Const-ruction (m)	Cover (m)	Revet-ment (m)	Puits (no.)	Basin (no.)	Re-profiling (m)	Const-ruction (m)
A - 51	**Ait Oulghoume**	**Dar Oumira**	**11.40**	**1,207**	**169**	**1,955**	**1,907**	**48**		**750**			**250**						
A - 52	Dar Omira Lakdima	Dar Oumira	1.80	210	250	700	700												
A - 53	Ikhf N'lghir	Dar Oumira	0.70	1,000		500	500												
A - 54	Dar Omira Jdida	Dar Oumira	7.90	3,000		600		600											
A - 55	Azag N'ouchen	Azag N'ouchen	4.50	3,200	50	3,500	1,750		1,750				161						360
A - 56	lzilf	lzilf	4.50	7,005	120	6,000	2,800	3,200											
A - 58	**Diba**	**Ksiba**	**4.10**	**1,700**	**700**	**750**	**710**	**40**		**500**			**300**						**300**
A - 59	**Ait Ben Omar**	**Ait Ben Amar**	**10.90**	**1,050**	**150**	**1,510**	**830**	**680**		**110**			**1,020**						**300**
A - 60	Cheikh	Ktaa Oued	12.50	6,140		290	290												
A - 61	Tamagourte	Tamagourte	1.30	900	450	300		300					450						
A - 63	Khamssine	Assoul	1.40	900	100	600	244	356			81								
A - 64	El Mach	Ait Ben Omar	2.30	1,506	260	500	500						260						
A - 65	Ait M'hmed	Ait M'hmed	1.40	2,000	215	1,000	1,000						215						
A - 66	Ihandar	Ihandar	9.70	1,000		1,200	1,200												
A - 67	Tighfarte	Tighfarte	9.70	5,405		2,000	1,700	300											1,000
A - 68	Lakdima (Ait Maamer)	Lakdima (Ait Maamer)	2.30	3,000	620	1,060	1,000	60					440				1		
A - 70	Ami Lhoussa	Agoudime	6.80	1,500		700	300	400											
A - 73	**Taghouchte**	**Taghouchte**	**5.40**	**1,057**	**422**	**1,412**	**1,227**	**185**											
A - 74	Taghya	Taghya	8.40	1,300	63	3,000	3,000				144		123						
A - 98	Kdima Assoul	Assoul	2.30	1,200		4,000		4,000											
A - 100	Drain Tamtatouchte	Tamtatouchte	9.10	3,500															

Zone No.*3	Khettara	Ksar	Discharge (lit/sec)	Khettara length (m)		Irrigation Canal Length (m)				Rehabilitation Work by ORMVA/TF (1992 to 2002) *2								Small scale grant / Verification study	
			(Observed discharge in 2005 multiplies 1.3)	Total Length	Rehabilitated Length *1	Total Length	Earth	Concrete	Masonry	Re-profiling (m)	Extension (m)	Protection (m)	Construction (m)	Cover (m)	Revetment (m)	Puits (no.)	Basin (no.)	Re-profiling (m)	Construction (m)
A - 101	Tamajjal Nouaoulzi		0.60	750		400	80	320											
A - 102	Aoulzi Tamazirte		9.10	450		1,600	1,600												
A - 103	Tamda	Tamda	6.80	455		4,100	820	3,280											
A - 104	Drain imider	Imider	6.80	6,000															
A - 105	Idmouma	Idmouma	1.80	1,550		1,100	220	880											
A - 106	Agoudime	Agoudime	7.90	970	850	1,300	1,300			600			926				2		
A - 107	Ouj	Oje	6.20	890		700	700												
A - 108	Tasskountite	Tasskountite	2.40	144		1,200	1,200						20						
A - 109	Outalamine	Outalamine	6.30	505	105	1,800	1,800						105						
A - 110	Oukhalk	Tiguida	0.80	550		2,100	2,100			400			1,660			1			
A - 111	Ait Mkhoun	Ait Mkhoun	3.70	960		400	400												
A - 112	Idelssene	Idelssine	2.40	236		1,400	280	1,120											
A - 113	Taltafroute	Taltafrout	23.50	1,275		3,200	640	2,560											
A - 114	Laaouina	Laaouina	4.30	964		1,770	1,770			1,060		71	340		1				
A - 115	Bouhadachia	Bouhadachia	0.10	1,107		86	86												
A - 116	El Maghzen	El maghzen	4.50	1,932		750		750					300						
A - 117	Elboutahiri	El boutahiri	2.30	600		120	120												
A - 118	Chrif	Chrif	1.10	479		200	200												
A - 119	Lhaj Thami	Lhaj Tahami	2.20	971		660	660												
A - 120	El arb	El arb	1.70	900		300	300												
A - 121	**El Hassania**	**Tilioulne**	**6.80**	**2,062**	**402**	**7,860**		**7,860**		**1,360**			**1,100**						
A - 126	Oultamayoust	Oultamayoust	3.40	288	19	660		660		200			635						
A - 127	Tourtite	Tourtite	6.80	871		1,200	240	960											
A - 128	Taldounte	Taldounte	4.50	514		1,200	240	960											
A - 129	Imider	Imider	1.10	6,120		600	120	420	60										
A - 130	Iguerguit	Iguerguit	4.00	156		806	806						120	100			1		
A - 131	Taourirte	Taourirte	0.60	289		250	250						43		360				
A - 132	Ihouna	Ait taghi	2.30	57		160	160												
A - 134	Imider	Imider	1.70	124		200	200												
A - 135	Oul N'tnayouste	Oul N'tnayouste	1.70	288		660		660											
A - 136	Lagar	Taoudaate	0.20	195		5			5										
			392.00	129,415	12,308	118,033	70,501	45,696	1,836	16,230	225	71	13,926	100	361	13	7		2,260
				(100%)									(11%)						(2%)

Zone No.*[3]	Khettara	Ksar	Discharge (lit/sec)	Khettara length (m)		Irrigation Canal Length (m)				Rehabilitation Work by ORMVA/TF (1992 to 2002) *[2]								Small scale grant / Verification study	
			(Observed discharge in 2005 multiplies 1.3)	Total Length	Rehabilitated Length *[1]	Total Length	Earth	Concrete	Masonry	Re-profiling (m)	Exten-sion (m)	Protec-tion (m)	Const-ruction (m)	Cover (m)	Revet-ment (m)	Puits (no.)	Basin (no.)	Re-profiling (m)	Const-ruction (m)
B - 1	Agoummad	Ait wazag	27.30	840		3,200	1,400	1,800		800									
B - 2	**Tamazaroute**	**Ait wazag**	**20.50**	**500**	**400**	**2,000**	**1,600**	**400**											
B - 3	Ait Sbaa	Ait sbaa	1.50	44		50		50											
B - 4	EL Ain	Almou chorfa	6.80	292		150		150										850	
B - 5	**Bousfssaf**	**Almou chorfa**	**11.40**	**1,000**		**3,500**	**2,500**	**1,000**											
B - 6	El Majen	Almou chorfa	6.80	312		66		66											
B - 7	El Fougania	Almou Vhorfa	1.10	1,000		450	450						250						
B - 8	Ait Yakoub (2)	Ait Yaakoub	2.80	9,350		4,500	4,500			3,800									
B - 10	Roda	Sbaik	17.00	1,300		2,000		2,000											
B - 12	Beni Tajit	Beni Tajit	22.70	670		2,500		2,500											
B - 13	Ait My Hachem	Almou chorfa	20.50	657		453		453					200						
B - 14	Jdida	Zaouit El Hajoui	20.50	2,084		4,000	1,000	3,000											
B - 15	El Hajoui Sidi Abrerrahmane	Zaouit El Hajoui	4.20	135		600	600												
B - 16	Tafejjaret	Tafejaret	4.50	1,519		1,200		1,200											
B - 17	Ain Chouater	Chouater	21.90	1,160		1,500		1,500											
B - 18	Douimniaa	Chouater	11.40	2,400		1,100	500	600											
B - 19	El Hajoui	Chouater	12.30	1,700		1,500		1,500											
B - 20	Talssinte		0.60	188		1,000		1,000											
B - 22	Ait Boubker / Youssef	Talsint	10.20	402		3,000		3,000											
B - 23	Talhamsoust	Talsint	1.70	210		7		7											
				25,763	400	32,776	12,550	20,226		4,600			450					850	45
				(100%)									(2%)						
C - 1	Oued Naam	Beni Ouzieme	10.20	4,300		1,500	300	1,050	150				125						
C - 2	Ouled Ali	Oued Naam	16.70	9,000	800	3,700	740	2,590	370	2,500			800						
C - 3	**Taouz**	**Oued Naam**	**19.30**	**3,500**	**1,500**	**4,990**	**1,300**	**3,690**					**150**						
C - 4	Lakbira	Labkira	10.20	5,500	200	2,000	1,000		1,000				200						
C - 5	**Lakdima**	**Oued Naam**	**13.60**	**3,079**	**2,330**	**1,077**		**1,077**					**470**						
C - 6	Jdida	Jida	22.70	5,850		2,400	480	1,680	240	1,000			300						
C - 7	Torba	Torba	3.90	4,400	3,000	1,400	700		700	1,500			1,500						
C - 8	Lahcen	CR	8.40	6,200	400	1,600	160	1,440					400						
				41,829	8,230	18,667	4,680	11,527	2,460	5,000			3,945						
				(100%)									(9%)						

Zone No.*[3]	Khettara	Ksar	Discharge (lit/sec)	Khettara length (m)		Irrigation Canal Length (m)				Rehabilitation Work by ORMVA/TF (1992 to 2002) *[2]								Small scale grant / Verification study	
			(Observed discharge in 2005 multiplies 1.3)	Total Length	Rehabilitated Length *[1]	Total Length	Earth	Concrete	Masonry	Re-profiling (m)	Exten-sion (m)	Protec-tion (m)	Const-ruction (m)	Cover (m)	Revet-ment (m)	Puits (no.)	Basin (no.)	Re-profiling (m)	Const-ruction (m)
D - 31	Lakbira	Taraa	9.10	9,800	7,000	3,000	2,000	1,000											
D - 34	Souihla	Oulad Ghanem	13.60	1,600	1,100	5,000	2,000	3,000					1,100						200
D - 35	Aissaouia	Oulad Ghanem	2.30	3,160		500		500											
D - 36	Saidia	Oulad Ghanem	3.90	4,360		900		900					400						
D - 41	**El Aissaouia**	**Oulad Aissa**	**6.40**	**8,800**	**2,065**	**1,591**	**1,591**												
D - 42	**Lambarkia**	**Mounkara**	**23.40**	**6,200**	**2,200**	**440**	**440**												
D - 44	**Lambarkia**	**Oulad M'barek**	**19.70**	**7,500**	**390**	**2,468**	**1,287**	**1,181**											**450**
D - 47	**Lahloua**	**Mounkara**	**21.50**	**9,000**	**1,500**	**6,675**	**4,765**	**1,910**											
D - 53	Kdima	Bouya	28.20	8,000	600	1,000		1,000										300	450
D - 54	**Jdida**	**Bouya**	**16.50**	**6,200**	**800**	**2,819**	**829**	**1,878**	**112**										
D - 55	**Kdima**	**Krair**	**16.70**	**5,700**	**2,000**	**2,865**	**1,850**	**1,015**											
D - 56	**Jdida**	**Krair**	**14.00**	**6,000**	**2,000**	**2,331**		**2,331**					**300**						
D - 58	**Khtitira**	**Hannabou**	**21.00**	**5,000**	**1,170**	**2,460**	**302**	**2,158**											
D - 59	**Sayed**	**Hannabou**	**11.70**	**5,500**	**1,326**	**1,542**	**305**	**1,237**											
D - 60	**Fougania**	**Hannabou**	**50.20**	**7,000**	**1,341**	**2,948**	**932**	**2,016**					**677**						
D - 61	**Oustania**	**Hannabou**	**6.80**	**7,700**	**1,200**	**1,440**		**1,440**					**1,070**					**200**	**300**
D - 62	Kdima	Krair	10.90	5,850		2,400	400	2,000											
D - 64	**Lagrinia**	**Hannabou**	**6.40**	**6,500**	**2,375**	**1,330**	**470**	**860**					**500**					**200**	**290**
D - 65	Laalouia (Hannabou)	Hannabou	8.20	6,500		1,900	400	1,500					810						
D - 66	Mostafia	Hannabou	5.30	6,800	1,250	800		800					1,250						
D - 69	Kdima		22.10	6,300		1,000		1,000											
				133,470	28,317	45,409	17,571	27,726	112				6,107					700	1,690
				(100%)									(5%)						(1%)

Zone No.*[3]	Khettara	Ksar	Discharge (lit/sec)	Khettara length (m)		Irrigation Canal Length (m)				Rehabilitation Work by ORMVA/TF (1992 to 2002) *[2]								Small scale grant / Verification study	
			(Observed discharge in 2005 multiplies 1.3)	Total Length	Rehabilitated Length *[1]	Total Length	Earth	Concrete	Masonry	Re-profiling (m)	Exten-sion (m)	Protec-tion (m)	Const-ruction (m)	Cover (m)	Revet-ment (m)	Puits (no.)	Basin (no.)	Re-profiling (m)	Const-ruction (m)
E - 1	El Ghanamia	A.S. Ziz	1.10	5,847		300	300												
E - 2	El bour	Sifa	4.90	7,570		30		30											
E - 4	Laagaya	Sifa	2.30	4,800		500		400											
E - 5	Jdida Bel Houcine	Sifa	0.60	7,120		30			30	1,600			500						
E - 6	Jdida Bel Houcine	Sifa	4.50	7,951		51		51											
E - 7	**Ramlia**	**Sifa**	**14.40**	**5,924**	**1,424**	**2,432**	**338**	**2,094**					**700**						
E - 8	**Lakdima Douar**	**Sifa**	**27.10**	**7,000**	**1,035**	**2,118**	**1,443**	**675**					**300**						
E - 9	Lihoudia	Sifa	1.40	5,940		1,300		1,300											
E - 10	Laglaglia	Sifa	3.40	5,473		100		100											
E - 12	Jdida Lhaj El Madani	Sifa	3.40	5,830	1,507	500	500						1,507	280					
E - 13	Laaguilia Kbour Lihoud	Sifa	4.00	6,540		15			15										
E - 14	Lhaj Alal	Sifa	28.30	9,039	250	130		130					250						
E - 15	Ighzer	Sifa	2.30	5,550		400			400										500
E - 16	**Charchmia**	**Sifa**	**21.10**	**5,500**	**717**	**1,879**	**777**	**1,102**					**300**						
				90,084	4,933	9,785	3,358	5,882	445	1,600			3,557	280					500
				(100%)									(4%)						(1%)
F - 1	**Loujarchia**	**Loujarcha**	**4.50**	**4,525**	**2,650**	**984**	**920**	**64**					**1,300**						
F - 24	Harounia	Haroun	0.60	7,000	675	600		600		3,000	100		1,175						
F - 27	Agaroum	Tagaroumte	1.10	500	250	400		400					500						
F - 32	Talaabast	Merzouga	6.80	3,000	1,510	1,800		1,700					1,510	1,200					500
F - 33	Tamaright	Merzouga	2.30	5,500	375	1,000	1,000						450						
F - 34	Tamazante	Merzouga	2.30	3,800	498	1,200	300	900					423						
F - 35	Taachaboute	Khamlia	0.60	2,100	300	400	200	200											
F - 36	**Hassi Labied**	**Hasi Labied**	**4.50**	**4,700**	**1,033**	**800**	**145**	**655**					**1,100**	**450**					
F - 38	El Bagaa	ElBagaa	1.70	6,000	1,470	1,100	300	700	100				1,470						
F - 40	Tamaright		2.90	2,250	300	1,000	950	50					300						
F - 42	Ait Taghla	Ramlia	1.10	3,400		1,100	700	320	80										
				42,775	9,061	10,384	4,515	5,589	180	3,000	100		8,228	1,650					500
				(100%)									(19%)						(1%)

Zone No.*[3]	Khettara	Ksar	Discharge (lit/sec) (Observed discharge in 2005 multiplies 1.3)	Khettara length (m)		Irrigation Canal Length (m)				Rehabilitation Work by ORMVA/TF (1992 to 2002) *[2]								Small scale grant / Verification study	
				Total Length	Rehabilitated Length *[1]	Total Length	Earth	Concrete	Masonry	Re-profiling (m)	Exten-sion (m)	Protec-tion (m)	Const-ruction (m)	Cover (m)	Revet-ment (m)	Puits (no.)	Basin (no.)	Re-profiling (m)	Const-ruction (m)
G - 1	M'Cissi	M'Cissi	0.60	3,400	875	22		22					875						
G - 3	Bouadil	Bouadil	5.70	1,500	600	180		180					600						
G - 4	Azag	Azag	1.10	1,900	361	700		700											
G - 13	Taghroute	Taghroute	1.20	1,252	894	400		320	80				894						
G - 14	Agoumad	Taghroute	0.80	690	550	1,000	300	700					550						800
G - 15	Alnif	Alnif	3.00	7,700	4,000	1,500		1,500											
G - 17	Ait Lahbib	Taghroute	0.30	3,050	300	1,100	700	400				103	267						
G - 18	Tizi Lakdima	Tizi	3.10	4,200	680	1,600	800	800					680						
G - 21	Jdida Ammar	Ammar	12.60	3,500	300	3,080	1,600	1,480					900						
G - 22	Azrag	Azrag	0.60	1,000		200	200						250						
G - 37	Ait Ben Said	Ait Ben Said	5.70	3,800	250	55		55		250			300						
G - 46	Tanoute Noumardoul	Tanout	1.10	490		300	300												
G - 47	Tagualgoulte	Taguelgout	1.20	1,590		680		680					250						
G - 48	Jorf	Jorf	1.10	2,800		700	700												
G - 52	Iminouzrou	lminouzrou	0.80	1,568	600	960		960			100		600						
G - 53	Tiguirna	Tiguirna	2.20	1,856	800	176		176					800						
G - 55	**Tinififte**	**Tinififte**	**5.50**	**1,410**		**2,545**	**1,745**	**800**					**660**						
G - 56	Afrou	Afrou-AdLghazi	1.10	1,093		1,800	1,800												
G - 57	Talghazit	Talghazite	0.60	513		500	500												
G - 58	Tihammate	Talghazite	2.30	900		600	600												
G - 59	Lakbira	Taoumart	0.50	1,000	423	3,013	1,240	1,773			120								
G - 60	**JdidaTaoumarte**	**Taoumart**	**2.00**	**600**		**500**		**500**					**250**					**300**	

Zone No.*[3]	Khettara	Ksar	Discharge (lit/sec) (Observed discharge in 2005 multiplies 1.3)	Khettara length (m)		Irrigation Canal Length (m)				Rehabilitation Work by ORMVA/TF (1992 to 2002) *[2]								Small scale grant / Verification study	
				Total Length	Rehabilitated Length *[1]	Total Length	Earth	Concrete	Masonry	Re-profiling (m)	Exten-sion (m)	Protec-tion (m)	Const-ruction (m)	Cover (m)	Revet-ment (m)	Puits (no.)	Basin (no.)	Re-profiling (m)	Const-ruction (m)
G - 61	Afrou	Taoumart	0.60	753		1,200	1,200												
G - 62	Tassamamte	Tassamamte	3.50	720		2,000		2,000			50								
G - 63	Toufassamman	Toufassamame	1.50	1,600		64		64											500
G - 64	**Timzarzit**	**Timarzit**	**2.00**	**2,100**	**290**	**700**		**700**					**250**						**450**
G - 65	Tajohrate	Tajouhart	1.70	570	300	600	600			250	116		300						
G - 67	Ait Mouhou	Ouihlane	0.20	1,200		2,400	2,400												
G - 77	Izougaghine	Ramlia	0.20	1,800	500	6,000	5,500	500											
G - 78	Tamlalt	Hsia	2.80	3,200		6,000		6,000											
G - 80	Tissamoumine	Tissamoumine	1.80	349	300	450	450						300						
G - 83	Takacha	Takacha	3.40	5,400	700	1,500	1,500						800						
G - 87	**Aachich Ait Iaza**	**Aachich**	**11.40**	**3,465**	**1,700**	**2,879**	**850**	**2,029**					**1,979**						
G - 89	Fouk Talilate	Aachich	0.60	2,414	300	1,300	1,300			100			300						
G - 94	Battou	Battou	2.30	3,000	300	160		160					300						
G - 95	Khtart Battou	Battou	1.70	2,120		2			2										
G - 103	Tizagarne	Tizagarne	2.30	2,160		2,000	2,000												
				76,663	15,023	48,866	26,285	22,499	82	600	386	103	12,105					300	1,750
				(100%)									(16%)						(2%)
			1668.90	539,999	78,272	283,920	139,460	139,145	5,115	31,030	711	174	48,318	2,030	361	13	7	1,850	6,745
											(1)	(2)	(3)	(4)	(5)			(6)	(7)

Rahabilitation rate : 10.2 (%)

Total (3) + (7)= 55,063

9. Design Standard and Interpretations

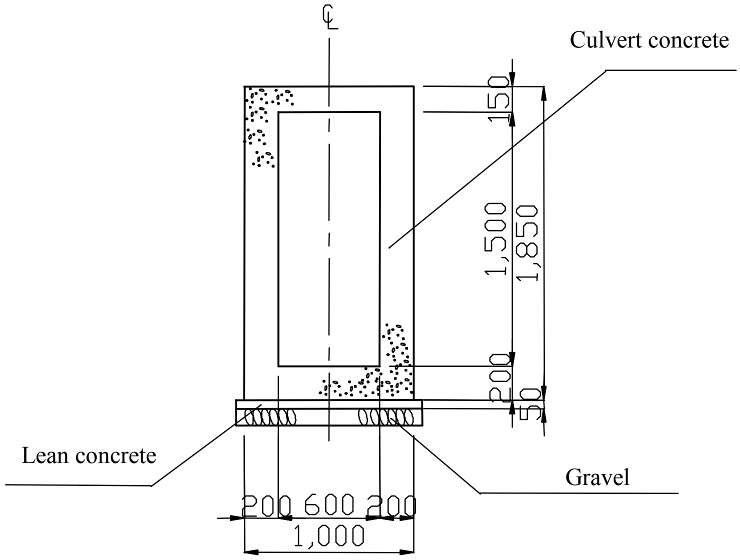
(1) Section of gallery

Code:	Classification	Gallery
	Items	Dimension
Revision record	Date	Competent authorities
First copy	mm/yy	
Design standard and interpretation		

(1) For smooth maintenance works, 0.6 m width is applicable to inside of gallery.

(2) For smooth maintenance works, 1.5 m height is applicable to inside of gallery.

Inside wall height of 1.5 m is recommended to decrease the work for the maintenance such as removal of sediment, etc. When comparing 1.2 m and 1.5 m height, the latter requires additional construction cost of about 15 %. In conducting a rehabilitation work, gallery height is deliberated from the view points of economical efficiency, and working environment (reducing workers' fatigue).



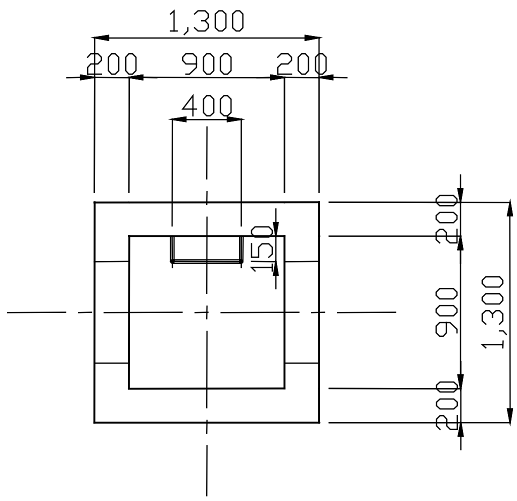
(2) Section of vertical shaft

Code:	Classification	Vertical shaft
	Items	Dimension
Revision record	Date	Competent authorities
First copy	mm/yy	
Design standard and interpretation		

(1) Section of vertical shaft is 0.9 m square.

When comparing 0.75 m square and 0.9 m square, the latter is recommended in terms of accessibility and space for disposal of accumulated sediment in the gallery.

(2) For safety purpose, step (diameter 20 mm) is in principle installed on the inside wall of the vertical shaft.



(3) Slope of excavation (Open excavation)

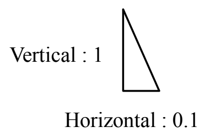
Code:	Classification	Earth work
	Items	Dimension
Revision record	Date	Competent authorities
First copy	mm/yy	
Design standard and interpretation		

(1) Slope for excavation is standardize as tabulated below:

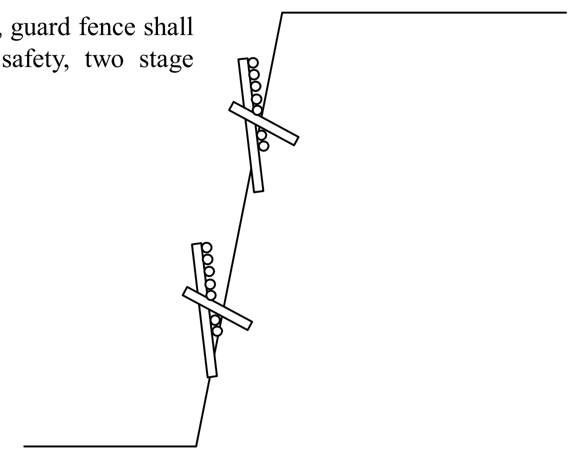
Slope of Excavation

Cutting height / Geology	less than 2 m	2 m < H < 5 m	5 m or higher
Rock , firm clay	0 - 0.1	0 - 0.3	0.3 -
Clayey soil	0 - 0.3	0.2 - 0.5	0.6 -
Silt	0.2 - 0.4	0 3 - 0.6	1.0 -
Sandy soil	0.4 - 0.6	0.5 - 1.2	1.2 -
Sand	1.5	1.5 -	not applicable
Gravel and gravel sand	0.3 - 0.8	0.6 - 1.5	not applicable

Note: In the case there exists berm of its width of more than 2.0 m on the cutting slope, slope height is estimated from the berm surface.



To avoid accident by a fall of rock, guard fence shall be installed on the slope. For safety, two stage fence is applicable.



(4) Water stop

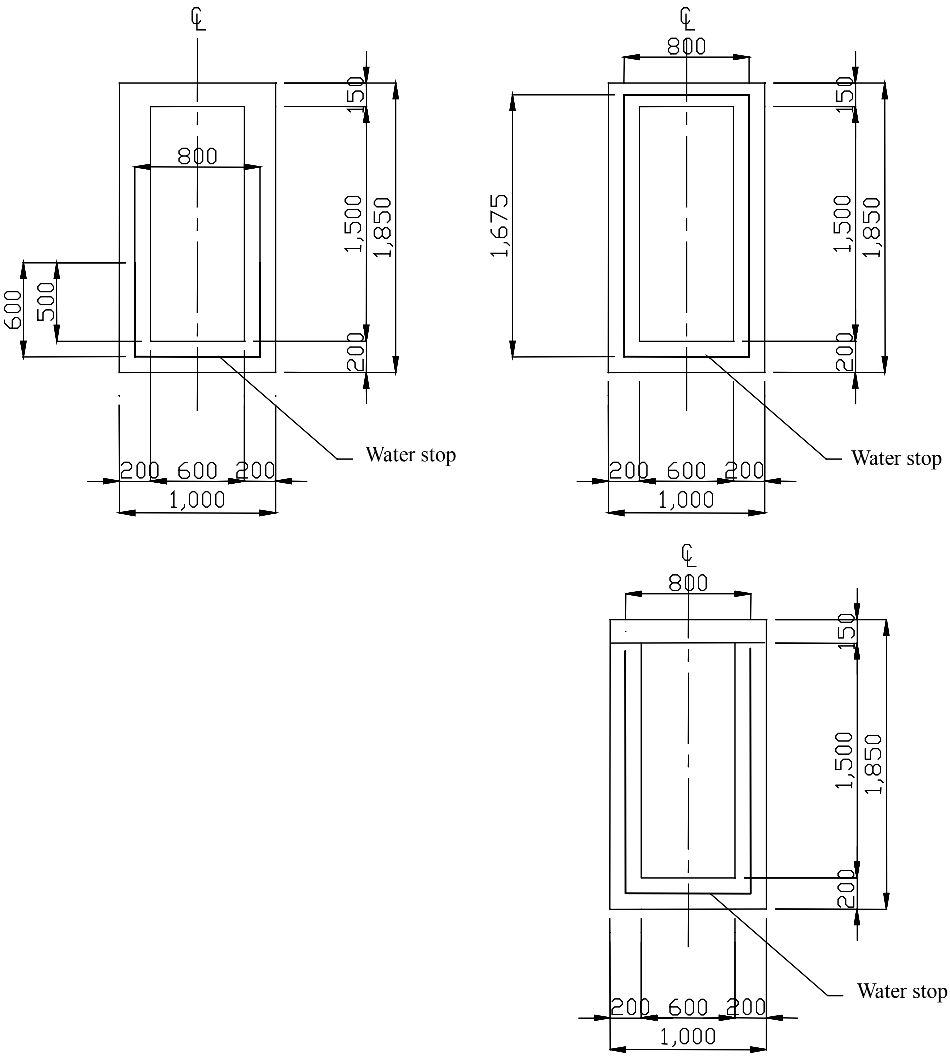
Code:	Classification	Earth work
	Items	Dimension
Revision record	Date	Competent authorities
First copy	mm/yy	

Design standard and interpretation

(1) Water stop is installed to prevent leakage of water from joints.

Water stop has its width 150 mm in principle. Both polyethylene and polyvinyl chloride materials are available for the water stop.

In the case water leakage does not occur, e.g. gallery foundation is composed of rock, water stop is not installed. Water stop is installed along the surrounding of concrete member except the cases as that water stop is limitedly installed above the water level to minimize the construction cost.



(5) Joint

Code:	Classification	Earth work
	Items	Dimension
Revision record	**Date**	**Competent authorities**
First copy	mm/yy	

Design standard and interpretation

Joints shall be provided at suitable positions in suitable intervals in accordance with the type and size of the structure and construction conditions.

(1) Contract joints

Contract joint is provided to prevent cracking of the concrete due to contraction, mainly by fluctuation of temperature. Generally, contract joints are mainly used in siphons, culverts and buried structure. Position of the contract joint is determined according to the type of structure, foundation and other conditions. Contraction joint is provided at standard intervals of 3 to 5 m in thin concrete linings of 10 cm or less, and in other structures at intervals of 9 to 12 m.

Pedestals or dowel bars are installed to prevent uneven settlement of the structure due to unconsolidated foundation.

(2) Expansion joints

The position of the expansion joint is determined according to the type of structure, foundations and other conditions. Expansion joint is provided at points where section and form change in principle. For a series of structures exposed above ground such as open channel, expansion joints are provided at intervals of 24 m. Expansion plates are inserted into a void of the joints.

Pedestals or dowel bars are installed to prevent uneven settlement of the structure due to unconsolidated foundation.

(6) Minimum thickness of member

Code:	Classification	Earth work
	Items	Dimension
Revision record	Date	Competent authorities
First copy	mm/yy	

Design standard and interpretation

1) Double reinforcement: 13 cm

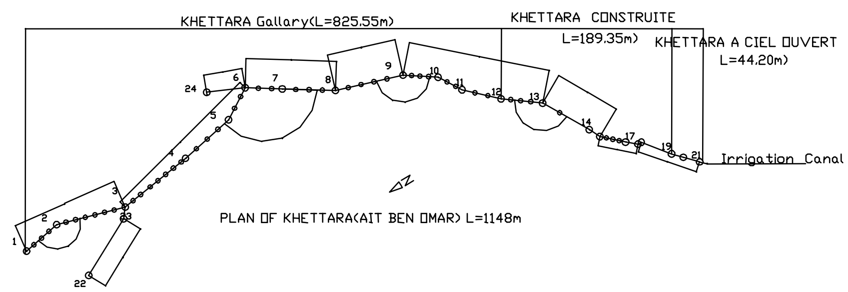
2) Single reinforcement: 20 cm

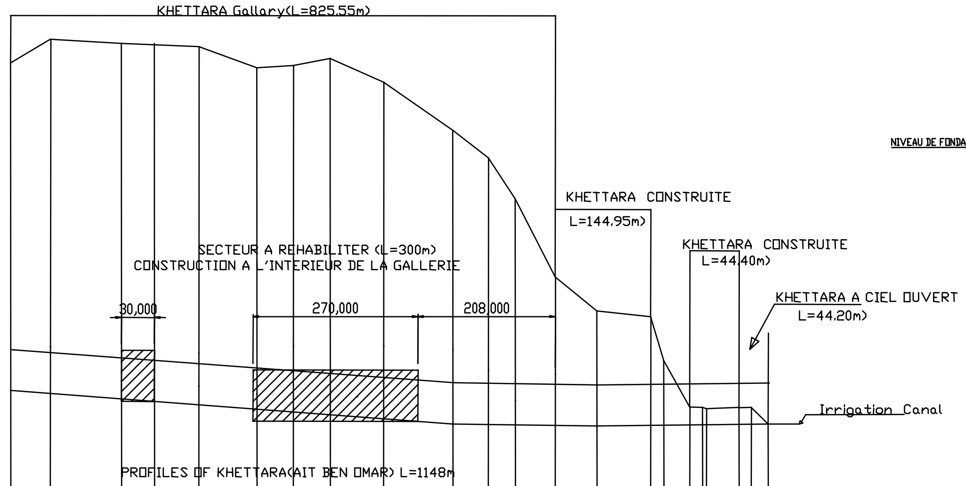
The minimum thickness of members used in concrete structure is generally determined in consideration of workability and water-tightness requirements. For good workability, vertical wall of 2.0 m or taller which use double reinforcement have a minimum thickness of 20 cm, and vertical wall shorter than 2.0 m using single reinforcement have a minimum thickness of 13 cm. Siphons and other structures subject to water pressure shall have a minimum thickness of 20 cm to ensure good workability and water tightness.

10. Standard Drawing

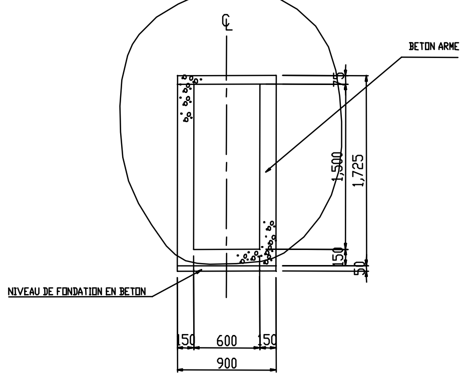
CP. 1 (1/10)

PLAN DE REHABILITATION DE LA KHETTARA





SECTION A REHABILITER



ECHELLE X=1/ 5000
ECHELLE Y=1/ 100

Point	COTE AU NIVEAU DU SOL	DISTANCE	DISTANCE CUMULEES	COTE DU LIT DU CANAL	ALIGNEMENT ET COURBE
1	1010.28		.00	1000.37	
2	1011.00	60.76	60.76		
3	1010.87	107.42	168.18		L=107.42
4	1010.78	117.56	285.74	999.94	L=117.56
5	1010.14	87.53	373.27		
6	1010.21	55.01	428.29		
7	1010.42	56.34	484.63		
8	1009.70	80.72	565.35		
9	1008.25	105.02	670.36	999.37	L=105.02
10	1007.41	53.54	723.90		
11	1006.18	41.04	764.94		
12	1003.81	60.62	825.56		
13	1002.78	63.43	888.99	999.30	
14	1002.60	81.48	970.48		
15	1001.28	19.32	989.80		
16	999.87	39.76	1029.56		
17	999.86	19.08	1048.64		
18	999.81		1054.71		
19	999.86	49.22	1103.94		
20	999.86	18.49	1122.42		
21	999.36	25.72	1148.14	999.36	

REMARQUES:
1.L'UNITE DE MESURE EST LE MM ET LES COTES SONT DONNEES EN M, SAUF SI AUTREMENT INDIQUES PAR LES DESSINS.

2.L'ENTREPRENEUR DOIT PREPARER LA PARTIE DES TRAVAUX RELATIVE AUX TERRASSEMENTS AVANT LE COMMENCEMENT DES TRAVAUX PROPREMENT DITS ET LA PRESENTER A L'INGENIEUR ET A L'ORMVA/TF POUR APPROBATION.

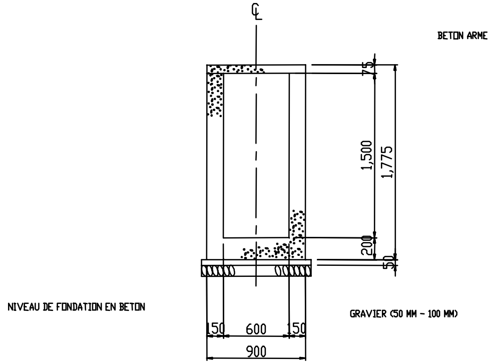
3. L'ENTREPRENEUR DOIT PREPARER LE PLAN DE DERIVATION AVANT LE COMMENCEMENT DES TRAVAUX ET LE SOUMETTRE A L'APPROBATION DE L'INGENIEUR ET DE L'ORMVA/TF.

PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC	
STUDY TEAM ORMVA/TF	CP. 1 PLAN NO 1-1 PLAN DE REHABILITATION DE LA KHETTARA AIT BEN OMAR
DATE:JUIN 2004	AGENCE JAPONAISE DE COOPERATION INTERNATIONALE

SECTION STANDARD ET DISPOSITION DES BARRES D'ARMATURE

CP. 1 (2/10)

SECTION A - A



REMARQUES:

1.L'UNITE DE MESURE EST LE MM ET LES COTES SONT DONNEES EN M, SAUF SI AUTREMENT INDIQUES PAR LES DESSINS.

2. LES CONTRAINTES ADMISSIBLES POUR LE BETON ARME SONT LES SUIVANTES :
CONTRAINTE DE COMPRESSION : 225 KG/CM² (22.5N/MM²)
CONTRAINTE DE CISAILLEMENT : 4,2 KG/CM² (0,4 N/MM²)
EFFORT D'ADHERENCE :15 KG/CM² (1,5 N/MM²)

3. LES CONTRAINTES DE COMPRESSION ADMISSIBLES DU BETON SONT LES SUIVANTES :
BETON ORDINAIRE (BA)176 KG/CM² (17.6N/MM²)
BETON MAIGRE (B4E):127 KG/CM² (12,7N/MM²)

4. LES BARS DEFORMEES SERONT UTILISEES LA CONTRAINTE DE TRACTION ADMISSIBLE DES BARRES D'ARMATURE EST DE 1400KG/CM² (140 N/MM²)

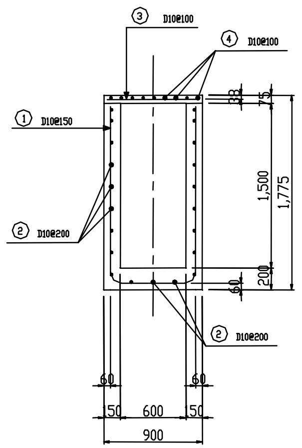
5. LA LONGUEUR DU JOINT DE RECOUVREMENT ET DE L'ANCRAGE N'EST PAS INFERIEURE A 30 FOIS LE DIAMETRE DE LA BARRE.

6. LES JOINTS DE RETRAIT SERONT INSTALLES AFIN D'EVITER LA FISSURATION DU BETON A CAUSE DE LA CONTRACTION. LES JOINTS DE RETRAIT SERONT INSTALLES A DES INTERVALS STANDARD DE 9 M SAUF SI LES DESSINS INDIQUENT D'AUTRES INTERVALS.

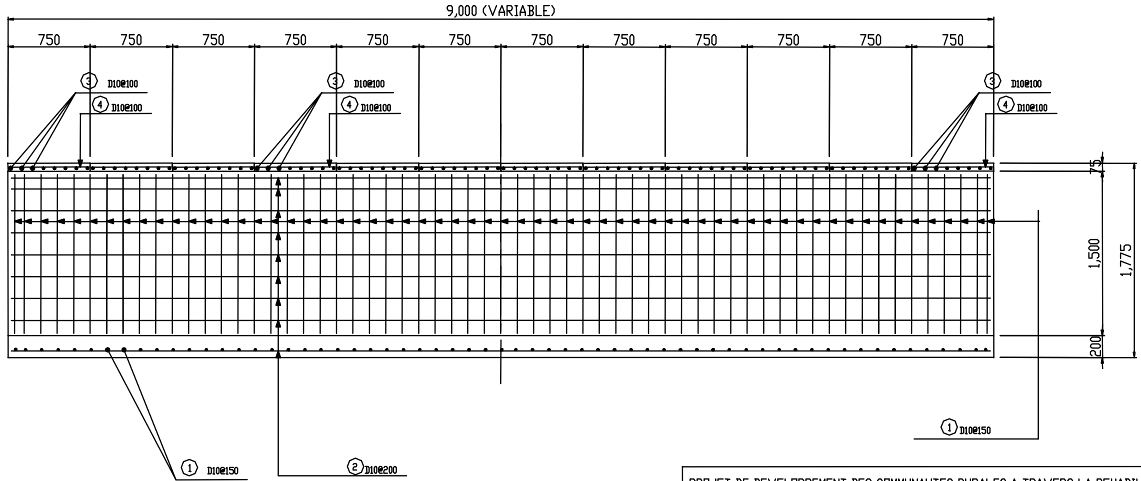
7. LE CHANFREINAGE DEVRAIT ETRE EMPLOYE POUR LES COINS DES MOULES AVEC UNE FACE DE 2 CM SAUF S'IL EST AUTREMENT INDIQUE DANS LES DESSINS.

8. LA SURFACE DE RECOUVREMENT DES BARRES D'ARMATURE EST DE 6 CM SAUF S'IL EST AUTREMENT INDIQUE DANS LES DESSSINS.

SECTION B - B



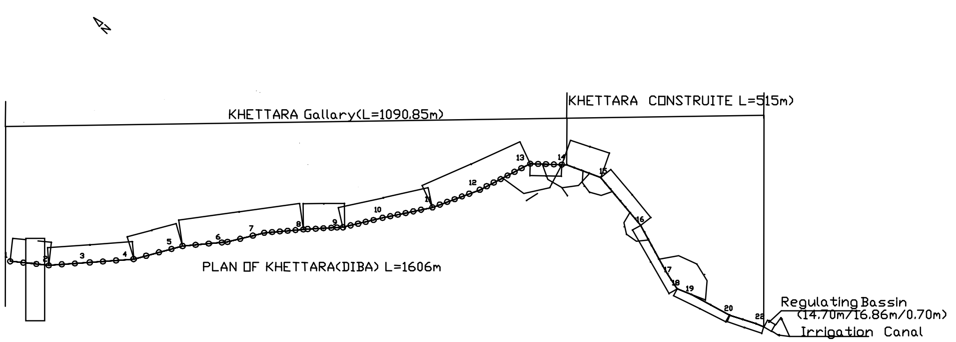
SECTION C - C

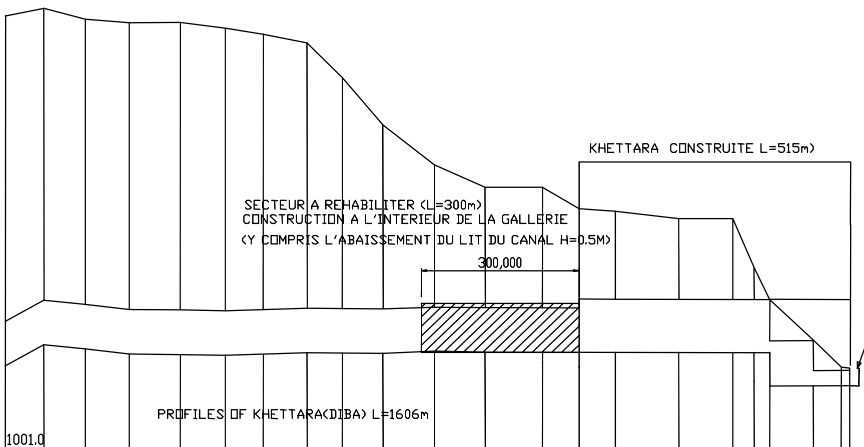


PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC		
STUDY TEAM	ORMVA/TF	CP.1 PLAN NO 1-2 PLAN DE REHABILITATION DES KHETTARAS AIT BEN OMAR
DATE:JUIN 2004		AGENCE JAPONAISE DE COOPERATION INTERNATIONALE

CP. 1 (3/10)

PLAN DE REHABILITATION DES KHETTARAS

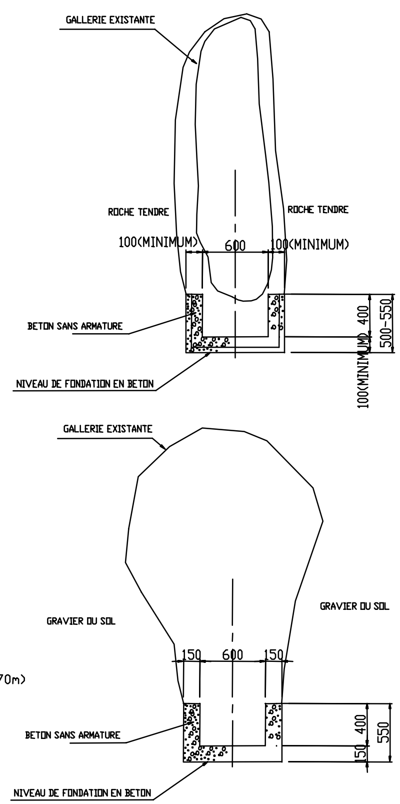




ECHELLE X=1/ 5000
ECHELLE Y=1/ 100

N°	COTE AU NIVEAU DU SOL	DISTANCE	DISTANCE CUMULEES	COTE DU LIT DU CANAL	ALIGNEMENT ET COURBE
1	1018.67		.00	1004.89	
2	1018.98	73.67	73.67	1005.72	
3	1018.54	78.36	152.03	1005.56	
4	1018.40	83.73	235.76	1005.36	
5	1018.42	96.73	332.49	1005.34	L=96.73
6	1018.20	85.71	418.21	1005.31	
7	1017.96	72.20	490.40	1005.35	
8	1017.60	83.36	573.76	1005.40	
9	1016.25	67.03	640.79	1005.40	
10	1014.38	77.60	718.39	1005.39	
11	1012.81	97.45	815.85	1005.47	L=97.45
12	1011.92	96.42	912.27	1005.44	L=96.42
13	1011.93	108.89	1021.16	1005.43	L=108.89
14	1011.08	69.70	1090.85	1005.42	
15	1010.98	68.77	1159.62	1005.42	
16	1010.68	121.14	1280.77	1005.42	L=121.14
17	1010.68	102.50	1383.27	1005.42	L=102.50
18	1008.75	40.78	1424.05	1005.42	
19	1007.50	29.42	1453.47	1005.42 / 1004.12	
20	1005.89	83.46	1536.93	1004.12	
21	1004.84	52.76	1589.68	1004.12	
22	1004.80	16.30	1605.98	1004.12	

SECTION A REHABILITER



REMARQUES:

1.L'UNITE DE MESURE EST LE MM ET LES COTES SONT DONNEES EN M, SAUF SI AUTREMENT INDIQUES PAR LES DESSINS.

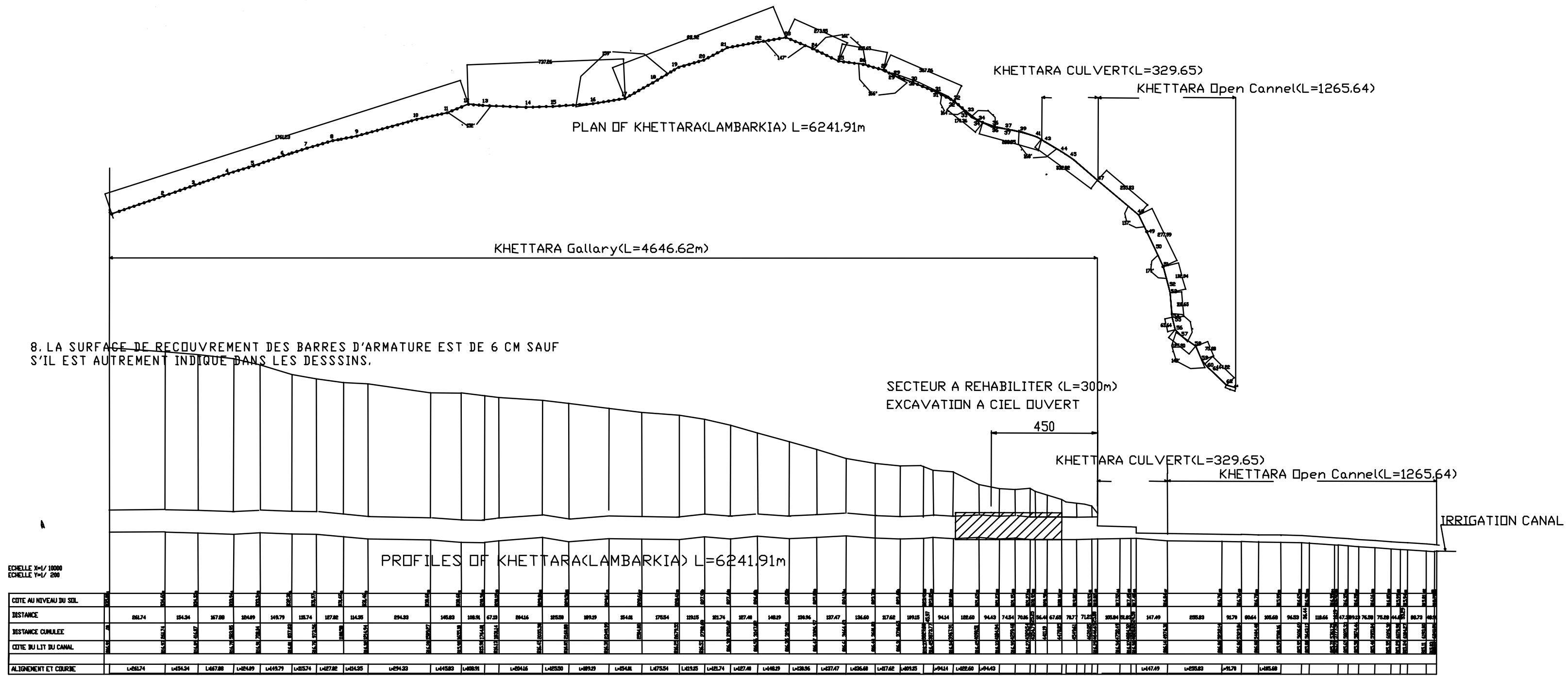
2.L'ENTREPRENEUR DOIT PREPARER LA PARTIE DES TRAVAUX RELATIVE AUX TERRASSEMENTS AVANT LE COMMENCEMENT DES TRAVAUX PROPREMENT DITS ET LA PRESENTER A L'INGENIEUR ET A L'ORMVA/TF POUR APPROBATION.

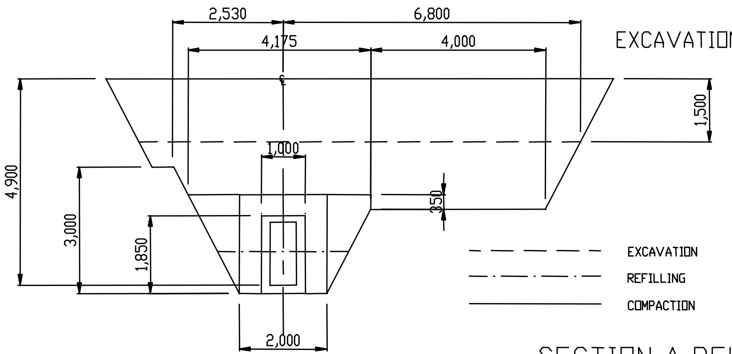
3. L'ENTREPRENEUR DOIT PREPARER LE PLAN DE DERIVATION AVANT LE COMMENCEMENT DES TRAVAUX ET LE SOUMETTRE A L'APPROBATION DE L'INGENIEUR ET DE L'ORMVA/TF.

PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC	
STUDY TEAM / ORMVA/TF	CP.1 PLAN NO 1-3 PLAN DE REHABILITATION DE LA KHETTARA DIBA
DATE:JUIN 2004	AGENCE JAPONAISE DE COOPERATION INTERNATIONALE

CP. 2 (1/6)

PLAN DE REHABILITATION DE KHETTARA LAMBARKIA





EXCAVATION CIEL OUVERT

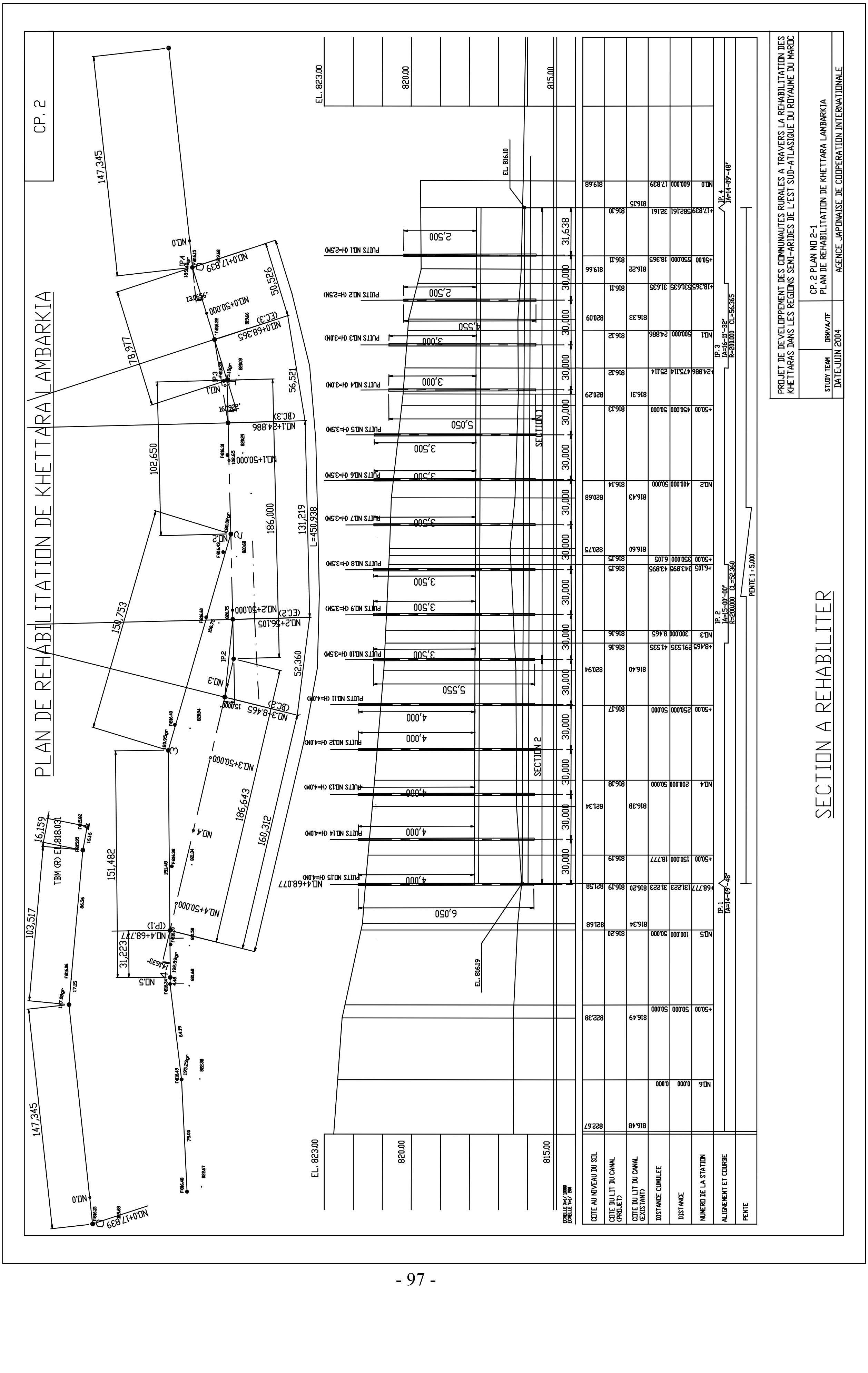
SECTION A REHABILITER

REMARQUES:
1.L'UNITE DE MESURE EST LE MM ET LES COTES SONT DONNEES EN M, SAUF SI AUTREMENT INDIQUES PAR LES DESSINS.

2.L'ENTREPRENEUR DOIT PREPARER LA PARTIE DES TRAVAUX RELATIVE AUX TERRASSEMENTS AVANT LE COMMENCEMENT DES TRAVAUX PROPREMENT DITS ET LA PRESENTER A L'INGENIEUR ET A L'ORMVA/TF POUR APPROBATION.

3. L'ENTREPRENEUR DOIT PREPARER LE PLAN DE DERIVATION AVANT LE COMMENCEMENT DES TRAVAUX ET LE SOUMETTRE A L'APPROBATION DE L'INGENIEUR ET DE L'ORMVA/TF.

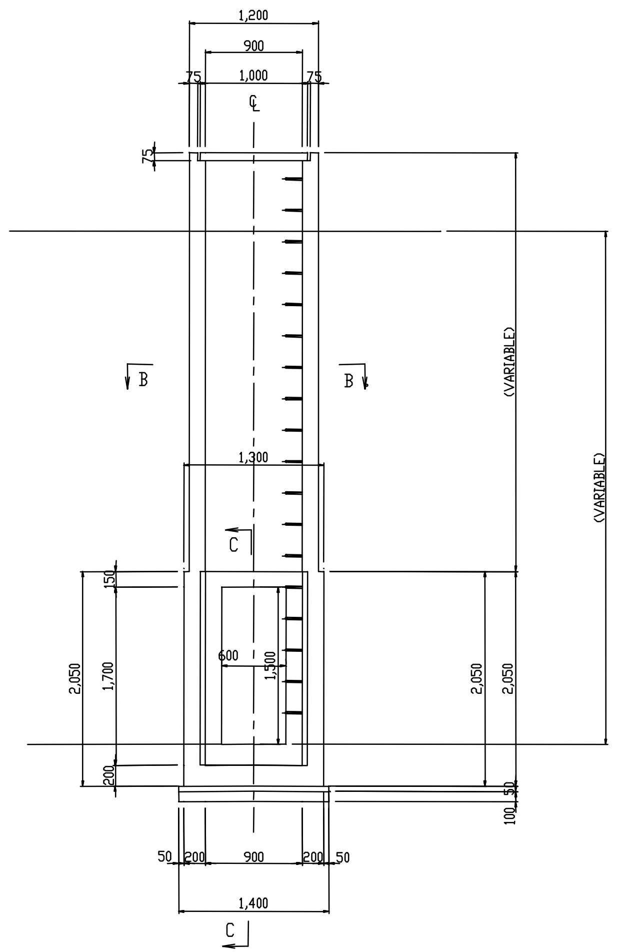
PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC		
STUDY TEAM	ORMVA/TF	CP. 2 PLAN NO 2-1 PLAN DE REHABILITATION DE KHETTARA LAMBARKIA
DATE:JUIN 2004		AGENCE JAPONAISE DE COOPERATION INTERNATIONALE


PLAN DE REHABILITATION DE KHETTARA LAMBARKIA
CP. 2
SECTION A REHABILITER
PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC
CP. 2 PLAN NO 2-1
PLAN DE REHABILITATION DE KHETTARA LAMBARKIA
STUDY TEAM
ORMVA/TF
DATE:JUIN 2004
AGENCE JAPONAISE DE COOPERATION INTERNATIONALE
COTE AU NIVEAU DU SOL
COTE DU LIT DU CANAL (PROJET)
COTE DU LIT DU CANAL (EXISTANT)
DISTANCE CUMULEE
DISTANCE
NUMERO DE LA STATION
ALIGNEMENT ET COURBE
PENTE
PENTE 1 : 5,000
EL. 823.00
820.00
815.00
SECTION 1
SECTION 2
L=450,938

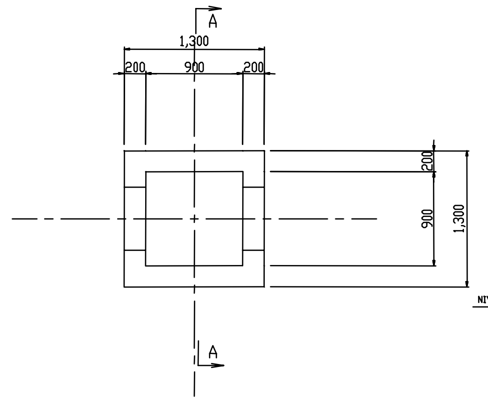
CP. 2 (4/6)

PLAN DE CONSTRUCTION DU PUITS

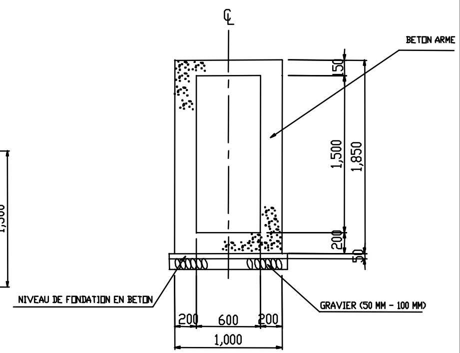
SECTION A - A



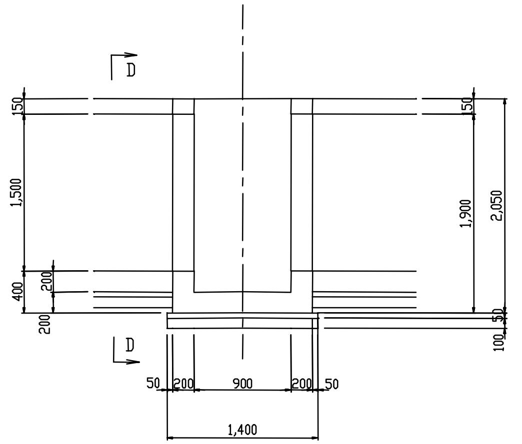
SECTION B - B



SECTION D - D



SECTION C - C



REMARQUES:

1.L'UNITE DE MESURE EST LE MM ET LES COTES SONT DONNEES EN M, SAUF SI AUTREMENT INDIQUES PAR LES DESSINS.

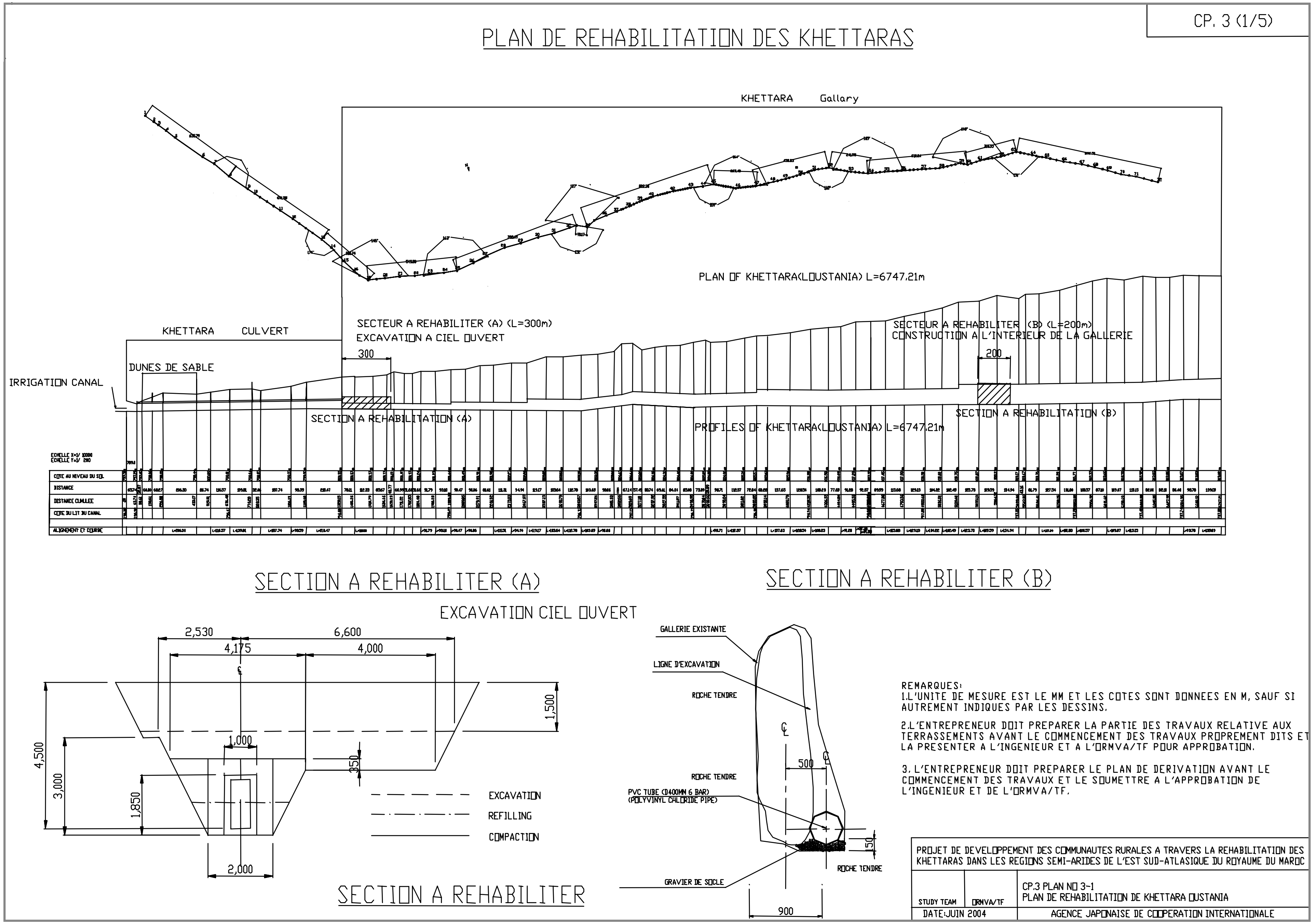
2. LES CONTRAINTES ADMISSIBLES POUR LE BETON ARME SONT LES SUIVANTES :
CONTRAINTE DE COMPRESSION : 225 KG/CM² (22,5N/MM²)
CONTRAINTE DE CISAILLEMENT : 4,2 KG/CM² (0,4 N/MM²)
EFFORT D'ADHERENCE :15 KG/CM² (1,5 N/MM²)

3. LES CONTRAINTES DE COMPRESSION ADMISSIBLES DU BETON SONT LES SUIVANTES :
BETON ORDINAIRE (BA)176 KG/CM² (17.6N/MM²)
BETON MAIGRE (B4E)127 KG/CM² (12,7N/MM²)

4. LE CHANFREINAGE DEVRAIT ETRE EMPLOYE POUR LES COINS DES MOULES AVEC UNE FACE DE 2 CM SAUF S'IL EST AUTREMENT INDIQUE DANS LES DESSINS.

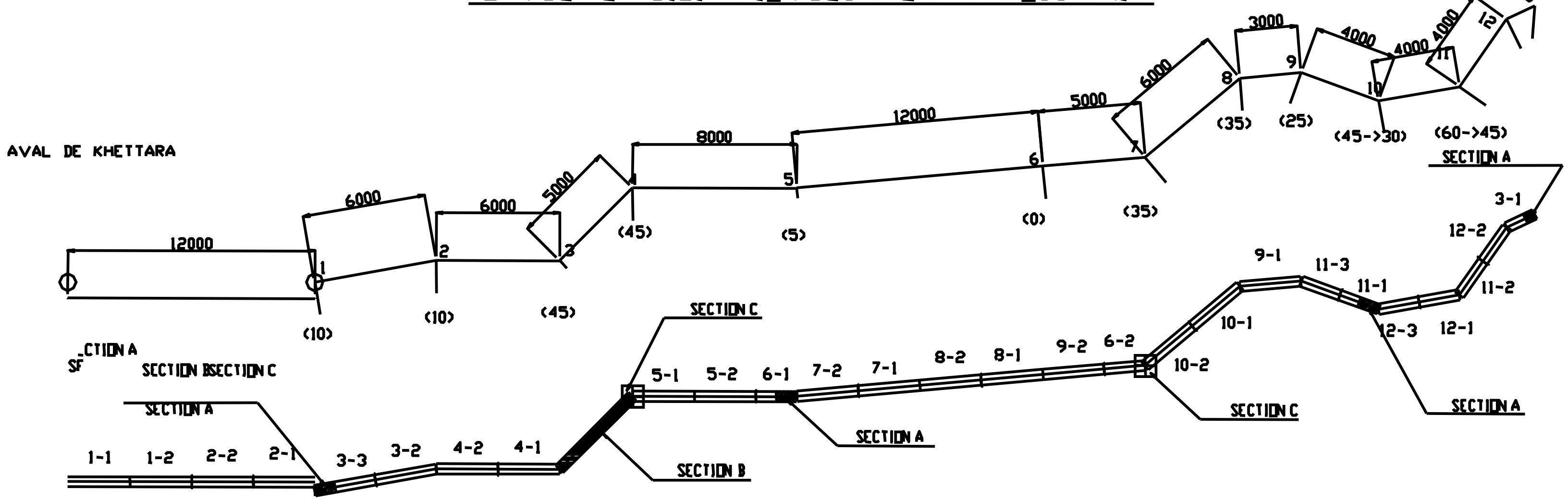
5. L'ANCRAGE DES BARRES DES MARCHES EST REQUIS POUR EVITER LE DETACHEMENT DES BARRES DU BETON.

PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC	
STUDY TEAM ORMVA/TF	CP. 2 PLAN NO 2-4 PLAN DE REHABILITATION DE KHETTARA LAMBARKIA
DATE:JUIN 2004	AGENCE JAPONAISE DE COOPERATION INTERNATIONALE


PLAN DE REHABILITATION DES KHETTARAS
CP. 3 (1/5)
KHETTARA Gallary
PLAN OF KHETTARA(LOUSTANIA) L=6747.21m
KHETTARA CULVERT
IRRIGATION CANAL
DUNES DE SABLE
SECTEUR A REHABILITER (A) (L=300m)
EXCAVATION A CIEL OUVERT
300
SECTION A REHABILITATION (A)
SECTEUR A REHABILITER (B) (L=200m)
CONSTRUCTION A L'INTERIEUR DE LA GALLERIE
200
SECTION A REHABILITATION (B)
PROFILES OF KHETTARA(LOUSTANIA) L=6747.21m
COTE AU NIVEAU DU SOL
DISTANCE
DISTANCE CUMULEE
COTE DU LIT DU CANAL
ALIGNEMENT ET COURBE
SECTION A REHABILITER (A)
EXCAVATION CIEL OUVERT
2,530
6,600
4,175
4,000
1,500
1,000
350
4,500
3,000
1,850
2,000
EXCAVATION
REFILLING
COMPACTION
SECTION A REHABILITER
SECTION A REHABILITER (B)
GALLERIE EXISTANTE
LIGNE D'EXCAVATION
ROCHE TENDRE
ROCHE TENDRE
PVC TUBE (Ф400MM 6 BAR)
(POLYVINYL CHLORIDE PIPE)
500
150
ROCHE TENDRE
GRAVIER DE SOCLE
900
REMARQUES:
1.L'UNITE DE MESURE EST LE MM ET LES COTES SONT DONNEES EN M, SAUF SI AUTREMENT INDIQUES PAR LES DESSINS.
2.L'ENTREPRENEUR DOIT PREPARER LA PARTIE DES TRAVAUX RELATIVE AUX TERRASSEMENTS AVANT LE COMMENCEMENT DES TRAVAUX PROPREMENT DITS ET LA PRESENTER A L'INGENIEUR ET A L'ORMVA/TF POUR APPROBATION.
3. L'ENTREPRENEUR DOIT PREPARER LE PLAN DE DERIVATION AVANT LE COMMENCEMENT DES TRAVAUX ET LE SOUMETTRE A L'APPROBATION DE L'INGENIEUR ET DE L'ORMVA/TF.
PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC
STUDY TEAM ORMVA/TF
CP.3 PLAN NO 3-1
PLAN DE REHABILITATION DE KHETTARA OUSTANIA
DATE:JUIN 2004
AGENCE JAPONAISE DE COOPERATION INTERNATIONALE

	CP. 3

PLAN DE REHABILITATION DES KHETTARA (OUSTANIA)



	1	2	3	4	5	6	7	8	9	10	11
1.0M			3-1			6-1					11-1
1.0M											
1.5M											
1.5M											
1.5M()											
2.0M											
2.0M						6-2					11-2
2.0M()			3-2			(6-3)					11-3
3.0M	1-1	2-1	3-3	4-1	5-1		7-1	8-1	9-1	10-1	
3.0M()	1-2	2-2		4-2	5-2		7-2	8-2	9-2	10-2	

PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUB-ATLASIQUE DU ROYAUME DU MAROC

STUDY TEAM ORMVA/TF

CP. 3
PLAN DE REHABILITATION DES KHETTARA (OUSTANIA)

DATE:AOUT 2004

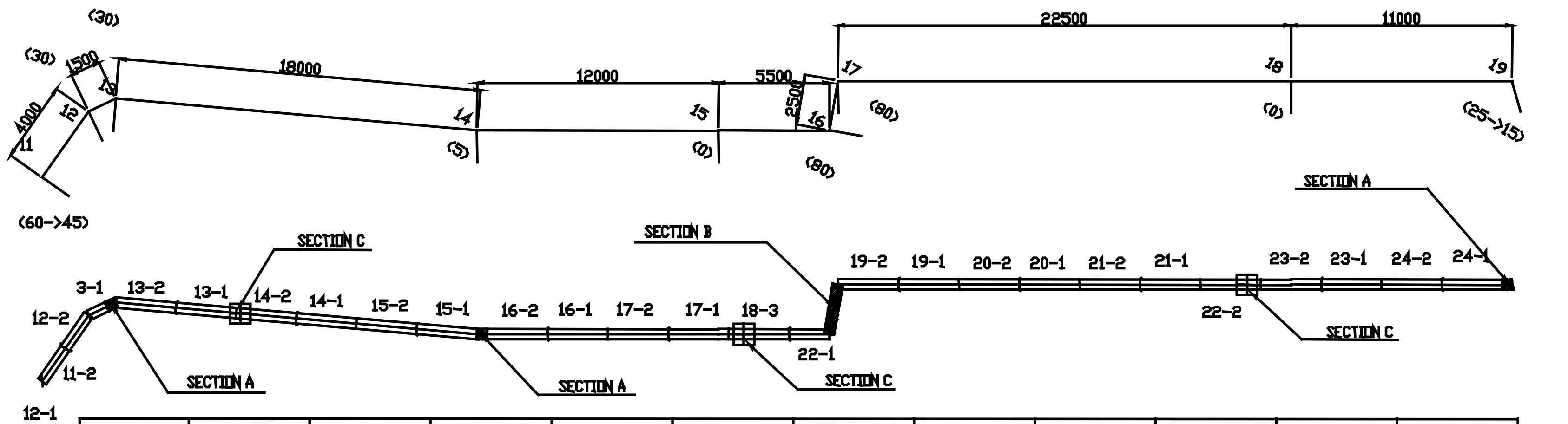
AGENCE JAPONAISE DE COOPERATION INTERNATIONALE

PLAN DE REHABILITATION DES KHETTARA (OUSTANIA)

CP. 3

AVAL DE KHETTARA

AMONT DE KHETTARA



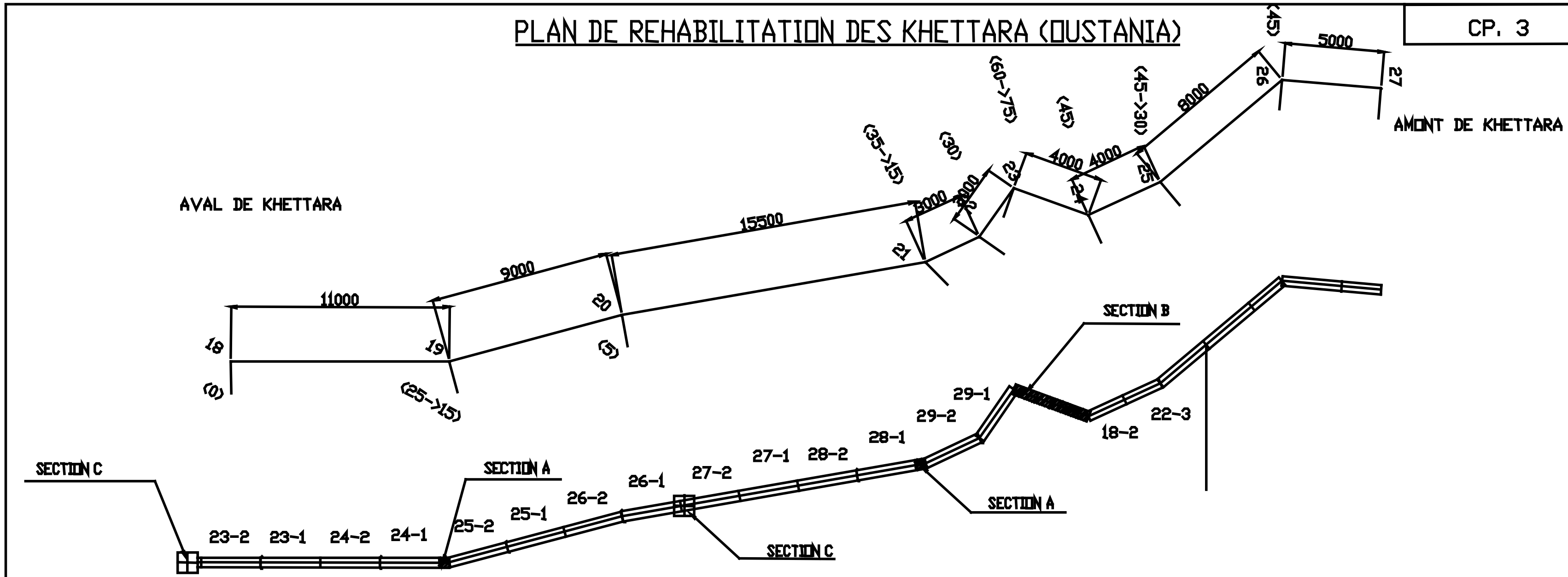
	12	13	14	15	16	17	18	19	20	21	22
1.0M											
1.0M											
1.5M											
1.5M											
1.5M()											
2.0M	12-1						18-1				22-1
2.0M	12-2						(18-2)				22-2
2.0M()	12-3						18-3				22-3
3.0M		13-1	14-1	15-1	16-1	17-1		19-1	20-1	21-1	
3.0M()		13-2	14-2	15-2	16-2	17-2		19-2	20-2	21-2	

PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC

STUDY TEAM	ORMVA/TF	CP. 3 PLAN DE REHABILITATION DES KHETTARA (OUSTANIA)
DATE:AOUT 2004		AGENCE JAPONAISE DE COOPERATION INTERNATIONALE

PLAN DE REHABILITATION DES KHETTARA (OUSTANIA)

CP. 3



	23	24	25	26	27	28	29	30	31	32	33
1.0M											
1.0M											
1.5M											
1.5M											
1.5M()											
2.0M											
2.0M											
2.0M()											
3.0M	23-1	24-1	25-1	26-1	27-1	28-1	29-1				
3.0M()	23-2	24-2	25-2	26-2	27-2	28-2	29-2				

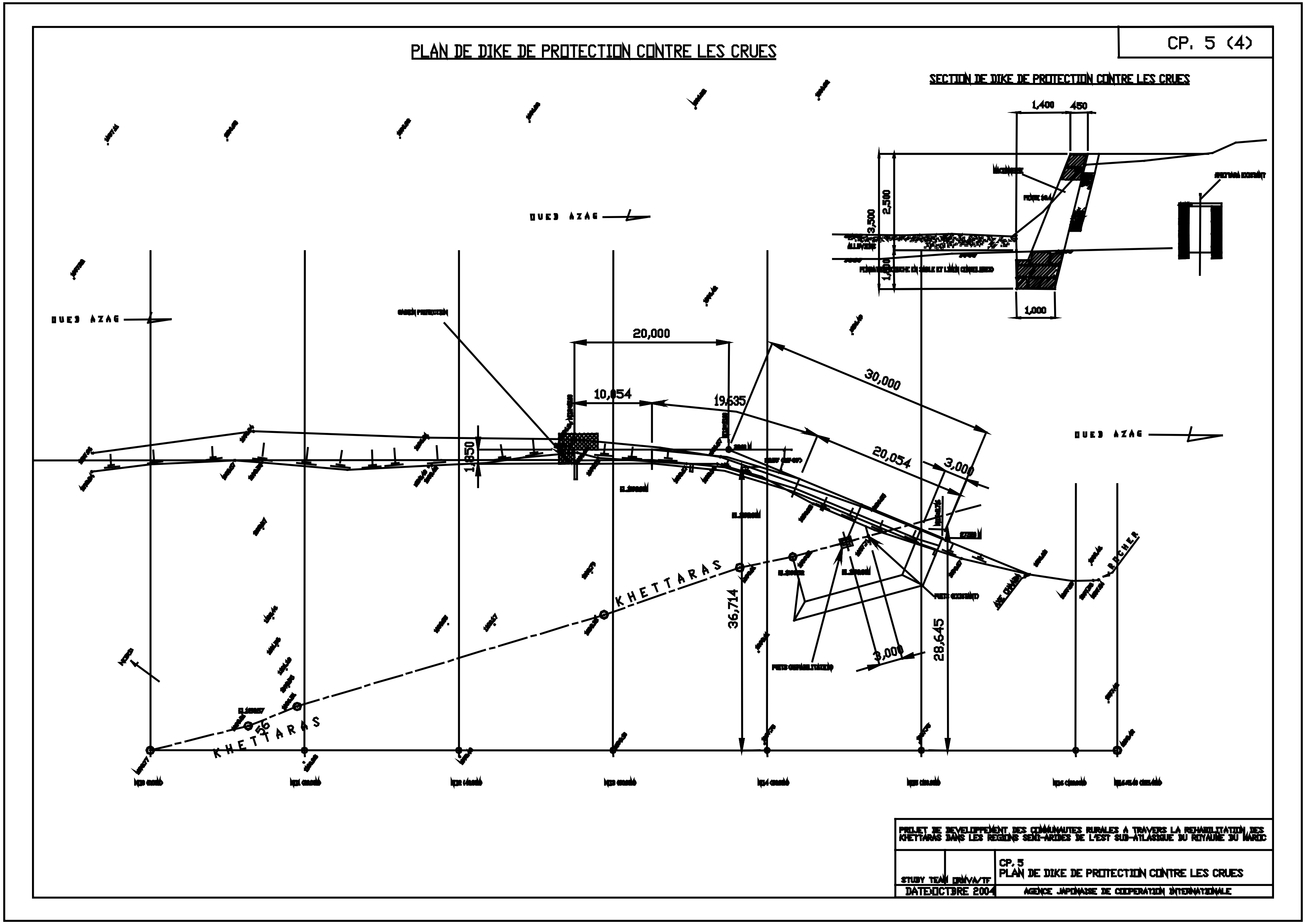
PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC

STUDY TEAM | DRIVA/TF

CP. 3
PLAN DE REHABILITATION DES KHETTARA (OUSTANIA)

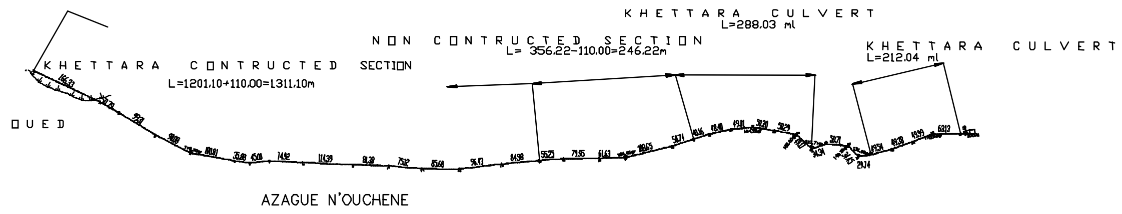
DATE:AOUT 2004

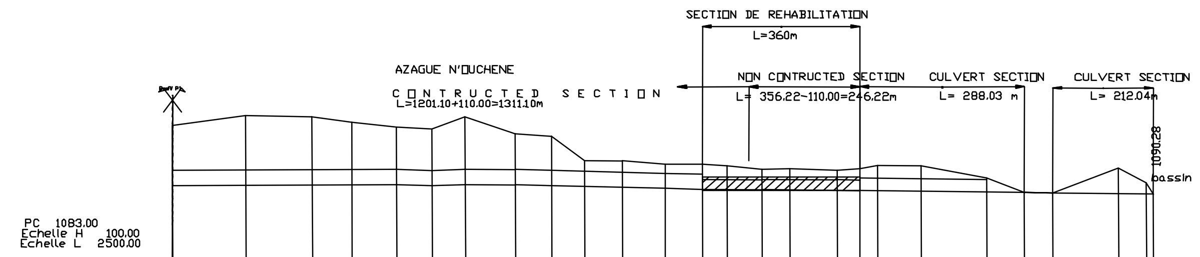
AGENCE JAPONAISE DE COOPERATION INTERNATIONALE


PLAN DE DIKE DE PROTECTION CONTRE LES CRUES
CP. 5 (4)
SECTION DE DIKE DE PROTECTION CONTRE LES CRUES
1,400
450
2,500
3,500
1,000
OUED AZAG
OUED AZAG
OUED AZAG
20,000
10,054
19,635
30,000
20,054
3,000
1,850
36,714
28,645
3,000
KHETTARAS
KHETTARAS
PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC
CP. 5
PLAN DE DIKE DE PROTECTION CONTRE LES CRUES
STUDY TEAM DRHA/TF
DATE:OCTOBRE 2004
AGENCE JAPONAISE DE COOPERATION INTERNATIONALE

CP. 5 (1)

PLAN DE REHABILITATION DES KHETTARA (AZAG)

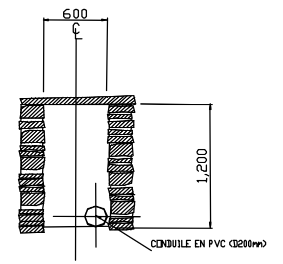




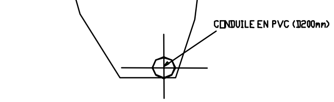
N° Point	GROUND ELEVATION	DISTANCES	ACUMULATED	CANAL BED ELEVATION	ALIGNEMENTS - CURVES
0			0.00		
1	1097.97	166.33	166.33		
2	1097.84	150.10	316.43		
3	1097.27	90.08	406.51		
4	1096.81	100.81	507.32	1091.15	
5	1096.68	80.88	588.20	1091.08	
6	1097.81	74.92	663.12	1091.15	
7	1096.17	114.39	777.51	1091.17	
8	1095.92	81.38	858.89	1091.12	
9	1093.54	75.12	934.01	1091.14	
10	1093.53	85.68	1019.69	1090.93	
11	1093.17	96.43	1116.12	1090.81	
12	1093.24	84.98	1201.10	1090.79	
13	1093.02	55.25	1256.35	1090.79	
14	1092.66	79.95	1336.30	1090.73	
15	1092.78	61.63	1397.93	1090.68	
16	1092.61	108.65	1506.58	1090.68	
17	1092.78	50.74	1557.32		
18	1093.09	40.16	1597.48	1090.58	
19	1093.04	98.21	1695.69	1090.49	
20	1091.80	149.66	1845.35	1090.31	
21	1090.42	85.05	1930.40	1090.42	
22	1090.40	64.19	1994.59	1090.40	
23	1092.82	148.91	2143.50	1090.37	
24	1091.33	63.15	2206.65	1090.28	
25	1090.28	15.53	2222.16	1090.28	

SECTION A REHABILITER

SECTION CONSTRUITE



SECTION NON CONSTRUITE



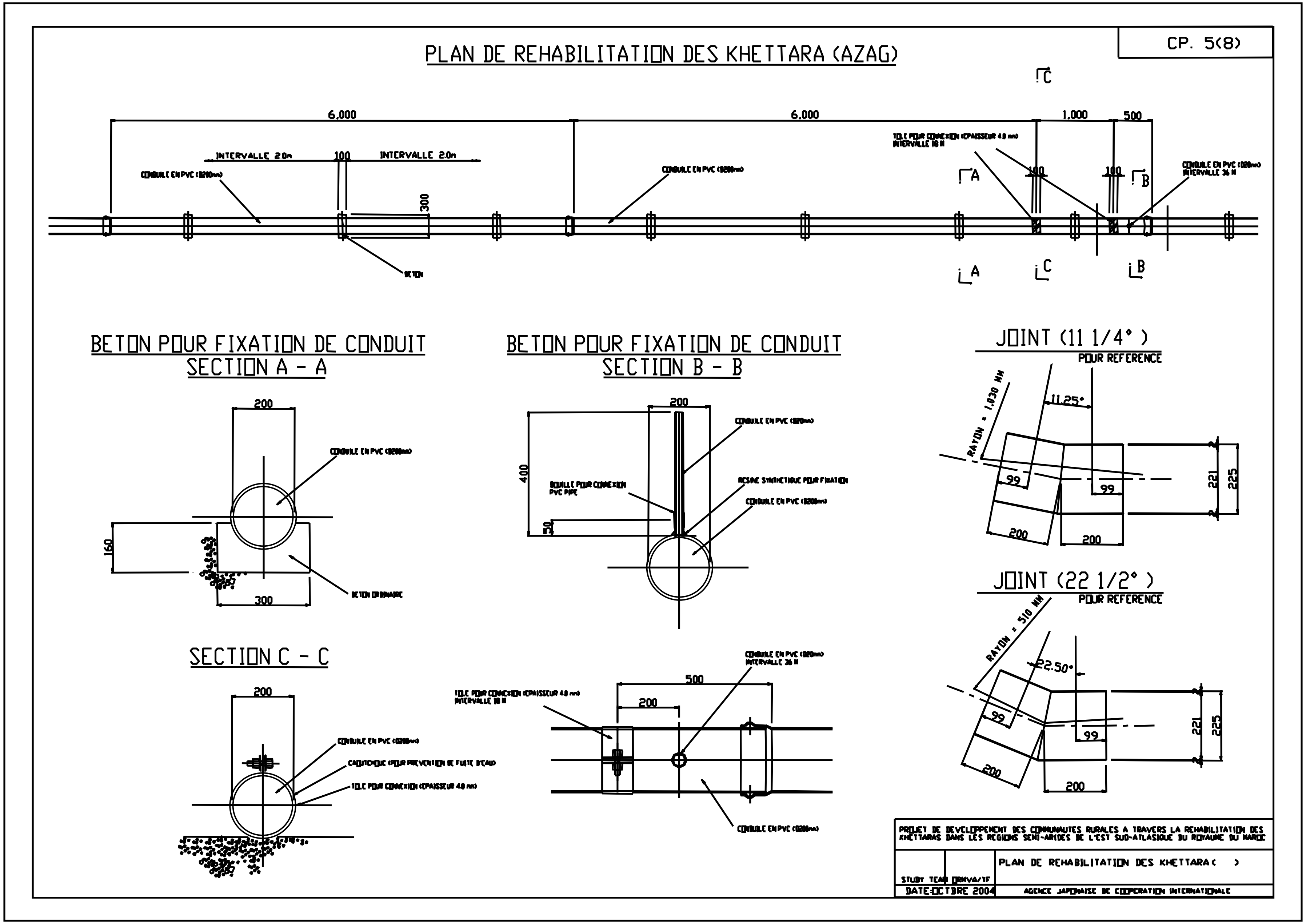
PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC

STUDY TEAM ORMVA/TF

DATE:AOUT 2004

CP. 5
PLAN DE REHABILITATION DES KHETTARA (Azag)

AGENCE JAPONAISE DE COOPERATION INTERNATIONALE

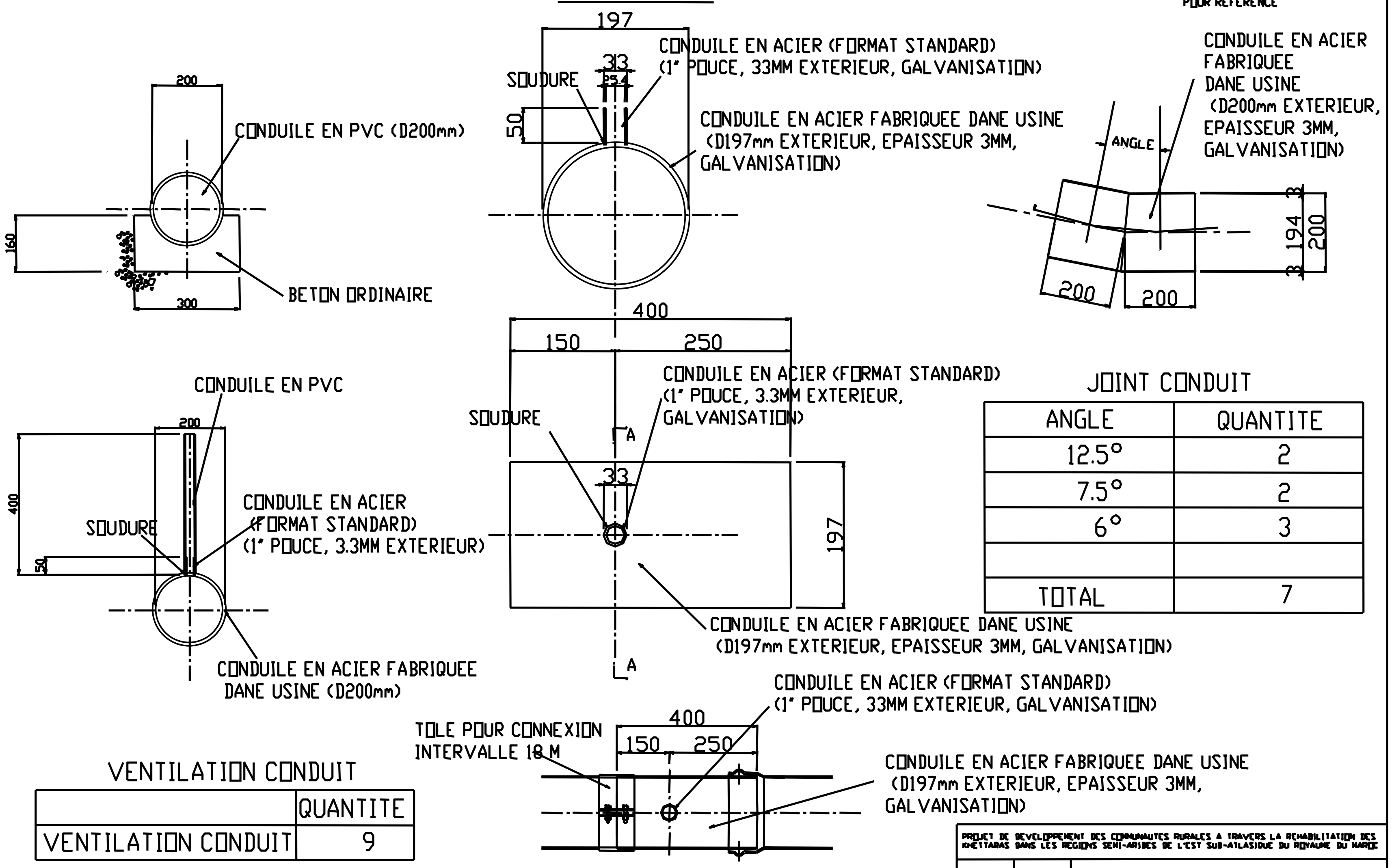

PLAN DE REHABILITATION DES KHETTARA (AZAG)
CP. 5(8)
6,000
6,000
1,000
500
INTERVALLE 2.0m
100
INTERVALLE 2.0m
300
BETON
A
B
C
BETON POUR FIXATION DE CONDUIT
SECTION A - A
200
160
300
BETON POUR FIXATION DE CONDUIT
SECTION B - B
200
400
50
SECTION C - C
200
500
200
JOINT (11 1/4°)
POUR REFERENCE
RAYON = 1,030 MM
11.25°
99
200
221
225
JOINT (22 1/2°)
POUR REFERENCE
RAYON = 510 MM
22.50°
99
200
221
225
PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC
PLAN DE REHABILITATION DES KHETTARA( )
DATE:OCTOBRE 2004
AGENCE JAPONAISE DE COOPERATION INTERNATIONALE

CP. 5(9)

PLAN DE VENTILATION CONDUIT

SECTION A - A

PLAN DE JOINT CONDUIT
POUR REFERENCE



JOINT CONDUIT

ANGLE	QUANTITE
12.5°	2
7.5°	2
6°	3
TOTAL	7

VENTILATION CONDUIT

	QUANTITE
VENTILATION CONDUIT	9

PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUB-ATLASIQUE DU ROYAUME DU MAROC

PLAN DE REHABILITATION DES KHETTARA ( )

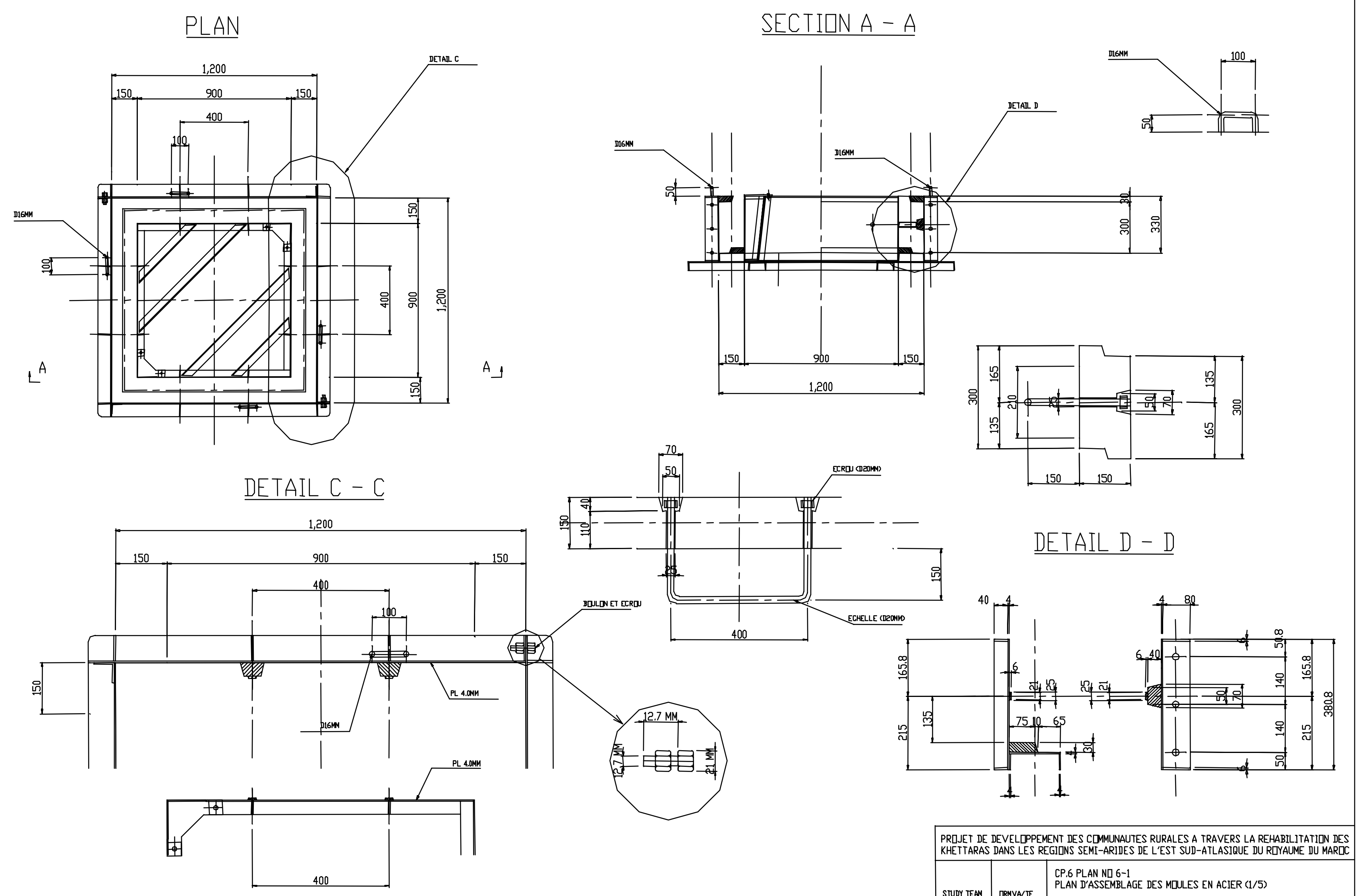
STUDY TEAM ORMVA/TF

DATE: OCTOBRE 2004

AGENCE JAPONAISE DE COOPERATION INTERNATIONALE

CP. 6 (1/5)

PLAN D'ASSEMBLAGE DES MOULES EN ACIER (1/5)

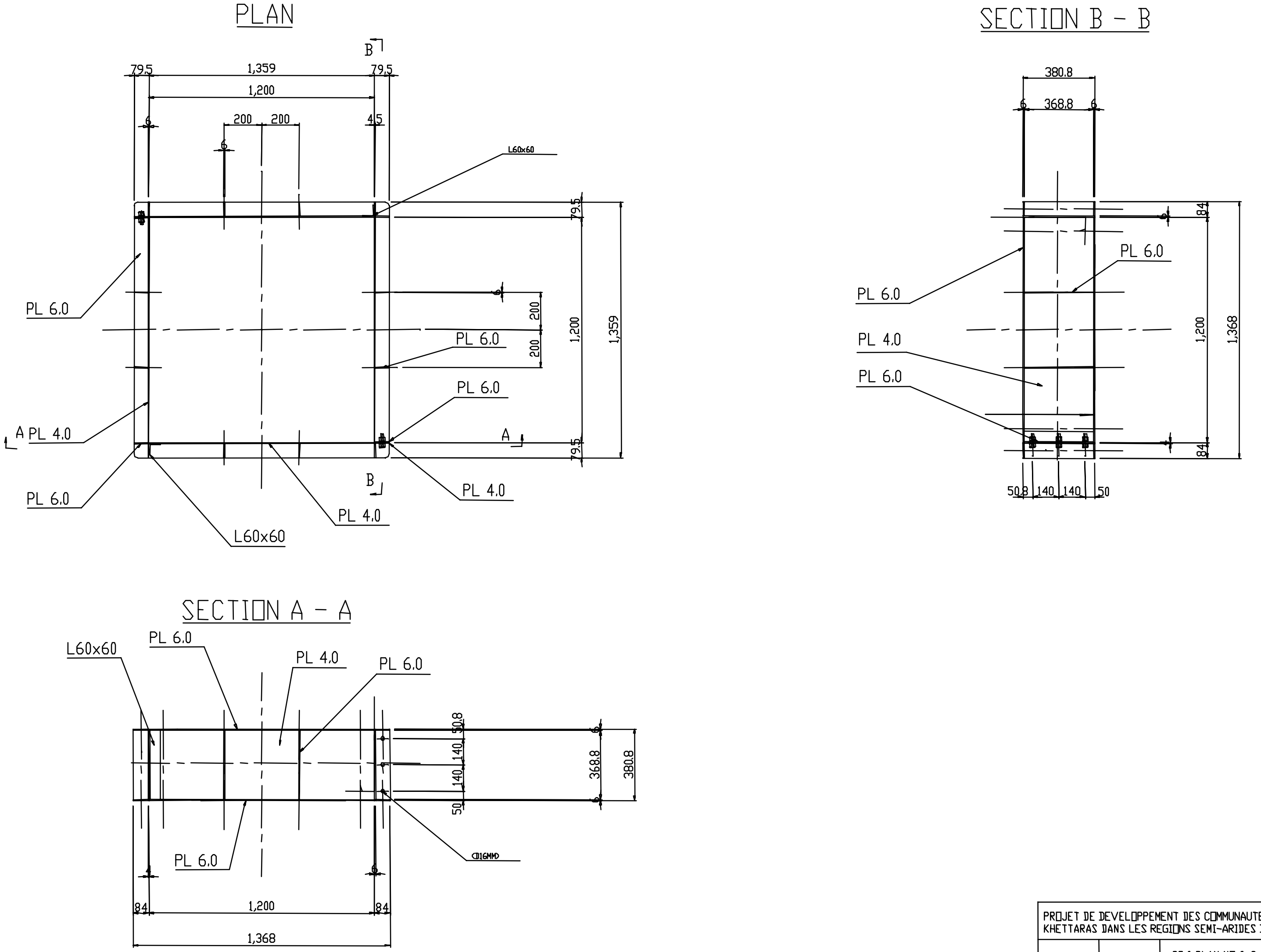


PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC

STUDY TEAM	ORMVA/TF	CP.6 PLAN NO 6-1 PLAN D'ASSEMBLAGE DES MOULES EN ACIER (1/5)
DATE:JUIN 2004		AGENCE JAPONAISE DE COOPERATION INTERNATIONALE

CP. 6 (2/5)

PLAN D'ASSEMBLAGE DES MOULES EN ACIER (2/5)



PROJET DE DEVELOPPEMENT DES COMMUNAUTES RURALES A TRAVERS LA REHABILITATION DES KHETTARAS DANS LES REGIONS SEMI-ARIDES DE L'EST SUD-ATLASIQUE DU ROYAUME DU MAROC

STUDY TEAM	ORMVA/TF	CP.6 PLAN NO 6-2 PLAN D'ASSEMBLAGE DES MOULES EN ACIER (2/5)
DATE:JUIN 2004		AGENCE JAPONAISE DE COOPERATION INTERNATIONALE