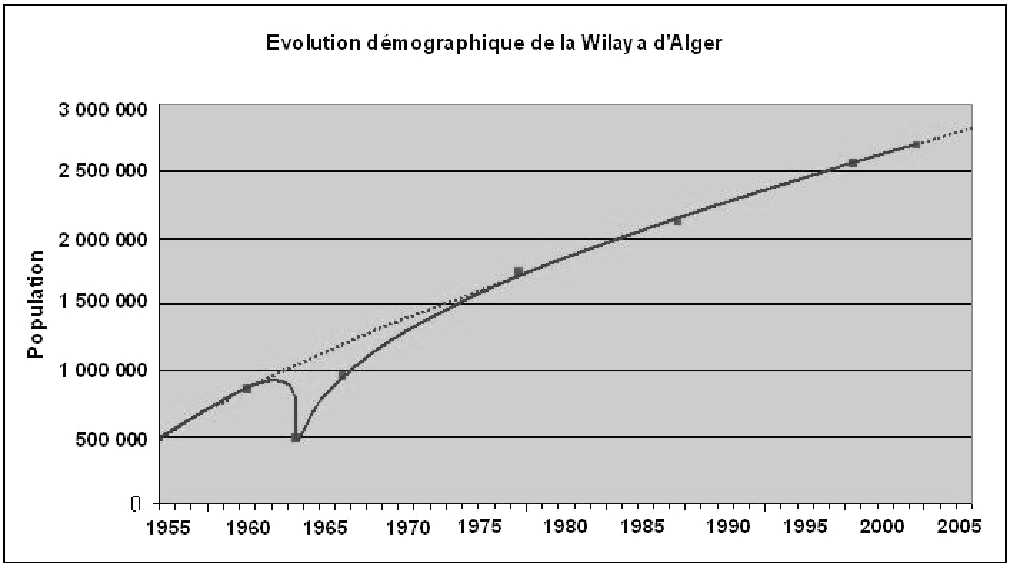
### 2-2-4 Population and Households

(1) Population in the Wilaya of Algiers

The population of Algiers decreased significantly when nearly 400,000 French citizens left at the time of independence (1962). This led to a major exodus of people from rural areas to the rich coastal plains and cities in the north as shown in Figure 2-23[1]. Following independence, the Algerian population grew at a rate of 3.48% per year, which can justifiably be referred to as a "population explosion".

Population growth rates started to fall back to previous levels in 1997. The results of the censuses (RGPH[2]) undertaken in 1987 and 1998 confirmed this tendency, with annual growth rates declining from 3.1% to 2.15%, respectively.




Source: RGPH

Figure 2-23 Population of the Wilaya of Algiers over the Past 50 Years

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[3] with a density of 3,337 people per square kilometer.

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%. The high population density mentioned above is seen particularly in the center of Algiers, and this has resulted in overloading of various sectors such as education, transportation, housing, potable water supply, etc. The estimated figures for the population of communes in the Wilaya of Algiers, as of the end of 2002, are shown in Table 2-3.

1 That curve is not perfectly accurate since the territory of Algiers taken into account has changed, along with the administrative divisions that existed for each of the reference periods.
2 RGPH: General Population and Housing Census.
3 Source: Statistical Yearbook of Algiers Wilaya (2003)

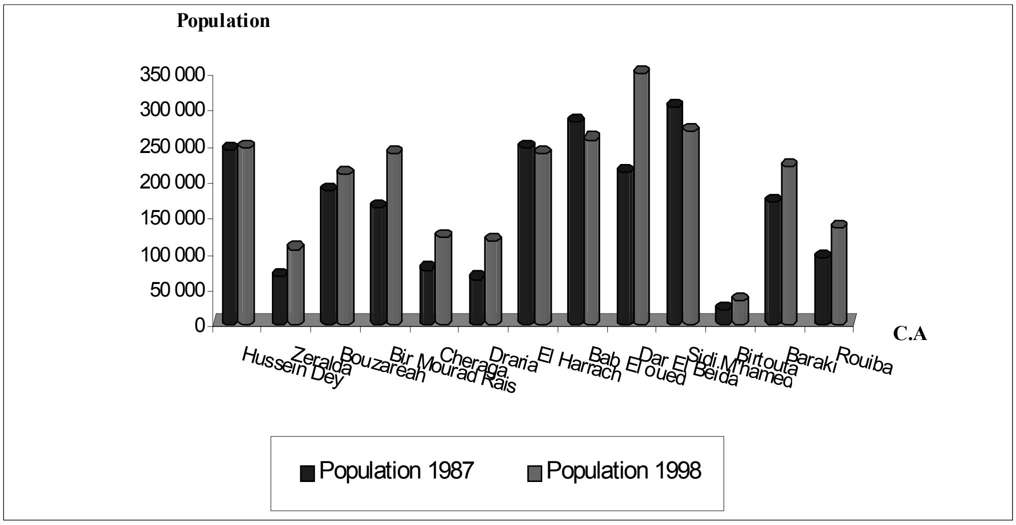
Table 2-3 Estimate of the Population of the Wilaya of Algiers, as of December 31, 2002

| COMMUNES | Superficie en Km² | Population au 31.12.2002 | Densité (Hab/Km²) |
|---|---|---|---|
| Bab El Oued | 1,21 | 90.499 | 74.792 |
| Bologhine | 2,76 | 44.976 | 16.295 |
| Casbah | 1,08 | 52.170 | 48.305 |
| Oued Koriche | 2,24 | 55.435 | 24.748 |
| Rais Hamidou | 4,94 | 22.408 | 4.536 |
| **S / TOTAL** | **12,23** | **265.488** | **21.708** |
| Baraki | 32,15 | 100.613 | 3.129 |
| Eucalyptus | 30,32 | 102.622 | 3.385 |
| Sidi Moussa | 43,27 | 28.744 | 664 |
| **S / TOTAL** | **105,74** | **231.979** | **2.194** |
| Bir Mourad Rais | 4,15 | 45.243 | 10.902 |
| Birkhadem | 8,89 | 58.302 | 6.558 |
| Gué de Constantine | 14,54 | 90.851 | 6.248 |
| Hydra | 6,12 | 37.220 | 6.082 |
| Saoula | 25,00 | 33.087 | 1.323 |
| **S / TOTAL** | **58,70** | **264.703** | **4.509** |
| Birtouta | 27,01 | 23.402 | 866 |
| Ouled Chebel | 29,30 | 17.241 | 588 |
| Tessala El Merdja | 20,51 | 11.548 | 563 |
| **S / TOTAL** | **76,82** | **52.191** | **679** |
| Bouzaréah | 12,44 | 72.446 | 5.824 |
| Ben Aknoun | 3,83 | 20.342 | 5.311 |
| Beni Messous | 7,91 | 18.694 | 2.363 |
| El Biar | 4,08 | 54.542 | 13.368 |
| **S / TOTAL** | **28,26** | **166.024** | **5.875** |
| Cheraga | 36 | 64.865 | 1.802 |
| Ain Benian | 16 | 55.467 | 3.467 |
| Dely Brahim | 7,72 | 32.260 | 4.179 |
| Hammamet | 8,54 | 20.955 | 2.454 |
| Ouled Fayet | 25 | 16.378 | 655 |
| **S / TOTAL** | **93,26** | **189.925** | **2.036** |
| Dar El Beida | 33.29 | 49.455 | 1.486 |
| Ain Taya | 9,55 | 31.202 | 3.267 |
| Bab Ezzouar | 8,23 | 98.662 | 11.988 |
| Bordj El Bahri | 7,48 | 29.582 | 3.955 |
| Bordj El Kiffan | 21,70 | 111.009 | 5.116 |
| El Marsa | 3,88 | 9.252 | 2.384 |
| Mohammadia | 7,99 | 44.519 | 5.572 |
| **S / TOTAL** | **92,12** | **373.681** | **4.056** |

| COMMUNES | Superficie en Km² | Population au 31.12.2002 | Densité (Hab/Km² |
|---|---|---|---|
| Draria | 14 | 25.215 | 1.801 |
| Baba Hacène | 11 | 15.167 | 1.379 |
| Douera | 41 | 44.463 | 1.084 |
| El Achour | 12 | 21.224 | 1.769 |
| Khraicia | 20 | 18.929 | 946 |
| **S / TOTAL** | **98** | **124.998** | **1.275** |
| El Harrach | 9,42 | 50.160 | 5.325 |
| Bachedjerah | 3 | 93.174 | 31.058 |
| Bourouba | 3,39 | 80.274 | 23.685 |
| Oed Smar | 8,15 | 22.549 | 2.767 |
| **S / TOTAL** | **24,29** | **246.177** | **10.135** |
| Hussein Dey | 4,26 | 51.803 | 12.160 |
| Belouizdad | 2,16 | 61.410 | 28.430 |
| Kouba | 10,05 | 110.439 | 10.989 |
| Megharia | 1,57 | 31.705 | 20.194 |
| **S / TOTAL** | **18,04** | **255.357** | **14.155** |
| Rouiba | 41,15 | 53.108 | 1.291 |
| Reghaia | 12,4 | 19.387 | 1.563 |
| Heraoua | 27,25 | 70.041 | 2.570 |
| **S / TOTAL DAIRA** | **80,8** | **142.536** | **1.764** |
| Sidi M'hamed | 2,18 | 93.569 | 42.921 |
| Alger Centre | 3,7 | 99.843 | 26.985 |
| El Madania | 2,17 | 52.500 | 24.193 |
| El Mouradia | 1,91 | 30.664 | 16.054 |
| **S / TOTAL DAIRA** | **9,96** | **276.576** | **27.768** |
| Zeralda | 30 | 35.226 | 1.174 |
| Mahelma | 35 | 15.602 | 446 |
| Rahmania | 9 | 6.119 | 680 |
| Souidania | 15 | 12.338 | 822 |
| Staouali | 22 | 41.529 | 1.888 |
| **S / TOTAL** | **111** | **110.814** | **998** |
| **TOTAL WILAYA** | **809,22** | **2.700.449** | **3.337** |

**Source :**
**Annuaire statistique de la Wilaya d'Alger (2003)**

The estimated growth for each commune at the end of 2002 indicates that the lowest rates might be recorded in a number of communes in the center of Algiers, for example -1.40% in BAB El OUED, -1.60% in CASBAH, and -1.41% in SIDI M'HAMED, as shown in Figure 2-24.



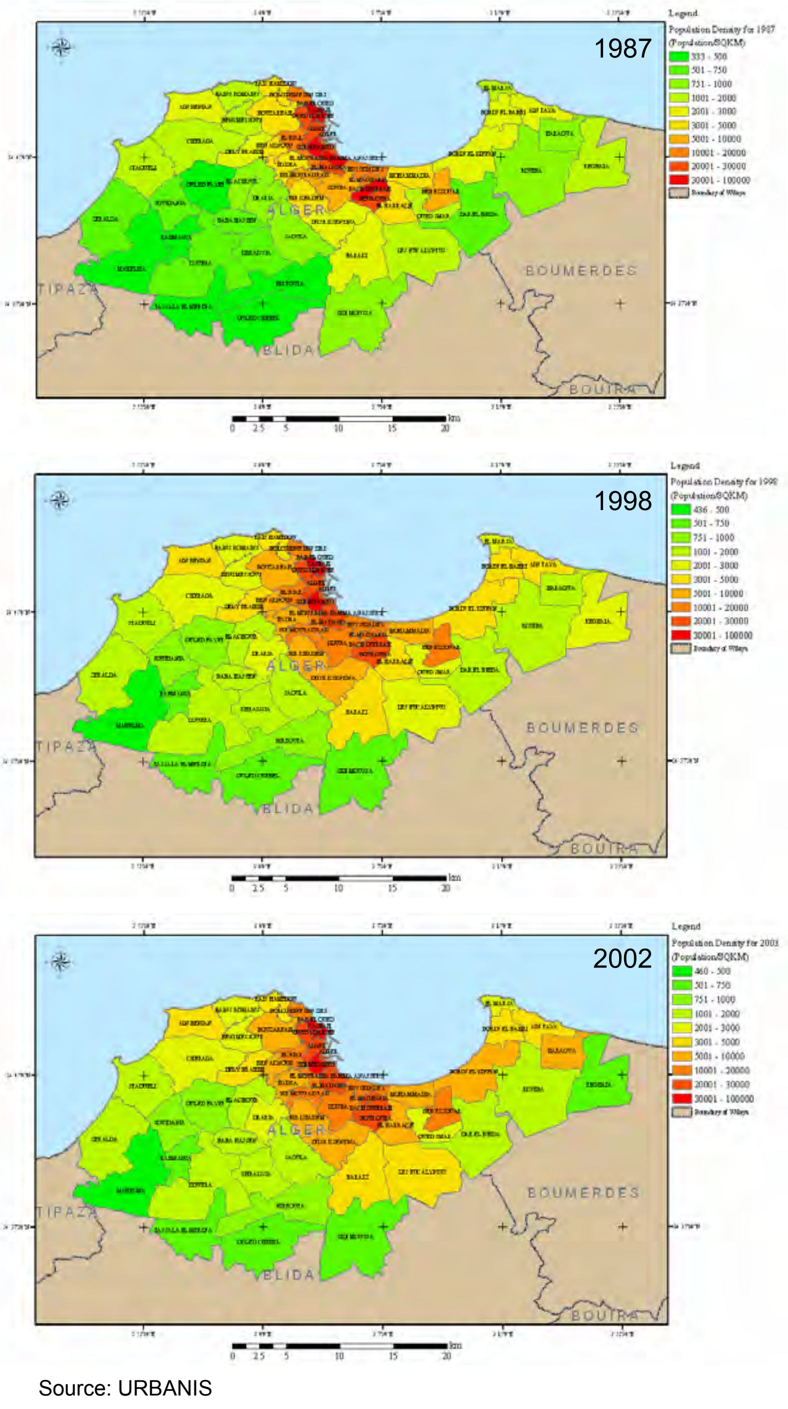

Source: RGPH

Figure 2-24 Population of Communes between the Censuses of 1987 and 1998

Figure 2-24 shows the change in population distribution for thirteen (13) selected communes between 1987 and 1998. There was a general movement of the population towards the periphery of the Wilaya, although important buildings occupied by national and international organizations, engineering and design departments, and headquarters of private firms and services still remained in the central area.

The highest rate of population growth was seen in the communes of DAR El BEIDA (+8.76%), BABA HASSEN (+8.08%) and DRARIA (+7.65%). An exception was GUE DE CONSTANTINE (+8.9%), which is considered to be a ward that was in the process of urbanization during 1987 - 1998.

There is a direct connection between the demographic development of certain communes of the Wilaya and their population density. Figure 2-25 shows the evolution of the population density of the communes of the Wilaya of Algiers over the period from 1987 to 2003.

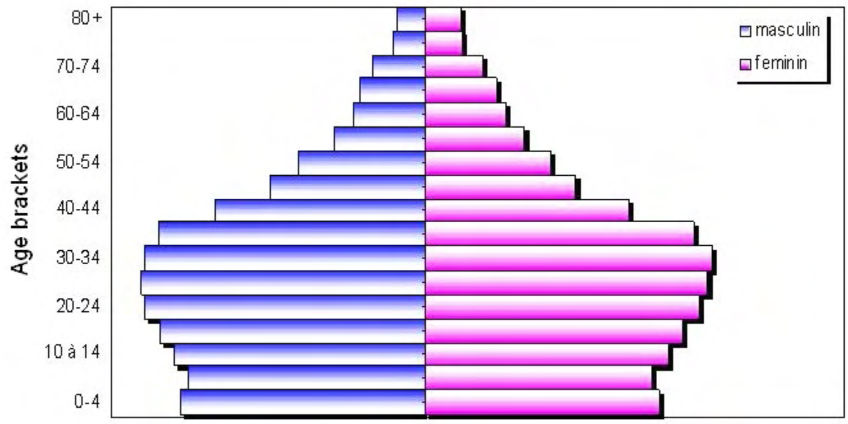



Source: URBANIS

Figure 2-25 Change in Population Density between 1987 and 2002

(2) Population by Gender

The population of the Wilaya of Algiers comprised 49.7% females and 50.3% males in 1998, as shown in Figure 2-26.




Source: RGPH 1998

Figure 2-26 Population Pyramid for 1998

(3) Population by Age

A decline in birth rate affects both the total population and the population structure, as shown in Figure 2-26. 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 2-4 presents the results of the 1998 census concerning work activity in the Wilaya of Algiers.

Table 2-4 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 2-5 shows the population and the number of households within the Study Area in 1998.

Table 2-5 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 Condition

1) Generalized Land Cover Maps

In order to reliably determine the land cover in the Wilaya of Algiers, land cover maps from two seasons were prepared by the JICA study team. Geo-referenced LANDSAT TM/ETM 5/7 images of the Algiers region were acquired from the USGS by the JICA Study Team. About 95% of the study area is covered by WRS-2 Path 196

Row 035 and the remainder is covered by WRS-2 Path 196 Row 034. Two generalized land cover maps (for 1987 and 2000/2001) were generated as GIS data layers (ESRI shapefiles). The land cover types and boundaries were determined by photo-interpretation of three (3) sets of LANDSAT TM images: 1987 (summer,), 2000 (late winter) and 2001 (early spring).

The final land cover maps show the generalized land cover classes listed in Table 2-6.

Table 2-6 Generalized Land Cover Classes[4]

| Code | Class |
|---|---|
| 1 | Bare Land |
| 2 | Crops |
| 3 | Forest |
| 4 | Grassland |
| 5 | Industry (areas characterized by large buildings[5]) |
| 6 | Infrastructure (airport, port facilities, large public facilities; each facility is clearly interpretable on the Landsat 30 m resolution images) |
| 7 | Mixed Urban (sparse building areas, and transitional areas between rural and urban) |
| 8 | Shrub |
| 9 | Urban (dense built-up areas, or dense residential areas) |
| 10 | Water |

(2) Interpretation of Land Cover Condition

The land cover of the Wilaya of Algiers in 1987 and 2000/2001 is summarized in Table 2-7.

Table 2-7 Comparison of Land Cover in 1987 and 2000/2001[6]

| Land Cover Class | Area | (Percent) | 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%) |

4 [Source] JICA Study Team
5 The general spatial arrangement and pattern suggests the presence of large buildings, as would be expected in an industrial area.
6 [Source] JICA Study Team

The results of a comparison between the land cover maps (1987-2000/2001) are described below.

1) Bare Land Class

"Bare Land" class is a land cover class that is seen as areas not covered by anything. Usually, the ground is covered with natural soil or rocks. The class is often seen on steep slopes in the Sahel Hills. The class is considered to have been caused by slope collapse, quarrying, or the development of residential sites. The area of the "Bare Land" class in 2000/2001 was 876 ha, and this comprised 1.1% of the area of the Wilaya of Algiers. The proportion of the total land area occupied by "Bare Land" decreased by 0.7% between 1987 and 2000/2001.

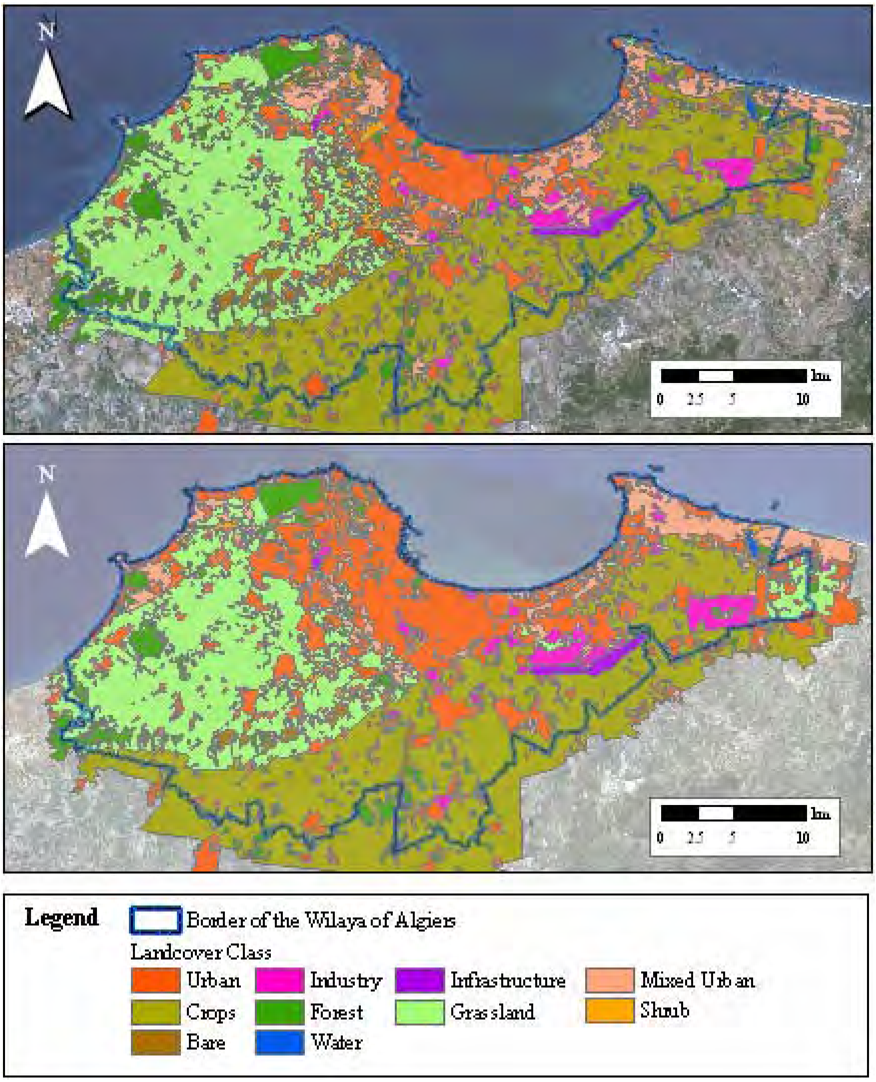



Figure 2-27 Land Cover Condition of the Wilaya of Algiers in 1987 and 2000/2001[7]

[7] [Source] Border of the Wilaya of Algiers (INCT); LANDSAT Image (USGS); Land Cover Map (JICA Study Team)

2) Crops Class

The “Crops” class is a land cover class that is generally limited to agricultural areas. The “Crops” class is widely seen in the southern half of the Wilaya of Algiers, for example, the south end of the Sahel Hills, the Plain of Mitidja, and the eastern side of the Bay of Algiers. The area of the “Crops” class in 2000/2001 was 20,613 ha, and this comprised 26.8% of the area of the Wilaya of Algiers. The proportion of the total land area occupied by “Crops” decreased by 3.3% between 1987 and 2000/2001.

3) Forest Class

The “Forest” class is mainly seen in the Sahel Hills. The area of the “Forest” class in 2000/2001 was 4,344 ha, and this comprised 5.6% of the area of the Wilaya of Algiers. The proportion of the total land area occupied by “Forest” decreased by 0.5% between 1987 and 2000/2001.

4) Grassland Class

The “Grassland” class is widely seen in the Sahel Hills area, and also in the far eastern part of the Wilaya of Algiers. The area of “Grassland” in 2000/2001 was 20,071 ha, and comprised 26.1% of the area of the Wilaya of Algiers. The proportion of the total land area occupied by “Grassland” decreased by 3.8％ between 1987 and 2000/2001.

5) Industry Class

The “Industry” class was recognized by interpreting the spatial arrangement and patterns that could be seen in the LANDSAT image. The “Industry” class may also include “Non industrial” features, such as universities and large residential complexes that appeared similar to industrial buildings in the LANDSAT image. The area of the “Industry” class in 2000/2001 was 2,776 ha, and this comprised 3.6% of the area of the Wilaya of Algiers. The proportion of the total land area occupied by “Industry” increased by around 1％ between 1987 and 2000/2001.

6) Infrastructure Class

The “Infrastructure” class includes large infrastructure facilities that are easily recognizable in the LANDSAT images. In general, the “Infrastructure” class includes airport and port facilities. The area of the “Infrastructure” class in 2000/2001 was 643 ha, and this comprised 0.8％ of the Wilaya of Algiers. There was very little change in the area of “Infrastructure” between 1987 and 2000/2001.

7) Mixed Urban

The “Mixed Urban” class is characterized by “mixed” features that include the sparser urban areas and other land cover classes. It is considered that the areas classified as “Mixed Urban” were areas in transition from rural to urban during the period between 1987 and 2000/2001. In 1987, the “Mixed Urban” class was mainly seen in coastal zones in the northeast of the Sahel Hills, and in the eastern coastal zones of the Bay of Algiers. Between 1987 and 2000/2001 the area of “Mixed Urban” land cover expanded in the east of the Wilaya along the coastline of the Bay of Algiers, with a corresponding decrease in the area of "Crops". However, in coastal areas of the northwest Sahel Hills, new mixed urban areas in and around STAOUELI commune replaced previous "Grassland". In other areas, the 1987 "Mixed Urban" class had almost completely changed to "Urban" class by 2000/2001. The area of the "Mixed Urban" class in 2000/2001 was 5,237 ha, and this comprised 6.8% of the Wilaya of Algiers. Overall, the area of "Mixed Urban" remained relatively constant, decreasing by only 0.1% of the total land area between 1987 and 2000/2001.

8) Shrub Class

Of the ten land cover classes that were identified, the "Shrub" class covered the smallest area. The "Shrub" class was generally seen in the east part of the Sahel Hills in 1987. Often the "Shrub" class represented remnant vegetation along water courses and in hilly areas that were too steep for agricultural or urban development. The area of "Shrub" class in 2000/2001 was 1,846 ha, and this comprised only 2.4% of the Wilaya of Algiers. The proportion of the total land area occupied by "Shrub" decreased by 3.9% between 1987 and 2000/2001.

9) Urban Class

The "Urban" class is recognized as dense building areas on the LANDSAT satellite image. In 1987 the "Urban" class was concentrated in the coastal zone between CASBAH and HUSSEIN DEY. Between 1987 and 2000/2001, the "Urban" class extended toward the east along the Bay of Algiers. In the Sahel Hills area, the "Urban" class expanded considerably, with a corresponding decrease in "Mixed Urban". As for the inland regions of the Wilaya, much of the "Mixed Urban" class also changed to "Urban". However, this represents only a small percentage of the overall increase in "Urban" areas. The area of "Urban" class in 2000/2001 was 20,420 ha, and this comprised 26.5% of the Wilaya of Algiers. The proportion of the total land area occupied by "Urban" class increased by 11.3% between 1987 and 2000/2001. This represents the largest land cover change in the study area.

10) Water Class

The "Water" class represents inland water bodies. This class includes relatively large ponds/lakes/reservoirs that are interpretable on LANDSAT images. There was very little change in the area of "Water" between 1987 and 2000/2001.

(3) Urbanization in the Whole Wilaya of Algiers

1) General Condition

As mentioned previously in this chapter, the "Urban" class represents the largest land cover change in the Wilaya of Algiers 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. Of the ten (10) land cover classes that were identified in 1987, three (3) land cover classes ("Grassland", "Mixed Urban", and "Crops") had mainly changed to the "Urban" class in 2000/2001.

Overall, only 3.7% of the area of “Urban” class in 1987 changed to other land cover classes in 2000/2001. These areas comprise only 0.5% of the total area of the Wilaya of Algiers.

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 2-28 shows the distribution of the “urbanized” areas in the Wilaya of Algiers in 1987 and in 2000/2001. These “urbanized” areas were re-interpreted by extracting the three (3) actual urban land cover classes (“Urban”, “Industry”, and “Infrastructure”) from the original land cover maps.

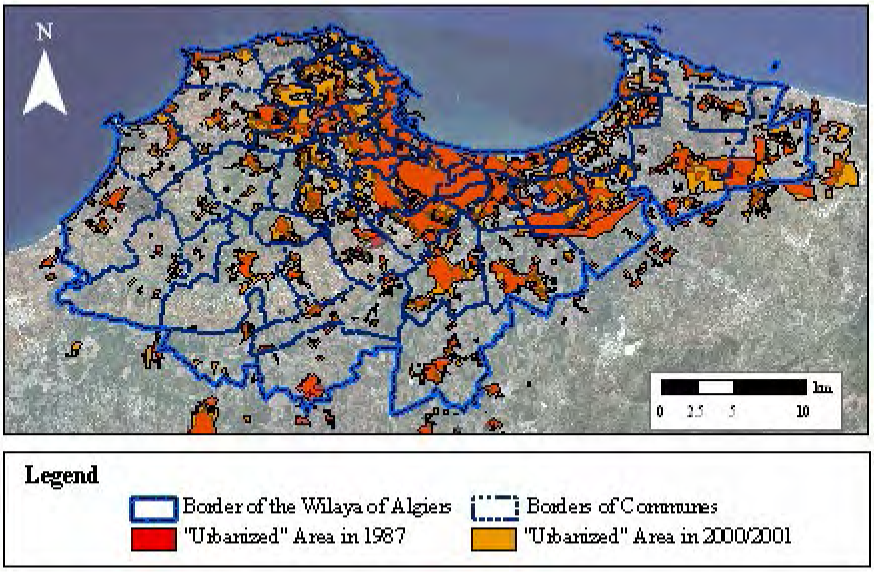


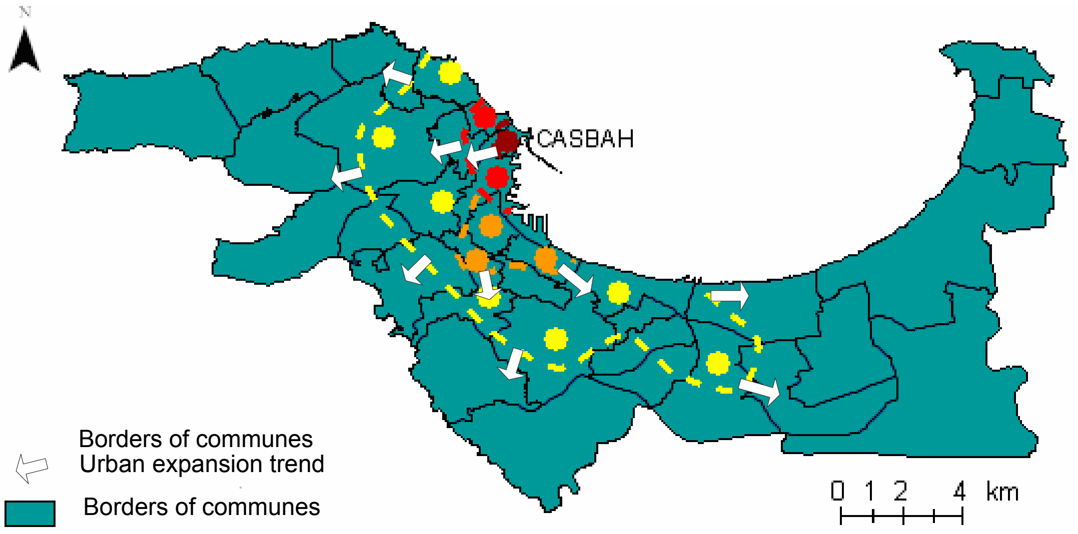

Figure 2-28 Comparison between Urbanized Areas in 1987 and 2000/2001[8]

2) Urbanization Trend

Figure 2-30 shows the percentage of urbanization of each commune in 1987 and 2000/2001. Urban growth within the Wilaya of Algiers seems to have spiraled, as a whole.

It is generally stated by Algerian people that the Wilaya of Algiers has (historically) been urbanized from the west, with CASBAH commune as the “starting point”, across to the east along the coastline of the Bay of Alger, as shown in Figure 2-29.

8 [Source] Border of the Wilaya of Algiers and Borders of Communes (INCT); “Urbanized” Areas (JICA Study Team)




Source: Gouvernorat du Grand Alger (1997), Alger, capitale 21e siècle, Gouvernorat du Grand Alger

Figure 2-29 Schematic Urban Expansion within the Study Area by the Early 1960's

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

Because two communes (BELOUZDAD and EL MADANIA) include "planned" forest areas that were identified as the "Forest" class in the land cover maps, the density of the urbanization within theses two communes in 2000/2001 was estimated to be around 60-80%. In reality, these two communes had been almost completely urbanized by 2000/2001.

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.

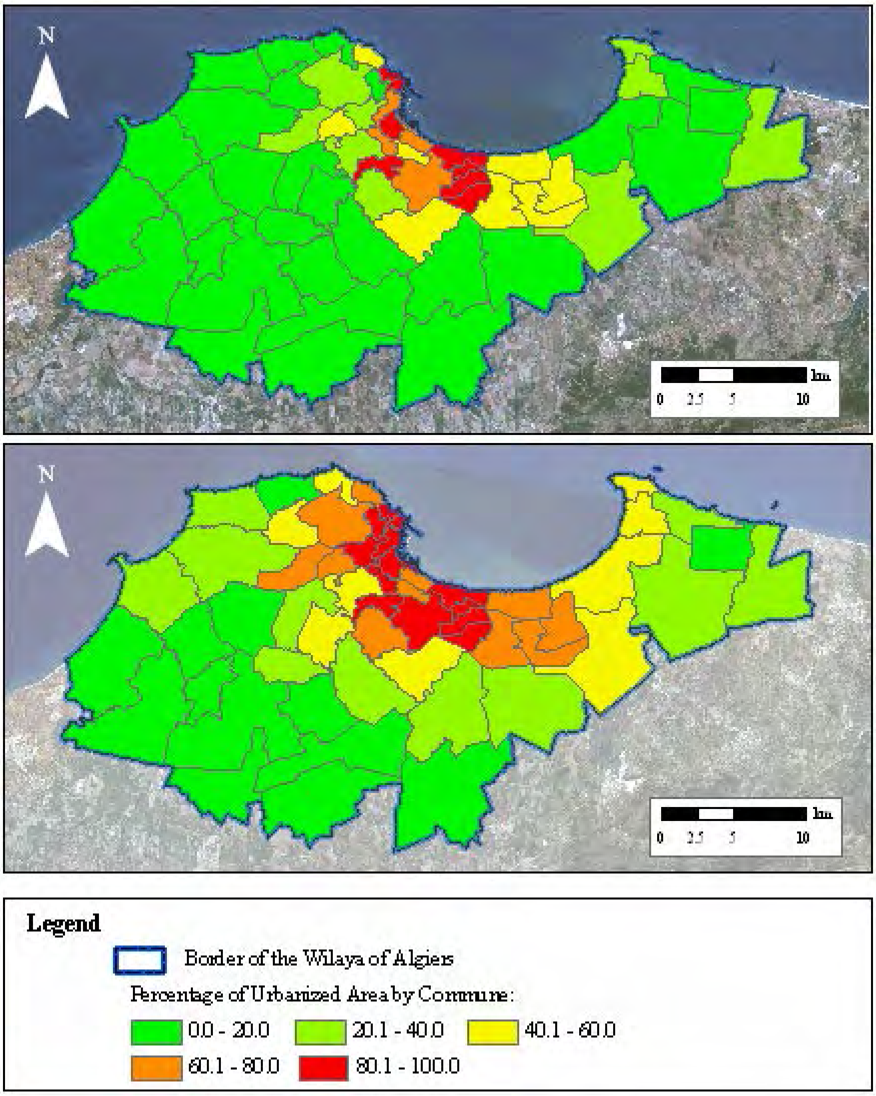



Figure 2-30 Percentage of Commune Urbanization in 1987 and 2000/2001[9]

3) Estimated Population for End of 2002

In the JICA Study, only the 1998 census was available as the latest population/households census. No official census has been available in the Wilaya of Alger since 1998. However, “the annual statistics of the Wilaya of Algier 2003” have estimated the demography of the Wilaya of Algiers for the end of 2002.

According to an estimation shown in the statistics mentioned above, the study area (comprising 34 communes) had been estimated to have a population of 1,892,379, and the average population density would be 7,853 people per $km^2$.

Within the Study Area, the population density of three (3) communes (BAB EL OUED, CASBAH, and SIDI M’HAMED) had been estimated as being more than 40,000 people per $km^2$ in 2002, and that of eight (8) communes (OUED KORICHE, ALGER

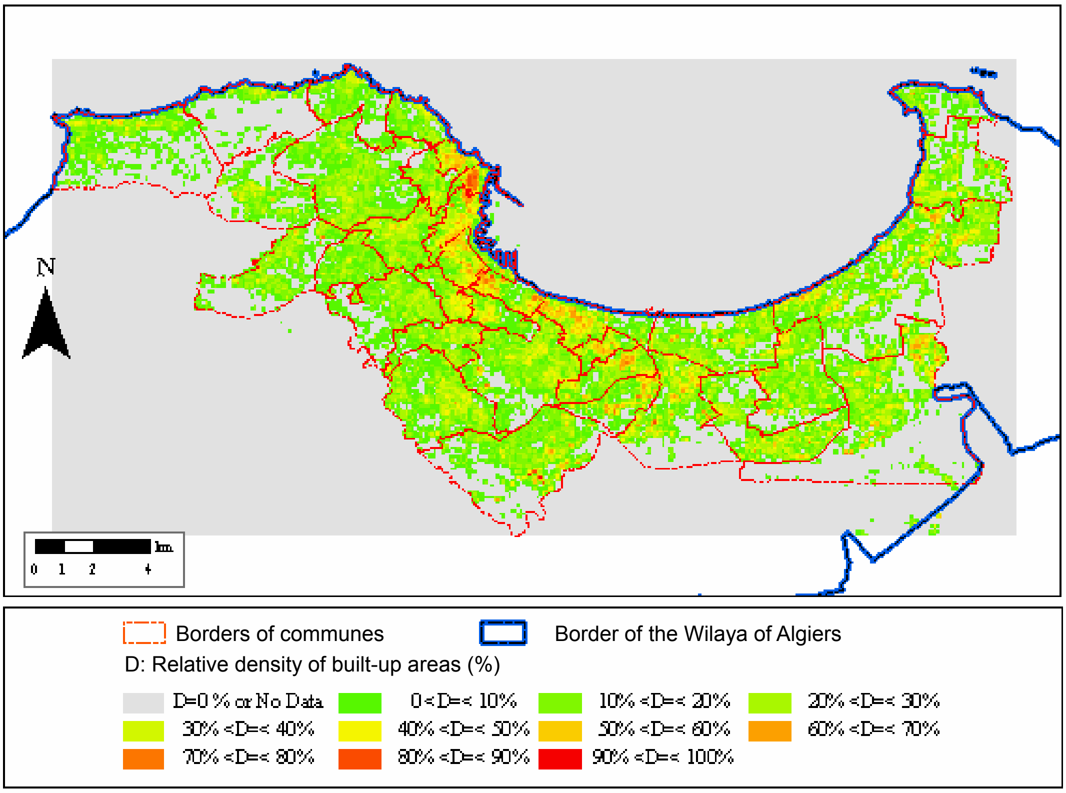
[9] [Source] Border of the Wilaya of Algiers (INCT); Percentage of Urbanized Area by Commune (JICA Study Team)

CENTRE, BELOUZDAD, EL MADANIA, EL MAGHARIA, BACH DJARAH, and BOUROUBA) would be between 20,001 and 40,000 people per $km^2$ in 2002. The population density of the other 23 communes within the study area had been estimated as being less than 20,000 people per $km^2$ in 2002.

The most densely populated commune within the study area would have been BAB EL OUED commune with a population density of 74,793 people per $km^2$ in 2002. CASBAH would follow BAB EL OUED with 48,306 people per $km^2$ in 2002. The most sparsely populated commune within the study area would have been DAR EL BEIDA commune, with only 1,486 people per $km^2$ in 2002.

4) Building Area

Figure 2-31 shows of the relative density of built up areas within the study area.




Source: JICA Study Team

Figure 2-31 Relative Density of Built-up Areas (%) within the Study Area[10]

The relative density of built up areas was determined by using GIS data that were prepared by URBANIS. Each colored pixel in Figure 2-31 above represents an area of one (1) ha and shows the ratio (%) of the land area occupied by buildings per hectare.

Areas where the relative density of built up areas is over 60% are considered to be densely built up areas. These are generally concentrated in the northeastern part of the

[10] [Source] Borders of Communes (INCT, revised by JICA Study Team); Borders of the Wilaya of Algiers (INCT); Relative Density of Built Up Area (URBANIS; processed by JICA Study Team)

Sahel Hills and the eastern part of the Wilaya of Algiers. Other areas where the building density is over 60% are located in different parts of the study area, e.g. the northeastern part of DAR El BEIDA commune.

Figure 2-32 shows the relative density of built up areas by commune. The built up area of the three most densely built up communes (BAB EL OUED, CASBAH, and SIDI M'HAMED) comprises over 30% of the area of each of these communes. The relative density of built up areas in Casbah commune is the highest of the 34 communes that comprise the study area. The built up area in CASBAH commune comprises 39% of the area of this commune. SIDI M'HAMED commune is the second most densely built up commune (relative built up density = 34%), and BAB El OUED commune is the third most densely built up commune (relative built up density = 33%). These three communes coincide with the most densely populated communes within the study area. As for the whole study area, the densely populated communes usually correspond to the densely built up communes.

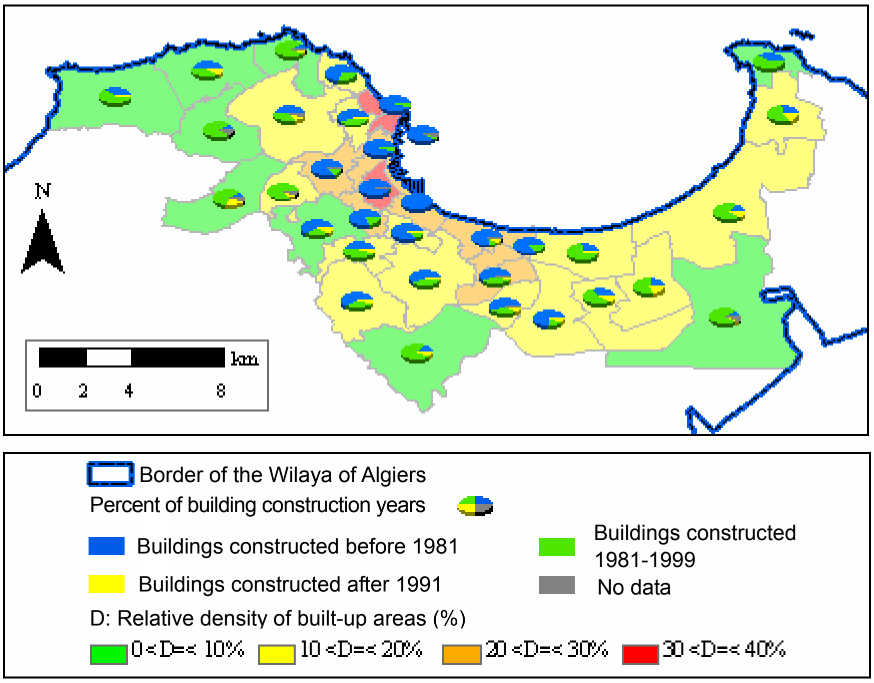



Figure 2-32 Relative Built Up Area Density and Building Construction Year[11] by Commune[12]

[11] Only the randomly selected buildings within the study area, those were checked in the "Building Inventory Survey" carried out by the JICA Study Team in 2005

[12] [Source] Borders of the Wilaya of Algiers (INCT); Percentage of Building Construction Years (JICA Study Team); Relative Density of Built Up Area (URBANIS; processed by JICA Study Team)

Table 2-8 Ratio (%) of Building Construction Periods by Commune[13]

| Commune | Before 1981 | 1981-1999 | After 1999 | Unknown |
|---|---|---|---|---|
| Alger Centre | 94.5 | 3.9 | 1.6 | 0.0 |
| Sidi M'hamed | 96.1 | 1.9 | 0.0 | 1.9 |
| El Madania | 86.4 | 10.4 | 3.2 | 0.0 |
| Belouzdad | 100.0 | 0.0 | 0.0 | 0.0 |
| Bab El Oued | 95.8 | 4.2 | 0.0 | 0.0 |
| Bologhine Ibnou Ziri | 70.8 | 29.2 | 0.0 | 0.0 |
| Casbah | 92.9 | 3.2 | 0.0 | 3.9 |
| Oued Koriche | 60.1 | 36.7 | 3.2 | 0.0 |
| Bir Mourad Rais | 45.5 | 50.3 | 4.2 | 0.0 |
| El Biar | 86.4 | 10.4 | 0.0 | 3.2 |
| Bouzareah | 44.8 | 36.7 | 13.3 | 5.2 |
| Birkhadem | 58.1 | 35.4 | 6.5 | 0.0 |
| El Harrach | 74.7 | 18.2 | 7.1 | 0.0 |
| Oued Smar | 33.1 | 58.4 | 8.4 | 0.0 |
| Bourouba | 55.8 | 33.1 | 9.1 | 1.9 |
| Hussein Dey | 78.6 | 10.7 | 6.8 | 3.9 |
| Kouba | 57.1 | 37.7 | 5.2 | 0.0 |
| Bach Djarah | 58.1 | 36.0 | 2.3 | 3.6 |
| Dar El Beida | 11.7 | 76.6 | 3.9 | 7.8 |
| Bab Ezzouar | 23.1 | 57.5 | 19.5 | 0.0 |
| Ben Aknoun | 0.0 | 82.1 | 8.8 | 9.1 |
| Dely Brahim | 11.7 | 59.1 | 24.0 | 5.2 |
| Hammamet | 44.8 | 46.1 | 9.1 | 0.0 |
| Rais Hamidou | 11.4 | 81.5 | 3.6 | 3.6 |
| Djasr Kasentina | 17.5 | 74.0 | 6.5 | 1.9 |
| El Mouradia | 81.5 | 18.5 | 0.0 | 0.0 |
| Hydra | 60.1 | 30.2 | 9.7 | 0.0 |
| Mouhammadia | 28.2 | 67.5 | 4.2 | 0.0 |
| Bordj El Kiffan | 16.9 | 73.4 | 9.7 | 0.0 |
| El Magharia | 82.5 | 17.5 | 0.0 | 0.0 |
| Beni Messous | 9.7 | 80.2 | 0.0 | 10.1 |
| Bordj El Bahri | 28.6 | 57.1 | 14.3 | 0.0 |
| El Marsa | 39.9 | 60.1 | 0.0 | 0.0 |
| Ain Benian | 38.3 | 58.4 | 3.2 | 0.0 |

Figure 2-32 and Table 2-8 also show the construction year of the buildings within each commune. Communes where most of the buildings were constructed before 1981 are concentrated along the southwest coastline of the Bay of Algiers. These communes coincide with the communes where the relative built up area density of each commune is over 20%.

In five (5) communes (BELOUZDAD, SIDI M'HAMED, BAB EL OUED, ALGER CENTRE, and CASBAH), 90% of all the buildings were constructed before 1981. These five communes are followed by a group of four (4) communes (EL MADANIA, EL: BIAR, El MAGARIA, and EL MOURADIA) where 82 to 86% of all the buildings were constructed before 1981.

[13] [Source] JICA Study Team

As for the remaining 14 communes[14], over 50% of all the buildings within each commune were constructed in the period between 1981 and 1999.

The construction year of the buildings within each commune indicates the main period of urban development within each commune.

5) Roads (as of the end of 2002)

Roads within the study area are administratively divided into three (3) categories: “National”, “Wilaya”, and “Communal” roads. Within the Wilaya of Algiers, the total lengths of the “National”, “Wilaya”, and “Communal” roads are 220.470 km, 222.386 km, and 110.220 km, respectively. Within the 34 communes that comprise the study area, the total lengths of the “National”, “Wilaya”, and “Communal” roads are 29.880 km, 16.177 km, and 24.934 km, respectively.

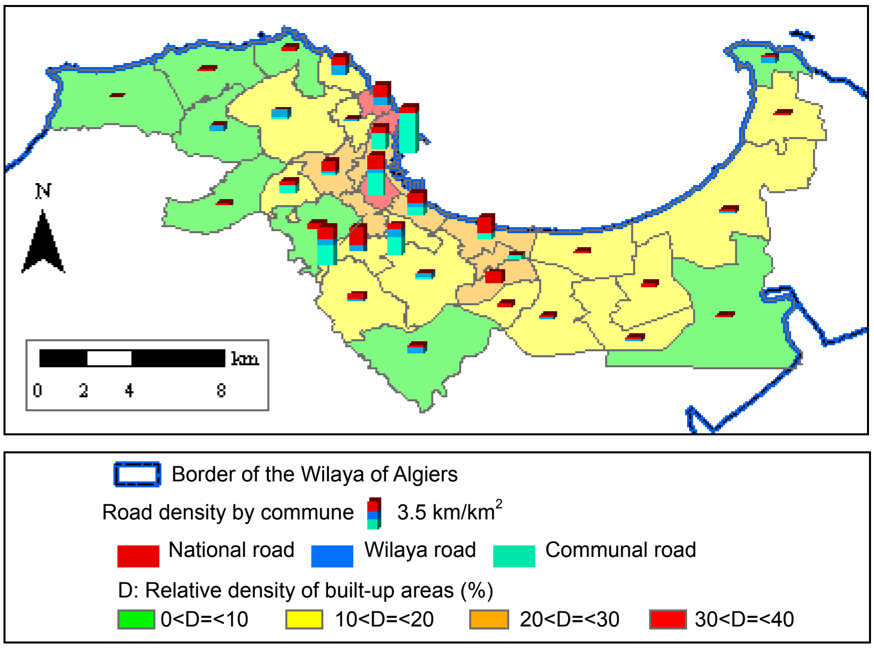



Figure 2-33 Road Density (km/km$^2$) by Commune and Relative Built Up Area Density[15]

Figure 2-33 shows the total road density (km/km$^2$) within each commune. The communal roads, which are generally narrower than the national and Wilaya roads, are often situated within communes where the relative built up area density is higher, e.g., CASBAH, ALGER CENTRE, SIDI M’HAMED, and EL MADANIA. Moreover, the administrative (“National”, “Wilaya”, and “Communal”) roads are often seen within communes that comprise the densely built up areas or the densely populated areas along the southwest coastline of the Bay of Algiers.

[14] El MARSA, BORDJ EL BAHRI, BORDJ EL KIFFAN, DAR El BEIDA, BEB EZZOUAR, OUED SMAR, MOUHAMMADIA, DJASR KASANTINA, BIR MOURAD RAIS, BEN AKNOUN, DELY BRAHIM, RAIS HAMIDOU, BENI MESSOUS, and AIN BENIAN.

[15] [Source] Borders of the Wilaya of Algiers (INCT); Road Density by Commune (“Annuaire Statistique de la Wilaya d’ Alger Annee 2003”, calculated by JICA Study Team); Relative Density of Built Up Area (URBANIS; processed by JICA Study Team)

Table 2-9 Road Density (km/km$^2$) by Commune[16]

| Commune | National Roads | Wilaya Roads | Communal Roads |
|---|---|---|---|
| ALGER CENTRE | 1.270 | 0.000 | 2.635 |
| SIDI M'HAMED | 2.362 | 0.550 | 3.784 |
| EL MADANIA | 0.956 | 1.406 | 3.028 |
| BELOUZDAD | 1.806 | 0.833 | 1.111 |
| BAB EL OUED | 2.066 | 1.405 | 0.000 |
| BOLOGHINE I. Z. | 1.123 | 1.920 | 0.000 |
| CASBAH | 0.972 | 0.000 | 6.944 |
| OUED KORICHE | 0.000 | 0.625 | 0.000 |
| BIR M. RAIS | 2.988 | 1.277 | 0.000 |
| EL BIAR | 1.703 | 0.404 | 0.294 |
| BOUZAREAH | 0.000 | 1.182 | 0.249 |
| BIR KHADEM | 1.020 | 0.326 | 0.000 |
| EL HARRACH | 0.318 | 0.106 | 0.000 |
| OUED SMAR | 0.307 | 0.307 | 0.000 |
| BOUROUBA | 0.826 | 0.000 | 0.000 |
| HUSSEIN DEY | 2.559 | 0.000 | 1.009 |
| KOUBA | 0.000 | 0.781 | 0.249 |
| BACH DJARAH | 1.833 | 0.000 | 0.000 |
| DAR EL BEIDA | 0.372 | 0.168 | 0.000 |
| BAB EZZOUAR | 0.674 | 0.000 | 0.000 |
| BEN AKNOUN | 0.574 | 0.000 | 1.305 |
| DELY BRAHIM | 0.214 | 0.194 | 0.000 |
| EL HAMMAMET | 0.562 | 0.000 | 0.000 |
| RAIS HAMIDOU | 0.607 | 0.000 | 0.000 |
| D. KASANTINA | 0.422 | 0.880 | 0.000 |
| EL MOURADIA | 1.832 | 1.283 | 3.560 |
| HYDRA | 0.850 | 0.196 | 0.000 |
| MOUHAMMADIA | 0.263 | 0.000 | 0.000 |
| BORDJ EL KIFFAN | 0.438 | 0.364 | 0.000 |
| EL MAGHARIA | 0.000 | 0.000 | 0.764 |
| BENI MESSOUS | 0.000 | 1.047 | 0.000 |
| BORDJ EL BAHRI | 0.421 | 0.000 | 0.000 |
| El MARSA | 0.374 | 0.860 | 0.000 |
| AIN BENIAN | 0.166 | 0.063 | 0.000 |

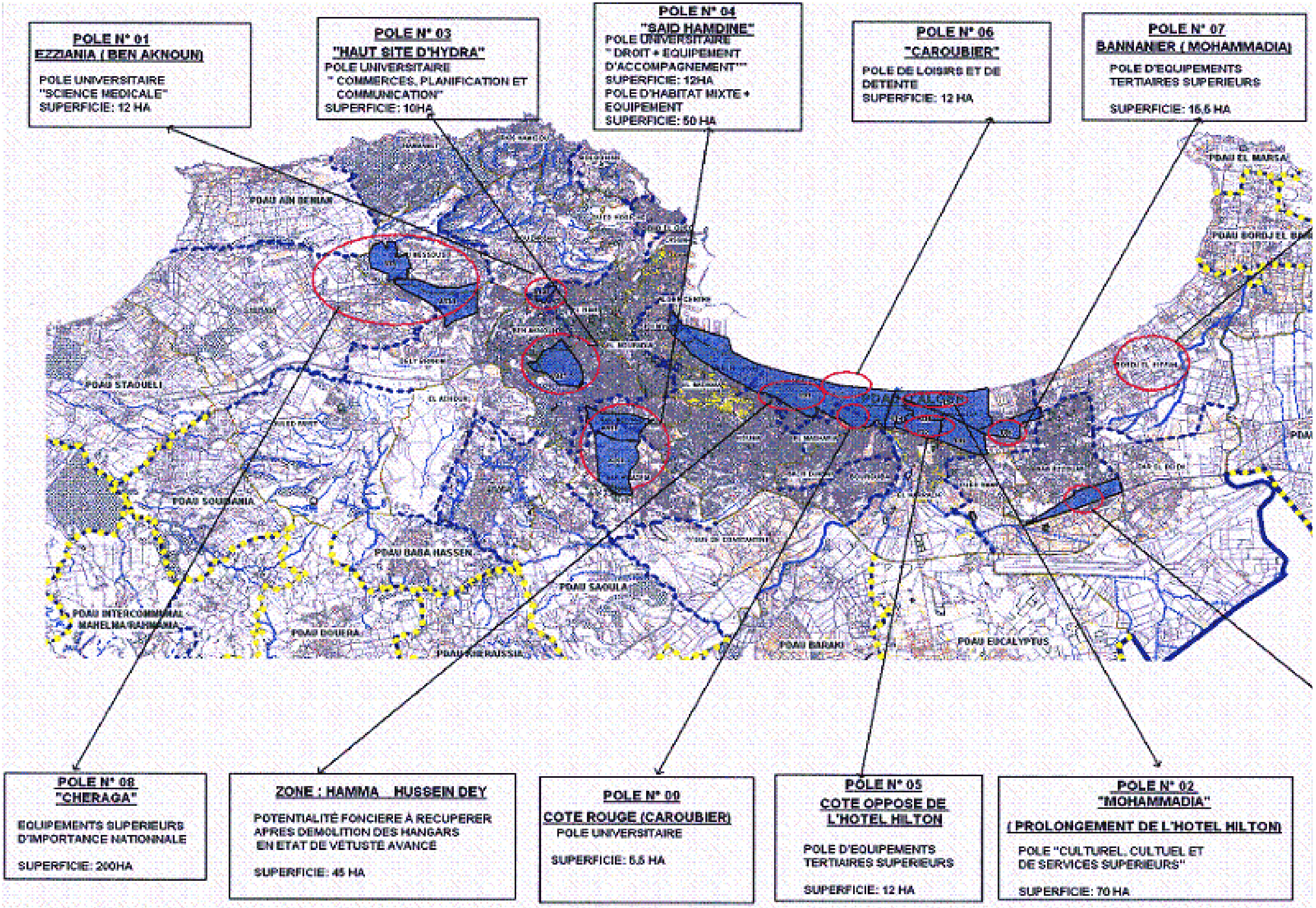
6) Summary of the Historical Background of Urbanization in the Wilaya of Algiers

Algeria gained independence from France in 1962. Immediately after this, 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. In addition, 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. Of these 57 communes, 28 communes were considered to be "urban" wards, while the remainder were given the status of peripheral communes. The GGA gave rise to the "Grand Urban Project for Algiers, the Capital of the 21st Century" (Figure 2-34).

Today, the GGA has reverted to its previous designation of a Wilaya, and the 28 "urban" wards (described above) have returned to the status of communes.

16 [Source] "Annuaire Statistique de la Wilaya d' Alger Annee 2003", calculated by JICA Study Team




Source: URBANIS

Figure 2-34 Grand Urban Project for Algiers, the Capital of the 21st Century

7) "Instruments" for Control of Urbanization

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 PADAU is used at communal and inter-communal levels, with nominal mapping scales of 1:5,000 and 1:10,000.

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.

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.

The PDAU determines, for a commune or an association of communes, four (4) urbanization zones: currently urbanized, to be urbanized (i.e. presently, or soon to be, under development), reserved for future urbanization, and non-urbanizable (i.e. not to be used for urban development). The POS fixes in a detailed way the rights of land-use and construction. The regulation is accompanied by graphic reference documents.

Before 2004, the basic instrument for urban planning was the "Plan d'Urbanisme Directeur" (PUD, which is referred to as the "Urbanism Director Plan" in English). In 2004, the general approach was modified by introducing citizen participation into the PDAU implementation process ("urbanisme de concertation"). This was complemented by the definition of 4 zones of urbanization: U (urbanisé) for urbanized areas, AU (à urbaniser) for areas to be urbanized, UF (urbanisation future) areas for future urbanization, NU (non-urbanizable) rural areas.

Currently, the PDAUs of Algiers are managed by the CNERU (Public Consultant Agency in Urbanism) under the supervision of the Wilaya's Directorate of Urbanism.

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; land-use and construction have to be adapted to these threats. The Minister for Habitat and Urbanism and the Wilaya of Algiers is planning the implementation of Hazards and Risks Maps.

- Control of the application of Laws 04-05 and 04-06 (which modify Legislative decree 94-07 on the profession of architects and architectural work).

The corresponding decrees for implementation have not yet been produced. Thus, the PDAU and POS define the conditions for prevention of natural and technological risks in land-use and building construction. The seismic zones in particular must be identified and classified according to their degree of vulnerability. In addition, the construction projects must be jointly evaluated by an architect and an approved engineer. Law 04-05 adds provisions for demolition of the structures which do not comply with the rules and procedures of town planning and construction.

8) Urbanism Instruments of the Wilaya of Algiers

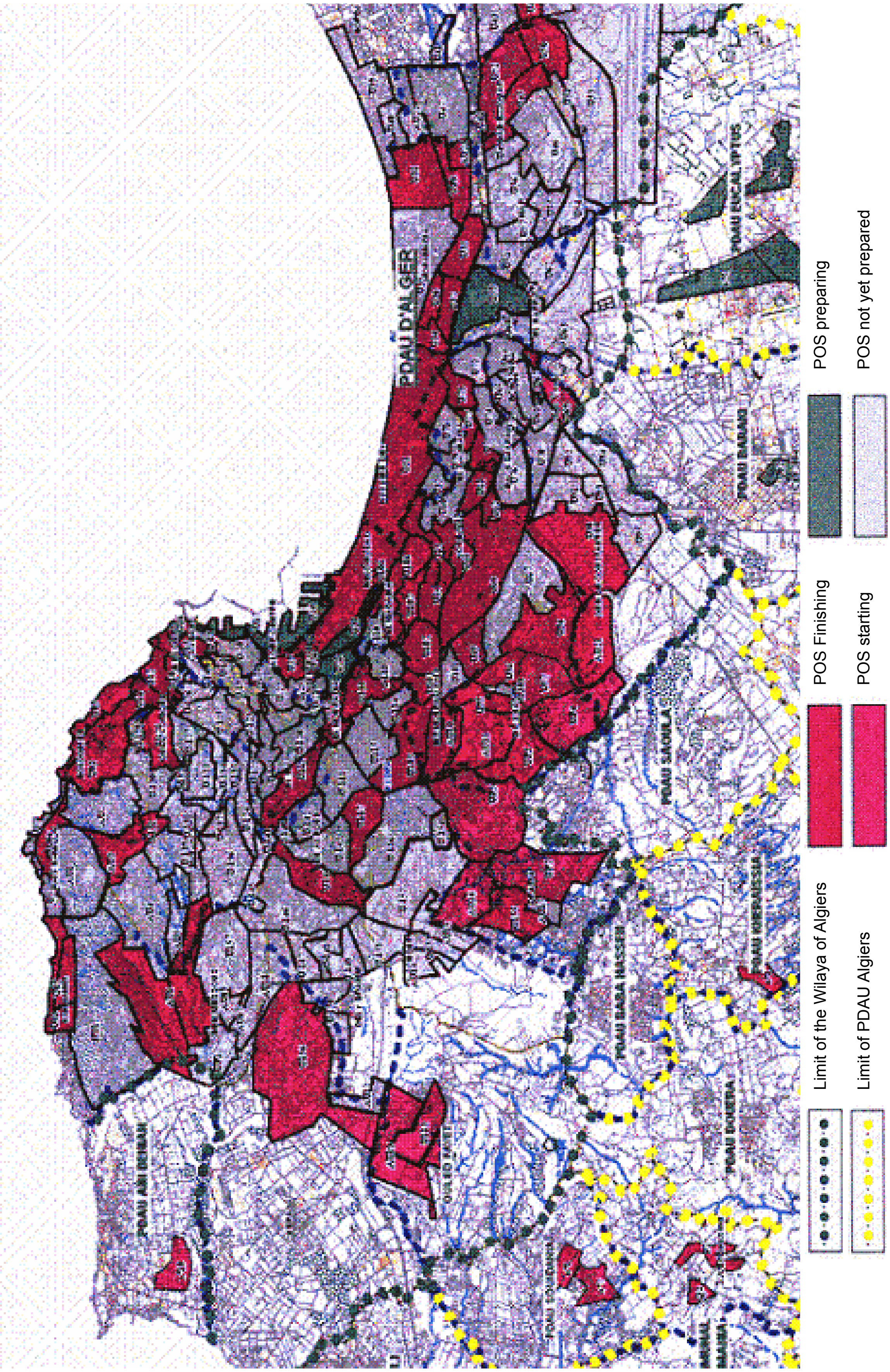
The Wilaya of Algiers has been implementing the Big PDAU of Algiers in 37 communes (31 of the original Algiers communes and 6 new communes) plus 20 communal PDAU's since 2005.

And, 126 POS's out of a total of 500 have been in force. In general, 8 months is required for the technical part, but 12 months is needed for the administrative procedures.

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.

The POS gives the main orientation for land-use, but the implementation phase depends on the Minister of Planning; realization and funding are managed by the DPAT (Direction de la Planification de l'Aménagement du Territoire), via the Director of Land-use Planning. 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. Figure 2-35 shows the current status of POS within the Study Area.




Source: Direction of Urbanism, the Wilaya of Algiers and URBAN

Figure 2-35 Current status of POS within the Study Area

### 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. In this JICA Study, the existing facilities within the Study Area, which consists of 34 communes, were evaluated for use as disaster management resources. The existing facilities that could be used as disaster management resources are listed in Table 2-10.

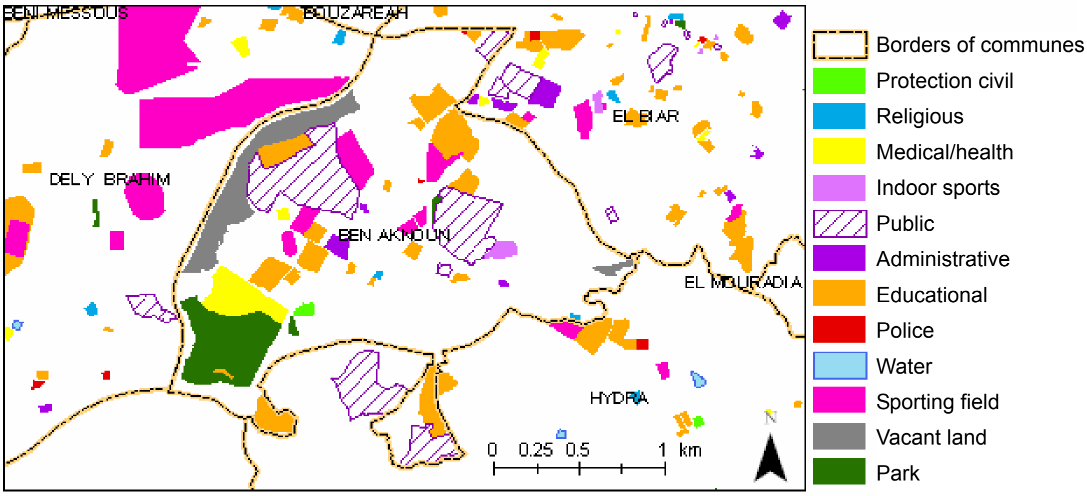
Table 2-10 Disaster Management Resources within the Study Area

| 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". Details of the urban disaster management database are described in Chapter 11.

In addition to the basic data mentioned above, the results of the micro-zoning study and the urban vulnerability assessment, which are described in the following Sections, were also incorporated into the database for disaster management resources. Figure 2-36 shows a sample view of the GIS data representing the disaster management resources in BEN AKNOUN and adjacent areas.




Source: JICA Study Team

Figure 2-36 Distribution of Disaster Management Resources in BEN AKNOUN and Adjacent Areas

(2) Existing Disaster Management Resources (Basic Data)

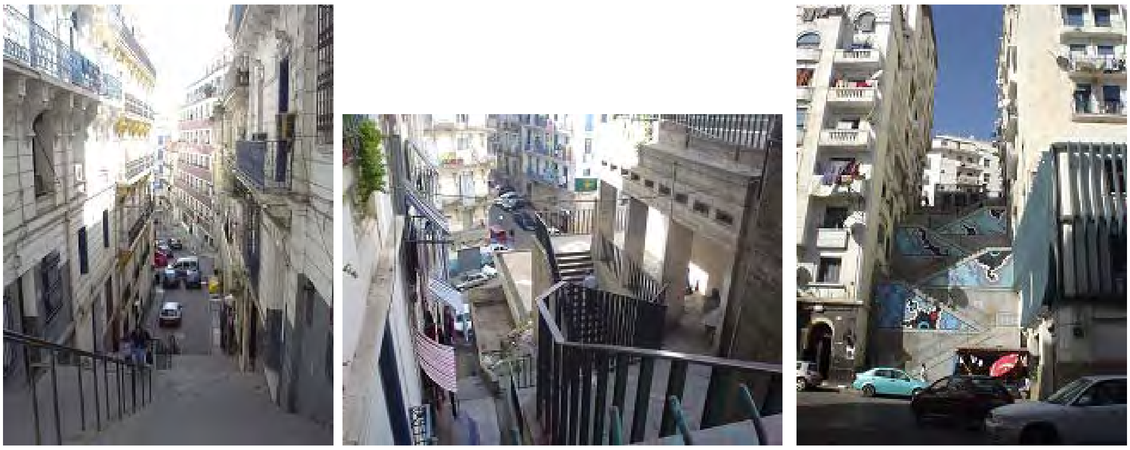
Table 2-11 shows the number and extent (ha) of existing disaster management resources by sector within the micro-zoning area, which consists of 34 communes.

Table 2-11 Summary of Existing Disaster Management Resources by Sector within the Micro-zoning Area

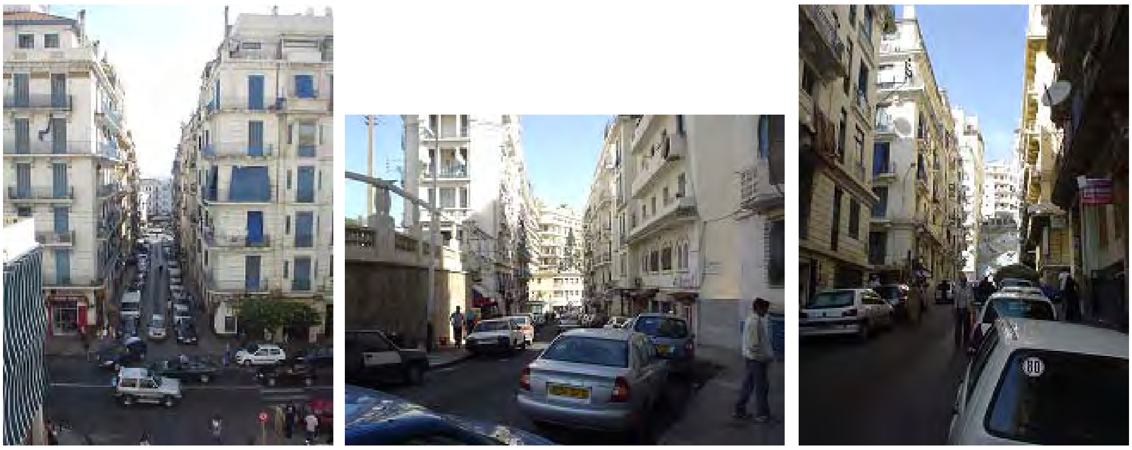
| Code | Resource | Type | Number | Gross area (ha) |
|---|---|---|---|---|
| 01 | Parks | Open-air | 118 | 175 |
| 02 | Vacant Land | Open-air | 28 | 49 |
| 03 | Sporting Fields | Open-air | 132 | 181 |
| 04 | Airports | Open-air | 1 | - |
| 06 | Ports | Open-air | 3 | - |
| 07 | Water | Open-air | 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

Figure 2-37 shows examples of disaster management resources.



Stairs as communal streets in the densely built up areas , Alger Centre



Cars parking on the streets in the densely built up areas, Alger Centre

(A park near the Hotel El Aurassi)

(Sports field, Alger Centre)

Examples of Disaster Management Resources

Source: JICA Study Team

Figure 2-37 Photographs of Existing Built-up Areas and Disaster Management Resources

# CHAPTER 3

# NATURAL CONDITION FOR MICROZONING

# Chapter 3. Natural Condition for Microzoning

## 3-1 Seismotectonics and Seismicity of the Region

### 3-1-1 Geodynamic Context

(1) The Africa-Eurasia Plate Boundary

The northern region of Algeria is a tectonically complex zone accommodating part of the relative convergence between Africa and Eurasia. The Algiers area, along the Mediterranean coast, is located in the vicinity of the boundary between the Eurasian plate to the north and the African plate to the south (Figure 3-1). This boundary, which is highlighted by a belt of seismic activity along the 36th parallel, is a seismically active zone connecting the Azores Islands to Sicily across the northern Maghreb (Hatzfeld, 1978 ; Udias et al., 1986 ; Mezcua et al., 1991).

The Africa-Eurasia plate boundary is rather complex as it is formed by segments of different geometry, nature and kinematics (Figure 3-2 and Figure 3-3). To summarize, it can simplified as:

- An ocean-ocean type boundary to the west, between the Azores triple junction and the Straight of Gibraltar (Terceira ridge and Gloria Fault);
- A continent-continent type boundary in its central part, east of Gibraltar, that crosses the Iberian Peninsula and Maghreb continental margins and includes the study area;
- A poorly identified boundary to the east, in the Adriatic region, where borders and natures of tectonic plates are still under discussion (e.g. Kiratzi and Papazachos, 1995).

In its central section, where the Africa-Eurasia boundary separates two continental lithospheres, the relative displacement is not accommodated on a single fault but is rather distributed on several structures. These include, among other possibilities, the Alboran Sea, the Iberian margin, and the Rif and Tell ranges in Morocco and Algeria, respectively.

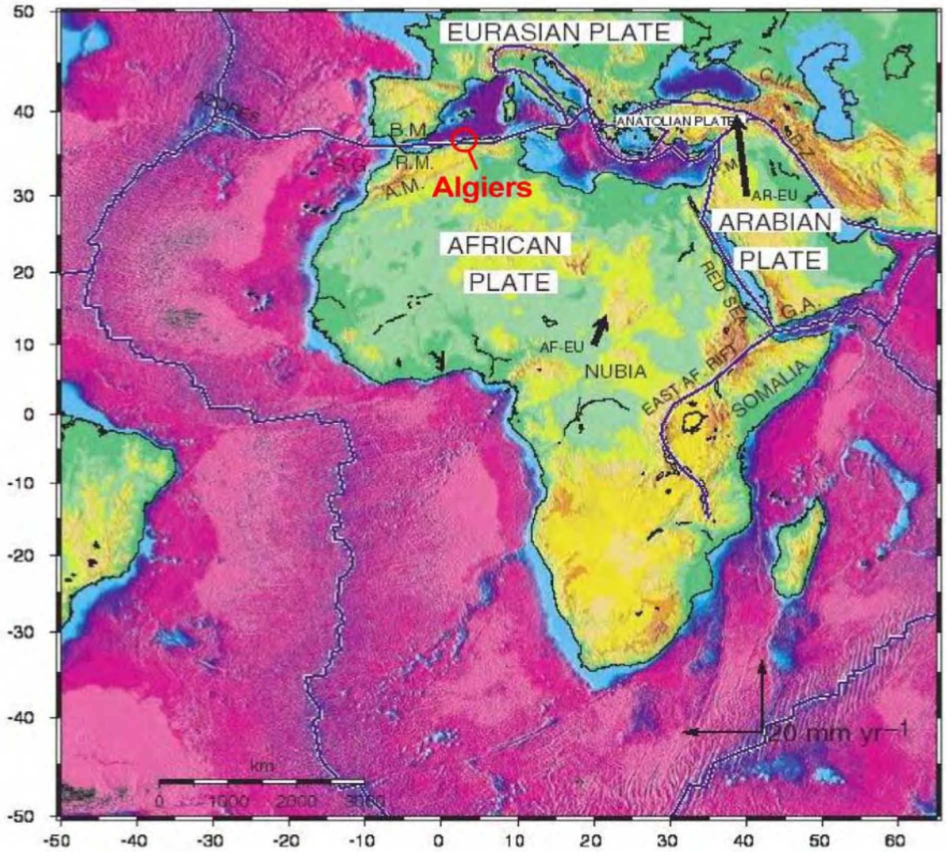



Figure 3-1 Topographic and Bathymetric Map of the African (Nubia-Somalia) Neighboring Plates and Their Boundaries, modified from McClusky et al (2003). Black arrows show displacements predicted by the NUVEL-1A model (DeMets et al, 1990, 1994). SG: Straight of Gibraltar; BM: Betic Massif; RM: Rif Massif; AM: Atlas Massif; PM: Palmyrid Massif; CM: Caucasus Massif; B-Z: Bitlis-Zagros Belt; GA: Gulf of Aden

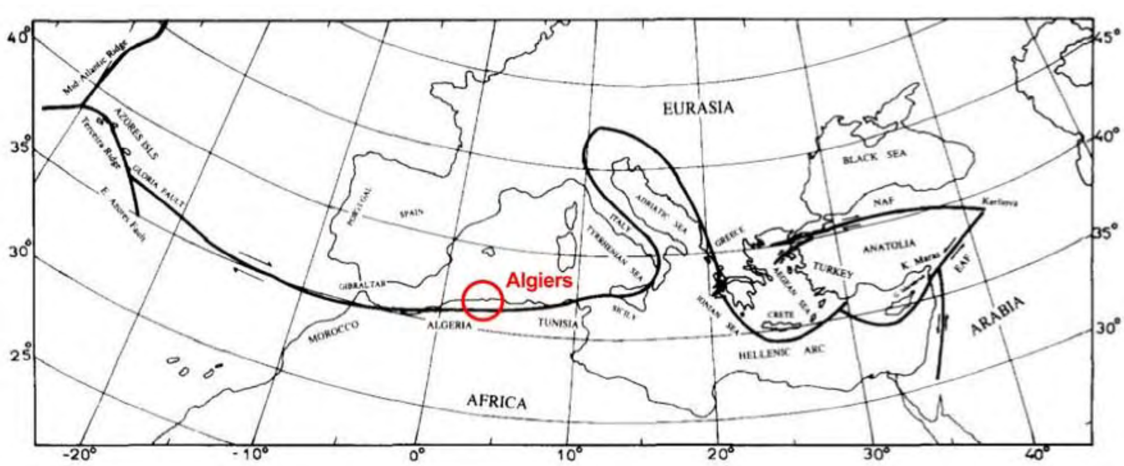



Figure 3-2 Schematic Trace of the Africa (Nubia)-Eurasia Plate Boundary, modified from Kiratzi and Papazachos (1995)

(2) Kinematic of the Africa-Eurasia Boundary

The eulerian pole that describes the Africa-Eurasia rotation, deduced from GPS measurements of the relative plate displacement, is located in the southern Atlantic (McClusky et al, 2003). The resulting relative displacements of the two plates (Figure 3-3) are:

- Extensional on the Azores ridge,
- Right-lateral on the Gloria Fault,
- Compressional in the Ibero-Maghrebian region and eastward, especially along the African margin (Algerian Tell and Moroccan Rif).

From the Azores (approx. longitude 30°W) to the western termination of the Gloria Fault (approx. longitude 24°W), the relative kinematics of the plate are extensional (oceanic accretionary ridge) and are well documented, along a N120°E direction. This accretional boundary produced earthquakes of low to moderate magnitudes.

Along the Gloria Fault, between longitudes 24° and 18°W, the extensional displacement becomes right-lateral strike-slip. Despite a relatively low seismic activity, this segment produced two strong earthquakes (M = 7.1 in 1939 and M = 8.4 in 1941). Its seismic activity, however, remains low and denotes with other seismically more active segments. This feature could be related to either i) an aseismic accommodation of displacement (creeping) or ii) a quiet period separating clusters of earthquakes. This quietness is interpreted by some researchers as an indicator of strong coupling between the two plates and, as a result, large accumulation of elastic stress likely to generate earthquakes of strong magnitude.

From longitude 17°W eastward, the plate boundary changes its orientation to N120°E. There, the Africa-Eurasia relative displacement becomes compressional. This shortening generates strong seismic activity. Near the Ibero-Moroccan domain (longitudes 12° to 8°W), the Gorringe-Guadalquivir region is located in a context of eastward thickening oceanic crust (Gulf of Cadix). Among the strongest earthquakes recorded in this region are those of February 28 1969, March 15 1964, April 14 1977 (Cherkaoui, 1991), and the dramatic event on November 1 1755. This area is characterized by an en-echelon system of faults and folds that reach lengths of over 100 km (Armijo, 1986 ; Udias et al,1986; Morel and Meghraoui, 1996 ; Zitellini, 1999). Focal mechanisms (compilation from Meghraoui et al., 1996) reveal thrusting reverse displacements on these crustal faults, that accommodate NW-SE to NNW-SSE striking compression (Armijo, 1986 ; Udias et al,1986; Morel and Meghraoui, 1996 ; Zitellini, 1999).

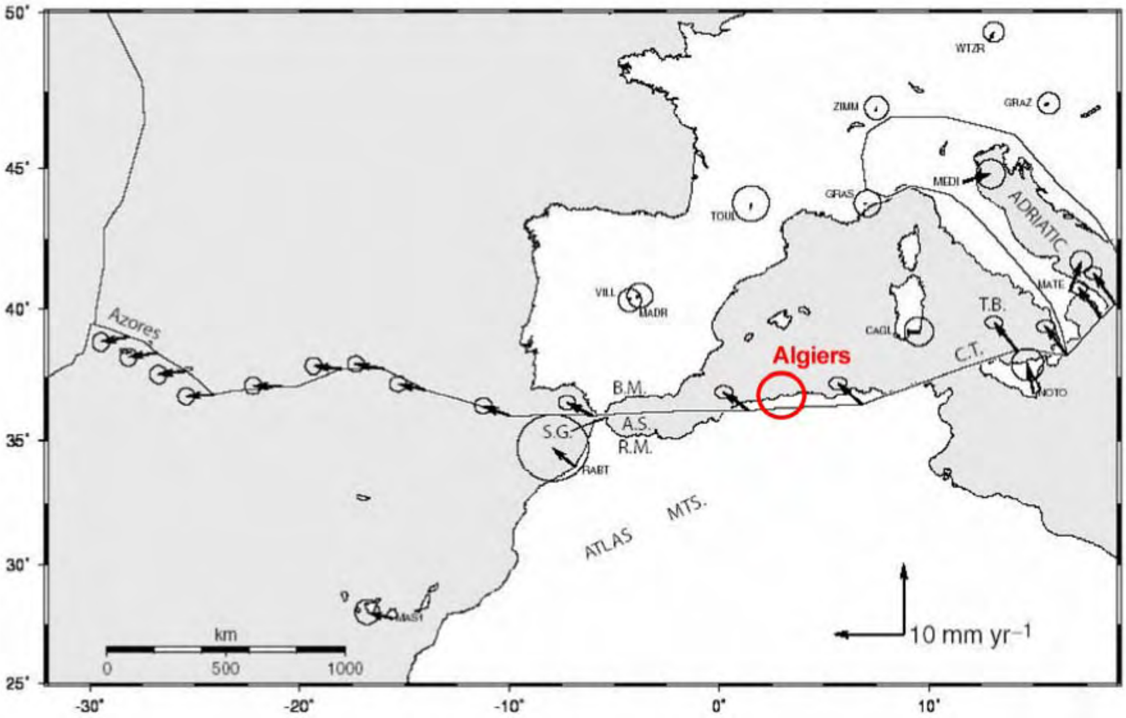



Figure 3-3 Africa/Eurasia Relative Displacement and Uncertainty Ellipses (2σ), on a Schematic Plate Boundary between the Azores Triple Junction and Italy, based on rotation pole from McClusky et al (2003). SG: Straight of Gibraltar; BM: Betic Massif; AS: Alboran Sea; RM: Rif Massif; CT: Calabrian Trench;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

East of the Gibraltar Straight, the plate boundary becomes more complex: one of its major structures could be the Alboran ridge area that is a location of an intense seismic activity. Among other strong events, the earthquake of September 22 1522 caused severe damage and casualties in the Moroccan Rif region.

To the east of the Maghreb, the plate boundary is poorly located. It turns northward, along the Apennine range in Italy and the Adriatic Sea where its nature is still debated.

Within Algiers at location latitude 36.75°N and longitude 3.05°E approx., the relative Africa/Eurasia motion given by geodesy data is:

- According to the NUVEL-1A model (DeMets et al., 1990, 1994), 5.8 mm/yr toward azimuth 329°;
- According to the REVEL model (Sella et al., 2002), 5.9 mm/yr toward azimuth 296°
- According to McClusky et al. (2003), 4.7 mm/yr toward azimuth 307°.

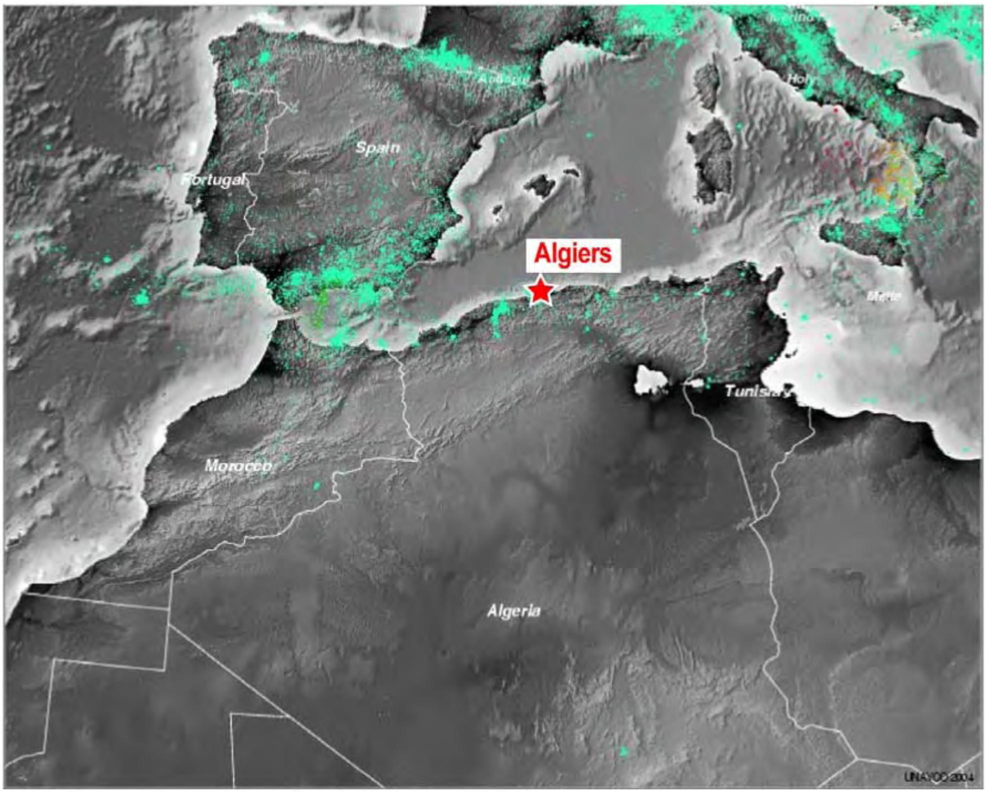
Based on structural criteria (e.g. Atlantic transform faults) and considering a displacement of western Europe independent from the rest of Eurasia, Albarello et al (1995) suggest a similar Africa/Iberia relative displacement, at the location of Algiers, of 5.5 mm/yr towards azimuth 332°. These results are summarized in Table 3-1 below. As geodetic and structural data yield similar results, we will consider hereafter a relative Africa/Eurasia displacement, at the location of Algiers, of 5 to 6 mm/yr towards the NNW.

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 |

One should, however, keep in mind that shortening between the two plates is not necessarily accommodated solely in the Algiers area. The plate boundary in the Maghreb region is a continent-continent type, which implies, as evidenced by instrumental seismicity (Figure 3-4), that relative displacement could be accommodated over a large zone that includes the Atlas and Algerian margin. Within this context, all active structures, with regard to their dimension and slip rate, do not have the same seismogenic capability.

In order to better assess regional seismic hazard, it then becomes necessary to precisely define the distribution of the Africa-Eurasia relative displacement over all significant active seismogenic structures within a radius of approximately 100 to 150 km covering the Algiers region.




(USGS NEIC catalog, 1961-2001; source: UNAVCO, Boulder).
Green: shallow events; Yellow: intermediate events; red: deep events

Figure 3-4 Location and Depth of Instrumental Seismicity in the Maghreb Region

(3) Regional Stress Pattern

Seismicity in Algeria is concentrated in the northern part of the country, where it highlights the diffuse boundary between the African and Eurasian plates (Figure 3-4). Available focal mechanisms in northern Algeria (Figure 3-5) suggest:

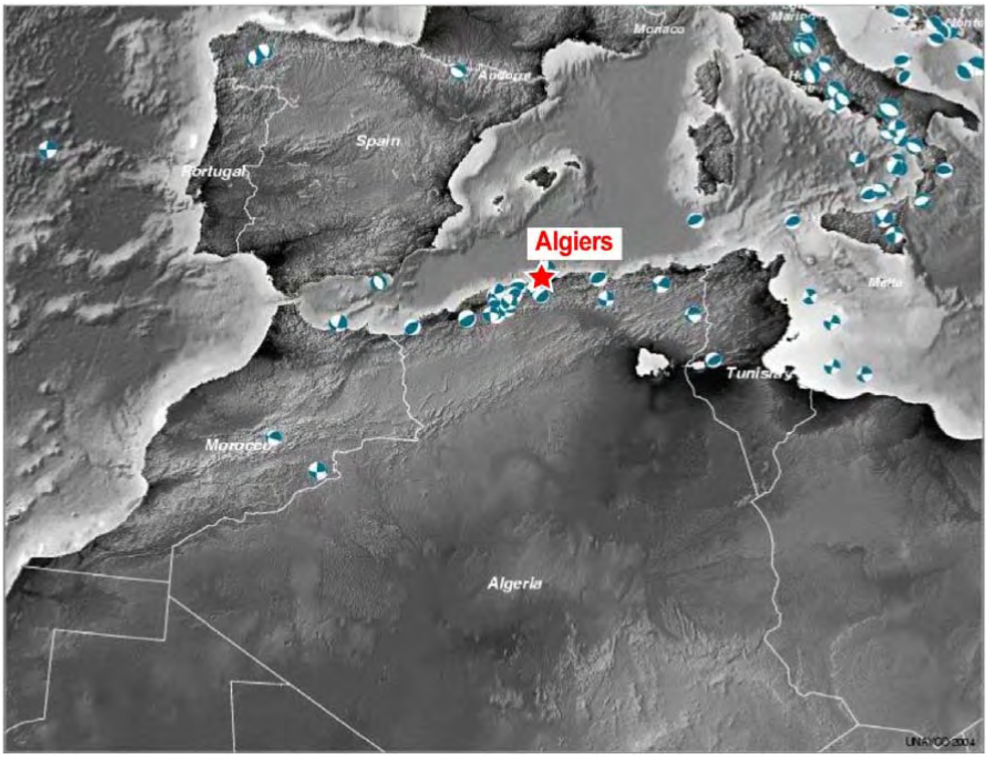
- a P (pressure) axis horizontal striking NW-SE to NNW-SSE;
- a T (tension) axis horizontal striking SW-NE to WSW-ENE and/or vertical.

These focal mechanisms in northern Algeria reveal a maximum horizontal stress trending NW-SE to NNW-SSE with compressional and strike-slip displacements.

Geodetic and seismologic data are consistent and suggest that in the region of Algiers a stress tensor exists characterized by:

- A maximum horizontal stress ($\sigma_{Hmax}$) trending NNW-SSE to NW-SE
- A minimum horizontal stress ($\sigma_{Hmin}$) trending ENE-WSW to NE-SW.

It should be noted that the minimum horizontal stress ($\sigma_{Hmin}$) could either be the $\sigma_2$ or $\sigma_3$ axis of the stress tensor1. As a consequence, one should expect on active faults in the Algiers region reverse displacements with a possible strike-slip component.




(Harvard CMT, lower hemisphere; source: UNAVCO, Boulder).

Figure 3-5 Focal Mechanisms from Instrumental Seismicity in the Maghreb Region

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

(1) Tectonic evolution of the Algerian Margin

The Tell range, that includes the Algiers region, covers the northern part of Algeria along the Mediterranean coast and extends beyond its borders. It is flanked by the algero-provençal basin and the Saharan Atlas to the north and south, respectively. The Tellian topography results from southward thrusting of the tellian margin and Kabylia micro-bloc, or Alboran micro-plate, during the Miocene period (Andrieux et al, 1971). These thrust fronts (southern kabylian front and northern tellian front), which trend approximately E-W (Figure 3-6), are major regional structures in northern Algeria.

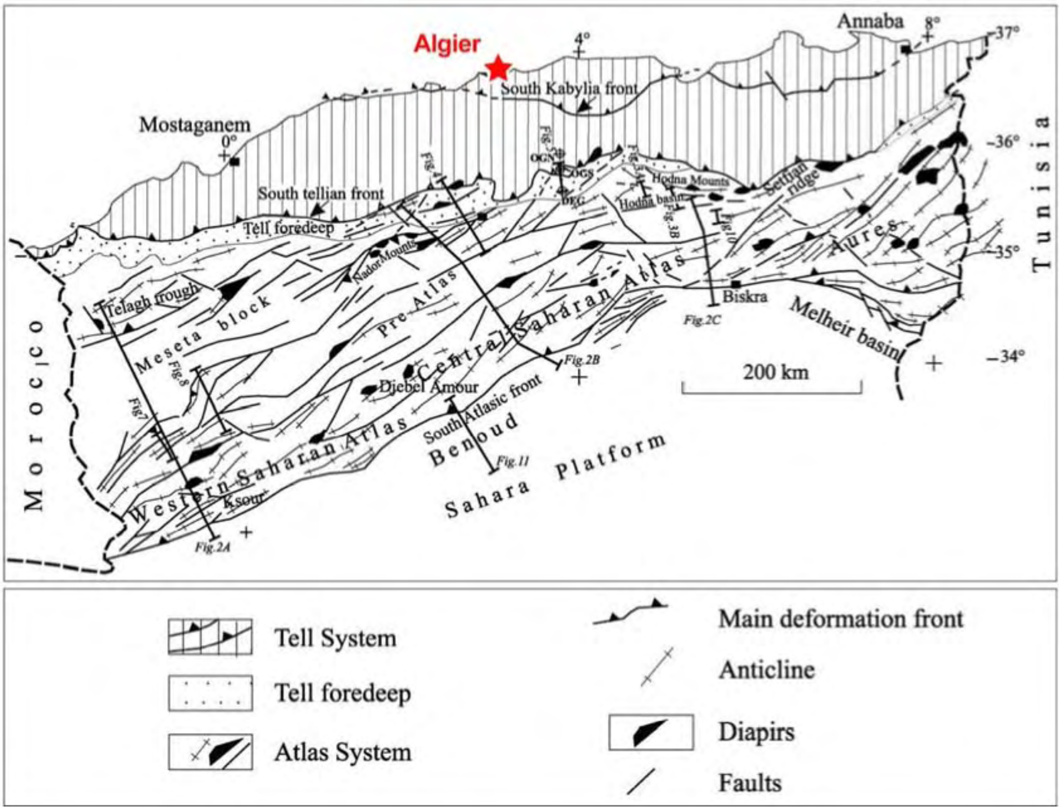



Figure 3-6 Schematic Map of Northern Algeria Showing Principal Structural Domains, modified from Bracène and Frizon de Lamotte (2002). Figure numbers refer to cross-sections in the article from Bracène and Frizon de Lamotte (2002).

From the Trias to the present, the geological history of northern Algeria has been closely linked to Africa/Eurasia relative plate displacements. The region successively recorded the following major events:

- Rifting associated with the opening of Tethysian and central Atlantic oceans (fragmentation of Pangea) from upper Trias to Lias (e.g. Mattauer et al, 1977; Andrieux et al, 1989);
- Opening of the Tethys Ocean since the Dogger;
- Inversion and closure of the Tethys from Oligocene to present time (e.g. Guiraud and Bosworth, 1997).

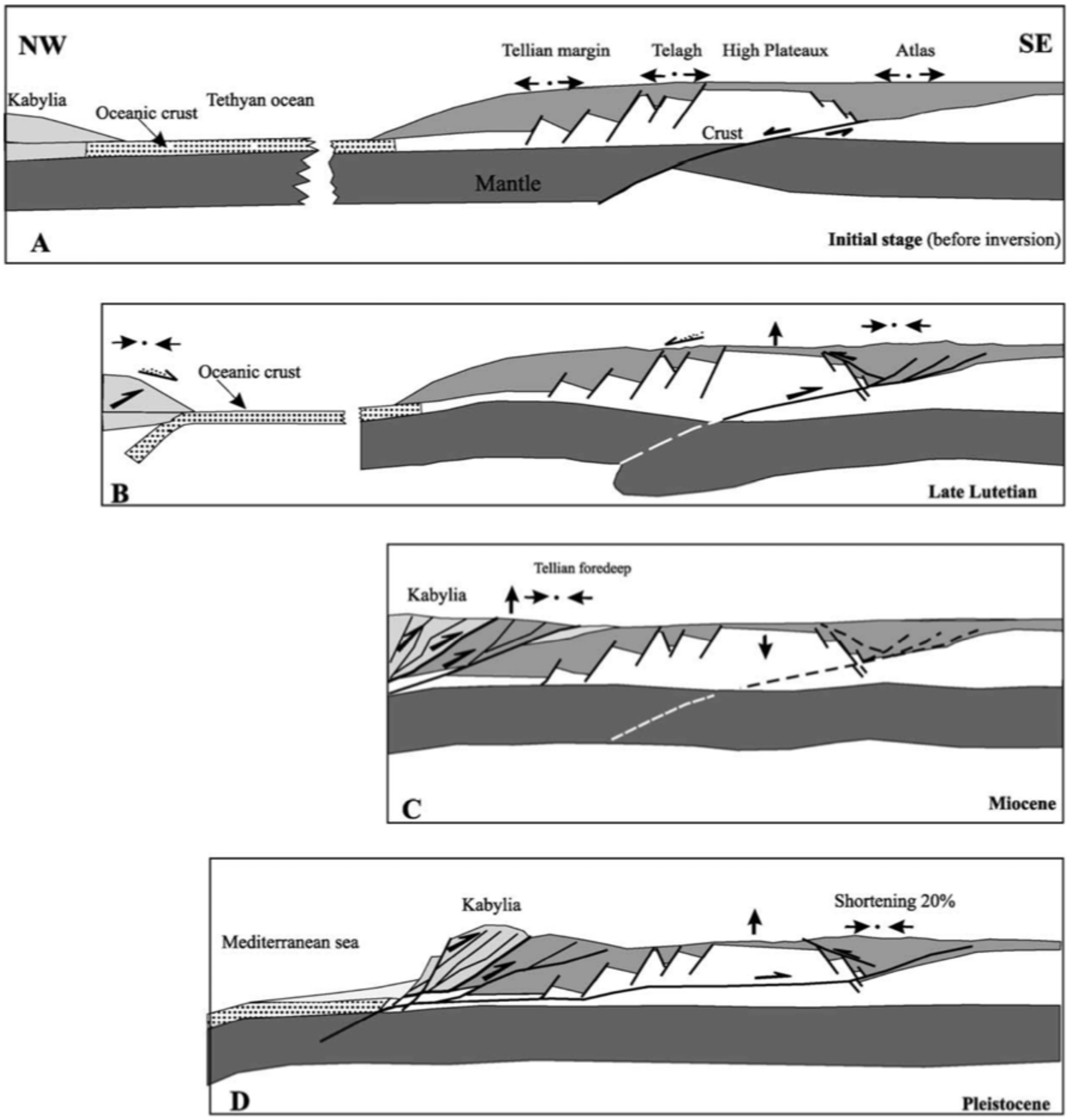



Figure 3-7 Conceptual Model of the Three Stages of the Inversion of the Tellian Margin and Atlas Range on a NW-SE Section, (Bracène and Frizon de Lamotte, 2002)

Inversion and closure of the Yethys ocean is described by Bracène and Frizon de Lamotte (2002) as a three-staged scenario:

- Tethysian ocean, which separates the northern Kabylian bloc from the southern tellian passive margin (Figure 3-7A), starts subducting northward from the Eocene (upper Lutetian). This subduction generates strong coupling between the plates and causes uplift of the tellian margin and inversion of the Atlas basins to the south (Figure 3-7B);
- During Oligo-Miocene, intra-plate coupling decreases and deformation is restricted to the plate boundary and the tellian wedge that forms by accretion of the Kabylian bloc (Figure 3-7C);
- From Upper Miocene, the subduction is locked and coupling again increases. It causes uplift of the Tell and Atlas ranges (Figure 3-7D) as well as distributed seismic activity.

As a result of this tectonic history, the Tell range is 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.

(2) Neogene and Quaternary Evolutions of Strain Regimes

Six strain regimes have been identified affecting the Tell range during Neogene and Quaternary periods. These strain regimes, along with structures they have generated, are summarized in Table 3-2 below.

Table 3-2 Evolution and Chronology of Strain Regimes in the Tellian Range during Post-Nappes Neogene and Quaternary Periods (Meghraoui, 1982)

| Périodes | Ma | Régime de Déformation | Failles | Plis |
|---|---|---|---|---|
| **Quaternaire** | | Compression Z2=N 161  | Décrochements Sénestres N-S à NNW-SSE Dextres Failles inverses SénestresNE-SW | pli déjeté pli-faille NE-SW à ENE-WSW |
| | 1.5 | Episode compressif N_S | ———— | Est-Ouest |
| **Pliocène supérieur** | | Compression Z1=N022  | ------------------ Décrochement Sénestre NE-SW dextre N-S | ------------- N 110 |
| **Pliocène Inférieur** | 3 | Episode distensif ? ? | Failles normales Syn-sédimentaires | --------------- |
| **Messinien Tortonien Supérieur** | 5.5 9 | Mouvements compressifs NE-SW Subsidence | ------------ | NW-SE à E-W |
| **Tortonien inférieur Serravalien** | | Phase de Distension NNW-SSE  | Failles normales Conjuguées NE-SW et E-W | |

Since the Miocene nappe tectonics, Algeria suffered several important strain regimes. From upper Burdigalian to lower Langhian, a N-S trending extension resulted in the opening of several basins including the Mitidja basin in the Algiers area. Opening of this basin was coeval with volcanic activity in the Thenia region, along its southern border and to its western termination. This period was marked by a sudden change in strain regime shifting from extensional to compressional along a N-S direction that initially turned to the NW-SE during the Quaternary period (Homas, 1985) and which is now NNW-SSE (Meghraoui, 1982; Philip and Meghraoui, 1983; Anderson and Jackson, 1987). The strain regime affecting the Tell range during the Quaternary period is then a NNW-SSE trending compression that is highly consistent with the stress tensor previously deduced from plate kinematic models.

In the Algiers area, 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, which 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 3-8 shows the distribution of earthquakes around Algiers from 1365 to 1995. For the historical period, the catalogue compiled by CRAAG was used while for the instrumental period the catalogue compiled by Dr. Benouar was applied. The significant points are:

- Several events extend along the entire length of the Sahel Fault, which bounds the Mitidja basin to the north;
- A cluster of events is located on the western part of the Blida Fault, which bounds the Mitidja basin to the south;
- Several events are distributed offshore, with a small cluster north-east of Mount Chenoua (Chenoua Fault).

These observations suggest that the faults bounding the Mitidja basin (Sahel and Blida Faults), as well as possible offshore structures, are active within the present-day stress pattern.

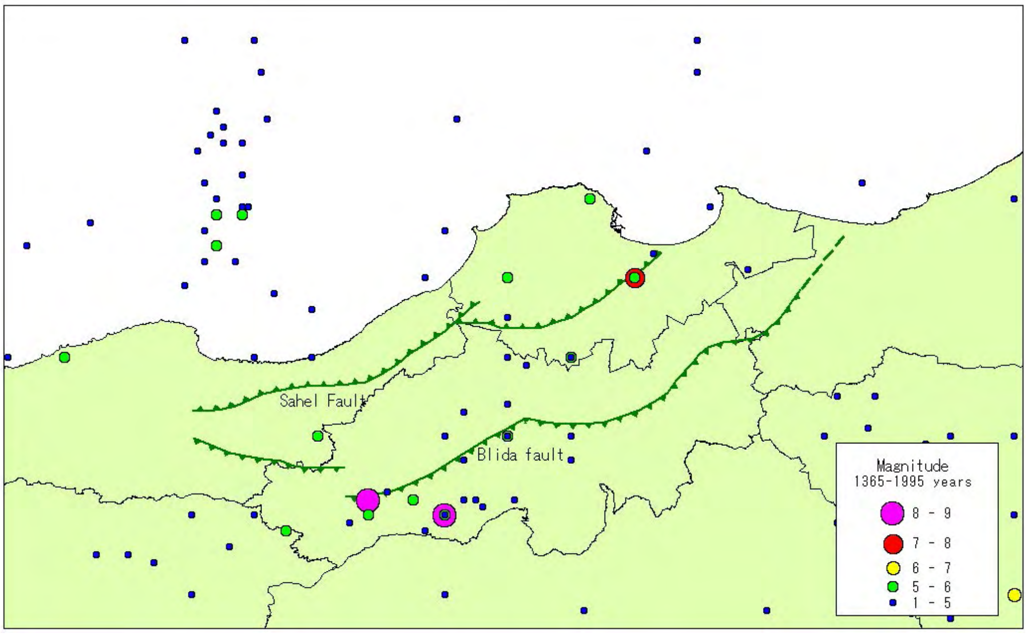



Figure 3-8 Distribution of Historical and Instrumental Seismicity in the Algiers Area

### 3-1-4 Historical Earthquakes in Northern Algeria

The Algiers area has been subject to several severe earthquakes throughout its history. The oldest recorded event is the 1365 Algiers earthquake that destroyed the entire city and triggered a tsunami. The last recorded event is 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 are 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 3-9 and Table 3-3). In addition, one should keep in mind that even stronger earthquakes affected northern Algeria, for example El Asnam (10/10/1980, Ms=7.2).

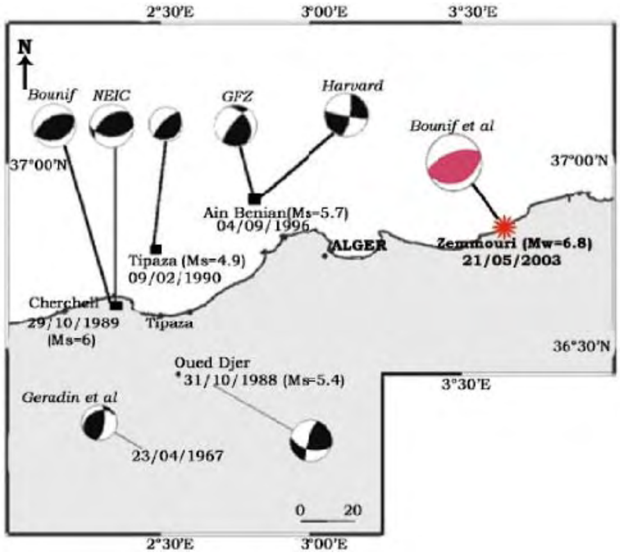



Figure 3-9 Recent Significant Earthquakes in the Algiers Area (Saadi, 2005)

Table 3-3 Major Historical and Instrumental Earthquakes Recorded in Northern Algeria (Saadi, 2005)

| Date | Location | Magnitude (Ms) | Intensity (Io) |
|---|---|---|---|
| 02/01/1365 | Algiers | | X |
| 03/02/1716 | Algiers | | IX |
| 02/03/1825 | Blida | | IX |
| 23/09/1903 | Blida | 5.6 | |
| 10/10/1980 | El asnum | 7.2 | X |
| 31/10/1988 | Oued Djer | 5.6 | V |
| 29/10/1989 | Mont Chenoua | 6.0 | VIII |
| 18/08/1994 | Mascara | 5.8 | |
| 04/09/1996 | Ain Benian | 5.3 | |
| 22/12/1999 | Ain Timouchent | 5.4 | |
| 10/11/2000 | Beni Ourtilene | 5.7 | |
| 21/05/2003 | Zemmouri | 6.8 | X |

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## 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 (Figure 3-10):

- Mitidja Plain: Eastern part of the study area, which has developed as a plain.
- Bouzareah Hill: Western part of the study area, which is hilly.
- Marine Terrace: The marine terrace, which has developed along the coastline.


Figure 3-10 Topographic Map (from Encarta)

(1) Mitidja Plain

This plain has extensive, very recent formations, and has formed due to major quaternary filling of a vast synclinal structure. With a WSW/ENE orientation, the plain of Mitidja narrows as a result of the syncline. Its longitudinal extension exceeds 120 km and it has a maximum width of 20 km. The plain is slightly tilted in a northerly direction; Blida is located at the foot of the Atlas Mountains, which have an altitude of around 260 m, except for Mount Mitidjiens which is around 1,600 m. The total surface area of the plain is 130,000 ha.

(2) Bouzareah Hill

In the western part of the study area, the metamorphic solid mass of Bouzareah has developed, reaching an altitude of 407 m. It has an anticline axis in a SE-NW direction. This solid mass, which is in the shape of a tortoise, reduces from east to west. Its contact with the sea is generally very complexed and slopes are singularly accentuated.

(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. The western Sahel is much more developed in the east than in the west, with a series of increasingly low hills extending towards the west.

Figure 3-11 shows the elevations of the study area. This indicates that the elevations in the northern parts, such as BOUZAREAH, exceed 500 m. In the west and east of the Mitidja Plain there are lowlands where the altitude is generally less than 30 m. In the western area, the marine terrace is distinct.

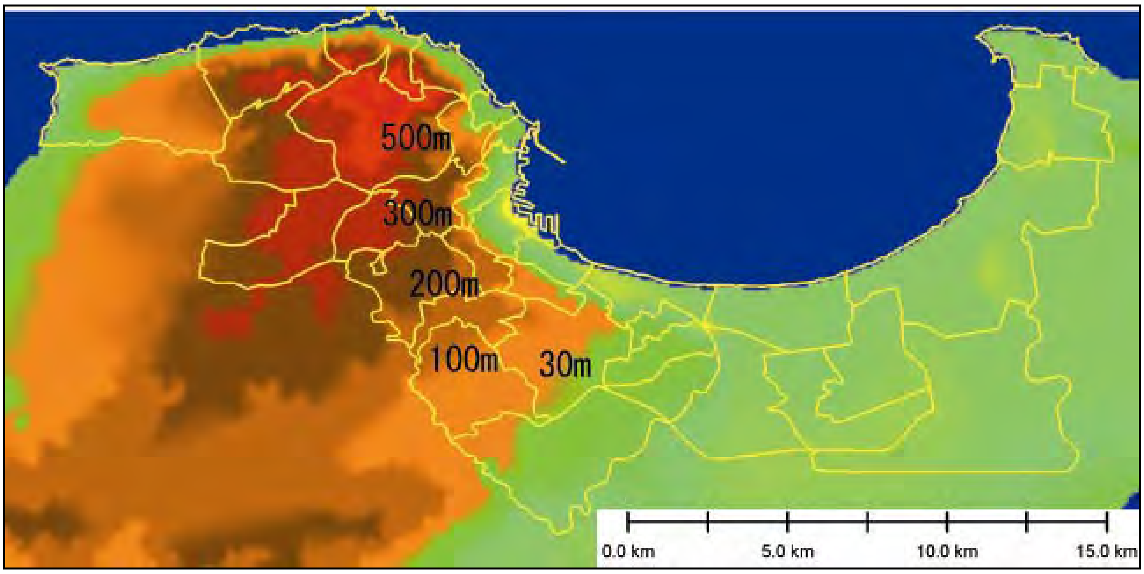


Figure 3-11 Topography of the Study Area

The River Harrach is located in the centre of the study area. This flows from south to north. The River Smar branches off from the River Harrach at EL HARRACH. The River El. Hamiz flows from south to north at the airport and bends at the BORDJ EL KIFFAN before flowing in a westerly direction. Most rivers flow during the rainy season but in the dry season gullies form as a result of erosion (see Figure 3-12).

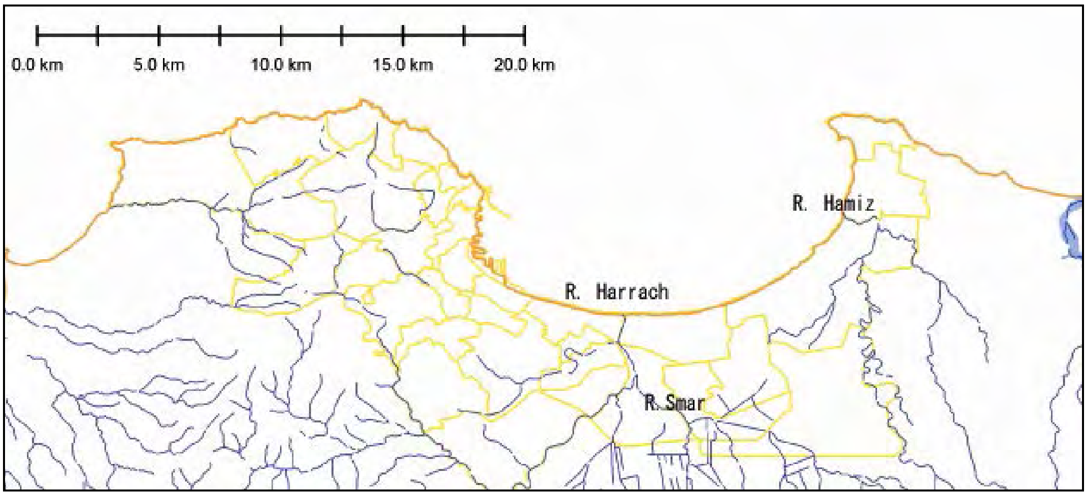


Figure 3-12 Distribution of Rivers in the Study Area

### 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. Beyond the mountain chain south of the coast, the climate is referred to as "Continental Clime", where summer temperatures differ quite considerably from those in winter.

The Sahara Desert is in the southern region and covers about 85% of the country. The temperature can rise to around 49 °C, and the sand from the dunes may at times reach Europe as a result of the hot wind (Sirocco) that blows toward the Mediterranean Sea. Moreover, it is extremely hot in the day but extremely cold at night in locations such as Ahagal.

The temperatures at Algiers University from 1913 - 1937 are presented in Figure 3-13, while the precipitation at Algiers along the River Harrach is shown in Table 3-4 and Figure 3-14. These data were provided by ANRH.

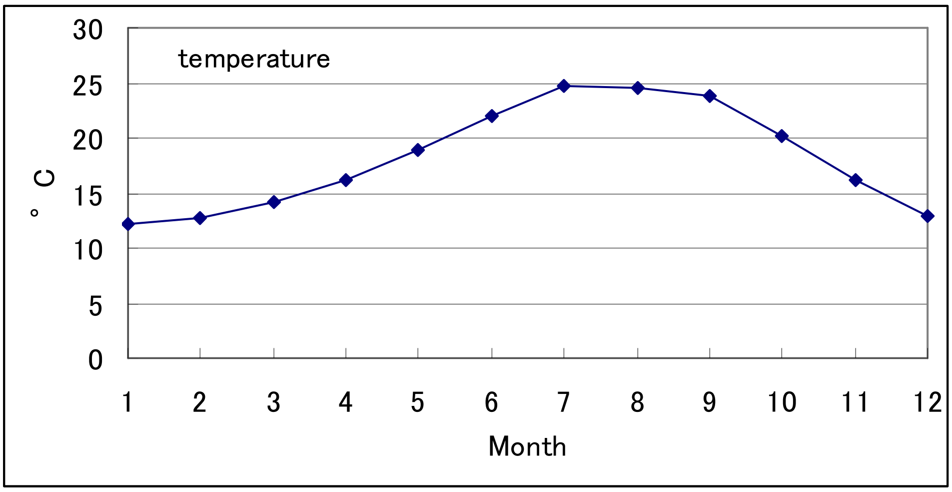


Figure 3-13 Average Monthly Temperature in Algiers (1913 – 1937)

Table 3-4 Precipitation in Algiers (Station Code: 020607) Provided by ANRH

| | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1999 - 2000 | - | 30.7 | 158.7 | 208 | 9.7 | 2.3 | 19 | 35.4 | 30.7 | 0.3 | 0 | 0 |
| 2000 - 2001 | 8.5 | 39.9 | 69 | 51 | 157.9 | 117.2 | 0 | 51.5 | 16.7 | 0 | 0 | 7.7 |
| 2001 - 2002 | 14.8 | 0 | 56.9 | 67.3 | 60.3 | - | - | 66.4 | 0 | 0 | 0 | 0 |
| 2002 - 2003 | - | - | - | - | - | - | - | 94.6 | 24.9 | 1.5 | 0 | 0 |
| 2003 - 2004 | 42.8 | 39.7 | 38.4 | 118.7 | 130.6 | 49.5 | 70 | 59.8 | 168.9 | 0 | 27.3 | 0 |
| 2004 - 2005 | 6.3 | 45.7 | 108.4 | 192.1 | 102 | 108 | 63 | 38.1 | | | | |

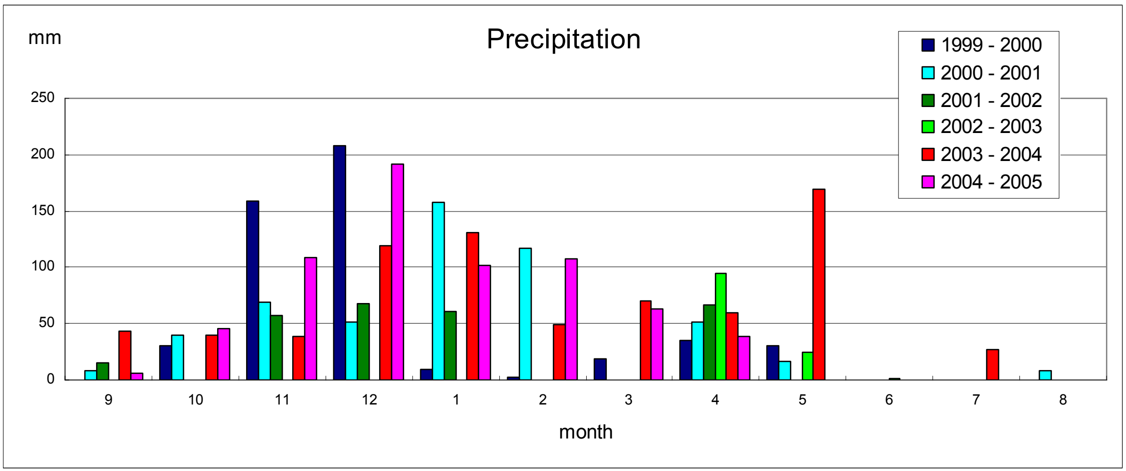


Figure 3-14 Precipitation in Algiers (Station Code: 020607) Provided by ANRH

(2) Groundwater Level

The Mitidja Plain is situated in the north of Algeria. The eastern part lies adjacent to the sea in the north and it is limited by the Atlas Mountains in the south.

The region of the Mitidia Plain has two main aquifers separated in places by the El-Harrach substratum, which extends over the whole area. The deepest aquifer is an Astian Formation. The second aquifer, which is the most important, is the Mitidja Formation (Tyrrhenian) and it is alluvial coastal and unconfined. The prevailing horizontal intergranular flow of the Mitidja aquifer is characterized by heterogeneity in the vertical direction. Locally, salt water occurs at a depth of a few meters.

Table 3-5 and Figure 3-15 show the groundwater levels observed during this project and existing records by LNHC and ANRH. As shown in this figure, the water level is comparatively similar to the topography.

Table 3-5 Observed Groundwater Level

| Borehole No. | Water table Altitude (m) | Borehole No. | Water table Altitude (m) | Borehole No. | Water table Altitude (m) |
|---|---|---|---|---|---|
| No.1 | -3.5 | No.33 | 93.6 | AH-6 | 85 |
| No.2 | 8.5 | No.34 | 0 | AH-8 | 8.4 |
| No.3 | 104.6 | No.35 | 14 | AH-9 | 5 |
| No.4 | 296 | No.36 | -12 | AH-11 | 11 |
| No.6 | 180 | No.38 | -18 | AH-12 | 11.9 |
| No.8 | 11.8 | No.39 | 8 | AH-15 | 6.9 |
| No.9 | -2 | No.40 | -1.1 | AH-23 | 14 |
| No.10 | 0 | No.41 | 22 | AH-24 | 12.13 |
| No.12 | 155.6 | No.42 | -11 | AH-25 | 58 |
| No.13 | 299.8 | No.43 | -10 | AH-35 | 42.6 |
| No.15 | 251 | No.44 | -6 | AH-44 | 16.01 |
| No.16 | 226 | No.45 | 13 | AH-47 | 75 |
| No.18 | 140 | No.46 | -3 | AH-51 | 39.5 |
| No.20 | 76.27 | No.47 | 1.5 | AH-52 | 37.7 |
| No.21 | 0 | No.48 | 4.4 | AH-57 | 9.3 |
| No.22 | -0.2 | No.49 | -0.12 | AH-58 | 15.02 |
| No.23 | 8.9 | C-2 | 251 | AH-60 | 15.35 |
| No.25 | 66 | H-3 | 85 | AH-61 | 9.9 |
| No.26 | 84.5 | J-4 | 278.5 | AH-66 | 21 |
| No.27 | 25 | M-2 | 22 | AH-67 | 19.3 |
| No.28 | 14 | Z-1 | 32 | AH-70 | 45.49 |
| No.29 | 0 | Zb-1 | 14 | AH-71 | 33 |
| No.30 | 10 | AH-3 | 22 | | |
| No.32 | 23 | AH-5 | 173 | | |

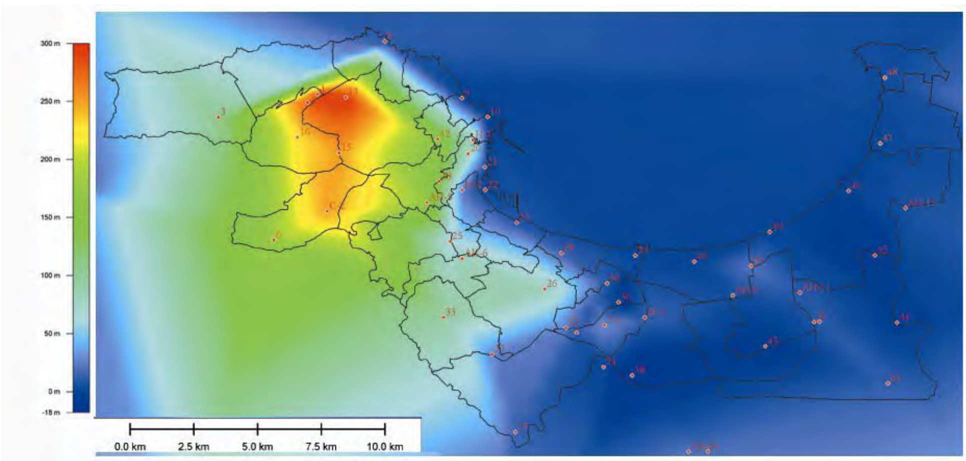


Figure 3-15 Map of Groundwater Elevations

(3) Seasonal Variations in River Discharge and Groundwater Depth

Figure 3-16 shows the seasonal variation in river discharge with precipitation for 1996-1997. In the same figure, the variation of seasonal groundwater depth is also depicted, these data being provided by CGS.

1) Seasonal Variations in River Discharge

The peak precipitation in Algiers is between November and January while peak river discharge is between February and April. The time lag between peak precipitation and peak river discharge suggests that the water emanates from some distances, such as from the mountain chains. The river discharge can, however, also be influenced by local peak rainfalls, such as in April and August.

2) Seasonal Variation in Groundwater Depth

The seasonal trend of precipitation in Algiers is difficult to read in Figure 3-16. The seasonal variation in groundwater depth is also difficult to assess without precise precipitation data. Roughly speaking, the groundwater depths are high between November and January. This trend may reflect the seasonal change of shallow groundwater, which has been influenced by precipitation.

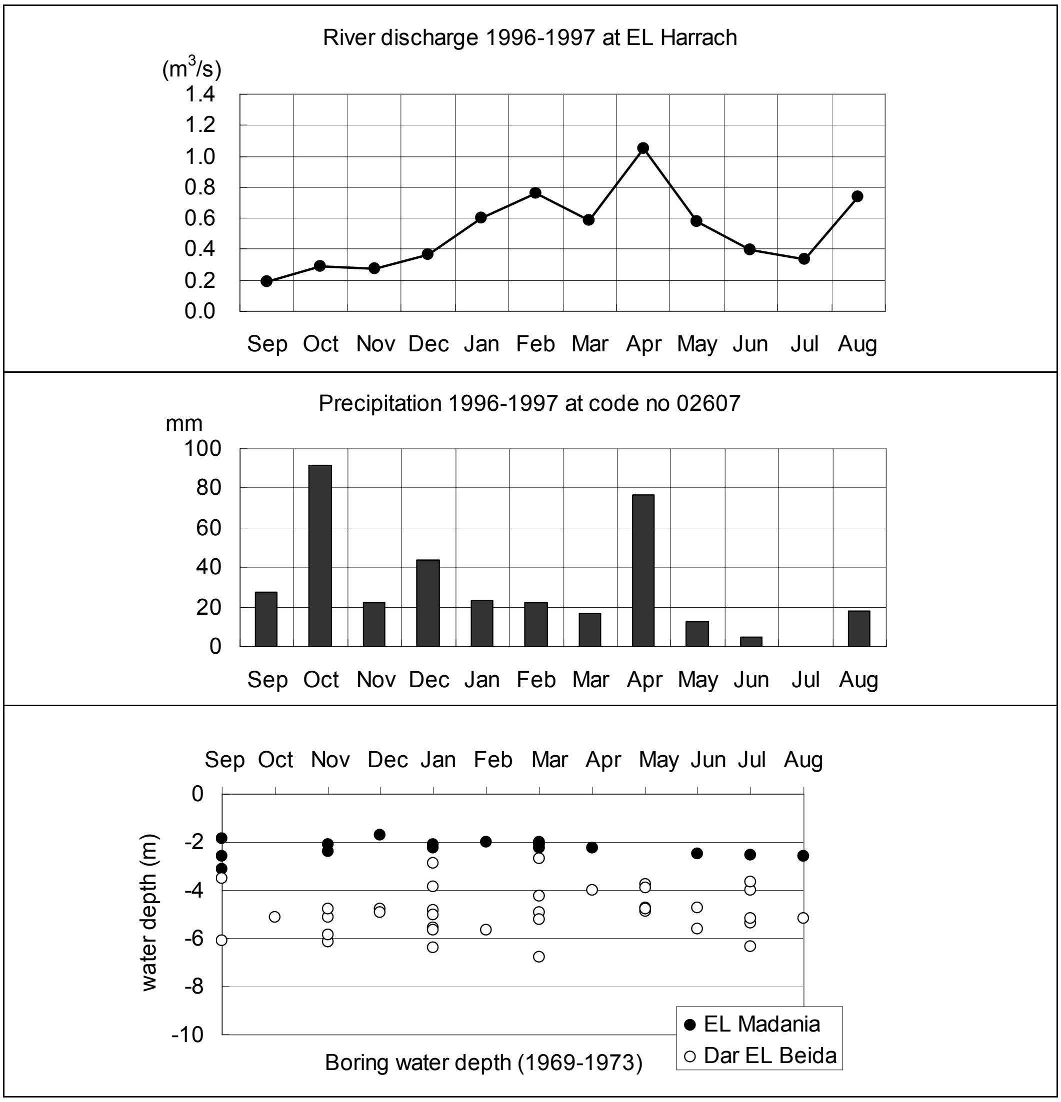


Figure 3-16 Seasonal Variation (River Discharge, Precipitation, Groundwater Depth)

### 3-2-3 Principal Geological Structure

Diagrammatically, the geological structure of the Maghrebide chain forms a littoral chain approximately 2,000 km in length and 150 km wide (Durand-Delga,1971; Durand-Delga and Fonboté, 1980, Figure 3-17). In this chain, two major structural fields, formed from the north to the south, are recognised:

- Internal zones
- External zones

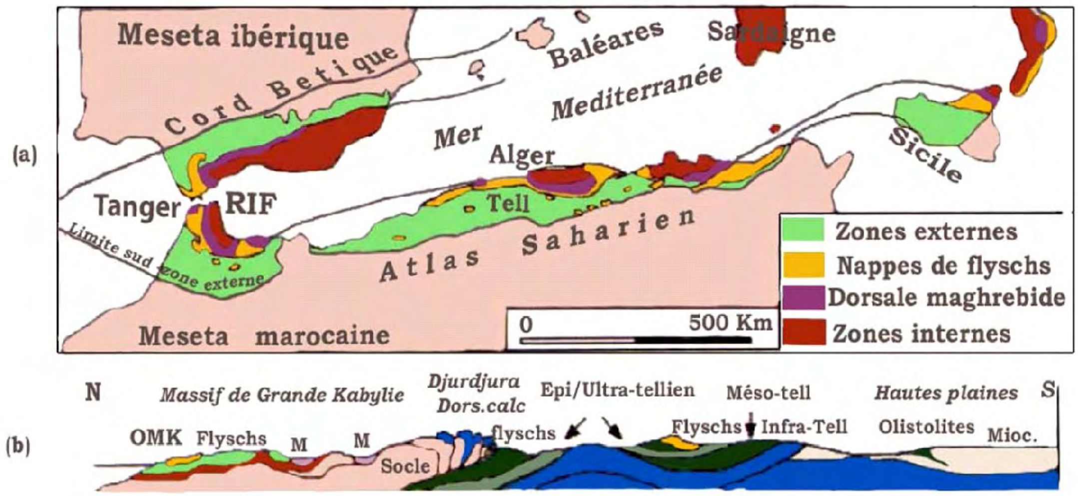


Figure 3-17 Diagrammatic Map (a) Diagrammatic Structural Map of the Maghrebide Chain, showing the layout of the internal and the external zones, (b) A Simplified Section looking East (Durand-Delga and Fonboté, 1980)

(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. The units of the internal zones overlap towards the southern side of the Flysch units, which are comprised of Cretaceous and Palaeocene deposits.

(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.

According to Vesnine (1971), from the base to the surface these deposits comprise the following:

- Fossil rich, yellowish limestone reaching a general thickness of 60 m, and 300 m locally;
- Clayey marls, reaching a thickness of 30 m to 50 m;
- Reddish conglomerates to pebbles, interleaved with sandstone, reaching an approximate thickness of 200 m.

(B) The Serravallian (Middle Miocene)

The Serravallian deposits appear on the surface of Thenia region with thicknesses reaching 1,000 m, decreasing to 50 m near Algiers (Glangeaud, et al 1932).

Vesnine (1971) subdivides these deposits into three units:

- Early Serravallian deposit, which is a volcanic-sedimentary set resting directly on the base. It comprises mica rich sandstone, marls and conglomerates.
- Middle Serravallian deposit, which comprises marls and bluish grey clays, sometimes yellowish, and reaches an approximate thickness of 250 m.
- Late Serravallian deposit, which comprises two sub-units: a) basaltic and andesitic tuffs associated with marls and sandstone reaching a thickness of approximately 350 m, b) basaltic and andesitic lava in an unconformity with the previous layer.

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 3-18).

(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 covered 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 rich in bivalves, molasses, sandstone and sand (Glangeaud et al 1952) (Figure 3-18).

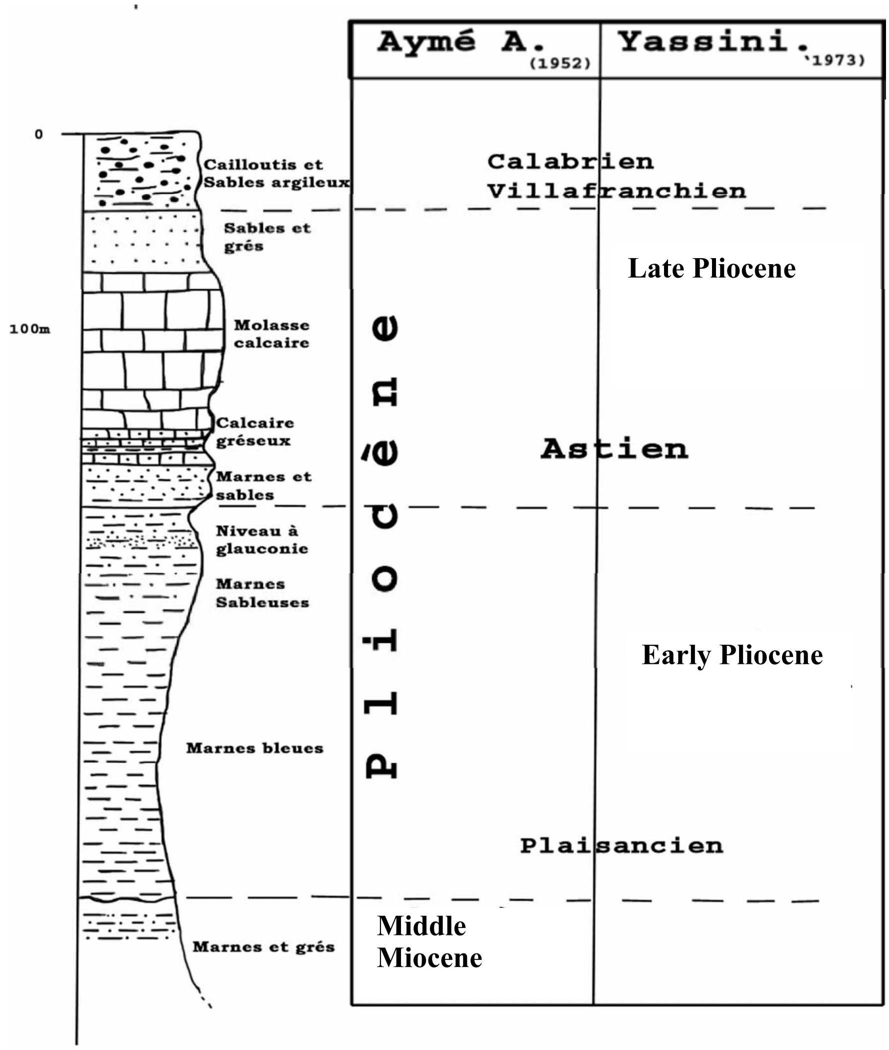


Figure 3-18 Pliocene Stratigraphy of Algiers Region (Djediat, 1996)

3) Quaternary

The Quaternary Formations cover a large area in 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 (Table 3-6).

To the east of Algiers, the terraces are characterised by milky quartz pebbles in reddish sand, with lenses of pebbles of limestone or beach sandstone.

To the west of Algiers, the terraces are characterised, from bottom to top, by limestone pebbles, beach sandstone, and deposits, which are more or less solidified.

The Quaternary marine terraces are found at higher altitudes, 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. Early Pleistocene is represented by red clay, while the Holocene is represented by dunes of beach sand. Figure 3-19 shows a geological map of the Study area.

Table 3-6 Geological Chronology of the Mediterranean; Neocene and Quaternary (Maouche, 2000). : The numbers in this table are geological age in Ma.

| | | | |
|---|---|---|---|
| Holocene<br>- 0.01 | | Versilian | |
| Pleistocene<br>0.01 -1.8 | Early<br>0.01 - 0.12<br>Middle<br>0.12 - 0.7<br>Late<br>0.7 - 1.8 | Tyrrhenian<br>Sicilian<br>Calabrian | Villafranchian age<br>(Middle and Late) |
| Neocene<br>1.8 - 24.6 | Pliocene<br>1.8 - 5.1 | Late | Villafranchian age (Early)<br>Astien<br>Plaisancian |
| | | Early | Zanclian age and Redonian<br>(not described in Algeria) |
| | Miocene<br>5.1 - 24.6 | Late<br>5.1 - 11.3 | Messinian age |
| | | | Tortonian age |
| | | Middle<br>11.3 - 14.4 | Serravallian age |
| | | | Langhian age |
| | | Early<br>14.4 - 24.6 | Burdigalian age |
| | | | Aquitanian age |

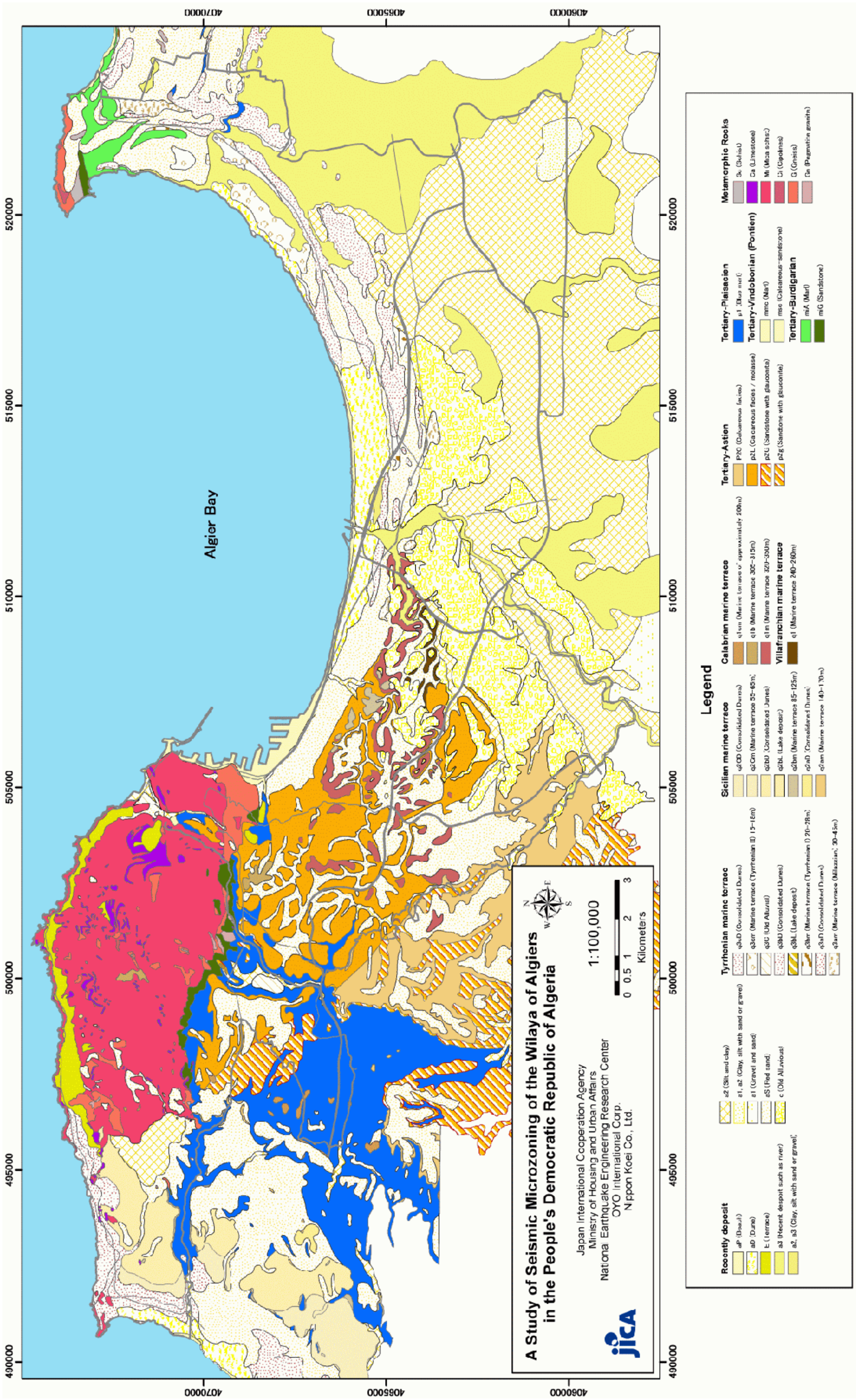


Figure 3-19 Geological Map of the Study Area