No.

Japan International Cooperation Agency (JICA)
Ministry of Housing and Urban Affairs
National Earthquake Engineering Research Center

A Study of Seismic Microzoning of the Wilaya of Algiers in the People's Democratic Republic of Algeria

Final Report

Volume I

Summary

December 2006

Oyo International Corp.
Nippon Koei Co., Ltd.

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PREFACE

In response to the request from the Government of the People's Democratic Republic of Algeria, the Government of Japan decided to conduct the Study on Seismic Microzoning of the Wilaya of Algiers in the People's Democratic Republic of Algeria and entrusted the study to Japan International Cooperation Agency (JICA).

JICA organized and dispatched a study team headed by Mr. Osamu NISHII of OYO International Corporation and composed of OYO International Corporation and Nippon Koei Co., Ltd., to Algeria six times from February 2005 to November 2006. In addition, JICA set up an advisory committee headed by Dr. Kimiro MEGURO, Professor of University of Tokyo, which examined the study from technical point of view.

The study was completed as scheduled with submission of the final report, technical guideline and associated products. The study also included technology transfer of the seismic microzoning to the counterpart agency. We hope that the output of the study will be shared by all the relevant organizations and staffs and utilized as the foundations of earthquake disaster prevention planning.

It is clear that continued endeavors for establishing sound and effective policies and projects on disaster management and for implementing them at national, local and community levels are inevitable to achieve sustainable development of the People's Democratic Republic of Algeria. We also hope that this study will contribute to the promotion of the future projects and to the enhancement of the friendship between two countries.

Finally, we wish to express our sincere appreciation to the officials concerned in the Government of Algeria for their close cooperation extended to the Study.

December 2006

Ariyuki
MATSUMOTO
Vice President
Japan International
Cooperation Agency

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Abbreviation

Organizations

ADE	Algerian Water Agency
ANRH	National Agency for Hydraulic Resources
APC	Popular Communal Assembly
ASAL	Algerian Space Agency
ATC	Applied Technology Council
ATM	Algerian Telecom
CCO	Operational Coordination Centre
CDMG	California Division of Mines and Geology
CENEAC	National Coordination Center
CGS	National Research Center for Earthquake Engineering
CNAD	National Operational Center for Decision Support
CNERU	Public Consultant Agency in Urbanism
CNIG	National Council of Geographic Information
CNSPR	National Centre of Safety and Road Prevention
CNTS	National Centre of Space Techniques
COM.EN.A	Commissariat for Atomic Energy
COMEDOR	Greater Algiers Permanent Study and Organization Committee
CRA	The Algerian Red Crescent
CRAAG	National Center for Research in Astronomy, Astrophysics and Geophysics
CTC	Technical Control of Construction
CTTP	National Technical Control Center of Public Works
DGF	General Direction of Forests
DGPC	Civil Protection General Directorate
DHW	Direction of Hydraulic of Wilaya
DL	Direction of Housing
DNRM	National Delegation for Major Risk
DOCS	Direction of Rescue Organization and Coordination
DPAT	Direction of Planification and Regional Development
DPC	Direction of Civil Protection
DRAG	Director of Regulatory and General Affairs
DT	Transport Direction
DTP	Public Works Direction
DTPW	Public Works Direction of Wilaya
DU Alger	Direction of Urban affairs of Algiers' Wilaya
DUC	Direction of Urbanism and Construction
EGSA	Establishment of Management of the Airport Services
EPAL	Algiers Port Enterprise
FEMA	Federal Emergency Management Agency

INCT	National Institute of Geography and Remote Sensing
INPV	National Institute of Vegetable Protection
ISSMGE	Iinternational Society for Soil Mechanics and Geotechnical Engineering
JICA	Japan International Cooperation Agency
JMA	Japan Meteorological Agency
LCTP	Central Laboratory of Public Works
LEM	Maritimes Studies Laboratory
LNHC	National Laboratory of Housing and Construction
MATE	Ministry of Ground Planning and Environment
MHU	Ministry of Housing and Urban Affairs
MICL	Ministry of Interior and Local Collectivities
MPT	Ministry of Post and Telecommunications
MPTIC	Ministry of Post and Technologies of Information and Communication
MRE	Ministry of Water Resources
MT	Ministry of Transportation
MTP	Ministry of Public Works
ONG/NGO	Non Governmental Organization
ONM	National Meteorology Office
ONS	National Office of Statistic
ORGM	Office for Geological and Mining Research
PC	Civil Protection
PCF	Fixed Command Post
PCO	Operational Command Post
SNTF	National Railway Transportation Company
SONATRACH	National Company for Search, Production, Transportation, Processing and Commercialization of hydrocarbons
SONELGAZ	National Company of Electricity and Gas
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNII	Intervention Instruction National Unit
UNO	United Nations Organization
UPPC	Civil Protection Principal Unit
URBANIS	Planning and Urbanism Agency of Algiers Wilaya
USGS	United States Geological Survey

Technical Terms

CA	Administrative Unit
CPT	Cone Penetration Test
EMS	European Macroseismic Scale
GIS	Geographic Information System
GPS	Global Positioning System
DEM	Digital Elevation Model

DIG	Disaster Imagination Game
MMI	Modified Mercalli Seismic Intensity
MSK	Medvedev Sponheuer Karnik Seismic Intensity
ORSEC Plan	Plan of Organization of Intervention and Assistance
PDAU	Urban Planning Master Plan
PGA	Peak Ground Acceleration
PGV	Peak Ground Velocity
POI	Intervention Organization Plan
POS	Ground Use Plan
PPI	Intervention Particular Plan
RC	Reinforced Concrete
Sa	Spectral Acceleration
SAR (MDN)	Search and Rescue (air/mer)
SPT	Standard Penetration Test
SRTM	Shuttle Radar Topography Mission
UTM	Universal Transverse Mercator
Vs	S Wave Velocity

Profile of the Study

1. Outline of the Survey

The outline of this Survey is as follows:

Survey Title
: The Seismic Microzoning Survey in the City of Alger, Algeria

Implementing Organization
: Japan International Cooperation Agency (JICA)

Partner Country's Implementing Organization
: The Ministry of Housing and Urban Affairs and
the National Earthquake Engineering Center (CGS)

Survey Period
: 23 months starting in February 2005 and ending in December 2006

This Survey aims at the following three aspects, and covers areas designated for urbanization and their neighboring areas in Algiers Province, extending for some 225 km^2.

- To create a seismic Microzoning map of Algiers Province and to estimate possible damage caused when an earthquake occurs
- To make recommendations concerning the seismic hazard management system
- To transfer, based on the survey results, the technology related to the system to the Algerian side

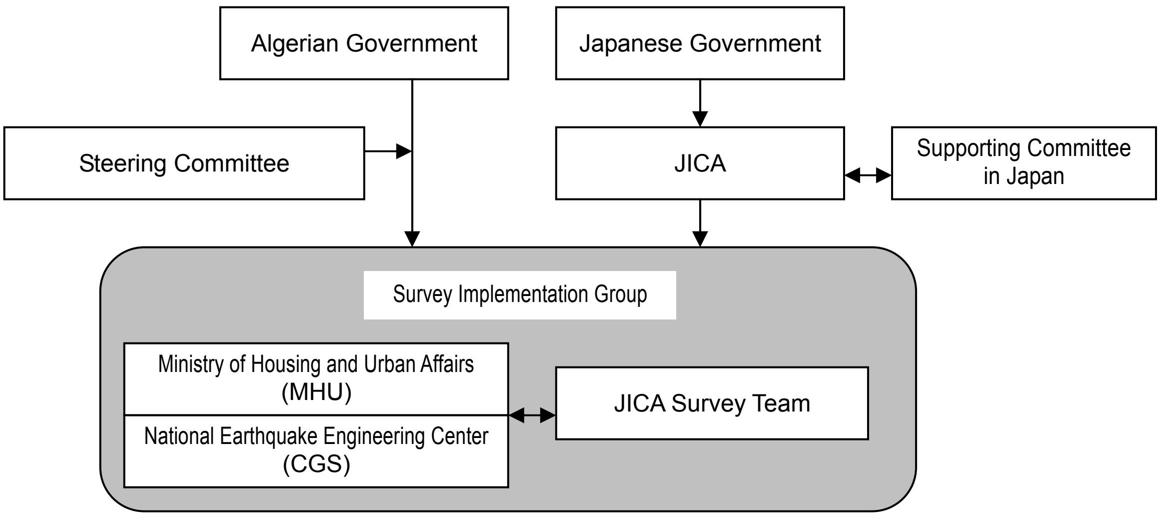


Figure-1 Organizational Chart for Survey Implementation

2. Information Gathering and Building up of GIS Database

First, a supporting information database was crated by making use of data provided by the Algerian side, including (1) 1:7500-scale map, (2) 1:10000-scale map; (3) 1:25000-scale map, and (4) LANDSAT satellite data.

Then, information concerning natural and social conditions was gathered from existing sources, while a geological survey, a building inventory survey, and a disaster prevention resource survey were carried out. At the same time, a GIS database concerning the following items was constructed based on the GIS supporting information database:

1) geological conditions; 2) disaster prevention resources; 3) slopes; 4) buildings; 5) road networks; 6) railways; 7) electric power supply networks; 8) gas pipelines; 9) water supply; and 10) water sewerage.

In order for the Algerian side to update the database on their own accord in future, a composite team was formed, consisting of CGS (Ministry of Housing and Urban Affairs); DGPC (Ministry of Internal Affairs); INCT (Defense Ministry); and URBANIS (Algiers Province).

3. Seismic Hazard Assessment

Six major faults were chosen at the periphery of the region subject to the survey, and used to create a seismic model so as to estimate magnitudes of possible future earthquakes in consideration of recurrence periods. Figure-2 and Table-1 show the locations of each active fault and expected magnitudes of earthquakes which are assumed to recur in 475 years' time.

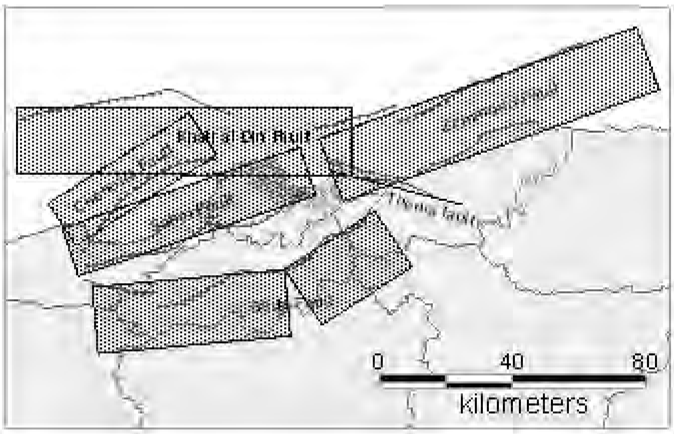


Figure-2 Scenario Earthquake Model

Table-1 Magnitudes of Scenario Earthquakes

Seismic sources	Magnitudes of recurring earthquakes in 475 years' time (Mw)
Sahel Fault	5.9 ± 0.3
Chenoua Fault	5.8 ± 0.3
Blida Fault	6.8 ± 0.2
Khair al Din Fault	6.8 ± 0.2
Zemmouri Fault	7.0 ± 0.1
Thenia Fault	5.9 ± 0.2

Making use of this model, earthquake ground motions, ground surface dimension, peak ground acceleration (PGA) and MSK earthquake intensity scales were computed for every 250-meter grid line. The earthquake ground motions were computed with the attenuation formula which is suitable for this Alger case. The PGA, on the other hand, was computed by applying the one-dimensional response calculation, while the MSK earthquake intensity scales were obtained from PGA, making use of empirical equations. The earthquake ground motion will be the greatest in the case of a scenario earthquake in Khair al Din fault, its seismic intensity expected to be grade 8 – 9.

Next, the degree of risk of liquefaction was assessed, using the PGA obtained in the previous stage, according to which a distribution map was drawn up concerning regions of high risks of liquefaction. The map suggests that regions subject to high risks of liquefaction are observed on the coast of the center of the Alger Bay and along River Harrach.

The slopes within the areas covered by the survey were classified into two large groups: steep slopes which could collapse when an earthquake occurs, and gentle slopes which could set off landslides. Then, the stability of those slopes was analyzed to draw up a distribution map concerning regions with high risk slopes. According to the map, it was found that many areas with high risk slopes, in the cases of scenario earthquakes in Khair al Din fault and Sahel fault, are distributed in the hilly terrain which stretches over the western half of the region under the survey. A composite team formed by CGS members and a JICA survey team carried out field surveys on 30 slopes extracted from these high-risk regions.

4. Damage Estimations

Damage to architectural structures was assumed to be "grade 4 (very heavy damage) + grade 5 (complete destruction)" in EMS-98 scales. Architectural structures were classified into eight groups in accordance with the results of the building inventory survey; the quake-resistance standards adopted in Algeria; the findings of surveys of the proportion of architectural structures damaged in the region subject to the survey; and other sources. Then a damage function for architectural structures was created in reference to data concerning damage to structures caused by the Boumerudes Earthquake and the El Asnam Earthquake in 1980.

The number of existing architectural structures was estimated in accordance with the GIS data and the results of the inventory survey, while estimated damage to those structures were computed for two scenario earthquakes of the Khair al Din and Zemmouri faults.

Records of damage caused by earthquakes occurring in the past in Algeria were investigated to clarify the relationship between damage to buildings and human suffering, so that a formula to compute human suffering was created. The findings of all these are summarized as follows.

Table-2 Damage to Architectural Structures and Human Suffering

Scenario earthquake	No. of buildings "very heavily damaged" and "completely destructed"	Proportion	No. of deaths	Proportion
Khair al Din	56,000	36.2 %	12,000	0.67 %
Zemmouri	29,000	18.9 %	4,600	0.25 %

Where the infrastructure is concerned, damage estimations were made concerning bridges, harbors and ports, and airports. The estimations followed Katayama's method for bridges, and data concerning damage caused by earthquakes all over the world in the past for harbors and ports, and airports.

Table-3 Damage to Infrastructure

Scenario earthquake	No. of bridges highly likely to fall	Damage to harbors and ports	Damage to airports
Khair al Din	22	Most will be seriously damaged. Major components of structures will be devastatingly deformed, and lose their functions.	All regions will be moderately damaged, and airport facilities will be closed for several days.
Zemmouri	11	Serious damage in the southern half of the region surveyed. Major components of structures will be devastatingly deformed, and lose their functions.	All regions will be moderately damaged, and airport facilities will be closed for several days.

Where lifeline facilities are concerned, damage estimations were made concerning water supply pipes, medium- and high-tension power lines, and medium-pressure gas pipes by applying Japanese method after it was examined and proved applicable to damage to these facilities by the Boumerudes Earthquake. As for the sewerage system and telephone lines, examinations were made concerning vulnerability only.

Table-4 Damage to Lifeline Facilities

Scenario earthquake	No. of points in water supply pipes damaged	Length of medium tension power lines damaged	No. of points in medium-pressure gas pipes damaged
Khair al Din	3,965 points	1,664 m	78 points
Zemmouri	1,636 points	546 m	42 points

5. Seismic Diagnoses of Existing Buildings

Seismic diagnoses were conducted on selected architectural structures: three buildings which are considered important in the disaster prevention policy, that is, the guest house (Le Palais), the building for the senate (Le Senat) and Mustafa Hospital on one hand; and on the other, two standard buildings, that is, a five-storied condominium and a two-storied school building. Of these, the guest house and the building for the senate are masonry buildings. The results of the diagnoses are presented below: problems were found in the seismic capacity of all the buildings.

Guest house	:	The entire building has problems with the seismic capacity.
Building for the Senate	:	The entire building has problems with the seismic capacity.
Mustafa Hospital	:	Problems with the seismic capacity are observed on the first floor.
Five-storied Condominium	:	Problems with the seismic capacity are observed on the first to fourth floors.
Two-storied School Building	:	The entire building has problems with the seismic capacity.

6. Assessment of Urban Vulnerability

Following the analysis of the GIS data, "urban vulnerability" to seismic hazards of 34 communes in the region surveyed was assessed, making use of six indices: population density, construction date, economic value, "unsolidness" of grounds, degree of risks for slopes to collapse, and degree of difficulty of evacuation and rescues. In line with this, the communes subject to the survey were classified into five groups in accordance with the nature of their urban vulnerability as shown in the following table.

Table-5 Grouping of Communes by Nature of Vulnerability

Group	Characteristics
I	Many were old and constructed before 1981. Since those old buildings are not made quake-resistant, they are relatively vulnerable to earthquakes and likely to be damaged by seismic shaking.
II	This group, as Group I, includes regions with the extremely high economic values. The population density is relatively higher than Group I. The degree of difficulty of evacuation and rescues is also relatively high.
III	Communes in this group are located on the sloping hills of Sahel, having a high risk of collapse of slopes due to earthquakes. Communes in this group have poor connectivity to broad road networks and a high degree of difficulty of evacuation and rescues.
IV	The grounds of communes in this group are likely to shake heavily when earthquakes occur. The economic risk is somewhat high.
V	The vulnerability to earthquakes is relatively low compared to other groups.

Based on the results of the assessment of urban vulnerability and the seismic Microzoning, three case studies were conducted as listed below.

(1) Case Study 1 : Capacity of evacuation areas
(2) Case Study 2 : Safety of broad road networks for evacuation and rescue efforts
(3) Case Study 3 : Measures to reduce impact of seismic hazards

As for the 34 communes surveyed, measures which may be feasible for minimizing damage caused by earthquakes from the viewpoint of urban planning and land use planning are:

- Improving the seismic capacity of architectural structures which currently bear low seismic capacity
- Restricting the construction of buildings close to lands with a very steep side, and conducting some measures to minimize the risk involved in steep sides
- Securing parking lots and reducing illegal street parking
- Widening narrow roads
- Securing and improving the connectivity to wide road networks (particularly for communes in Group III)
- Securing open spaces (parks, etc.)
- Reallocating and decentralizing the currently centralized urban functions (particularly for communes in Groups I and II)
- Preparing for great seismic shaking (such as taking steps to prevent objectives from falling off)

7. Scenarios of Seismic Hazards

Based on damage estimated under this survey, and in consideration of the current situation and past experience of Algeria, possible scenarios were drawn up under the conditions provided as follows.

- <u>Assumed earthquake</u>: A scenario earthquake of the Khair al Din fault occurs at eight o'clock in the evening
- <u>24 items concerning emergency activities in the scenarios</u>: (1) disaster headquarters; (2) supporting centers; (3) housings and shelters; (4) rescue and fire extinction activities; (5)

maintenance of order; (6) medical activities for the wounded; (7) medical and sanitary affairs; (8) missing persons; (9) handling of dead bodies; (10) false rumors and panic; (11) mental health care; (12) education; (13) acceptance of assistance; (14) foods; (15) drinking water; (16) electricity; (17) gas supply; (18) telecommunications; (19) mass media; (20) air transportation; (21) marine transportation; (22) land transportation – bridges: (23) land transportation – roads; and (24) removal of rubble

- Scenarios by individual items: The worst scenario and another scenario to improve the situation in the former scenario are both presented. And matters which will help improve the situation in the worst scenario are listed.
- Time axis: 5 stages – (1) immediately after the earthquake to one hour later; (2) one hour later – 24 hours later; (3) one day later – three days later; (4) three days later to seven days later; and (5) 7 days later and afterwards

For the purpose of gathering materials to form recommendations concerning emergency actions, specific recommendable actions commonly pertaining to many items or related to individual items were listed. Of these, the following six matters were finally extracted.

- Conducting seismic analyses and improving the seismic capacity of various centers and facilities
- Providing foreknowledge about earthquakes in advance
- Drawing up an emergency action plan and conducting various kinds of training
- Storing emergency relief goods
- Clearly presenting the procedure to draw up a full-scale rehabilitation plan
- Keeping records, reviewing activities, and clearly presenting a plan to improve activities

8. Recommendations

8.1 Recommendations concerning Organizations, Systems, and Disaster Prevention Plans

Tasks concerning seismic disaster prevention are sorted in the form of three matrices.

(1) Damage scenario (see Chapter 8): Concerning 24 functions necessary for emergency actions, assessments are made in consideration of the time axis after the earthquake occurs.

(2) Level of disaster prevention: Assessments are made over advantages and disadvantages, and recommendable actions for 62 small items categorized in seven large items (citizens, organizations and systems, disaster prevention resources, information and communications, moral improvement, and education and training).

(3) Roles in disaster prevention actions: Concerning four large items (preparation, reduction in damage, emergency actions, and recovery and rehabilitation), the current situation and tasks of a total 72 items are sorted in terms of three elements – public aid, mutual aid and self-help. Then, priority order is given.

Accordingly, top priority was given to the following tasks:

- Establishing a national disaster prevention committee (DNRM) (promulgation of a government decree according to Law No. 04-20)
- Drawing up of a national disaster prevention strategy and a national disaster prevention plan by DNRM
- Drawing up of local (individual) disaster prevention plans in line with the national plan

Upon drawing up the strategy and plans cited above, the importance of covering all the stages (before and after, and in the middle of the disaster) and all the entities participating in activities to minimize the damage (the central and local governments, local communities, and citizens) is emphasized. At the same time, in accordance with the tasks extracted from the results of the analysis, points to note in drawing up disaster prevention plans are also provided.

8.2 Recommendations concerning Strengthening of the Seismic Capacity of Architectural Structures, Infrastructure and Lifeline Facilities

Recommendable methods to reinforce the seismic capacity of the five buildings subject to the seismic diagnoses were provided, while suggested designs to improve the seismic capacity were outlined. Where the infrastructure and lifeline facilities are concerned, recommendations were given concerning the strengthening of the seismic capacity.

9. Transfer concerning Seismic Microzoning Technology

As the survey made progress, the technology transfer was carried out in the following manner. The nature and schedules of the technology transfer are shown in Table-6.

Table-6 Technology Transfer

Item	Algerian side	Survey team	Date
Setting of scenario earthquakes	Y. Bouhadad	Morlow and Bertland	May 14 – 16, 2006
Ground modeling and hazard analysis	N. Mezouer, L. Haderbache, N. Guessoum, D. Ait Benameur, M. Ait Ameur	Segawa and Nishii	May 21 – June 8, 2006
Damage function for architectural structures	Y. Mehani, A. Remas	Inoue	May 16 – June 19, 2006
Estimation of damage to infrastructure and lifeline facilities	A. Kibboua	Miyazaki	May 13 – June 9, 2006
Judgment on and strengthening of seismic capacity of masonry buildings	Y. Mehani, A. Remas	Kagawa	October 11, 2005 – June 8, 2006
Judgment on and strengthening of seismic capacity of reinforced concrete building	Y. Mehani, A. Remas	Inoue	May 16 – July 8, 2006
Creation of GIS data	S. Saadi (CGS) M. Boukri (CGS) R Douar (URBANIS) A. Gharbi (URBANIS) A. Allouane (URBANIS) H. Metref (URBANIS) F. Sahraoui (DGPC) R. Aliouat (DGPC) T. Benattou (INCT)	Kiyota and Tanaka	June 5 – 18, 2006

Chapter 1. Introduction

1-1 Background

A large earthquake with a magnitude of 6.8 struck Algeria on 21 May 2003. The tremor destroyed more than 20,000 buildings while the number of dead and injured reached 2,278 and 10,000, respectively in Wilaya Boumerdes and Algiers.

The northern coast of Algeria abuts the Mediterranean Sea. In this area, the African and Eurasian plates push against each other resulting in increased seismic activity. As a result, the area has historically suffered from repeated earthquakes.

Under such circumstances and in response to a request by the Government of the People's Democratic Republic of Algeria, the Government of Japan has decided to conduct "A Study of Seismic Microzoning of the Wilaya of Algiers, People's Democratic Republic of Algeria" (hereinafter referred to as "the Study") and the Japan International Cooperation Agency (hereinafter referred to as "JICA"), undertook the Study.

1-2 Scope of the Study

1-2-1 Study Objectives

Objectives of the Study are as follows:

- To prepare seismic microzoning maps in the Wilaya of Algiers, which will be used to evaluate likely human casualties and loss of properties due to earthquakes;
- To suggest an earthquake disaster management system for the Wilaya of Algiers; and
- To pursue technology transfer to the Counterpart personnel throughout the course of the Study.

1-2-2 Study Concepts

The Study consists of following 3 components.

(1) Microzoning

Microzoning study estimates hazards and damages by scenario earthquakes. These results shall be utilized to improve planning and capacity building for earthquake disaster management. The Study Team conducted the microzoning study in the Study Area and transfer the technology to the Counterpart personnel.

(2) Proposals for vulnerability analysis and retrofitting of strategic buildings

The Study Team and Counterpart personnel, together with related agencies had discussions and compiled a proposal for seismic retrofitting of buildings.

(3) Proposals for disaster management plan

The Study Team made proposals in order to construct a framework for a disaster management system and define those functions and responsibilities. The Study consists of the study of current disaster management capacity and proposals for enhancement of disaster management capacities.

1-2-3 Study Area

The study area covers the Wilaya of Algiers and the microzoning mapping covers a total of approximately 225 km^2, including the surrounding urbanized area, as shown in Figure 1-1.

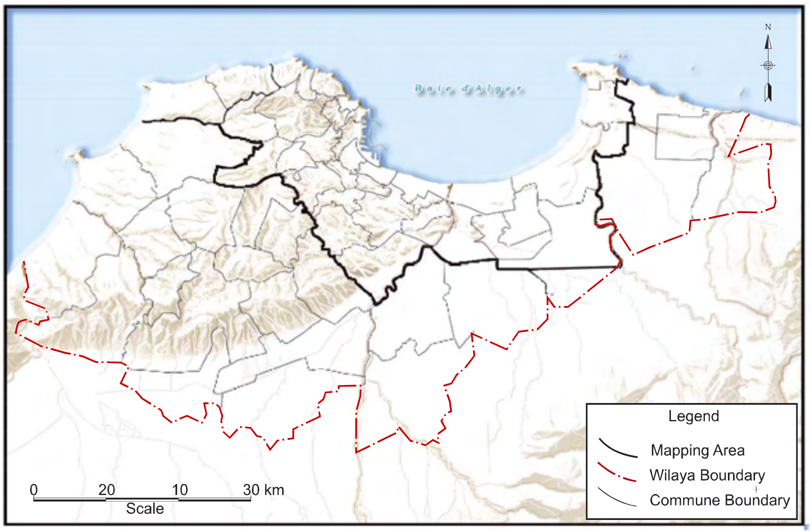


Figure 1-1 Map of the Study Area

1-2-4 Schedule of the Study

The Study comprises three phases as follows; the overall schedule is shown in Figure 1-2.

1st Phase: Data collection (February 2005 to August 2005, 7 months)
2nd Phase: Data analysis (September 2005 to March 2006)
3rd Phase: Preparation of microzoning maps and evaluation of vulnerability (April 2006 to December 2006)

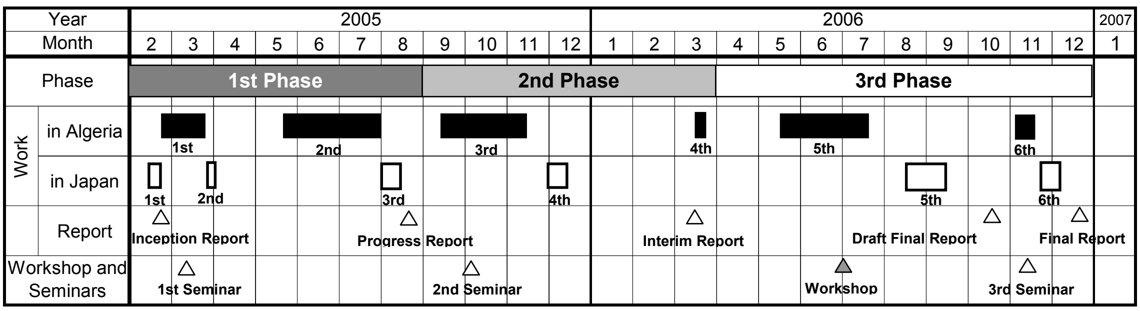


Figure 1-2 Overall Schedule

Figure 1-3 outlines the work items (Tasks) in the three phases. In August 2005, a Progress Report describing the work performed in the 1st Phase was submitted. In March 2006, a Interim Report summarizing the work in the 1st and 2nd Phase was submitted as scheduled.

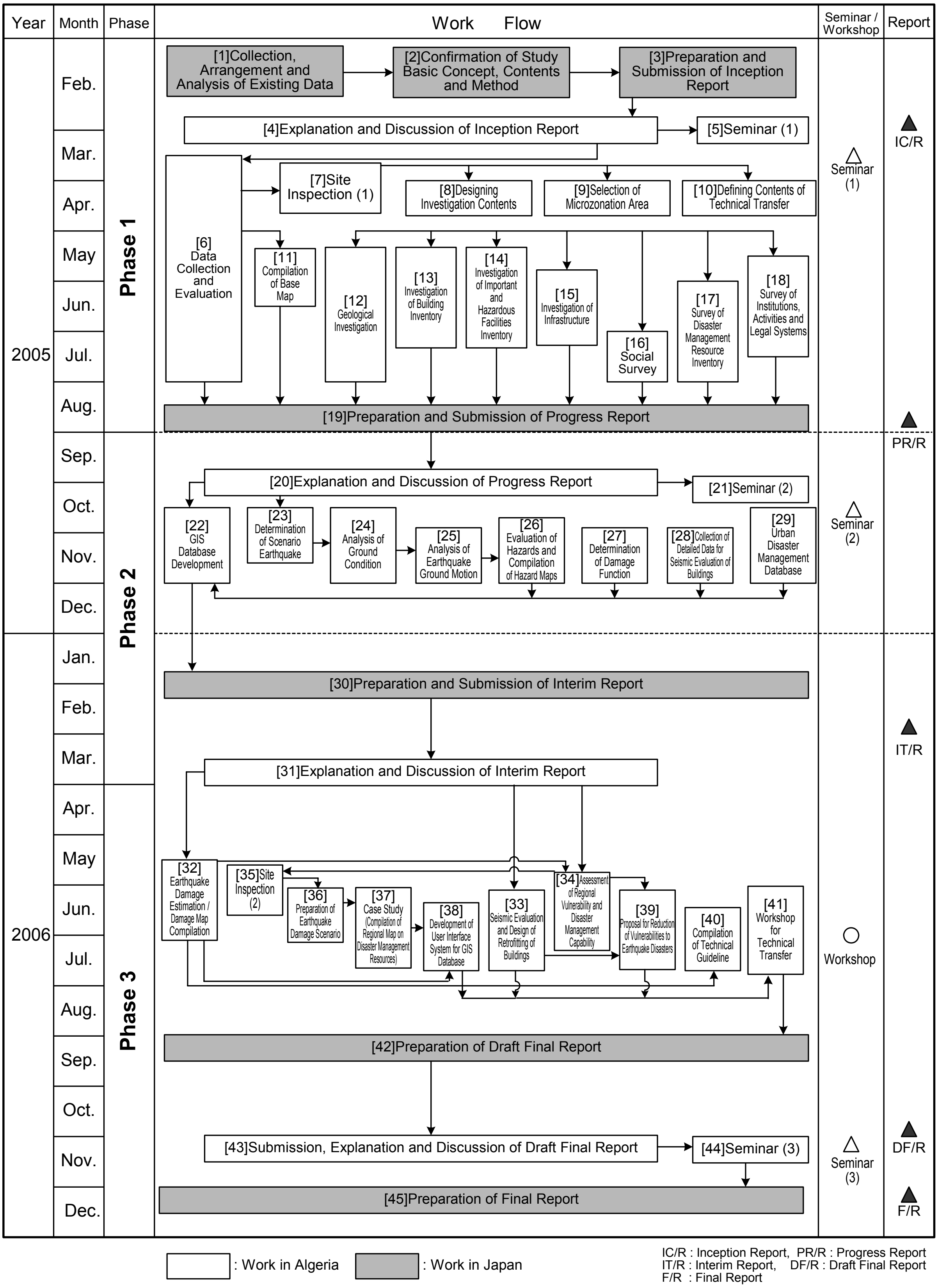


Figure 1-3 Work Schedule

1-2-5 Implementation Organization

The Study has been conducted through the joint efforts of the JICA Study Team and Algerian counterparts, which together have formed a study implementing body as shown in Figure 1-4.

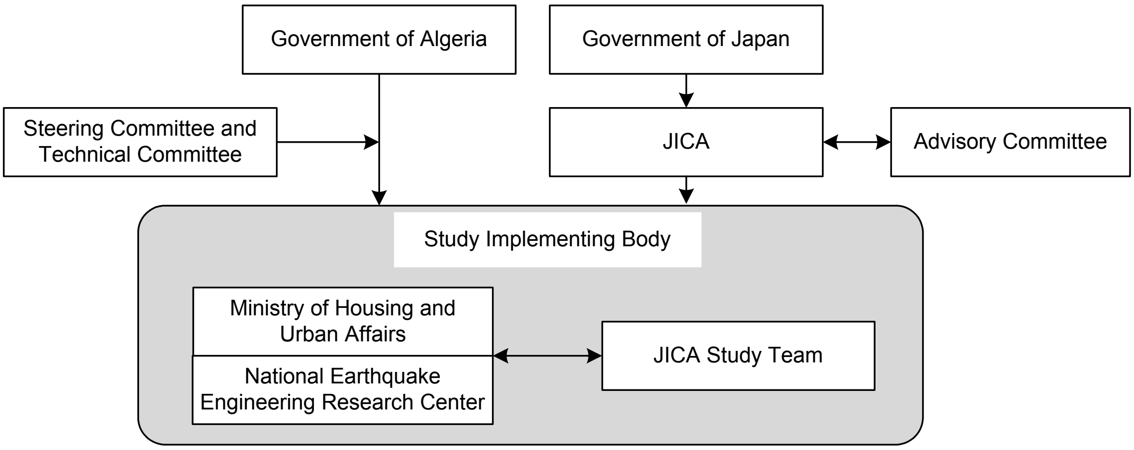


Figure 1-4 Organization for the Study

The members of the implementing body are as follows:

JICA Study Team

Name	Specialization
Mr. Osamu NISHII	Team Leader / Damage Estimation
Mr. Kenji YANO	Deputy Team Leader / Administration for Disaster Prevention
Dr. Pierre MOUROUX	Organization / Institution
Dr. Thierry WINTER	Seismology 1
Dr. Guillaume BERTLAND	Seismology 2
Mr. Jun MATSUO	Geology
Mr. Shukyo SEGAWA	Geotechnics
Mr. Hideo KAGAWA	Building Evaluation 1 (Earthquake resistance / Reinforcement)
Mr. Akira INOUE	Building Evaluation 2
Mr. Ryo MIYAZAKI	Infrastructure Evaluation
Mr. Kenichi TANAKA	Urban Prevention / Regional Planning
Dr. Philippe MASURE	Urban Prevention / Social Aspect
Mr. Daisaku KIYOTA	GIS / Database
Mr. Norihiko IGUCHI	Interpreter (Japanese/French)
Mr. Chihiro NISHIWAKI	Operational Coordination

Counterparts

Name	Organization
Dr. Mohamed FARSI	CGS
Mr. Djamel MACHANE	CGS
Mr. Youcef BOUHADAD	CGS
Mr. Hamou DJELLIT	CRAAG
Mrs. AIT BENAMEUR	CGS
Mr. Noureddine MEZOUER	CGS
Mr. Mourad AIT AMER	CGS
Mr. Abderrahmane KIBBOUA	CGS
Mr. Mehdi HADAD	INCT
Ms. Samira SADDI	CGS
Mr. Mehdi BOUKRI	CGS
Mr. M'Rizek KEFFOUS	DGPC
Ms. Rachida DOUAR	URBANIS
Mr. Youcef MEHANI	CGS
Mr. Abdelkader REMAS	CGS
Mr. Kamel NASRI	MHU
Mr. Mohamed AMRANE	DUC

For guidance and advice to the Study, JICA formulated an advisory committee comprising three members. In Algeria, a steering/technical committee has been organized to provide guidance/advice, assist in data collection, and to discuss earthquake disaster management.

JICA Advisory Committee

Name	Occupation
Dr. Kimiro MEGURO	University of Tokyo, Institute of Industrial Science International Center for Urban Safety Engineering
Mr. Mizuo INUKAI	Division Head, Evaluation System Division, Research Center for Land and Construction Management, National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure and Transport
Mr. Kenji KOSHIYAMA	Disaster Reduction and Human Renovation Institution

Steering/Technical Committee

Ministry of Housing and Urban Affairs (MHU)
National Earthquake Engineering Research Center (CGS)
Ministry of Interior and Local Collectives
Ministry of Foreign Affairs
Ministry of Land Management and Environment
Ministry of Finance
Local Government of Algiers Wilaya
National Center for Research in Astronomy
Astrophysics and Geophysics (CRAAG)
National Institute of Cartography and Remote Sensing (INCT)
Civil Defense General Directorate (DGPC)
National Council for Geographical Information (CNIG)

Chapter 2. Data Collection and GIS Database Development

2-1 Design of GIS Database

To reduce the risk of seismic hazard, it is very important to have realistic images of the hazard.

GIS helps us to understand what is happening in the real world by compiling scattered, unlinked information together

A Geographic Information System (GIS) is a kind of database system which links various types of information using geographically referenced electronic maps as the key interface, which requires a great deal of time and expertise to do without GIS.

A GIS database has a large volume of data and requires a specific structure; thus, the architecture and data modeling have an enormous influence on its performance, maneuverability and functionality.

The topographic information resources we have utilized for the basis of GIS database are as follows:

1) 1:7,500 topographic maps covering part of the study area (7 sheets)
2) 1:10,000 topographic maps covering part of the study area (14 sheets)
3) 1:25,000 topographic maps covering the study area (13 sheets)
4) SRTM (Shuttle Radar Topography Mission; NASA) height information covering the study area
5) LANDSAT (NASA; supplied by the USGS) images covering the study area
6) Administrative boundary information (MapInfo data format) supplied by INCT & URBANIS

To create the base map for this study, rectification and georeferencing of the scanned topographic maps and digitization of the administrative boundaries with the interpretation and compilation of the supplied information have been carried out. SRTM and LANDSAT images have also been georeferenced and transformed to "North Sahara 1959 Datum", which is adopted in Algeria. For the slope and height information, a digital elevation model (DEM) covering the study area is scheduled by INCT.

For this study, the study team planed to construct the following items for the GIS database as the foundation of analysis while considering the necessity and the availability of the existing resources.

Items:

1) Municipality (Commune boundaries)
2) Geology
3) Resources for disaster prevention
4) Slope (height and slopes of the surface)
5) Buildings
6) Road Networks
7) Rail Roads
8) Power Lines (electric power)

9) Gas Pipes
10) Water Supply System
11) Sewage System

The GIS database for this study aimed to be the platform for various types of information, with the ability to compile, update and better utilize information.

North Sahara 1959 UTM Zone 31N

Projection: Transverse Mercator
Project Easting: 500000.000000
Project Northing: 0.000000
Central Meridian: 3.000000
Scale Factor: 0.999600
Latitude of Origin: 0.000000
Angular Units: Degrees (0.017453292519943299)
Prime Meridian: Greenwich (0.000000000000000000)
Datum: North Sahara 1959
Spheroid: Clarke 1880 RGS
Semimajor Axis: 6378249.144999999600000000
Semiminor Axis: 6356514.869549775500000000
Inverse Flattening: 293.464999999999970000

The conceptual architecture of this database is described as follows:

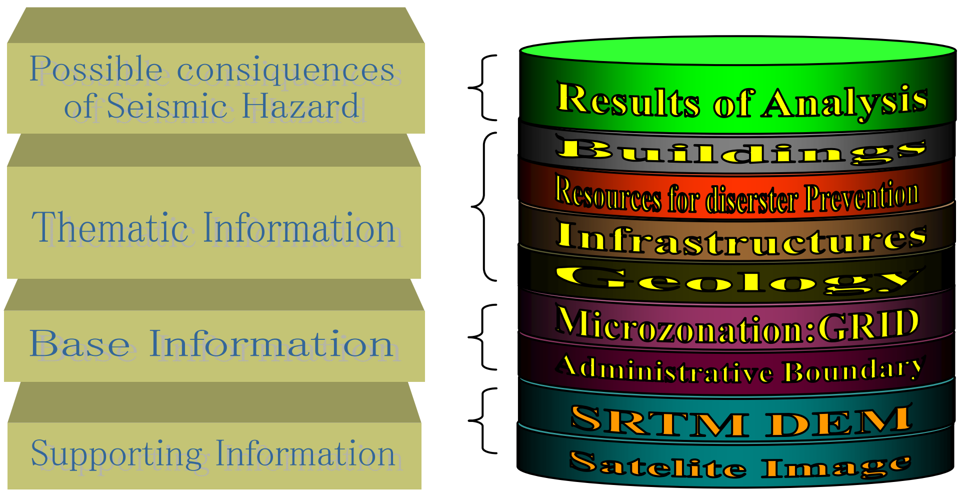


Figure 2-1 Conceptual Database Schematic

2-2 Design of Geographic Database

2-2-1 Topography and Geology

(1) Topography

The Study Team purchased 1:10,000 and 1:25,000 scale maps, which were published by INCT. The Study team digitized the contour lines of the 1:10,000 scale maps and created DEM (Digital Elevation Model) data.

(2) Elevations

The 5-m interval of the DEM data (Figure 2-2) was provided from INCT. The elevation obtained from the 1:10,000 topographic maps was used alongside the DEM from INCT in the hazard analysis.

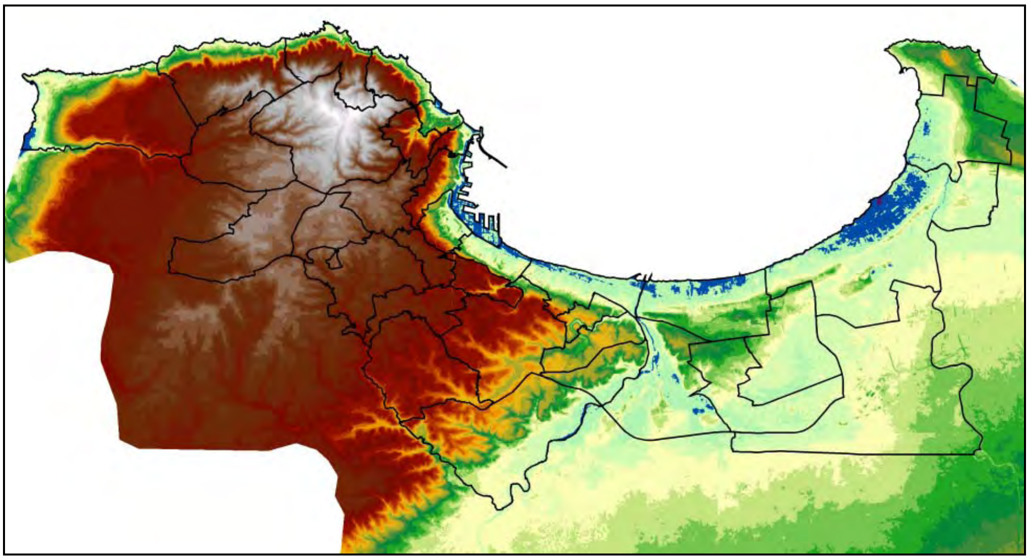


Figure 2-2 Digital Elevation Model

(3) Geology

The 1:50,000 scale printed maps cover the study area; however, some of them are very old. The study team interpreted these maps and created total geological classifications and distributions in the study area.

2-2-2 Buildings and Important Hazardous Facilities

(1) Buildings

1) Classification of Buildings

(A) Structural Type

Masonry structures prevailed for buildings in Algiers Center, Casbah and adjacent areas during the first half of the 20th century. Reinforced concrete structures with un-reinforced hollow brick walls became more typical post-1960 in Algiers.

Most existing buildings in Algiers are reinforced concrete or masonry structures. Steel structures are less numerous but it is noted that a few high-rise housing complexes with approximately 15 stories were constructed in the 1950s.

Followings are typical structural types;

a) Reinforced Concrete (RC) Moment Frames
b) Reinforced Concrete (RC) Moment Frames with RC Shear Walls

c) Reinforced Concrete Shear Walls without Moment Frames
d) Steel Moment Frames
e) Steel Moment Frames with Bracings
f) Masonry Structures

(B) Constructed Year

Buildings are classified by their constructed year and based on the particular period that a new seismic design code and a related regulation was introduced and applied in Algeria.

Constructed years for existing buildings are divided into five periods, namely on and before 1955, 1956 ~1980, 1981 ~ 1999, 2000 ~ 2002 and 2003 and after. This category has been simplified into three periods, 1980 and before, 1981 ~ 2002, and 2003 and after.

(C) Seismic Design Codes for Buildings

There was no official seismic design code in Algeria before 1955.

AS55 was introduced in 1955 and PS62 to PS69 were introduced in 1962 and 1969 respectively. These were guidelines and recommendations only; they were not a requirement for the design of buildings.

The first code of Algerian Earthquake Design Requirements (RPA) appeared as RPA81 in 1981 after the earthquake disaster of El Asnam on October 10 1980. This was revised in 1983 as RPA83. RPA81 and RPA83 were requirements for public buildings but not for private buildings.

RPA99 was introduced in 1999. ‘Elastic behavior of a structure while facing a relatively frequent moderate seismic event’ and ‘no collapse or loss of stability while facing a rare major seismic event’ were outlined as the objectives of the code. Seismic design code RPA99 was revised as RPA2003 through changes in seismic zones, with higher design accelerations in Algiers after the earthquake disaster of Boumerdes on May 21 2003.

(2) Important and Hazardous Facilities

The important facilities will be functioning strategic base buildings required for rescue and relief activities following an earthquake, and these facilities should not be vulnerable to fire or accidents after such an event. Accordingly, a survey of these must be performed to provide a statistical database for the evaluation of vulnerability in the microzoning study.

CGS and JST discussed and then defined the inventory survey plan for important and hazardous facilities. The result was outlined in the following Section 1). The distribution procedure is described in Section 2).

1) Plan of Important and Hazardous Facilities Inventory Survey

Based on discussions between CGS and JST, 530 of the following facilities, selected at random, were surveyed as a part of the building inventory survey.

(A) Important and Hazardous Facilities

Some 14 important and hazardous facilities in the 34 communes have a strategic disaster management function for which a total of 476 samples (facilities) were surveyed. The contents of the surveyed items are the same as those in the Building Inventory Survey, with additional items on the survey form including hazardous material and its storage and volume. For this detail contents refer to Chapter 2-2-2 (1).

(B) Particular (Important and Hazardous) Facilities

Some 54 important and hazardous facilities in special communes have a strategic disaster management function and are not vulnerable to fire and accidents during an earthquake. As for 1), the contents of surveyed items are basically the same as in the Building Inventory Survey.

2) Distribution of Important and Hazardous Facilities

An assessment of the distribution of important and hazardous facilities was undertaken based on discussions within the team (CGS, JST and URBANIS). This process involved:

a) Selection of 14 important and hazardous facilities based on their strategic disaster management function.
b) These selected facilities are distributed to all (34) communes.
c) All facilities in each commune are assigned a number in the digital mapping system.
d) The target facilities were decided randomly.

3) Distribution of Particular (Important and Hazardous) Facilities

As noted in Section 1), 54 important and hazardous facilities were selected based on strategic disaster management function.

Despite the fact that detailed census data on population and residential buildings was obtained, the total number of non-residential buildings i.e. governmental offices, offices, hospitals, schools and so on, are unknown. Therefore, the distribution of buildings was determined based on the coefficient of population in each commune.

2-2-3 Infrastructure and Lifelines

(1) Infrastructure

1) Roads

The road network information was compiled using the URBANIS data, topographic maps (1:10,000 and 1:25,000) issued by INCT, and a schematic road map provided by DTP. The road width and length information for the national roads and the Wilaya roads was provided by MTP. The digitized map is shown in Chapter 6.

Bridge data were compiled using the results of the bridge inventory survey conducted by a local contractor under the JST and the counterpart.

2) Railways

The length of the railway network in the Wilaya of Algiers totals 61 km. It is a double railroad with a reinforced rail type UIC 54.

The railway damage due to the Boumerdes Earthquake according to SNTF was slightly.

3) Ports and Airport

The layouts of the Algiers port and airport were obtained based on the URBANIS data.

(2) Lifelines

1) Water Supply

DHW provided the JST with digital data on the water supply pipelines and a hard copy of the water tower locations.

2) Sewerage

DHW provided the JST with hard copies of the sewerage network layout and a summary of its components. However, the network map and the components table did not contain all information.

3) Electricity

Sonelgaz electricity division provided the JST with the digital data for the high voltage (220,000V or 60,000V) cable network and hard copies of the medium voltage (30,000V for rural areas or 10,000V for urban areas) cable network.

4) Gas

Sonelgaz gas division provided the JST with hard copies of the high pressure gas pipeline (20 bar to 70 bar) and medium pressure gas pipeline (4 bar to 5 bar).

5) Telecommunications

The telecommunication cable network layout (optic fiber cable) was not available in map form for the study area.

2-2-4 Population and Households

(1) Population in the Wilaya of Algiers

The total population of the Wilaya of Algiers was 2,562,424 when the General Population and Housing Census was undertaken in 1998. By 31 December 2002, the population was estimated to have increased to 2,700,449[1] with a density of 3,337 people per square kilometer.

[1] Source: Statistical Yearbook of Algiers Wilaya (2003)

During the period between the previous two censuses (1987-1998) the population increased at an average annual rate of 1.6%, which is lower than the national rate of 2.5%. There is a general movement of the population towards the periphery of the Wilaya of Alger.

(2) Population by Gender

The population of the Wilaya of Algiers comprised 49.7% females and 50.3% males in 1998

(3) Population by Age

The 1998 census data also shows a decline in the labor population. Those aged from 15 to 59 accounted for 27% of the total population in 1998 in comparison to 34% in 1987. The population aged 60 or more increased in the same period from 5.8% to 8%.

(4) Population Attending School

Schooling in Algeria is compulsory for children from the age of 6 to 15. The number of children attending school between the ages of 6 and 15 totaled 449,788 in the last census (1998). This implies that the rate of school attendance is about 91% for the Wilaya of Algiers, compared to the national rate of 83%.

(5) Working Population

Table 2-1 presents the results of the 1998 census concerning work activity in the Wilaya of Algiers.

Table 2-1 Work Activity of Residents in the Wilaya of Algiers

Item	Number of people	Percentage of the total population	Percentage of the working population
Total population	2,562,428	-	-
Working-age population	1,632,584	63.71%	-
Active population	909,780	35.50%	55.73%
Employed population	524,852	20.48%	32.15%
Unemployed	384,928	15.02%	23.58%

Source: RGPH 1998

In 1998 the working-age population (15-59) totaled 1,632,584, which represented 63.7% of the total population. The unemployment rate in 1998 was high (23.58% of the working-age population).

(6) Physically Handicapped Persons

In the Wilaya of Algiers, the number of handicapped people was estimated to be 18,799 in 1998.

(7) Population and Households within the Study Area

The Study Area consists of 34 communes and it had a total population of 1,803,258 in 1998. There were 300,438 households within the 34 communes in 1998.

Table 2-2 shows the population and the number of households within the Study Area in 1998.

Table 2-2 Population and Number of Households by Commune within the Study Area

Code	Commune	Population	Households	Code	Commune	Population	Households
1601	ALGER CENTRE	96,330	17,888	1619	BACH DJERAH	90,073	14,408
1602	SIDI M'HAMED	90,454	15,469	1620	DAR EL BEIDA	44,752	7,025
1603	EL MADANIA	51,405	8,283	1621	BAB EZZOUAR	92,158	15,370
1604	HAMMA EL ANNASSER	59,248	9,807	1622	BEN AKNOUN	19,406	3,371
1605	BAB EL OUED	87,557	14,160	1623	DELY BRAHIM	30,577	4,992
1606	BOLOGHINE	43,284	7,341	1624	HAMMAMET	19,650	3,406
1607	CASBAH	50,453	9,326	1625	RAIS HAMIDOU	21,517	3,556
1608	OUED KORICHE	53,378	9,138	1626	D. KACENTINA	82,730	13,446
1609	BIR MOURAD RAIS	43,255	7,296	1627	EL MOURADIA	29,503	5,176
1610	EL BIAR	52,584	9,182	1628	HYDRA	35,727	6,429
1611	BOUZAREAH	69,152	11,362	1629	MOHAMMADIA	42,079	6,928
1612	BIRKHADEM	55,083	8,833	1630	BORDJ EL KIFFAN	103,690	16,136
1613	EL HARRACH	48,167	7,645	1631	EL MAGHARIA	30,459	5,055
1615	OUED SMAR	21,396	3,309	1632	BENI MESSOUS	17,489	2,895
1616	BOUROUBA	77,496	12,291	1639	BORDJ EL BAHRI	27,905	4,465
1617	HUSSEIN DEY	49,921	8,139	1640	EL MARSA	8,782	1,470
1618	KOUBA	105,253	18,095	1644	AIN BENIAN	52,345	8,746

Source: RGPH 1998

2-2-5 Land-use and Urban Development

(1) Land Cover/Land Use Condition

In order to reliably determine the land cover in the Wilaya of Algiers, land cover maps from two seasons (1987 and 2000/2001) were prepared by interpreting LANDSAT satellite images. The land cover of the Wilaya of Algiers in 1987 and 2000/2001 is summarized in Table 2-3.

Table 2-3 Comparison of Land Cover in 1987 and 2000/2001

Land Cover Class	1987 Area	(Percent)	2000/2001 Area (ha)	(Percent)
1: Bare Land	1,353	(1.8%)	876	(1.1%)
2: Crops	23,139	(30.1%)	20,613	(26.8%)
3: Forest	4,675	6.1%	4,344	(5.6%)
4: Grassland	23,044	29.9%	20,071	(26.1%)
5: Industry	2,093	2.7%	2,776	(3.6%)
6: Infrastructure	639	0.8%	643	(0.8%)
7: Mixed Urban	5,313	6.9%	5,237	(6.8%)
8: Shrub	4,863	6.3%	1,846	(2.4%)
9: Urban	11,685	15.2%	20,420	(26.5%)
10: Water	167	0.2%	132	(0.2%)
(Unknown Error)	(13)	-	(13)	-
Total (excluding error)	76,971	(100%)	76,958	(100%)

Source: JICA Study Team

The “Urban” class represents the largest land cover change in the Wilaya of Algeirs during the period between 1987 and 2000/2001. The proportion of the total land area occupied by “Urban” class increased by 11.3% between 1987 and 2000/2001.

Three (3) of the ten (10) land cover classes (“Urban”, “Industry” and “Infrastructure”) that were identified in the LANDSAT images are considered to represent the developed areas that correspond to actual “urbanized” areas within the Wilaya of Algiers. Figure 2-3 shows the distribution of the “urbanized” areas in the Wilaya of Algiers in 1987 and in 2000/2001.

There were eight (8) communes in 1987 and 13 communes in 2000/2001 where over 80% of the commune area had been urbanized.

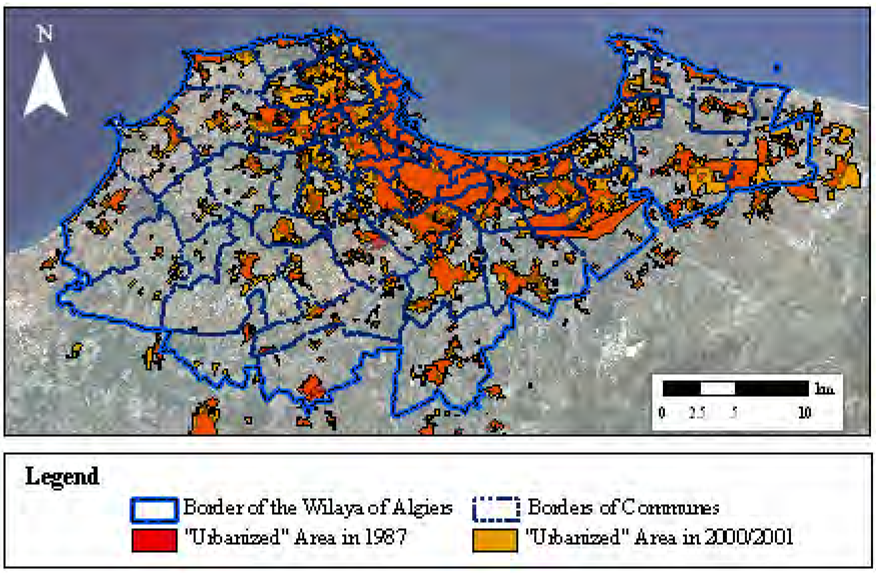
In the communes located further than about 10 km south of the coastline of the Bay of Algiers, the rate of urbanization between 1987 and 2000/2001 was not as remarkable as the communes situated within the coastal zone.

(2) Urban Development

1) Background

Immediately after the independence in 1962, Algeria was divided into 15 wilayas. Over the years, the number of wilayas within Algeria has increased, and by 1984 the number had reached 48.

In 1997, “Ordinance 97-14” was introduced to expand the Wilaya of Algiers by integrating 24 communes that had previously been within other wilayas adjacent to the Wilaya of Algiers.



Source: JICA Study Team

Figure 2-3 Comparison between Urbanized Areas in 1987 and 2000/2001

The “Governorate of Greater Algiers (GGA)” was installed in accordance with “Ordinance 97-15”. This new administrative division comprised 57 communes that were distributed in 13 districts. The GGA gave rise to the "Grand Urban Project for Algiers, the Capital of the 21st Century".

2) Related Legislation

The main legislative instruments that control land use and urban planning are the "Plan de Développement, d'Aménagement et d'urbanisme" (PDAU) and the "Plan d'Occupation des Sol" (POS).

The PDAU was prepared as the master development plan for land use and urbanization. The PDAU is used at communal and inter-communal levels, with nominal mapping scales of 1:5,000 and 1:10,000. The PDAU determines, for a commune or an association of communes, four (4) urbanization zones: currently urbanized (U), to be urbanized (i.e. presently, or soon to be, under development; AU), reserved for future urbanization (UF), and non-urbanizable (i.e. not to be used for urban development; NU).

The POS has been implemented in the form of detailed land use plans (5-10 POS's per commune), with a nominal mapping scale of 1:500.

The POS fixes in a detailed way the rights of land-use and construction. The regulation is accompanied by graphic reference documents.

The period of revision of the parameters of the POS units is 5 years for Zone U, 10 years for Zone AU, and 10 years for Zone UF. Both the PDAU and the POS were defined in various laws and decrees of application (regulations), especially by "Law 90-29 (1/12/1990)". This law was modified and complemented by "Law 04-05 (14/08/2004)" after the Boumerdes earthquake which occurred on May 21, 2003.

In 2004, the general approach was modified by introducing citizen participation into the PDAU implementation process.

Four decrees (regulations) relating to the application of Law 90-29 (28/05/1991) precisely set out the procedures to be followed:

- 91-175: RGA (Règles générales d'Urbanisme) General Rules of Urbanism.
- 91-176: Procedures for instruction and delivery of Urbanism Acts.
- 91-177: Procedures for elaboration and approval of the PDAUs.
- 91-178: Procedures for elaboration and approval of the POS.

The main modifications introduced by the Law 04-05 concern:

- Permits for construction: Civil engineering studies are necessary.
- Land-use planning studies: Natural and technological hazards are to be considered; and
- Land-use and construction have to be adapted to these threats.

Law 04-05 adds provisions for demolition of the structures which do not comply with the rules and procedures of town planning and construction.

A new PDAU for the Wilaya of Algiers (57 communes) was started in 2005, because the 20 communal PDAUs were not coherent and did not take into account the main items imposed by the Laws of 2004:

- Global approach;
- Environmental criteria;
- Sustainable development;
- Natural and technological hazards.

2-2-6 Disaster Management Resources

(1) Target Resources

Disaster management resources for earthquake disasters were checked through the "Disaster Management Resource Survey" undertaken by the JICA Study Team in 2005. Disaster Management Resources that could be utilized include evacuation/relief centers, temporary dwellings, tent towns, temporary hospitals, and temporary offices that could be provided during an emergency. The existing facilities that could be used as disaster management resources are listed in Table 2-4.

Table 2-4 Disaster Management Resources within the Study Area

Resource	Type	Target Objects
Parks	Open-air	Public Parks (all parks)
Vacant Land	Open-air	Vacant land (at least 1 ha in area)
Sporting Fields	Open-air	Open-air sports fields (athletics fields, tennis courts, etc.)
Airports	Open-air	Airfields
Ports	Open-air	Ports
Water	Open-air	Inland water (water bodies, as possible drinking water sources)
Police	Building/Facility	Police stations
Military	Building/Facility	Military buildings, and related buildings/facilities
Civil Protection	Building/Facility	Civil Protection Stations
Education	Building/Facility	Educational sites: schools, colleges, universities
Administration	Building/Facility	Governmental/administrative sites, including buildings/facilities
Public	Building/Facility	City auditoriums, public halls
Indoor Sports	Building/Facility	Gymnasiums (excluding those of schools, colleges, universities)
Medical/Health	Building/Facility	Hospitals, clinics, health care centers
Religious	Building/Facility	Mosques, churches, temples
Sanitation	Building/Facility	Sanitation sites
Disposal/Garbage	Building/Facility	Waste disposal treatment sites

Source: JICA Study Team

The location and various attribute data of the disaster management resources that were checked have been digitized into a GIS, and integrated into the “Database for Urban Disaster Management”. The results of the micro-zoning study and the urban vulnerability assessment were also incorporated into the database for disaster management.

(2) Existing Disaster Management Resources (Basic Data)

Table 2-5 shows the number and extent (ha) of existing disaster management resources by sector within the micro-zoning area, which consists of 34 communes.

Table 2-5 Summary of Existing Disaster Management Resources by Sector within the Micro-zoning Area

Code	Resource	Type	Number	Gross area (ha)
01	Parks	Open-air	118	175
02	Vacant Land	Open-air	28	49
03	Sporting Fields	Open-air	132	181
04	Airports	Open-air	1	-
06	Ports	Open-air	3	-
07	Water	Open-air	49	38
08	Police	Building/Facility	122	-
09	Military	Building/Facility	8	-
10	Civil Protection	Building/Facility	24	-
11	Educational	Building/Facility	770	661
12	Administrative	Building/Facility	107	53
13	Public	Building/Facility	163	460
14	Indoor Sports	Building/Facility	21	15
15	Medical/Health	Building/Facility	162	-
16	Religious	Building/Facility	207	-
18	Disposal/Garbage	Building/Facility	1	7.2

Source: JICA Study Team

Chapter 3. Natural Conditions for Microzoning

3-1 Seismotectonics and Seismicity of the Region

3-1-1 Geodynamic Context

The Algiers area is located along the Mediterranean coast in the vicinity of the boundary between the Eurasian plate to the north and the African plate to the south (Figure 3-1). Within Algiers, which is located at a latitude of approximately 36.75° N and longitude of 3.05°E, the relative motion of the Africa/Eurasia plates indicated by the geodesy data is summarized in Table 3-1. As geodetic and structural data yield similar results, we will hereafter consider the relative Africa/Eurasia displacement at Algiers, of 5 to 6 mm/yr towards the NNW.

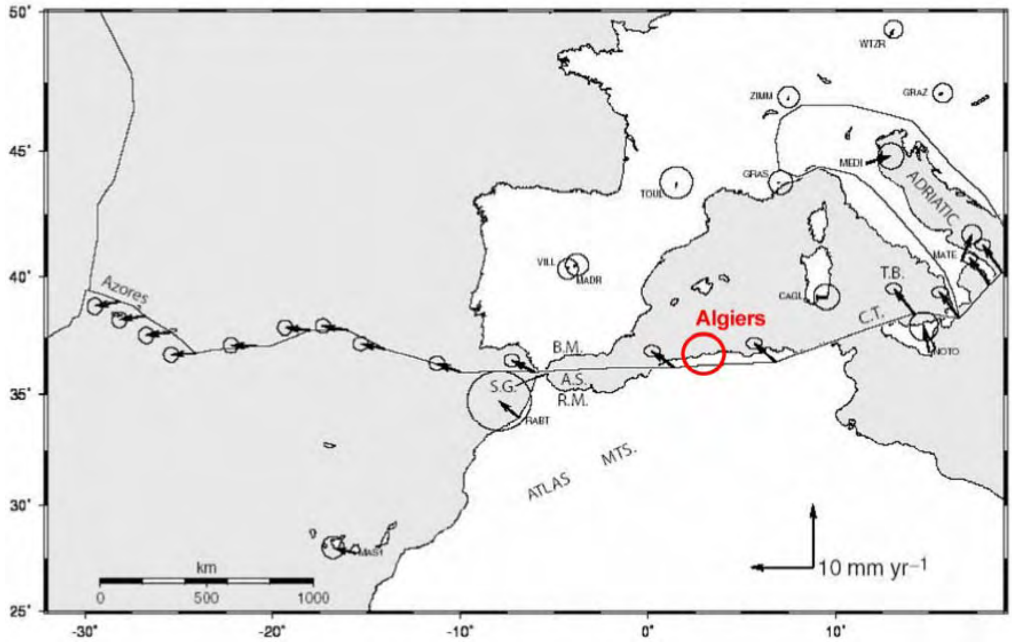


Figure 3-1 Africa/Eurasia Relative Displacement and Uncertainty Ellipses (2σ) on a Schematic Plate Boundary between the Azores Triple Junction and Italy, based on a rotation pole from McClusky et al (2003). SG: Straight of Gibraltar; BM: Betic Massif; AS: Alboran Sea; RM: Rif Massif; CT: Calabrian Trench; TB: Thyrrhenian Basin

Table 3-1 Azimuth and Velocity of Africa Relative to Eurasia, calculated at the location of Algiers (lat. 36.75°N, long. 3.05°E) from different plate kinematic models

	Rotation Pole				Displacement	
Reference	Relative Motion	Lat (°N)	Long (°E)	Rate (°/My)	Azim. °	Velocity (mm/y)
DeMets et al, 1994	Afr/Eur	21.0±4.2	-20.6±0.6	0.12±0.015	-30.9	5.8
Sella et al, 2002	Nubia/Eur	-18.23±9.5	-20.0 ±3.7	0.062±0.005	-64.3	5.9
McClusky et al, 2003	Nubia/Eur	-0.95±4.8	-21.8±4.3	0.06±0.005	-52.9	4.7
Albarello et al, 2003	Afr/Iberia	22.7	-20.6	0.119	-28.0	5.5

3-1-2 Structural and Tectonic Framework of the Algiers Region

From the Triassic to the present, the geological history of northern Algeria has been closely linked to Africa/Eurasia relative plate displacements. As a result of the tectonic history, the Tell range was formed by folds, faulted folds, and reverse faults trending E-W to NE-SW along the accommodation zone of the Africa/Eurasia convergence. Major brittle structures resulting from this evolution are:

- Normal faults heritated from mesozoic rifting, reactivated with reverse motion;
- Newly formed reverse faults, striking NE-SW to E-W.

Six strain regimes have been identified that affected the Tell range during the Neogene and Quaternary periods. The outcome from this tectonic evolution in the Algiers area is a structural framework dominated by compressional structures (folds and reverse faults) along a NE-SW to ENE-WSW direction. These structures are affected by a compression perpendicular to their trend and they are likely to accommodate this stress by reverse displacements with a possible strike-slip component.

3-1-3 Distribution of Seismicity

Seismic catalogues provide both: 1) macroseismic information related to historically large earthquakes (i.e. prior to 1900), and 2) more detailed information for the instrumental seismicity period. Figure 3-2 shows the distribution of earthquakes around Algiers from 1365 to 1995.

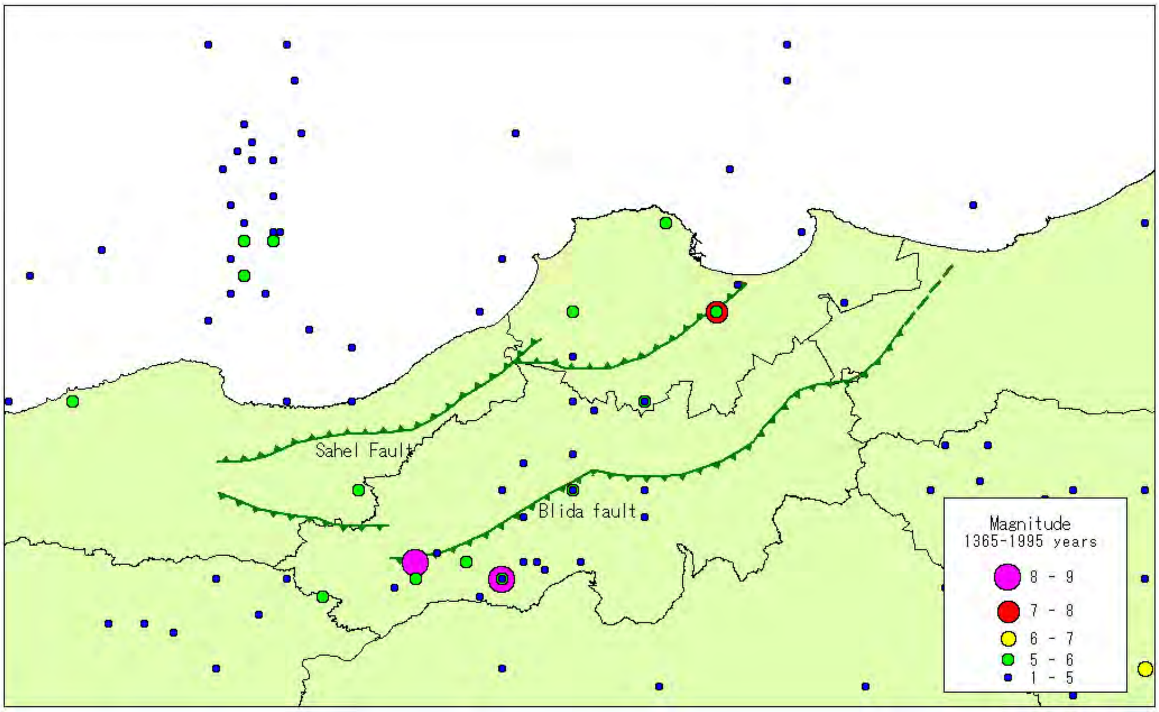


Figure 3-2 Distribution of Historical and Instrumental Seismicity in the Algiers Area

3-1-4 Historical Earthquakes in Northern Algeria

The Algiers area has been subject to several severe earthquakes throughout history. The oldest recorded event was the 1365 Algiers earthquake that destroyed the entire city and triggered a tsunami. The last recorded event was the Boumerdes (Zemmouri) earthquake of May 21 2003 (Ms=6.8), which killed 2278 people and injured several thousands. This recent earthquake occurred on a fault where little or no seismicity had previously been recorded. This highlights the point that historical seismic data are too scarce to allow reliable deterministic approaches for their estimation.

Other significant events affecting the Algiers area were the Oued Djer (31/10/1988, Ms=5.4), Mount Chenoua (29/10/1989, Ms=6.0), and Ain Benian (04/09/1996, Ms=5.7) earthquakes (see Figure 3-3). In addition, one should keep in mind that in the past even stronger earthquakes affected northern Algeria, for example El Asnam (10/10/1980, Ms=7.2).

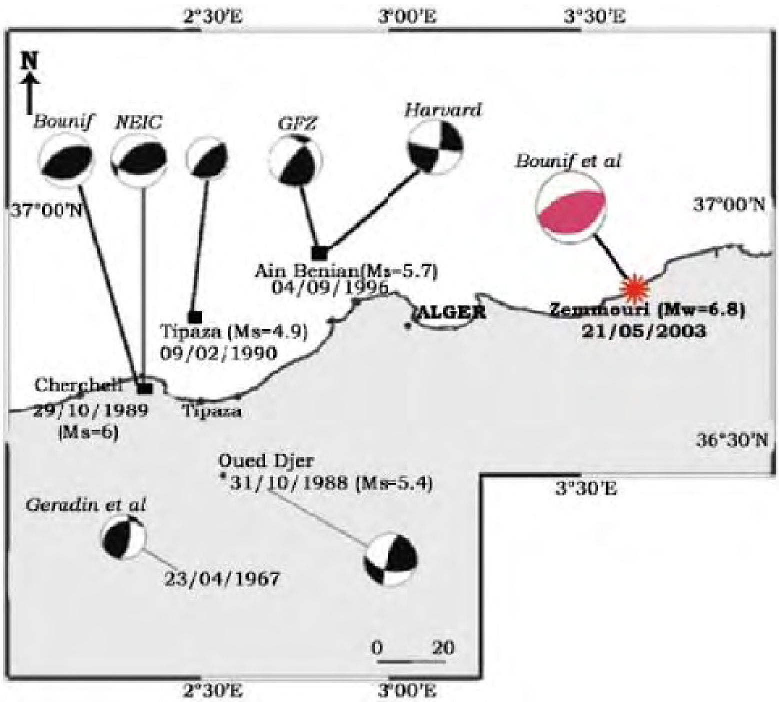


Figure 3-3 Recent Significant Earthquakes in the Algiers Area (Saadi, 2005)

[References]

DeMets C., Gordon R.G., Argus D.F., and Stein S., 1994, Effect of recent revisions to the geomagnetic reversal time scale on estimates of current plate motions. Geophysical Research Letters, 21, p. 2191-2194.

McClusky S., Reilinger R., Mahmoud S., Ben Sari D., and Tealeb A., 2003, GPS constraints on Africa (Nubia) and Arabia plate motions. Geophysical Journal International, 155, p. 126-138.

Saadi N., 2005, Etude sismotectonique de la région est-algéroise; Boumerdes, Zemmouri, Cap Djinet, Bordj Menaeil. Mémoire de projet de fin d'études d'Ingénieur, Université des Sciences et de la Technologie Houari Boumédiene, 109 pages, 68 figures, 1 annexe.

3-2 Geomorphological and Geological Features in the Study Area

3-2-1 Geomorphology

In the study area, three main morphological peculiarities exist as follows.

(1) Mitidja Plain

The Mitidja plain lies in the eastern part of the study area. This plain has extensive, very recent formations and has formed due to major quaternary filling of a vast synclinal structure. Its longitudinal extension is 120 km and it has a maximum width of 20 km.

(2) Bouzareah Hill

Bouzareah Hill is situated in the western part of the study area. The metamorphic solid mass of Bouzareah has developed to the degree that it reaches an altitude of 407 m. It has an anticline axis in a SE-NW direction.

(3) Marine Terrace

The marine terrace is a unit of outcrops between 50 m and 200 m in altitude separating the plain of Mitidja and the sea.

3-2-2 Meteorology and Hydrogeology

(1) Meteorology

In general, the coastal area of Algeria exhibits a typical "Mediterranean climate". The annual rainfall is low at around 600 mm. The average monthly temperature in Algiers is 12 °C in winter and 25 °C in summer.

(2) Groundwater Level

Figure 3-4 shows the groundwater levels observed during this project and as reported by existing records.

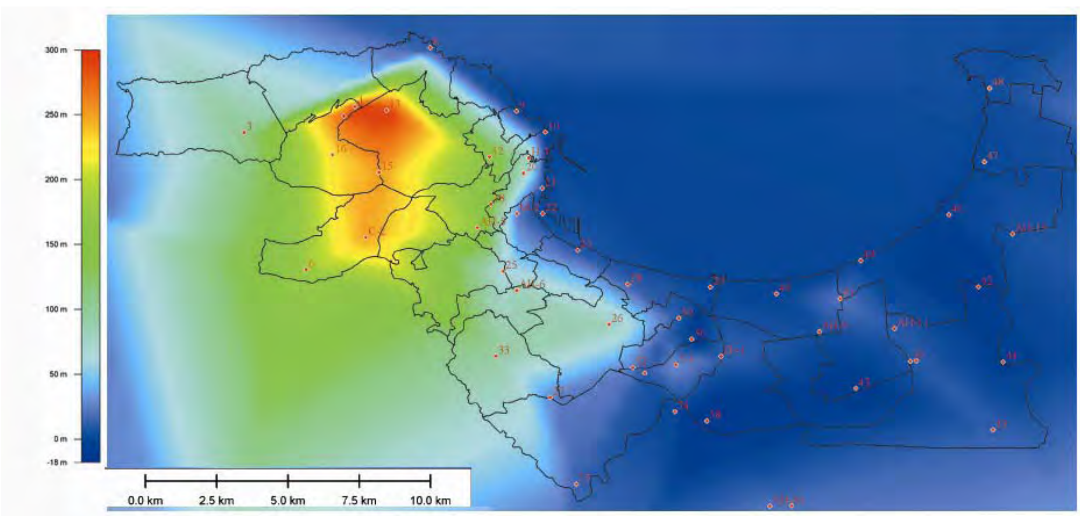


Figure 3-4 Map of Groundwater Elevations

3-2-3 Principal Geological Structure

In the geological structure of the Maghrebide chain, two major structural fields, formed from the north to the south, are recognised as follows.

(1) Internal Zones

The internal zones form a discontinuous band along the Mediterranean coast of the Maghreb. In the north of Algeria, they form the coastal massif, which is from the west to east, for example, Chenoua Mount, Bouzareah Hill, and so on. These old massif rocks are thought to be Palaeozoic.

(2) External Zones

The external zones are composed of mainly marl-limestone and sandstone from the Mesozoic and Cenozoic eras. These units are distributed in successive layers overlapping towards the south.

1) Miocene

(A) The Burdigalian (Early Miocene)

The Burdigalian deposits appear on the surface of the basin of Mitidja, on the anticline of the Sahel on the coast between EL MARSA and AIN TAYA, and on the periphery of the base south of Thenia.

(B) The Serravallian (Middle Miocene)

The Serravallian deposits appear on the surface of Thenia region with thicknesses reaching 1000 m, decreasing to 50 m near Algiers (Glangeaud, et al 1932).

2) Pliocene

The Pliocene is an unconformity with the Serravallian deposit. It is largely spread over the southern part of the Mitidja (Glangeaud et al; 1952). This deposit is primarily classified into two units, one being the Plaisancian deposit and the other the Astian deposit. These are sometimes separated by thicknesses varying between several centimeters to meters (Ayme, 1952, Yassini, Figure 3-5).

(A) The Plaisancian (Early Pliocene)

The Plaisancian deposit consists of blue marls and reaches a thickness of 1,000 m (Glangeaud et al; 1952). It is an unconformity with the covering layers.

(B) The Astian (Late Pliocene)

According to Glangeaud et al (1952), this comprises four units, these being (from the base to the top) yellowish marls, sandy limestone that is rich in bivalves and mollusks, then sandstone followed by sand (Glangeaud et al 1952) (Figure 3-5).

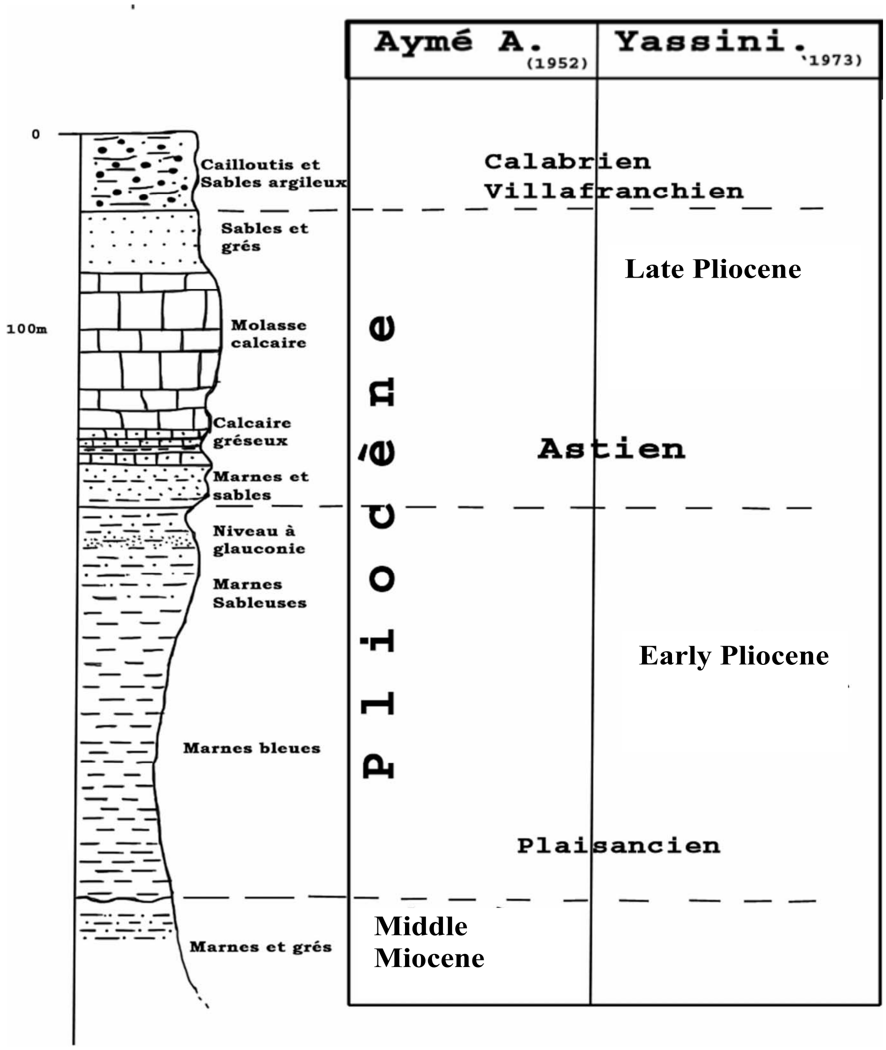


Figure 3-5 Pliocene Stratigraphy of Algiers Region (Djediat, 1996)

3) Quaternary

The Quaternary Formations cover a large area of the Algiers coastal region. They can be observed as terrace shapes comprising sand, gravels and sandy clay. The Quaternary terraces are subdivided into four periods corresponding to the principal Quaternary transgressions: the Calabrian, Sicilian, Tyrrhenian and Versilian.

The Quaternary marine terraces are found at higher altitudes, around 200 m in the east of Algiers and up to 325 m in the west (Djediat, 1996). The marine terrace is the result of vertical movements related to tectonic activity during the Quaternary. The early Pleistocene is represented by red clay, while the Holocene is represented by dunes of beach sand. Figure 3-6 shows a geological map of the Study area.

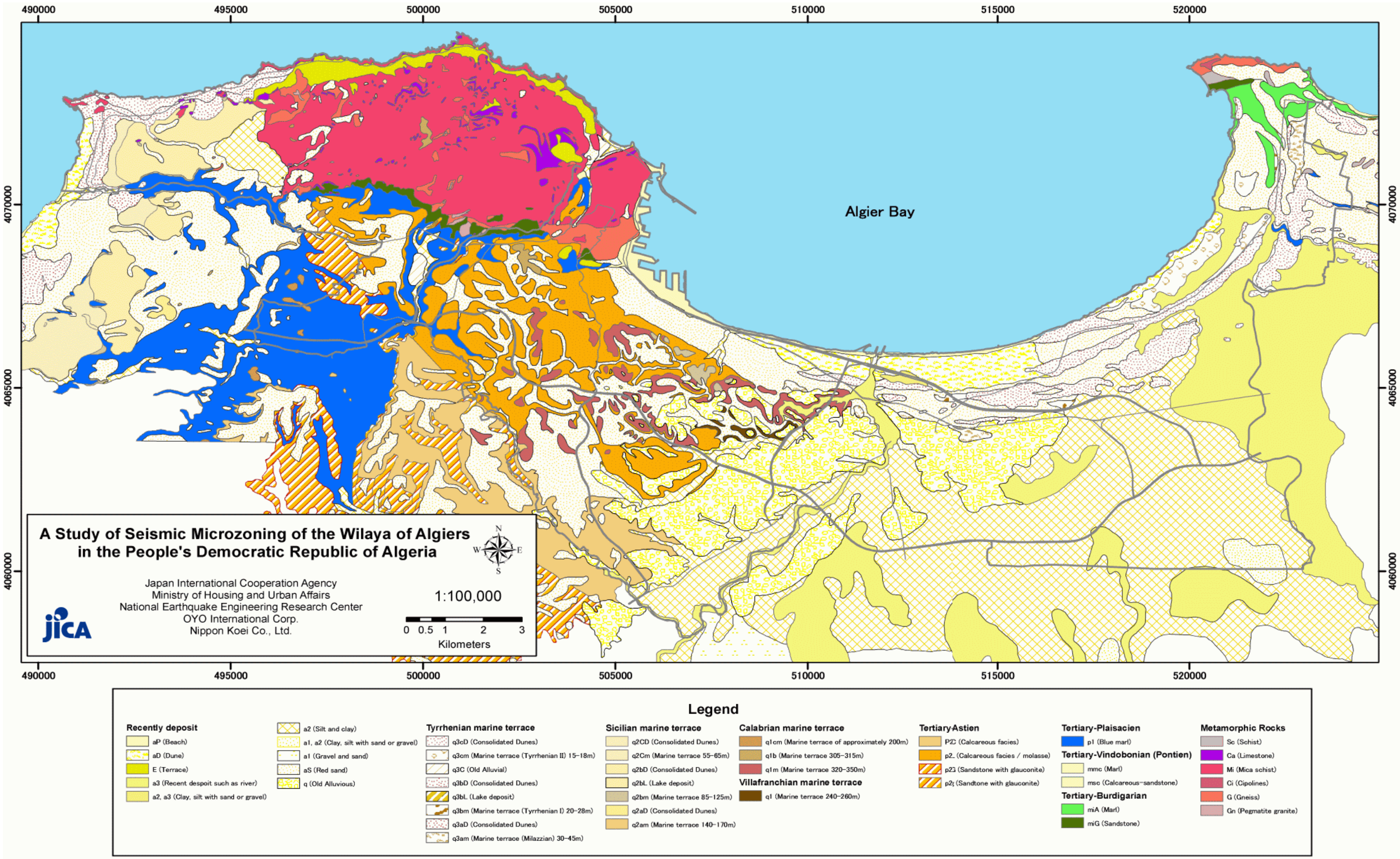


Figure 3-6 Geological Map of the Study Area

3-3 Supplemental Investigation

3-3-1 Boring

To assess the engineering geological structure, 50 new boreholes were drilled during the Study. The existing supplemental borehole data was also collected. The locations of the new and existing boreholes are shown in Figure 3-7. Existing borehole data were provided by LNHC (Laboratoire National de l'Habitat et la Construction) and ANRH (Agence Nationale des Ressources Hydriques). A total of 179 boreholes were used in the analysis.

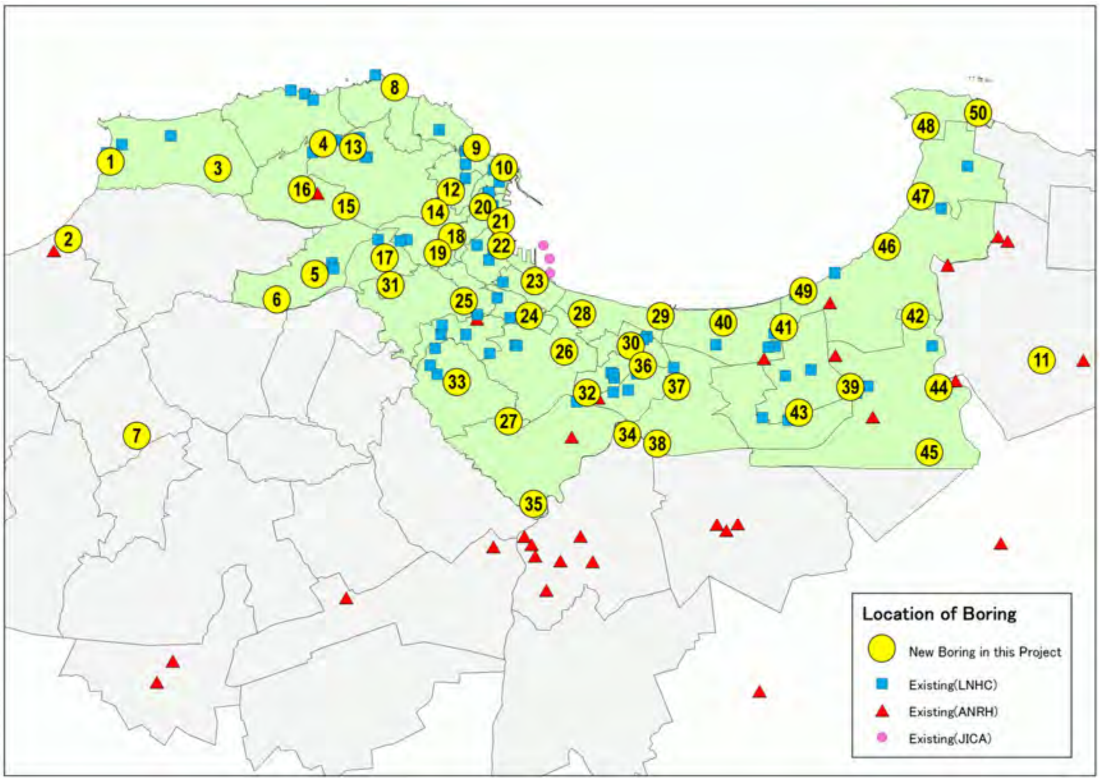


Figure 3-7 Boring Locations

Based on the boring data and technical papers, the geological strata were classified from an engineering geology viewpoint as shown in Table 3-2. The engineering properties of the materials, which were investigated by laboratory tests and geophysical investigations, were studied and compiled based on this classification.

Table 3-2 Engineering Classification of Geological Units

Symbol	Explanation
ap	Beach deposit and dune deposit
e	Slope deposit
a3	Quarternary deposit (sand)
a2	Quarternary deposit (clay)
q	Old Quarternary deposit
qt	Marine terrace
p2c	Astian layer (marl, weathered)
p2c-f	Astian layer (marl, fresh)
p2l	Astian calcareous layer (weathered)
p2l-f	Astian calcareous layer (fresh)
p1	Plaisancian layer (blue marl, weathered)
p1-f	Plaisancian layer (blue marl, fresh)
mi	Metamorphic rocks (schist, weathered)
mi-f	Metamorphic rocks (schist, fresh)

3-3-2 Laboratory Test

Several undisturbed specimens were retrieved during boring and the following parameters were measured in the laboratory tests. The results are summarized in Section 3-4.

- Wet density
- Water content
- Saturation ratio (Sr)
- Atterberg limits (LL, LP)
- Grain diameter of 50% passing (D50)
- Fine contents (FC)

3-3-3 Geophysical Investigation

Vs (S wave velocity) value is the most important parameter to conduct response analysis for amplification evaluation of seismic motion; however, there is very little information regarding Vs values in the study area. Therefore, PS logging was conducted at 34 boring points in the study area to a maximum depth of 99 meters. The down hole method was adopted in this study and the shear wave was generated by hammering both sides of a wooden board at the ground surface.

(1) Data quality control

The PS logging data quality was examined in two ways before analyzing the S wave velocity. First, the quality of the form of the S wave was checked. The phase of right hitting and left hitting of the S wave should be reversed. Poisson’s ratio was used in the next step. From P wave velocity and S wave velocity, Poisson’s ratio can be calculated analytically. Poisson’s ratio for rock is almost 0.25 and it becomes larger if the rock/soil is soft; however would not be expected to reach a value of 0.5. The velocities are considered reasonable because Poisson's ratio is generally between 0.3 and 0.49.

(2) Vs of Soils

The frequency distributions of observed Vs for each classified unit are shown in Figure 3-8. The velocity shows some variation even in the same geological unit reflecting the local ground condition. In the response analysis to evaluate the amplification characteristics of the surface soils, the Vs of each classified geological unit is necessary. It is ideal to use the local Vs value observed at each site; however, the data availability is limited. In this study, the average Vs value for each classified unit was calculated and shown in Table 3-3.

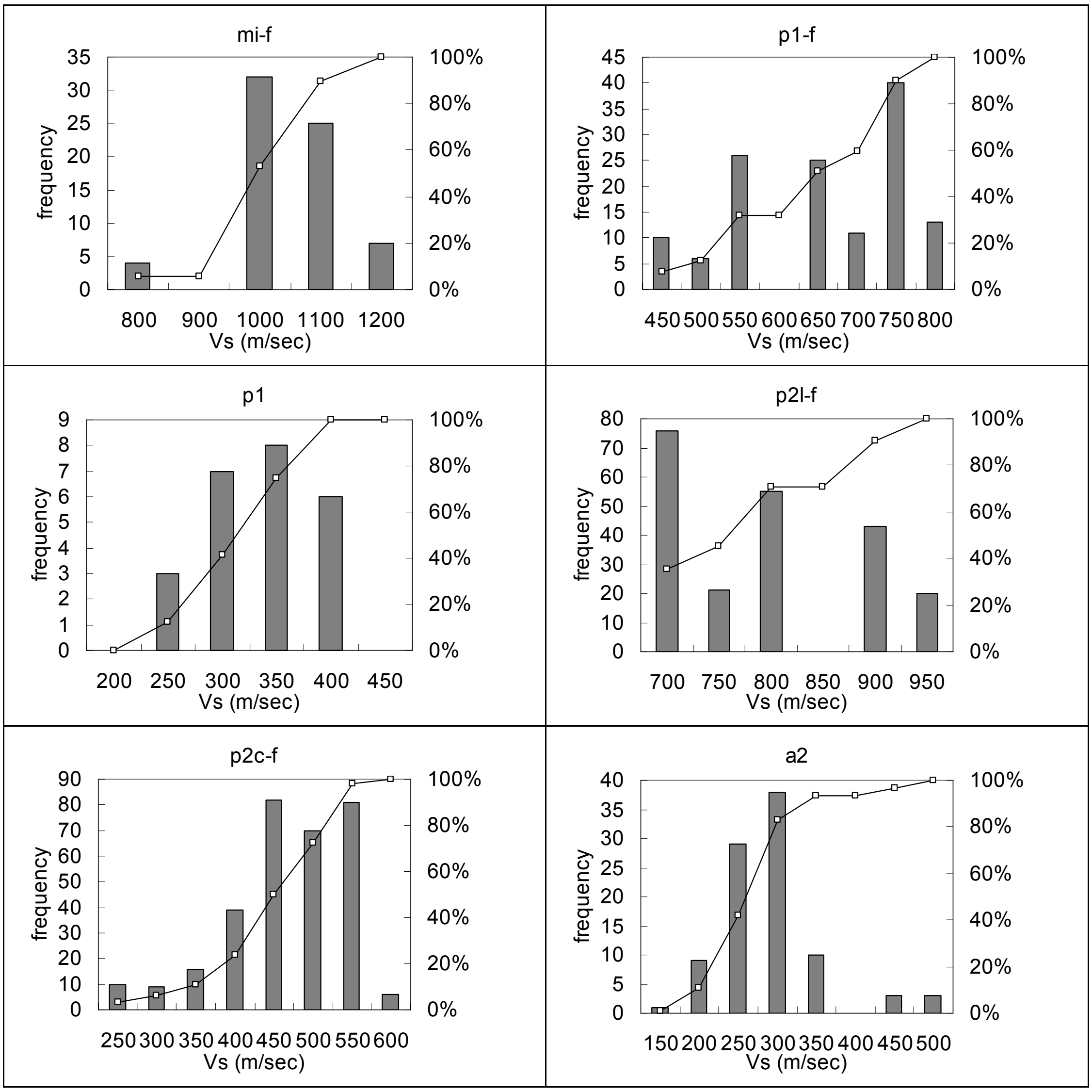


Figure 3-8 Frequency Distribution of S Wave Velocity

(3) Correlation between Vs and N Value

It is well known that S wave velocity and N value have a good correlation. Figure 3-9 shows the relationship between observed S wave velocity as determined by PS logging and N value by standard penetration test at the same point. The estimated correlation function and the function widely applied in Japan are also shown in this figure and these show similar relationships.

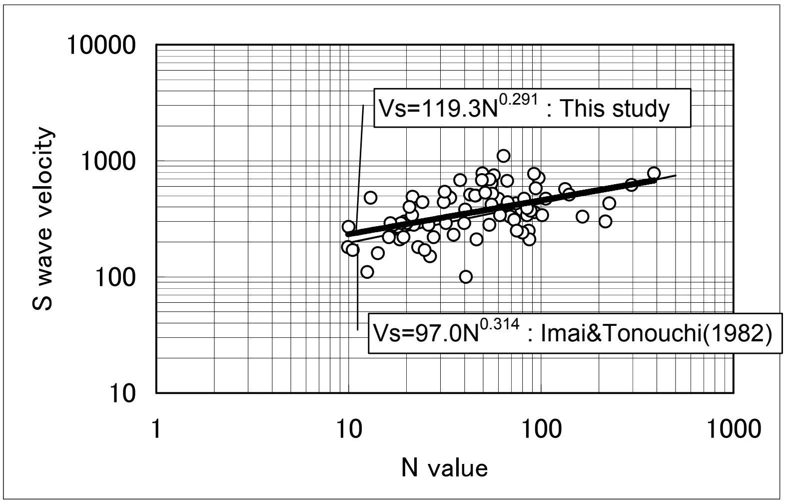


Figure 3-9 Correlation between S Wave Velocity and N Value

The layers for which S wave velocity was not determined by PS logging are ap, e, a3, q, qt, p2c and p2l. The S wave velocities of these layers were determined based on the N values using the correlation formula above.

[References]

Imai, T. and K. Tonouchi, 1982, Correlation of N value with S-wave velocity and shear modulus, Proc. 2nd European Symp. on Penetration Testing, Amsterdam.

3-4 Properties of Engineering Geology

Table 3-3 shows the properties of engineering geology based on the supplemental investigations. These values are used in the following hazard analysis.

Table 3-3 Properties of Engineering Geology

Symbol	N Value	S Wave Velocity (m/sec)	Density (g/cm^3)	D50 (mm)	Fc (%)	Ip	c (kgf/cm^2)	ϕ (degrees)
ap	18	275	1.80	0.51	16	26	0.6	34
e	24	300	1.80	0.24	11	21	0.5	27
a3	10	240	1.80	0.20	23	24	0.9	27
a2		270	1.74	0.01	84	23	0.8	22
q	24	300	1.81	0.42	29	23	0.6	25
qt	33	330	1.90	0.15	32	24	0.7	28
p2c		310	1.92				0.7	23
p2c-f		450	2.02					
p2l	27	310	1.92				0.4	27
p2l-f		770	2.10					
p1		310	2.00				0.7	22
p1-f		630	2.09					
mi		490	1.89				0.4	28
mi-f		1030	2.55					

Chapter 4. Urban Condition for Microzoning

4-1 Building

4-1-1 Inventory Survey

(1) Building Inventory Survey

1) General

A building inventory survey was conducted for existing buildings in the study areas of Wilaya Algiers. This survey covered a total of 34 communes including Casbah. The purpose of the survey was to obtain data on the distribution of building types in each commune. Main items of the survey included:

> building zone, usage, owner (public or private), structural type, number of stories, constructed year, extension work, retrofitting work, irregularities, ground condition, engineered or non-engineered (seismic design code applied or not) and other structural items

A structural survey sheet was used for the survey.

The total sampling number was set at 1,000 as a target. This number is optimal in view of the size of the survey area (224 km^2) and population of approximately 1.8 million, and was determine after considering the duration, cost and accuracy of a survey.

Since the number of building in each commune had not been counted at the time of the survey, buildings to be surveyed were decided at random in each commune proportional to the number of residents, resulting in a range of 11 to 59 buildings being surveyed.

2) Results of Building Inventory Survey

A total of 1003 buildings were surveyed at random in the 34 communes. The survey was carried out by URBANIS under the direction of JST.

A summary of the results is presented below;

(A) Structural Type

A total of 33.5% of buildings are masonry structures. Most masonry is stone with a few brick masonry structures. A total of 64.6% are reinforced concrete structures with the majority being moment frame structures.

Reinforced concrete shear wall structures and a dual system of moment frame and RC wall are also used. Steel structures account for only 0.9% of the total.

(B) Constructed Year

Some 41% of buildings were constructed before 1955, 17.1% were constructed from 1956 to 1980, 34.7% were constructed from 1981 to 1999 and 5.7% have been constructed since 2000.

Construction of masonry buildings was dominant in the first half of the 1900s, with reinforced concrete structures predominating in the latter half of the 1900s.

For example, masonry buildings in Algiers Center were constructed from 1880 to 1940, over a range of approximately 60 years.

(C) Number of Stories

Some 59.8% of buildings are 1 to 3 stories, 35.4% are 4 to 8 stories, and 3.6% are 9 stories or more. (Note: this category of number of stories was revised to, 1 to 2, 3 to 5, and, 6 and more, at a later stage.)

(D) Seismic Design

Buildings with seismic design comprise 23% of the total, while buildings without seismic design account for 77% of the total . Buildings without seismic design are those constructed before 1981 and the majority of private houses constructed after 1980 and before 2003.

(2) Important and Hazardous Facilities Inventory Survey

The location and condition of important and hazardous facilities are useful for inclusion in the hazard and risk map for a "Seismic Microzoning Study" in the same way as building inventory data. Initially, the Counterparts (CGS) and the JICA Study Team (JST) discussed and selected a target of 530 sample facilities at random. These 530 samples consist of some 14 important and hazardous facilities such as schools, gas stations, mosques, hospitals, police station and so on in the 34 communes, and 54 particular facilities such as the governmental offices, hospitals, universities, air port, central railway station, and so on. However, some of the originally allocated target facility numbers had to be shifted to other communes, because there were no qualifying facilities in the originally chosen communes. These facilities are classified into 36-structural types the same as building inventory survey. This classification is explained in Chapter 4-1-1 (1). No big storage facilities for hazardous materials were found except for gas stations. The major structural type of facility is reinforced concrete, which represents 75% of all structures. This is numerous compared to the building inventory result (65%). Steel structures for the facilities are more numerous at 8% compared with the building inventory (1%), and masonry structures accounted for 34% in the building survey and 16% of the important and hazardous facilities as shown in Table 4-1.

Table 4-1 Result of Building and Facility Inventory Survey

Type of Structure			Building Inventory Survey		Important and Hazardous Facility Survey	
			Numbers	Percentage	Numbers	Percentage
1	Masonry	At Casbah	6	0.6%	11	2.1%
2		Stone & Brick	330	32.9%	75	14.1%
3	Reinforced Concrete	Pre-code	407	40.6%	184	34.7%
4		Low-code	100	10.0%	142	26.8%
5		Mid-code	17	1.7%	20	3.8%
6		High-code	4	0.4%	5	0.9%
7		Shear W. & Mix.	119	11.8%	47	8.9%
8	Steel	Steel	9	0.9%	43	8.1%
9	Others	Others	11	1.1%	3	0.6%
Total			1,003	100%	530	100%

4-1-2 Building Damage Data of Past Earthquakes

A review was done of the building damage due to two major earthquakes in Algeria near Algiers the 1980 El Asnam Earthquake and the 2003 Boumerdes Earthquake.

(1) The 1980 El Asnam Earthquake

At 12:25 (Local time) on October 10, 1980, a strong earthquake (Ms = 7.3) struck El Asnam city in the north of Algeria. The epicenter was cross to El Asnam city which is located 180 km west of the capital city Algiers. According to the governmental report, the earthquake caused 2,633 deaths, 8,369 injured and 392,727 sufferers. Contrôle Technique de la Construction (CTC) surveyed approximately 10,000 buildings for damage. Among these buildings, 40% had collapsed or were heavily damaged, 20% were moderately damaged, and 40% had to be checked in detail for evaluation of their structural safety. The summery of CTC's investigation report is shown in Chapter 4-1-2 (2). However, the report does not describe the total number of buildings. Therefore, the ratio of buildings damaged can not be obtained.

A Japanese Government team executed a disaster investigation and offered technical support. The investigation report by the Architectural Institute of Japan team described the details of building damage for each structure type and some building usage types, and included the CTC's investigation. These detail data are shown in Chapter 4-1-2 (1).

1) The summery (an extract) of the Building Damage Investigation by CTC

CTC performed an emergency investigation of building damage level due to the El Asnam Earthquake during the one month immediately after the earthquake. It required 90 persons for 25 working days to inspect approx. 8,000 buildings in El Asnam city, and 30 persons for 14 working days to inspect approx. 2,000 buildings in the outskirts of El Asnam.

The purpose of this investigation was to evaluate the level of building damage, to judge the building safety and show it by three-color marking as follows;

- Green color: Permitted for building use; No damage or light damage (Level 1 & 2)
- Red color: Forbidden for building use; Condemned or collapsed buildings (Level 5)
- Orange color: Requires further investigation to determine status (Level 3 & 4)

A part of the above disaster repot by CTC Chlef is shown in Table 4-2.

Table 4-2 Disaster Report of El Asnam Earthquake on 10 October, 1980 by C.T.C

Magnitude (Ms) 7.3,

Judgment of building safety

Color *2	Number	Percentage (%)
Green	1,720	33.41
Orange	2,162	41.99
Red	1,200	23.31
Non use card	66	1.28
Total *1	5,148	100.00

Source: CTC Chlef
Note; *1 : Total building number is the surveyed buildings only.
*2 : Damage Level 1&2: Green, Damage Level 3&4: Orange, Damage Level 5: Red

(2) The 2003 Boumerdes Earthquake

At 19:44 (local time) on May 21, 2003, a strong earthquake (Mw = 6.8) struck Boumerdes city. The epicenter of the earthquake was located offshore, 7 km north of Zemmouri city in the Willaya of Boumerdes, which located 36 km east of the capital city, Algiers. According to the governmental report, the earthquake caused 2,278 deaths, more than 10,000 injured and 182,000 homeless, 19,000 buildings collapsed, and approx. 4.3 billion euros worth of damage was inflected.

1) Investigation of Building Damage by CTC and CGS

CGS and CTC performed “the emergency safety level judgment of buildings” for over 400,000 dwelling units in Algiers, and over 16,000 dwelling units in Boumerdes, as they had for the 1980 El Asnam Earthquake case. CGS surveyed mainly in Willaya of Boumerdes, and CTC covered mainly in Willaya of Algiers. All buildings of limited area and block size were investigated. Not all buildings in each commune were surveyed. The structural types included masonry, reinforced concrete moment frame, reinforced concrete wall and steel structure (wooden structures were include as “others”). These investigation reports by CGS analyzed in detail five types of structures and other classifications in each commune. This analysis is just now nearing completion. JST obtained the above data partly from CGS as an initial report, and it was used to determine the extent of building damage function. Damage numbers for each damage level from 1 to 5 as specified by EMS-98 and damage numbers of damage levels 4+5 for each structural type in Willaya of Algiers are shown in Table 4-3, and for Willaya of Boumerdes in Table 4-4.

Table 4-3 The Number of Damaged Buildings Investigated in Willaya of Algiers (an extract) Due to Boumedes Earthquake

Commune Code No.	Type of Structure	Structural Damage Level						Total
		1	2	3	4	5	4+5	
Bab Ezzouar 1621	Masonry	9	25	22	18	30	48	104
	RC Frame	18	111	80	55	6	61	270
	RC Wall	144	118	135	36	0	36	433
	Steel	1	1	1	0	0	0	3
	Others	0	0	1	0	13	13	14
Total		172	255	239	109	49	158	824
Bordj El Kiffan 1630	Masonry	137	63	91	33	127	160	451
	RC Frame	995	257	189	144	250	394	1,835
	RC Wall	7	127	50	4	2	6	190
	Steel	2	42	3	1	2	3	50
	Others	1	0	0	0	3	3	4
Total		1,142	489	333	182	384	566	2,530
Bordj El Bahri 1639	Masonry	247	63	28	20	19	39	377
	RC Frame	567	75	47	68	143	211	900
	RC Wall	3	34	15	8	0	8	60
	Steel	3	1	0	1	1	2	6
	Others	2	0	0	0	0	0	2
Total		822	173	90	97	163	260	1,345

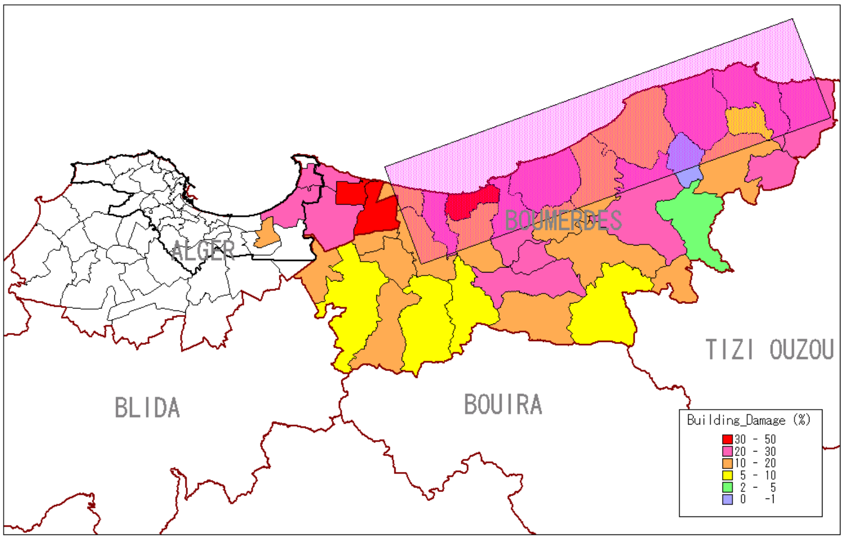
Source: CGS

Table 4-4 The Investigated Numbers of Damaged Buildings in Wilaya of Boumerdes (an extract) Due to Boumedes Earthquake

Name of Commune	Type of Structure	Structural Damage Level						Total
		1	2	3	4	5	4+5	
Boumerdes	Masonry	0	156	103	100	51	151	410
	RC Frame	1	214	200	257	107	364	779
	RC Wall	0	60	32	18	8	26	118
	Steel	0	0	2	3	5	8	10
	Others	0	16	6	3	5	8	30
Total		1	446	343	381	176	557	1,347
Zemmouri	Masonry	0	143	118	66	23	89	350
	RC Frame	2	380	140	63	22	85	607
	RC Wall	0	6	6	2	0	2	14
	Steel	0	0	1	0	0	0	1
	Others	0	1	3	2	3	5	9
Total		2	530	268	133	48	181	981

Source: CGS

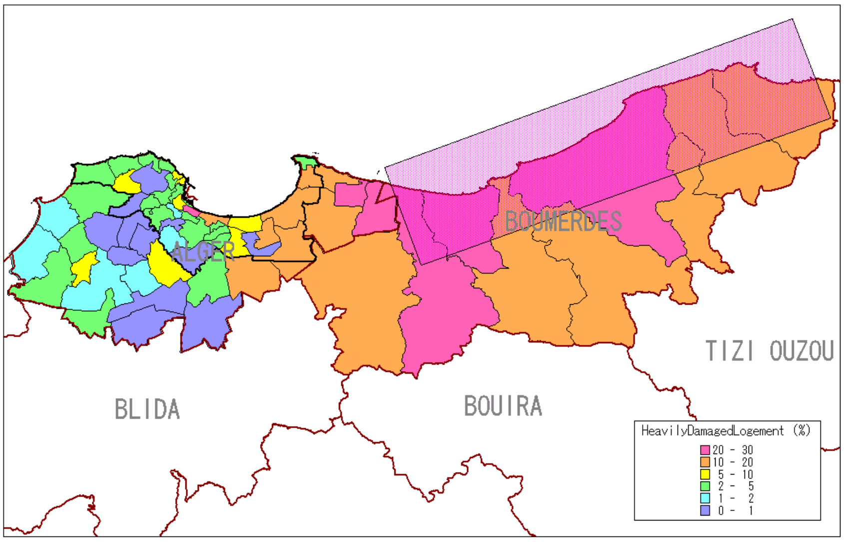
Building damage map in Wilaya of Boumerdes and 3-communes in the eastern part of Algiers based on building numbers is shown in Figure 4-1.



Source: CGS

Figure 4-1 Building Damage Map for Wilaya of Boumerdes and 3-Communes in the eastern part of Algiers due to 2003 Boumerdes Earthquake based on Building Numbers

Building damage map in Wilaya of Algiers and Wilaya of Boumerdes based on dwelling units is shown in Figure 4-2.



Source: CTC Chelf

Figure 4-2 Building damage map for Wilaya of Algiers and Wilaya of Boumerdes Due to 2003 Boumerdes Earthquake based on Dwelling Units

2) Investigation by an Expert Team from Japan

According to the investigation report of an expert team from Japan, the Japanese Government received a request from the Algerian government after the earthquake and decided to send an International Emergency Aid Unit at once. The investigation report was described the earthquake with peak ground acceleration at seismography points, and an outline of building damage at Wilaya of Boumerdes and Wilaya of Algiers with photographs, and summarized the characteristics of building damage. This detail information refer to Chapter 4-1-2 (2) 2).

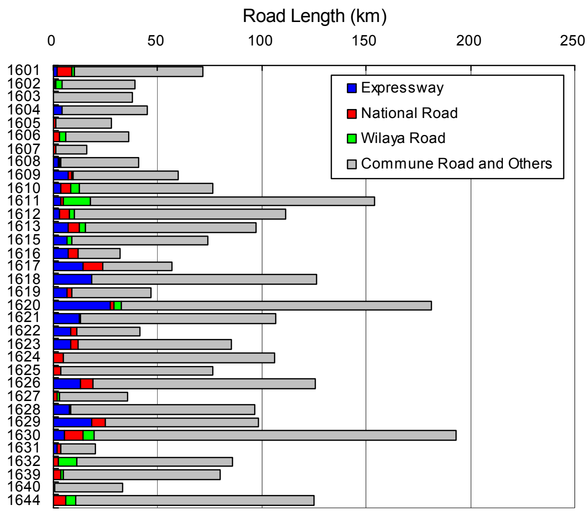
4-2 Infrastructure and Lifelines

4-2-1 Roads

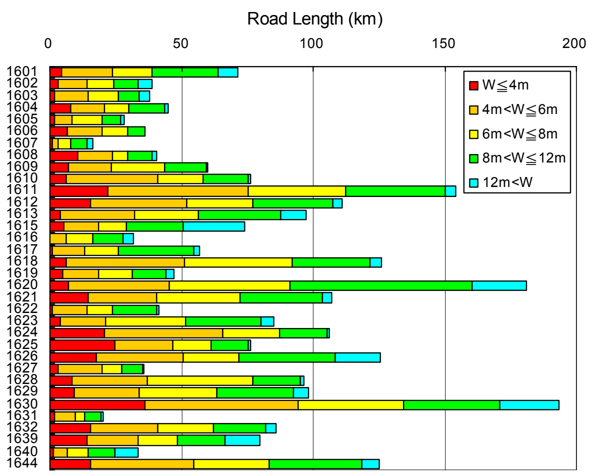
The roads in the Wilaya of Algiers are divided into 5 classes as follows:

Expressways	National roads	Wilaya roads	Commune roads	Other roads

The road networks in the Study Area by road class were compiled by the JST. It is noted that the commune roads could not be distinguished from other narrow roads, thus the roads were classified into 4 categories, expressways, national roads, Wilaya roads and lastly, a class including both commune roads and other types of roads.



The commune that has the greatest total length of expressways in the Study Area is DAR EL BEIDA (26.97 km out of 190.03 km). The commune that has the greatest total length of national roads is HUSSEIN DEY (9.28 km out of 101.54 km). The commune that has the greatest total lengths of Wilaya roads is BOUZAREAH (12.76 km out of 58.84 km) and the commune that has the greatest total combined length of commune and other types of roads is BORDJ EL KIFFAN (173.67 km out of 2,289.79 km).



The road network classified by road width was compiled by the JST The commune that has the longest narrow road (W ≤ 4 m) is RAIS HAMIDOU and the longest wide road (W > 12 m) is OUED SMAR.

4-2-2 Bridges

There are 148 bridges in the Study Area (including 1 bridge, which is located in CHERAGA, on the commune boundary with DELY BRAHIM) according to the bridge inventory survey.

There are 103 bridges across roads, 26 bridges across rivers, 17 bridges across railways and 14 bridges across other things. There are some bridges that cross more than one object. Thus, the number of the bridges across roads is the largest group in the Study Area.

The characteristics of the bridge structures are summarized in Figure 4-3. Seat width is 70 cm or more for most bridges (121 bridges). This is a reasonable design to prevent bridge failure.

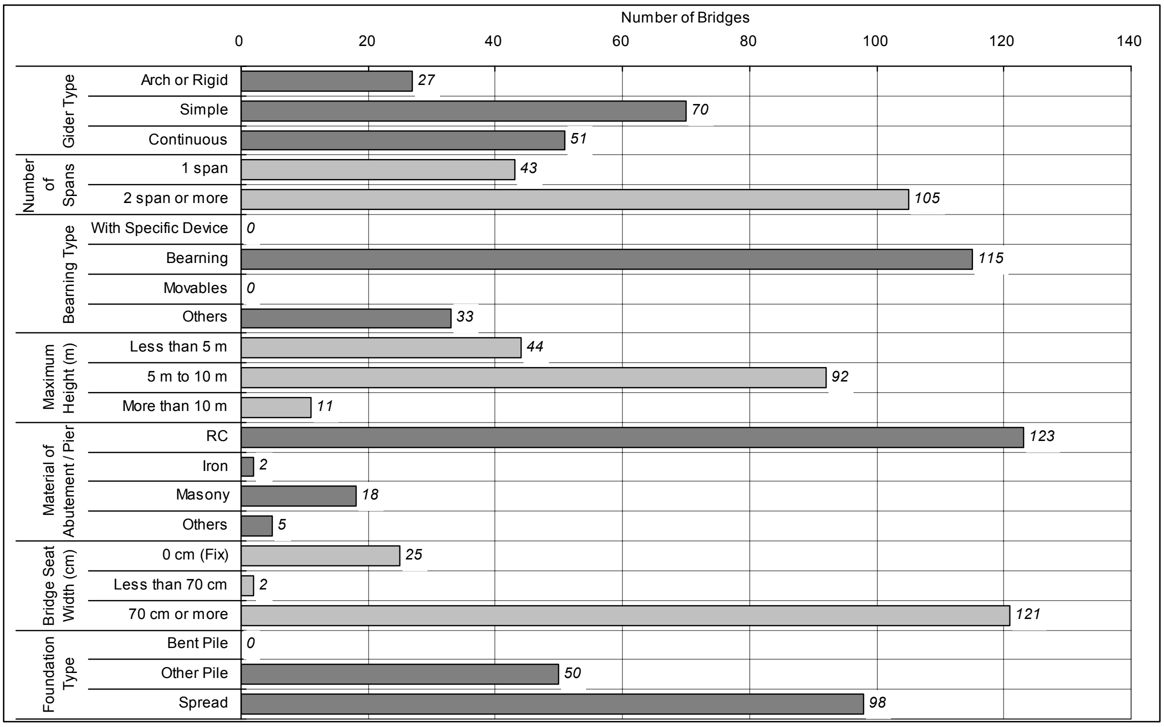


Figure 4-3 Characteristics of Bridge Structures

There are 105 (71%) existing bridges in low land areas and 43 (29%) in mountainous areas (refer to Figure 4-4). Low land areas are defined as having a surface geology code of q, qt, e, a2, a3, or ap based on the geology map, while the mountainous areas are defined as having a geological code of mi, p1, p2c or p2l.

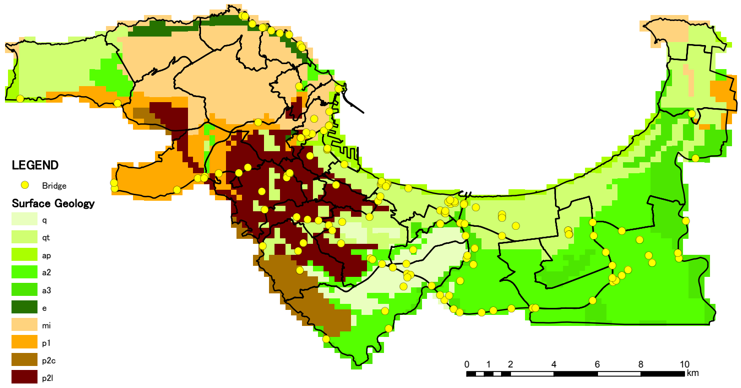
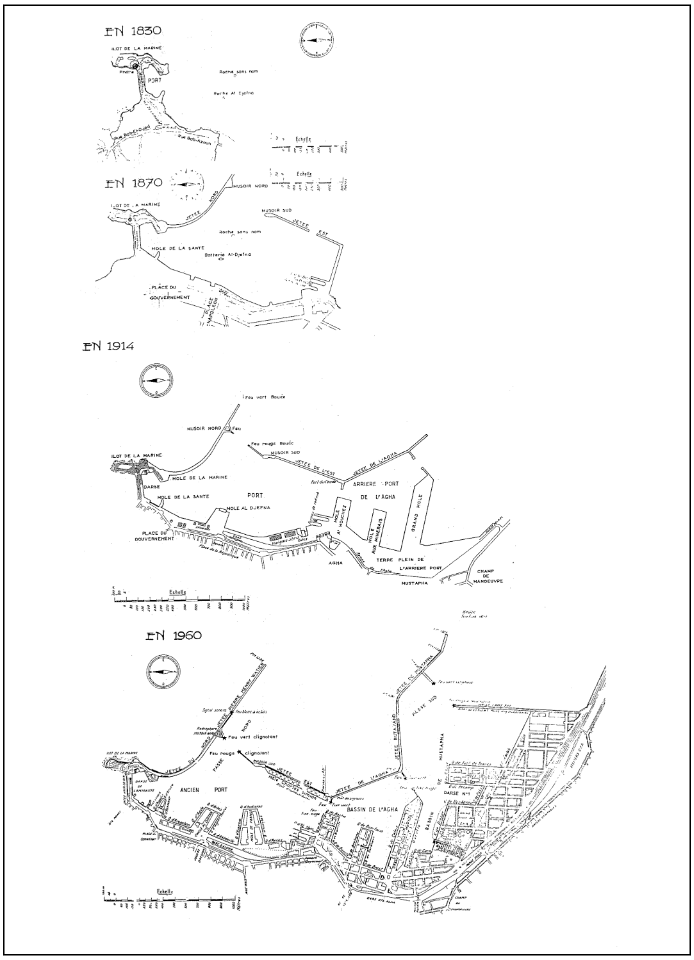


Figure 4-4 Bridge Locations and Geological Features

(The geological features are classified into the low land areas and the mountainous areas)

4-2-3 Port

The history of the development of the port was provided by LEM. The current port shape was constructed in 1960, as shown in Figure 4-5.



Source: LEM

Figure 4-5 History of Port Development

4-2-4 Airport

The Algiers Airport area is outlined in Table 4-5, based on data provided by EGSA. This airport is around 60 years old.

Table 4-5 Facility of Algiers Airport Area

Designation	Area	Nature of the building
Air Passenger Terminal Domestic : Ground floor 1st floor International including the extension : G floor 1st floor	 10,100 m^2 988.90 m^2 14,126 m^2 5,200 m^2	 Masonry (R+1 after demolition of the 2nd and 3rd floors)
Cargo Terminal	10,966 m^2	03 steel frame hangars
Control Tower	1,077 m^2	In masonry (R+7)
Service Area	855 m^2	masonry
Weather forecasting station	2,400 m^2 (old one) 3,591 m^2 (new one)	masonry
SSIS Block	870 m^2	Masonry (category 8)
Power plant	960 m^2	Masonry
VIP Room	796 m^2	Masonry
Fuel Storage Area	51,700 m^2	Storage capacity: Jet: 2,500 m^3 Avgas: 150m^3 Fuelling: fueling trucks
Car parking. International	36, 622 m^2	
Car parking. Domestic	9, 083 m^2	
Engineering base H400	11,442 m^2	hangar /steel framework
Rotorcraft services Hangar 01: Hangar 02:	 4,735 m^2 790 m^2	 02 hangars /steel framework
New Air passenger Terminal	85,000 m^2	Masonry
Hangar New engineering base AH	 31,200 m^2	 Hangar steel framework
Planning of the old gas station	2,198 m^2	Hangar steel framework
Technical Zone: Hangar 01: Hangar 02:	 9,161 m^2 9,161 m^2	 02 hangars /steel framework
New Power Plant	2,780 m^2	Masonry

Source: EGSA

A new international terminal with aseismic design in conformity with RPA 99 has been placed in service besides the old airport building.

4-2-5 Water Supply

There is a total of around 2,148.2 km of water supply pipelines and a total of 23 elevated water tanks in the Study Area.

Regarding the pipelines, 8 types of materials have been used, and cast iron pipe (total length 979 km) has been in use for the longest in the Study Area as shown in Table 4-6.

Table 4-6 Summary of Water Supply Pipeline Materials

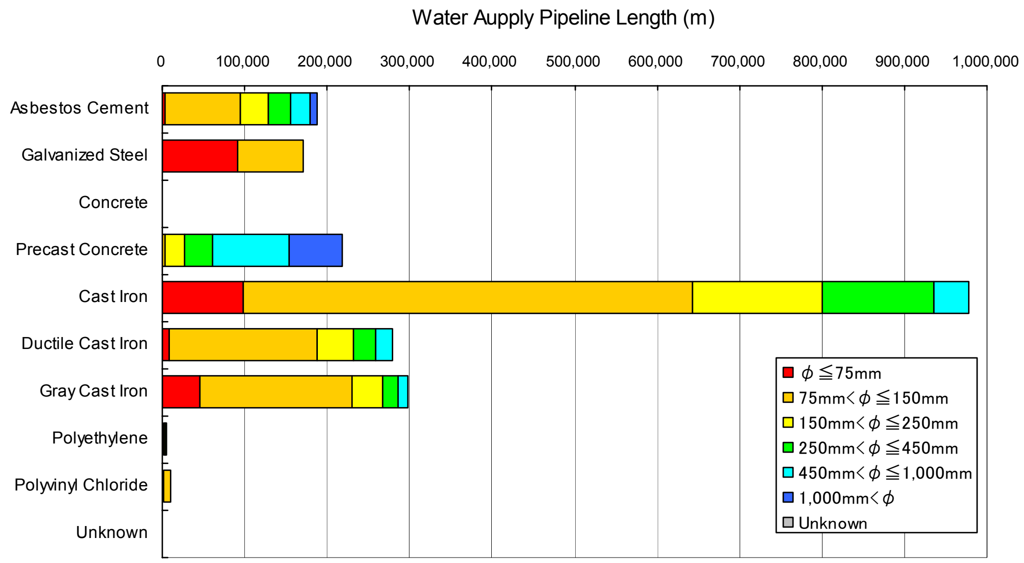
Material		Length (m)	Ratio (%)
AC, AMC	: Asbestos Cement	187,817	8.74
AG	: Galvanized Steel	171,470	7.98
B	: Concrete	8	0.00
BPAT	: Precast Concrete	218,211	10.16
F	: Cast Iron	978,598	45.55
FD	: Ductile Cast Iron	278,471	12.96
FG	: Gray Cast Iron	297,950	13.87
PEHD	: Polyethylene	4,433	0.21
PVC	: Polyvinyl Chloride	10,590	0.49
Unknown		788	0.04
Total		2,148,336	100

Source: DHW

Table 4-7 shows a cross tabulation between pipeline material and diameter. Cast iron of 75mm to 150 mm in diameter has the greatest distribution.

Table 4-7 Cross Tabulation between Pipeline Material and Diameter

Material \ Diameter	ϕ ≤ 75 mm	75 mm < ϕ ≤ 150 mm	150 mm < ϕ ≤ 250 mm	250 mm < ϕ ≤ 450 mm	450 mm < ϕ ≤ 1,000 mm	1,000 mm < ϕ	Unknown	Total
AC, AMC : Asbestos Cement	2,603	91,727	33,957	26,768	23,530	9,232	-	187,817
AG : Galvanized Steel	91,836	79,634	-	-	-	-	-	171,470
B : Concrete	-	-	-	-	8	-	-	8
BPAT : Precast Concrete	-	2,772	23,954	34,940	91,807	64,738	-	218,211
F : Cast Iron	98,005	545,781	156,987	135,705	41,104	1,016	-	978,598
FD : Ductile Cast Iron	7,907	179,370	44,122	28,032	19,040	-	-	278,471
FG : Gray Cast Iron	46,166	183,861	36,647	19,740	11,536	-	-	297,950
PEHD : Polyethylene	1,357	147	1,212	1,717	-	-	-	4,433
PVC : Polyvinyl Chloride	2,191	8,337	62	-	-	-	-	10,590
Unknown	-	521	-	-	-	-	267	788
Total	250,065	1,092,150	296,941	246,902	187,025	74,986	267	2,148,336



Source: DHW

4-2-6 Sewerage System

The total length of sewerage pipelines in the Study Area is around 221 km based on a digitized map by the JST (refer to Table 4-8). The old sewerage pipelines (constructed in the colonial period) are distributed in ALGIER CENTER and its surrounds. In rural areas, old pipelines are being replaced, and/or new pipelines are being installed and more are being planned in order to cover the Wilaya of Algiers.

Table 4-8 Sewerage Pipeline Length by Status

Status	Length (km)
Old Pipeline	74
Existing Pipeline	78
Under Construction Pipeline	41
Planned Pipeline	28
Total	221

Source: DHW

4-2-7 Electric Power Supply

A high voltage electric power supply cable network of 220 KV or 60 KV was compiled/digitized by the SONELGAZ high voltage electricity section. Information regarding the medium voltage (30 KV for rural areas or 10 KV for urban) cable was compiled by JST based on the data provided by SONELGAZ medium voltage electricity section.

The length of the high voltage and the medium voltage electric cable in the Study Area is around 98.8 km and 795.2 km respectively, which is based on the digitized map (it is noted that the cable was assumed to have only a single line in each section). Both aerial and buried distribution cables are in service in the area. The cable in urban areas is mainly underground while in rural area it is aerial cable. Table 4-9 shows a cross tabulation between voltage and distribution cable type.

Table 4-9 Cross Tabulation between Voltage and Distribution cable Type

Distribution Type \ Voltage	High Voltage	Medium Voltage	Total
Aerial Cable	36.0	123.8	159.8
Underground Cable	62.8	671.4	734.2
Total	98.8	795.2	894.0

Source: SONELGAZ

The cable network is mainly buried. The high voltage cables are protected by pipes / culvert structures, but the medium voltage cables may not be protected.

The aerial cable is supported by power pylons and electric poles are used for both high voltage and the medium voltage cables.

4-2-8 Gas Supply

Information regarding high pressure gas supply pipelines (20 to 70 bar) and medium pressure (4 to 5 bar) lines was compiled/digitized by the JST based on the data provided by SONELGAZ.

Length of the high and the medium pressure pipeline in the Study Area is around 71.2 km and 776.8 km respectively, based on the digitized map (refer to Table 4-10). The high pressure gas pipelines are made of steel, which are based on API (American Petroleum Institute) standards. The medium pressure gas pipelines are made of steel, polyethylene or copper, which are mostly steel or polyethylene as shown in Table 4-10.

Table 4-10 Length of Gas Supply Pipeline by Pressure

Pressure		Length (km)	
High Pressure		71.2	Ratio (%)
Medium Pressure	Steel	379.0	48.8
	Polyethylene	372.3	47.9
	Copper	25.5	3.3
	Total	776.8	100

Source: SONELGAZ

4-2-9 Telecommunications

Detailed telecommunications cable network (optic fiber cable) information was not obtainable.

We learned that most cable running from one station to another is buried with no form of protection.

4-3 Population and Dwelling Units

4-3-1 Population

The population of each commune was derived from the statistics of the "General Population and Housing Census in 1998". The numbers are shown in Table 4-11.

4-3-2 Number of Buildings

As for the number of buildings in each commune in the study area, no official statistical information is available. In this study, the number of buildings in each commune is based on the building polygon included in the GIS data that was purchased from URBANIS, and revised by the Study Team. The "Building Number/ In Commune Boundary" column in Table 4-11 shows the number of buildings counted in a polygon, the center of which lies within the commune.

The building damage was estimated by 250 m grids in this study, therefore, the number of buildings in each 250 m grid sector should be estimated beforehand. The building polygons the center of which lies within each 250 m grid sector were counted and used as the basis in the damage estimation. The estimated number of damaged building will be summed up for each commune and tabulated; therefore each grid sector was assigned to one of the 34 communes. The "Building Number/ In Commune Assigned Grids" column in Table 4-11 shows the total number of buildings in the grids that are assigned to that commune.

4-3-3 Dwelling Units

In this study, the casualties were estimated based on the number of damaged dwelling units instead of the number of damaged buildings. The number of existing and damaged dwelling units in each grid and commune were calculated from number of buildings based on the average number of dwelling units in one building in each commune.

4-3-4 Summary

Columns (a) and (b) in Table 4-11 show the exact number in each commune; and (c) and (d) are the numbers that correspond to the grid based commune. In the damage estimation, the 250 m grid was used as the basic unit and the estimated damage number in each grid was summed to tabulate the damage in each commune. Therefore, the existing dwelling unit number in the table of estimated damage may be different than the number in the census. The damage ratio in each commune was calculated based on the numbers in (c) and (d) instead of (a) and (b) in Table 4-11.

Table 4-11 Number of Buildings and Dwelling Units in each Commune

ID	Commune Name	Census 1998 [1)]		Building Number [2)]		Dwelling Unit in Assigned Grids [3)]	
		Population	Occupied Dwelling Unit	In Commune Boundary	In Assigned Grids		
			(a)	(b)	(c)	(d)	
1601	ALGER CENTRE	96,329	18,320	3,836	3,396	16,219	4)
1602	SIDI M'HAMED	90,455	15,005	2,388	2,206	13,863	
1603	EL MADANIA	51,404	7,741	2,752	3,124	8,788	
1604	HAMMA EL ANNASSER	59,248	9,181	2,317	2,169	8,594	
1605	BAB EL OUED	87,557	13,297	1,900	1,884	13,184	
1606	BOLOGHINE	43,283	6,717	2,965	2,933	6,643	
1607	CASBAH	50,453	9,164	2,467	2,739	10,175	
1608	OUED KORICHE	53,378	8,629	2,528	2,585	8,823	
1609	BIR MOURAD RAIS	43,254	6,865	4,654	4,696	6,927	
1610	EL BIAR	52,582	8,846	7,606	7,408	8,616	
1611	BOUZAREAH	69,153	10,847	9,578	9,804	11,098	
1612	BIRKHADEM	55,084	8,312	6,348	6,459	8,455	
1613	EL HARRACH	48,167	7,109	4,442	4,560	7,296	
1615	OUED SMAR	21,397	2,858	3,193	3,455	3,092	
1616	BOUROUBA	77,498	10,192	5,222	4,808	9,385	
1617	HUSSEIN DEY	49,921	7,489	4,326	4,630	8,015	
1618	KOUBA	105,253	17,039	9,573	8,940	15,913	
1619	BACH DJERAH	90,073	13,294	5,337	6,041	15,048	
1620	DAR EL BEIDA	44,753	6,302	8,366	8,094	6,095	5)
1621	BAB EZZOUAR	92,157	14,549	5,519	5,138	13,544	
1622	BEN AKNOUN	19,404	3,223	3,136	3,299	3,391	
1623	DELY BRAHIM	30,576	4,603	3,877	3,813	4,526	
1624	HAMMAMET	19,651	3,219	2,179	2,223	3,283	
1625	RAIS HAMIDOU	21,518	3,211	3,410	3,364	3,169	
1626	DJASR KACENTINA	82,729	12,527	3,427	3,458	12,639	
1627	EL MOURADIA	29,503	4,981	3,253	3,277	5,017	
1628	HYDRA	35,727	6,215	7,135	6,980	6,080	
1629	MOHAMMADIA	42,079	6,481	4,148	4,321	6,749	
1630	BORDJ EL KIFFAN	103,690	14,501	11,010	10,915	14,375	
1631	EL MAGHARIA	30,457	4,704	2,727	2,643	4,559	
1632	BENI MESSOUS	17,490	2,668	2,286	2,254	2,630	
1639	BORDJ EL BAHRI	27,905	4,092	4,797	4,724	4,030	
1640	EL MARSA	8,784	1,308	1,273	1,330	1,366	
1644	AIN BENIAN	52,343	8,221	6,340	6,362	8,252	
	Total	1,803,255	281,710	154,315	154,032	279,838	6)

1) The “General Population and Housing Census in 1998” includes the population and number of occupied dwelling units in each commune.
2) The number of building polygons included in the GIS data that was purchased from URBANIS.
3) (d)=(c)*(a)/(b)
4) “In Assigned Grids” doesn’t include the 16 buildings on the seawall in Algiers port.
5) “In Assigned Grids” doesn’t include the 267 buildings in DAR EL BEIDA, which is outside of the study area.
6) “In assigned Grids” building numbers are less than GIS data by 283 and the dwelling units number is smaller by 872 than the census because of 4) and 5).