

3-3 Supplemental Investigation

3-3-1 Boring

To assess the engineering geological structure, 50 new boreholes were drilled during the Study. The supplemental existing borehole data was also collected. The locations of the new and existing boreholes are shown in Figure 3-20. Existing borehole data were provided by LNHC (Laboratoire National de l'Habitat et la Construction) and ANRH (Agence Nationale des Ressources Hydriques). The number of boreholes that was used in the analysis is 179 in total, and a summary of the data is shown in Table 3-7.

For each boring point, the depth of the Astian layer and the depth of engineering bedrock are decided from geological, geotechnical and geophysical data. As for the engineering bedrock, two layers are used; one is the Plaisancian Marl layer and the other is the Metamorphic Schist layer.

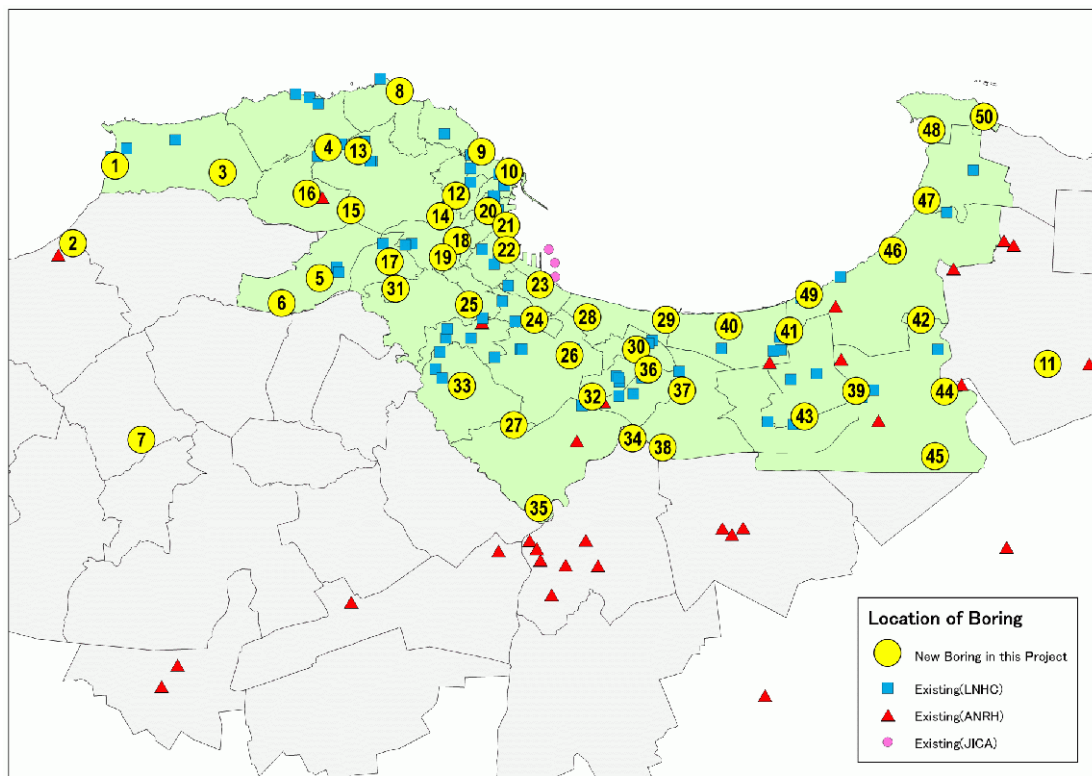


Figure 3-20 Boring Locations

Table 3-7 Boring Data (cont.)

No	Location		drilling deth (m)	Borehole Name	Data source	Water level (Altitude (m))	Engineering geology	
	X	Y	Altitude (m)				Calcareous sand stone	bed rock altitude (m)
101	509729	4063422	47	12	T-2			
102	510808	4064832	37	15	T-3			
103	503340	4065019	175	12	U-3			
104	503132	4064318	101	12	V-1			
105	503380	4065363	190	12	V-2			
106	504251	4065016	167.5	10	V-3			
107	502939	4063881	145	12	W-1			
108	503118	4064506	155	10	W-2			
109	503193	4063552	137	12	W-3			
110	503347	4062536	62	9	X-2			
111	509705	4062891	57.1	10	Y-1			
112	509703	4063556	35	14	Y-2			
113	510252	4062966	36	12	Z-1			
114	510572	4063571	59	11	Z-2			
115	511932	4063794	9.6	13	Za-1			
116	513494	4064643	24.3	9	Za-2			
117	511825	4063268	17	9	Zb-1			
118	516152	4061852	12.6	12	Zb-2			
119	515198	4061949	16.3	10	Zb-3			
120	515639	4065052	31.3	15	Zc-1			
121	515675	4064592	24	14	Zc-2			
122	515418	4064555	25	20	Zc-3			
123	506137	4064608	128	8	Zd-1			
124	516055	4063494	19.6	20	Zd-2			
125	517000	4063720	11.5	15	Zd-3			
126	519100	4063110	16	11	Ze-1			
127	518880	4062850	16	15	Ze-2			
128	521470	4064600	18	18	Ze-4			
129	517880	4067280	4	13	Zf-2			
130	521800	4068650	9	15	Zf-3			
131	522775	4071213	25	15	Zg-1			
133	516415	4066500	7	9	Zh-1			
134	507123	4068292	-14.5	18	Port-1			
135	507348	4067791	-14.4	19.5	Port-2			
136	507360	4067287	-7.8	24	Port-3			
137	489049	4068091	32	18	AH-3			
138	498776.5	4070220	265	87	AH-4			
139	503276.6	4067793	213	54	AH-5			
140	504666.9	4065592	105	74.6	AH-6			
141	508166.7	4061237	30	68	AH-7			
142	509150.1	4062681	50	34.1	AH-8			
143	515270.7	4064133	31	64	AH-9			
144	517699.2	4066196	12	100	AH-10			
145	517907	4064248	14	65	AH-11			
146	518666.8	4063107	14.5	81	AH-12			
147	519281.9	4061972	19	214	AH-13			
148	519553.2	4068235	2	156	AH-14			
149	522047.6	4067578	12	82	AH-15			
150	522343.9	4063309	21	243.25	AH-16			

No	Location		drilling deth (m)	Borehole Name	Data source	Water level (Altitude (m))	Engineering geology	
	X	Y	Altitude (m)				Calcareous sand stone	bed rock altitude (m)
151	523908.4	4068610	12	64.3	AH-17			-25.6
152	524257.3	4068449	12.25	43.5	AH-18			-
153	527052.4	4064066	28	309.9	AH-19			-11.8
154	527908	4059071	55.5	96	AH-20			-34.5
155	528457.6	4059218	36	84	AH-21			-16
156	529528.5	4065430	21	62.9	AH-22			-
157	528925.8	4064433	27	74.6	AH-23			-
158	530482.9	4067049	19	48	AH-24			-
159	533061.4	4069037	62	16	AH-25			-
160	472381.4	4044841	43	163	AH-35			-
161	486175.9	4053473	15.01	120	AH-44			-
162	487823.9	4044463	90	150	AH-47			-
163	492852.6	4052165	40	118	AH-51			-
164	493442.3	4052950	38	105	AH-52			-
165	498839.6	4055275	58	209	AH-53			-142
166	505272.2	4057153	27.5	98	AH-54			-
167	506423.7	4057544	21.95	101.6	AH-55			-
168	506685.3	4057248	22	150	AH-56			-
169	508813.6	4056818	18	150	AH-57			-
170	508939.5	4056612	24	144.5	AH-58			-
171	508493.5	4057557	18	149.1	AH-59			-
172	507746.5	4056636	24	150	AH-60			-
173	507228.5	4055349	19	150	AH-61			-
174	513526.9	4057993	22	136.2	AH-66			-
175	514295.8	4058011	20	120.3	AH-67			-
176	513875.5	4057763	20	120	AH-68			-
177	515102.8	4051828	50	72	AH-69			-
178	519798.4	4052760	68	80	AH-70			-
179	524007.7	4057287	41	62	AH-71			-

HC: High ratio of calcareous sandstone
 MC: Medium ratio of calcareous sandstone
 LC: Low ratio of calcareous sandstone
 M: Blue marl
 S: Metamorphic rocks and Miocene rocks
 -: not find

Based on the boring data and technical papers, the geological strata were classified from an engineering geology viewpoint as shown in Table 3-8. The engineering properties of the materials, which were investigated by laboratory tests and geophysical investigations, were studied and compiled based on this classification.

Table 3-8 Engineering Classification of Geological Units

Symbol	Explanation
ap	Beach deposit and dune deposit
e	Slope deposit
a3	Quaternary deposit (sand)
a2	Quaternary deposit (clay)
q	Old Quaternary 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.

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

The results are shown in Table 3-9.

The existing laboratory test results are collected from study reports of LNHC and compiled in Table 3-10. The corrected geotechnical parameters that were compiled include all of the above and additionally, C (cohesion) and ϕ (friction angle).

Table 3-9 Summary of Laboratory Tests Conducted in the Study

No.	Boring No.	Specimen name	from	to	Engineering geology	DENSITE HUMIDE				MITES D'ATTERBER		Analyse Granulo,etrique		
						DENSITE HUMIDE /Wet density (g/cm3)	TENEUR EN EAU/Water content	Sr(%)	LL	LP	D50	FC (%)		
1	No.1	1-1	0.7	0.9	ap	1.99	2.00							
2		1-2	9.00	9.30	pl2-a	1.97	1.99							
3		1-3	13.00	13.45	pl2-a	2.07	2.06							
4		1-4	17.40	17.75	pl2-a	1.93	1.91							
5		1-5	23.30	23.60	pl2-a	1.81	1.85							
6		1-6	26.20	26.50	p1-f	2.13	2.11	19.28	19.28	100	34	22	0.0016	99.52
7		1-7	30.10	30.30	p1-f	2.22	2.2	15.39	15.05	100	52	23	0.0012	99.6
8		1-8	30.50	30.65	p1-f	2.15	2.14	15.42	15.78	88	59	34	0.001	99.64
9		1-9	33.20	33.50	p1-f	2.17	2.16							
10		1-10	40.40	40.70	p1-f	2.11	2.11							
11		1-11	44.20	44.50	p1-f	2.19	2.18							
12		1-14	49.40	49.45	p1-f	2.14	2.16	15.42	15.78	88	59	34	0.001	89
13	No.2	2-1	1.00	1.45	ap								0.4	4.4
14		2-2	2.00	2.45	ap								0.4	5
15		2-3	3.00	3.45	ap								1.2	4.4
16		2-4	14.00	14.45	p2a-f								1	6.79
17		2-5	29.10	29.30	p1-f	2.07	2.03	21.24	19.47	93.37	70	33.37	-	100
18	No.3	3-1	7.00	7.60	p2a-f	2.07	2.01	24.42	23.3	100	44	29	0.001	99.2
19		3-2	9.40	9.70	p2a-f	1.94	1.96	30.9	31	100	59	31	0.012	99.7
20		3-3	10.20	10.50	p2a-f	1.96	1.96	28	28.79	90	62	32	0.003	98.52
21		3-4	12.40	13.00	p2a-f	1.95	1.96	29.5	29.86	100	47	28	0.001	98.72
22	No.4	4-1	1.00	1.45	mi								0.7	20
23		4-2	2.00	2.45	mi								0.38	22
24		4-3	3.00	3.45	mi								0.25	33
25		4-4	7.00	7.45	mi-f								0.65	10
26		4-5	8.00	8.45	mi-f								0.4	16
27		4-6	21.00	21.45	mi-f								0.5	30
28		4-7	22.00	22.45	mi-f								0.45	11
29		4-8	26.00	27.00	mi-f								0.21	42
30	No.6	6-1	3.40	3.70	p1	2	2.02	27.06	25.58	100	60	30	0.001	99.2
31		6-2	7.00	8.00	p1	2.07	2.13	15.68	17.3	89	50	27	0.001	99.8
32		6-3	9.00	10.00	p1	2.04	2.05	21.62	13.93	94	54	26	0.001	99.64
33		6-4	16.50	16.80	p1	2.5	2.55	13.04	14.01	100	47	28	0.0025	99.96
34		6-5	18.50	18.65	p1	2.29	2.25	13.93	13.67	100	47	26	0.013	99.8
35		6-6	30.40	30.70	p1	2	2.02	27.06	25.58	100				
36	No.7	7-1	1.00	1.45	p2c						33	19		
37		7-2	1.20	1.40	p2c	2.14	2.17	13.72	13.77	88			0.06	73.24
38		7-4	4.10	4.20	p2a-f	2.03	2.04	23.14	22.18	96	44	20	0.009	95.84
39		7-5	8.50	8.80	p2a-f	2		24.42		94	61	33	0.015	99.48
40		7-6	11.70	11.90	p1	2	2.02	21.45	18.69	89	41	22	0.009	98.32
41		7-7	17.30	17.70	p1-f	2.19	2.18	15.9	15.48	98	36	20	0.003	99.84
42		7-8	24.00	24.30	p1-f	2.19	2.1	16.35	18.27	100	30	21	0.014	99.88
43		7-9	28.00	28.60	p1-f	2.14	2.14	18.76	19	100	47	20	0.025	99.4
44	No.8	8-1	7.80	8.00	mi-f	2.48								
45		8-2	14.40	14.60	mi-f	2.64								
46	No.9	9-1	2.00	2.45	B						32	15.6	0.81	8
47		9-2	4.00	4.45	e						29.5	15	0.28	7
48		9-5	5.00	5.40	e						28.2	16.2	0.2	38
49		9-4	9.00	9.40	mi						39.5	18.2	0.025	98
50	No.10	10-1	1.00	1.45	B								1.8	11
51		10-2	2.00	2.15	B								3.2	7
52		10-3	4.00	4.45	B								9	7
53		10-4	10.00	10.80	ap	1.94	1.935	24.58	26.41					
54		10-5	11.00	11.45										
55	No.11	11-1	unknown Ech1										0.005	83.3
56		11-2	1.00	1.45	B								0.05	16.52
57		11-3	2.00	2.45	B								2	13
58		11-4	3.00	3.45	B								5	6.52
59		11-5	5.00	5.40	B								0.006	100
60		11-6	6.00	6.45	a2								0.055	60
61		11-7	10.00	10.45	B								4.5	6.5
62		11-9	15.00	15.45	B								1.75	4.4
63		11-10	16.00	16.45	B								2.6	2.2
64		11-11	17.00	17.45	p2a-f								2.5	1.01
65		11-12	17.40	17.60	p2a-f	1.97	1.94	33.12	31.78	100	60	30.93	-	98.4
66		11-13	21.00	21.50	p2a-f	1.87	1.9	33.94	32.97	98.56	75	38.22	-	93.6
67		11-14	22.00	22.45	p2a-f						36	17.49	1.1	64.4
68		11-15	26.00	26.45	p2a-f								0.28	20
69		11-16	27.00	27.50	p2a-f								0.22	32.67
70		11-17	unknown Ech2										2.8	22.22
71		11-18	unknown Ech3										0.03	87
72	No.13	13-1	1.00	1.45	B								1.4	11.5
73		13-2	2.00	2.45	B								1.8	13
74		13-3	2.70	2.90	B	2	1.94	19.74	20.8	84.53			0.06	58.4
75	No.14	14-1	1.00	1.45	B								2	22.8
76		14-2	2.00	2.45	B								2	22
77		14-3	3.00	3.45	mi									

Table 3-9 Summary of Laboratory Tests Conducted in the Study (cont.)

No.	Boring No.	Specimen name	from	to	Engineering geology	DENSITE HUMIDE				MITES D'ATTERBER		Analyse Granulo,etrique		
						DENSITE HUMIDE ./Wet density (g/cm3)	TENEUR EN EAU/Water content		Sr(%)	LL	LP	D50	FC (%)	
78	No.15	15-1	1.00	1.45	B							0.06	66.61	
79		15-2	4.00	4.45	p2a-f							0.65	7.45	
80		15-3	10.20	10.80	p2a-f	1.94	1.935	24.58	26.41	65	32.41	-	99.13	
81		15-4	28.20	28.60	p2a-f	1.9	1.9	27.36	28.48	63	32.5	-	98.33	
82		15-5	29.00	29.50	P1-f									
83	No.16	16-1	1.00	1.45	B					50.5	23.3	0.0018	96	
84		16-2	1.70	1.80	P1					52.5	23.5	0.0014	98	
85		16-3	5.50	5.80	P1	2.01	2.04	25.6	29.8	100	52.5	24.4	0.003	98
86		16-4	12.30	12.80	P1	2.01	2.04	25.6	29.8	100	51.5	23.6	0.001	98
87		16-5	14.60	14.80	P1	1.82	1.84	21.1	19.7	71	48.5	22.6	0.001	98
88		16-6	20.60	20.80	P1	1.97	2.02	14.5	25.2	99	44.5	20.4	0.001	99
89		16-7	22.30	22.70	P1	1.97	2	28.5	27	100	42	19.3	0.001	98
90	N017	17-1	1.00	1.45	p2l								1.818	11.5
91		17-2	2.00	2.45	p2l								2.415	13
92		17-3	2.70	2.90	p2l								0.122	58.4
93		17-4	20.00	20.45	p2l-f	2.14	2.15	18.16	17.5	99	57	31.2	0.001	98.56
94		17-5	21.00	21.20	p2l-f	2.19	2.17	13.83	14.33	93	48	24	0.002	99
95		17-6	23.20	23.70	P1-f	2.26	2.26	8.6	9.25	81	41	22	0.008	99.12
96		17-7	28.00	28.40	P1-f								0.0025	99.84
97		17-8	28.80	29.00	P1-f	2.15	2.19	13.46	13.95	89	57	27	0.003	99.7
98	No.18	18-1	1.00	1.45	B								1.5	23
99		18-2	2.00	2.45	B								0.35	31
100		18-3	3.00	3.45	a2								0.015	63
101		18-4	3.50	3.80	a2	1.89	1.89	31.8	33.2	97			0.003	98
102		18-5	6.00	7.00	a2	1.89	1.89	33.2	32.7	98			0.0021	95
103		18-6	11.00	11.45	p2a-f								0.88	3
104		18-7	12.20	12.50	p2a-f	2.07	2.08	22.1	22.6	100			0.0025	98
105		18-8	17.10	17.50	p2a-f	2.04	2.07	19.9	20.6	94			0.005	98
106	No.19	19-1	1.00	1.45	B	2.01		4		27				
107		19-2	4.00	4.45	B	2.01		2.45		17				
108		19-3	6.00	6.45	ap	2.02		5.89						
109		19-4	10.00	11.00	p2a-f	1.92		0.2		1				
110	No.21	21-1	3	3.45	B	1.98	1.99						3.6	2.67
111		21-2	7	7.45	B								3.8	2.5
112		21-3	16.40	16.60	p2a-f	2.09	1.98							
113		21-4	20.60	21.00	p2a-f	2.06	2.05						0.005	90.93
114		21-5	26.60	27.00	p2a-f	1.96	1.95						0.018	87.45
115		21-6	27	27.45	p1-f								0.02	87.5
116		21-7	29.50	29.80	p1-f	1.97	1.94						0.019	91.5
117		21-8	35.70	39.00	p1-f	2.01	2.04							
118		21-9	40.50	41.00	p1-f	2.09	2.06						0.065	62.39
119		21-10	46.00	46.60	p1-f	2.11	2.11						0.07	52.79
120		21-11	48.20	48.80	p1-f	1.95	1.94						0.05	64.8
121		21-12	49.50	49.90	p1-f	2.05	2.04							
122		21-13	57.20		p1-f	2.01	2.02							
123		21-14	59.40	60.00	p1-f	2.02	2.03						0.008	93.8
124		21-15	63.50	64.00	p1-f	1.99	1.99						0.055	76.07
125	21-16	67.40	68.00	p1-f	1.98	2.00						0.004	89.67	
126	No.22	22-1	1.00	1.45	B								0.8	18.95
127		22-2	2.00	2.45	B								0.35	7.92
128		22-3	4.00	4.45	B								0.38	4.6
129		22-4	5.00	5.45	B								0.16	21.3
130		22-5	6.00	6.45	B								0.14	22.33
131		22-6	7.00	7.45	B								0.18	5.57
132		22-7	10.00	10.45	B								1.5	2.32
133		22-8	11.40	11.60	p2a-f	1.93	1.94	30.85	30.29	84	51	27	0.0085	99.98
134	No.23	23-1	1.00	1.45	q								0.85	21
135		23-2	2.30	2.50	q	1.9	1.9	23.3	23.9	83			0.09	55
136		23-3	3.50	3.80	q						48.5	22.4		
137		23-4	4.00	4.45	q								0.66	30
138		23-5	5.00	5.45	q								0.82	8
139		23-6	6.00	6.45	q						43.5	20.6	0.8	12
140		23-7	7.30	7.50	p2a-f						36.5	17		
141		23-8	12.20	12.50	p2a-f						50.5	22.5	0.032	75
142		23-9	13.00	13.45	p2a-f								0.85	11
143		23-10	16.30	16.60	p2a-f	1.95	1.99	27.9	25.8	97	45.5	20.3	0.098	50
144		23-11	17.10	17.50	p2a-f						52.5	24.5		
145		23-12	19.60	19.90	p2a-f	2.03	1.99	26.3	25.9	100	43.5	20.5	0.1	49
146		23-13	26.50	27.00	p2a-f	2.1	2.06	19.1	19.3	94	42.5	20.5	0.03	69
147		23-14	31.50	31.70	p1-f	2.03	2.01	23.5	23.7	97	43.5	20.4	0.009	88
148		23-15	37.00	37.50	p1-f	2.04	2.03	23.8	24	99	46.5	21.1	0.05	58
149	23-16	42.50	43.00	p1-f	2.07	2.06	21.8	21.7	98	47.5	21.4	0.006	87	
150		23-17	48.20	48.50	p1-f	1.98	1.97	25.9	26.9	97	46.5	21.4	0.007	98
151	No.24	24-1	1.00	2.00										
152		24-2	2.00	2.45									0.065	55

Table 3-9 Summary of Laboratory Tests Conducted in the Study (cont.)

No.	Boring No.	Specimen name	from	to	Engineering geology	DENSITE HUMIDE				MITES D'ATTERBER		Analyse Granulométrique	
						DENSITE HUMIDE/Wet density (g/cm3)		TENEUR EN EAU/Water content	Sr(%)	LL	LP	D50	FC (%)
153	No. 25	25-1	22.00	22.45	p2l-f					46.5	22.2		
154		25-2	24.60	25.00	p2l-f	2.01	2.03	24.50	22.2	96	48.5	21.4	
155		25-3	28.50	29.00	p2l-f						41.5	19.7	
156		25-4	29.00	29.45	p2l-f	2.08	2.14	12.30	12	67	41.5	20.5	
157		25-5	39.40	39.80	p2l-f	2.01	2.07	25.00	20.3	96	46.5	21.3	
158		25-6	48.00	48.50	p2l-f	1.99	1.99	27.4	29.5	100	45.5	20.3	- 97
159	No. 26	26-1	1.20	1.50	B	2.06	2.04	14.2	15	76	28.5	18.3	0.07 62
160		26-2	3.30	3.45	B						33	16.9	0.15 48
161		26-3	4.00	4.45	B						28	16.1	0.15 46
162		26-4	8.40	9.00	B	2.09	2.07	21.2	22.7	100	41.5	20.6	0.0035 99
163		26-5	13.00	13.45	B								0.29 26
164		26-6	21.00	21.45	p2l-f						28.5	16.3	0.15 42
165	No. 27	26-7	32.00	32.45	p2l-f						31	16	
166		26-8	48.30	48.70	p1-f	2.23	2.26	16.2	14.5	100			
167		26-9	76.30	77.00	p1-f	2.2	2.18	16.6	17.6	100	33.5	16.8	0.018 90
168		27-1	1.00	1.45	q	1.85		3.54		18.87			
169		27-2	2.00	2.50	q	2.03	2	19	19.19	87	48	19	0.0045 92.88
170		27-3	3.00	3.45	q	1.98		2.89		19			
171	No. 28	27-4	4.00	4.45	p2a-f	1.93		2.81		17			
172		28-1	1.80	2.00	qt	2.17	2.17	13.84	13.12	89	33	16	0.015 65.2
173		28-2	3.20	4.00	p2a-f	2.18	2.17	13.8	3.6	91	34	15	0.06 61
174		28-3	4.40	4.80	p2a-f	2.16	2.17	16.24	16.13	98	43	21	0.2 37
175		28-4	6.00	6.45	p2a-f								0.9 9.6
176		28-5	8.00	8.45	p2a-f								0.075 51
177	No. 30	28-6	9.00	9.45	p2l-f								0.2 10.5
178		28-7	10.00	10.45	p2l-f								0.25 4.2
179		28-8	11.00	11.45	p2l-f								0.5 8.5
180		28-9	35.00	35.45	p1-f	2.01	1.99	27.17	26.68	74	46	22	0.09 95.28
181		30-1	9.00	9.30	a2	1.97	1.99	21	19.7	84	46.5	21.4	0.015 83
182		30-2	13.00	13.40	a2	2.07	2.06	19.1	20.2	93	44.5	20.6	0.008 89
183	No. 31	30-3	16.00	16.45	p2a-f								0.25 7
184		30-4	17.40	17.75	p2a-f	1.93	1.91	26.9	25.7	91	38.5	18.4	0.011 75
185		30-5	21.00	21.45	p2a-f								0.25 7
186		30-6	23.30	23.60	p2a-f	1.81	1.85	34.9	35	94	36.5	18	0.11 45
187		30-7	33.00	33.45	p1-f								0.007 82
188		30-8	33.20	33.50	p1-f	2.17	2.16	19	19	100	40.5	18.6	0.009 98
189	No. 32	30-9	40.40	40.70	p1-f	2.11	2.11	17.3	21.4	99	34.5	17.4	0.011 82
190		30-10	41.00	41.45	p1-f								0.0055 95
191		30-11	44.20	44.50	p1-f	2.19	2.18	16.5	18.6	100			0.011 97
192		30-12	49.40	49.90	p1-f	2.14	2.16	17.4	18.2	99			0.012 78
193		31-1	1.00	1.45	B	1.99		10.44		56	53	27	- 93.72
194		31-2	1.40	1.70	B	2.06	2.09	17.42	17.6	90			
195	No. 33	31-3	2.00	2.45	B	2.05		10.51		63			
196		32-1	1.75	1.90	q	2.09	2.01						0.003 99.04
197		32-2	3.60	4.00	q	2.14	2.10						0.005 98.87
198		32-3	4.95	4.99	q						40.4	24.9	
199		32-4	7.50	7.75	p2a-f	2.16	2.15						0.003 91.57
200		32-5	10.40	10.60	p2a-f						28.3	15	
201	No. 34	32-6	11.50	12.00	p2a-f	2.15	2.16				43.3	21.9	0.03 78.73
202		32-7	16.60	16.80	p2a-f	2.17	2.15				36.9	18.3	0.02 73.71
203		32-8	17.20	18.00	p2a-f						49.5	28.4	
204		32-12	29.60	30.00	p2a-f	1.96	1.98				40.4	21.9	0.03 73.82
205		32-13	34.00	35.00	p2a-f								0.007 80.25
206		32-14	35.00	36.00	p2a-f								0.01 83
207	No. 35	32-15	37.00	38.00	p2a-f						33.9	15.7	
208		32-18	48.20	48.80	p2a-f	1.95	1.94						- 98.92
209		32-20	50.04	50.60	p2l-f	2.19	2.20						0.09 31.74
210		33-1	1.00	1.45	p2l								1.6 20.47
211		33-2	2.00	2.45	p2l								0.3 29.1
212		33-3	3.00	3.45	p2l								0.3 13.21
213	No. 36	33-4	4.00	4.45	p2l								0.4 10
214		33-5	5.00	5.45	p2l								0.28 20
215		34-1	11.20	11.60	p2l-f	2.04	2	19.36	18.99	88	44	21	0.008 92.56
216		34-2	20.10	20.60	p2l-f	2.15	2.13	17.63	19.71	100	29	16.3	0.07 57.8
217		34-3	28.00	28.40	p2l-f	2.08	2.04	23.08	23.24	100	18	29	0.001 99.84
218		34-4	34.40	34.60	p2l-f	2.1	2.16	17.81	18.95	99	33	22	0.004 92.4
219	No. 37	34-5	43.40	43.80	p2l-f	2.18	2.22	15.42	15.04	99	36	18	0.012 96.36
220		34-6	47.10	47.30	p2l-f	2.07	2.11	14.64	15.65	84	36	20	0.01 95.36
221		34-7	52.20	52.50	p2l-f	2.16	2.14	17.05	17.35	98	31	6	0.05 99.68
222		34-8	61.10	61.50	p2l-f	2.11	2.1	20.14	20.21	100	44	25	0.004 98.68

Table 3-9 Summary of Laboratory Tests Conducted in the Study (cont.)

No.	Boring No.	Specimen name	from	to	Engineering geology	DENSITE HUMIDE				MITES D'ATTERBER			Analyse Granulo,etrique	
						DENSITE HUMIDE./Wet density (g/cm3)		TENEUR EN EAU/Water content		Sr(%)	LL	LP	D50	FC (%)
223	No.35	35-1	1.00	1.45	ap						34	15.54	0.04	63.5
224		35-2	2.00	2.45	ap	2.1	2.09	13.22	14.88	80.29			0.025	99
225		35-3	3.00	3.45	ap						58	25.57	0.8u	99.2
226		35-4	5.80	6.00	ap	2.08	2.06	19.14	20.22	93.85	75	37.52	-	98.8
227		35-5	10.00	10.50	ap	2.04	2.08	21.86	23.61	100	52	27.13	9u	95.6
228		35-6	12.80	13.00	p2a-f	2.1	2.1	20.7	22.54	100	60	29.79	0.6	-
229		35-7	16.00	17.00	p2a-f	2.19	2.2	17.47	16.91	100	58	28.36	0.014	94.4
230		35-8	33.90	34.00	p2l-f	2.08	2.1	21.4	20.3	100	42	20.57	0.014	88.8
231		35-9	36.00	36.30	p2l-f	2.15	2.21	20.59	17.65	100	63	30.43	0.02	64
232		35-10	43.60	44.00	p2l-f	2.06	2.15	25.27	22.12	100	66	32.78	-	88
233		35-11	53.00	53.80	p2l-f	2.2	2.19	16.93	16.32	100	61	27.27	-	98.33
234	No.36	36-1	0.70	0.90	q	1.99	2.00	18.8	17.7	81	33.5	16	0.003	98
235		36-2	6.00	6.45	p2a-f								1.5	5
236		36-3	14.50	15.00	p2a-f	2.1	2.09	19.6	15	90	46.5	20.8	3.2u	91
237		36-4	16.00	17.00	p2a-f						58	28.36		
238		36-5	20.00	20.45	p2a-f	1.87	1.9	29.4	31.6	94	50.5	23.1	2.1u	90
239		36-6	21.00	21.50	p2a-f								0.038	66
240		36-7	26.00	26.45	p2a-f								0.5	9
241		36-8	29.50	30.00	p2a-f	1.89	1.88	27	28	90	46.5	21.5	0.0038	95
242		36-9	37.00	37.45	p2l-f								0.22	33
243	No.37	37-1	8.40	8.90	ap	2.02	1.97	25.2	19.5	92.7	44.5	20.8	0.0051	98
244		37-2	13.00	13.45	ap	1.96	2.01	18.9	19.2	83	46.5	21.4	0.004	91
245		37-3	15.45	15.70	p2a-f	1.99	2.02	19.9	22.7	90	43.5	20.6	0.008	75
246		37-4	16.30	16.60	p2a-f	1.99	2.02	11.7	9.8	75	34.5	16.4	0.24	38
247		37-5	16.50	17.00	p2a-f						36.5	16.4		
248		37-6	22.00	22.45	p2a-f								0.007	71
249		37-7	22.40	22.60	p2a-f	2.17	2.19	19.5	18.5	100	41.5	19.4	0.008	87
250		37-8	24.60	25.00	p2a-f								0.065	51
251		37-9	26.50	27.00	p2a-f	2.19	2.15	13.3	13.4	87			0.005	94
252		37-10	27.30	27.60	p2a-f	2.15	2.15							
253		37-11	28.50	29.40	p2a-f								0.007	67
254		37-12	29.00	29.45	p2a-f								0.007	83
255		37-13	37.00	37.45	p2l-f	2.19	2.15						0.045	85
256		37-14	62.00	62.45	p2l-f								0.32	39
257		37-15	63.70	63.90	p2l-f	2.09	2.17	10.4	11.9	72.7			0.3	42
258		37-16	67	67.45	p2l-f								0.21	38
259		37-17	67.30	67.40	p2l-f	2.20	2.21	11.2	10.7	80			0.22	40
260		37-18	68	68.40	p2l-f								0.26	40
261		37-19	68.50	68.70	p2l-f	2.01	2.01	10.7	12.7	60			0.4	11
262		37-20	70.8	71.00	p2l-f								0.21	12
263			37-21	71	71.45	p2l-f	2.01	1.99	19.9	23	97			0.21
264	No.39	39-1	8.00	8.45	a2								0.01	44
265		39-2	9.00	9.45	a2								0.02	85.2
266		39-3	9.70	10.00	a2	2.16	2.13	16.99	16.88	96.03	38	17.64	0.05	61.2
267		39-4	12.30	12.60	p2a-f	2.03	1.99	24.99	25.73	99.45	60	29.48	0.02	77.2
268		39-5	16.00	16.45	p2a-f								0.03	81.33
269		39-6	17.60	17.95	p2a-f	2.15	2.15	15.56	16.18	93.9			0.21	37
270		39-7	25.00	25.45	p2a-f						60	28.63	0.018	80.4
271		39-8	26.00	26.40	p2a-f	2.17	2.19	16.46	15.28	99.75	46	24.4	0.016	72
272		39-9	41.00	41.25	p2l-f								0.35	5.8
273		39-10	62.70	62.85	p2l-f	2.1	2.1	22.47	22.17	100				
274		39-11	65.50	65.80	p2l-f	2.1	2.18	20.86	18.93	100	54	25.37	0.016	90.67
275		39-12	67.00	67.45	p2l-f						33	16.33	0.07	54.4
276		39-13	68.00	68.45	p2l-f								0.25	28
277		39-15	79.00	79.45	p2l-f						73	37.48	-	99.2
278		39-16	80.00	80.45	p2l-f						71	37.52	-	86
279	No.40	40-1	19.00	19.45	p2a-f								0.5	5
280		40-2	20.70	21.00	p2a-f	2.03	2.04	26.1	23.1	100	42.5	21.4	0.0018	98
281		40-3	31.60	32.00	p2a-f	2.04	2.04	19.1	16.5	85	33.5	28.1	0.16	34
282		40-4	34.00	34.45	p2a-f						29.5	18.2	0.3	20
283		40-5	42.30	42.50	p1-f	1.96	1.98	19.4	19.1	81	31	15.3	0.19	18
284		40-6	48.30	48.80	p1-f	2.23	2.26				34	19	0.026	71
285	No.41	41-1	1.00	1.45	qt								0.3	5.56
286		41-2	3.00	3.45	p2a-f								0.35	3.75
287		41-3	5.00	5.45	p2a-f								0.35	3.53
288		41-4	13.00	13.45	p2l-f								0.23	2.75
289		41-5	26.00	26.45	p2l-f								0.4	13.6
290		41-6	26.80	27.00	p2l-f	2.27	2.28	19.22	19.07	100				
291		41-7	28.20	28.40	p2l-f	1.74	1.99	15.31	16.04		29.5	20.26	0.07	54.86
292		41-8	34.50	35.00	p1-f	2.095	2.062	20.6	23.29	100	41.5	20.88	0.025	92.33
293	No.42	41-9	36.50	37.00	p1-f	2.086	2.11	22.83	22.2	100	40	20.22	0.02	90.33
294		42-1	0.70	0.90	a2	1.97	1.96	8.4	8	56	48.5	22.2	0.006	97
295		42-2	1.50	1.80	a2	2.06	2.06	20	21.5	97	44.5	20.7	0.002	99
296		42-3	3.00	3.50	a2	2.02	2.03	24	23.9	98	43.5	20.7	0.001	96
297		42-4	5.40	5.80	a2	2.16	2.14	17.4	17.3	98	46.5	22.2	0.0085	82
298		42-5	8.40	8.90	a2	2.1	2.14	16.7	18.4	95	49.5	22.2	0.0025	95
299		42-6	18.40	19.00	a2									
300		42-7	20.30	20.90	p2l-f	2.14	2.13	10	10.8	91	46.5	21.3	0.035	55
301		42-8	28.20	28.40	p2l-f	1.74	1.99	15.31	16.04	52.4/75.9				

Table 3-9 Summary of Laboratory Tests Conducted in the Study (cont.)

No.	Boring No.	Specimen name	from	to	Engineering geology	DENSITE HUMIDE				MITES D'ATTERBER		Analyse Granulo,etrique			
						DENSITE HUMIDE/Wet density (g/cm3)		TENEUR EN EAU/Water content		Sr(%)	LL	LP	D50	FC (%)	
302	No.44	44-1	1.20	1.80	a2	2.12	2.11				44	21	0.007	94.92	
303		44-2	2.30	2.80	a2	2.11	2.11				39	24	0.0065	97.6	
304		44-3	3.20	3.60	a2	2.13	2.10				40	24	0.007	97.16	
305		44-4	5.60	5.90	a2	2.08	2.10				39	21	0.0058	88.96	
306		44-5	7.00	7.35	a2	2.08	2.07								
307		44-6	11.15	11.25	a2	2.12	2.04				38	22	0.005	97.72	
308		44-7	18.30	18.70	a2	1.93	1.92				31	18	0.014	85.28	
309		44-8	45.30	45.90	p2a-f	2.02	2.04				29	19	0.001	89	
310		44-9	58.20	58.60	p2a-f						61	32	0.0014	96.72	
311		44-10	69.30	69.90	p2a-f	1.93	1.98				44	26	-	95.27	
312		44-12	79.70	80.00	p2l-f						29	14	0.0022	91.92	
313	No.46	46-1	1.00	1.45	B								0.29	17	
314		46-2	2.00	2.45	B								0.27	17	
315		46-3	12.00	12.45	B								0.21	11	
316		46-4	14.10	14.40	a2	2.06	2.06	23.6	23.2	100	45.5	20.6			
317		46-5	14.70	14.90	a2								0.004	98	
318		46-6	17.30	17.90	a2	2.00	2.00	27.7	28.8	100	47.5	21.9	0.006	99	
319		46-7	20.20	20.70	p2l-f	2.01	2.02	25	25.9	100	46.5	21.8	0.006	97	
320		46-8	23.50	23.90	p2l-f	2.10	2.10	19.1	22	100	44.5	20.8	0.005	96	
321		46-9	27.00	27.40	p2l-f	2.03	2.05	17	16.5	100	46.5	21.4	0.003	99	
322	No.47	47-1	1.00	1.45	qt	2.15	2.13	16.58	16.125	94	45	20	0.008	82.04	
323		47-2	4.50	5.20	p1	2.09	2.1	21.415	21.145	100	38	21	0.006	99.6	
324		47-3	7.00	7.35	p1	2.25	2.24	10.85	11.68	90	43	22	0.018	80.12	
325		47-4	9.70	10.30	p1	2.06	2.06	21.905	21.33	99	32	22.4	0.2	99.76	
326		47-5	15.00	15.30	p1	2.00	1.98	22.23	22.91	92	43	25	0.009	99.24	
327		47-6	20.00	20.40	p1	2.17	2.15	23.89	23.23	65	52	22	0.009	99.87	
328		47-7	24.50	25.00	p1						42	27	0.007	87.56	
329		47-8	29.80	30.30	p1						57	27	0.004	99.6	
335	No.49	49-1	3	3.45	B								2	3	
336		49-2	9	9.45	B								4	18.24	
337		49-3	10	10.45	ap								0.2	28	
338		49-4	11	11.45	ap								2	40.54	
339		49-5	20	20.45	p2a-f								0.25	10.94	
340		49-6	21	21.45	p2a-f								0.25	5	
341		49-7	23	23.45	p2a-f								0.25	4.71	
342		49-8	28.4	29	p2a-f	2.064	2.055	25.81	22.22	100	61	30.26	0.014	98.33	
343		49-9	29	29.45	p2a-f						60	28.94	0.014	99	
344		49-10	30.2	30.5	p2a-f	2	2.01	25.2	27.86	100	59	30.31	0.016	99.3	
345		49-11	31.6	31.9	p2a-f	2.01	2.015	25.54	23.03	98.26	59	29.31	0.014	98.67	
346		49-12	32	32.45	p2a-f						65	32.53	0.011	97.5	
347		49-13	34	34.4	p2a-f	2.03	2.01	19.84	22.73	93.06	58	28.45	0.016	93.67	
348		49-14	36	36.6	p2a-f	2.05	2	21.83	21.33	92.86	57	26.8	0.018	99	
349		49-15	38	38.4	p2a-f	1.96	1.97	30.52	27.58	100	71	36.62	0.005	99.33	
350		49-16	39.5	40	p2a-f	1.97	1.97	29.01	28.57	100	58	30.01	0.014	98.67	
351		49-17	41.2	41.7	p2a-f	2	1.996	20.98	21.84	89.99	79	38.09	0.005	99.67	
352		49-18	42.6	43	p2a-f	2.03	2.03	22.64	18.96	92.4	37	23.3	0.01	99	
353		49-19	45.2	45.7	p2a-f	2.02	2.01	22.6	22.17	93.45	58	28.42	0.014	98.33	
354		49-20	46.7	47	p2a-f	2.008	2.02	23.52	24.24	97.31	58	29.49	0.012	99.33	
355		49-21	47	4.45	p2a-f									0.012	99.33
356		49-22	49	49.2	p2a-f	1.97	1.99	19.56	24.17	88.26	64	31.76	0.01	99.67	
357	No50	50-1	7.80	8.00	mi	2.48									

Table 3-10 Summary of Existing Laboratory Test Data

No.	Boring No.	Specimen name	from	to	Sample Number	model	DENSITE HUMIDE			LIMITES D'ATTERBERG		Analyse Granulo,etrique		C (kgf/cm2)	Fai (degree)
							Wet density	Water content	N	LL	LP	D50	FC(%)		
1	B-2	B-2-1	1	2	4	e	1.82	14.9	5	46.7	21				
2		B-1-2	2	3	4	e	1.94	13.2	2	37.5	17.6			0.5	27
3		B-2-3	4	5	4	e	1.91	12.7	15	44.5	17.2				
4		B-2-4	5	6	4	e	1.84	14.9	15	45.3	20				
5	B-4	B-2-5	9	10	15	mi	1.8	16	15	39.2	16.3				
6		B-4-1	2	3	1	mi				31	16	0.3	39		
7		B-4-2	4	5	2	mi				30	18	0.65	18		
8		B-4-3	7	8	2	mi				34	18	1.4	18		
9	C-2	B-4-4	14	15	2	mi				32	18	2	8		
10		C-2-1	0	1	1	p2l	1.42	30.7	5	55	63.2	0.018	87	0.3	3
11		C-2-2	1	2	12	p2l	1.43	31.9					72	0.5	3.5
12		C-2-3	3	4	12	p2l	1.65	24	63	80	65	0.0045	73		
13	C-3	C-2-4	4	5	18	p2l	1.65	24.9	100	75	63.8	0.006	82	0.4	12
14		C-2-5	5	6	18	p1	1.59	17.9	136	75	61.4	0.006	78	0.9	24
15		C-3-1	5	6	17	p1						0.001	93		
16		C-3-2	6	7	18	p1						0.001	97	0.4	21
17	C-4	C-3-3	8	9	17	p1						0.005	76		
18		C-4-1	1	2	4	p2l	1.63	23.3						0.71	14
19		C-4-2	4	5	17	p2l	1.7	21.3		52	24.6			0.53	7
20		C-4-3	7	8	17	p1	1.53	23.5		47	22.3			0.32	7
21	E-1	C-4-4	10	11	17	p1	1.6	23.5		49	23.2			0.44	1
22		E-1-1	1	2	2	mi						0.05	54		
23		E-1-2	4	5	15	mi						0.006	78		
24		E-1-3	8	9	15	mi						0.4	32		
25	F-2	E-1-4	10	11	15	mi						0.035	58		
26		F-2-1	6	7	15	mi		25.5	44	34	16	0.05	55	0.35	27
27		F-2-2	7	8	15	mi		32.2	27	40	22	0.04	55	0.3	27
28		F-3-1	1	2	1	mi			20			0.004	80		
29	F-5	F-3-2	2	3	1	mi			30			0.002	80		
30		F-3-3	4	5	1	mi			45			0.14	68		
31		F-5-1	3	6	1	mi	1.49	29.2		62	35	0.003	98	0.66	20
32		F-5-2	6	9	1	mi	1.51	28.6		63	34	0.0018	98	0.25	33
33	G-3	F-5-3	9	12	1	mi	1.43	31.1				0.002	96	0.15	25
34		F-5-4	12	15	1	mi	1.52	28.1		64	36	0.0008	98	0.75	36
35		F-5-5	12	15	1	mi	1.67	25.5		59	31	0.0005	98	0.8	22
36		G-3-1	2	3	17	p2a	1.57	21	25	41	26	0.016	75		
37	H-1	G-3-2	3	4	12	p2a	1.64	16	50	51	28			0.2	31
38		G-3-3	4	5	12	p2a	1.58	23	43	42	24	0.05	55	0.4	17
39		G-3-4	6	7	17	p2a	1.52	29		32	20			0.65	16
40		H-1-1	6	7	15	mi	2.05	13.3	148	40.5	23.1	0.16	44	0.46	19
41	H-2	H-1-2	9	10	15	mi	2.07	12.8		36.5	19.9	0.05	54		
42		H-2-1	1	2	4	mi		31.1	3	35.8	17	0.35	34		
43		H-2-2	3	4	1	mi	1.33	32	23	35.5	17.3	0.15	42		
44		H-3-1	7	8	1	mi	1.72	20	9	40	20	1	40		
45	J-4	H-3-2	9	10	1	mi	1.88	17.6	16	44	25	0.6	48		
46		J-4-1	1	2	15	mi	1.32		156			0.012	90	0.4	30
47		J-4-2	4	5	15	mi	1.42					1.1	32	0.15	32
48		J-4-3	5	6	15	mi	1.38					1.2	28	0.45	28
49	K-2	K-2-1	3	4	12	p2l	1.74	21		23.2	25.8	0.002	90	0.64	33
50		K-2-2	4	5	12	p2l	1.99	21.4		42	19.8	0.0023	96	1.4	14
51		K-2-3	6	7	18	p1	1.74	20		21.1	23.9	0.0014	96	0.61	26
52		K-2-4	7	8	18	p1	1.63	24.7		23.4	25.6	0.0012	94	0.91	16
53	L-1	K-3-1	3	4	17	p2a			60			0.0003	99		
54		K-3-2	5	6	17	p2a			70			0.0003	96		
55		L-1-3	13	14	1	p2a	1.67	22.4	999	33	19	0.5	22	0.3	13
56		L-1-4	14	15	1	p2a	1.71	22.3	999	38	21	0.12	44	0.1	30
57	M-1	M-1-1	1	2	15	mi			4			1.15	8		
58		M-1-2	11	12	15	mi			999			0.4	8		
59		N-2-1	3	4	17	p2a	1.81	18.1	26	45.4	20		74	1.7	17
60		N-2-2	4	5	17	p2a	1.81	17.7	31	59.5	25.7		55	1.2	21
61	N-2	N-2-3	5	6	12	p2a	1.81	17.6	18	59.5	25.7		57	1.2	24
62		N-2-4	7	8	12	p2l	1.84	16.9	184	63	27.2		42		
63		N-2-5	10	11	18	p1	1.49	30.4	999	47.2	18.4		74		
64		O-1-1	8	8.5	17	p2a						0.0014	97		
65	R-1	R-1-1	4.6	5	12	q	2.09	5.2	21	40.5	25.2	0.05	60		
66		R-1-2	9.4	9.8	12	q	2.03	9	31	29.4	13.1	0.003	52		
67		R-1-2	6.2	6.5	12	q	2.03	6.2	56	34.7	13.2	0.05	76		
68		R-2-1	2	3	12	qt			31			0.08	50		
69	R-2	R-2-2	4	5	12	qt			3			0.1	48		
70		R-2-3	5	6	12	qt			9			0.08	50		
71		R-2-4	6	7	12	qt			18			0.12	47		
72		R-2-5	9	10	12	qt			999			0.0014	92		
73	S-1	S-1-1	1	2	12	a2			33	52		0.015	42		
74		S-1-2	2	3	12	p2a	1.84	14.5	38	47	21.9	0.004	58		
75		S-1-3	3	4	12	p2a	1.92	13	33	35	17.8				
76		S-1-4	4	5	12	p2l-f	2.02	9.4	44	23.3	14.5	0.09	45		

Table 3-10 Summary of Existing Laboratory Test Data (cont.)

No.	Boring No.	Specimen name	from	to	Sample Number	model	DENSITE HUMIDE			LIMITES D'ATTERBERG		Analyse Granulo,etrique		C (kgf/cm ²)	Fai (degree)
							Wet density	Water content	N	LL	LP	D50	FC(%)		
77	T-2	T-2-1	2	3	12	q	1.91	14.2	31	60.1	31.8	0.02	60	0.6	25
78		T-2-2	3	4	12	q	1.84	16.7	40	72	34.2	0.008	67		
79		T-2-3	4	5	12	p2a	1.68	22.1	54	48	17.3	0.05	51		
80	T-3	T-3-1	6	7	17	p2a	1.91	14.4		57	37.8	0.2	40		
81	U-3	U-3-1	1	2	3	p2l	1.99	11.7	12	41	22	0.014	68	0.25	37
82		U-3-2	4	5	3	p2l	1.96	12.4	12	65	27	0.04	63	0.55	35
83		U-3-3	8	9	13	p2l						1.4	35		
84		U-3-4	9	10	13	p2l	1.92	13		41	22	0.1	46	0.25	37
85	V-1	V-1-1	1	2	12	p2l	1.39					0.2	5	0	40
86		V-1-2	3	4	12	p2l	1.41					0.3	14	0	38
87		V-1-3	5	6	12	p2l	1.41					0.22	16	0	39
88		V-1-4	7	8	12	p2l	1.33					0.2	25	0	33
89	V-2	V-2-1	2	3	13	p2l	1.43		5			0.6	8	0	36
90		V-2-2	7	7.5	13	p2l	1.65	13	15	31	22	0.3	20	0.05	32
91		V-2-3	9	10	13	p2l	1.5	25		30	20	0.18	25		
92		V-2-4	10	11	13	p2l	1.69	16		30	22	0.18	26		
93	V-3	V-3-1	1	2	2	p2l	1.85	12	26	31	18	0.18	27	0.25	29
94		V-3-2	2	3	2	p2l	1.68	13	52	30	17	0.25	27	0.15	37
95		V-3-3	4	5	2	p2l	1.65		31			0.32	19	0.25	34
96		V-3-4	7	8	2	p2l	1.65		999			0.21	6	0	37
97	W-1	W-1-1	2	3	2	B			18	25	11	0.12	43		
98		W-1-2	4	5	2	qt	1.28		40			0.25	17	0	34
99		W-1-3	7	8	12	qt	1.21		24			0.28	18	0	32
100		W-1-4	10	11	12	qt	1.25		999			0.19	27	0	34
101	W-2	W-2-1	2	3	2	p2l	1.86	9.5	13			0.12	47	0.17	32
102		W-2-2	3	4	2	p2l	1.84	11.6	13			0.18	44	0.28	38
103	X-2	X-2-1	1	2	1	q	1.77	17.6	44	50	24	0.014	81	1.3	13
104		X-2-2	2	3	17	q	1.68	21.9	48	65.5	38.1	0.011	88	1.2	12
105		X-2-3	6	7	17	q	1.85	17.1	60	52	18.4	0.013	95	2.4	12
106		X-2-4	8	9	17	q	1.67	23.3	160	80.2	78.5	0.013	100	0.9	12
107	Y-1	Y-1-1	1.5	3	17	a2			54	37	17	0.014	86		
108		Y-1-2	5	7.5	17	a2			68	53	36	0.01	88		
109	Z-1	Z-1-1	2	3	1	a2	1.45	22	11	44.5	20	0.009	92	1	23
110		Z-1-2	3	4	1	a2	1.69	21.6	13	38	17.3	0.001	68	0.65	25
111		Z-1-3	4	5	1	a2	1.8	18.7	31	38.5	18	0.005	96	1.2	27
112		Z-1-4	5	6	1	a2	1.65	24.2	45	54	25	-	97	1.1	32
113		Z-1-5	8	9	12	p2a	1.88	14.4	33	60.3	28.1	0.018	58	0.4	37
114	Z-2	Z-2-1	4	5	1	a2	1.9	12.8	27	41.5	20.9	0.006	75	0.5	18
115		Z-2-2	5	6	1	a2	1.78	18.4	44	40.4	24.8	0.006	93		
116		Z-2-3	6	7	17	a2	1.82	16.7	33	37	19.7	0.008	99		
120	Za-2	Za-2-1	2	3	12	a3	1.84	16.8		53	26.6	0.02	62	0.6	35
121		Za-2-2	3	4	12	a3	1.84	14.6				0.16	40		
122		Za-2-3	4	5	12	a3	1.85	12.3		31	14.6	0.2	44	1.1	19
123	Zb-1	Zb-1-1	1	2	1	a2	1.77	17.6	36	50	24	0.013	81	1.3	13
124		Zb-1-2	2	3	1	a2	1.68	21.9	45	65.5	27.1	0.01	90	1.2	12
125		Zb-1-3	5	6	12	p2l	1.99	13.6	54	37.5	19.5	0.014	85	2.1	34
126		Zb-1-4	6	7	12	p2l	1.85	17.1	59	52	18.4	0.01	96	1.1	6
127		Zb-1-5	8	9	17	p2l	1.67	23.3	186	80.2	28.5	0.012	100	0.9	11
128	Zb-2	Zb-2-1	1	2	1	a3	1.5	30	11	56	29	0.0025	98	0.55	9
129		Zb-2-2	2	3	1	a3	1.57	25	22	50	28	0.004	97	0.3	27
130		Zb-2-3	4	5	1	a3	1.55	27	27	58	27			0.55	18
131		Zb-2-4	6	7	1	a3	1.44	33	44	55	29			0.45	12
132		Zb-2-5	10	11	17	a3	1.64	24	42	38	19	0.65	3	0.35	17
133	Zc-1	Zc-1-1	2	3	12	qt			64			0.7	2		
134		Zc-1-2	5	6	12	p2l						0.6	5		
135		Zc-1-3	7	8	12	p2l						0.42	1		
136	Zc-2	Zc-2-1	1	2	4	qt	1.83	14.9	46	59	27.6			0.65	28
137		Zc-2-2	2	3	4	qt	1.82	15.5	37	51	24.7				
138		Zc-2-3	9	10	17	p2l	1.67	24	81	40	20.3				
139	Ze-1	Ze-1-1	0	1	1	a2	1.79	15	11	45	21.4	0.002	91	0.5	18
140		Ze-1-2	1	2	1	a2	1.85	11.8	22	39.5	18.2	0.0027	77	0.2	25
141		Ze-1-3	3	4	1	a2	1.64	25	11	50	24.8	0.003	71		
142		Ze-1-4	8	9	1	a2	1.77	20.1	22	49	23.3		75		
143		Ze-1-5	10	11	17	p2l	1.76	19.8	999	47.6	22.7	0.001	63		
144	Ze-3	Ze-3-1	2	3	4	a2	1.73	20.1	13	62	21.5			1	24
145		Ze-3-2	4	5	4	a2	1.75	18.7	11	41.5	20			0.7	21
146		Ze-3-3	5	6	1	a2	1.43	32	11	43.8	18.1				
147		Ze-3-4	7	8	1	a2	1.65	23.5	11	31.2	19.2			0.25	26
148		Ze-3-5	10	11	1	a2	1.41	32	11	44.5	22.2			0.1	25
149		Ze-3-6	11	12	1	a2	1.59	25.9	13	34.8	18.8			0.6	17
150		Ze-3-7	14	15	1	a2	1.43	31	11	58.8	22.4			0.25	22
151		Ze-3-8	17	18	1	a2	1.47	34.6	11	27.1					
152		Ze-3-9	19	20	1	a2	1.71	22.3	16	47.5	20.2			0.7	23
153		Ze-3-10	20	21	17	p2l	1.76	12.6		43	15				
154		Ze-3-11	24	25	17	p2l	1.73	23		30.8	15.9			0.75	24
155		Ze-3-12	26	27	17	p2l	1.6	25		67.9	24.9				
156		Ze-3-13	27	28	17	p2l	1.52	27		77.9	32.4				
157		Ze-3-14	34	35	12	p2l	1.58	25.2		72.5	46.6				

Table 3-10 Summary of Existing Laboratory Test Data (cont.)

No.	Boring No.	Specimen name	from	to	Sample Number	model	DENSITE HUMIDE			LIMITES D'ATTERBERG		Analyse Granulo,etrique		C (kgf/cm ²)	Fai (degree)
							Wet density	Water content	N	LL	LP	D50	FC(%)		
158	Ze-4	Ze-4-1	1	2	3	a2	1.76	19.6	11	49	22.6	0.004	93	1.25	17
159		Ze-4-2	3	4	1	a2	1.67	23.2	16	57.8	23.9	0.004	93		
160		Ze-4-3	5	6	1	a2	1.66	24.3	16	59.8	32.2	0.004	89	0.5	19
161		Ze-4-4	10	11	1	a2	1.81	18.2	22	54	24	0.008	89		
162	Zf-2	Zf-2-1	3	4	12	ap	1.32					0.3	11		
163		Zf-2-2	11	12	12	qt	1.46	31		45	24	0.4	19	0.2	34
164		Zf-2-3	12	13	12	p2a									
165	Zf-3	Zf-2-4	10	11		p2a	1.7	20				0.01	84		
166		Zf-3-1	10	11	14	p2a						0.1	82		
167	Zg-1	Zg-1-1	1	2	15	qt			21			0.048	62.2		
168		Zg-1-2	3	4	15	mi	1.86	8.5	999			1.8	20.6	0.1	34
169		Zg-1-3	8	9	15	mi	2.07	13.6	999						
170	Zh-1	Zh-1-1	2.6	3	2	ap	1.7	30	40	41	19	0.07	51	0.28	13

(1) Density

Density is an important parameter for evaluating the surface amplification of seismic motion. The frequency distributions of density for several of the geological units are shown in Figure 3-21 and Figure 3-22.

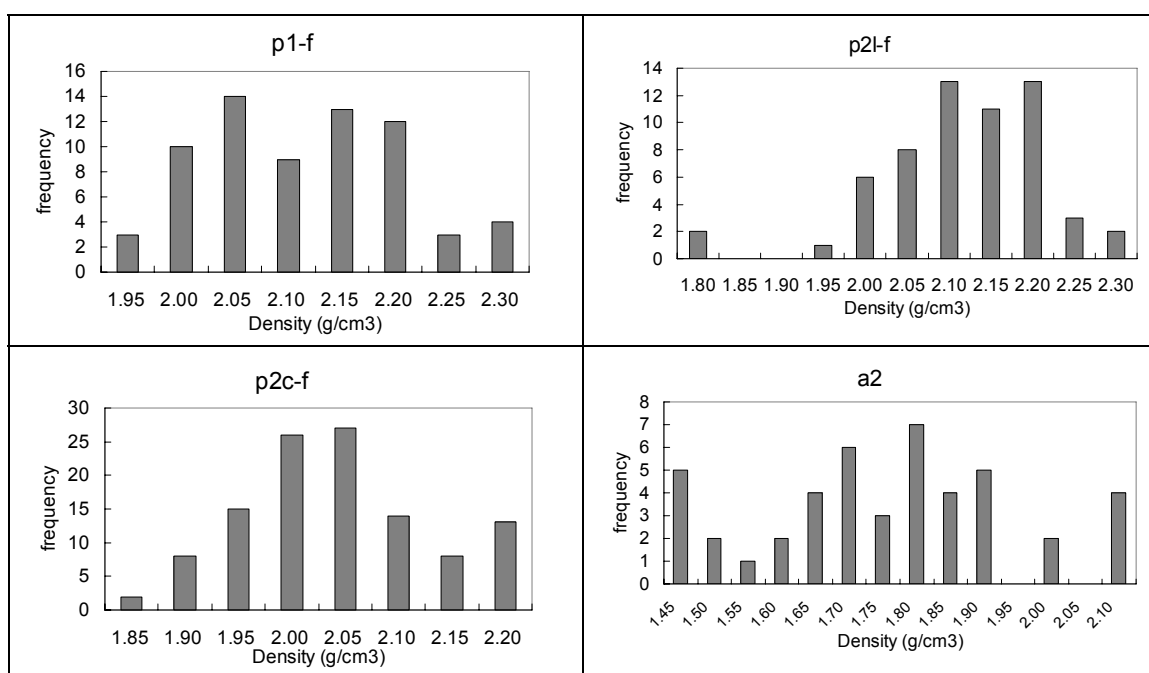


Figure 3-21 Frequency Distribution of Density (p1-f, p2l-f, p2c-f, a2)

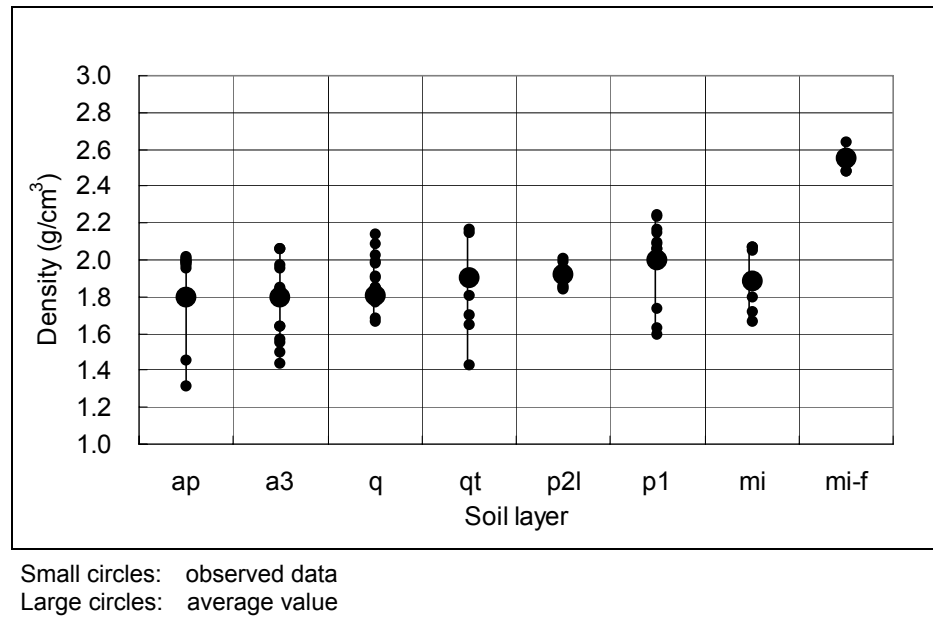


Figure 3-22 Distribution of Density (ap, a3, q, qt, p2l, p1, mi, mi-f)

Based on Figure 3-21 and Figure 3-22, the density of each classified unit was estimated as shown in Table 3-11.

Table 3-11 Estimated Density

Symbol	Density (g/cm ³)	Symbol	Density (g/cm ³)
ap	1.80	e	1.80 (same as ap)
a3	1.80	a2	1.74
q	1.81	qt	1.90
p2c	1.92 (same as p2l)	p2c-f	2.02
p2l	1.92	p2l-f	2.10
p1	2.00	p1-f	2.09
mi	1.89	mi-f	2.55

(2) D50, Fc and Ip

D50 (grain diameter of 50% passing), Fc (fine fraction content ratio) and Ip (plasticity index) are necessary soil parameters for liquefaction analysis. Fc is defined in the Japanese standards and ASTM (US standards) as the ratio of fine soil particles of less than 0.075 mm. In this study, Fc is defined as the ratio of fine soil particles of less than 0.08 mm grain size following the Algerian standards.

Figure 3-23 and Table 3-12 show the distribution of raw data and estimated data of D50, Fc and Ip.

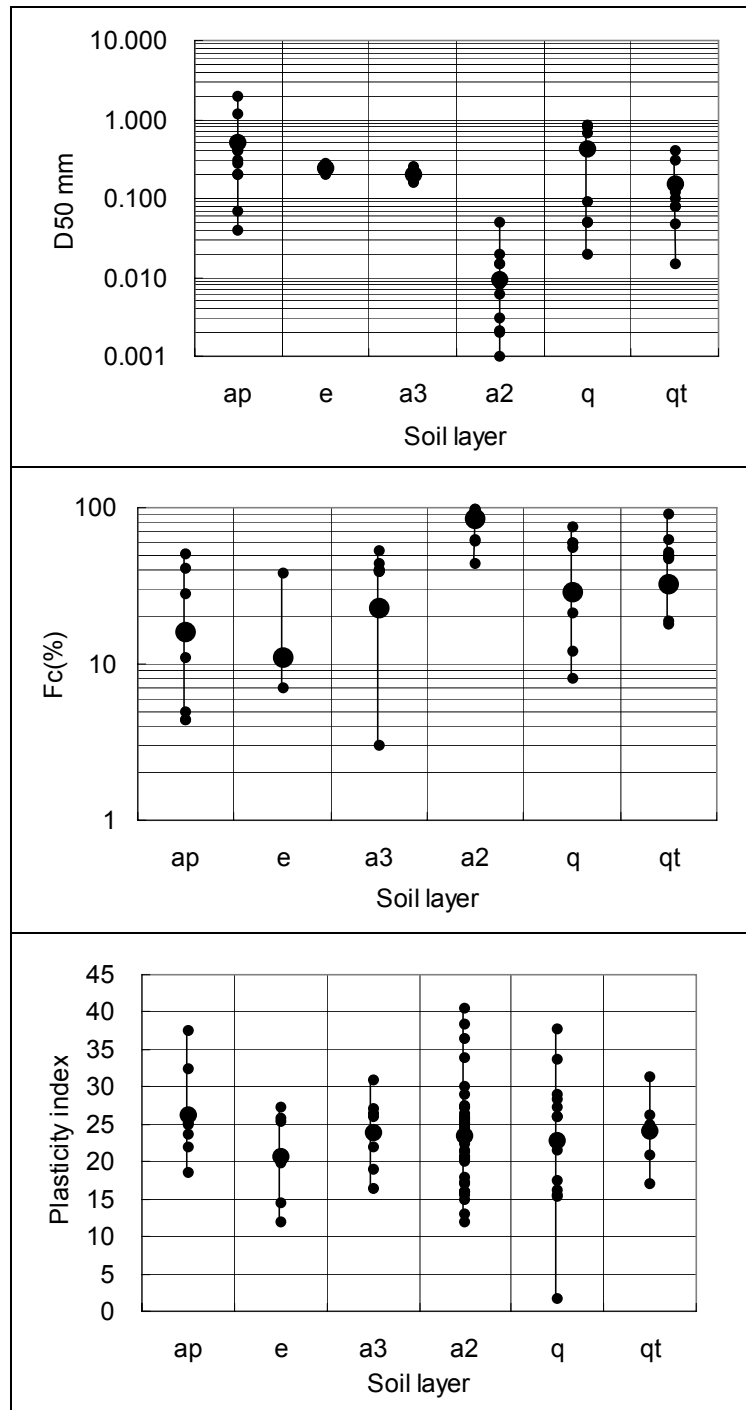


Figure 3-23 Distribution of D50, Fc and Ip

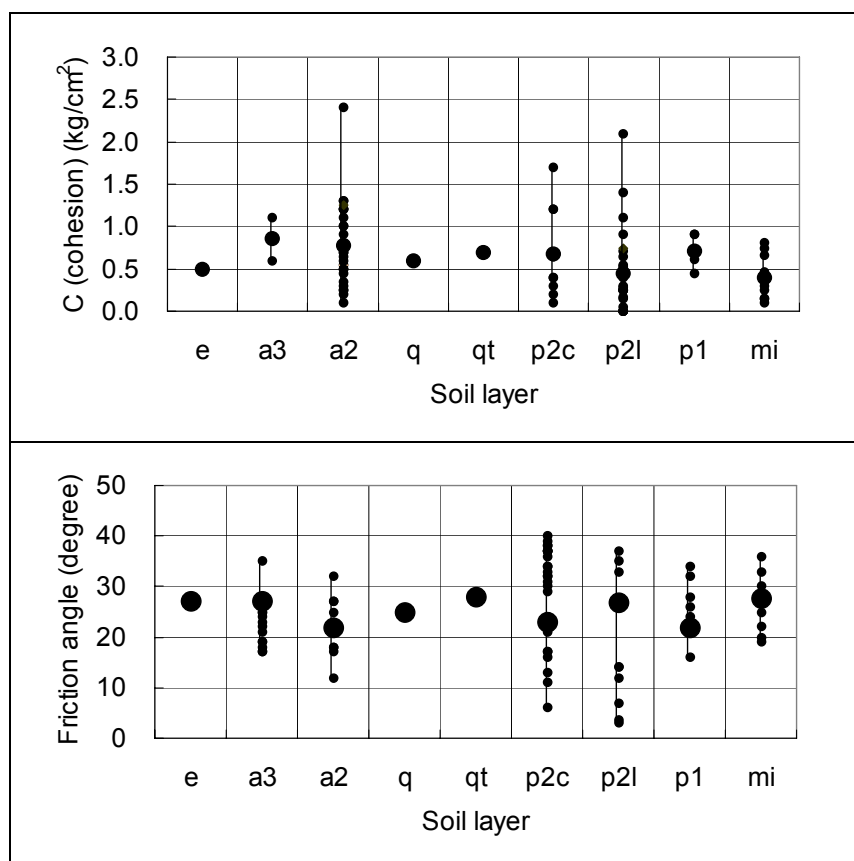
Table 3-12 Estimated D50 Fc and Ip

Symbol	D50 (mm)	Fc (%)	Ip	Symbol	D50 (mm)	Fc (%)	Ip
ap	0.51	16	26	e	0.24	11	21
a3	0.2	23	24	a2	0.01	84	23
q	0.42	29	23	qt	0.15	32	24

(3) c and ϕ

The c (cohesion) and ϕ (friction angle) were studied for slope stability analysis. This analysis was conducted based on the existing laboratory tests by LNHC. Figure 3-24 and Table 3-13 show the results.

There was no information for “ap”, ϕ was estimated by existing empirical formula from the N -values.

Figure 3-24 Distribution of c and ϕ Table 3-13 Estimated c and ϕ

Symbol	$c(\text{kgf/cm}^2)$	$\phi(\text{degree})$	Symbol	$c(\text{kgf/cm}^2)$	$\phi(\text{degree})$
ap	0.6	34 ¹⁾	e	0.5	27
a3	0.9	27	a2	0.8	22
q	0.6	25	qt	0.7	28
p2c	0.7	23	p2l	0.4	27
p1	0.7	22	mi	0.4	28

1) $\phi = \sqrt{20N + 15}$ after Ohsaki (1959)

N : N value

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. The Vs profile from surface to engineering seismic bedrock, namely to the schist or blue marl layer is necessary to evaluate the seismic motion. Therefore, the 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.

Table 3-14 shows the list of boring points for which PS loggings were conducted.

Table 3-14 PS Logging

Boring No	Depth of Borehole (m)	Depth of PS Logging (m)	Boring No	Depth of Borehole (m)	Depth of PS Logging (m)
1	32	31	31	30	28
3	41	37	32	100	83
4	32	30	33	30	11
6	20	19	34	75	21
9	30	25	35	70	41
12	20	13	37	72	68
13	37	27	38	70	41
14	15	13	39	100	68
16	30	28	40	51	43
17	30	28	41	42	41
18	30	28	42	30	24
21	70	67	43	102	99
23	55	43	44	80	53
25	50	46	45	66	53
27	80	79	47	31	27
28	70	73	49	50	49
30	70	23	50	22	18

(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 S wave should be reversed. Figure 3-25 shows a sample of high quality S wave signals.

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 become larger if the rock/soil is soft; however it should be less than 0.5. Figure 3-26 shows the distribution of Poisson's ratio in this study. The velocities are considered reasonable because Poisson's ratio is generally between 0.3 and 0.49.

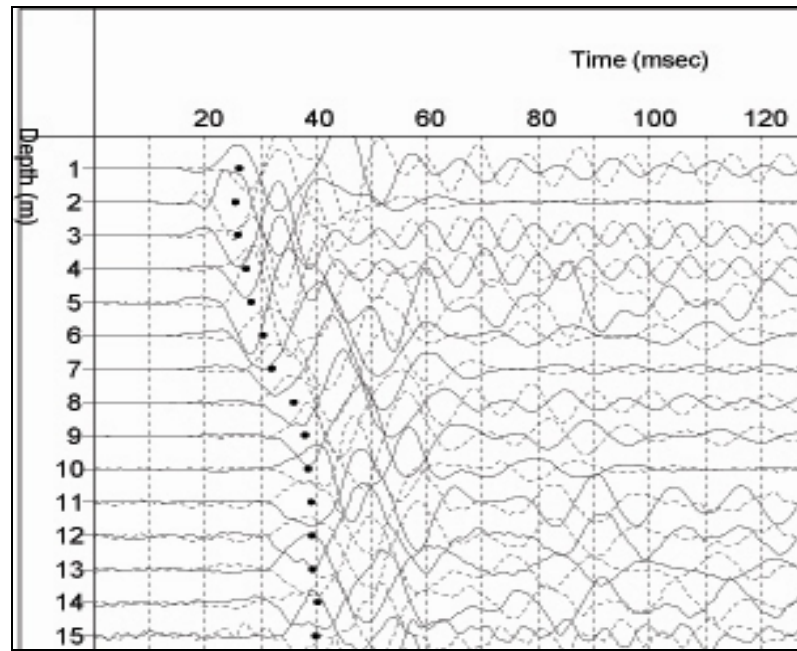


Figure 3-25 Example of S Wave Signals

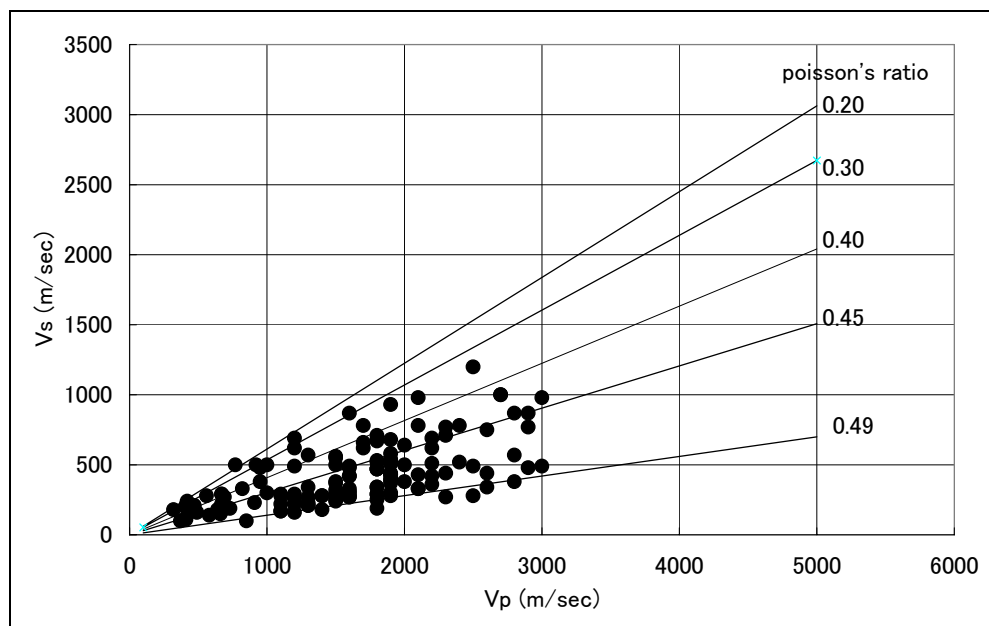


Figure 3-26 Distribution of Poisson's Ratio

(2) Vs of Soils

The frequency distributions of observed Vs for each classified unit are shown in Figure 3-27. 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 3-15.

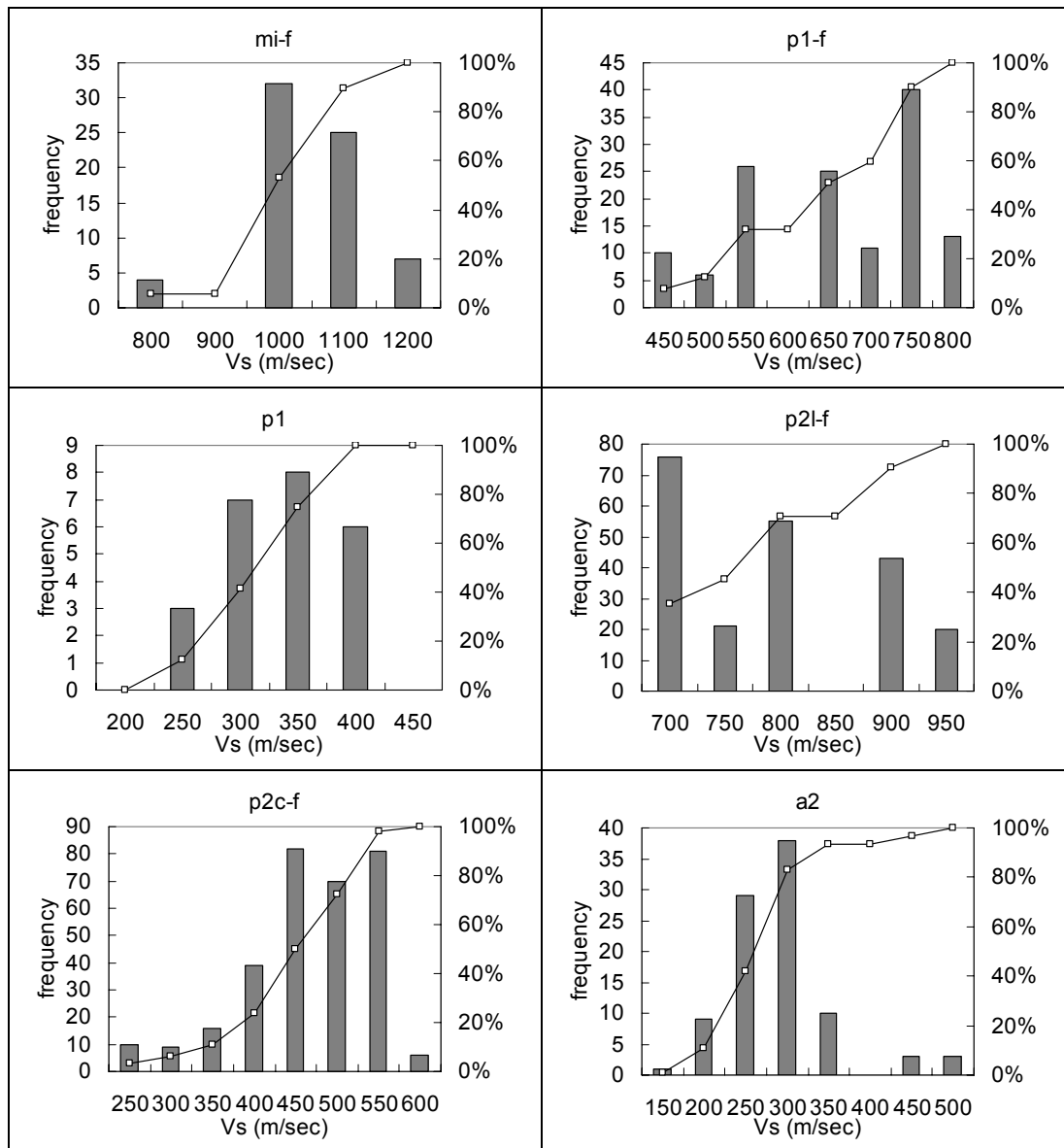


Figure 3-27 Frequency Distribution of S Wave Velocity

Table 3-15 S Wave Velocity of Geological Layers (1)

Symbol	S Wave Velocity (m/sec)
a2	250
p2c-f	450
p2l-f	770
p1	310
p1-f	630
mi	490
mi-f	1030

Characteristics of S wave velocity of soils are as follows:

- The velocity in the “mi-f (schist)” is the greatest. This observation suggests that “mi-f” can be used as engineering seismic bedrock, however this layer is not found in the southern part of the study area.
- The velocity in the Astian layer (p2c-f, p2l-f) varies greatly from site to site. The velocity of fresh calcareous sand stone (p2l-f) is higher than that of the Plaisancian layer.
- The difference of S wave velocity is the key information to decide whether it is weathered or not for “p1” and “mi”.

(3) Correlation between Vs and N Value

It is well known that S wave velocity and N value have a good correlation. Figure 3-28 shows the relationship between observed S wave velocity by PS logging and N value by standard penetration test at the same point. The estimated correlation function and the widely applied function in Japan are also shown in this figure and these show similar relationships.

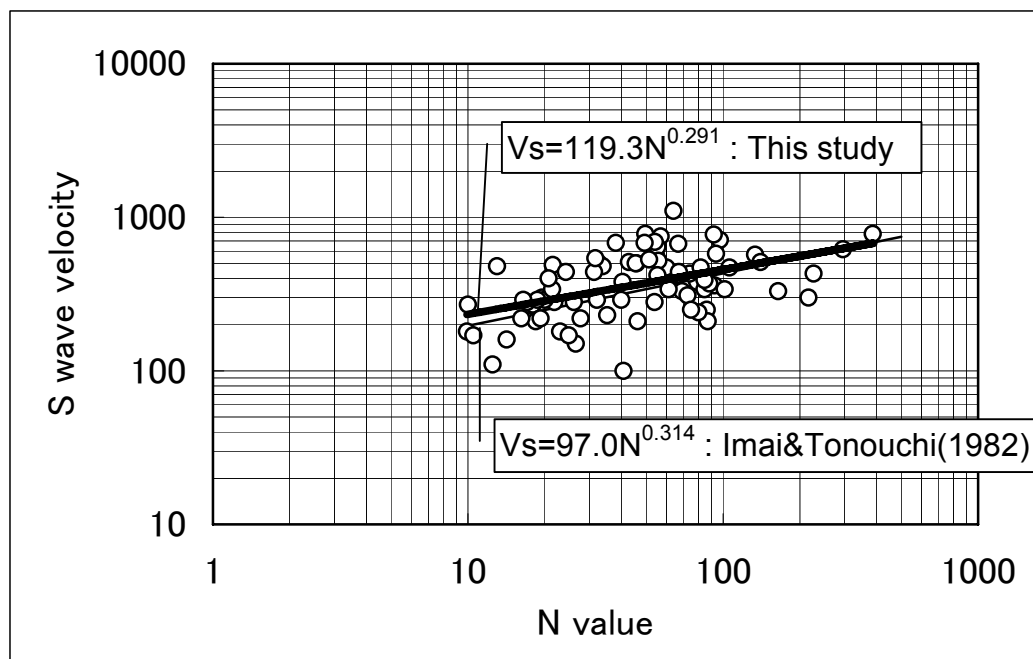


Figure 3-28 Correlation between S Wave Velocity and N Value

The layers for which S wave velocity was not determined by PS logging are ap, e, a3, q, qt, p2c and p2l. S wave velocities of these layers were determined based on the N values using the correlation formula above. Figure 3-29 shows the observed N values of these layers. The small circles show the observed data and the large circles show the average of observed data. The estimated S wave velocities are shown in Table 3-16. Since there was not enough standard penetration test data for “p2c” to evaluate the average N value, S wave velocity was assumed to be the same as “p2l”.

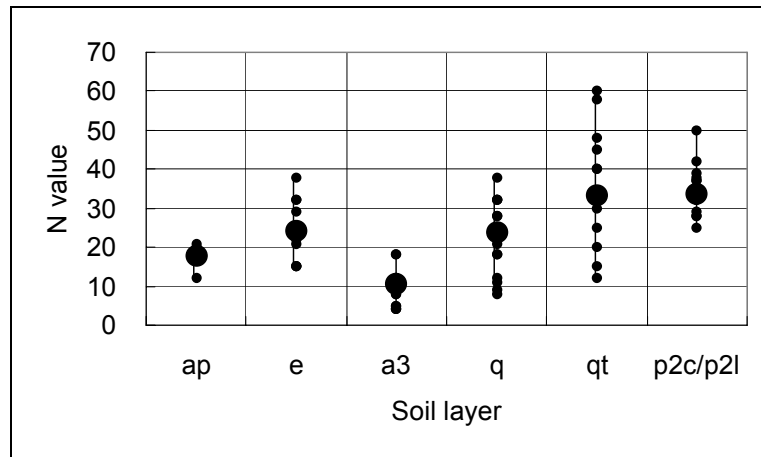


Figure 3-29 Distribution of N Values

Table 3-16 S wave Velocity of Geological Layers (2)

Symbol	N Value	S Wave Velocity (m/sec)
ap	18	275
e	24	300
a3	10	240
q	24	300
qt	33	330
p2c	-	310
p2l	27	310

[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 3-17 shows the properties of engineering geology based on the supplemental investigations. These values are used in the following hazard analysis.

Table 3-17 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 (degree)
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

Chapter 4. *Urban Condition for Microzoning*

4-1 Buildings

4-1-1 Inventory Survey

(1) Building Inventory Survey

1) General

In this chapter, an outline of a building inventory survey is described. This survey provided the basic data for the preparation of a 'Damage Function' to be used for the damage evaluation of buildings against scenario earthquakes in Wilaya Algiers.

2) Building Inventory Survey

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. There are many building types and their ratio was estimated through this survey. The flow chart of the building inventory survey is shown in Figure 4-1.

The details of the survey were discussed between the Study Team and CGS before being finally decided. Main items of the survey included:

Building zone, Usage, Owner (public or private), Structural type, Number of stories, Year constructed, 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 is shown in Figure 4-2.

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 (224km²) and population of approximately 1.8 million, and was determined after considering the duration, cost and accuracy of a survey.

Since the number of buildings 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.

(Refer to Table 4-1 Number of Buildings and Dwelling Units in Communes Chapter 4-3).

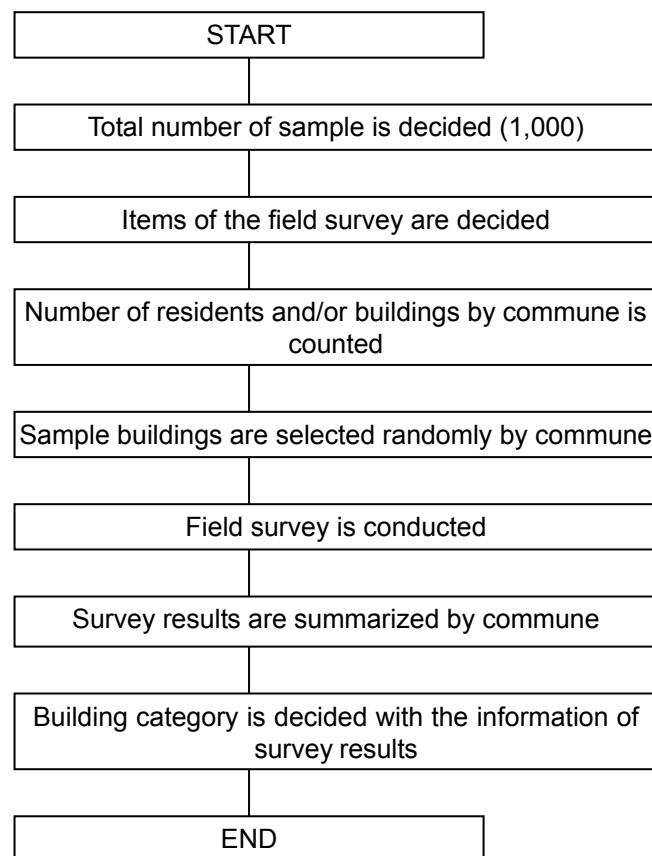


Figure 4-1 Flow Chart of Building Inventory Survey

A STUDY ON SEISMIC MICROZONING OF ALGIERS
IN THE PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

Structural Survey Sheet☐ Building☐ Facility

Date:

Time:

Surveyor:

Structure Name:

Owner of Structure: ☐ Government ☐ Community ☐ Private ☐ Co-Ownership

Name of Daira, Commune:

Structure ID No.:

Full Address:

Land Use Zoning: ☐ Urban Zone ☐ Commercial ☐ Industrial ☐ Rural ☐ Residential

Structure Usage: ☐ Office(government, wilaya, commune, others) ☐ Dwelling House ☐ Apartment House
☐ Police ☐ Hospital ☐ Fire Station ☐ University ☐ School
☐ Mosque ☐ Church ☐ Gas Station ☐ Traditional House ☐ Others

Number of Household: _____ (Apartment House only)

Structure Type: ☐ Reinforced Concrete (R.C.) Moment Frame ☐ R.C. Shear Wall without Moment Frame
☐ R.C. Moment Frame with R.C. Shear Wall ☐ Steel Moment Frame
☐ Steel Moment Frame w/Bracing ☐ Stone Masonry
☐ Brick Masonry ☐ Hollow Conc. Block ☐ Others

Year of Completion: ☐ Before 1955 ☐ 1956-1980 ☐ 1981-1998 ☐ 1999-2002 ☐ After 2003
 (Structure age: _____ Years)

Stories above Ground: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6~8 ☐ 9~12 ☐ 13~17 ☐ Over 18Crawl Space(Short Column): ☐ None ☐ YesNos. of Basement Floor: ☐ None ☐ 1 ☐ 2 ☐ 3 ☐ 4

Number of Penthouse: ☐ None ☐ 1 ☐ 2 ☐ 3 ☐ 4
 (Small projection on roof)

Plan Irregularity ☐ No Problem ☐ "H" shape ☐ "L"s. ☐ "U"s. ☐ "E"s. ☐ "T"s. ☐ "+" s.

Vertical Irregularity ☐ No Problem ☐ Major setbacks ☐ Major cantilevers ☐ Pilotis
 (Over 3 meters)

Structure Damage: ☐ None ☐ Fire: Year _____ on _____ Floor(s)
☐ Earthquake: Year _____ Damage level ☐ Light ☐ Moderte

Extension Work etc.: ☐ None ☐ Year _____ ☐ Upwards; _____ stories ☐ Lateral; _____ storiesRetrofitting Work: ☐ None ☐ Year _____ by ☐ Columns ☐ Beams ☐ Shear Wall ☐ OthersMaintenance: ☐ Good ☐ Moderate ☐ BadQuality of Construction: ☐ Engineering Structure ☐ Non-Engineering StructureSlope of Ground: In case over 30° Slope ☐ Structure on hill ☐ Structure on slope ☐ Structure at hill bottomGround Condition: ☐ Rock ☐ Stiff ☐ Soft ☐ Very soft ☐ N.A.Pounding ☐ Yes (☐ Exp.J is not Sufficient ☐ Lag of Floor) ☐ None

Influence to and from Adjacent Structures:

The structure damages to adjacent structures ☐ Yes ☐ No
 The structure is damaged by adjacent structures ☐ Yes ☐ No
 The structure supports adjacent structures ☐ Yes ☐ No
 The structure is supported by adjacent structures ☐ Yes ☐ No

Hazardous Facility ☐ Gas Station ☐ Petro Tank ☐ Gas Tank☐ Chemical TankType of storage ☐ Cylinder ☐ Sphere ☐ Underground

Capacity : _____ kl x nos.
 _____ kl x nos.
 _____ kl x nos.

Figure 4-2 Structural Survey Sheet

3) Results of Building Inventory Survey

A total of 1003 buildings were surveyed at random in the 34 communes. The number surveyed was decided based on the ratio of the population and the survey was carried out by URBANIS under the direction of JST.

A summary of the results is presented below.

(A) General

Ownership: 37% of buildings are owned by the public including co-ownership, and 62% of buildings are privately owned.

Usage: 99.7% of buildings are residential, including buildings with shops on the 1st floor. 0.3% of buildings are offices. Private houses account for more than 50%, and public houses are more than 40% of residential buildings.

(B) 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. The predominant structural type of each commune is shown in Figure 4-3.

(C) Year of Construction

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.

The year of construction of the buildings in each commune is shown in Figure 4-4.

(D) 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. The number of stories in buildings in each commune is shown in Figure 4-5. (Note: this category of number of stories was revised to, 1 to 2, 3 to 5, and, 6 and more, at a later stage.)

(E) Number of Buildings of Each Structural Category at Each Commune

The summary of the building inventory survey is shown in Table 4-1.

The structural types have been categorized based on some 36 factors, such as structural type, constructed age, and number of stories.

(F) 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.

(G) Number of Buildings

The total number of existing buildings as determined from the maps of each commune in the study area is shown in Table 4-1 Number of Buildings and Dwelling Units in the Communes Chapter 4-3.

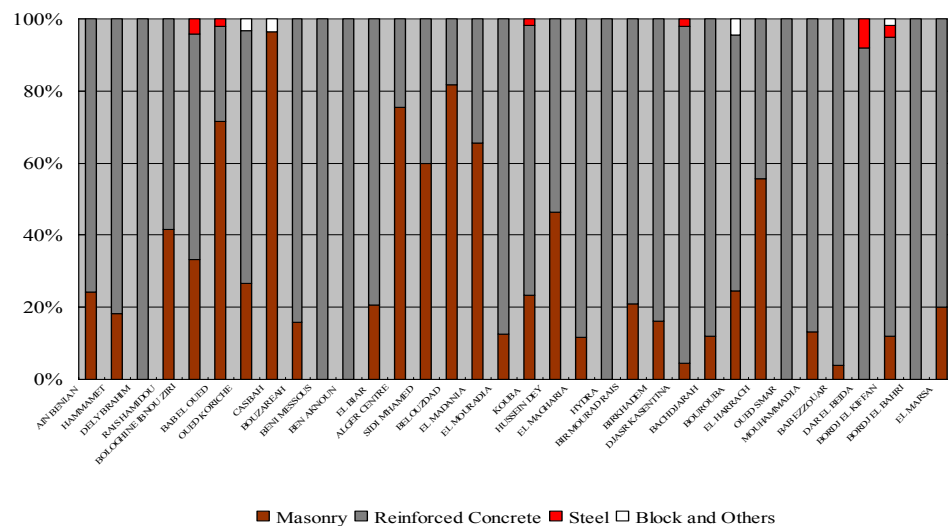


Figure 4-3 Structural Type of Buildings in Each Commune

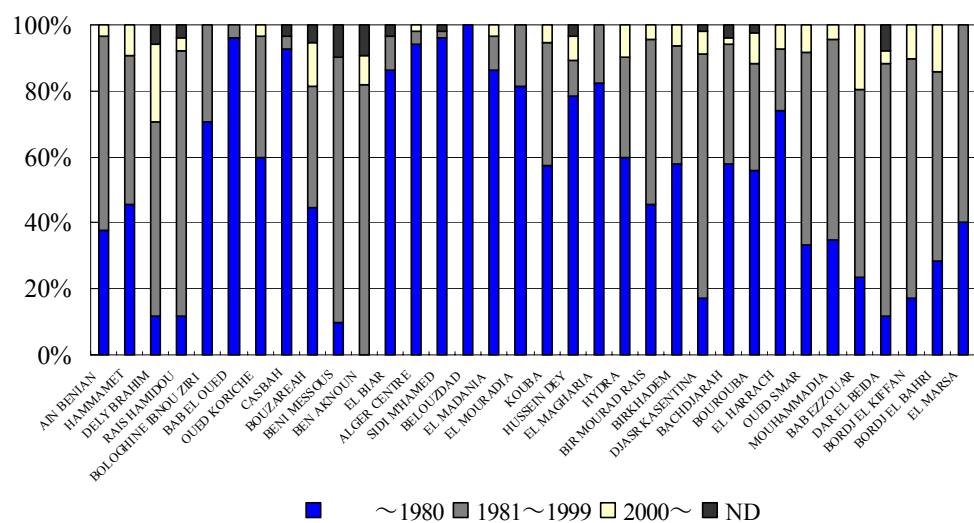


Figure 4-4 Year of Construction of the Buildings in Each Commune

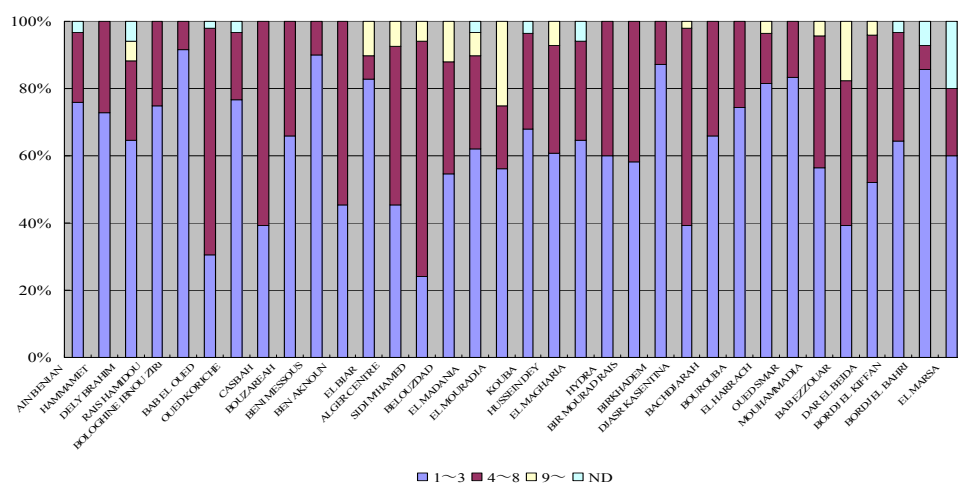


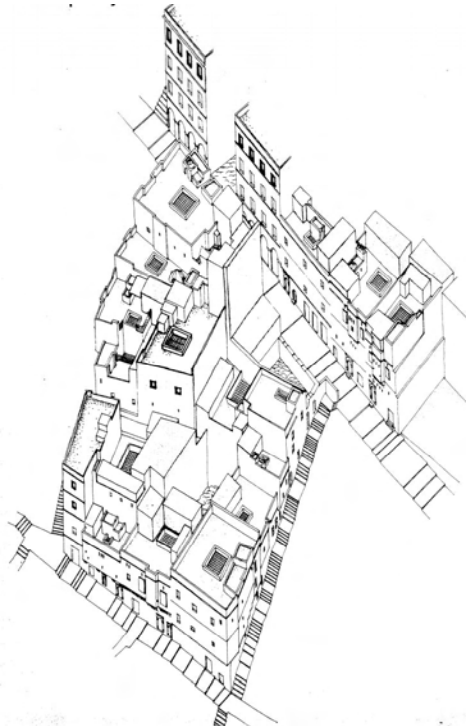
Figure 4-5 Number of Stories of the Buildings in Each Commune

4) Survey in CASBAH

A survey of CASBAH was done separately from the inventory survey through the cooperation of related organizations. It is said that some 70% of brick masonry structures in CASBAH were damaged by the big earthquake in 1716, according to verbal history.

Structures in CASBAH consist of two categories, one being the traditional houses of brick masonry (joint mortar is a mix of lime, sand and water) of Ottoman age, and the other being houses of stone masonry (joint mortar is a mix of cement, lime, sand and water) of colonial age. However the strength of joint mortar for both categories is not well known.

According to the report, “Studies for Elaboration of the Code for Repair and Strengthening of Damaged Buildings in the Region of El Asnam”, issued by Skopje University in June 1982, shear strength of lime mortar for a stone masonry building is from 0.05 N/mm^2 to 0.08 N/mm^2 . This was based on a series of experiments.



source; CASBAH Architectural and Urban Design
Survey Office

Figure 4-6 Perspective View of
Traditional Houses at
CASBAH



(Traditional houses near side, houses of
colonial age far side)

Photo 4-1 General view of CASBAH

(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, CGS and the Study Team 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. The number of important and hazardous facilities surveyed in each commune is shown in Table 4-3. These facilities are classified into 36 structural types the same as the building inventory survey. This classification is explained in Chapter 4-1-1 (1). No big storage facilities for hazardous materials were found in surveyed area except for gas stations. The results of the investigation for structure type of the 530 samples of the important and hazardous facilities are shown in Table 4-4. The major structural type of facility is reinforced concrete, which represents 75% of all structures. This is large compared to the building inventory result (65%). However, steel structures for the facilities were 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 4-2.

Table 4-2 Comparison between 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%

Table 4-3 Number of Important and Hazardous Facilities Surveyed in Each Commune

Daira	Code of Commune	Name (Use) of Facility																		Total
		Police	Fireman Station	Hospital	Clinic	Health Center	School	University	Gymnasium	Cultural Center	Library	Market	Museum	Mosque	Church	Urban Safety Department	Leisure youth house	Governmental Office	Gas Station	
I	1644	1	1	0	1	0	4	0	1	0	1	0	0	1	0	0	0	1	2	13
	1624	1	1	1	0	1	4	0	1	1	0	0	0	1	0	0	0	1	1	13
	1623	1	0	0	1	0	4	0	0	1	0	1	0	1	0	1	0	1	2	13
II	1625	1	0	0	0	0	4	0	1	0	0	0	0	1	0	0	1	1	1	10
	1606	2	1	1	2	1	6	0	0	0	0	0	0	2	2	0	0	2	1	18
	1605	2	1	1	0	2	5	0	0	2	0	1	0	2	0	0	0	2	2	20
	1608	2	1	1	1	2	6	0	0	0	0	0	0	2	0	0	0	1	2	18
	1607	1	0	1	1	1	5	0	0	1	0	0	1	3	0	1	0	1	0	16
III	1611	3	0	0	0	2	5	1	1	0	0	0	0	2	0	0	1	2	0	17
	1632	0	1	1	0	0	4	0	0	1	0	0	0	2	0	1	1	2	0	13
	1622	1	0	1	1	0	7	1	1	0	1	0	0	1	0	0	0	2	1	17
	1610	2	0	2	0	0	6	0	1	1	0	1	0	2	0	0	0	1	3	19
IV	1601	1	1	0	0	2	5	2	1	1	1	0	0	2	0	0	0	4	2	22
	1602	1	1	2	1	0	6	0	1	1	0	1	0	2	0	0	0	3	2	21
	1627	1	0	3	0	0	6	0	1	0	1	0	1	2	0	0	0	1	2	18
	1603	1	0	2	0	0	5	0	1	1	1	0	0	2	0	1	0	1	2	17
V	1604	1	0	1	0	1	6	0	1	1	0	0	0	2	0	1	0	2	2	18
	1618	1	1	1	0	1	6	2	1	0	0	1	0	2	0	1	1	1	2	22
	1617	1	0	1	0	2	7	0	0	1	0	0	0	2	0	0	0	2	3	19
	1631	1	0	0	1	1	6	1	1	0	0	0	0	2	0	0	0	2	2	17
VI	1628	1	1	0	1	0	7	0	1	0	0	0	0	2	0	0	0	3	3	19
	1609	1	1	0	1	0	4	0	1	0	1	0	0	2	0	1	0	2	2	16
	1612	1	0	0	0	1	4	0	1	1	0	0	0	1	0	0	0	2	2	13
	1626	1	0	0	0	1	3	0	1	0	0	0	0	1	0	0	1	1	2	11
VII	1619	1	0	1	0	0	4	0	0	1	0	1	0	1	0	0	0	1	2	12
	1616	1	0	1	0	0	4	0	1	1	0	0	0	1	0	0	0	1	2	12
	1613	1	1	2	0	0	4	0	1	1	0	0	0	1	0	1	0	2	2	16
	1615	1	0	0	0	1	4	2	1	1	0	0	0	1	0	1	0	1	1	14
VIII	1629	1	0	0	0	1	4	0	1	1	0	0	0	1	0	0	0	1	2	12
	1621	1	1	0	0	1	4	1	1	0	0	0	0	1	0	1	1	2	1	15
	1620	1	1	0	0	1	4	0	1	1	0	0	0	1	0	1	0	1	1	13
	1630	1	0	0	0	1	5	0	1	0	0	0	0	1	0	1	0	1	2	13
	1639	1	0	0	0	1	4	0	1	1	0	0	0	1	0	1	0	1	2	13
Total		39	14	23	11	25	165	10	26	21	6	6	2	52	2	13	6	53	56	530

Note 1. Daira: I: CHERAGA, II: BAB EL OUD, III: BOUZAREAH, IV: SIDI M'HAMED, V: HUSSEIN DAY, VI: BIR MOURAD RAIS, VII: EL HARRACH, VIII: DAR EL BEIDA

2. Code/Name of Commune: 1644/AIN BENIAN, 1624/HAMMAMET, 1623/DELY BRAHIM, 1625/RAIS HAMIDOU, 1606/BOLOGHINE IBNOU ZIRI, 1605/BAB EL OUED, 1608/OUED KORICHE, 1607/CASBAH, 1611/BOUZAREAH, 1632/BENI MESSOUS, 1622/BEN AKNOUN, 1610/EL BIAR, 1601/ALGER CENTRE, 1602/SIDI M'HAMED, 1627/EL MOURADIA, 1603/EL MADANIA, 1604/BELOUZAD, 1618/KOUBA, 1617/HUSSEIN DEY, 1631/EL MAGHARIA, 1628/HYDRA, 1609/BIR MOURAD RAIS, 1612/BIRKHADEM, 1626/DJASR KASENTINA, 1619/BACHDJARAH, 1616/BOUROUBA, 1613/EL HARRACH, 1615/OUED SMAR, 1629/MOUHAMMADIA, 1621/BAB EZZOUAR, 1620/DAR EL BEIDA, 1630/BORDJ EL KIFFAN, 1639/BORDJ EL BAHRI, 1640/EL MARSA

Table 4-4 Result of Important and Hazardous Facilities Survey

Building Categories			Code Number of Commune (16--)																																				
Type/Structure		Stories	44	24	23	25	06	05	08	07	11	32	22	10	01	02	27	03	04	18	17	31	28	09	12	26	19	16	13	15	29	21	20	30	39	40	Subtotal		
1	Masonry	Simple stone (note 5)	2																																		37	Simple stone (note 5)	
2		1, 2																																			36	3, 4, 5	
3		3, 4, 5																																				2	6+
4		6+																																				8	Unreinforced Masonry of Brick
5	Unreinforced Masonry of Brick	1, 2																																				1	1, 2
6		3, 4, 5																																				1	3, 4, 5
7		6+																																				1	6+
8		1, 2																																				0	Unreinforced Masonry of Brick
9	Unreinforced Masonry of Brick	3, 4, 5																																				1	3, 4, 5
10		6+																																				0	Unreinforced Masonry of Brick
11		1, 2																																				1	1, 2
12		3, 4, 5																																				1	3, 4, 5
13	Reinforced Concrete	RC frame with pre-slab (note 6)	3	3	3	1	5	5	2	1	3	1	1	1	2	3	3	4	2	8	7	2	1	5	4													102	RC frame with pre-slab (note 6)
14		RC frame with pre-slab (note 1)	1	1	2	3	7	1	3																													68	(note 1)
15		RC frame with low-code (note 2)	3	3	2	1	2	2																														14	6+
16		RC frame with moderate code (note 3)	2	4	4	2	3	6																														71	RC frame with moderate code (note 3)
17	Reinforced Concrete	RC frame with moderate code (note 3)	1	1		1																																69	(note 2)
18		RC frame with high-code (note 4)	1																																			2	6+
19		RC frame with high-code (note 4)	1																																			11	RC frame with high-code (note 4)
20		RC frame with high-code (note 4)	1																																			8	code (note-3)
21	RC frame with high-code (note 4)	RC frame with high-code (note 4)																																				1	(note-3)
22		RC frame with high-code (note 4)																																				2	RC frame with high-code (note 4)
23		RC frame with high-code (note 4)																																				3	(note-4)
24		RC frame with high-code (note 4)																																				0	6+
25	RC frame with high-code (note 4)	RC frame with high-code (note 4)																																				2	RC frame with high-code (note 4)
26		RC frame with high-code (note 4)																																				13	RC shear
27		RC frame with high-code (note 4)																																				12	3, 4, 5
28		RC frame with high-code (note 4)																																				4	6+
29	RC frame with high-code (note 4)	RC frame with high-code (note 4)																																				7	RC frame with high-code (note 4)
30		RC frame with high-code (note 4)																																				9	3, 4, 5
31		RC frame with high-code (note 4)																																				1	6+
32		RC frame with high-code (note 4)																																				2	Steel frame
33	Steel frame	Steel frame																																				29	Steel frame
34		Steel frame																																				6	3, 4, 5
35		Steel frame																																				0	6+
36		Steel frame																																				3	Steel with
37	Steel with bracing	Steel with bracing																																				4	3, 4, 5
38		Steel with bracing																																				1	6+
39		Steel with bracing																																				3	Block and others
40		Steel with bracing																																					530

Note 1. 'Pre-Code' means buildings constructed till 1980 for public and till 1999 for private generally.

2. 'Low-Code' means buildings constructed during 1981 to 1999 for public generally or designed by RPA81 (83).

3. 'Moderate-Code' means buildings constructed during 2000 to 2002 for public and private generally or designed by RPA99.

4. 'High-Code' means buildings constructed 2003 and after for public and private or designed by RPA2003.

5. Masonry for individual house is estimated as 'simple stone' of 1 and 2 storey generally.

6. Masonry for 3, 4, 5F and 6+F is estimated as 'unreinforced masonry of stone with composite floor slab'.

7. Code and Name of Commune: 1644 AIN BENIAN, 1624 HAMMAMET, 1623 DELY BRAHIM, 1625 RAIS HAMIDOU, 1606 BOLOGHINE, 1605 BAB EL OUED, 1608 OUED KORICHE, 1607 CASBAH, 1611 BOUZAREAH, 1632 BENIME, 1622 BEN AKNOUN, 1610 EL BIAR, 1601 ALGER CENTRE, 1602 SIDI MHAMED, 1627 EL MOURADIA, 1603 EL MADANIA, 1604 HAMMA EL ANNASSER, 1618 KOUBA, 1617 HUSSEIN DEY, 1631 EL MAGHARIA, 1628 HYDRA, 1609 BIR MOURAD RAIS, 1612 BIRKHADIM, 1626 DJASR KACENTINA, 1619 BACH DJERAH, 1613 EL HARRACH, 1615 OUED SMAR, 1629 MOHAMMADIA, 1621 BAB EZZOUAR, 1620 DAR EL BEDA, 1630 BORDJ EL KIFFAN, 1639 BORDJ EL BAHRI, 1640 EL MARSA

Source: URBANIS and JST

4-1-2 Building Damage 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 ($M_s = 7.3$) struck El Asnam city in the north of Algeria. The epicenter 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. 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 summary of CTC's investigation report is shown in section 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.

1) The summary of building damage as reported by the Architectural Institute of Japan's Investigation Team

(A) Masonry buildings:

Adobe or brick masonry had basically low seismic capacity, and approximately 90% of masonry structures suffered very heavy damage.

(B) Reinforced Concrete (RC) structure buildings:

There were many kinds of usage such as dwelling houses, schools, governmental offices, hospitals, hotels, market buildings and factories etc., and most were low rise buildings.

The damage to these buildings was summarized as follows;

- a) Horizontal and/or vertical irregularity of infill wall, and Piloti.
- b) Shear failure with short columns due to a wainscot and hanging wall.
- c) Shear failure with very short columns due to semi-basement floor.
- d) Lack of seismic capacity: bending failure of 1st floor columns.
- e) Pounding due to lack of space at expansion joint.

(C) Steel structures and Wooden structures:

Most buildings suffered no damage.

(D) RC structures for elevated water tanks:

These were moderately damaged, except for one structure that totally collapsed.

2) The Summary 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 to 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 report by CTC Chlef is shown in Table 4-5.

Table 4-5 Disaster Report of El Asnam Earthquake on 10 October, 1980 by C.T.C

Magnitude (Ms) 7.3,

Damage level of Buildings

Damage Level	Number	Percentage (%)
1	442	8.58
2	1,348	26.18
3	1,393	27.05
4	943	18.31
5	951	18.47
Non use card	71	1.37
Total ^{*1}	5,148	100.00

^{*1} : Total building number is the surveyed buildings only.

Source: CTC Chlef

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

^{*1} : Total building number is the surveyed buildings only.

^{*2} : Damage Level 1&2: Green, Damage Level 3&4: Orange, Damage Level 5: Red

Source: CTC Chlef

Number of Damaged Buildings in each Usage Group











Usage Group	El Asnam		Other Areas	
	Number	%	Number	%
Houses	4,490	81.74	415	26.83
Government Offices	115	2.10	189	12.22
Social Facilities	34	0.62	51	3.30
Schools	110	2.00	345	22.30
Hospitals	22	0.40	74	4.78
Sport Facilities	15	0.27	8	0.52
Commercial Buildings	322	5.86	127	8.21
Industrial Facilities	110	2.00	111	7.17
Water Storage Facilities	12	0.22	18	1.16
Other	263	4.79	209	13.51
Total	5,493	100	1,547	100

(2) The 2003 Boumerdes Earthquake

At 19:44 (local time) on May 21, 2003, a strong earthquake ($M_w = 6.8$) struck Boumerdes city. The epicenter of the earthquake was located offshore, 7 km north of Zemmouri in Wilaya 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 inflicted.

1) Investigation 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 1800 El Asnam Earthquake case. CGS surveyed mainly in Wilaya Boumerdes, and CTC covered mainly Wilaya Algiers. All buildings at limited area and block only were investigated, that is mean not all buildings in each commune were surveyed. The structural types classified 5-types as masonry, reinforced concrete moment frame, reinforced concrete wall and steel (wooden structures were include as “others”) and others. These investigation reports by CGS analyzed in detail five types of structures and other classifications in each commune. The investigation 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. Damage numbers for each damage grade from 1 to 5 as specified by EMS-98 and damage numbers of damage grades 4+5 for each structural type in Wilaya Algiers are shown in Table 4-6, and for Wilaya Boumerdes in Table 4-7. Classification of damage to masonry and RC buildings is shown in Figure 4-7.

Classification of Damage		
	Masonry	RC Building
Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)	Hair-line cracks in very few walls. Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases. 	Fine cracks in plaster over frame members or in walls at the base. Fine cracks in partitions and infills 
Grade 2: Moderate damage (slight structural damage, moderate non-structural damage)	Cracks in many walls. Fall of fairly large pieces of plaster. Partial collapse of chimneys. 	Cracks in columns and beams of frames and in structural walls. Cracks in partition and infill walls; fall of brittle cladding and plaster. Falling mortar from the joints of wall panels. 
Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage)	Large and extensive cracks in most walls. Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls). 	Cracks in columns and beam column joints of frames at the base and at joints of coupled walls. Spalling of concrete cover, buckling of reinforced rods. Large cracks in partition and infill walls, failure of individual infill panels. 
Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)	Serious failure of walls; partial structural failure of roofs and floors 	Large cracks in structural elements with compression failure of concrete and fracture of rebars; bond failure of beam reinforced bars; tilting of columns. Collapse of a few columns or of a single upper floor. 
Grade 5: Destruction (very heavy structural damage)	Total or near total collapse 	Collapse of ground floor or parts (e. g. wings) of buildings. 

Source: EMS-98

Figure 4-7 Classification of Damage to Masonry and RC Buildings

Table 4-6 The Number of Damaged Buildings Investigated in Wilaya Algiers
due to Boumedes Earthquake (1/2)

Commune Code No.	Type of Structure	Structural Damage Level						Total
		1	2	3	4	5	4+5	
Dar El Beida 1620	Masonry	0	1	4	2	1	3	8
	RC Frame	18	3	2	4	1	5	28
	RC Wall	---	---	---	---	---	---	---
	Steel	1	0	0	0	0	0	1
Total		19	4	6	6	2	8	37
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
Ain Taya* 1638	Masonry	77	122	60	65	100	165	424
	RC Frame	112	135	60	68	13	81	388
	RC Wall	2	8	1	0	0	0	11
	Steel	11	5	71	0	2	2	89
	Others	0	0	0	0	5	5	5
Total		202	270	192	133	120	253	917
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
El Marsa 1640	Masonry	1	2	0	5	0	5	8
	RC Frame	5	2	0	1	0	1	8
	RC Wall	1	0	0	0	0	0	1
Total		7	4	0	6	0	6	17

Source: CGS

Table 4-6 The Number of Damaged Buildings Investigated in Wilaya Algiers due to Boumedes Earthquake (2/2)

Commune Code No.	Type of Structure	Building Damage Level						Total
		1	2	3	4	5	4+5	
Haraoua* 1641	Masonry	219	164	243	247	447	694	1,320
	RC Frame	333	475	178	171	71	242	1,228
	RC Wall	11	13	6	4	5	9	39
	Steel	9	8	1	0	1	1	19
	Others	2	5	10	17	69	86	103
Total		574	665	438	439	593	1,032	2,709
Rouiba* 1642	Masonry	228	289	449	417	233	650	1,616
	RC Frame	531	471	316	157	11	168	1,486
	RC Wall	4	66	7	11	0	11	88
	Steel	13	18	15	7	0	7	53
	Others	18	30	38	43	7	50	136
Total		794	874	825	635	251	886	3,379
Masonry RC Frame RC Wall Steel Others	Masonry	84	126	155	141	68	209	574
	RC Frame	448	328	337	362	58	420	1,533
	RC Wall	9	10	5	7	0	7	31
	Steel	0	7	5	1	0	1	13
	Others	0	3	10	3	0	3	16
Total		541	474	512	514	126	640	2,167
Note: Marked “*”: This commune is located outside of the Study Area.								

Source: CGS

Table 4-7 The Number of Damaged Buildings Investigated in Wilaya Boumerdes (located in out of Study Area) due to Boumedes Earthquake (1/4)

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

Source: CGS

Table 4-7 The Number of Damaged Buildings Investigated in Wilaya Boumerdes
(located in out of Study Area) due to Boumedes Earthquake (2/4)

Name of Commune	Type of Structure	Structural Damage Level						Total
		1	2	3	4	5	4+5	
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
Tidjelabine	Masonry	0	124	102	66	21	87	313
	RC Frame	0	267	141	74	17	91	499
	RC Wall	0	16	5	3	0	3	24
	Steel	0	2	1	2	0	2	5
	Others	0	1	0	1	0	1	2
Total		0	410	249	146	38	184	843
Corso	Masonry	1	354	243	108	69	177	775
	RC Frame	1	545	202	106	61	167	915
	RC Wall	0	5	3	0	3	3	11
	Steel	0	2	1	1	3	4	7
	Others	0	10	12	2	8	10	32
Total		2	916	461	217	144	361	1,740
Lagata	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
Boudeouaou	Masonry	0	584	395	120	212	332	1,311
	RC Frame	1	1,176	429	125	99	224	1,830
	RC Wall	0	32	9	5	2	7	48
	Steel	0	7	19	1	0	1	27
	Others	0	5	9	7	23	30	44
Total		1	1,804	861	258	336	594	3,260

Source: CGS

Table 4-7 The Number of Damaged Buildings Investigated in Wilaya Boumerdes
(located in out of Study Area) due to Boumedes Earthquake (3/4)

Name of Commune	Type of Structure	Structural Damage Level						Total
		1	2	3	4	5	4+5	
El Kharouba	Masonry	1	198	28	27	0	27	254
	RC Frame	0	184	21	1	0	1	206
	RC Wall	0	1	1	0	0	0	2
	Others	0	2	1	0	0	0	3
Total		1	385	51	28	0	28	465
Bouzegza Keddara	Masonry	0	22	7	7	5	12	41
	RC Frame	0	198	62	10	0	10	270
	RC Wall	0	2	1	0	0	0	3
	Steel	0	4	0	1	0	1	5
Total		0	226	70	18	5	23	319
Boudeouaou El Bahri	Masonry	0	120	31	15	6	21	172
	RC Frame	0	83	20	15	7	22	125
	RC Wall	0	1	0	0	0	0	1
	Others	0	1	1	3	0	3	5
Total		0	205	52	33	13	46	303
Ouled Hedadj	Masonry	1	144	78	49	63	112	335
	RC Frame	1	401	183	74	29	103	688
	RC Wall	0	7	6	5	2	7	20
	Steel	0	2	0	0	0	0	2
	Others	0	1	5	3	2	5	11
Total		2	555	272	131	96	227	1,056
Souk El Hed	Masonry	0	152	79	37	13	50	281
	RC Frame	2	78	17	8	1	9	106
	RC Wall	0	0	1	1	0	1	2
	Steel	0	1	0	0	0	0	1
	Others	0	0	0	0	3	3	3
Total		2	231	97	46	17	63	393
Beni Amrane	Masonry	0	264	185	325	103	428	877
	RC Frame	0	789	161	44	6	50	1,000
	RC Wall	0	19	8	1	1	2	29
	Steel	0	4	0	1	1	2	6
	Others	0	0	7	4	5	9	16
Total		0	1,076	361	375	116	491	1,928

Source: CGS

Table 4-7 The Number of Damaged Buildings Investigated in Wilaya Boumerdes
(located in out of Study Area) due to Boumedes Earthquake (4/4)

Name of Commune	Type of Structure	Structural Damage Level						Total
		1	2	3	4	5	4+5	
Isser	Masonry	1	540	315	20	55	75	931
	RC Frame	0	572	240	32	10	42	854
	RC Wall	0	13	17	0	1	1	31
	Steel	0	6	0	0	0	0	6
	Others	0	9	9	1	1	2	20
Total		1	1,140	581	53	67	120	1,842
Chabet El Amer	Masonry	1	311	194	11	22	33	539
	RC Frame	0	478	137	4	0	4	619
	RC Wall	0	15	2	1	0	1	18
	Steel	0	19	23	0	0	0	42
	Others	0	13	4	0	2	2	19
Total		1	836	360	16	24	40	1,237
Si Mustapha	Masonry	0	199	119	1	6	7	325
	RC Frame	0	145	74	1	1	2	221
	RC Wall	0	4	3	0	0	0	7
	Others	0	2	3	0	1	1	6
Total		0	350	199	2	8	10	559
Hamadi	Masonry	0	77	47	0	0	0	124
	RC Frame	0	131	65	0	0	0	196
	RC Wall	0	1	0	0	0	0	1
	Steel	0	1	2	0	0	0	3
	Others	0	1	0	0	0	0	1
Total		0	211	114	0	0	0	325
Ouled Moussa	Masonry	0	224	151	0	0	0	375
	RC Frame	0	286	125	0	0	0	411
	RC Wall	0	41	6	0	0	0	47
	Others	0	0	4	0	0	0	4
Total		0	551	286	0	0	0	837

Source: CGS

Building damage map in Wilaya Boumerdes and 3 communes of the eastern part of Algiers based on building numbers is shown in Figure 4-8.

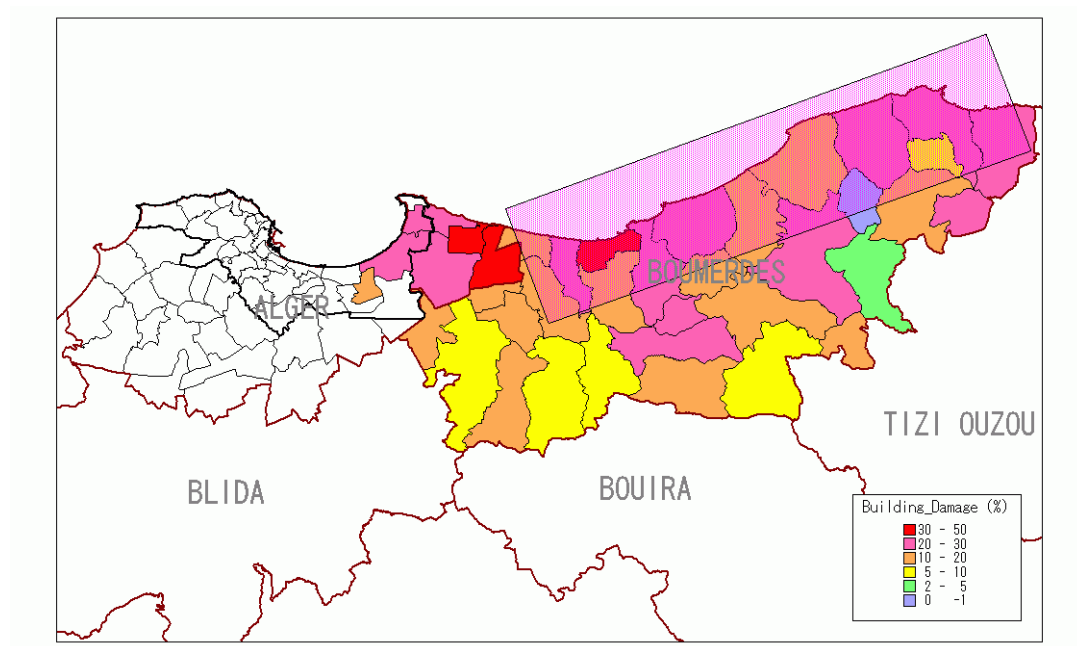


Figure 4-8 Building Damage Map for Wilaya Boumerdes and 3 Communes of the eastern part of Algiers Due to 2003 Boumerdes Earthquake Based on Building Numbers

JST obtained the summary of damage data by dwelling unit for the communes in the study area due to the 2003 Boumerdes Earthquake. This is shown in Table 4-8 and Table 4-9.

Table 4-8 Summary of Damage by Dwelling Unit in Communes in the Study Area
Due to 2003 Boumerdes Earthquake

Commune		Green		Orange		Red		Total	MSK
Code	Name	Nos.	%	Nos.	%	Nos.	%		
1644	AIN BENIAN	7,518	92.7%	494	6.1%	96	1.2%	8,108	6.7
1624	HAMMAMET	3,722	95.0%	165	4.2%	29	0.7%	3,916	6.4
1623	DELY BRAHIM	5,605	98.3%	63	1.1%	33	0.6%	5,701	6.7
1625	RAIS HAMIDOU	7,475	97.2%	167	2.2%	50	0.7%	7,692	6.6
1606	BOLOGHINE IBNOU ZIRI	5,613	94.1%	349	5.8%	5	0.1%	5,967	6.6
1605	BAB EL OUED	9,444	79.2%	2,320	19.5%	158	1.3%	11,922	6.7
1608	Oued KORICHE	2,055	72.3%	614	21.6%	173	6.1%	2,842	6.8
1607	CASBAH	6,942	84.3%	1,036	12.6%	256	3.1%	8,234	6.7
1611	BOUZAREAH	10,443	99.3%	58	0.6%	19	0.2%	10,520	6.5
1632	BENI MESSOUS	3,567	89.9%	401	10.1%	0	0.0%	3,968	6.7
1622	BEN AKNOUN	2,615	86.2%	415	13.7%	5	0.2%	3,035	6.8
1610	EL BIAR	7,452	92.7%	388	4.8%	196	2.4%	8,036	7.0
1601	ALGER CENTRE	16,329	92.0%	1,414	8.0%	11	0.1%	17,754	6.8
1602	SIDI M'HAMED	12,075	77.5%	3,137	20.1%	367	2.4%	15,579	6.9
1627	EL MOURADIA	4,335	48.6%	2,859	32.1%	1,721	19.3%	8,915	7
1603	EL MADANIA	6,723	94.8%	300	4.2%	66	0.9%	7,089	7.1
1604	BELOUZDAD	4,323	97.3%	110	2.5%	9	0.2%	4,442	7.1
1618	KOUBA	16,160	95.2%	535	3.2%	275	1.6%	16,970	7.2
1617	HUSSEIN DEY	4,999	70.4%	1,582	22.3%	524	7.4%	7,105	7.4
1631	EL MAGHARIA	4,463	94.4%	123	2.6%	143	3.0%	4,729	7.5
1628	HYDRA	5,361	93.3%	382	6.7%	0	0.0%	5,743	6.8
1609	BIR MOURAD RAIS	8,283	98.5%	55	0.7%	63	0.8%	8,401	6.9
1612	BIRKHADEM	8,686	97.7%	124	1.4%	76	0.9%	8,886	6.9
1626	DJASR KASENTINA	18,203	98.4%	264	1.4%	29	0.2%	18,496	7.3
1619	BACH DJERAH	11,253	89.3%	1,121	8.9%	231	1.8%	12,605	7.5
1616	BOUROUBA	8,576	92.5%	610	6.6%	88	0.9%	9,274	7.6
1613	EL HARRACH	5,333	79.1%	1,104	16.4%	308	4.6%	6,745	7.7
1615	Oued SMAR	2,897	97.5%	71	2.4%	2	0.1%	2,970	7.8
1629	MOHAMMADIA	5,905	81.7%	1,254	17.4%	67	0.9%	7,226	7.7
1621	BAB EZZOUAR	1,688	19.6%	6,907	80.2%	22	0.3%	8,617	7.9
1620	DAR EL BEIDA	5,932	70.9%	2,369	28.3%	66	0.8%	8,367	8.2
1630	BORDJ EL KIFFAN	11,803	72.5%	4,073	25.0%	398	2.4%	16,274	8.2
1639	BORDJ EL BAHRI	2,813	64.9%	1,376	31.7%	147	3.4%	4,336	8
1640	EL MARSA	1,335	91.9%	116	8.0%	1	0.1%	1,452	7.9
Total		239,926	85.1%	36,356	12.9%	5,634	2.0%	281,916	

Source: CTC Chlef, except MSK by CGS and JST

Note: Damage survey by CTC Chlef shows the data of dwelling units (lodgments) and not the data of buildings.

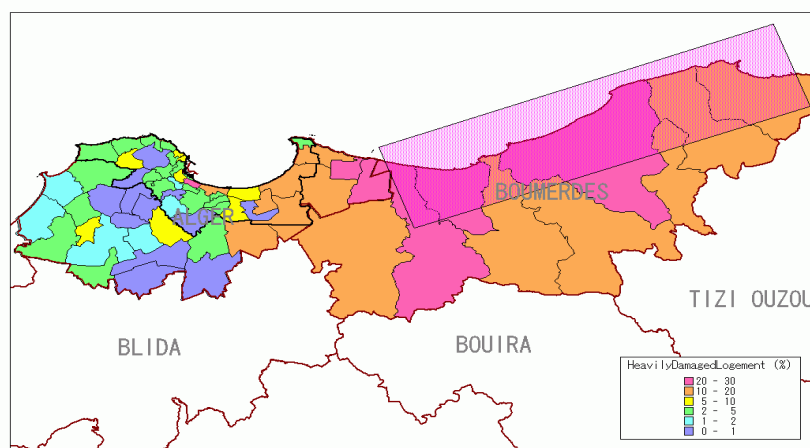
Table 4-9 Classification of Damage by Dwelling Unit in Algiers
Due to 2003 Boumerdes Earthquake

	Green		Orange		Red		Total
	Nos.	%	Nos.	%	Nos.	%	
ROUIBA	9,931	48.2%	8,965	43.5%	1,729	8.3%	20,625
BARAKI	26,998	86.5%	1,464	4.7%	2,748	8.8%	31,210
BIR MOURAD RAIS	44,848	97.1%	909	2.0%	417	0.9%	46,174
BOUZAREAH	24,076	94.2%	1,262	4.9%	220	0.9%	25,558
CHERAGA	28,556	95.2%	1,163	3.9%	284	0.9%	30,003
DAR EL BEIDA	32,407	63.5%	17,554	34.4%	1,065	2.1%	51,026
DRARIA	22,253	99.3%	82	0.4%	68	0.3%	22,403
EL HARRACH	28,058	88.8%	2,906	9.2%	629	2.0%	31,593
HUSSEIN DEY	29,958	79.4%	5,099	13.5%	2,663	7.1%	37,720
SIDI M'HAMED	39,450	87.9%	4,961	11.1%	453	1.0%	44,864
ZERALDA	15,178	95.4%	603	3.8%	128	0.8%	15,909
BIRTOUTA	7,161	98.1%	126	1.7%	14	0.2%	7,301
BAB EL OUED	31,528	86.0%	4,486	12.2%	642	1.8%	36,656
Total Wilaya Algiers	340,402	84.9%	49,580	12.4%	11,060	2.7%	401,042
Study Area: 34 Commune	239,926	85.10%	36,356	12.90%	5,634	2.00%	281,916

Source: CTC Chlef

Note: Damage survey by CTC Chlef shows the data of dwelling units (lodgments) and not the data of buildings.

Building damage map in Wilaya Algiers and Wilaya Boumerdes based on dwelling units is shown in Figure 4-9.



Source: CTC Chlef

Figure 4-9 Building Damage Map for Wilaya Algiers and Wilaya 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. It sent a rescue team (61 persons) on May 22nd, a medical care team (22 persons) on May 25th, and an expert team (7 persons) on June 12th.

This investigation report described the earthquake with peak ground acceleration at seismography points, and an outline of building damage at Wilaya Boumerdes and Wilaya Algiers with photographs, and summarized the characteristics of building damage as follows;

(A) The characteristics of building damage were almost the same as from the 1980 El Asnam Earthquake.

(B) RC moment frame structures with infill brick walls were heavily damaged;

A shear failure or bending failure occurred at both the top and the bottom of slender columns in lower stories. This damage was probably inflicted by the collapse of brick walls due to the large amount of deflection of the frames. Additional possible causes include slender columns, piloti structures, low quality of concrete and construction techniques i.e. no shear reinforcements in connection zones, rusting of main re-bars etc.

(C) RC moment frames with very short columns due to semi-basement floors;

Shear failure occurred at short columns for building equipment floors.

(D) RC structures with shear walls;

This structural system was applied mainly in low-to-mid-rise apartment houses. Since this type of structure was confirmed to have good seismic performance, little damage was found even in old buildings.

(E) It was pointed out that most of the damaged buildings were constructed before 1980 when the anti-seismic design became popular. Many similar old buildings need to be checked for seismic capacity and repaired as occasion demands and retrofit the existing buildings that are not found to be earthquake-resistant by these seismic evaluations. They exist in all cities in Algeria in addition to the area damaged this most recent time.

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, which was compiled by the JST, are shown in Figure 4-10. 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.

Table 4-10 shows road lengths by road class for each commune in the Study Area based on Figure 4-10. 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, which was compiled by the JST, and the road length by classification for each commune are shown in Figure 4-11 and Table 4-11, respectively. The commune that has the longest narrow road ($W \leq 4$ m) is RAIS HAMIDOU and the longest wide road ($W > 12$ m) is OUED SMAR.

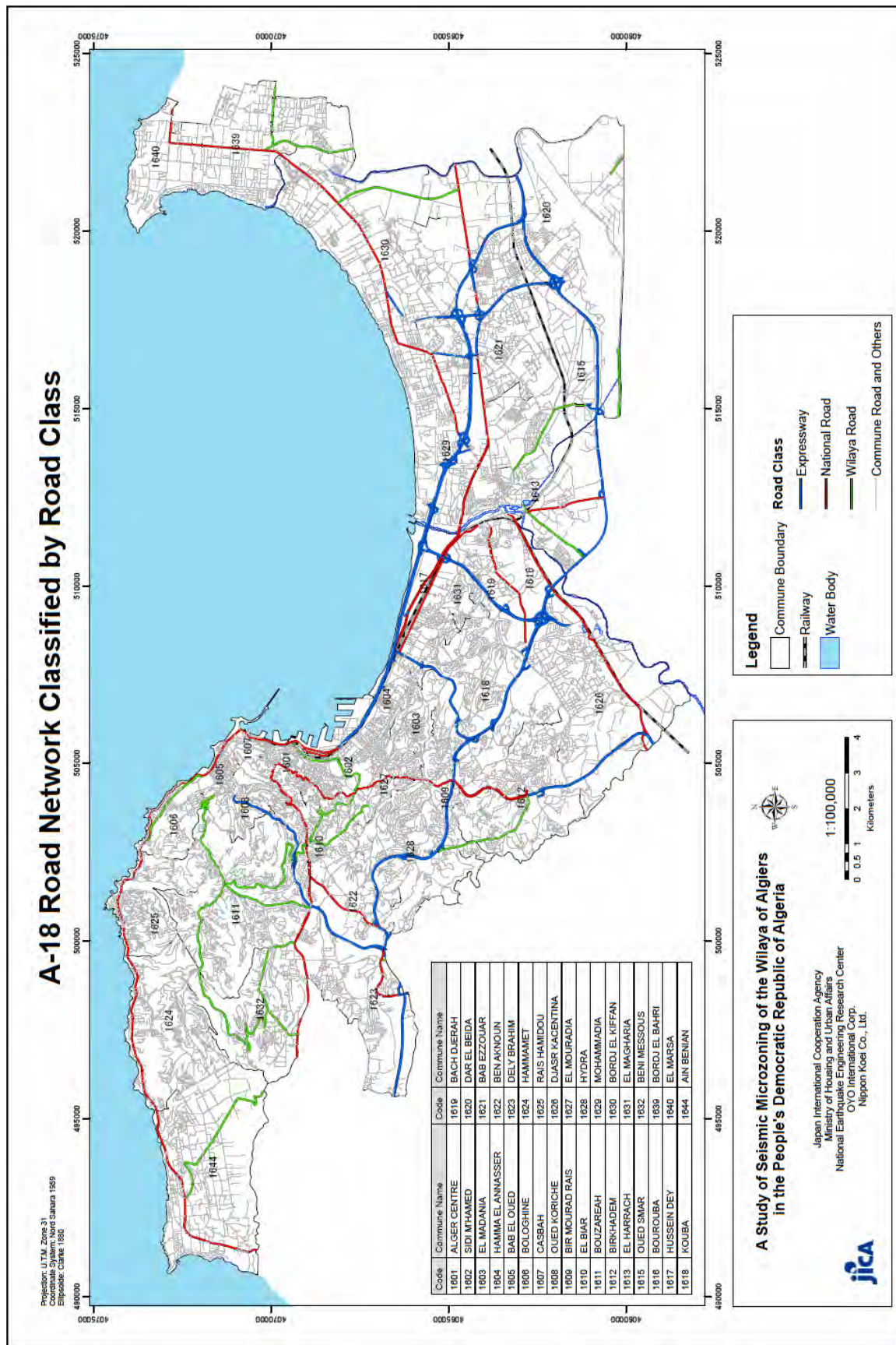
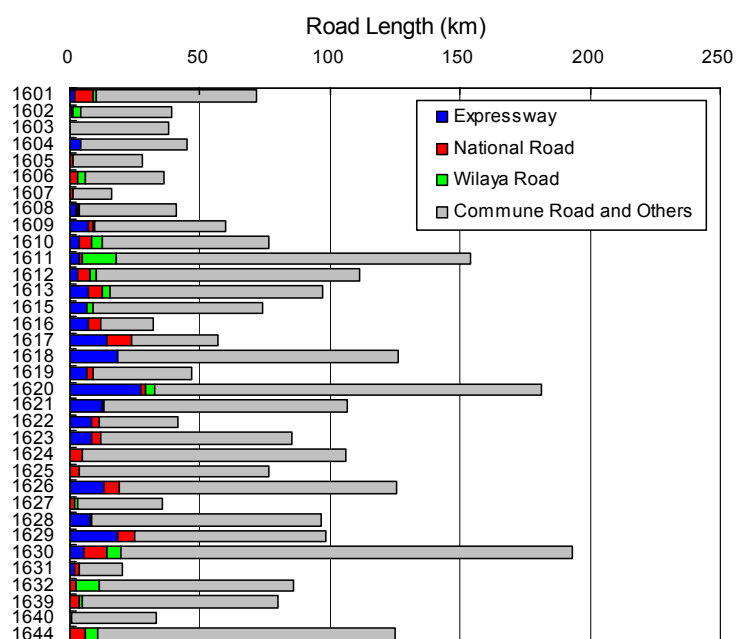


Figure 4-10 Road Networks by Road Class

Table 4-10 Road Length by Road Class for Each Commune

Commune		Length (km)				
Code	Name	Expressway	National Roads	Wilaya Roads	Commune and Other Roads	Total
1601	ALGER CENTRE	1.74	6.96	1.16	61.66	71.52
1602	SIDI M'HAMED	0.75	0.65	2.68	34.88	38.96
1603	EL MADANIA	0.28	-	-	37.63	37.91
1604	HAMMA EL ANNASSER	4.43	-	-	40.54	44.97
1605	BAB EL OUED	-	1.29	0.02	26.77	28.08
1606	BOLOGHINE	-	3.06	3.09	29.98	36.13
1607	CASBAH	-	1.31	-	14.89	16.20
1608	OUED KORICHE	2.42	0.56	0.57	37.04	40.59
1609	BIR MOURAD RAIS	7.23	1.59	0.76	50.37	59.95
1610	EL BIAR	3.77	4.44	4.41	63.56	76.18
1611	BOUZAREAH	3.80	0.97	12.76	136.54	154.07
1612	BIRKHADEM	2.90	4.73	2.35	101.23	111.21
1613	EL HARRACH	7.14	5.35	3.00	81.90	97.39
1615	OUED SMAR	6.63	0.08	2.44	64.87	74.02
1616	BOUROUBA	7.08	4.68	-	20.16	31.92
1617	HUSSEIN DEY	14.33	9.28	-	33.42	57.03
1618	KOUBA	18.42	-	-	107.67	126.09
1619	BACH DJERAH	6.59	2.49	-	37.90	46.98
1620	DAR EL BEIDA	26.97	1.90	3.72	148.43	181.02
1621	BAB EZZOUAR	12.34	0.63	-	93.96	106.93
1622	BEN AKNOUN	8.09	2.91	-	30.39	41.39
1623	DELY BRAHIM	8.47	3.41	0.13	73.23	85.24
1624	HAMMAMET	-	4.64	-	101.67	106.31
1625	RAIS HAMIDOU	-	3.46	0.07	72.72	76.25
1626	DJASR KACENTINA	13.27	5.92	-	106.43	125.62
1627	EL MOURADIA	-	1.99	0.73	33.06	35.78
1628	HYDRA	7.82	0.04	0.30	88.51	96.67
1629	MOHAMMADIA	18.49	6.54	-	73.25	98.28
1630	BORDJ EL KIFFAN	5.05	9.21	5.47	173.67	193.40
1631	EL MAGHARIA	2.02	1.27	-	16.77	20.06
1632	BENI MESSOUS	-	2.25	9.03	74.57	85.85
1639	BORDJ EL BAHRI	-	3.43	1.29	75.17	79.89
1640	EL MARSA	-	0.52	-	32.85	33.37
1644	AIN BENIAN	-	5.98	4.86	114.10	124.94
Total		190.03	101.54	58.84	2,289.79	2,640.20



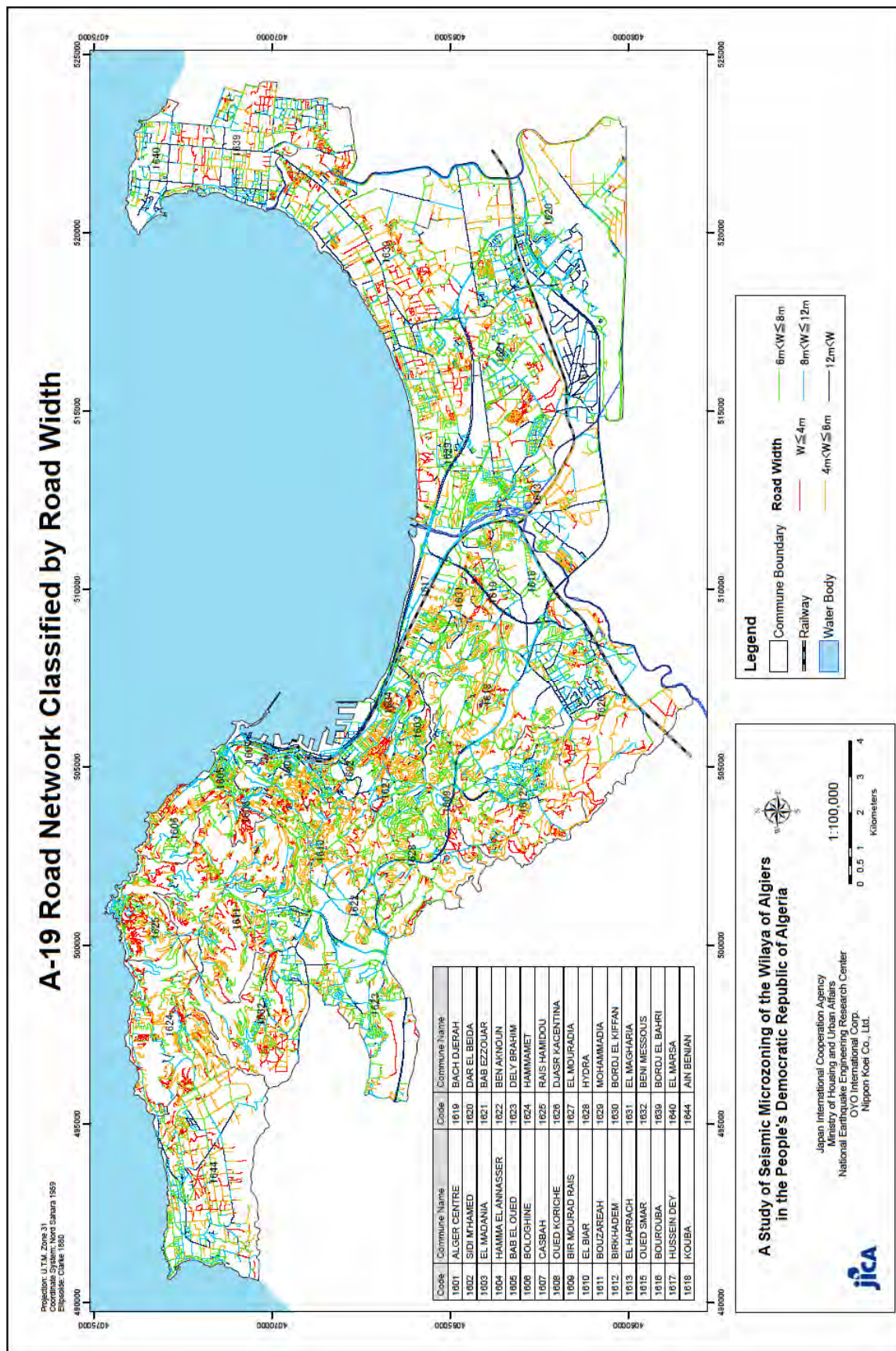
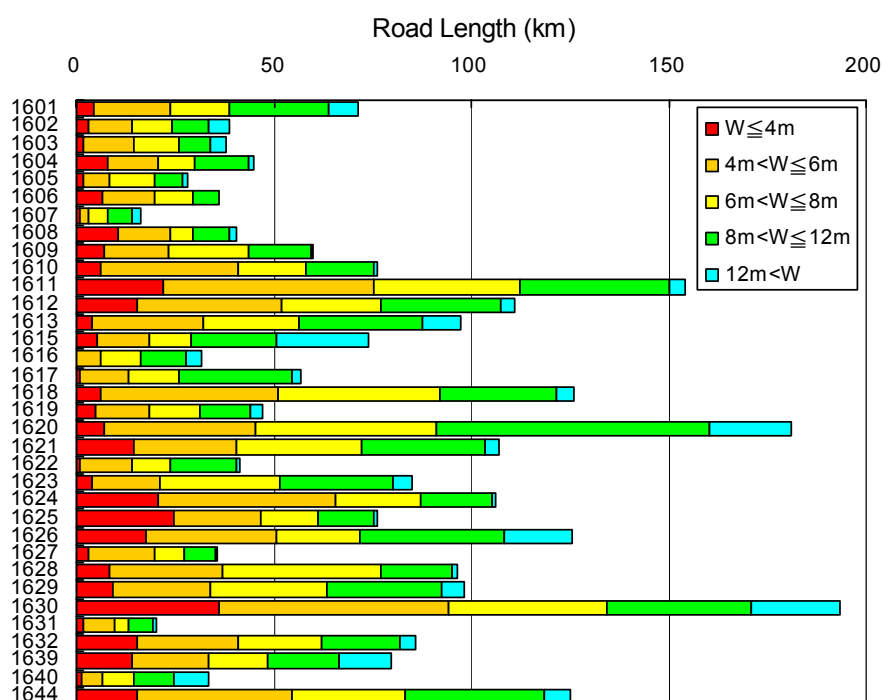


Figure 4-11 Road Network classified by Road Width

Table 4-11 Road Length by Road Width for Each Commune

Commune		Length (km)					Total
Code	Name	W≤4m	4m<W≤6m	6m<W≤8m	8m<W≤12m	12m<W	
1601	ALGER CENTRE	4.35	19.53	14.95	25.19	7.50	71.52
1602	SIDI M'HAMED	3.05	11.05	10.04	9.54	5.28	38.96
1603	EL MADANIA	1.77	12.84	11.44	7.78	4.08	37.91
1604	HAMMA EL ANNASSER	7.71	13.03	9.23	13.80	1.20	44.97
1605	BAB EL OUED	1.84	6.60	11.18	7.28	1.18	28.08
1606	BOLOGHINE	6.54	13.15	9.75	6.60	0.09	36.13
1607	CASBAH	0.95	2.05	4.88	6.04	2.28	16.20
1608	OUED KORICHE	10.46	13.31	5.90	8.94	1.98	40.59
1609	BIR MOURAD RAIS	7.14	16.10	20.42	15.71	0.58	59.95
1610	EL BIAR	6.31	34.74	17.17	17.05	0.91	76.18
1611	BOUZAREAH	21.94	53.58	36.90	38.02	3.63	154.07
1612	BIRKHADEM	15.47	36.65	24.97	30.44	3.68	111.21
1613	EL HARRACH	3.94	28.41	23.87	31.32	9.85	97.39
1615	OUED SMAR	5.29	13.11	10.73	21.72	23.17	74.02
1616	BOUROUBA	0.05	5.98	10.42	11.40	4.07	31.92
1617	HUSSEIN DEY	0.96	12.44	12.65	28.79	2.19	57.03
1618	KOUBA	5.98	44.92	41.09	29.78	4.32	126.09
1619	BACH DJERAH	4.94	13.49	13.03	12.69	2.83	46.98
1620	DAR EL BEIDA	6.90	38.46	45.97	69.23	20.46	181.02
1621	BAB EZZOUAR	14.40	26.08	31.63	31.36	3.46	106.93
1622	BEN AKNOUN	1.02	12.95	9.88	16.70	0.84	41.39
1623	DELY BRAHIM	3.82	17.50	30.14	28.92	4.86	85.24
1624	HAMMAMET	20.81	44.93	21.30	18.05	1.22	106.31
1625	RAIS HAMIDOU	24.65	21.92	14.77	14.01	0.90	76.25
1626	DJASR KACENTINA	17.50	33.03	21.14	36.78	17.17	125.62
1627	EL MOURADIA	3.15	16.80	7.25	7.88	0.70	35.78
1628	HYDRA	8.56	28.28	40.11	18.28	1.44	96.67
1629	MOHAMMADIA	9.39	24.33	29.50	29.38	5.68	98.28
1630	BORDJ EL KIFFAN	36.15	58.07	40.02	36.78	22.38	193.40
1631	EL MAGHARIA	1.64	7.89	3.59	6.20	0.74	20.06
1632	BENI MESSOUS	15.63	25.55	21.01	19.91	3.75	85.85
1639	BORDJ EL BAHRI	14.05	19.24	15.21	18.19	13.20	79.89
1640	EL MARSA	1.40	5.22	7.81	10.41	8.53	33.37
1644	AIN BENIAN	15.63	38.98	28.59	35.52	6.22	124.94
Total		303.39	770.21	656.54	719.69	190.37	2,640.20



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 as shown in Figure 4-12 and Table 4-12.

Table 4-12 Number and type of Bridges by Commune

Commune		Number of Bridges				Total
Code	Name	Expressways	National Roads	Wilaya Roads	Commune and Other Roads	
1601	ALGER CENTRE	-	3	-	8	11
1602	SIDI M'HAMED	-	-	1	3	4
1603	EL MADANIA	-	-	-	1	1
1604	HAMMA EL ANNASSER	-	-	-	1	1
1605	BAB EL OUED	-	-	-	-	0
1606	BOLOGHINE	-	7	-	-	7
1607	CASBAH	-	-	-	1	1
1608	OUED KORICHE	-	-	-	1	1
1609	BIR MOURAD RAIS	2	-	-	1	3
1610	EL BIAR	-	-	-	-	0
1611	BOUZAREAH	-	-	1	-	1
1612	BIRKHADEM	-	2	-	2	4
1613	EL HARRACH	3	6	4	3	16
1615	OUED SMAR	1	-	1	1	3
1616	BOUROUBA	1	1	-	-	2
1617	HUSSEIN DEY	15	-	-	2	17
1618	KOUBA	5	-	-	4	9
1619	BACH DJERAH	3	-	-	2	5
1620	DAR EL BEIDA	7	5	-	2	14
1621	BAB EZZOUAR	1	-	-	5	6
1622	BEN AKNOUN	3	-	-	2	5
1623	DELY BRAHIM	-	1	2*	1	4
1624	HAMMAMET	-	-	-	-	0
1625	RAIS HAMIDOU	-	3	-	3	6
1626	DJASR KACENTINA	3	-	-	5	8
1627	EL MOURADIA	-	-	-	-	0
1628	HYDRA	2	-	-	4	6
1629	MOHAMMADIA	6	1	-	-	7
1630	BORDJ EL KIFFAN	-	1	1	-	2
1631	EL MAGHARIA	2	-	-	-	2
1632	BENI MESSOUS	-	-	-	-	0
1639	BORDJ EL BAHRI	-	-	-	-	0
1640	EL MARSA	-	-	-	-	0
1644	AIN BENIAN	-	1	1	-	2
Total		54	31	11	52	148

*: The number includes the 1 bridge of CHERAGA.

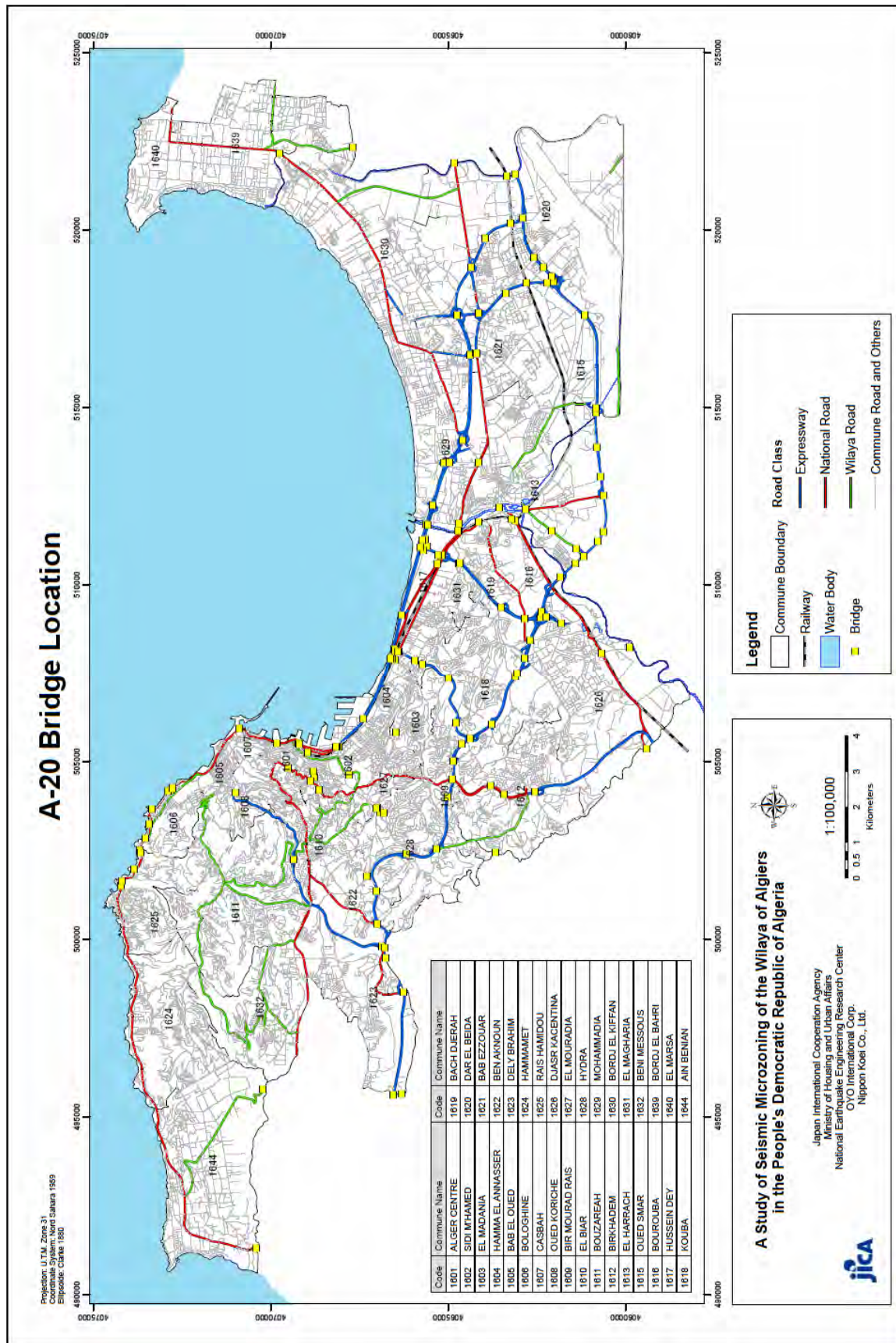


Figure 4-12 Bridge Locations

There are bridges 103 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 4-13. Seat width is 70 cm or more for most bridges (121 bridges). This is a reasonable design to prevent bridge failure.

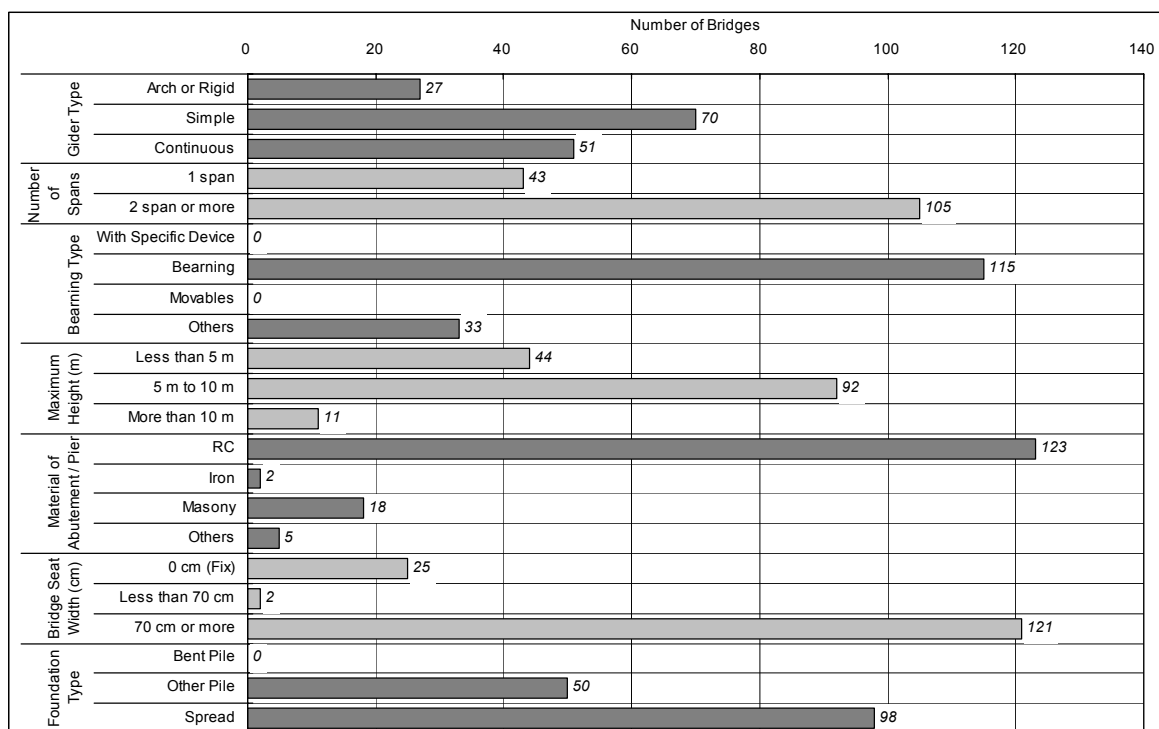
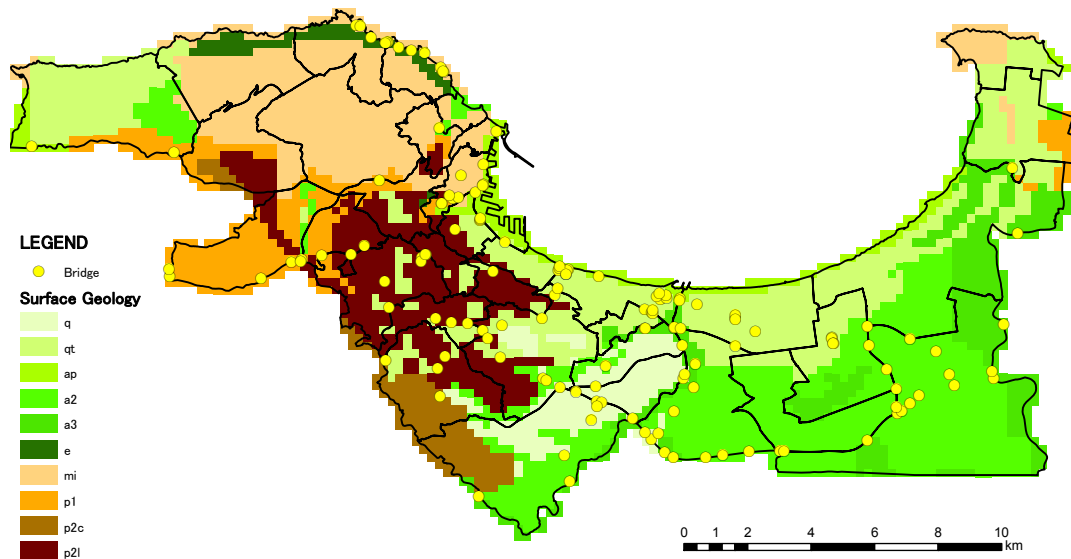


Figure 4-13 Characteristics of Bridge Structures

There are 105 (71%) existing bridges in low land areas and 43 (29%) in mountainous areas (refer to Figure 4-14). 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.



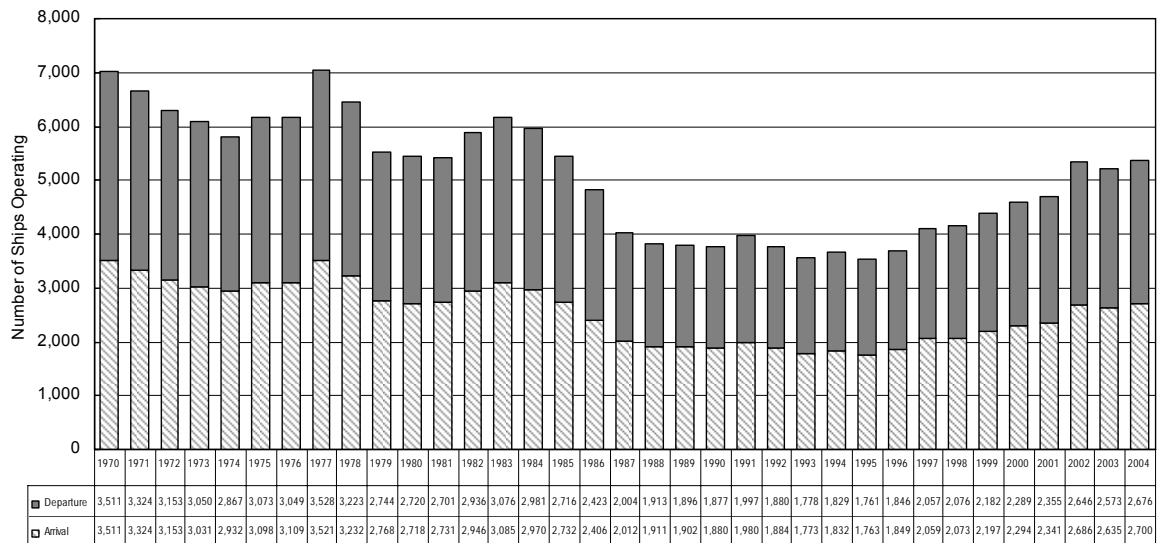
(The geological features are classified into the low land areas and the mountainous areas)

Figure 4-14 Bridge Locations and Geological Features

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 4-15.

Figure 4-16 shows the number of ships operating in Algiers Port. Recently, the number of ships operating has gradually recovered after the civil conflict due to an open market policy.



Source: EPAL

Figure 4-16 Number of Ships Operating in Algiers Port

4-2-4 Airport

The Algiers Airport area is outlined in Table 4-13, based on data provided by EGSA. This airport is around 60 years old.

Table 4-13 Facility of Algiers Airport Area

Designation	Area	Nature of the building
Air Passenger Terminal		
Domestic: Ground floor	10,100 m ²	Masonry
1 st floor	988.90 m ²	
International including the extension		(R+1 after demolition of the 2 nd and 3 rd floors)
: G floor	14,126 m ²	
1 st floor	5,200 m ²	
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:	4,735 m ²	
Hangar 02:	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:	9,161 m ²	
Hangar 02:	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 beside 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 (refer to Figure 4-17).

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 time in the Study Area as shown in Table 4-14.

Table 4-14 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

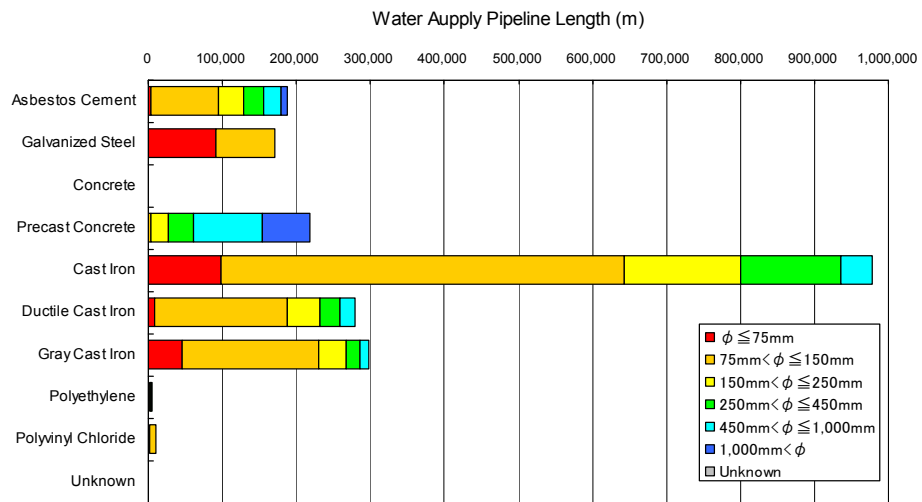
Source: DHW

Table 4-15 shows a cross tabulation between pipeline material and diameter. Cast iron of 75mm to 150 mm in diameter has the greatest distribution.

Table 4-15 Cross Tabulation between Pipeline Material and Diameter

Material \ Diameter	$\phi \leq 75$ mm	75 mm $< \phi \leq 150$ mm	150 mm $< \phi \leq 250$ mm	250 mm $< \phi \leq 450$ mm	450 mm $< \phi \leq 1,000$ mm	1,000 mm $< \phi$	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



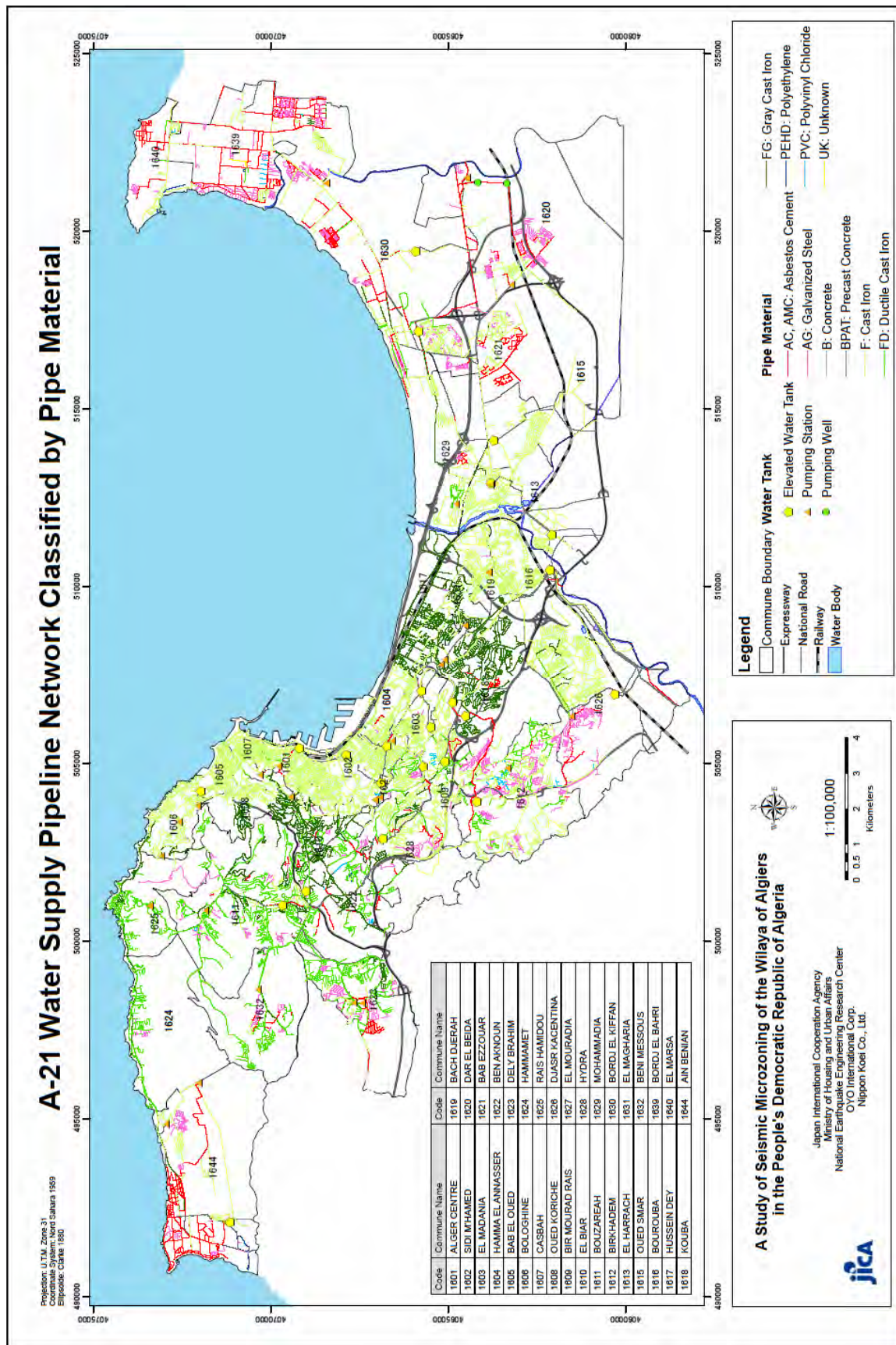


Figure 4-17 Distribution of Water Supply Pipelines and Location of Elevated Water Tanks

In the Boumerdes Earthquake, the damage to the water supply system was reported as follows:

Table 4-16 Summary of Damage to Water Supply System

Location / Facility	Damage
Boudouaou Water treatment plant	A pipe failed at the interface with a rigid concrete bloc, and a pipe was dislodged from a pipe to pipe flanged connection
Water Treatment Plant near Boudouaou	Two 50,000 m ³ reinforced concrete semi-buried rectangular reservoirs
Reghaia: 1,000 m ³ RC Water Tank	Severely damaged and was subsequently demolished
Ten Other 50 to 100 m ³ Elevated Water Tanks	Damaged
Ait Ouarzine Reservoir	Damaged
Rais Djinet and Tidjelabine: 4 Pumping Station	Damaged and out of service

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 Figure 4-18 and Table 4-17). 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 4-17 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

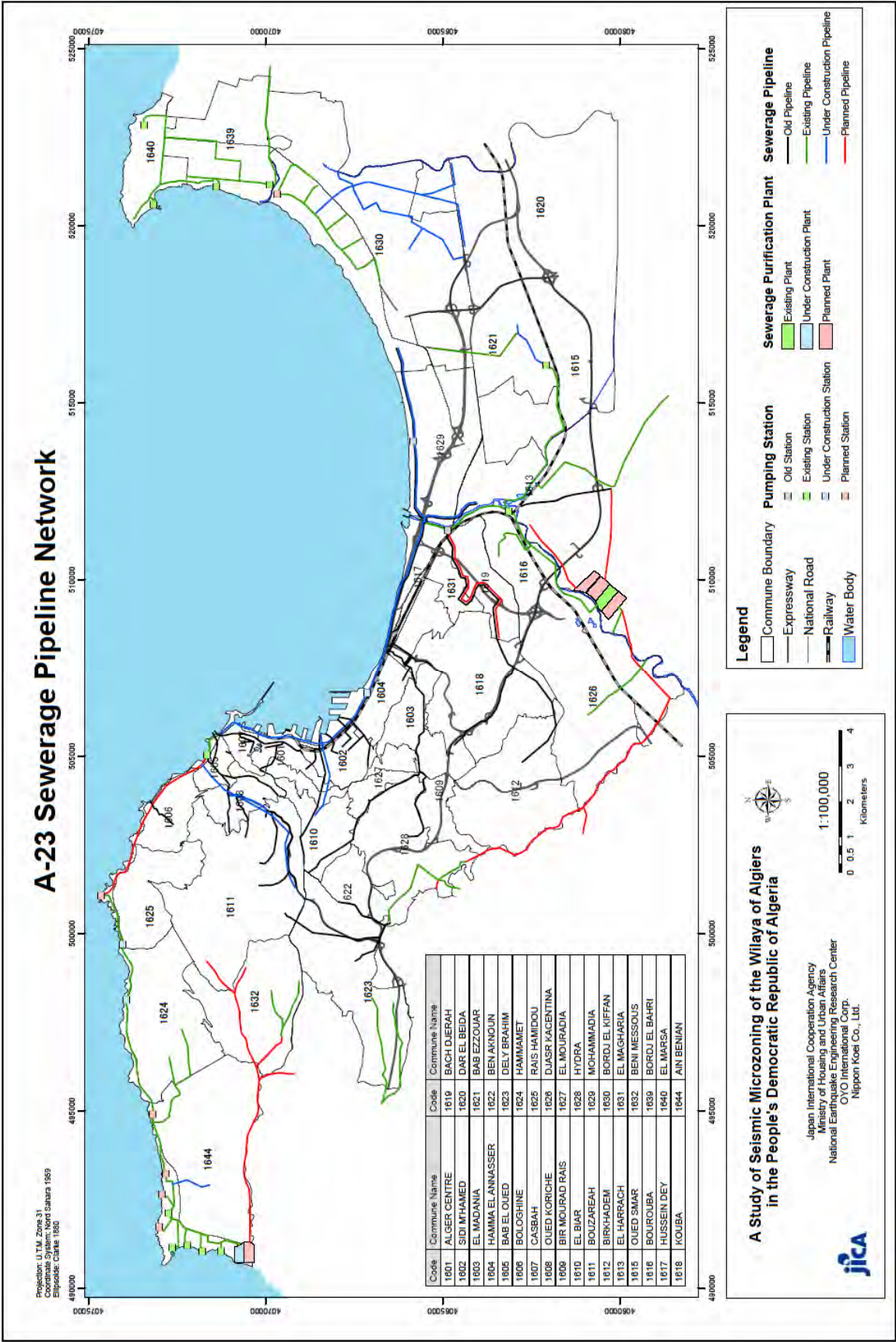


Figure 4-18 Distribution of Sewerage Pipelines and Location of Pumping Stations

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, refer to Figure 4-19). 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 4-18 shows a cross tabulation between voltage and distribution cable type.

Table 4-18 Cross Tabulation between Voltage and Distribution Cable Type

Voltage Distribution Type	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

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.

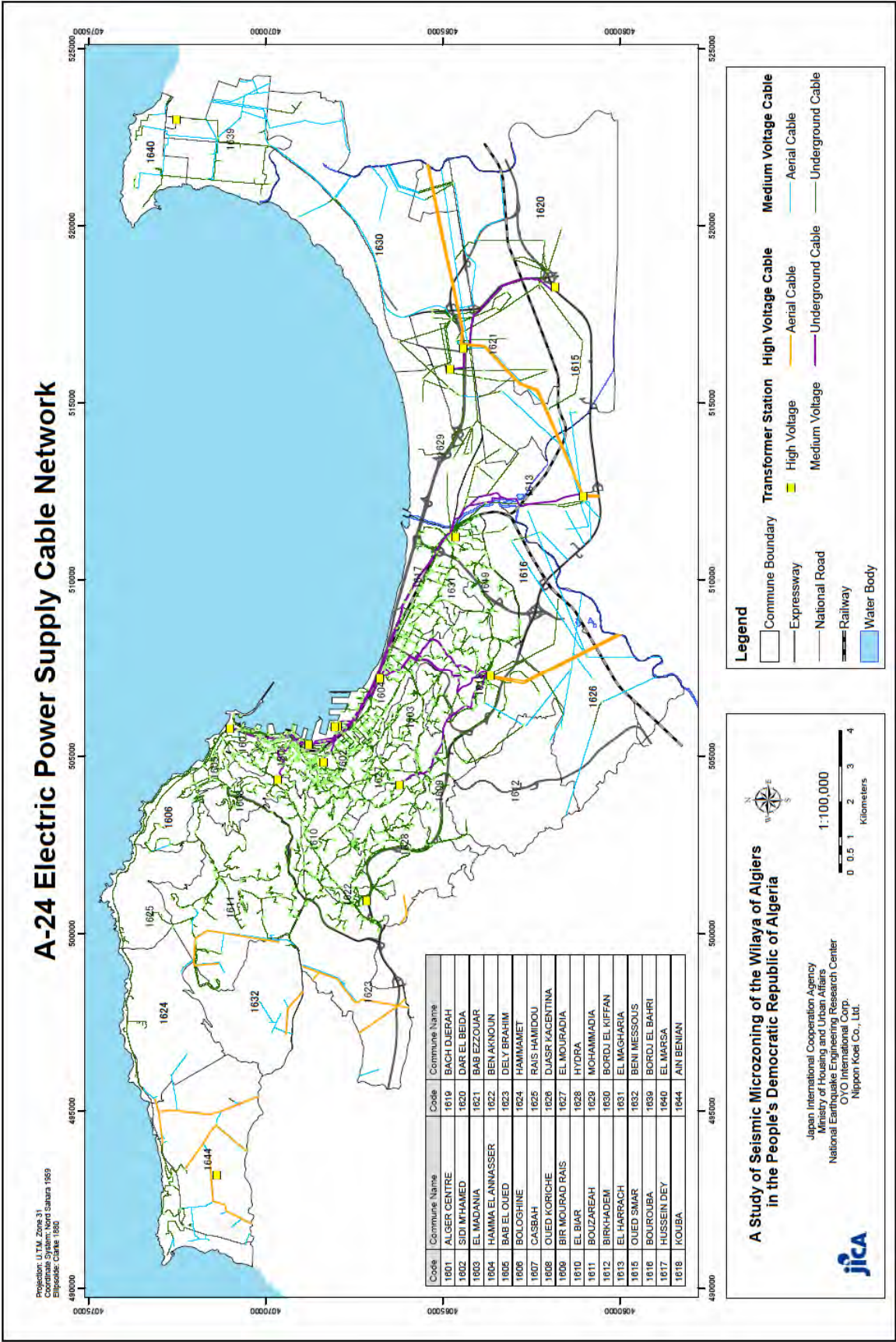


Figure 4-19 Distribution of Electric Power Supply Cable

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 SONEGGAZ.

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 Figure 4-20 and Table 4-19). The high and the medium pressure gas supply pipelines are made of steel, polyethylene or copper, which are based on API (American Petroleum Institute) standards. The medium pressure gas pipelines are mostly steel or polyethylene as shown in Table 4-19.

Table 4-19 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: SONEGGAZ, Digitizing: JST

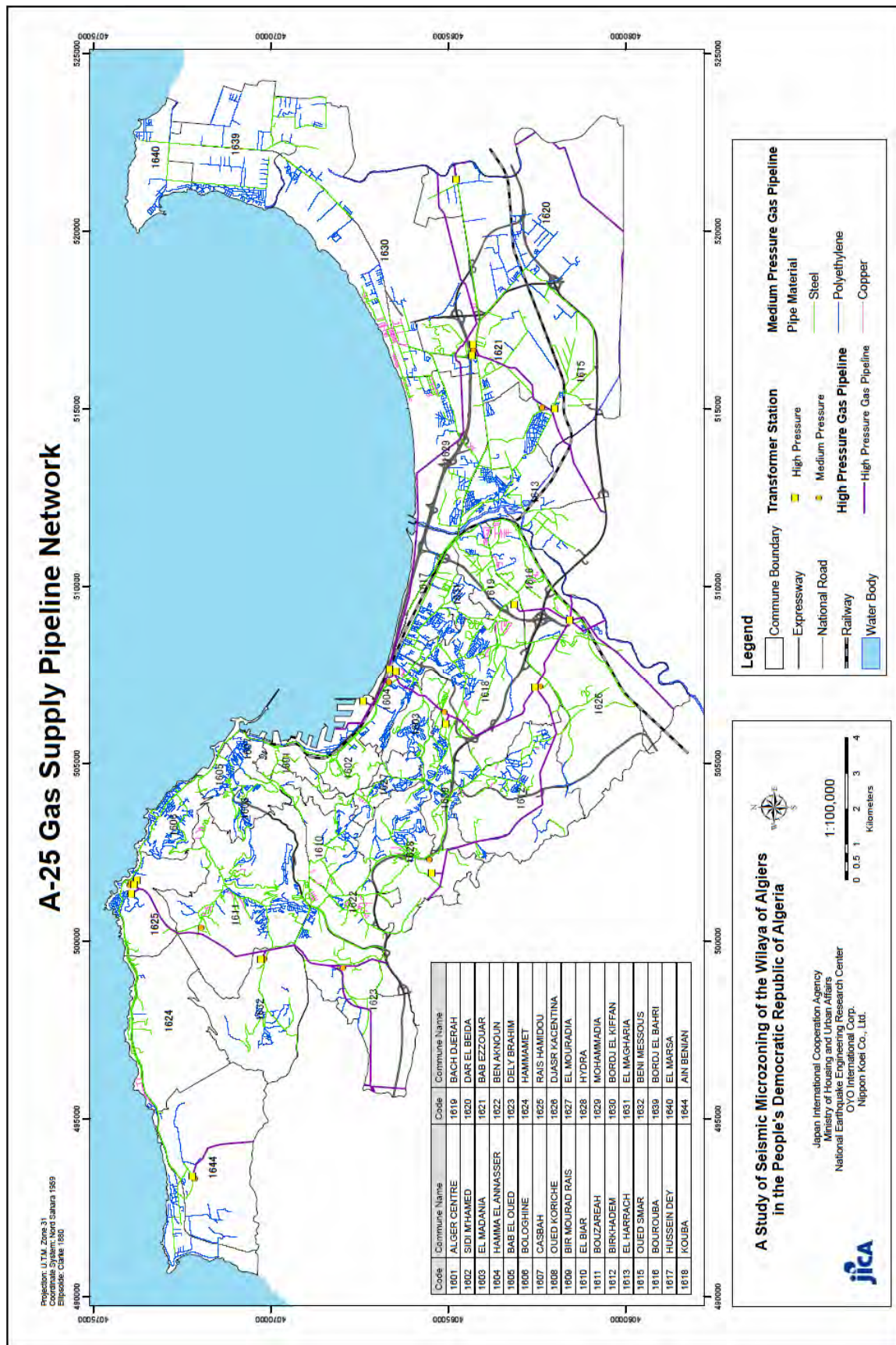


Figure 4-20 Distribution of Gas Supply Pipelines

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 4-20.

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. The latest General Population and Housing Census was carried out in 1998 and the number of dwelling units in each commune at that time is known. However the information regarding the number of buildings is not included in those released statistics. 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 4-20 shows the number of buildings counted in a polygon, the center of which lies within the commune.

The building damage was estimated by 250m grids in this study, therefore, the number of buildings in each 250m grid sector should be estimated beforehand. The building polygons the center of which lies within each 250m 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 4-20 shows the total number of buildings in the grids that are assigned to that commune.

As exemplified in Figure 4-21, the grid that lies mostly in “A” commune may be assigned to “B” commune because the center of the grid is located in “B” commune according to the complex commune boundaries. The “Building Number/ In Commune Boundary” column and the “Building Number/ In Commune Assigned Grids” in Table 4-20 differ for this reason. Of course, the total of these two columns are the same exclusive of footnote 6).

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 were calculated as follows;

$$DH_g = DB_g \times \frac{H_c}{B_c}$$

$$EH_g = EB_g \times \frac{H_c}{B_c}$$

DH_g : number of damaged housing unit in the grid

DB_g : number of damaged building in the grid

EH_g : number of existing housing unit in the grid

EB_g : number of existing building in the grid

H_c : number of existing occupied housing unit by census in the commune that the grid is assigned

B_c : number of existing building in the commune that the grid is assigned

The casualties were estimated for each commune, not for each grid because of the restriction of damage function. The number of existing and damaged dwelling units in each commune was calculated as follows;

$$DH_c = \sum_1^n DH_g$$

$$EH_c = \sum_1^n EH_g$$

DH_c : number of damaged housing unit in the commune

DH_g : number of damaged housing unit in the grid

EH_c : number of existing housing unit in the commune

EH_g : number of existing housing unit in the grid

n : number of assigned grid to the commune

The column (a) in Table 4-20 corresponds to H_c and column (d) corresponds to EH_c .

4-3-4 Summary

Columns (a) and (b) in Table 4-20 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 250m 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 4-20.

Table 4-20 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 MARSAS	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).



Figure 4-21 Example of Commune Boundary and Assigned Grid Relationship