4 ATLAS FOR METRO CEBU

4.1 This Atlas contains the many outputs of the GIS-processed information for analyses of the physical, environmental, socioeconomic and transport attributes of Metro Cebu. A visual presentation of the study area in these aspects contributes significantly to planning its development framework.

4.1 Physical, Environmental and Socioeconomic Features of Metro Cebu

4.2 Using the digitized topographic maps, satellite images and results of the HIS, a series of thematic maps was prepared. These maps were used as bases for detailed analyses on existing land use, infrastructure development planning, and socioeconomic conditions. Table 4.1.1 is an index of the thematic maps included in this Atlas for Metro Cebu.

4.3 The secondary sources of the maps and processed information in this compilation are the Mines and Geosciences Bureau (MGB), Provincial Planning and Development Office (PPDO) of Cebu, National Mapping and Resources Information Authority (NAMRIA), Philippine GIS Data Clearinghouse (PhilGIS), Philippine Institute of Volcanology and Seismology of the Department of Science and Technology (PHIVOLCS-DOST), Bureau of Soil and Water Management (BSWM), Philippine Economic Zone Authority (PEZA), and National Statistics Office (NSO).

Table 4.1.1 List of Thematic Maps for Metro Cebu

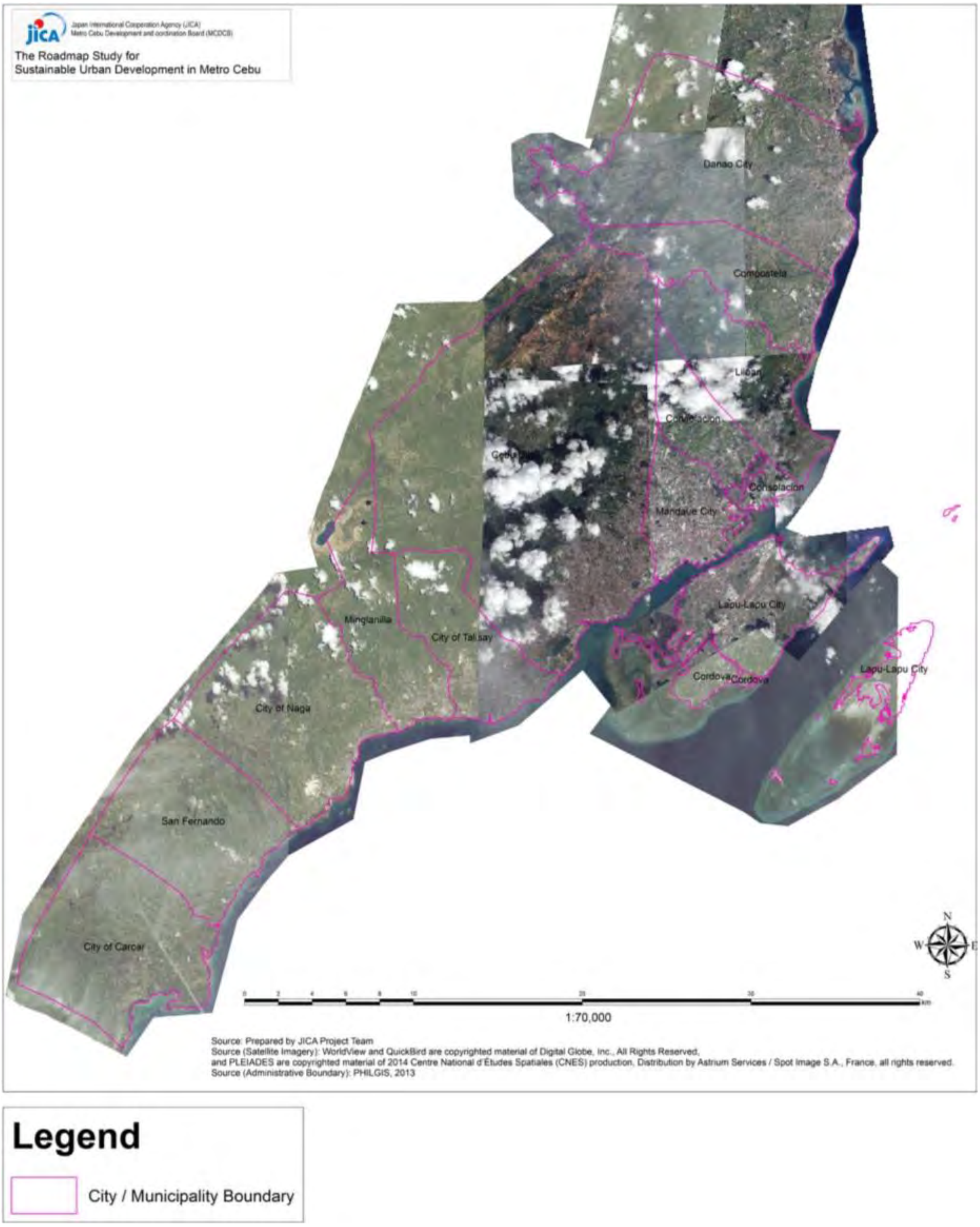
Category		Figure Number	Theme	Remarks
1) Base Map		4.1.1	Satellite Imagery	
		4.1.2	Topography	
2) Natural Conditions		4.1.3	Elevation	
		4.1.4	Rivers and River Basins	
		4.1.5	Geology	MGB, DENR
3) Reservation Areas		4.1.6	NIPAS	Republic Act 7586
4) Hazardous Areas	(1) Identified by National Agencies	4.1.7	Geology by Softness	MGB, DENR
		4.1.8	Active Faults and Liquefaction	PHIVOLCS, DOST
		4.1.9	Earthquake-Triggered Landslide	PHIVOLCS, DOST
		4.1.10	Tsunami-Prone Areas	PHIVOLCS, DOST
	(2) Identified based on Topographic Map in 1:10,000	4.1.11	Lowland Hazard Area (less than 2 m)	Less than 2 m area using detailed contour is identified as lowland hazard areas
		4.1.12	Slope Hazard Area	Slope is calculated based on detailed contours and Digital Terrain Model (DTM)
		4.1.13	Flood Hazard Area	Identified by flood simulation using available rainfall and river data.
		4.1.14	Landslide Hazard Area	Identified with the aid of remote sensing technology.
	(3) Social Constraints	4.1.15	Building Area Ratio	Building areas are calculated using 250 m x 250 m grid system and divided by the grid area.
		4.1.16	Informal Settlement Area	Identified by local land use expert based on field survey.
		4.1.17	Areas Difficult to Access by Emergency Vehicle in Residential Area	Defined as an area not connected to roads with width of more than 4 m in residential area
		4.1.18	Fire Hazard Area in Residential Area	Overlapped areas by the above three maps in residential area.
5) Land Use		4.1.19	Existing Land Use	Identified and digitized based on the satellite images.
		4.1.20	Existing Urban Land Use	Type of urban land use is identified by LGUs through

Category	Figure Number	Theme	Remarks
			the Land Use Workshop.
	4.1.21	Development Suitable Area and Urbanization	Defined as an area not covered by constraints and hazards.
	4.1.22	Location of PEZA by Status	Location is identified by GPS survey based on the list of PEZA.
	4.1.23	Location of Subdivision	Location is identified by GPS survey.
6) Urban Transport	4.1.24	Transport System	Road network is identified by topographic map and linked with inventorial information.
	4.1.25	Existing Road Network by Type	
	4.1.26	Existing Road Network by Width of Carriage Way	
	4.1.27	Existing Road Network by Number of Lanes	
	4.1.28	Existing Road Network by Existence of Median	
7) Socioeconomic Conditions	4.1.29	Population Distribution by City/ Municipality	City/ Municipal and barangay boundaries are linked with census population and utilized for analysis.
	4.1.30	Administrative Boundary and Socioeconomic–Population Density	
	4.1.31	Administrative Boundary and Socioeconomic–Population Growth Rate	
	4.1.32	Administrative Boundary and Socioeconomic–Urban Area defined by NSO	
	4.1.33	Night time and Daytime Population Distribution by City / Municipality	Based on the results of the HIS.
	4.1.34	Distribution of Workers at Residence and at Workplace	
	4.1.35	Daytime / Night time Ratio of Workers by Traffic Zone (Barangay)	
	4.1.36	Employment by Industrial Sector	
	4.1.37	Daytime / Night time Ratio of Students by Traffic Zone (Barangay)	
	4.1.38	Average Household Income by Traffic Zone	
	4.1.39	Car Ownership by City/ Municipality	
	4.1.40	Car Ownership by Traffic Zone (Barangay)	
8) Living Conditions	4.1.41	Average Housing Floor Area per Capita	Average Housing Floor Area per Capita is calculated based on the results of the HIS.
	4.1.42	Land and House Ownership by City/ Municipality	Based on the results of the HIS.
	4.1.43	Average Length of Habitation by Traffic Zone (Barangay)	Based on the results of the HIS.
	4.1.44	Ownership of Air Conditioner	Based on the results of the HIS, Form1 Q11.
	4.1.45	Ownership of Washing Machine	
	4.1.46	Ownership of Refrigerator	
	4.1.47	Ownership of Radio	
	4.1.48	Ownership of TV	
	4.1.49	Ownership of Satellite TV	
	4.1.50	Ownership of Mobile Phone	
	4.1.51	Ownership of PC	
	4.1.52	Ownership of Internet	
9) Urban Services	4.1.53	Connectivity of Piped Water Supply	Based on the results of the HIS, Form1 Q10.
	4.1.54	Source of Water for Drinking in House by City/ Municipality	Based on the results of HIS

Category		Figure Number	Theme	Remarks
		4.1.55	Fuel Used for Cooking/ Boiling Water in House by City/ Municipality	
		4.1.56	Connectivity of Sewage	Based on the results of the HIS, Form1 Q10.
		4.1.57	House Sewerage Treatment by City/ Municipality	Based on the results of the HIS.
		4.1.58	Connectivity of Solid Waste Collection	Based on the results of the HIS, Form1 Q10.
		4.1.59	Provision of Solid Waste Collection Service at House by City/ Municipality	Based on the results of the HIS.
		4.1.60	Connectivity of Electricity	Based on the results of the HIS, Form1 Q10.
		4.1.61	Connectivity of Fixed Telephone	
		4.1.62	Location of City Hall	Location is identified by GPS survey.
		4.1.63	Location of Fire and Police Station	
		4.1.64	Location of Hospital	
		4.1.65	Location of Shopping Mall and Bus Terminal	
		4.1.66	Location of Schools by Class	
		4.1.67	Location of Schools	
10) Grid Analysis				A grid system of 250 m x 250 m is applied to evaluate the potential of the land for future development. It is assessed by according to 6 categories from (1) ~ (6), as shown below.
	(1) Constraints	4.1.68	Slope more than 18%	Constraints indicators from “2) Natural Conditions” and “3) Reservation Area” are converted into the grid with values. Those values are aggregated into an overall map.
		4.1.69	Preservation Area	
		4.1.70	Overall Constraint Map	
	(2) Natural Hazards	4.1.71	Lowland Hazard Area	Natural hazards indicators from “4) Hazardous Areas” are converted into the grid with values. Those values are aggregated into an overall map.
		4.1.72	Flood Hazard Area	
		4.1.73	Landslide Hazard Area	
		4.1.74	Overall Natural Hazard Map	
	(3) Man-made Hazards	4.1.75	Building Area Ratio	Man-made hazards indicators from “4) Hazardous Areas” are converted into the grid with values. Those values are aggregated into an overall map.
		4.1.76	Squatter Area	
		4.1.77	Difficult Areas to Access by Emergency Vehicles	
		4.1.78	Overall Man-made Hazard Map	
	(4) Accessibility to Roads	4.1.79	Trunk/ Primary Roads	Accessibility to roads indicators are assessed based on distance to the roads and hierarchy of the roads and converted into the grid with values. Those values are aggregated into an overall map.
		4.1.80	Secondary/ Tertiary Roads	
		4.1.81	Other roads	
		4.1.82	Overall Accessibility to Road Map	
	(5) Accessibility to Public Services	4.1.83	City/ Municipality Hall	Accessibility to public services are assessed based on distance to the facility and converted into the grid with values. Those values are aggregated into an overall map.
		4.1.84	Schools	
		4.1.85	Hospitals	
		4.1.86	Overall Accessibility to Public Service Map	
	(6) Population Attraction Area	4.1.87	Shopping Centers	Population attraction areas are assessed based on distance to the facility or area and converted into the grid with values. Those values are aggregated into an overall map.
		4.1.88	PEZA	
		4.1.89	Subdivision	
		4.1.90	Overall Population Attraction Area Map	
	Overall	4.1.91	Land Potential Area	Aggregation of the above 6 maps. It shows the potential of the land for future development.

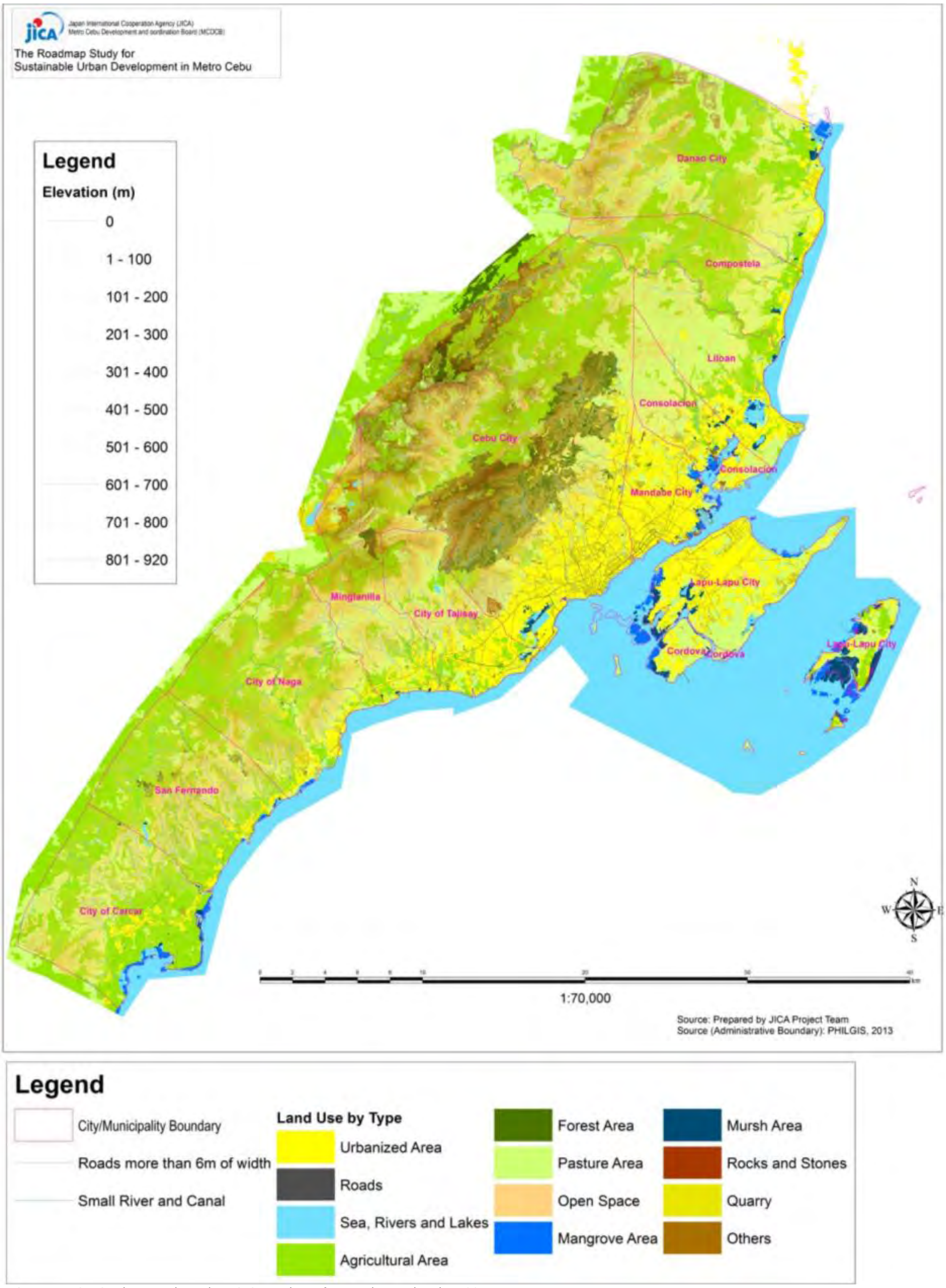
Source: JICA Study Team.

1) Base Map



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

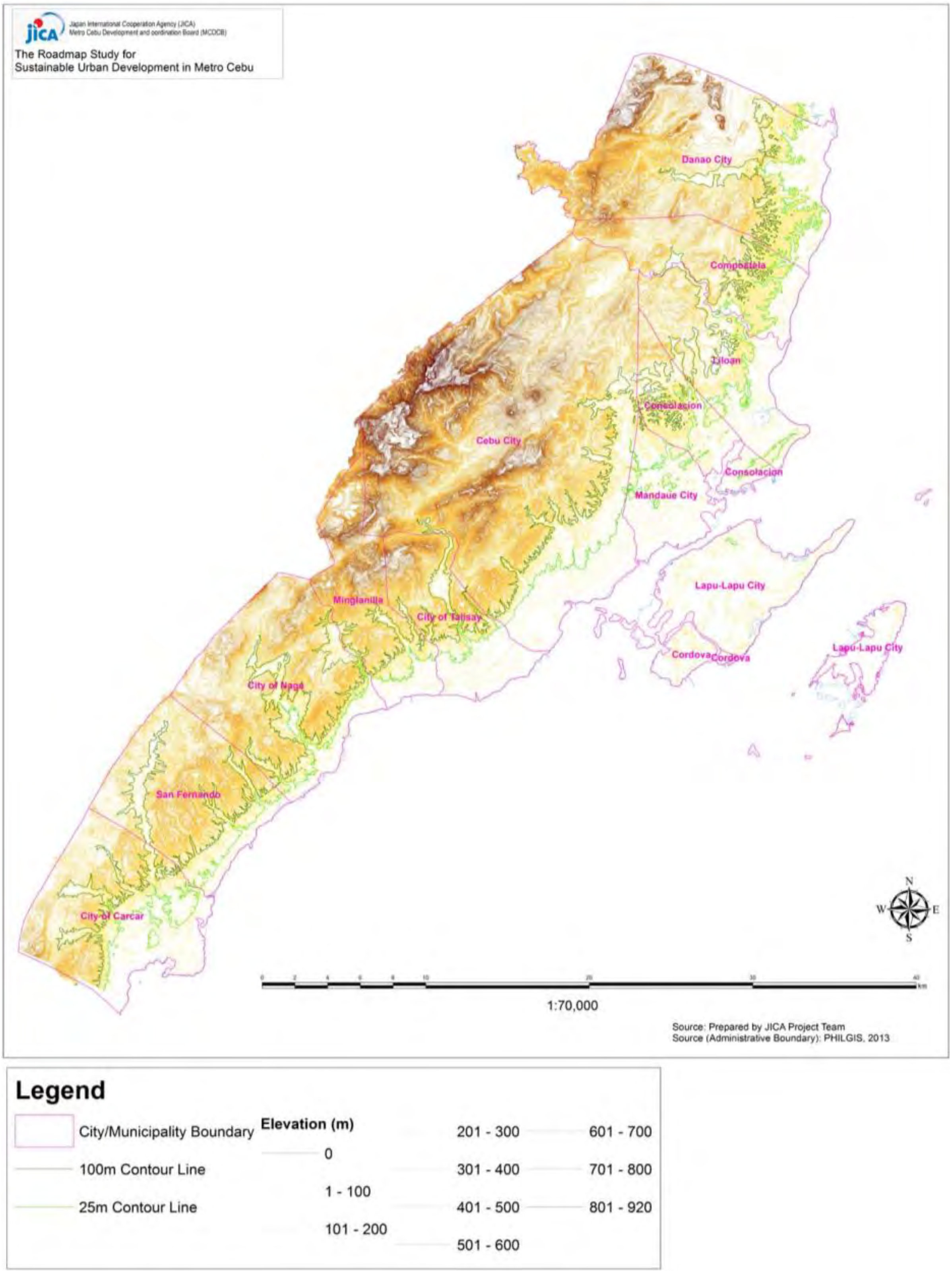
Figure 4.1.1 Satellite Imagery



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

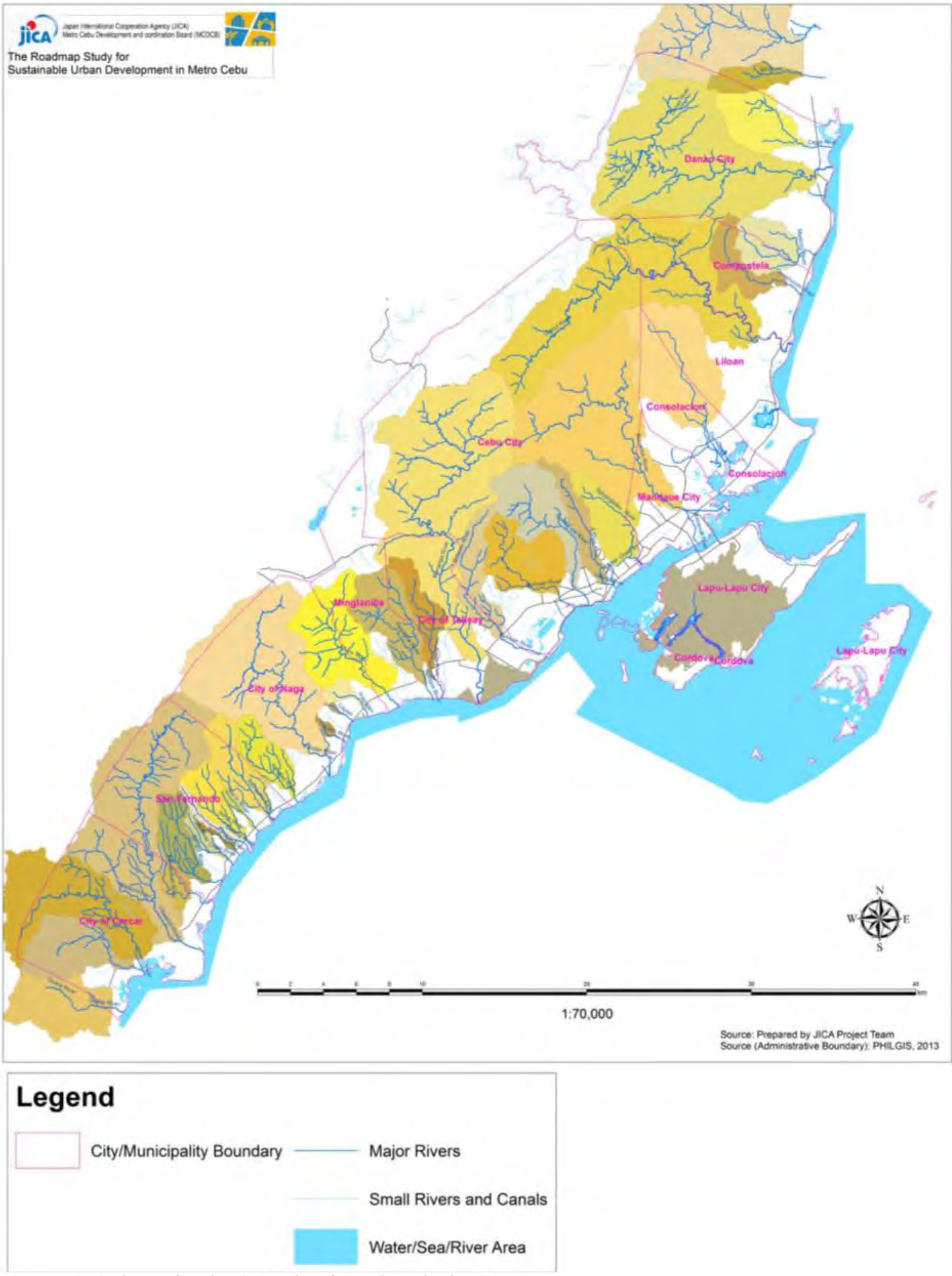
Figure 4.1.2 Topography

2) Natural Conditions



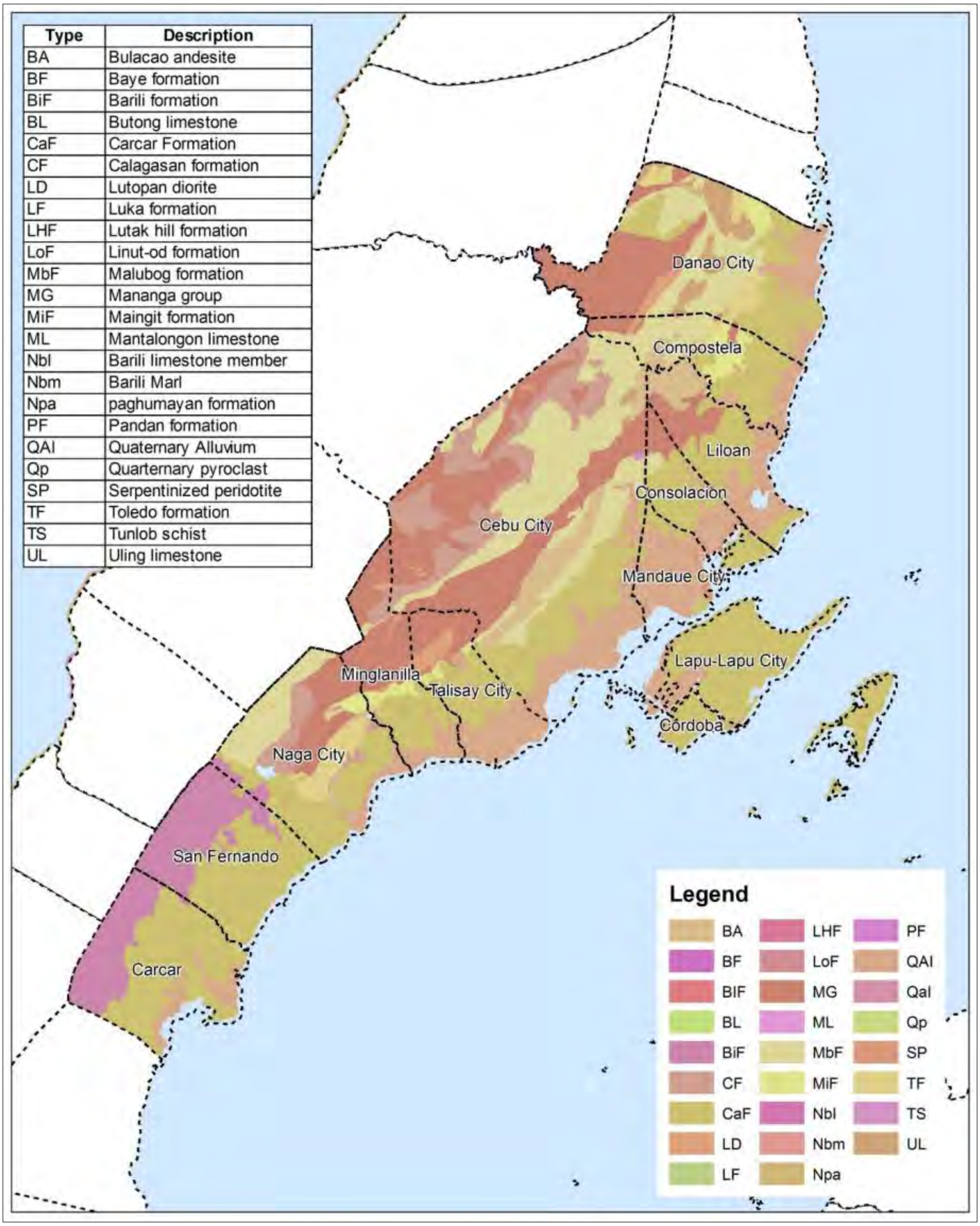
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.3 Elevation



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

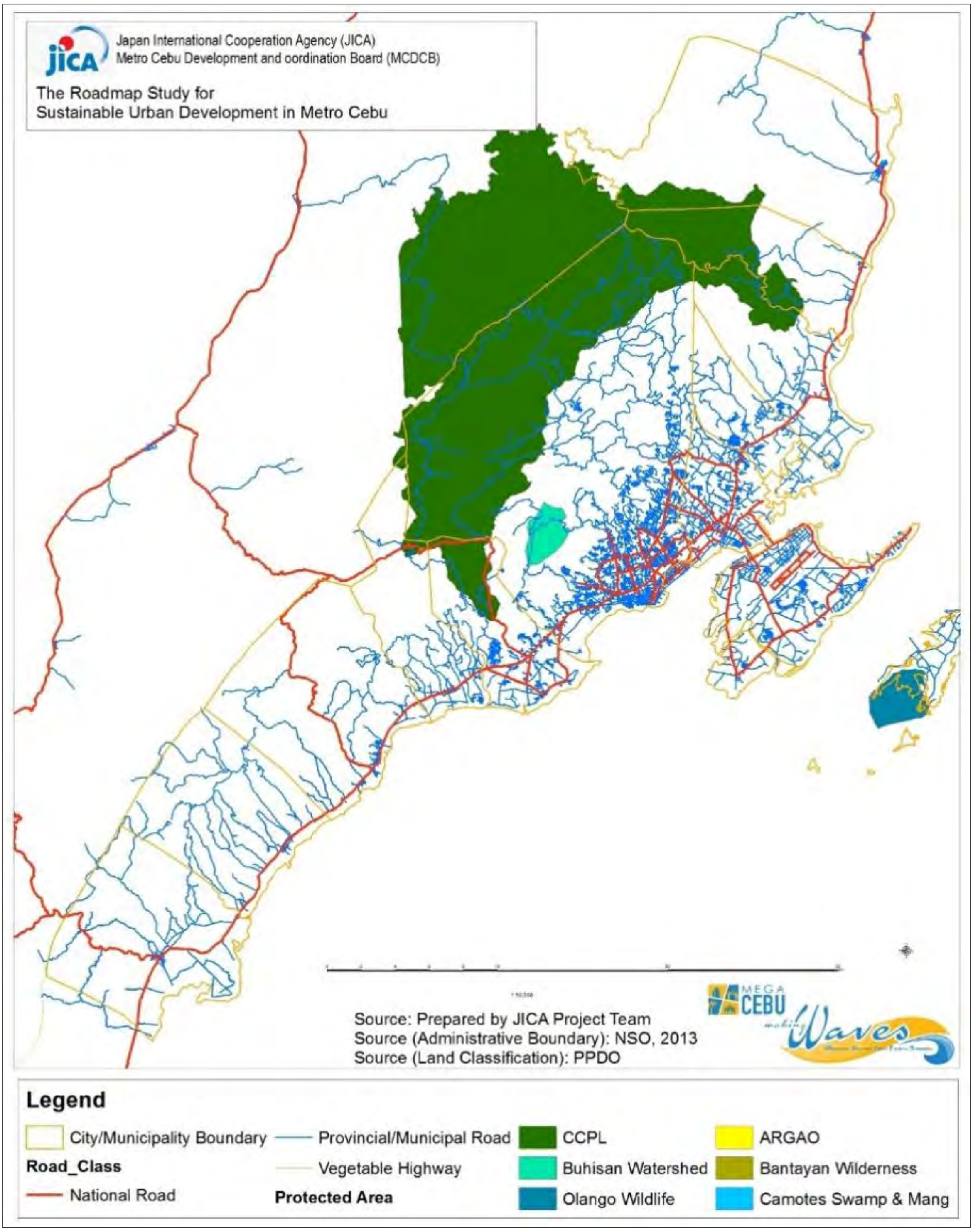
Figure 4.1.4 Rivers and River Basins



Source: JICA Study Team based on the Geology Map published by MGB.

Figure 4.1.5 Geology

3) Reservation Areas

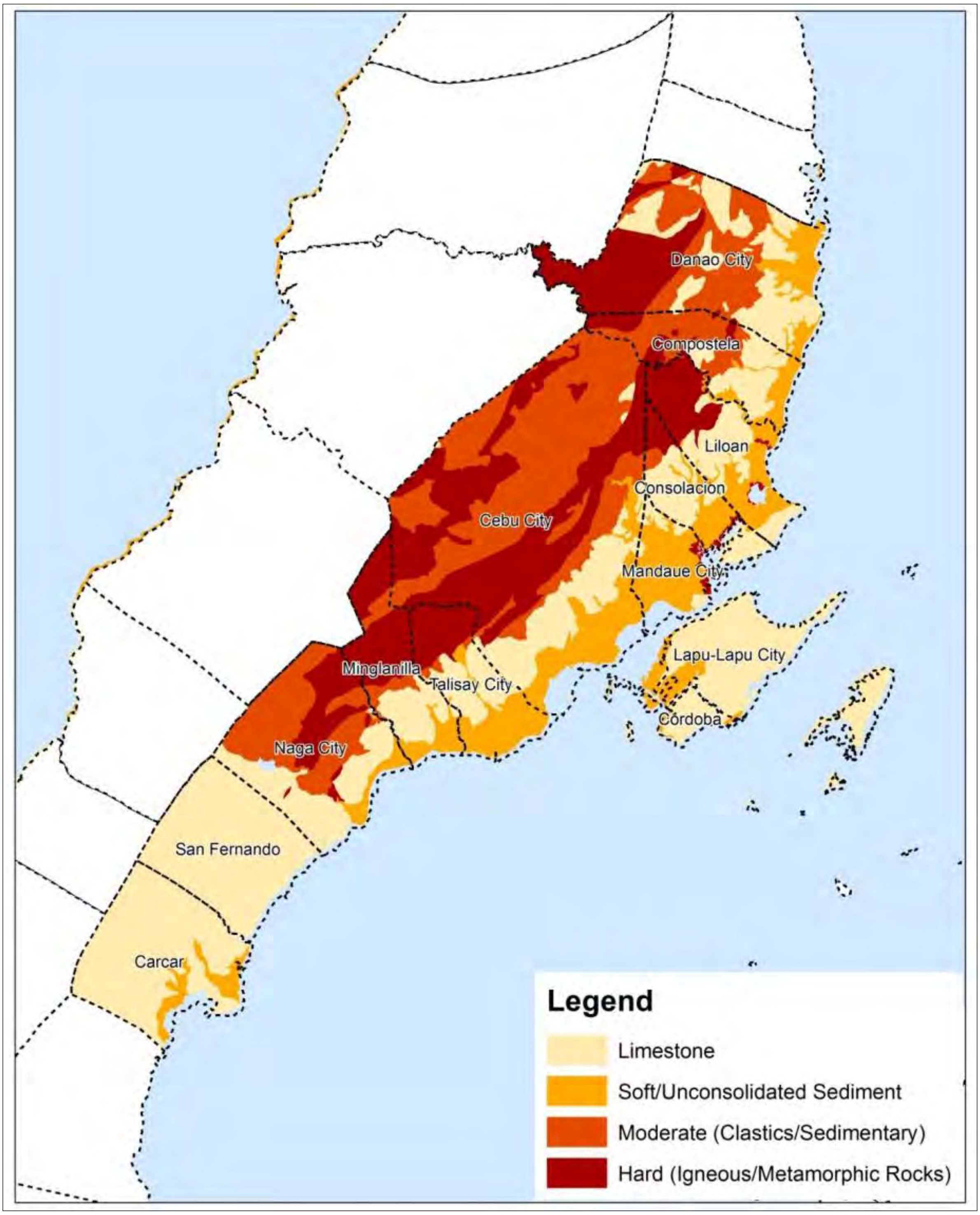


Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.6 National Integrated Protected Areas System (NIPAS) Areas

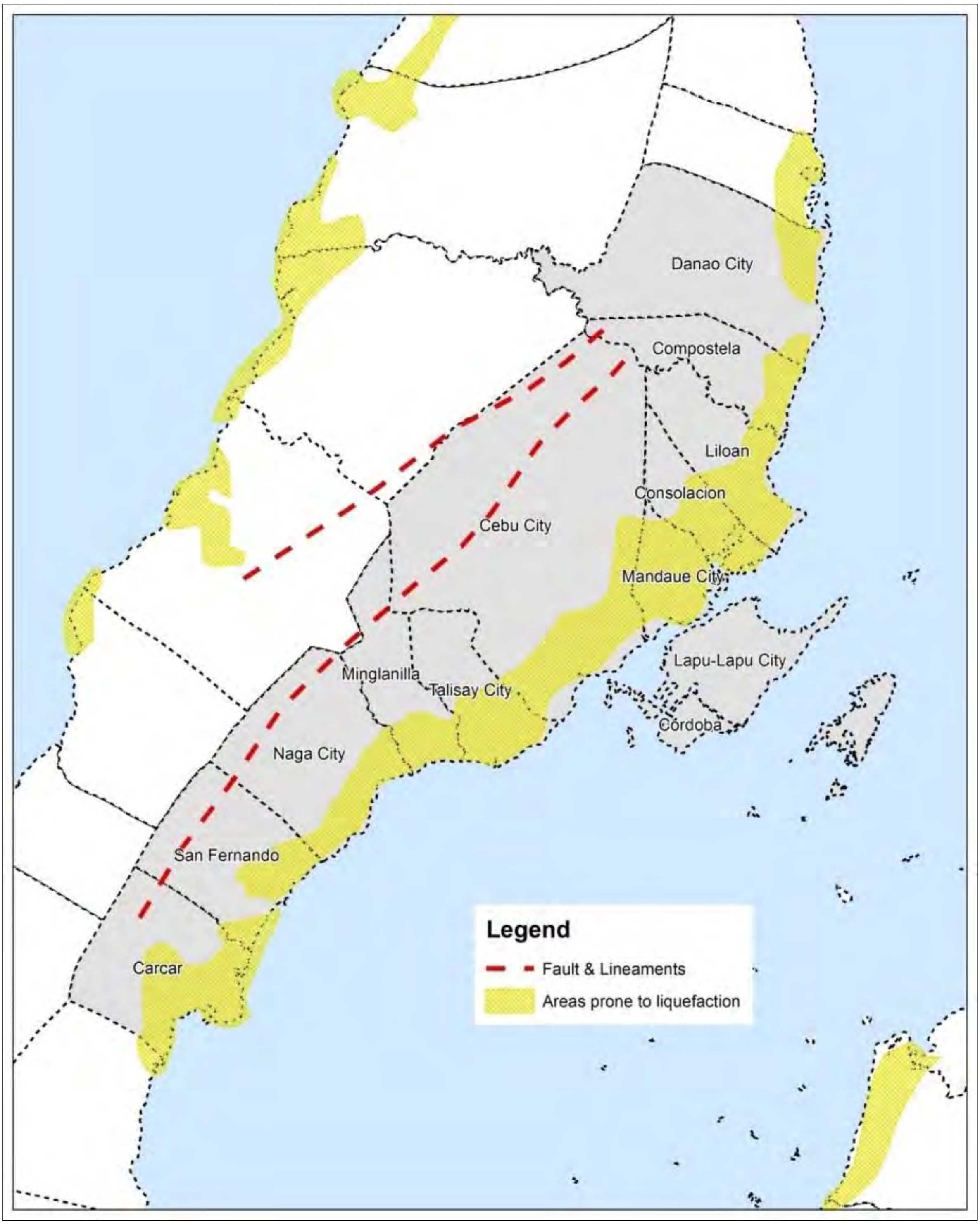
4) Hazardous Areas

(1) Identified by National Agencies



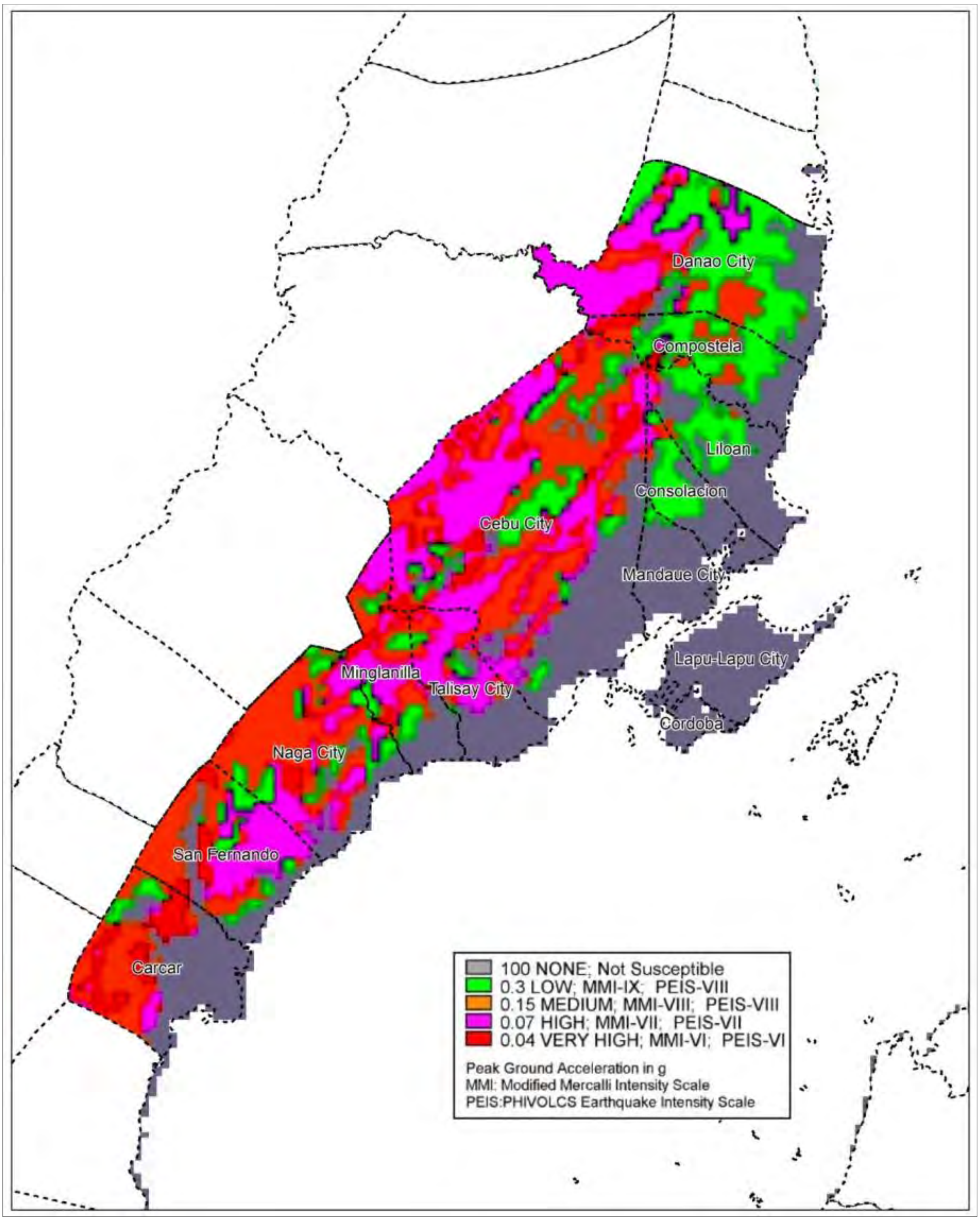
Source: MGB, DENR, JICA Study Team.

Figure 4.1.7 Geology Classified by Softness



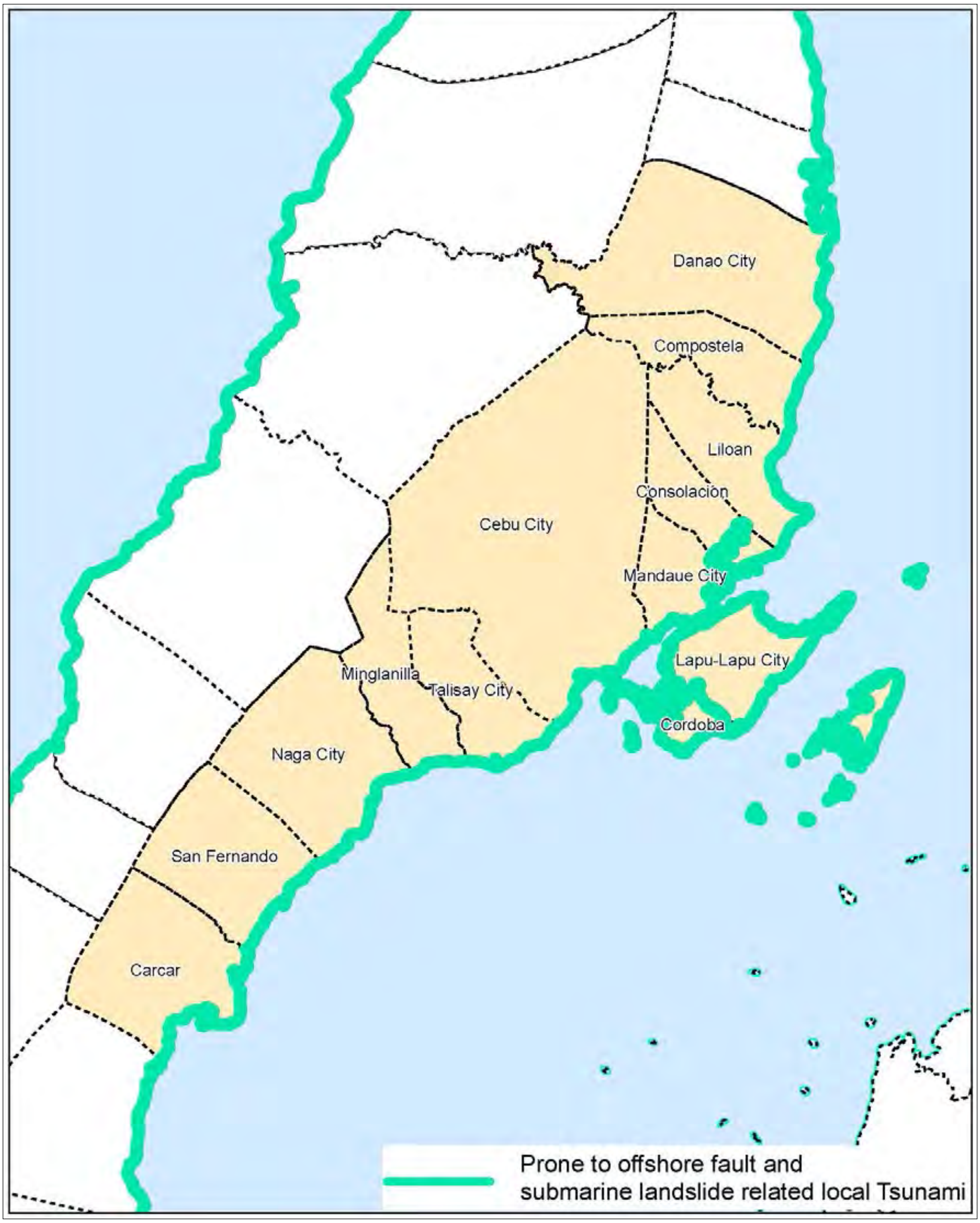
Source: PHIVOLCS, DOST, JICA Study Team.

Figure 4.1.8 Active Faults and Liquefaction



Source: PHIVOLCS, DOST, JICA Study Team.

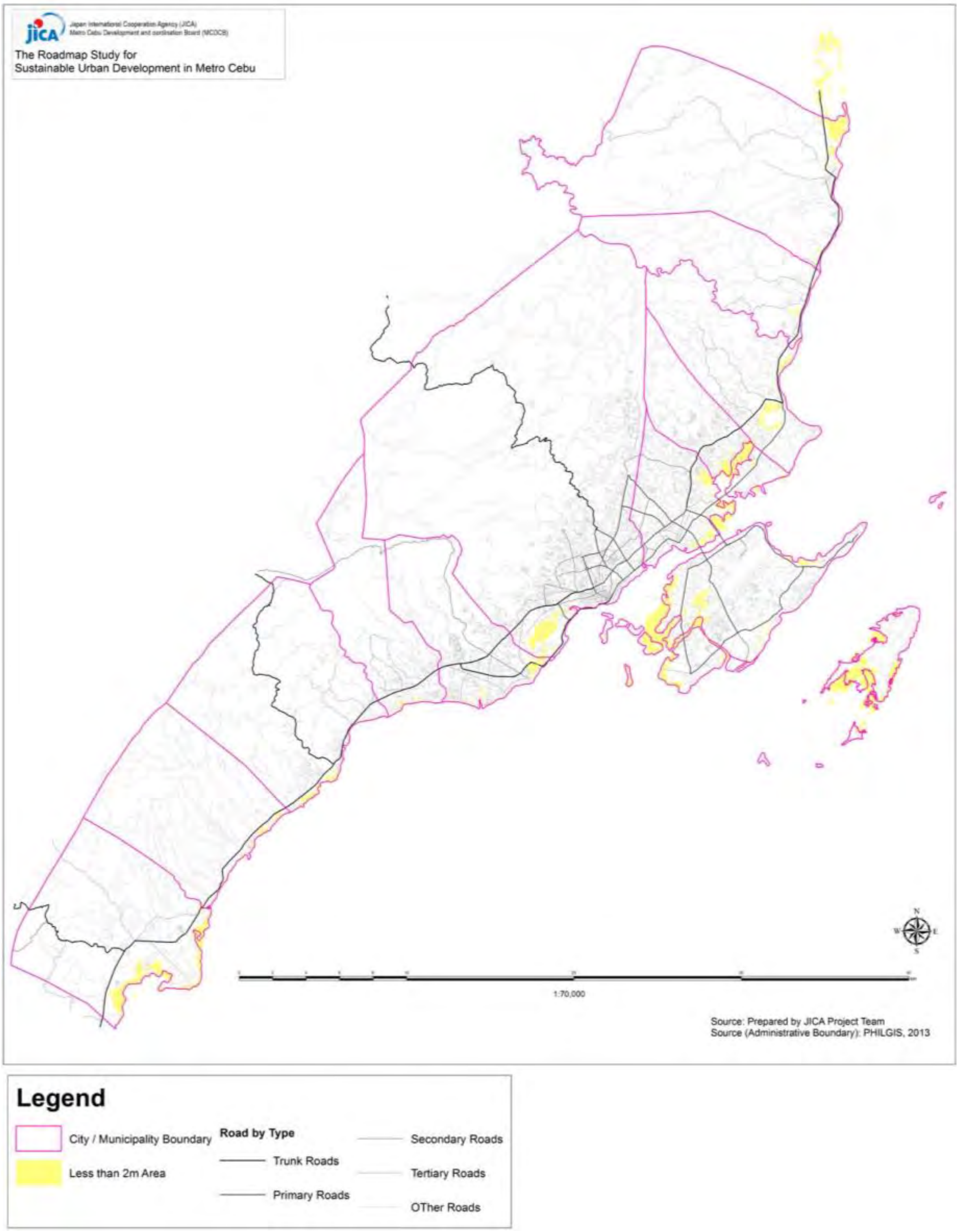
Figure 4.1.9 Earthquake-Triggered Landslide



Source: PHIVOLCS, DOST, JICA Study Team.

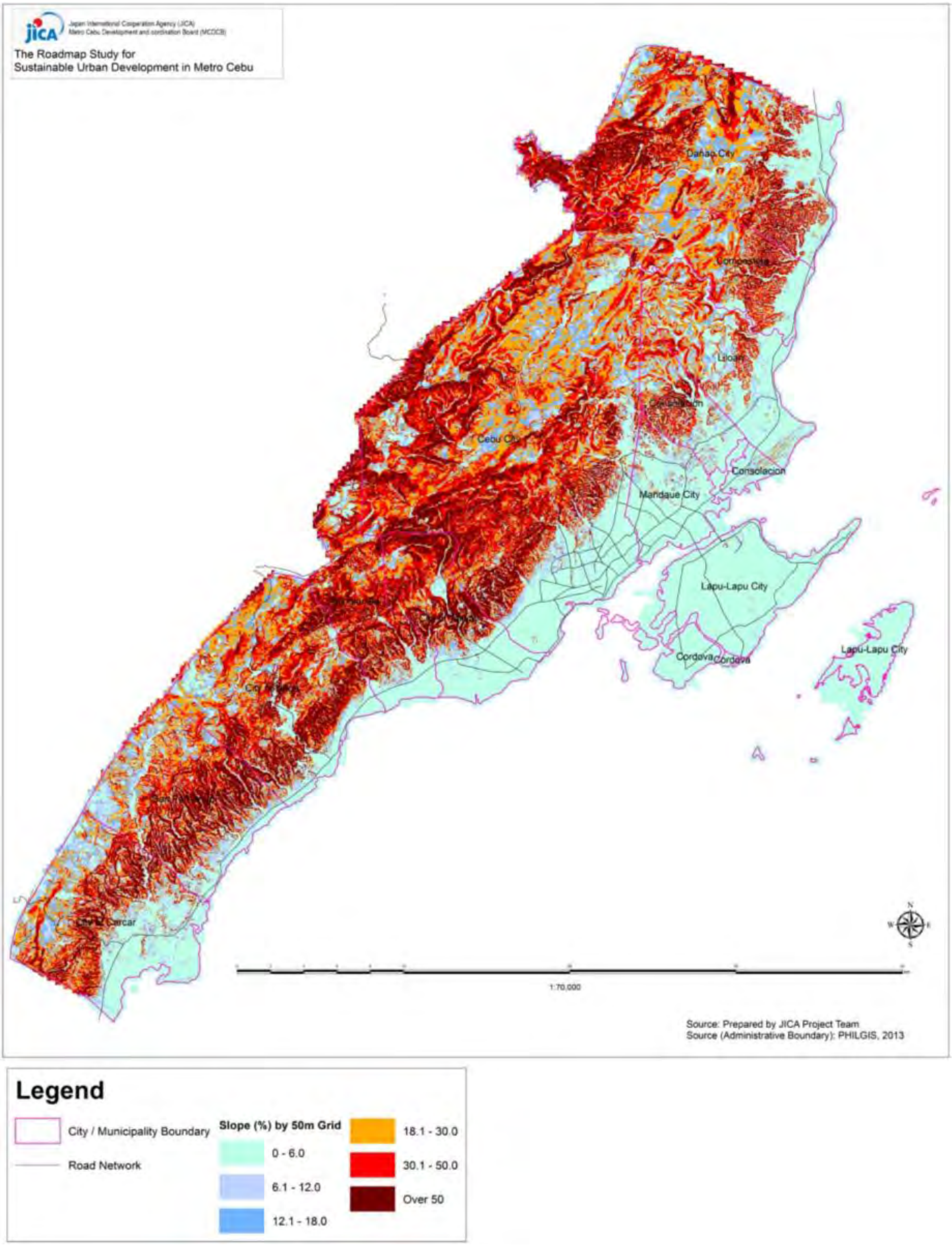
Figure 4.1.10 Tsunami-Prone Areas

(2) Identified Based on Topographic Map in 1:10,000



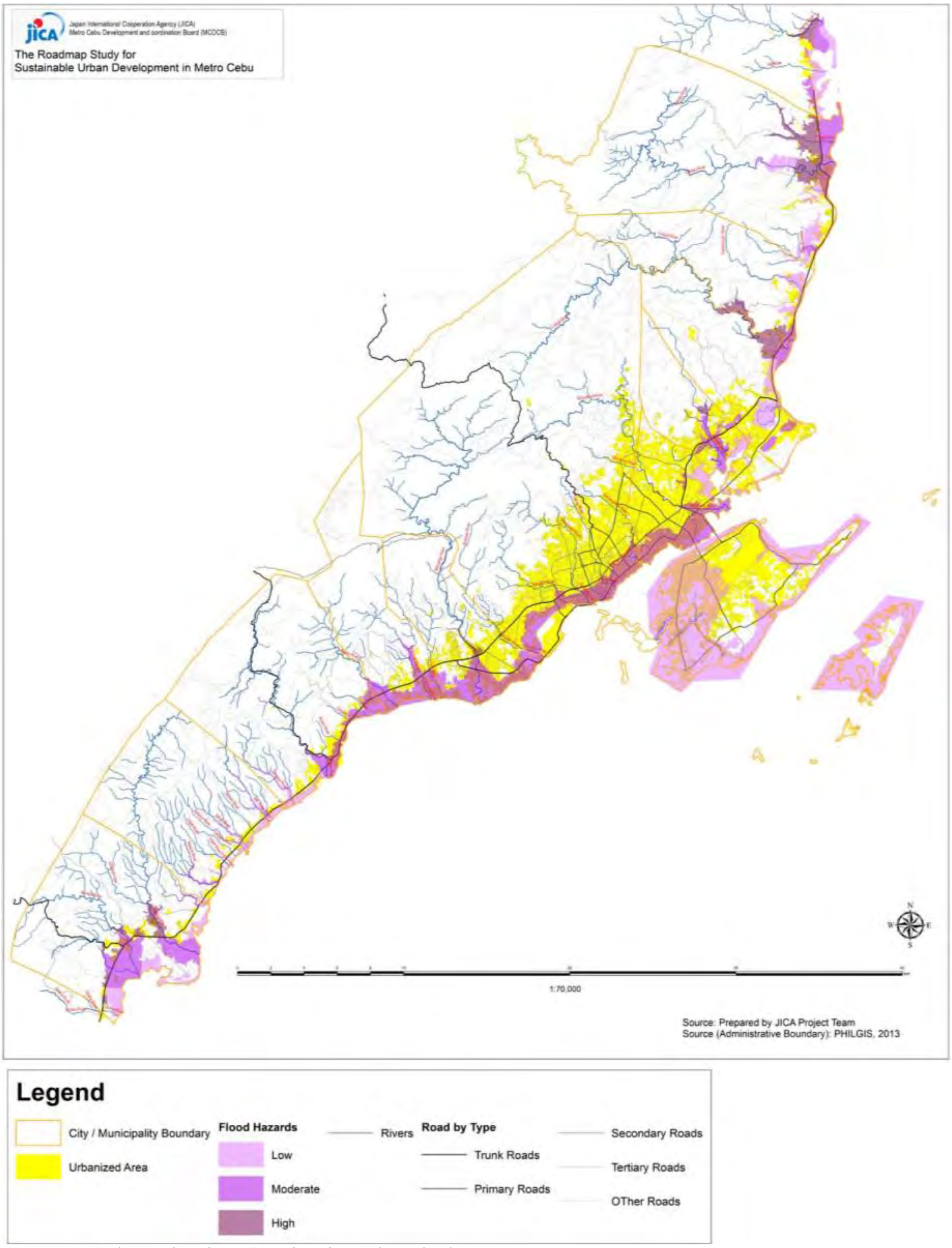
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.11 Lowland Hazard Area (Less than 2 m)



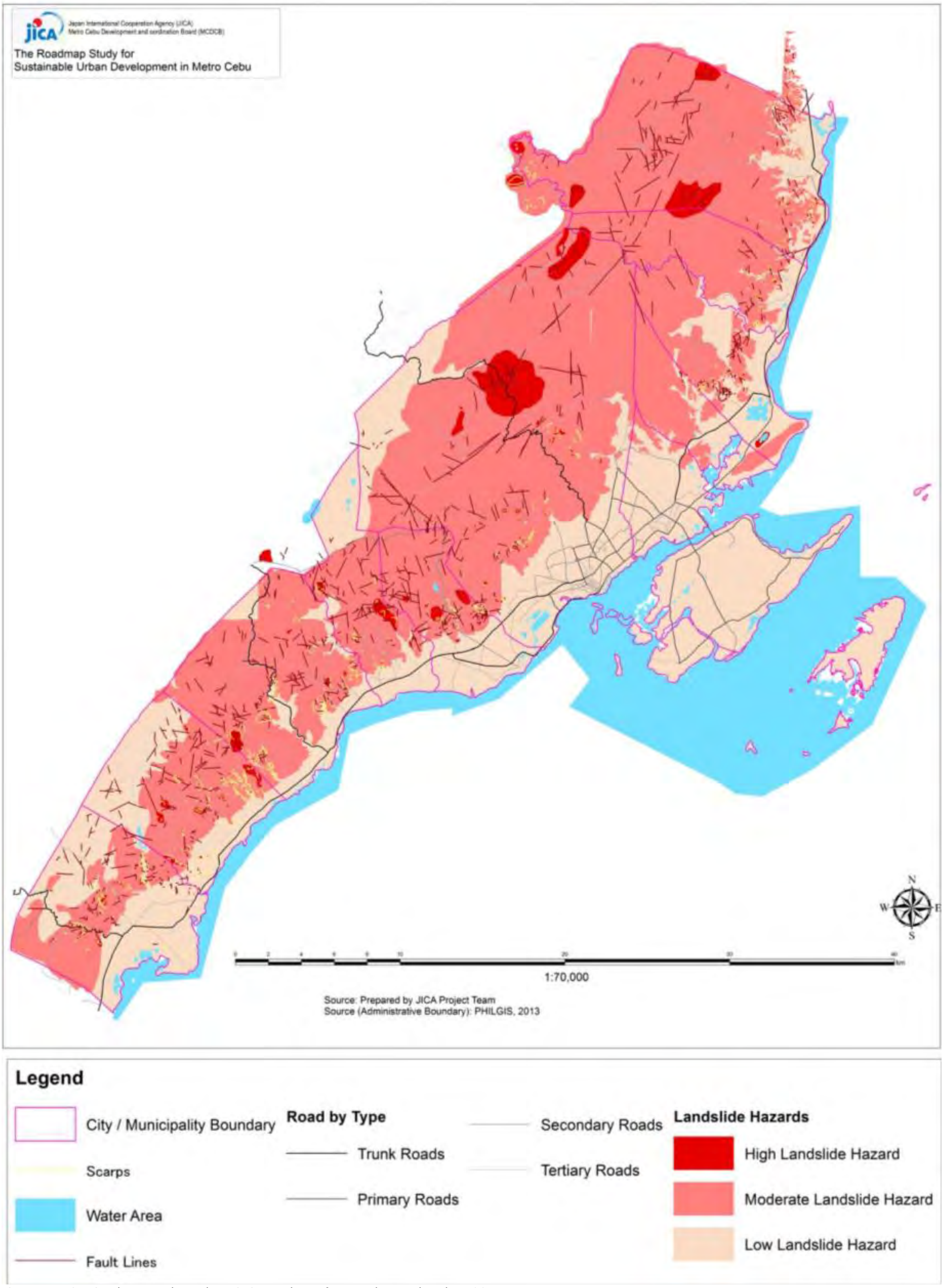
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.12 Slope Hazard Area



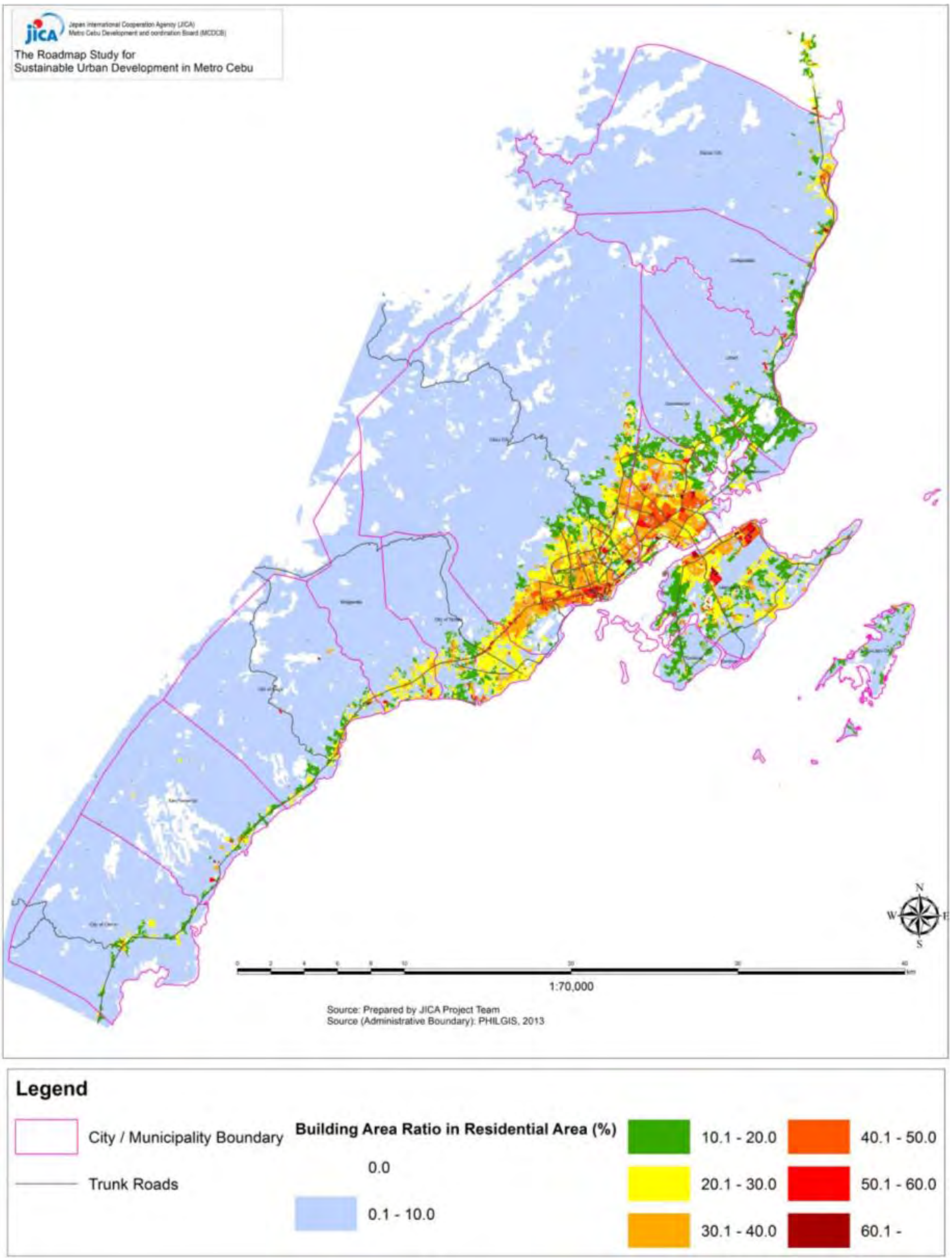
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.13 Flood Hazard Area



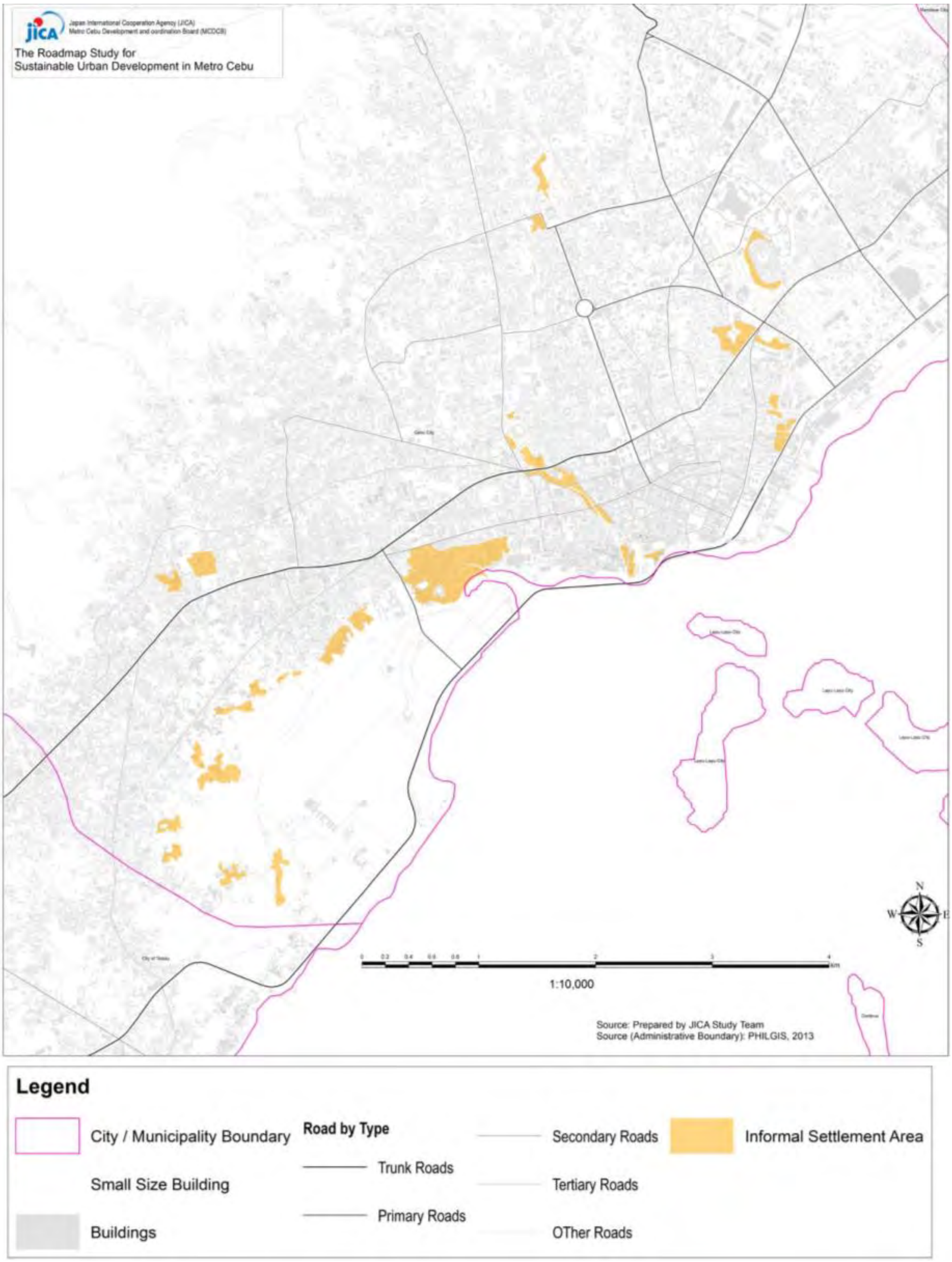
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.14 Landslide Hazard Area



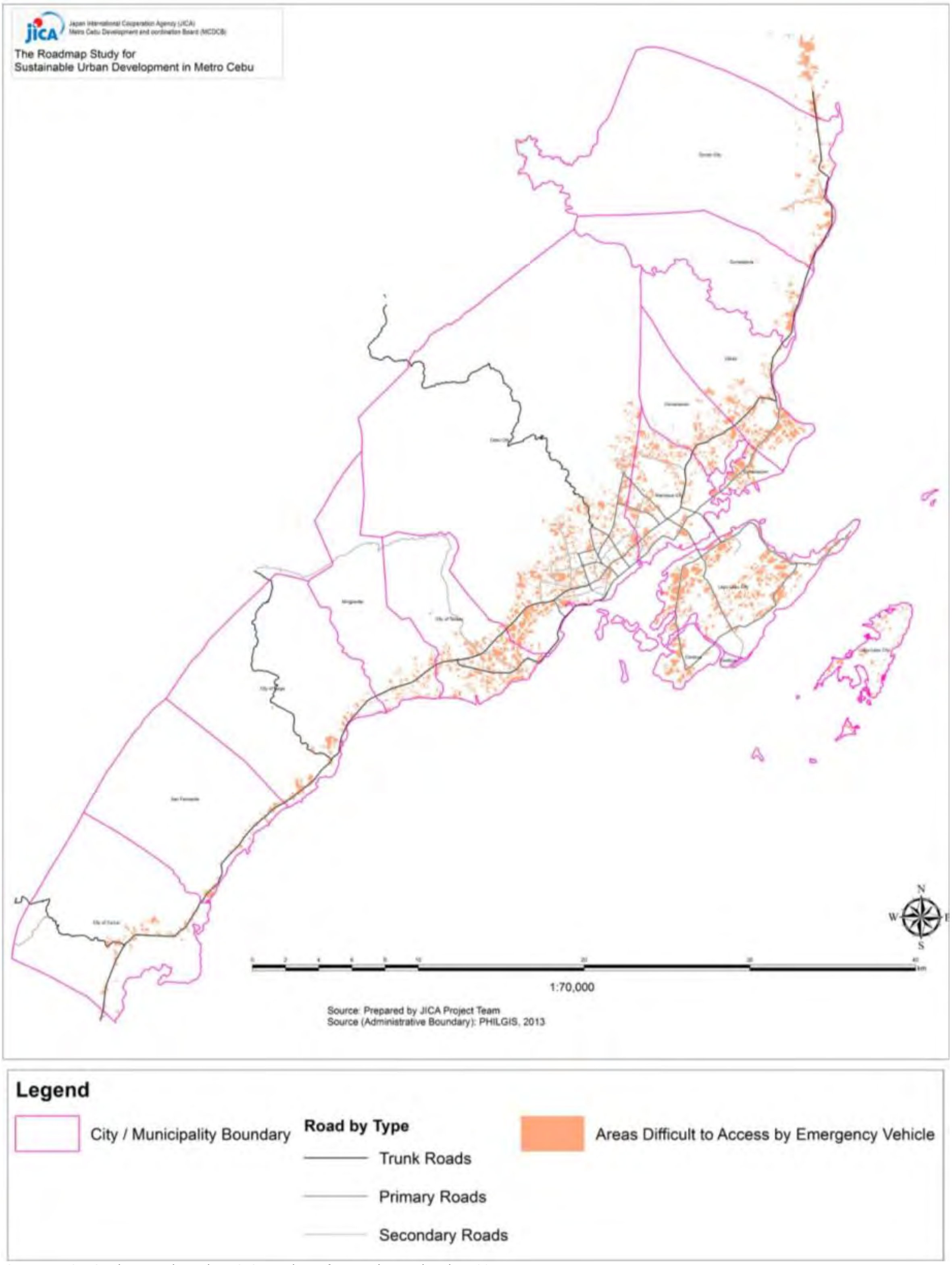
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.15 Building Area Ratio



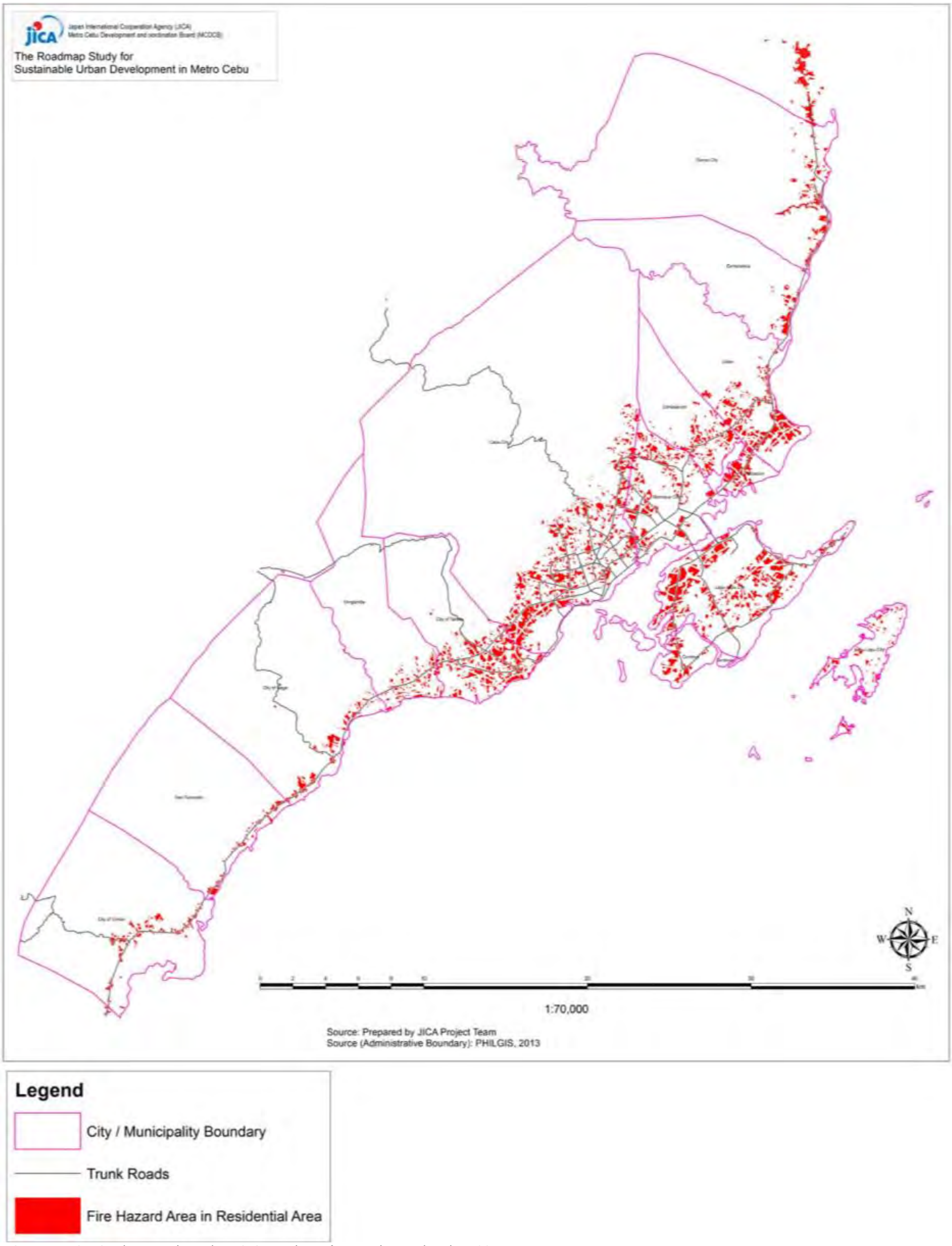
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.16 Informal Settlement Area



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

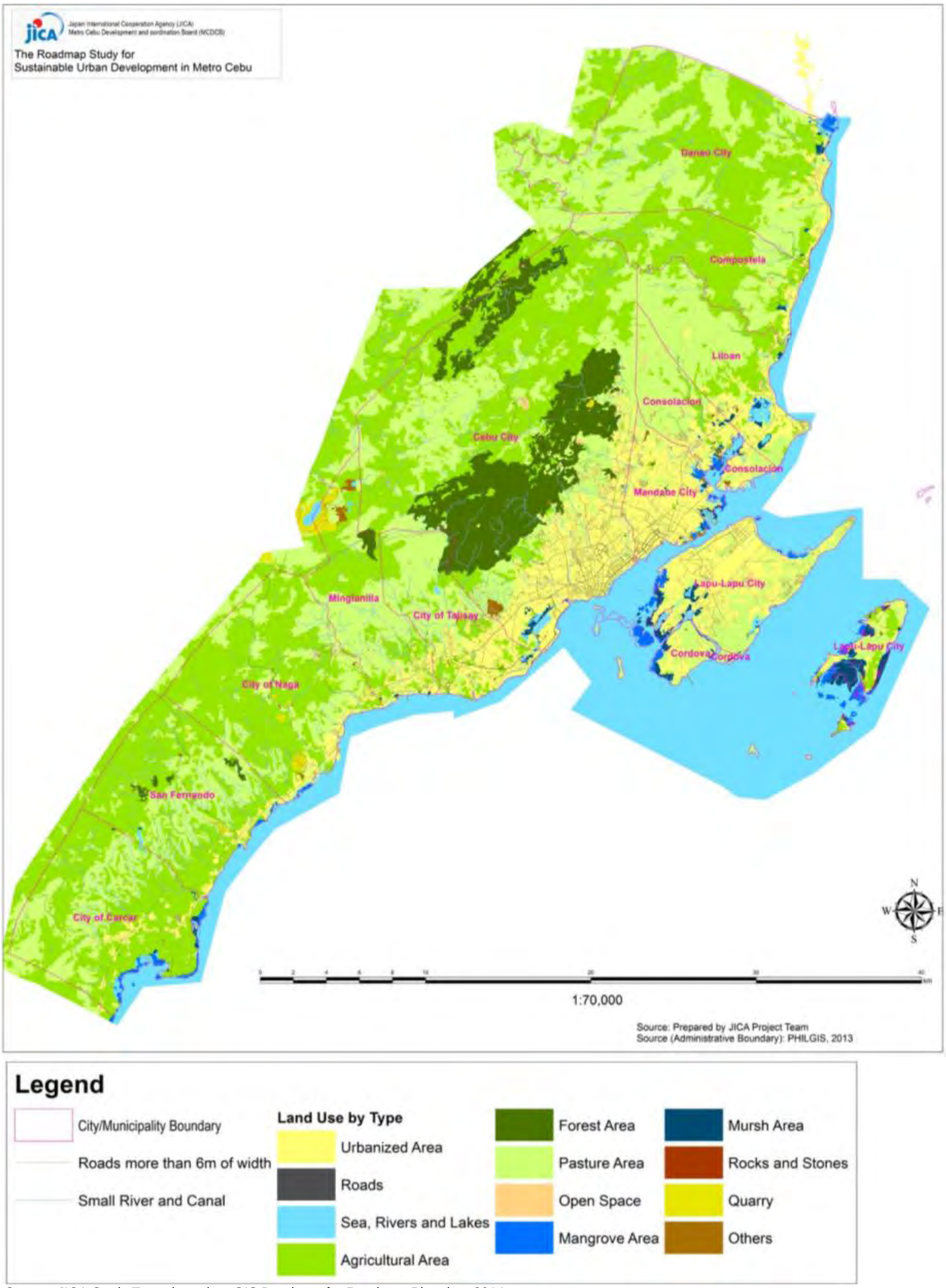
Figure 4.1.17 Areas Difficult to Access by Emergency Vehicle in Residential Area



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

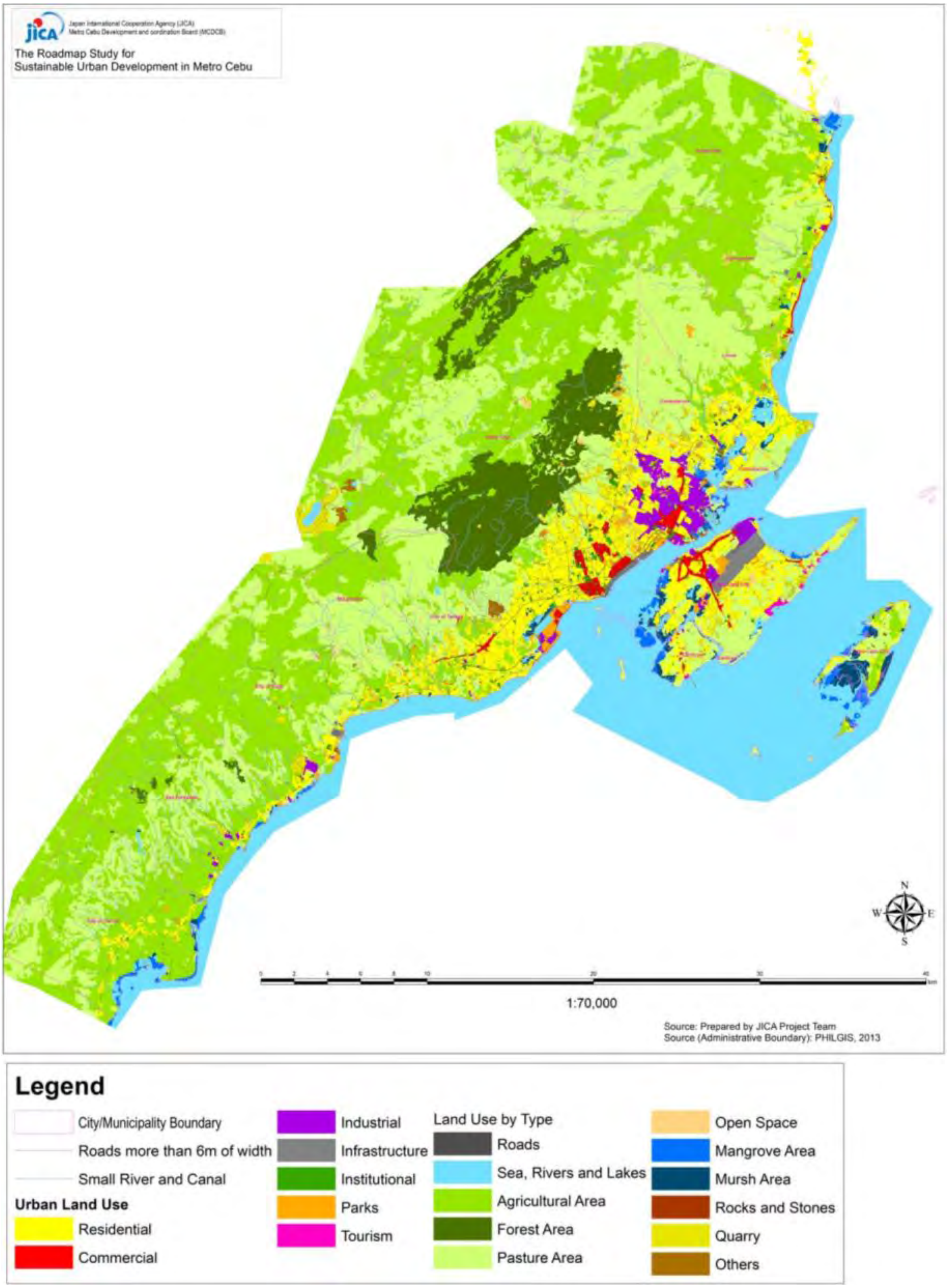
Figure 4.1.18 Fire Hazard Area in Residential Area

5) Land Use



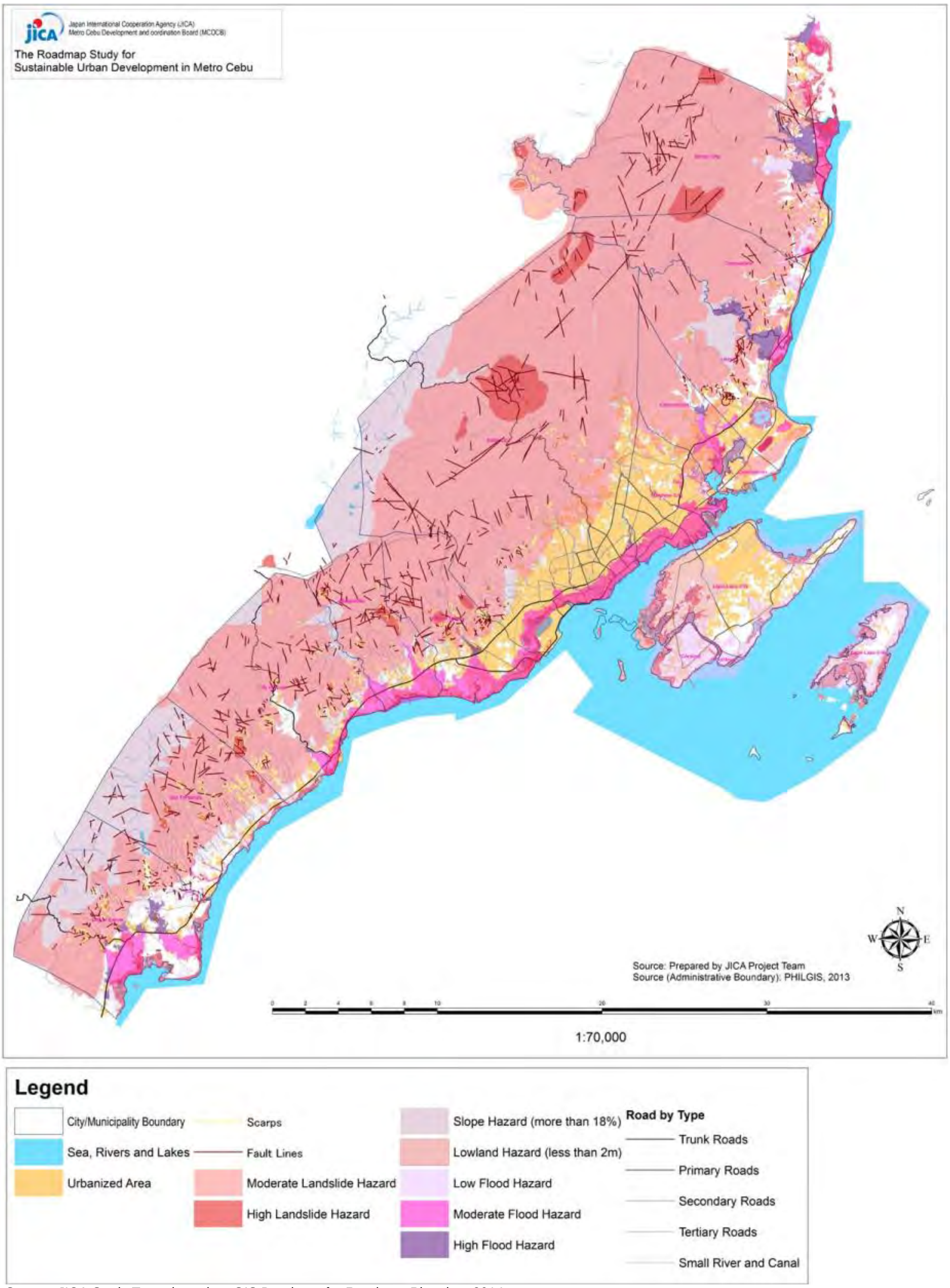
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.19 Existing Land Use



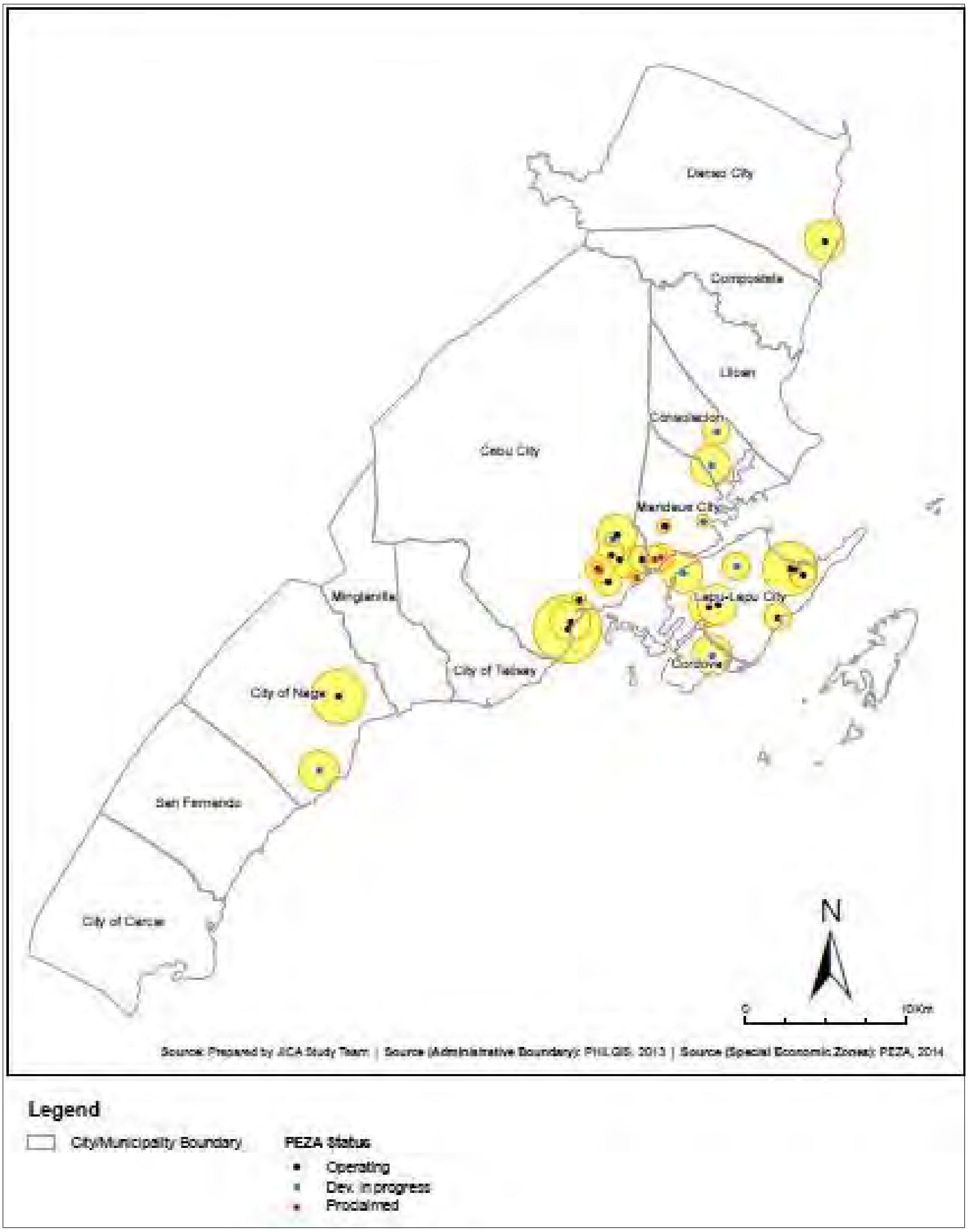
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.20 Existing Urban Land Use



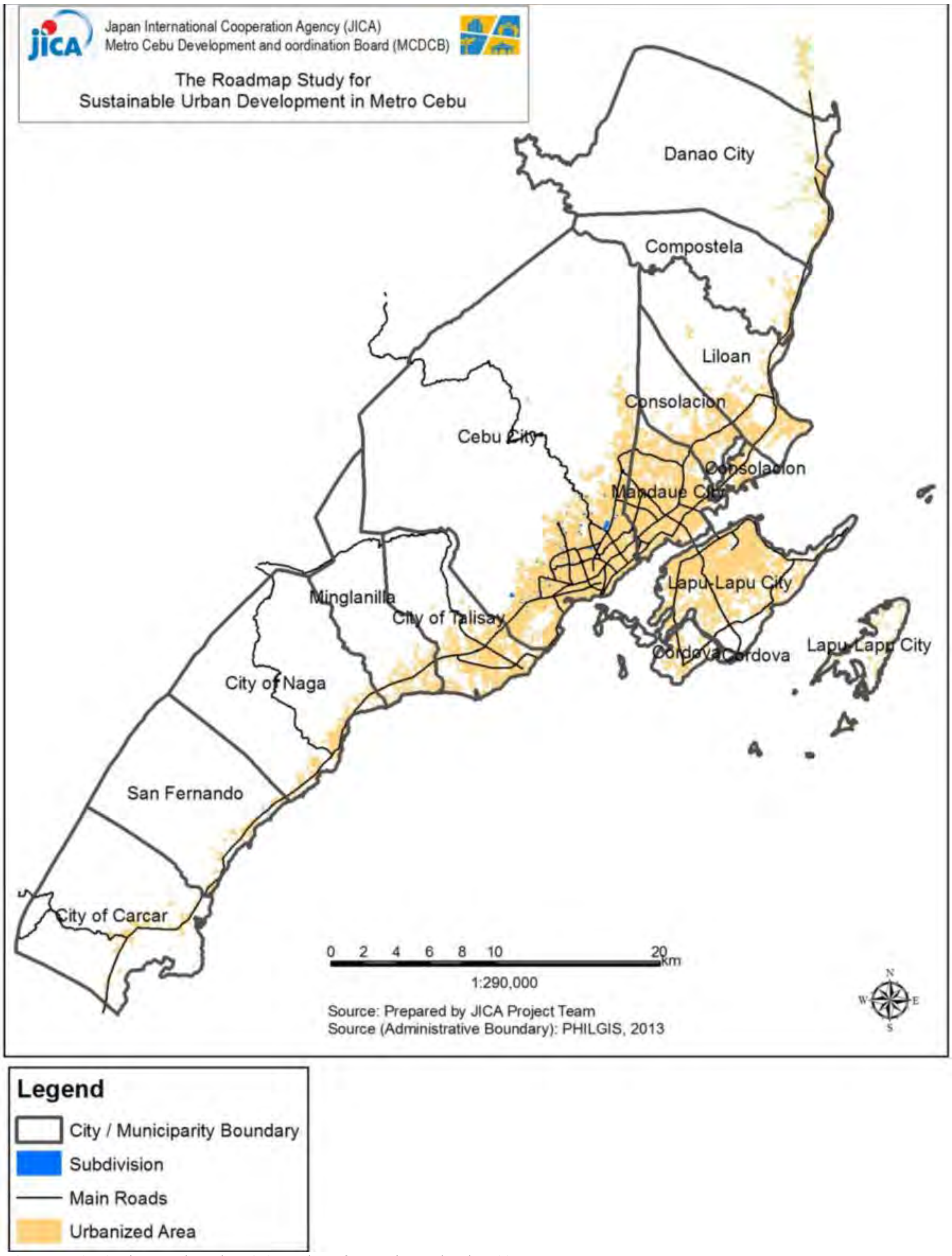
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.21 Development Suitable Area and Urbanization



Source: JICA Study Team based on Special Economic Zones of PEZA, 2014.

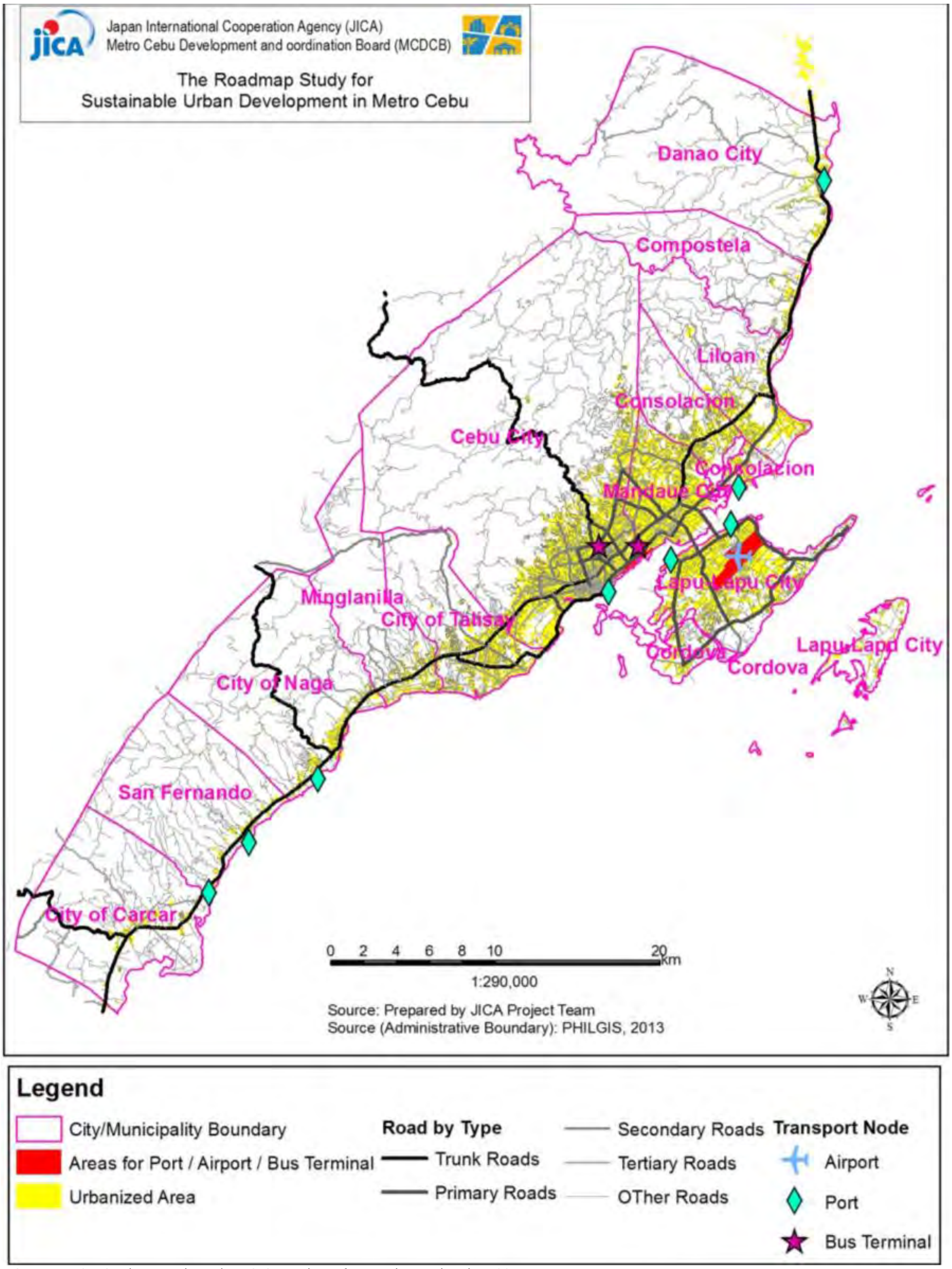
Figure 4.1.22 Location of PEZA by Status



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

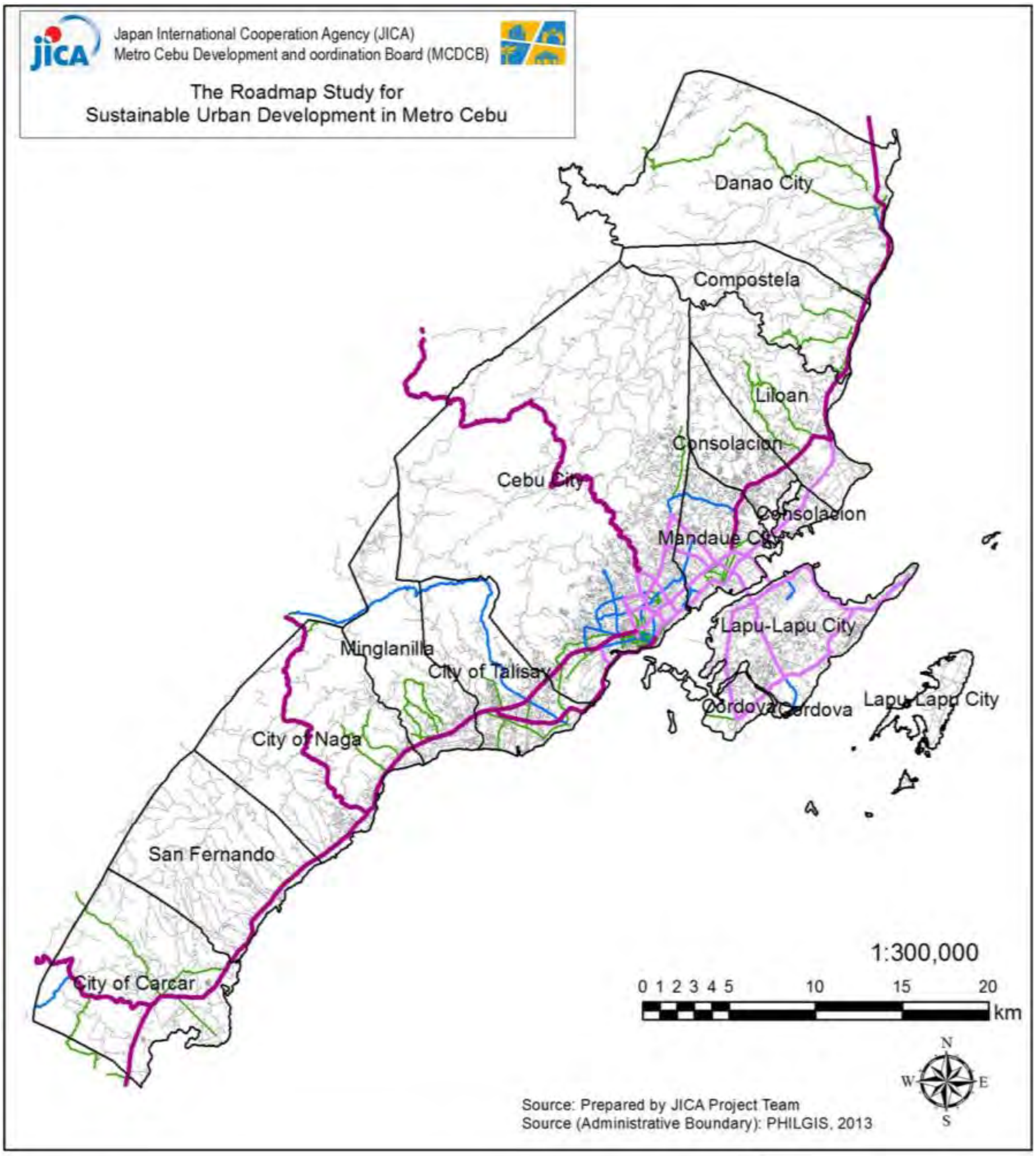
Figure 4.1.23 Location of Subdivision

6) Urban Transport



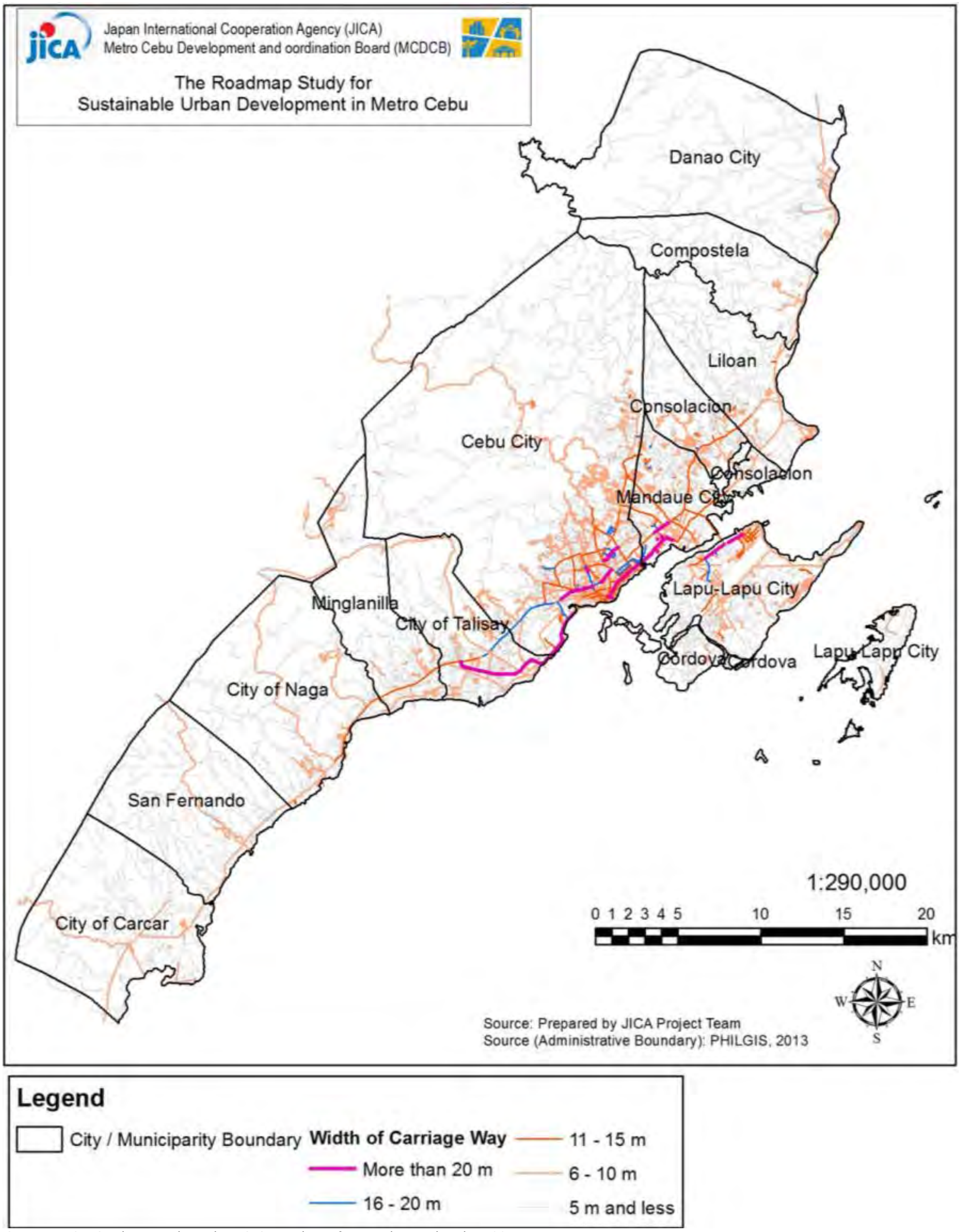
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.24 Transport System



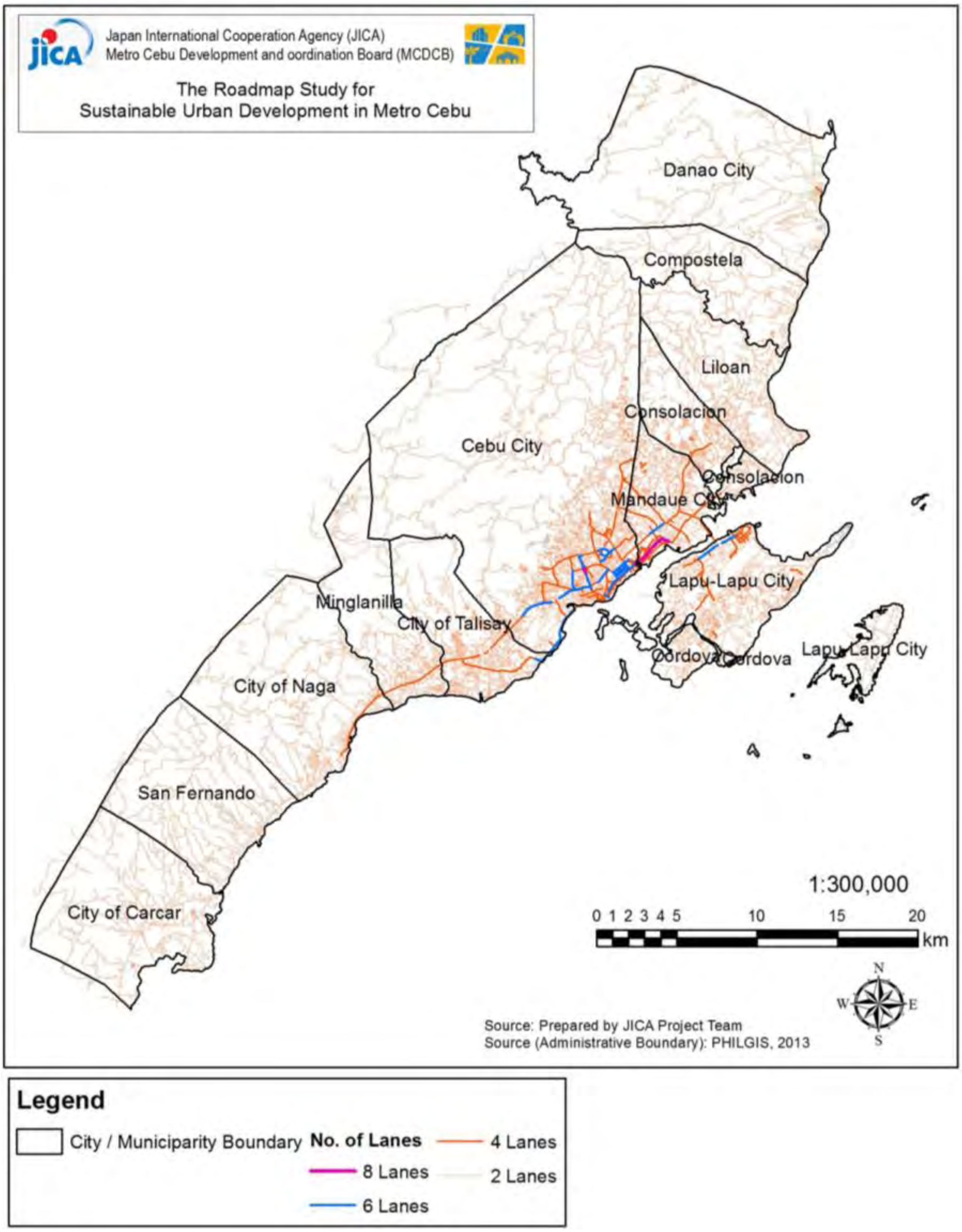
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.25 Existing Road Network by Type



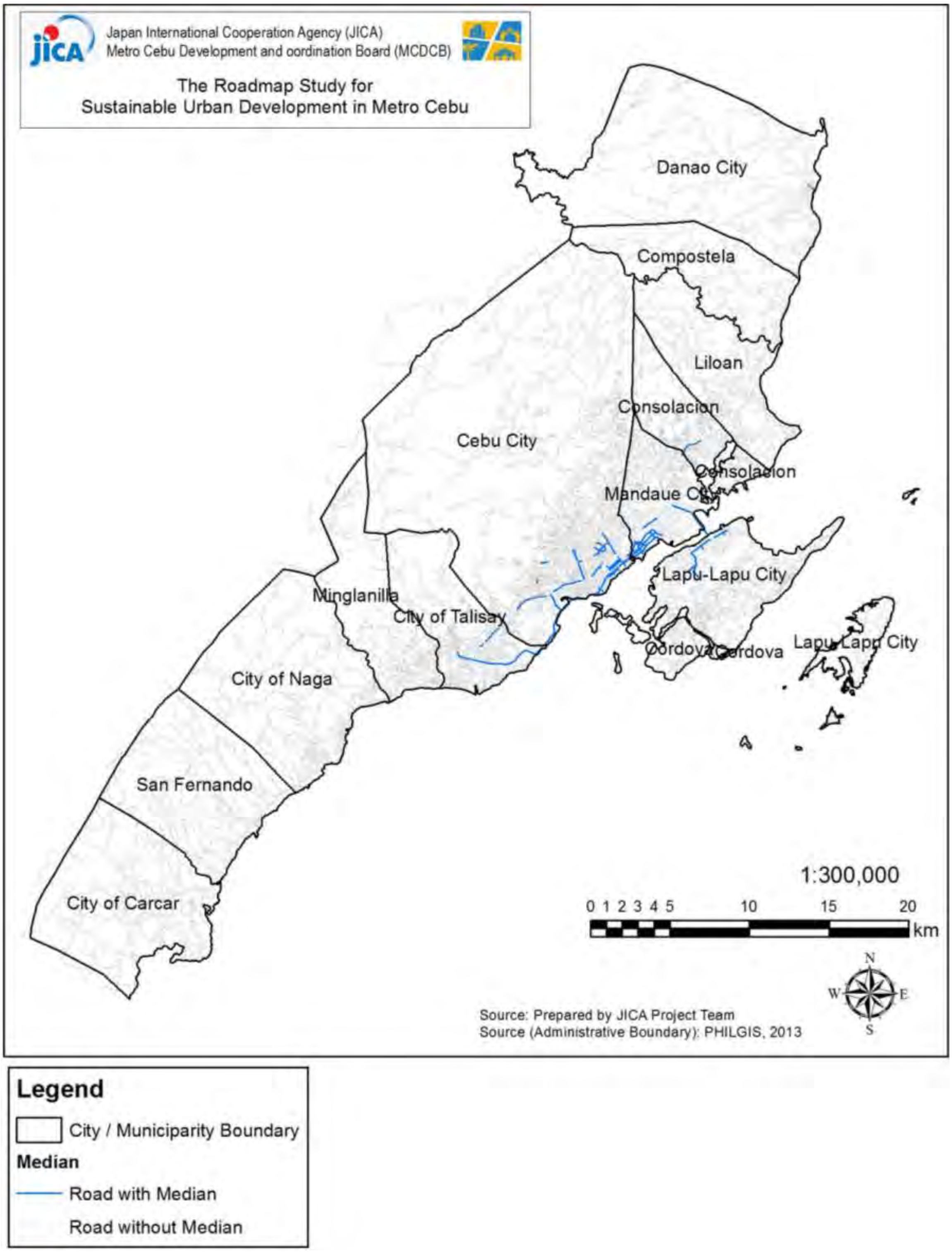
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.26 Existing Road Network by Width of Carriage Way



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

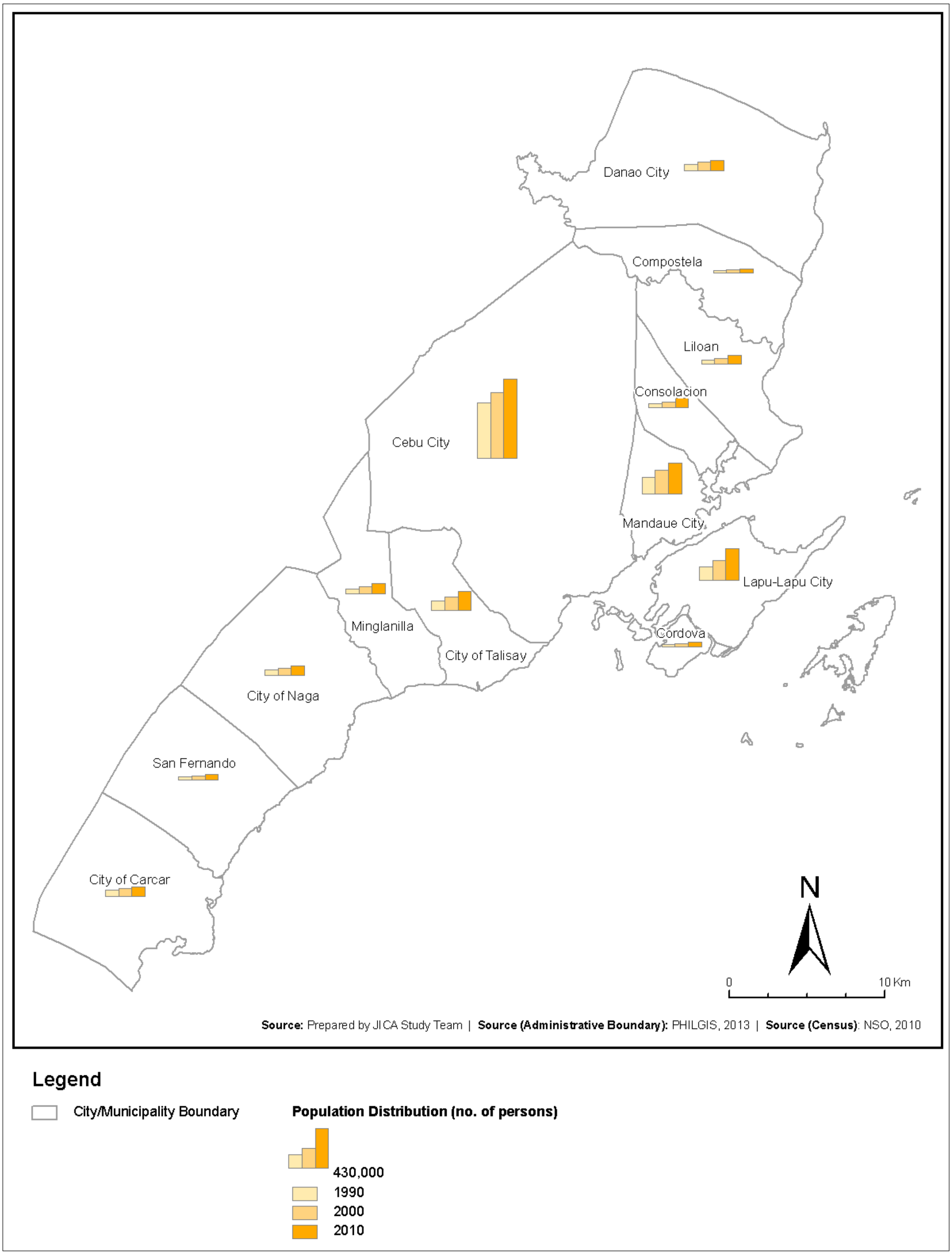
Figure 4.1.27 Existing Road Network by Number of Lanes



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 4.1.28 Existing Road Network by Existence of Median

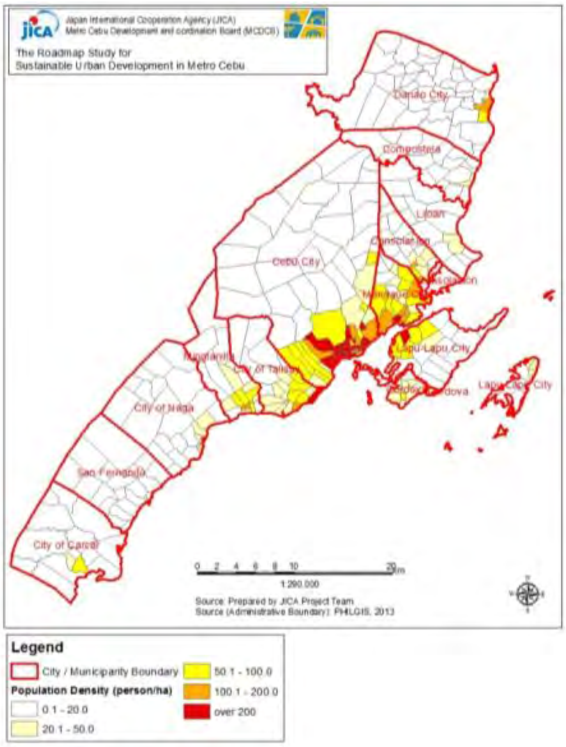
7) Socioeconomic Conditions



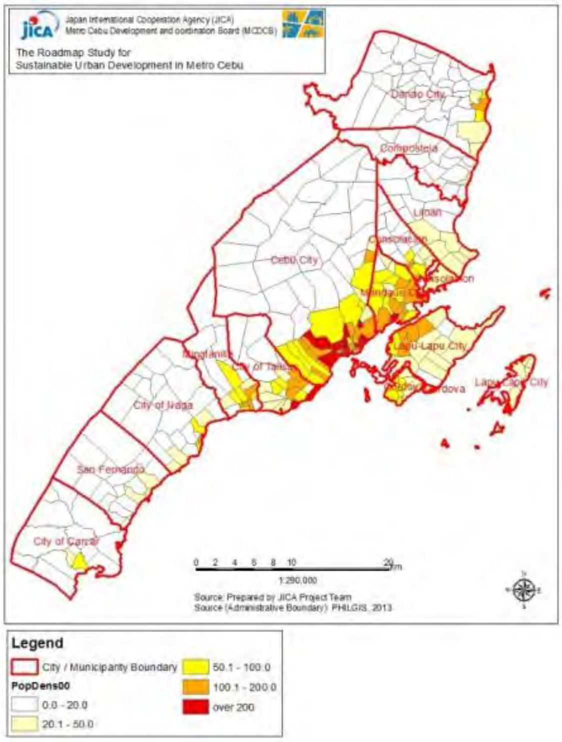
Source: JICA Study Team based on Census 2013, NSO.

Figure 4.1.29 Population Distribution by City / Municipality

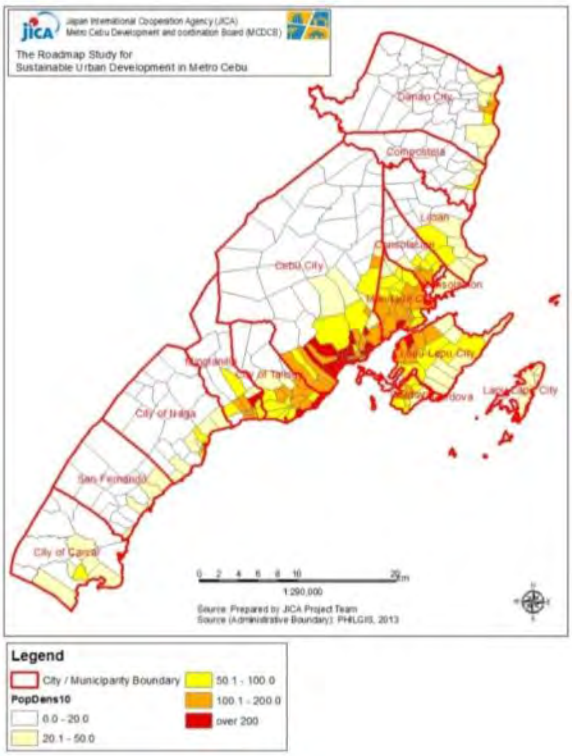
Year 1990



Year 2000



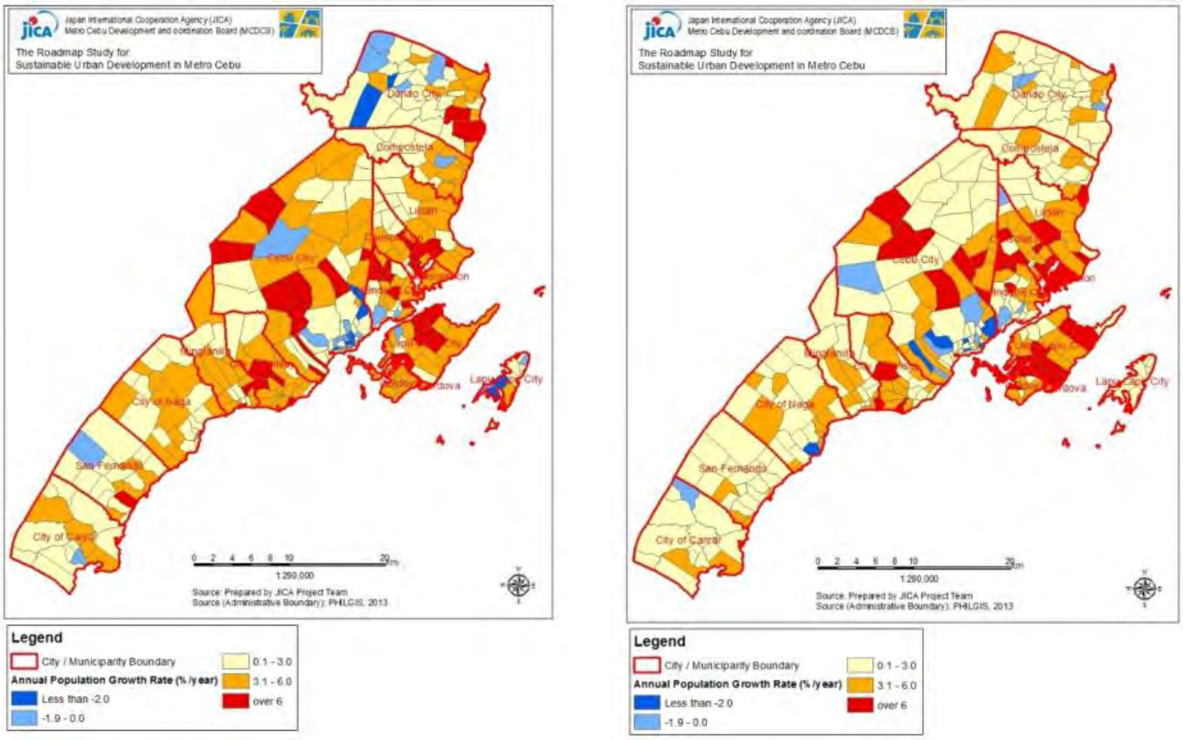
Year 2010



Source: JICA Study Team based on Census 2013, NSO.

Figure 4.1.30 Administrative Boundary and Socioeconomic – Population Density

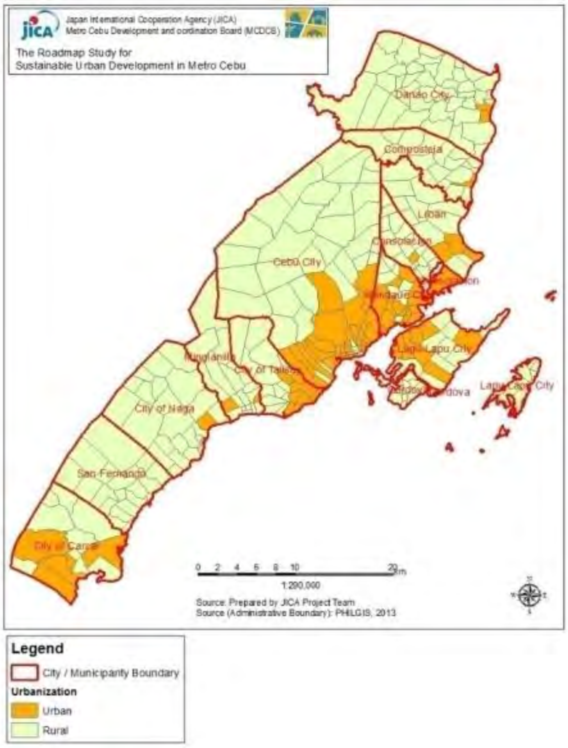
Year 1990–2000 Year 2000–2010



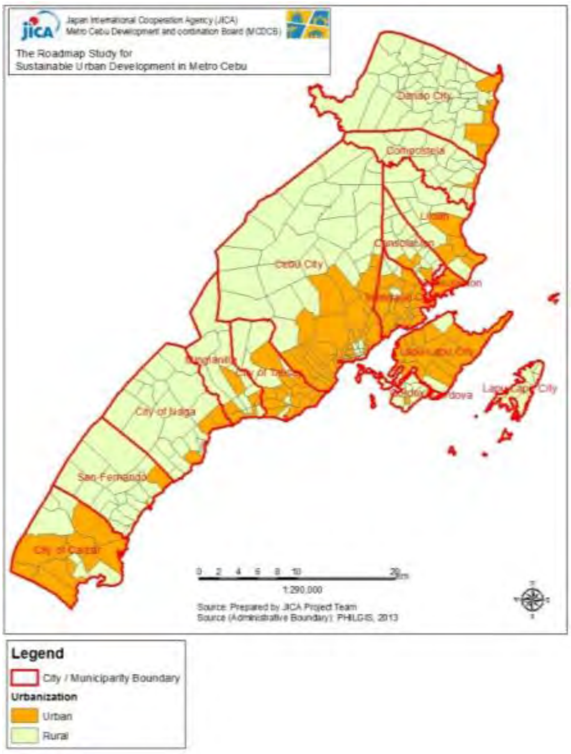
Source: JICA Study Team based on Census 2013, NSO.

Figure 4.1.31 Administrative Boundary and Socioeconomic – Population Growth Rate

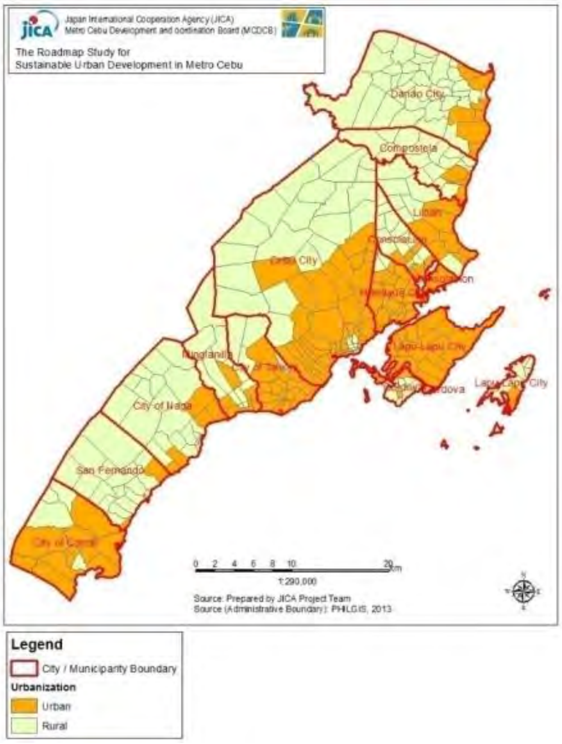
Year 1990



Year 2000

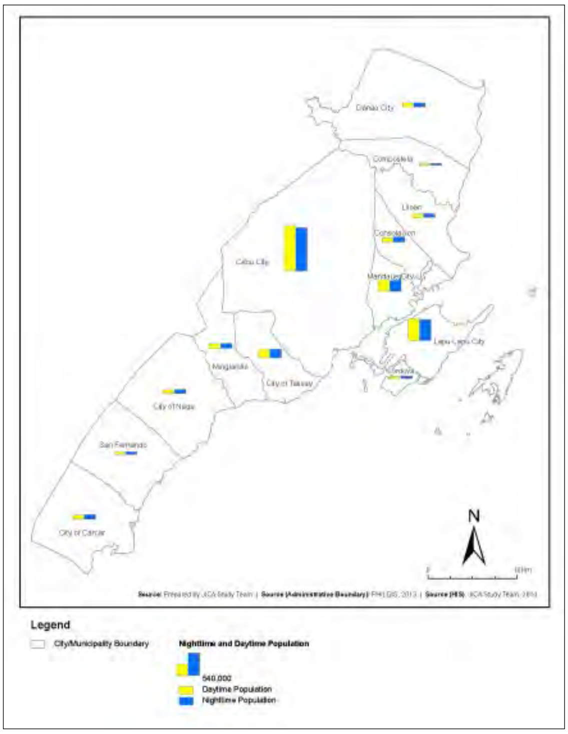


Year 2010



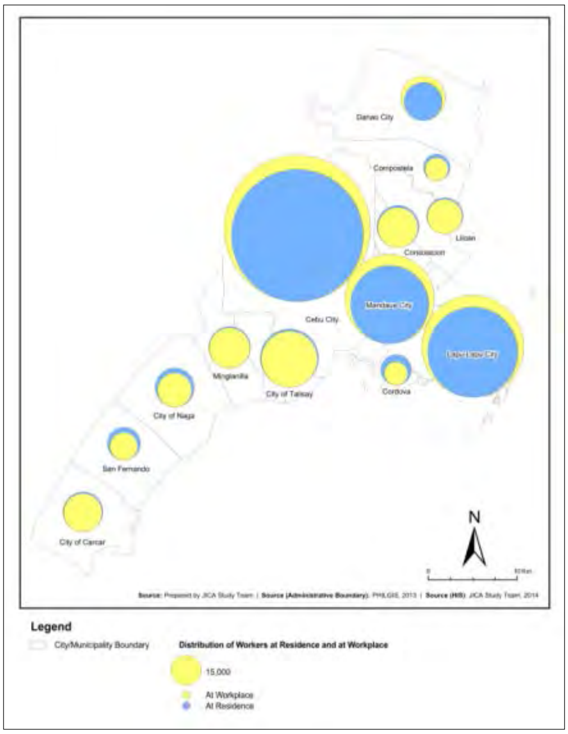
Source: JICA Study Team based on Census 2013, NSO.

Figure 4.1.32 Administrative Boundary and Socioeconomic – Urban Area Defined by NSO



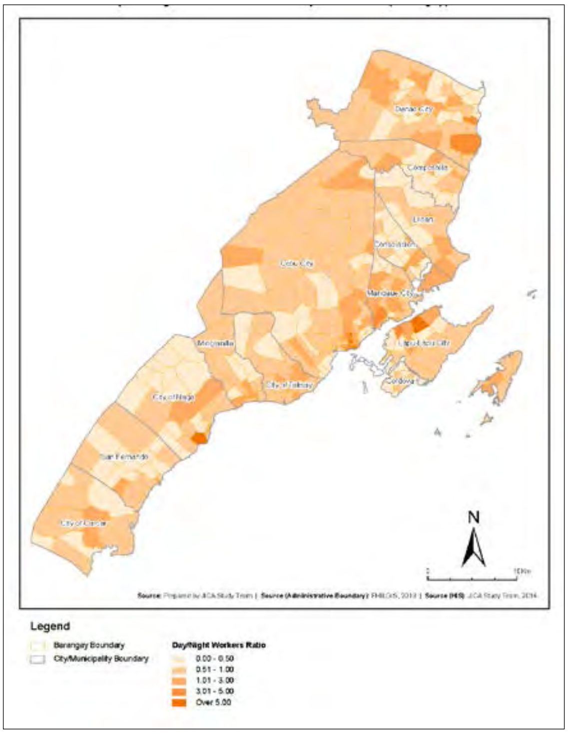
Source: JICA Study Team, HIS 2014.

Figure 4.1.33 Nighttime and Daytime Population Distribution by City / Municipality



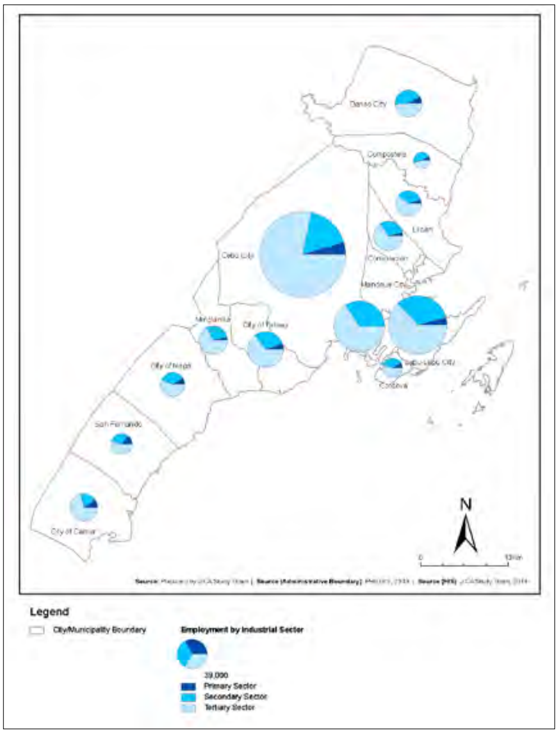
Source: JICA Study Team, HIS 2014.

Figure 4.1.34 Distribution of Workers at Residence and at Workplace



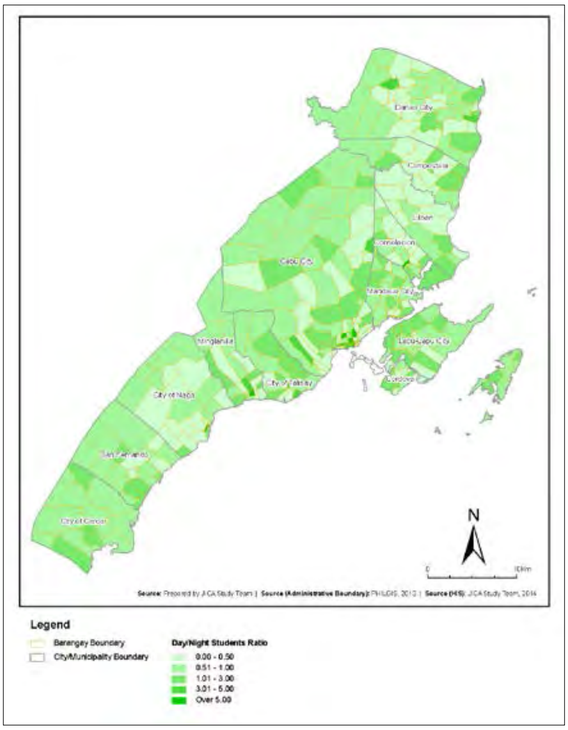
Source: JICA Study Team, HIS 2014.

Figure 4.1.35 Daytime / Nighttime Ratio of Workers by Traffic Zone (Barangay)



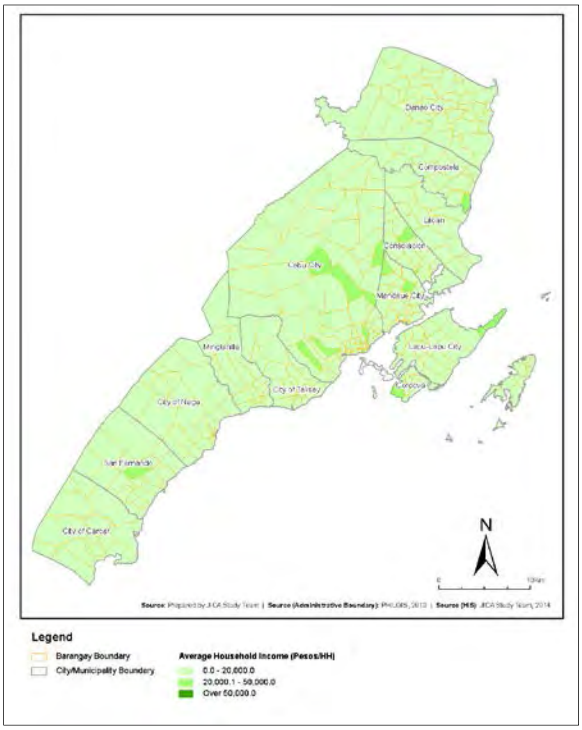
Source: JICA Study Team, HIS 2014.

Figure 4.1.36 Employment by Industrial Sector



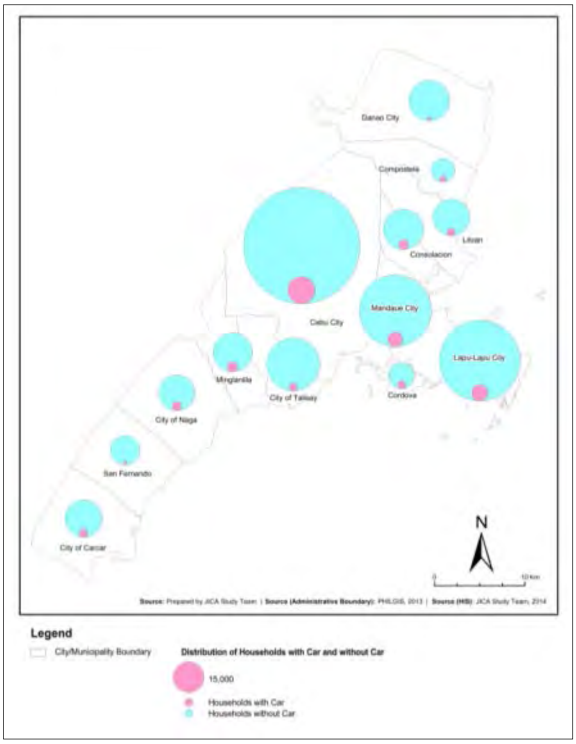
Source: JICA Study Team, HIS 2014.

Figure 4.1.37 Daytime / Nighttime Ratio of Students by Traffic Zone (Barangay)



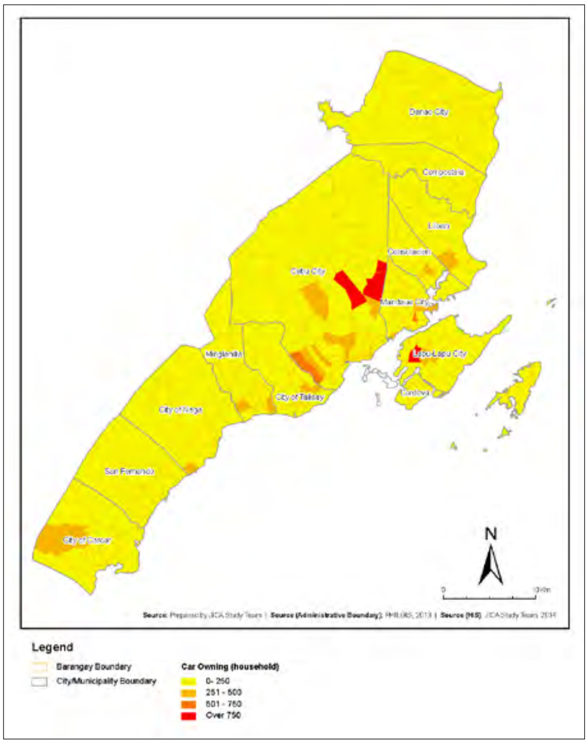
Source: JICA Study Team, HIS 2014.

Figure 4.1.38 Average Household Income by Traffic Zone (Barangay)



Source: JICA Study Team, HIS 2014.

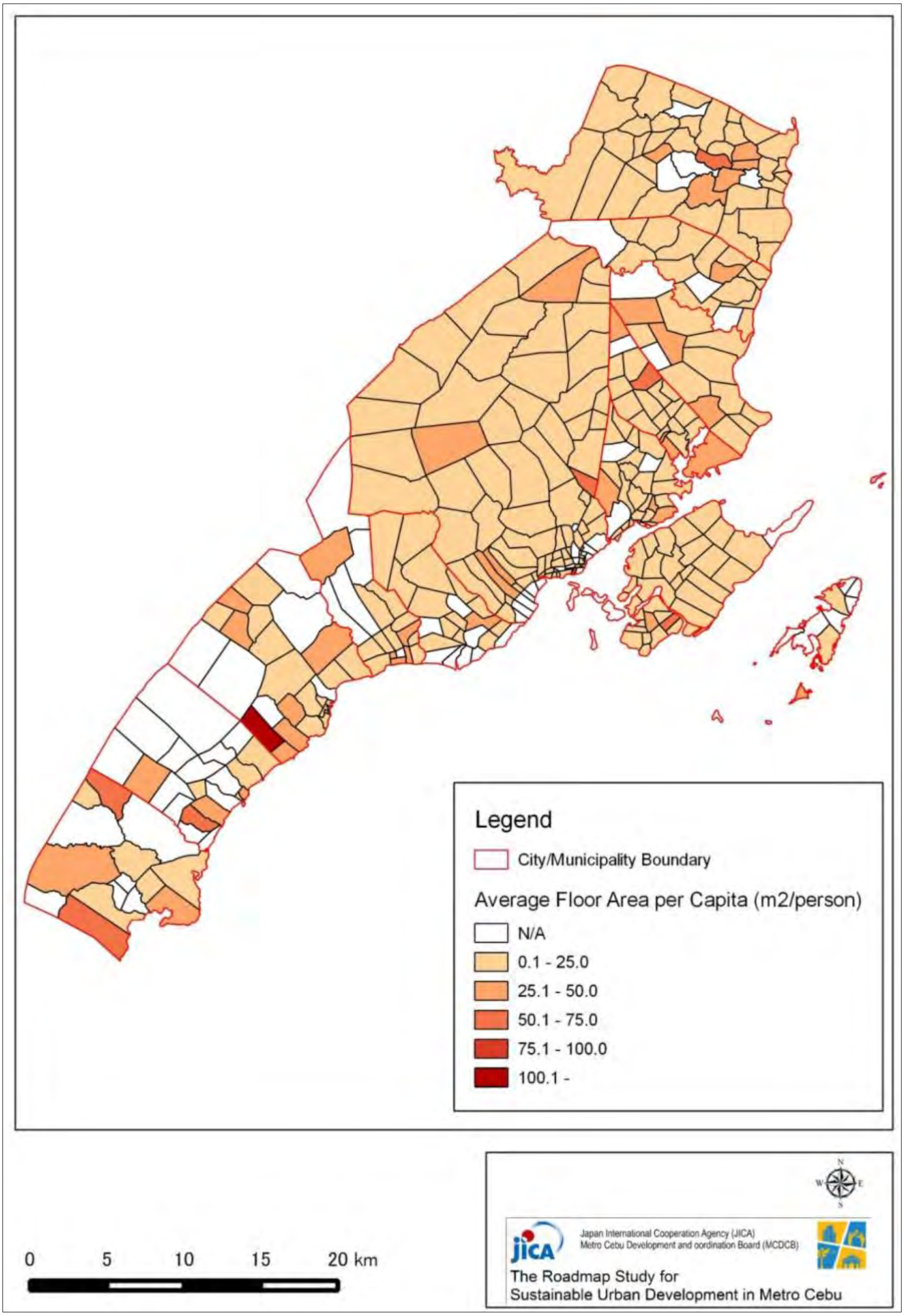
Figure 4.1.39 Car Ownership by City / Municipality



Source: JICA Study Team, HIS 2014.

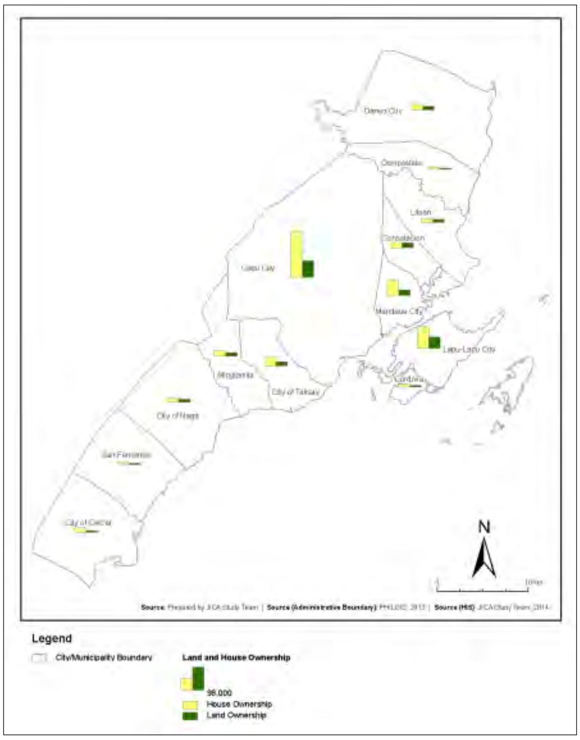
Figure 4.1.40 Car Ownership by Traffic Zone (Barangay)

8) Living Conditions



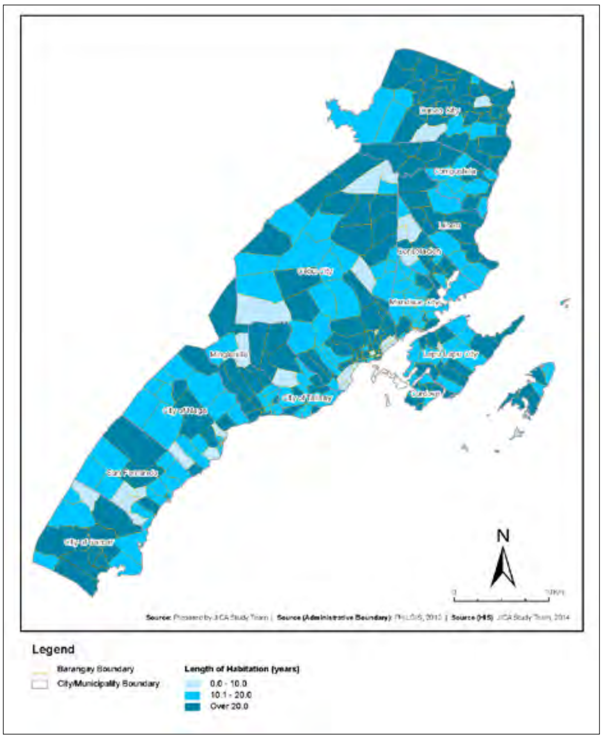
Source: Prepared by JICA Study Team based on HIS.

Figure 4.1.41 Average Housing Floor Area per Capita



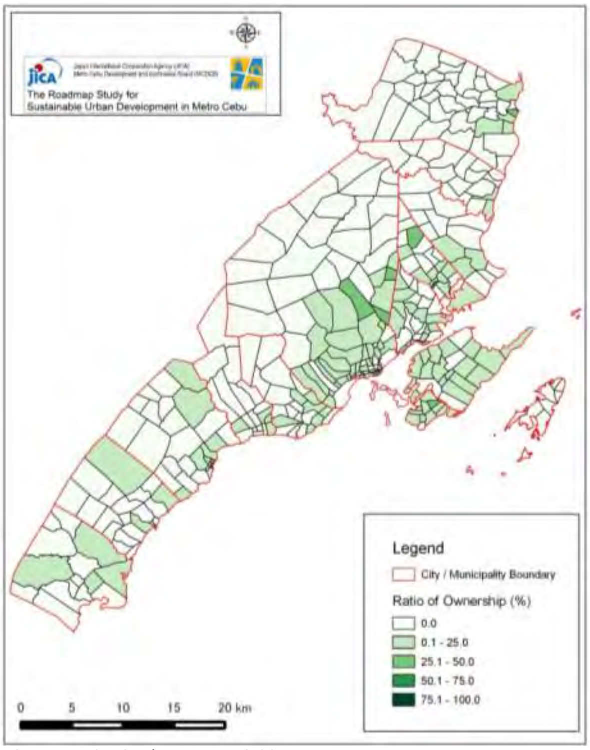
Source: JICA Study Team, HIS 2014.

Figure 4.1.42 Land and House Ownership by City / Municipality



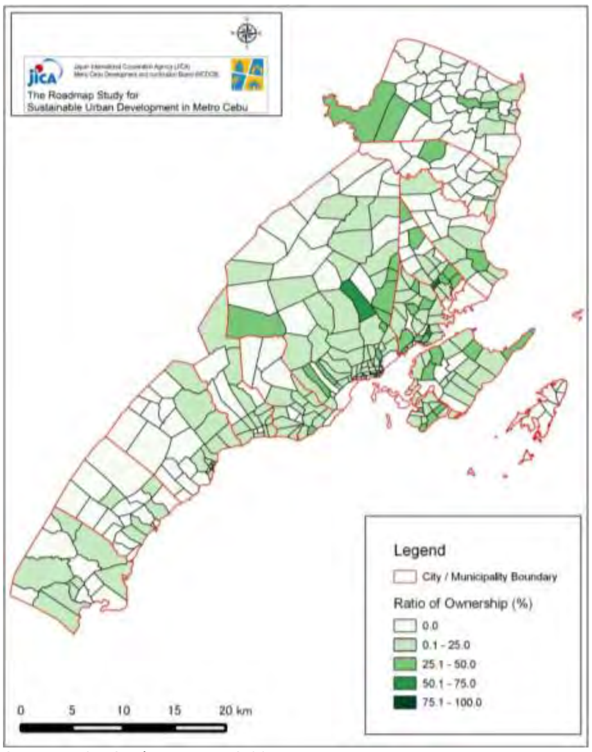
Source: JICA Study Team, HIS 2014.

Figure 4.1.43 Average Length of Habitation by Traffic Zone (Barangay)



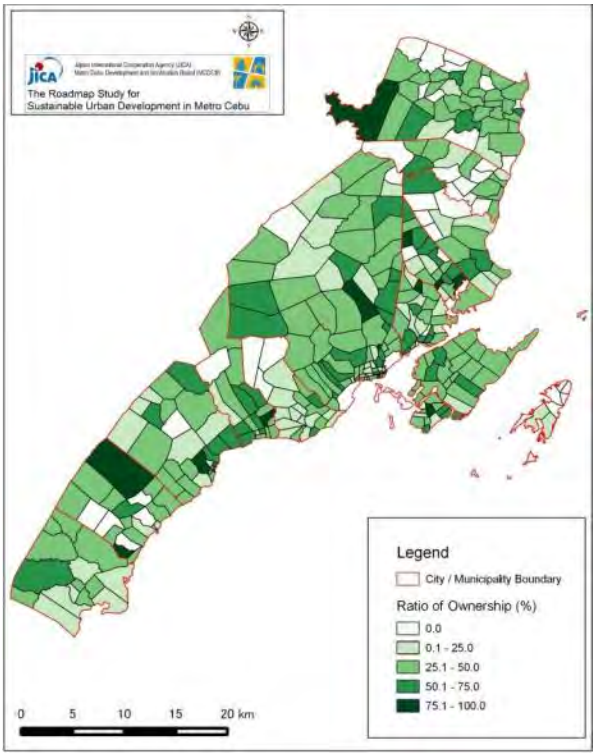
Source: JICA Study Team, HIS 2014.

Figure 4.1.44 Ownership of Air Conditioner



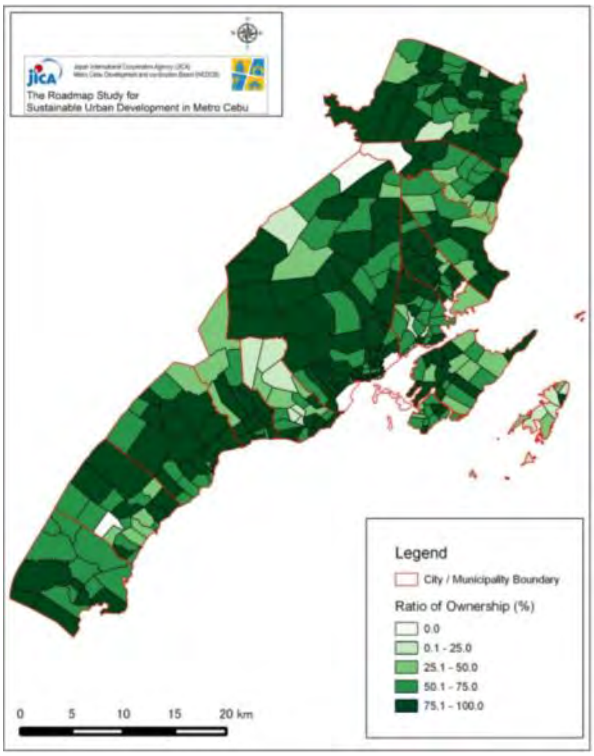
Source: JICA Study Team, HIS 2014.

Figure 4.1.45 Ownership of Washing Machine



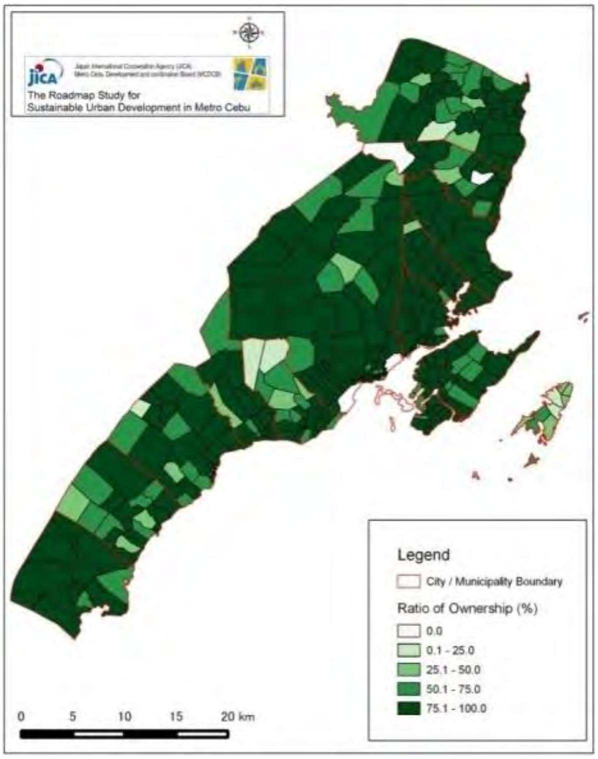
Source: JICA Study Team, HIS 2014.

Figure 4.1.46 Ownership of Refrigerator



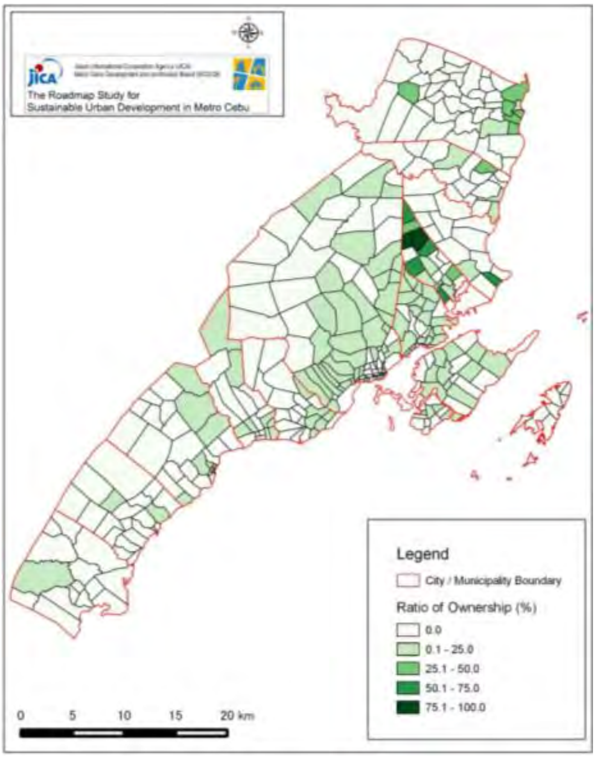
Source: JICA Study Team, HIS 2014.

Figure 4.1.47 Ownership of Radio



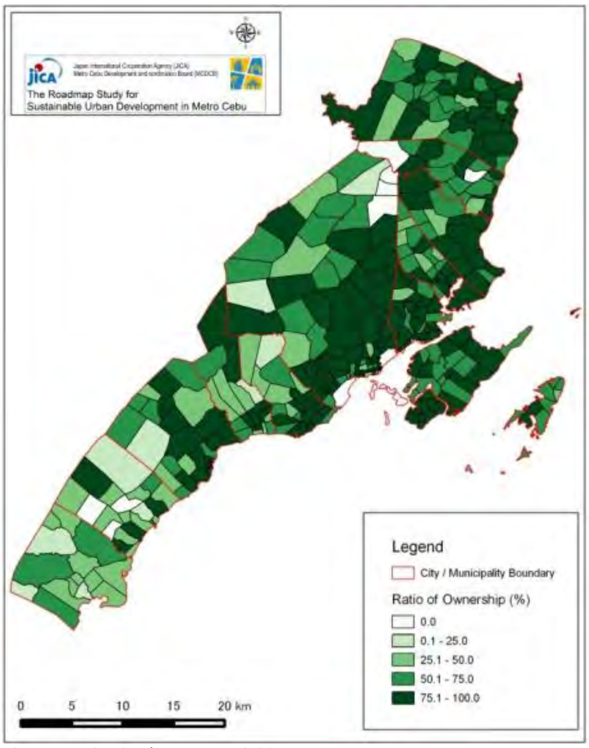
Source: JICA Study Team, HIS 2014.

Figure 4.1.48 Ownership of TV



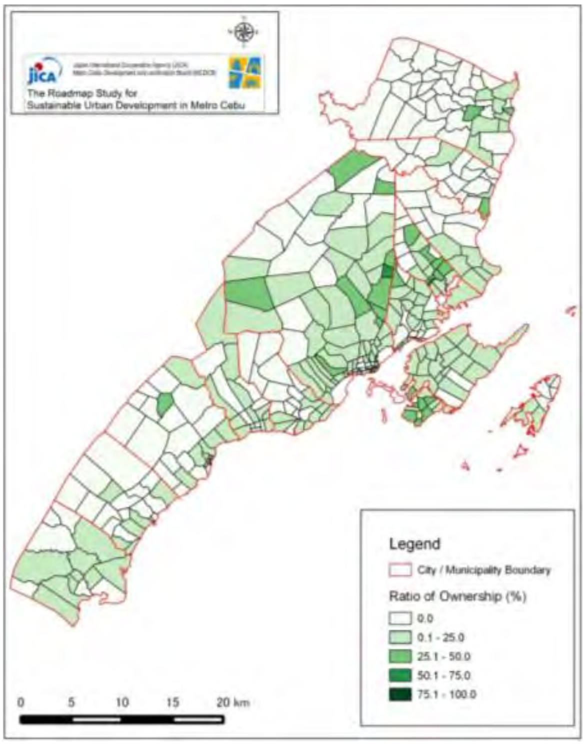
Source: JICA Study Team, HIS 2014.

Figure 4.1.49 Ownership of Satellite TV



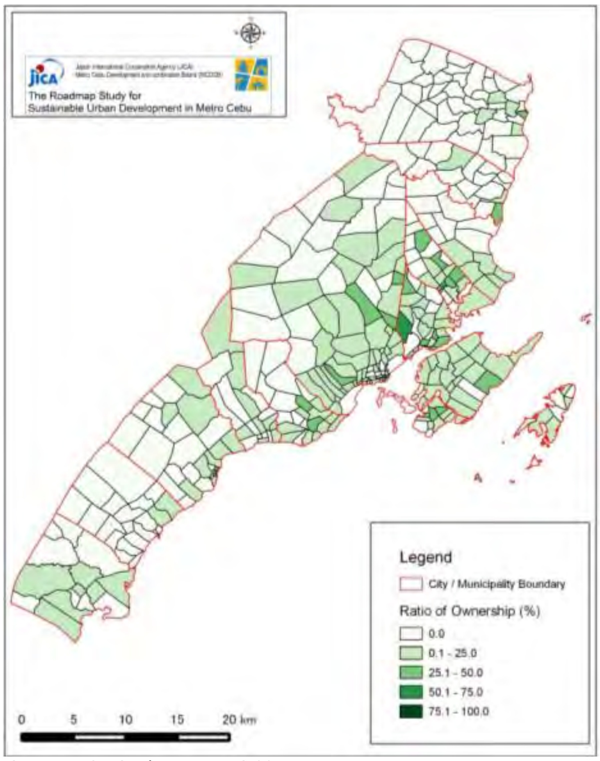
Source: JICA Study Team, HIS 2014.

Figure 4.1.50 Ownership of Mobile Phone



Source: JICA Study Team, HIS 2014.

Figure 4.1.51 Ownership of PC

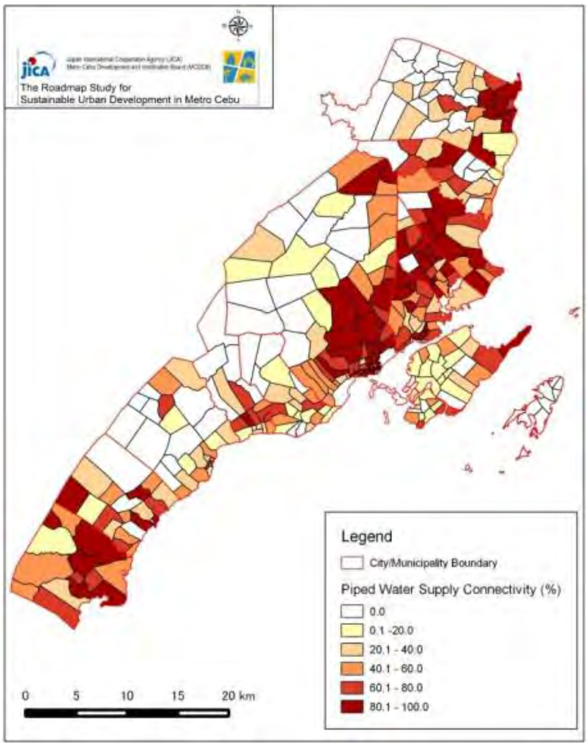


Source: JICA Study Team, HIS 2014.

Figure 4.1.52 Ownership of Internet

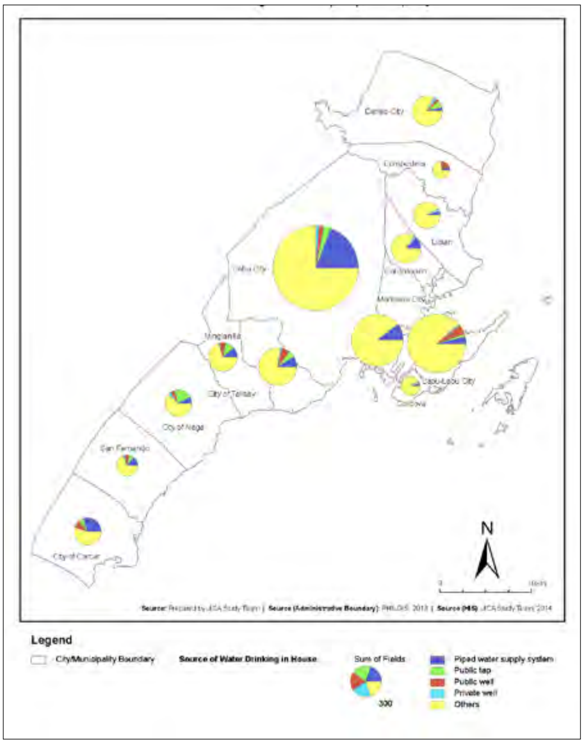
9) Urban Services

(1) Connectivity of Urban Services



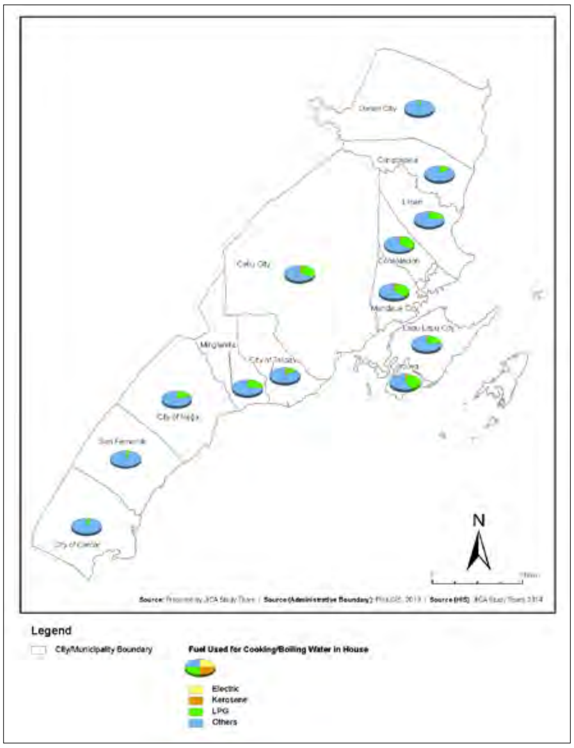
Source: JICA Study Team, HIS 2014.

Figure 4.1.53 Connectivity of Piped Water Supply



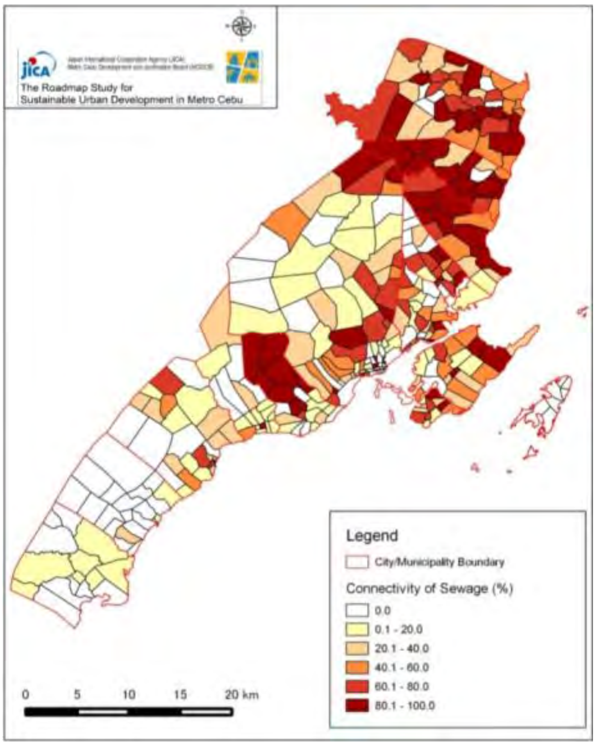
Source: JICA Study Team, HIS 2014

Figure 4.1.54 Source of Water for Drinking in House by City / Municipality



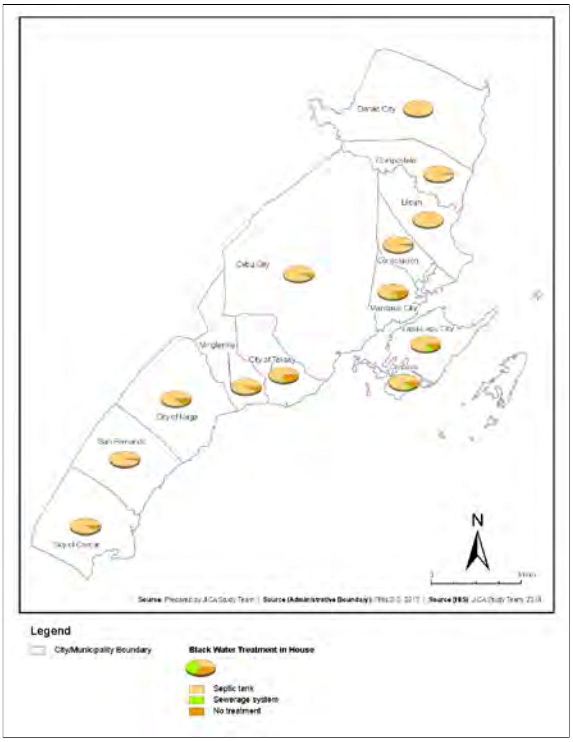
Source: JICA Study Team, HIS 2014.

Figure 4.1.55 Fuel Used for Cooking / Boiling Water in House by City / Municipality



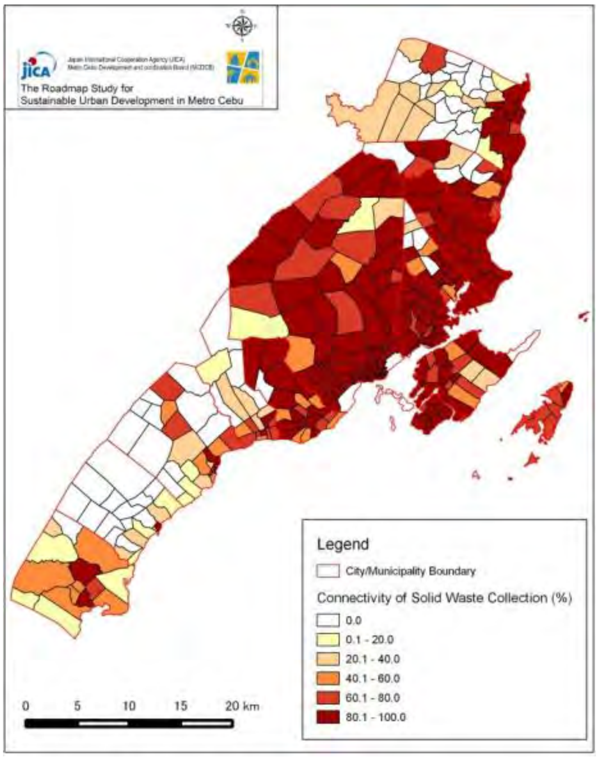
Source: JICA Study Team, HIS 2014.

Figure 4.1.56 Connectivity of Sewage



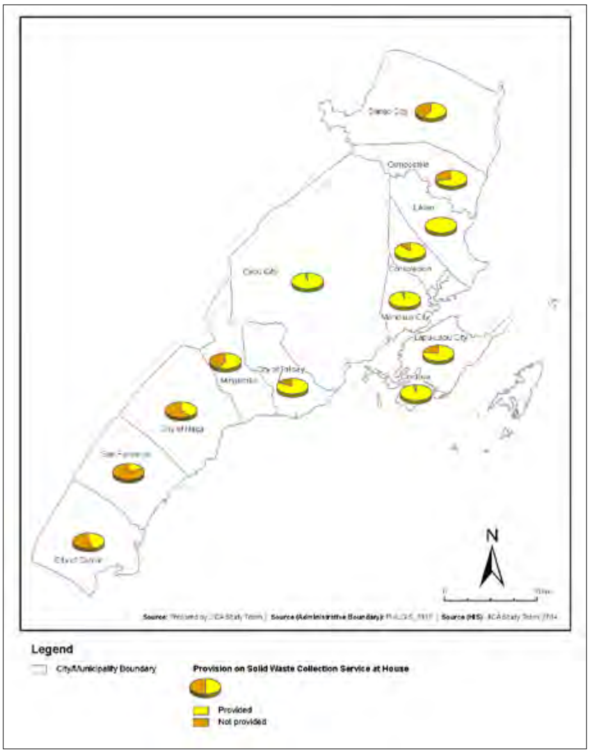
Source: JICA Study Team, HIS 2014.

Figure 4.1.57 House Sewerage Treatment by City / Municipality



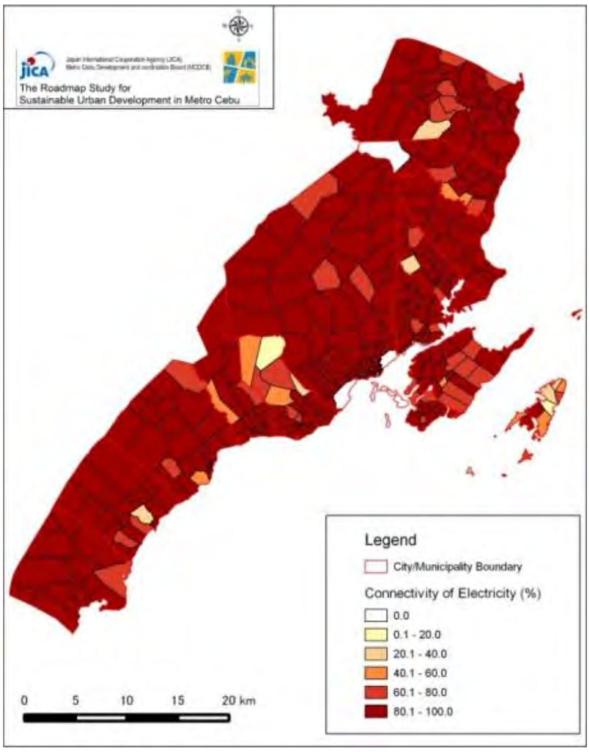
Source: JICA Study Team, HIS 2014.

Figure 4.1.58 Connectivity of Solid Waste Collection



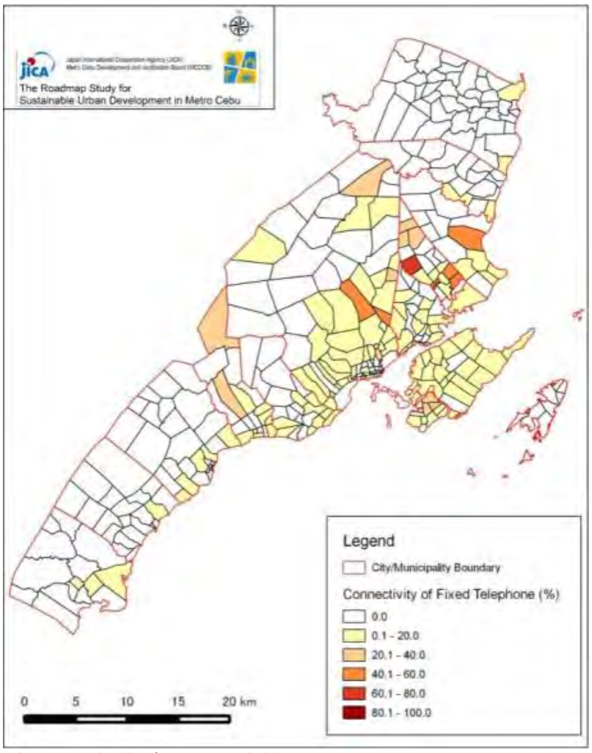
Source: JICA Study Team, HIS 2014.

Figure 4.1.59 Provision of Solid Waste Collection Service at House by City / Municipality



Source: JICA Study Team, HIS 2014.

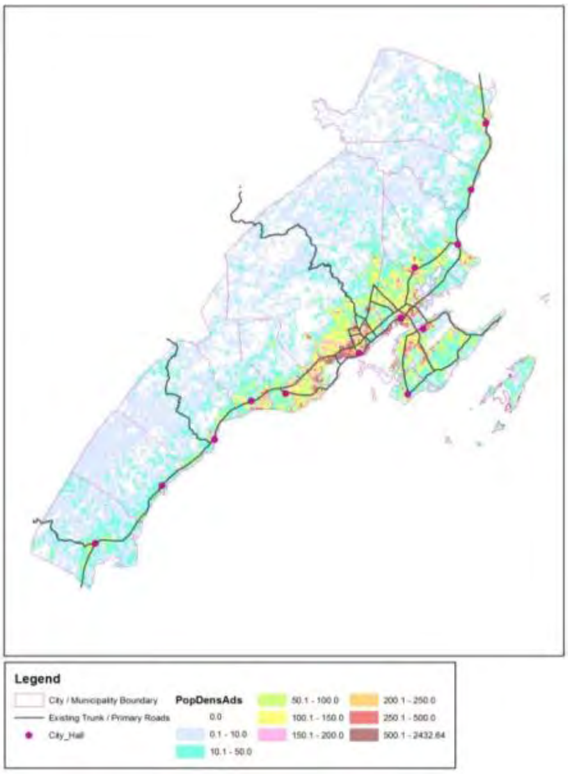
Figure 4.1.60 Connectivity of Electricity



Source: JICA Study Team, HIS 2014.

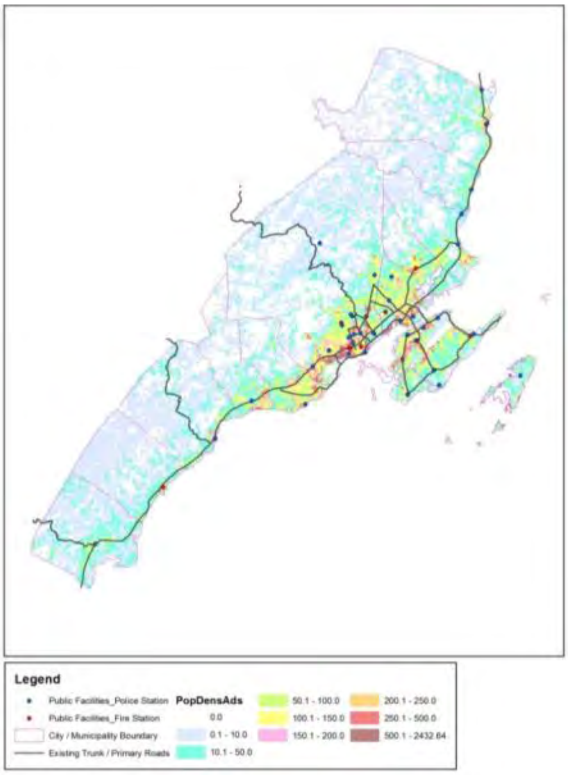
Figure 4.1.61 Connectivity of Fixed Telephone

(2) Location of Public Facilities



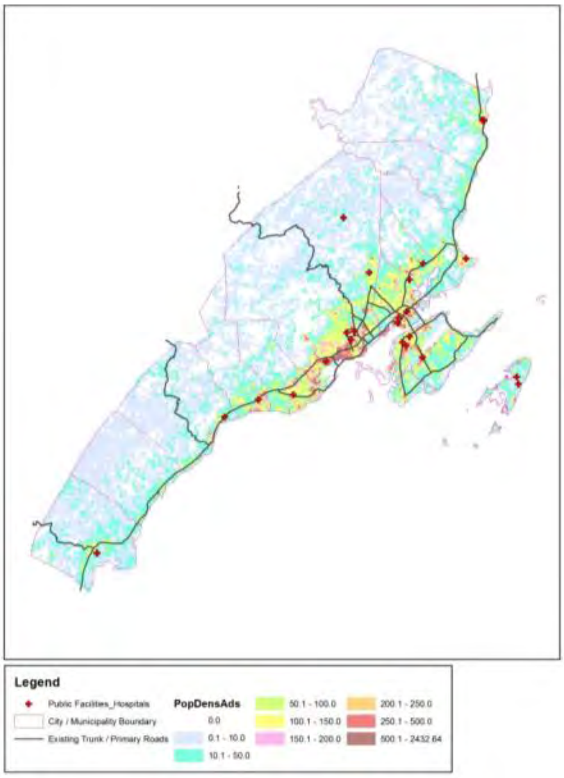
Source: JICA Study Team.

Figure 4.1.62 Location of City Hall



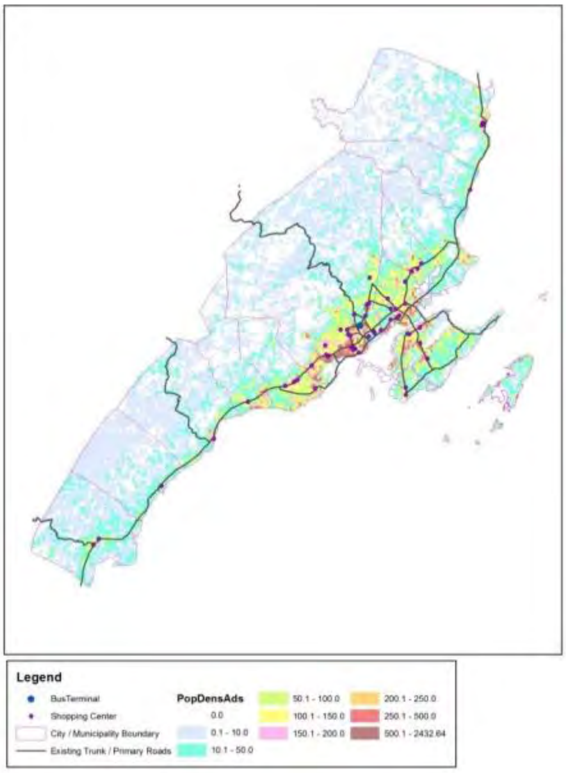
Source: JICA Study Team.

Figure 4.1.63 Location of Fire and Police Station



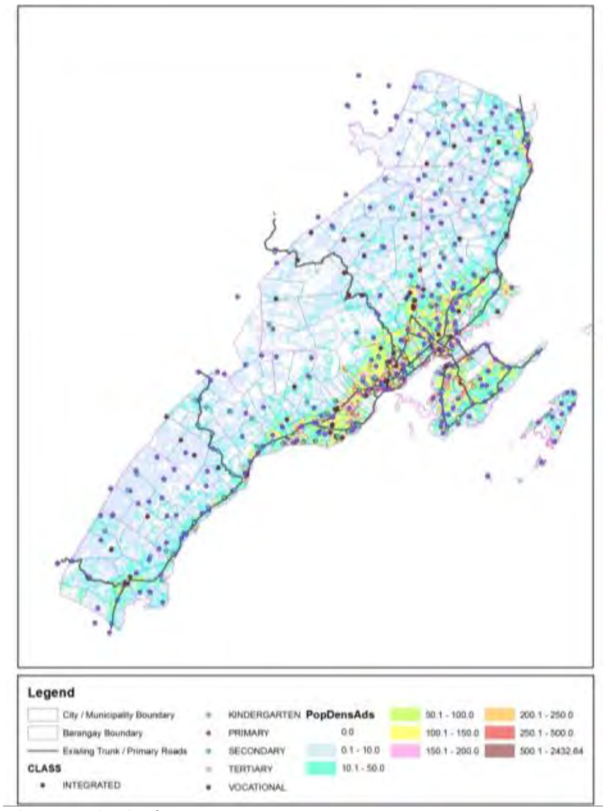
Source: JICA Study Team.

Figure 4.1.64 Location of Hospital



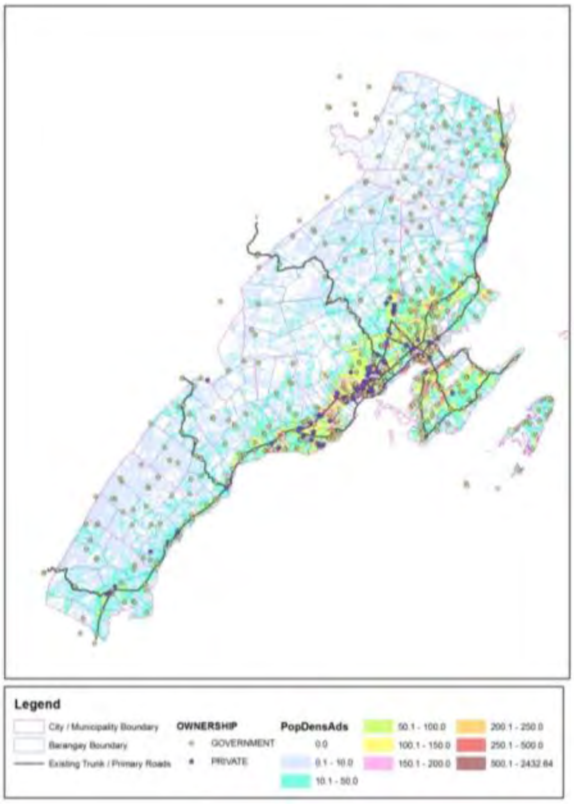
Source: JICA Study Team.

Figure 4.1.65 Location of Shopping Mall and Bus Terminal



Source: JICA Study Team

Figure 4.1.66 Location of Schools by Class



Source: JICA Study Team.

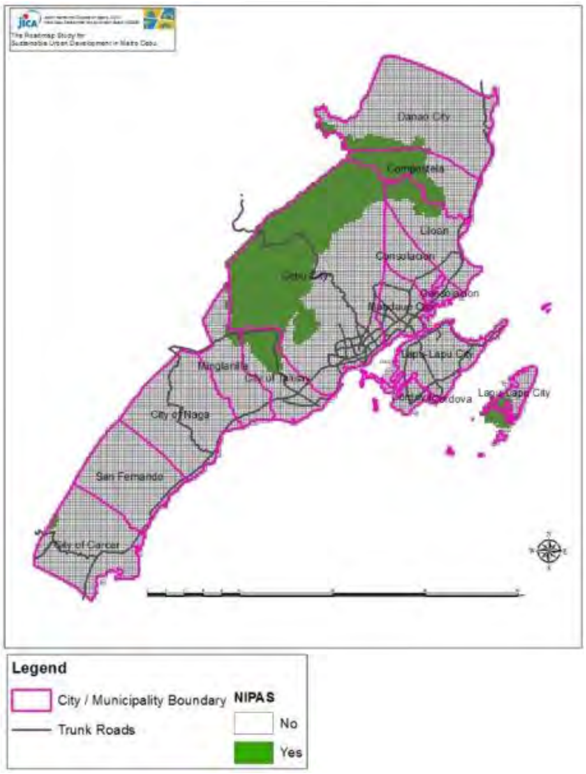
Figure 4.1.67 Location of Schools by Ownership

10) Grid Analysis

(1) Constraints

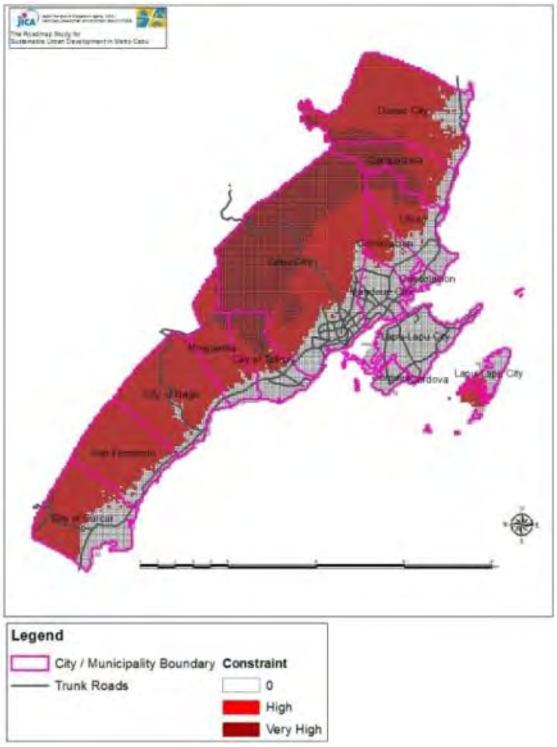
Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.68 Slope (%) by Grid System



Source: JICA Study Team based on Topographic Map 1:10,000.

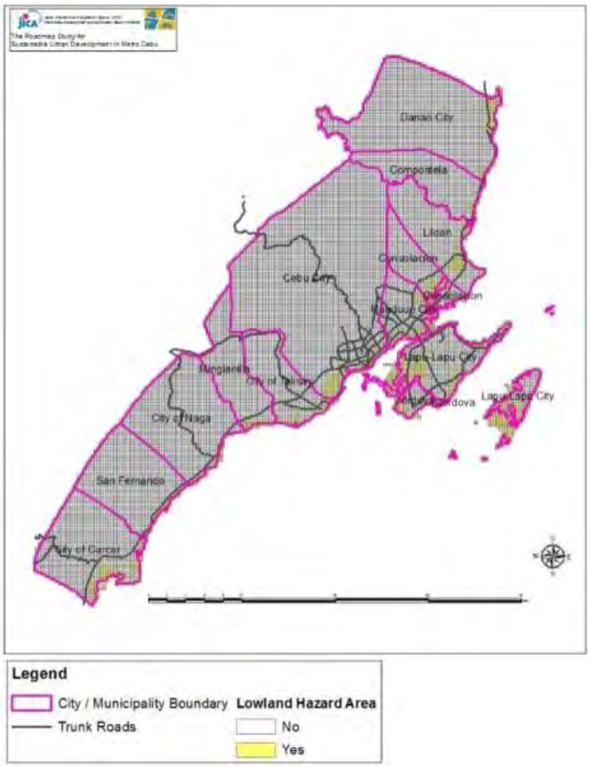
Figure 4.1.69 Preservation Area by Grid System



Source: JICA Study Team based on Topographic Map 1:10,000.

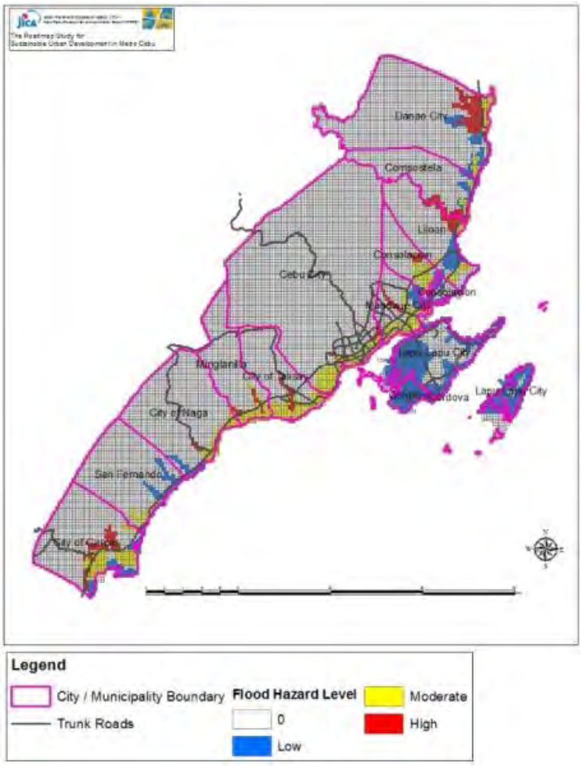
Figure 4.1.70 Constraint Areas by Grid System

(2) Natural Hazards



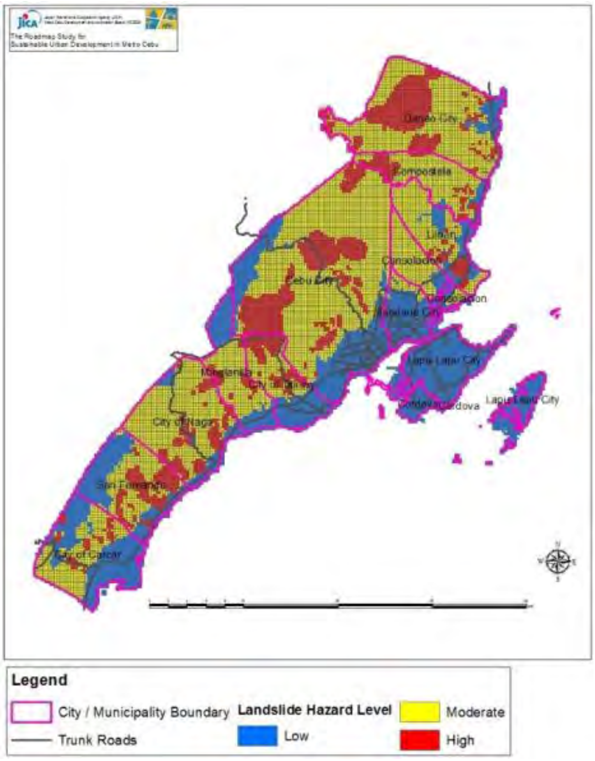
Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.71 Lowland Hazard Area by Grid System



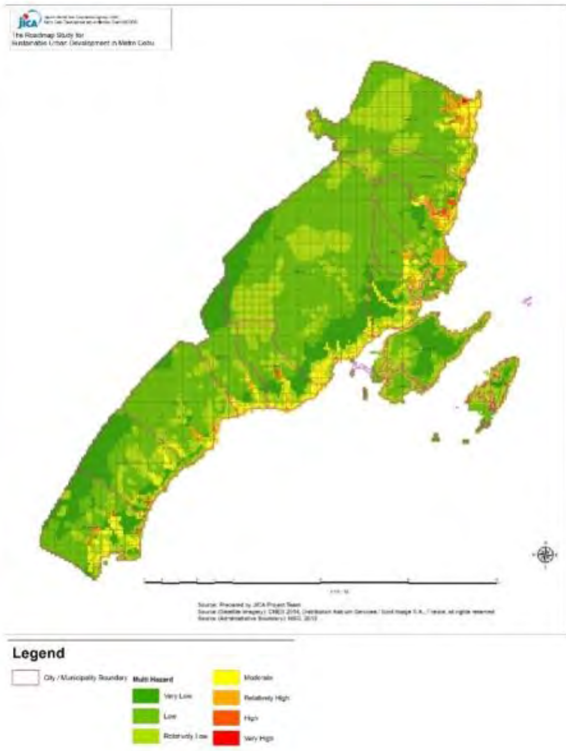
Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.72 Flood Hazard Area by Grid System



Source: JICA Study Team based on Topographic Map 1:10,000.

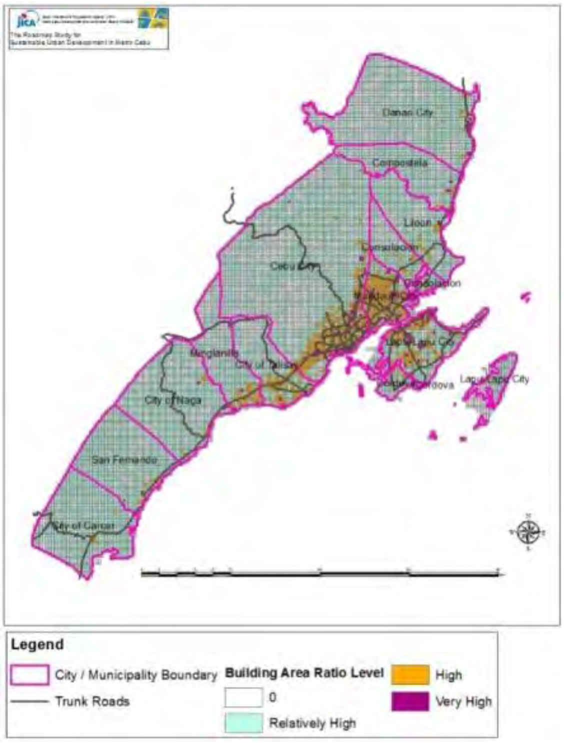
Figure 4.1.73 Landslide Hazard Area by Grid System



Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.74 Natural Hazard Level by Grid System (Multi-Hazard)

(3) Man-made Hazards

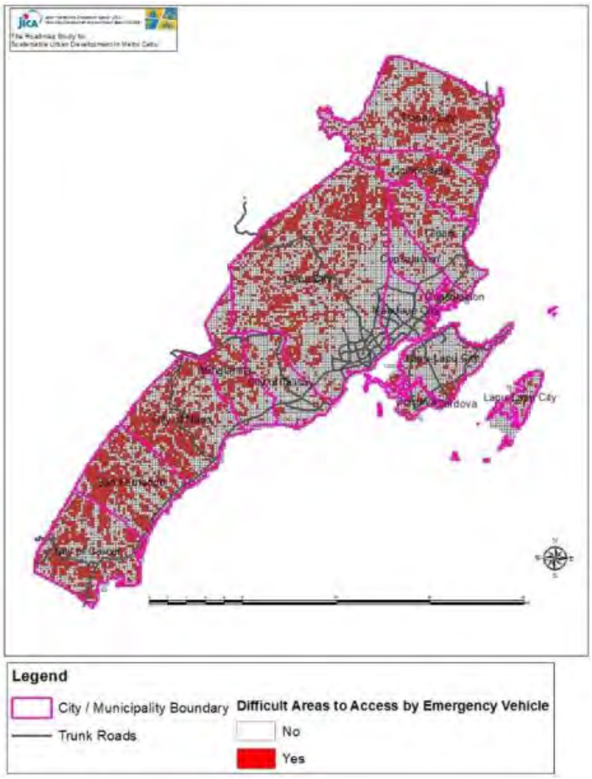


Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.75 Building Area Ratio by Grid System

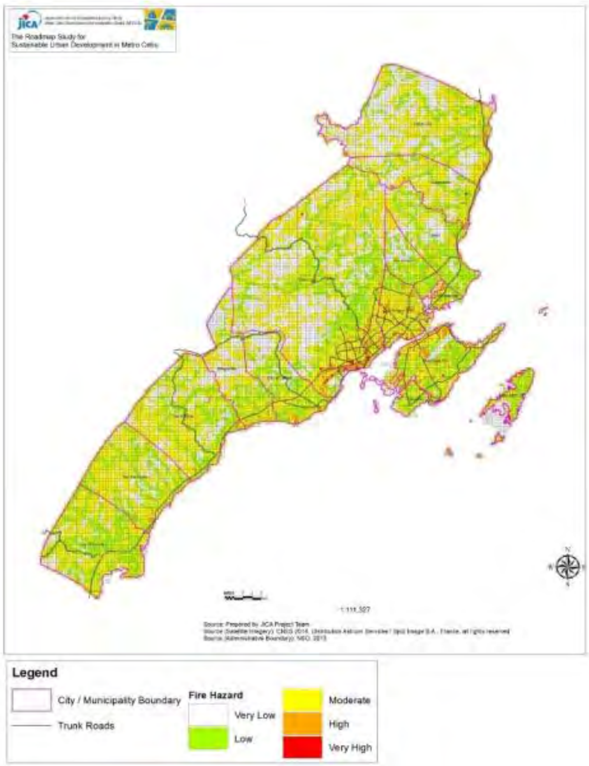
Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.76 Squatter Area by Grid System



Source: JICA Study Team based on Topographic Map 1:10,000.

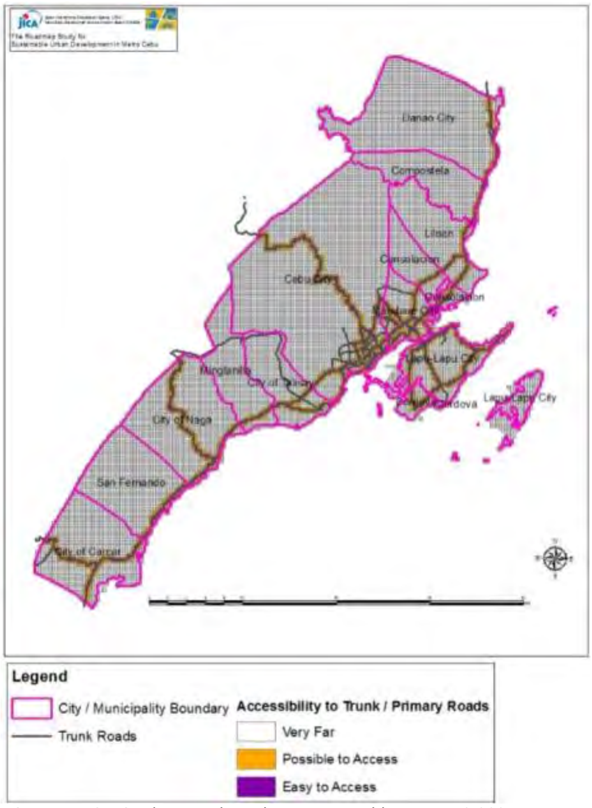
Figure 4.1.77 Difficult Areas to Access by Emergency Vehicles by Grid System



Source: JICA Study Team based on Topographic Map 1:10,000.

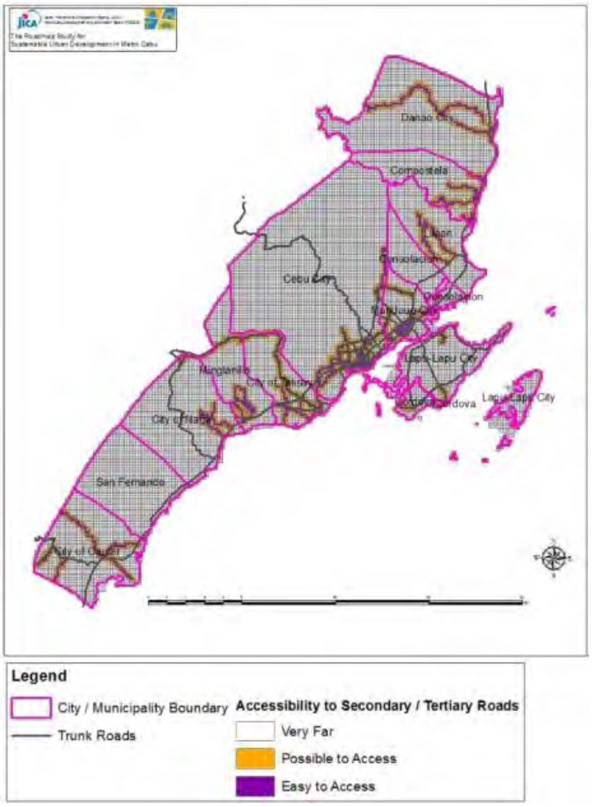
Figure 4.1.78 Man-made Hazard Level by Grid System

(4) Accessibility to Road



Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.79 Accessibility to Trunk / Primary Roads by Grid System

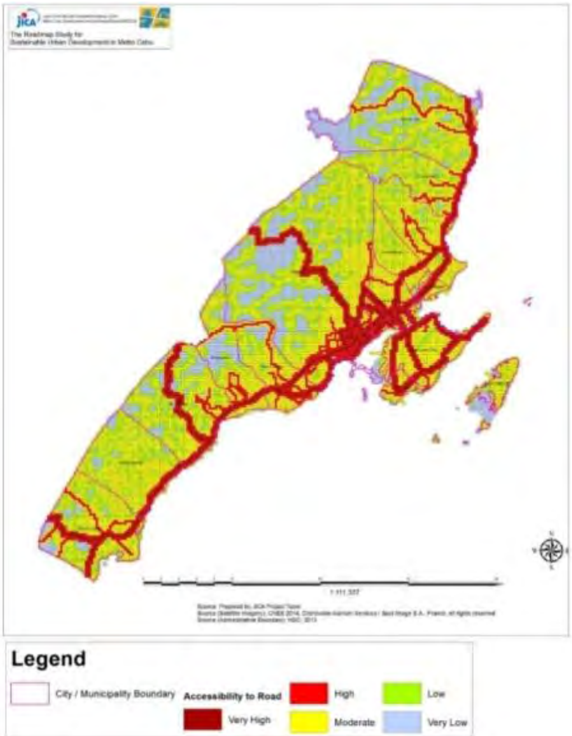


Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.80 Accessibility to Secondary / Tertiary Roads by Grid System

Source: JICA Study Team based on Topographic Map 1:10,000.

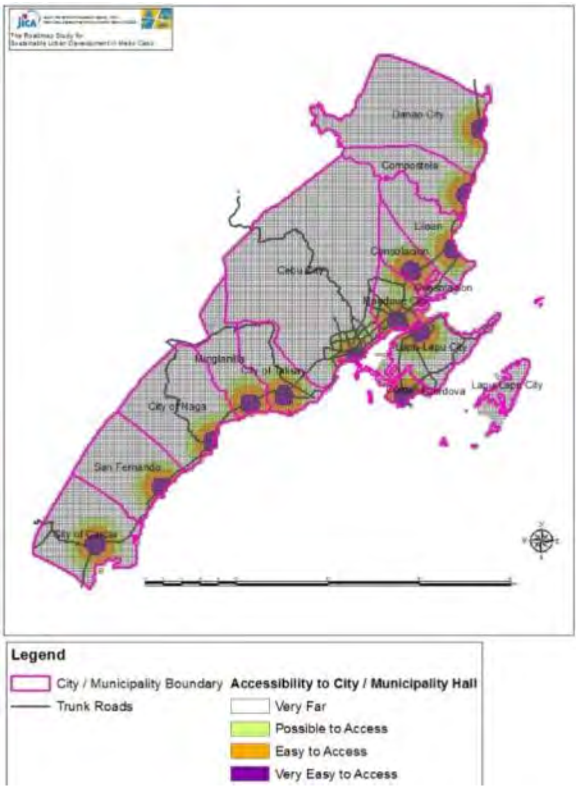
Figure 4.1.81 Accessibility to Other Roads by Grid System



Source: JICA Study Team based on Topographic Map 1:10,000.

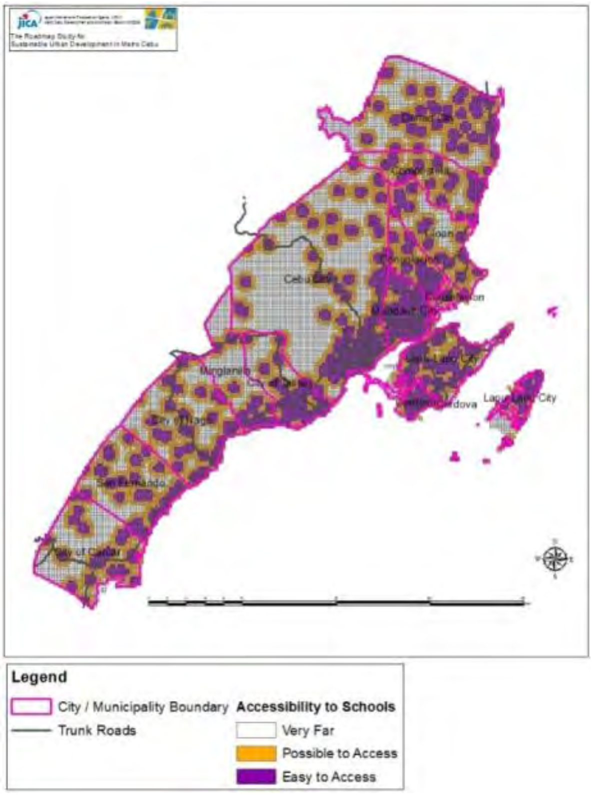
Figure 4.1.82 Overall Accessibility to Roads by Grid System

(5) Accessibility to Public Service



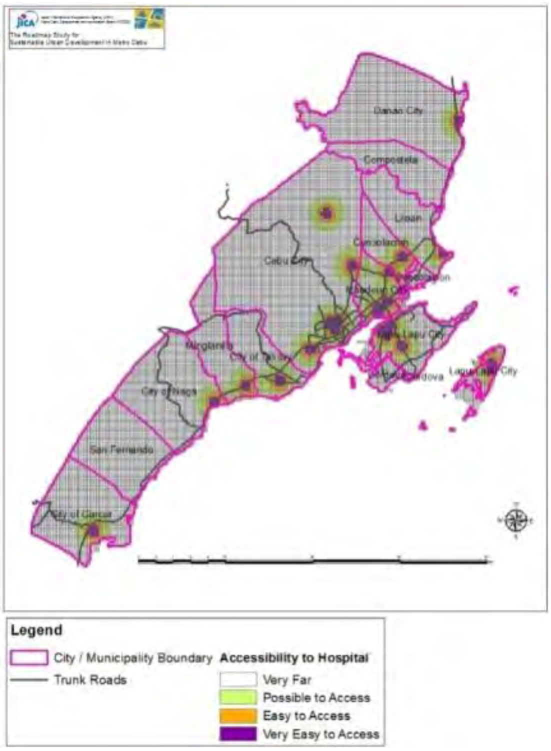
Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.83 Accessibility to City / Municipal Hall by Grid System



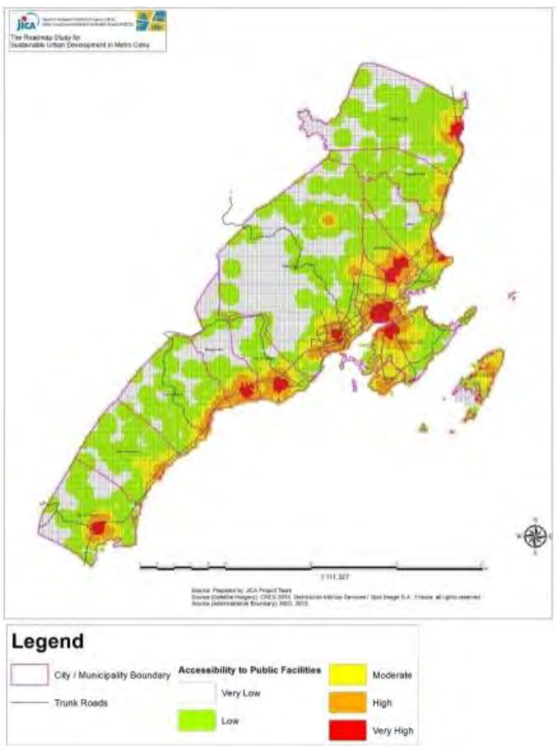
Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.84 Accessibility to Schools by Grid System



Source: JICA Study Team based on Topographic Map 1:10,000.

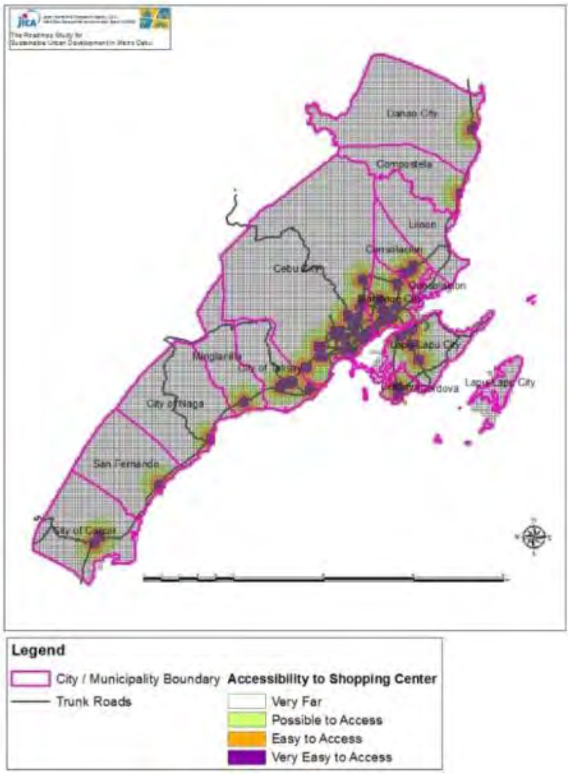
Figure 4.1.85 Accessibility to Hospitals by Grid System



Source: JICA Study Team based on Topographic Map 1:10,000.

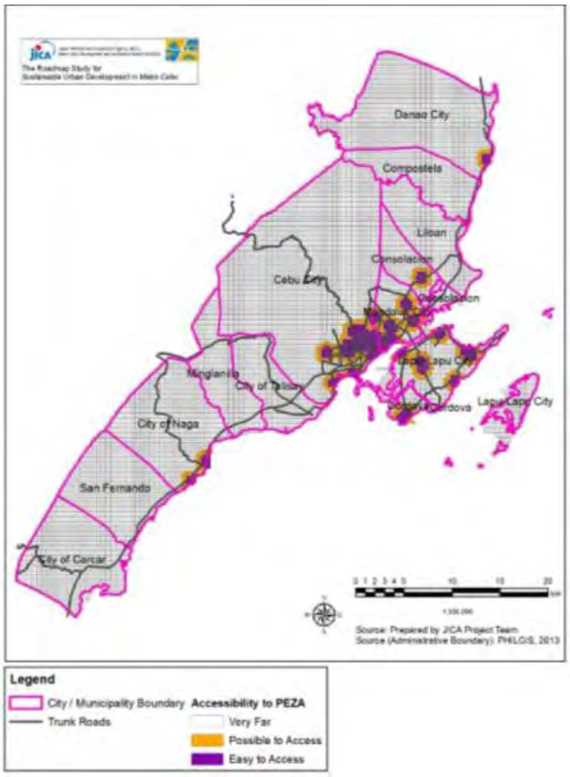
Figure 4.1.86 Overall Accessibility to Public Service by Grid System

(6) Population Attraction Area



Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.87 Attractiveness of Shopping Centers by Grid System

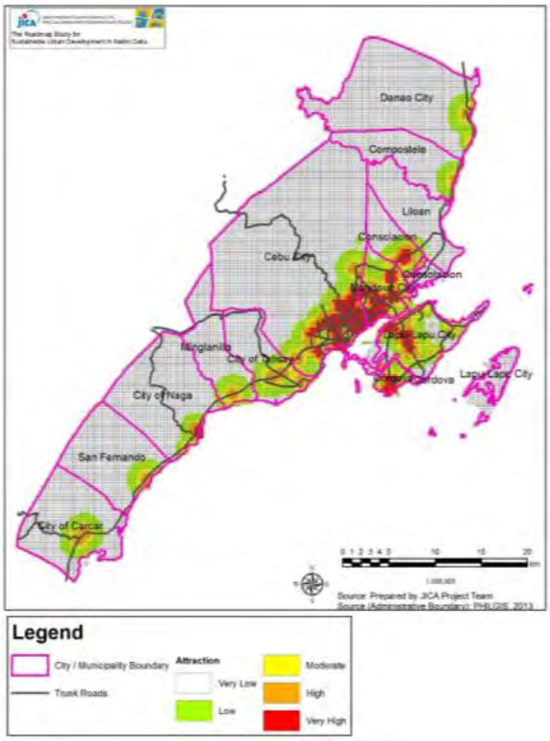


Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.88 Location of PEZA by Grid System

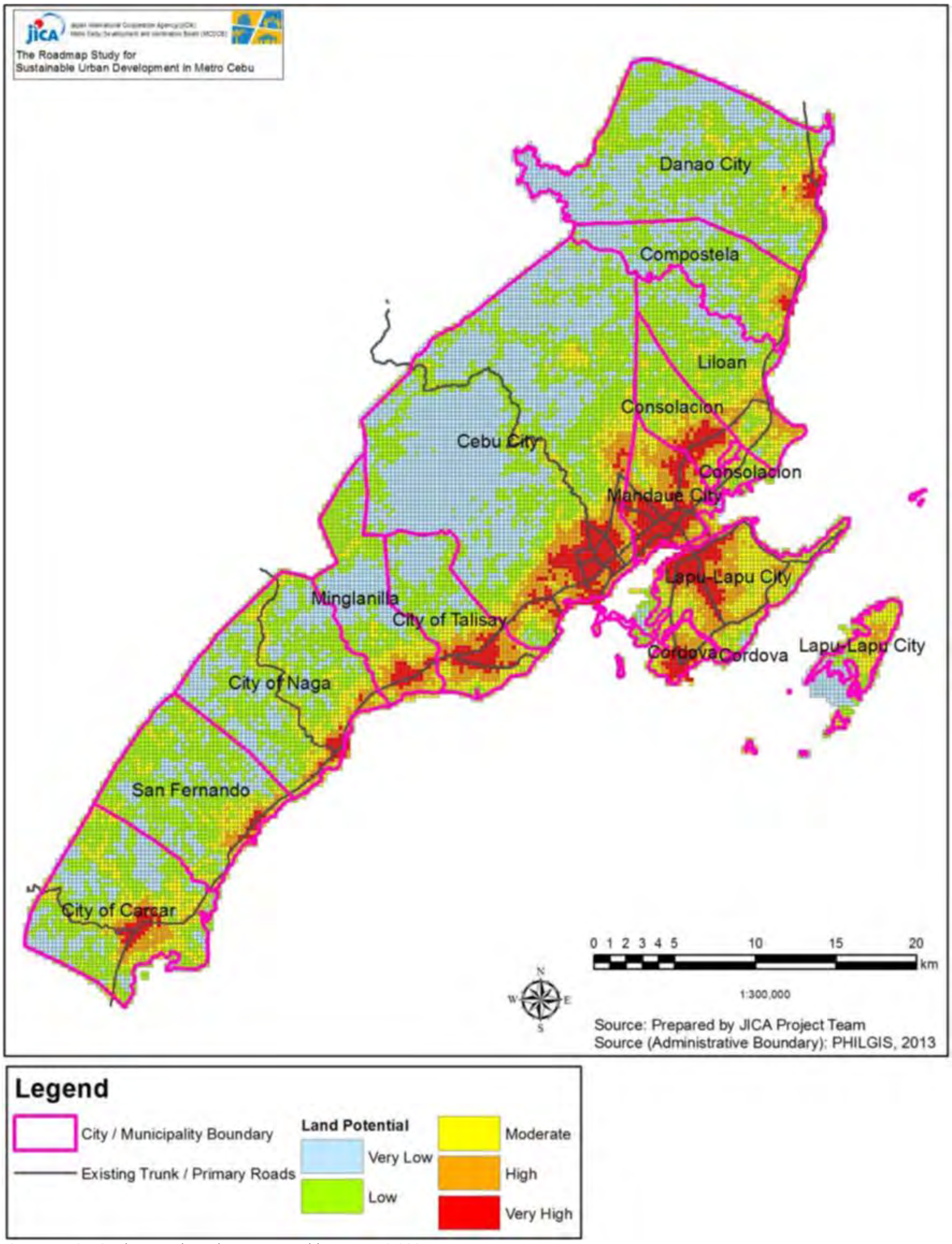
Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.89 Location of Subdivision by Grid System



Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.90 Overall Population Attraction Areas by Grid System



Source: JICA Study Team based on Topographic Map 1:10,000.

Figure 4.1.91 Land Potential Area

4.2 Methodology to Identify Hazard Areas

1) Flood Hazard

(1) Current Situation

4.4 Floods have been caused by a combination of various factors, in general, such as (i) geologic and topographic characteristics, (ii) river characteristics, and (iii) human factors.

(a) **Geologic and Topographic Characteristics**

4.5 River topographic features are generally formed through river erosion, sediment transportation, and sedimentation. These topographic features form river characteristics.

4.6 In the Province of Cebu, a mountain range traverses longitudinally to the south from the periphery of Catmon and Tuburan. The 700 m-class mountains tend around Metro Cebu, and 900 m-class mountains in the southern areas of Cebu. Northern Cebu, however, is located high above sea level and includes a terrain of low relief with a maximum altitude of approximately 400 m.

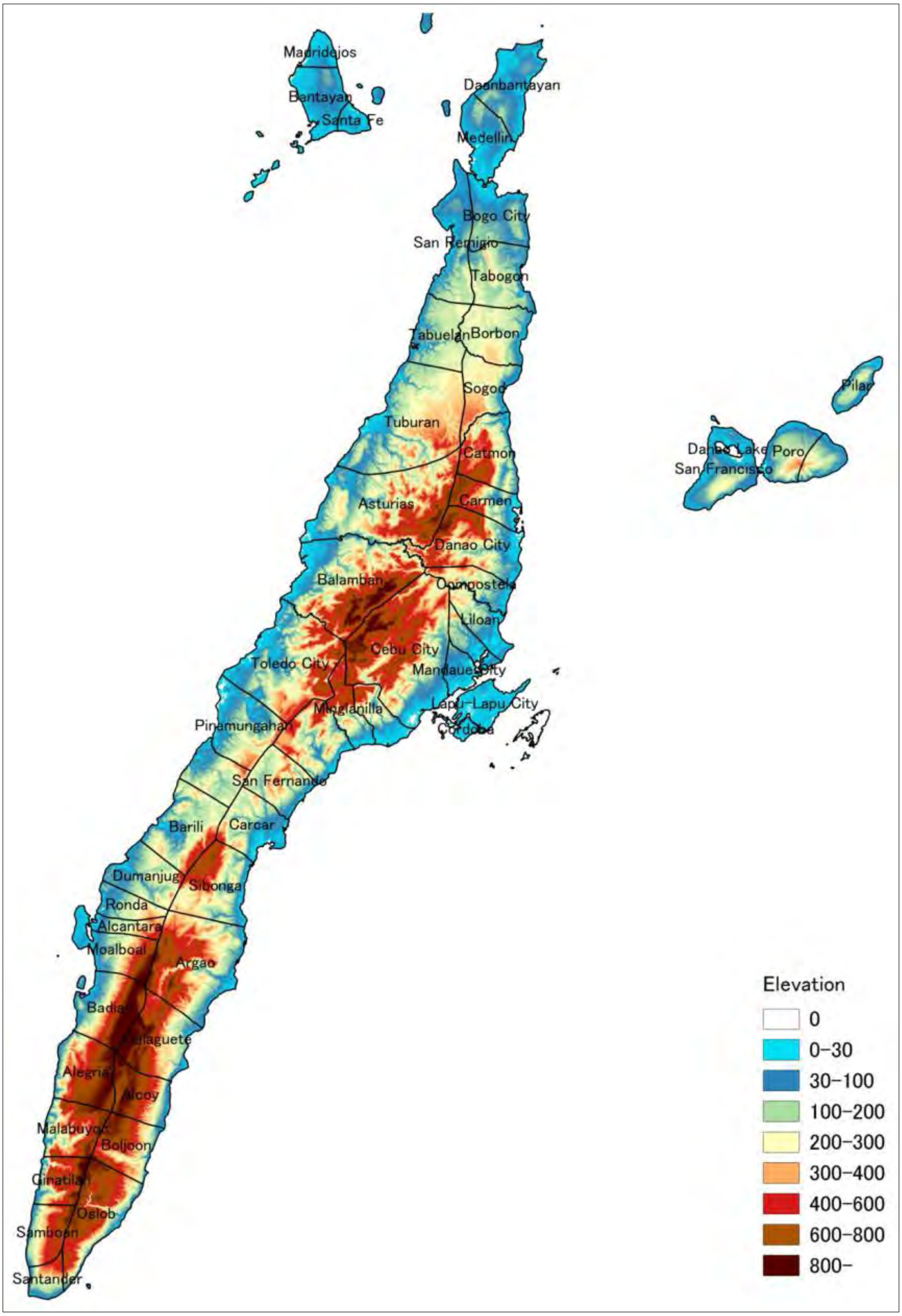
4.7 Looking at low-lying areas, alluvial plains extend only around Daanbantayan and Cebu City. Since mountainous land or hill approaches the vicinity of the coastline in other areas, valley plains are formed instead of the alluvial plains.

4.8 Focusing on the geology of Cebu, geological layers formed from the Jurassic Period and the Miocene Epoch (approximately 199.6 million years ago to 5 million years ago) are concentrated on the perimeter of central mountains, which consist of various lithological characters of limestone to basalt.

4.9 The southern areas and northern center of the Province include a Barili belt that was formed during the Pliocene Epoch (5 million years ago to 2.58 million years ago), and are made up of hard and porous limestone.

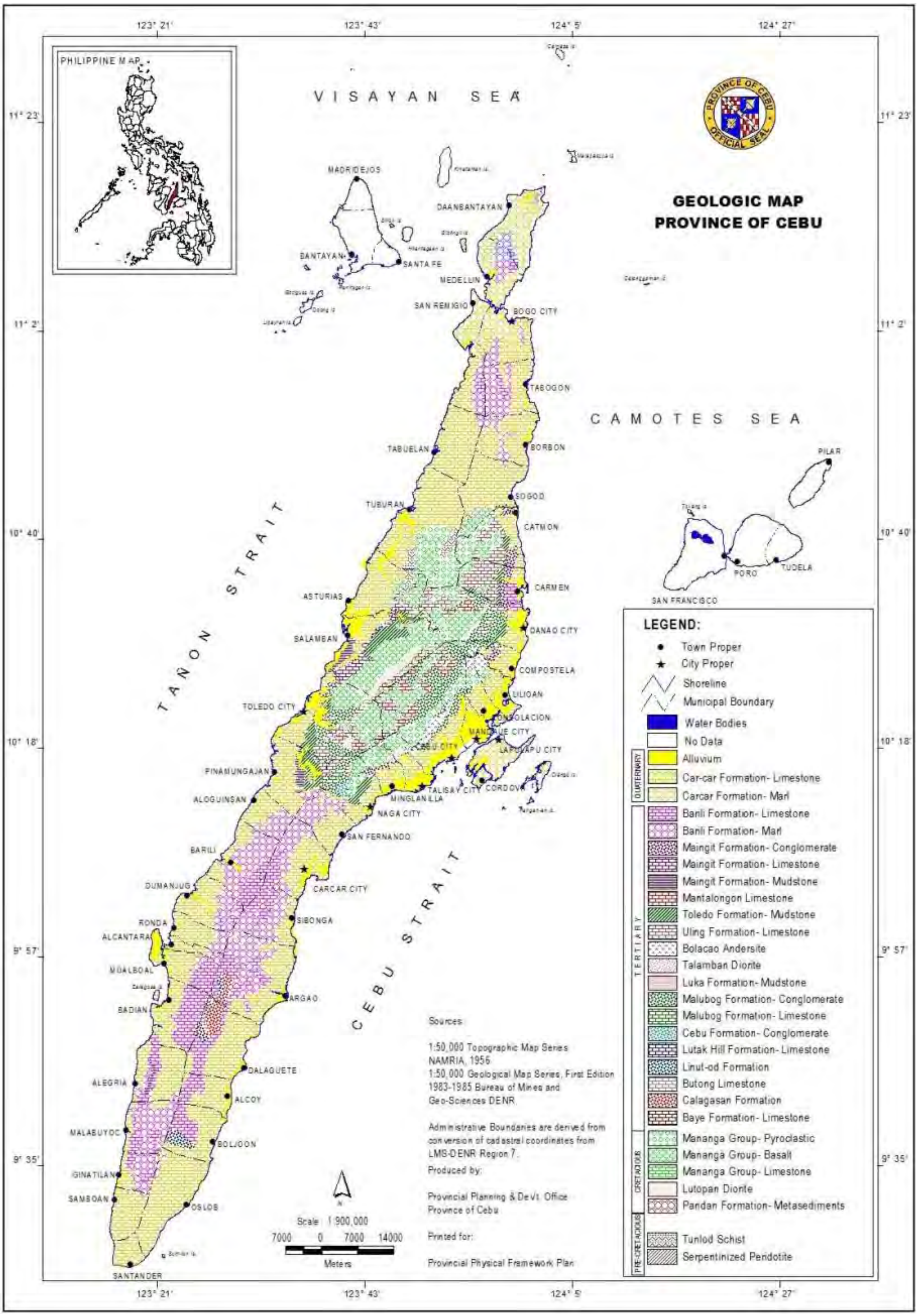
4.10 The whole region of Cebu is covered with a CarCar belt formed during the Pleistocene Epoch (2.58 million years ago to 10,000 years ago) as if the belt surrounds mountains. This CarCar belt consists of coralline limestone that is relatively resistant to weathering but soluble in water. For this reason, the belt contains a lot of pores and has permeability.

4.11 Furthermore, coastal areas have an extended alluvial deposit that was formed with sea level rise at the beginning of the Holocene Epoch (from 10,000 years ago onward). This layer was formed with sediment that had been transported by rivers. Consequently, it generally consists of sand and silt.



Source: JICA Study Team.

Figure 4.2.1 Altitude Map



Source: Provincial Hazard Profile (PDPFP).

Figure 4.2.2 Geological Map

(b) **River Characteristics**

4.12 Most of the small rivers run through Metro Cebu and northern Cebu due to their topographic characteristics. The following table shows a list of rivers with a catchment area of 10 km^2.

Table 4.2.1 River Characteristics

Name of River / Creek		Location (LGU)	Catchment Area (sq.km)	Length of River /Creek (km)
1	Pondol River	Carcar	44.6	23.1
2	Villadolid River	Carcar	50.3	24.1
3	Pandan River	Naga	45.9	17.8
4	Abuno River	Naga, Minglanilla	21.2	10.3
5	Pakigne River	Minglanilla	14.4	7.2
6	Mananga River	Talisay, Cebu	68.4	28.9
7	Buhisan River	Cebu	14.3	7.4
8	Guadalupe River	Cebu	15.3	10.7
9	Subangdaku River	Cebu, Mandaue	10.2	6.6
10	Butuanon River	Mandaue	50.8	20.1
11	Guinsaga River	Consolacion	26.9	8.7
12	Cotcot River	Compostela	63.9	32.9
13	Danao River	Danao	59.3	23.4
14	Cagat River	Danao	11.2	6.1
15	Luyang River	Carmen	39.9	12.9
16	Panalipan River	Catmon	12.7	5.6
17	Naghalin River	Catmon	30.2	18.9
18	Bawo River	Catmon, Sogot	19.2	18.9
19	Bagatayan River	Sogot	19.7	9.4
20	Sagay River	Borbon	21.3	13.8
21	Labangon River	Tabogon	21.1	10.7
22	Samosa River	Tabogon	15.0	6.4
23	Combado River	Bogo	16.1	5.1
24	San Reque River	Bogo	10.1	6.1
25	Polambato River	Bogo	11.3	9.7
26	Dagusongan River	Medellin	16.4	9.8
27	Dalingding River	Daanbantayan	17.2	10.1
28	Male River	San Remigio	17.9	5.3
29	Tambon River	San Remigio	27.9	18.6
30	Bagtic River	San Remigio	13.1	10.0
31	Olivo River	Tabuelan	11.4	4.7
32	Batauang River	Tabuelan	89.5	20.0

Source: JICA Study Team.

4.13 The central area of Cebu, with extended mountains, has a relatively large river with a catchment area of approximately 50 km^2, and an alluvial plain formed with river deposits that extends in the lower reaches of the river.

4.14 Since the northernmost areas of Cebu, such as Medellin, Daanbantayan and San Remigio, have a maximum altitude of only about 100 m, the rivers meander at a moderate stream gradient, and consequently, tend to have a long length (see Figure 4.2.3). Most of these rivers have a marshy estuary where valuable environments such as tidal land and mangrove forest are observed.

4.15 Northern Cebu areas such as Catmon and Borbon have hills with an altitude of approximately 20 m that approach coastal areas with an extended valley plain formed with river erosion. The upper reaches of the river in the central area of Cebu also form a valley plain.

Mananga River (Cebu City)

Dagusongan River (Medellin)

Source: JICA Study Team.

Figure 4.2.3 River Status

4.16 Few flood control facilities have been developed. As a water supply facility, only dams or weirs have been constructed (see Figure 4.2.4). Most of the rivers consist of natural levees. It is only at river-crossing sections on roads where banks are protected.

Mananga River (Cebu City)

Luyang River (Carmen)

Source: JICA Study Team.

Figure 4.2.4 Development / Improvement Situation

(c) **Human Factors**

4.17 In recent years, illegal occupation of the river zones, waste disposal into rivers, or other adverse practices have inhibited the flow of rivers during heavy rains and floods, contributing to the flooding in Cebu (see Figure 4.2.5).

4.18 In Metro Cebu and northern Cebu, roads crossing rivers have been constructed so as to provide a continuous fill structure. In case of occurrence of large-scale flood, this structure may block inundated water. In particular, closed topographic features such as valley plains should be noted because the upper reaches of a fill structure cause an increase of inundation depth or a longer inundation period.

4.19 In areas with drainage facilities such as Cebu City, Mandaue City and Talisay City, sediment or waste clogging these facilities have caused inland inundation, being more likely to have also protracted the inundation period.

4.20 If impermeable pavements such as concrete and asphalt are increased in the future, the amount of underground percolating water during flood may be reduced, possibly leading to the increase of a flood flow rate or prolongation of the inundation period. For this reason, attention should be paid to these factors for urbanization.

Source: JICA Study Team (left), MCDCB (right).

Figure 4.2.5 Human Factors

(2) Flood Characteristics

4.21 In Metro Cebu and in northern Cebu, statistical data on both observed flow rates during flood and on observed rainfall in the upper reaches of rivers are not available. Hence, it is difficult to conduct a detailed investigation on the flood characteristics of each river. Based on the topographic and geological characteristics and the river characteristics in Cebu, however, the following flood characteristics are estimated:

(i) Because an inundation flow spreads on an alluvial fan in a river with an alluvial plain, shallow inundation occurs extensively. An inundation depth or period is partially increased at a segment of the river that partially has a low level of ground height or at an upstream of a fill structure.

(ii) Since a river running through valley plain flows through a narrow flood plain as a main channel, rapid and deep inundation occurs.

(iii) In areas with drainage facilities such as Cebu City, Mandaue City and Talisay City, clogging of the facilities are more likely to increase inundation depth or period.

(iv) Alluvial deposits have been formed through past inundations. According to the geological map, the alluvial deposits in Cebu extend to the coast and exist in the areas with an altitude of up to almost 5 m.

(v) Rivers originating from more steeply sloped mountains exhibit significant rise in water level that is caused by rainfall.

(3) Flood Hazards

(a) Flood Runoff

4.22 Inasmuch as the flood characteristics depend on rivers, these characteristics were collected and organized for each river to estimate flood flow rates. The results are shown in Table 4.2.3. The flow rates were calculated with the following rational formula:

$$Q = \frac{1}{3.6} f r A$$

Where:

Q : Runoff [m^3/s]
f : Runoff coefficient
r : Rainfall intensity [mm/h]
A : Catchment area [km^2]

4.23 The following values necessary for the calculation were set as follows:

(i) ***A*: Catchment Area:** Based on the altitude map that was newly obtained from the Light Detection and Ranging (LiDAR) survey and aerial survey, the basin divide is evaluated to calculate catchment areas.

(ii) ***f*: Runoff Coefficient:** In this study, flood runoffs were calculated at the top of a fan or at the middle of a river. Consequently, most of the catchments to be studied are mountains and hills. For this reason, the following runoff coefficients were given, depending on topographic features, in consideration of various criteria similarly adopted in Japan:

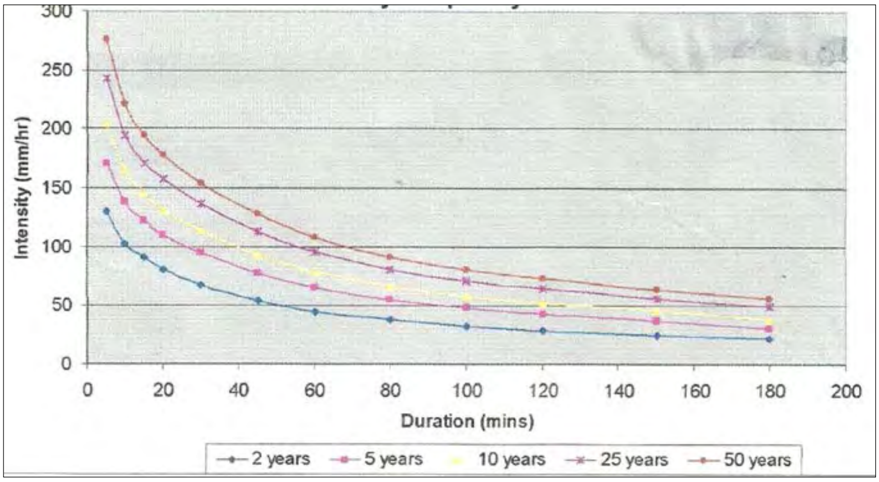
- Steeply sloped mountain: 0.75,
- Moderately sloped mountain: 0.70, and
- Hill: 0.60

Table 4.2.2 Runoff Coefficient Reference

Situations of Topographic Features	Fp
Steep mountain	0.75–0.90
Tertiary zone mountain	0.70–0.80
Rolling land and wood land	0.50–0.75
Flat arable land	0.45–0.60
Paddy field with irrigation	0.70–0.80
Mountain stream	0.75–0.85
Small stream in flat area	0.45–0.75

Source: The Japanese Ministry of Land, Infrastructure, Transport and Tourism Technical Criteria for River Works: Practical Guide for Planning, (October 1997).

(iii) ***r:* Rainfall Intensity:** Based on the altitude map that was obtained from the LiDAR survey and aerial survey, the length of a river channel, the gradient, and other parameters were evaluated to calculate a time of flood concentration. Furthermore, Intensity Frequency Duration that was developed based on the observed values of PAGASA was used to calculate levels of rainfall intensity for 2-year, 10-year and 50-year return frequency probabilities (see Figure 4.2.6).



Source: Flood Mitigation and Drainage Study for Cebu City (2006.3).

Figure 4.2.6 Rainfall Intensity Formula

Table 4.2.3 Flood Runoff in Each River

	Name of River / Creek	Flood Type	Topography	Runoff Coefficient	Catchment Area (km^2)	2-Year Period		10-Year Period		50-Year Period	
						Rainfall Intensity (mm/h)	Runoff (m^3/s)	Rainfall Intensity (mm/h)	Runoff (m^3/s)	Rainfall Intensity (mm/h)	Runoff (m^3/s)
1	Pondol River	Alluvial	Moderate mountain	0.70	44.6	47.3	280	74.8	443	98.8	585
2	Villadolid River	Alluvial	Moderate mountain	0.70	50.3	24.3	238	45.7	447	64.5	631
3	Pandan River	Alluvial	Moderate mountain	0.70	45.9	32.5	291	56.9	508	78.2	699
4	Abuno River	Alluvial	Steep mountain	0.75	21.2	44.1	195	70.9	314	94.4	417
5	Pakigne River	Alluvial	Steep mountain	0.75	14.4	48.8	147	76.6	230	101	303
6	Mananga River	Alluvial	Steep mountain	0.75	68.4	23.7	338	44.9	640	63.5	905
7	Buhisan River	Alluvial	Steep mountain	0.75	14.3	48.5	145	76.2	228	100.5	300
8	Guadalupe River	Alluvial	Steep mountain	0.75	15.3	43.4	139	70.1	224	93.5	298
9	Subangdaku River	Alluvial	Hill	0.60	10.2	49.7	85	77.8	133	102.3	175
10	Butuanon River	Alluvial	Steep mountain	0.75	50.8	30	318	53.7	569	74.5	789
11	Guinsaga River	Alluvial	Moderate mountain	0.70	26.9	46.5	244	73.9	387	97.8	512
12	Cotcot River	Alluvial	Steep mountain	0.75	63.9	21.5	286	41.8	557	59.4	791
13	Danao River	Alluvial	Steep mountain	0.75	59.3	27.7	343	50.5	624	70.4	870
14	Cagat River	Alluvial	Moderate mountain	0.70	11.2	51	111	79.4	173	104.3	227
15	Luyang River	Alluvial	Steep mountain	0.75	39.9	40.1	334	66	549	88.8	739
16	Panalipan River	Valley	Moderate mountain	0.70	12.7	49.8	124	77.8	193	102.4	254
17	Naghalin River	Alluvial	Steep mountain	0.75	30.2	31	196	55	347	76.1	480
18	Bawo River	Alluvial	Steep mountain	0.75	19.2	31	124	55	220	76.1	304
19	Bagatayan River	Valley	Moderate mountain	0.70	19.7	45.4	175	72.5	279	96.2	370
20	Sagay River	Valley	Hill	0.60	21.3	38.7	138	64.3	229	86.8	309
21	Labangon River	Valley	Hill	0.60	21.1	40.7	144	66.8	236	89.7	317
22	Samosa River	Valley	Hill	0.60	15.0	50.1	125	78.2	195	102.8	257
23	Combado River	Valley	Hill	0.60	16.1	51.8	140	80.6	217	105.7	285
24	San Reque River	Valley	Hill	0.60	10.1	60.6	62	92.7	95	120.8	123
25	Polambato River	Alluvial	Hill	0.60	11.3	42.5	80	69	130	92.2	174
26	Dagusongan River	Alluvial	Hill	0.60	16.4	34.9	96	59.7	163	81.5	223
27	Dalingding River	Alluvial	Hill	0.60	17.2	34	98	58.7	169	80.3	231
28	Male River	Valley	Hill	0.60	17.9	46.3	123	73.5	194	97.4	257
29	Tambon River	Valley	Hill	0.60	27.9	46.2	108	73.5	171	97.4	227
30	Bagtic River	Valley	Moderate mountain	0.70	13.1	44.6	114	71.5	183	95.1	243
31	Olivo River	Valley	Moderate mountain	0.70	11.4	57.3	127	88.2	195	115.1	255
32	Batauang River	Valley	Moderate mountain	0.70	89.5	27.8	484	50.5	880	70.5	1228

Source: JICA Study Team.

(b) **Present-State Capacity of Flow**

4.24 Damages due to floods frequently occur in Metro Cebu and northern Cebu. It has not been determined whether these flood-related damages are due to insufficient capacity of flow of rivers or the poor drainage facilities.

4.25 In this study, the capacity of flow is calculated from the current channel shape of each river (see Table 4.2.5). The current shape is obtained from the result of the latest LiDAR survey, and the capacity of flow is calculated from the following standard flow calculation:

$$Q = \frac{1}{n} A R^{\frac{2}{3}} I^{\frac{1}{2}}$$

Where:

Q : Runoff (m^3/s)
n : Coefficient of roughness
A : Cross-sectional area (m^2)
R : Hydraulic radius (m)
I : Slope of hydraulic gradient

4.26 The following values necessary for the calculation of capacity flow were set:

(i) ***n*: Coefficient of Roughness:** In consideration of the state of the main channel in Metro Cebu and northern Cebu, n = 0.030 will be set for mountainous flow channels (gravel, boulder). For the detailed study, however, it is necessary to set the relevant coefficient, taking into account the transverse shape figure of each river, grain sizes of river bed materials, vegetation growth in the river, and other parameters (see Table 4.2.4).

Table 4.2.4 Relevant Coefficient of Roughness for River Flows

State of River and Water Channel		Scope of Manning's n
Artificial Channel and Improved River	Artificial channel of concrete	0.014–0.020
	Spiral half-pipe channel	0.021–0.030
	Stone pitching small channel on both banks of a river (mud bed)	0.025 (mean value)
	Bedrock excavation without facing	0.035–0.050
	Bedrock excavation with facing	0.025–0.040
	Clay river bed, flow velocity without scour	0.016–0.022
	Sandy loam, clay loam	0.020 (mean value)
	Drag line excavation dredging, limited weeds	0.025–0.033
Natural River	Distributary minors on plain, no weeds	0.025–0.033
	Distributary minors on plain, with weeds and shrubs	0.030–0.040
	Distributary minors on plain, with a lot of weeds, and gravel river bed	0.040–0.055
	Mountainous flow channel with gravel and boulder	0.030–0.050
	Mountainous flow channel with boulder and large boulder	0.040 or more
	Large flow channel, clay, sandy bed, limited meander	0.018–0.035
	Large flow channel with gravel river bed	0.025–0.040

Source: The Japanese Ministry of Land, Infrastructure, Transport and Tourism Technical Criteria for River Works: Practical Guide for Planning (October 1997).

(ii) ***R*: Hydraulic radius:** Using the cross-section that was obtained from the results of the latest LiDAR survey, the hydraulic radius is calculated with the following equation:

$$\mathrm{R} = \frac{A}{\mathrm{S}}$$

Where:

A : Cross-sectional area
S : Wetted perimeter

(iii) ***I*: Slope of Hydraulic Gradient:** Upstream and downstream altitudes on the cross-section are obtained from the results of the latest LiDAR survey to calculate a slope of hydraulic gradient.

Table 4.2.5 Flood Runoff in Each River

Name of River / Creek		Coefficient of Roughness	Left Bank Height (m)	Right Bank Height (m)	Discharge Capacity (m^3/s)	Flood Frequency[1]
1	Pondol River	0.030	3.89	3.87	24	–1/2
2	Villadolid River	0.030	7.50	7.74	314	1/2–1/5
3	Pandan River	0.030	5.13	5.12	220	–1/2
4	Abuno River	0.030	3.38	2.99	45	–1/2
5	Pakigne River	0.030	4.29	4.33	55	–1/2
6	Mananga River	0.030	4.35	4.01	429	1/2–1/5
7	Buhisan River	0.030	8.93	9.47	104	–1/2
8	Guadalupe River	0.030	3.63	2.88	43	–1/2
9	Subangdaku River	0.030	3.25	30.10	13	–1/2
10	Butuanon River	0.030	8.64	9.15	268	–1/2
11	Guinsaga River	0.030	5.35	5.56	26	–1/2
12	Cotcot River	0.030	4.20	4.26	56	–1/2
13	Danao River	0.030	4.64	3.25	62	–1/2
14	Cagat River	0.030	3.89	3.54	16	–1/2
15	Luyang River	0.030	4.14	4.27	135	–1/2
16	Panalipan River	0.030	3.20	3.16	52	–1/2
17	Naghalin River	0.030	3.81	3.61	204	1/2–1/5
18	Bawo River	0.030	3.47	3.79	109	–1/2
19	Bagatayan River	0.030	10.76	10.90	137	–1/2
20	Sagay River	0.030	2.30	2.44	7	–1/2
21	Labangon River	0.030	3.44	3.33	52	–1/2
22	Samosa River	0.030	5.15	5.48	287	1/50 or more
23	Combado River	0.030	6.63	5.36	260	1/25–1/50
24	San Reque River	0.030	1.45	1.86	2.5	–1/2
25	Polambato River	0.030	4.98	5.00	37	–1/2
26	Dagusongan River	0.030	-	-	-	-
27	Dalingding River	0.030	1.85	1.58	10	–1/2
28	Male River	0.030	1.46	1.75	13	–1/2
29	Tambon River	0.030	2.53	2.37	3.5	–1/2
30	Bagtic River	0.030	2.15	1.92	3.4	–1/2
31	Olivo River	0.030	3.55	4.05	32	–1/2
32	Batauang River	0.030	2.55	1.98	4.5	–1/2

Source: JICA Study Team.
Note: [1] Flood frequency of 1/2 means once every 2 years or a 2-year return period; 1/5 is 5-year return; 1/25 is 25-year return and 1/50 is 50-year return.

(c) Flood Hazard Map

4.27 Based on the comparison of the calculated flood runoffs and the present-state capacity of flow in 32 rivers in Metro Cebu and in northern Cebu (see the previous Tables 4.2.3 and 4.2.5), flood damages are likely to occur once a year to two years in most of the rivers. The comparison shows that discharge capacities of most rivers are not sufficient to accommodate calculated water runoff even with rainfall intensity that occurs during a 2-year return period.

4.28 In order to develop a flood hazard map, the inundation patterns and expected impact/damage types were evaluated on basically 3 hazard levels (i.e., low, moderate, high). These are shown in Table 4.2.6 below.

Table 4.2.6 Flood Hazards Evaluation

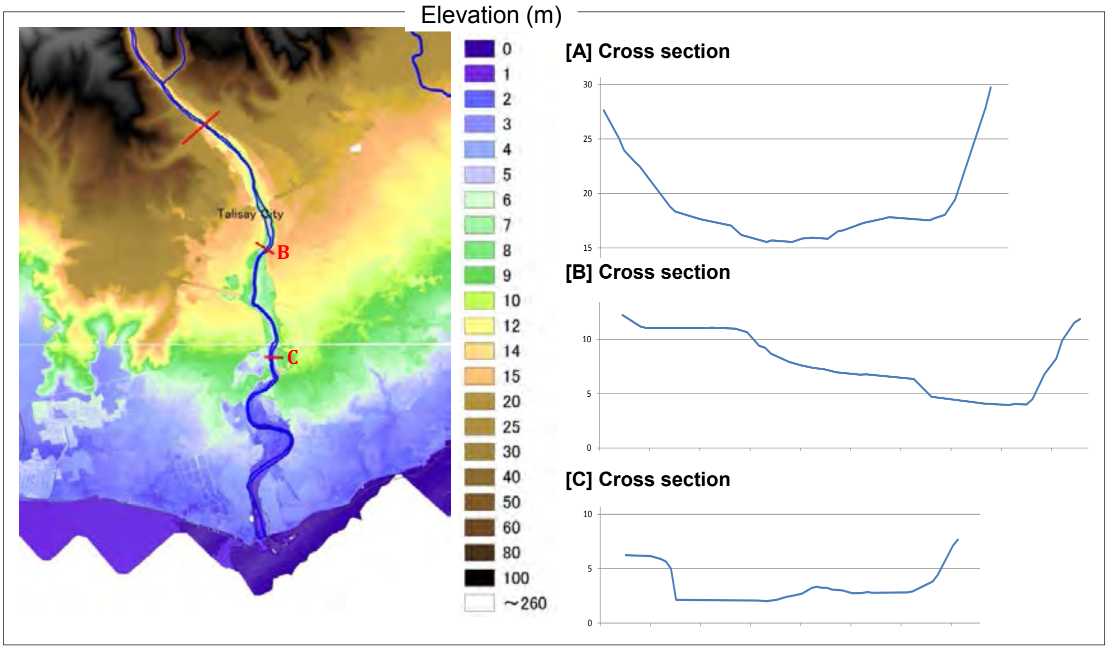
Hazard Level	Topographic and Geological Characteristics	Inundation Patterns	Type of Damage Expected
Low	• Area where an alluvial deposit formed from past flood is observed (Range of altitudes of 4 m or less to 6 m or less)	• If large-scale flood occurs when a flood frequency is low but a tide level is high, flood damage may occur.	• A large amount of water flows on the surface of a mountain like a river, causing shallow inundation. • A ground lower than its surroundings becomes a pool.
Moderate	• Inundation area in river with an alluvial plain (alluvial fan) • Area where clogging of drainage facilities may cause inner water inundation	• It is diffusion inundation, and inundation depth or flow velocity is relatively small. • Inundation spreads from a clogged point of a drainage facility. • An inundation time may be protracted around a low-lying depression or fill structure.	• Inundation occurs extensively, and buildings and other facilities are inundated, but inundation time is short. • The perimeter of a water channel or road is flooded like a river. • A ground lower than its surroundings becomes a pool.
High	• Inundation area in river with a valley plain • Area where an inundation flow may be blocked by a continuous fill structure	• Because it flows through the whole valley as a main channel, inundation depth or flow velocity is relatively large. • Since inundation is blocked by a fill structure, the level of inundation depth becomes higher and inundation time is protracted.	• Due to a sharp rise in water level, buildings and other facilities along a river may be inundated. • The upper reaches of a fill structure becomes a pool. • The range of inundation, inundation depth or flow velocity becomes large, and inundation time becomes longer, depending on flood scales.

Source: JICA Study Team.

4.29 The setting of an inundation range is conducted according to the following procedures:

(i) Obtain wide-area cross sections at several points of each river from the latest LiDAR survey (see Figure 4.2.7).

(ii) Calculate the flood level for each cross-section by standard flow calculation. Use the equation given in *(b) Present-State Capacity of Flow* for the standard flow calculation, and apply to a flood plain, a coefficient of roughness, n=0.025 (fields etc.).



Source: JICA Study Team.

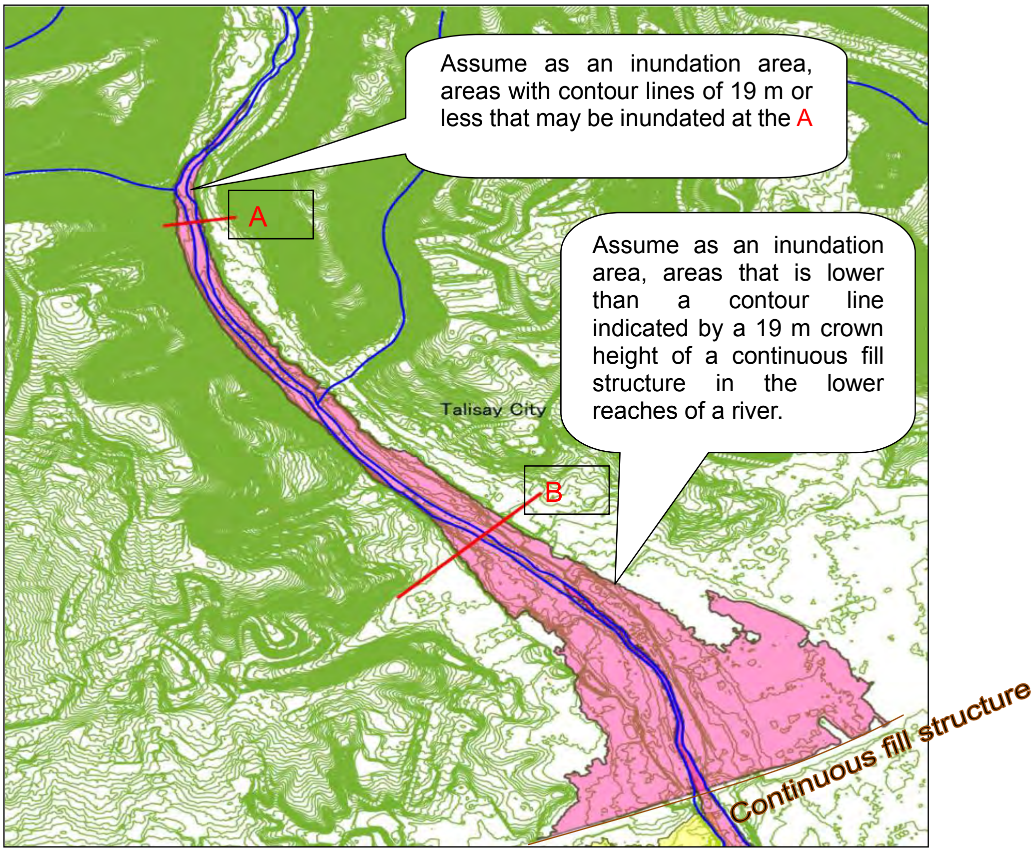
Figure 4.2.7 Acquired Wide-Area Cross-Sections (Case: Mananga River)

Table 4.2.7 Calculated Flood Levels (Case: Mananga River)

Point	Calculated Water Level (m)		
	50-Year Return Probability	10-Year Return Probability	2-Year Return Probability
A	19.9	19.3	18.6
B	9.1	8.5	7.5
C	8.2	7.2	5.7

Source: JICA Study Team.

(iii) Referring to contour lines prepared through the latest LiDAR survey, the valley plain inundation for a 50-year return period or more was identified by color classification (see Figure 4.2.8). When there are fill structures in the lower reaches of a river, the "High" flood level are at the areas lower than the crown height of the structures. For the "Moderate" level inundation areas are with potential diffusion of inundation, based on the gradients of an alluvial plain. The "Low" level inundation areas are those set on the basis of contour lines (4 to 6 m) depending on geological features.



Source: JICA Study Team.

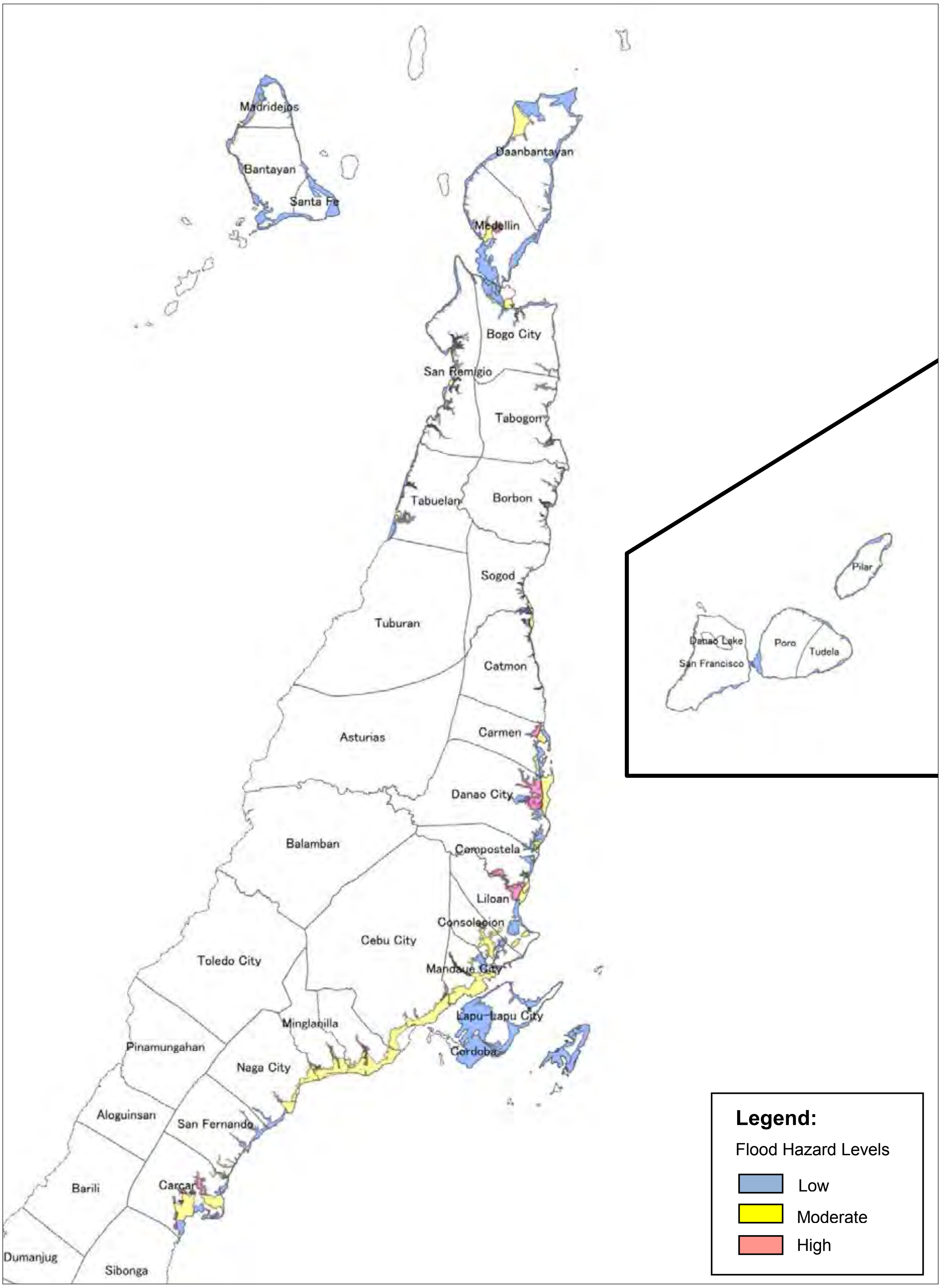
Figure 4.2.8 Acquired Wide-Area Cross-Section (Case: Mananga River)

Table 4.2.8 Calculated Flood Levels (Mountains)

Name of River / Creek[1]		Water Level at 50-Year Period (m)	Water Level at 10-Year Period (m)	Water Level at 2-Year Period (m)
1	Pondol River	15.0	14.7	13.5
2	Villadolid River	23.6	22.9	21.9
3	Pandan River	12.2	11.7	10.9
4	Abuno River	14.9	14.4	13.5
5	Pakigne River	26.2	25.9	25.5
6	Mananga River	19.9	19.3	18.6
7	Buhisan River	9.4	9.1	8.3
8	Guadalupe River	12.8	12.3	11.7
9	Subangdaku River	11.3	10.6	10.1
10	Butuanon River	16.3	15.5	14.3
11	Guinsaga River	-	-	-
12	Cotcot River	11.7	11.4	8.7
13	Danao River	19.1	18.2	17.0
14	Cagat River	24.8	24.7	24.6
15	Luyang River	10.6	10.3	9.8
16	Panalipan River	6.5	6.3	6.0
17	Naghalin River	9.3	8.9	8.1
18	Bawo River	11.9	11.4	10.7
19	Bagatayan River	14.1	13.9	13.7
20	Sagay River	4.3	4.0	3.6
21	Labangon River	5.0	4.9	4.7
22	Samosa River	5.0	4.4	4.0
23	Combado River	12.2	11.6	10.7
24	San Reque River	6.1	5.9	5.6
25	Polambato River	15.5	15.1	14.5
26	Dagusongan River	-	-	-
27	Dalingding River	-	-	-
28	Male River	4.1	3.7	3.1
29	Tambon River	7.3	7.1	6.8
30	Bagtic River	6.5	6.3	6.1
31	Olivo River	3.3	3.0	2.6
32	Batauang River	-	-	-

Source: JICA Study Team.

Note: [1] The rivers with blank fields are those where flood levels are difficult to calculate due to topographic features and status of data development. Inundation areas in these rivers shall be set based on topographic features.



Source: JICA Study Team.

Figure 4.2.9 Flood Hazard Map of Cebu

(4) Considerations

4.30 For future large-scale development in Metro Cebu and in northern Cebu, it is necessary to note the following points in order to prevent flood damages from worsening:

(i) As enormous damages are expected in the areas designated with "High" flood hazard level, it is recommended that large-scale development such as new town center or industrial area be prohibited or avoided in these locations. For the case of inundation caused by a continuous fill structure, it is important to alleviate flood damage through effective drainage countermeasures. And in consideration of the status of inundation in the lower reaches of a river, it is necessary to take measures against flooding for areas where appropriate.

(ii) In the areas designated with "Moderate" flood hazard level, surrounding elevations and the status of drainage facilities should be checked. After that, it is possible to develop the areas in combination with countermeasures such as raising the ground level and improving drainage facilities.

(iii) When a continuous fill structure is additionally installed, it is necessary to conduct a preliminary evaluation on whether the structure is effective in blocking flood waters.

(iv) It is necessary perform checks and maintenance of the drainage facilities and its surroundings to prevent clogging during floods.

(v) It is important to continuously monitor rainfalls, river levels and river discharge and properly determine the flood characteristics of each river. It is desirable to place a rainfall gauging station in mountainous areas and a water level gauging station on alluvial fans, plains and other points.

(vi) Prior undertaking a river improvement project, preliminary evaluation should be conducted for points that cause inundation as well as the effects of inundation on upper and lower reaches of the river. Subsequently, it is necessary to take measures for points to be affected, as needed.

(vii) It is necessary to carefully place a bank or tide embankment as such facility may exacerbate flood damage during landslide.

2) Landslide Hazard

(1) Introduction

4.31 Interpretation of very high resolution remotely sensed data covering Metro Cebu shows some areas that are highly susceptible to landslides. This data provides a synoptic view over a wide area and allows correlation of features observed in the said area. The data has a spatial resolution that ranges from about 0.5 m to 0.65 m while the LiDAR data has higher spatial resolution. Their very high spatial resolution allows detailed observation of features that otherwise would be difficult to see in images having lower spatial resolution.

4.32 While the remotely sensed data have a very high resolution, it is prudent to verify important features on the ground to fully appreciate the information extracted from the images and gain additional insights at ground level. In addition, some important information, such as rock mass strength and degree of weathering, is best obtained in the field.

(2) Methodology

4.33 This work followed the MGB criteria for rain-induced landslide susceptibility with minor modifications because the main technique and data used in the analysis are interpretation of very high-resolution remotely sensed data, digital terrain models (DTM), and contours. The MGB criteria for "High" and "Very High" categories are lumped together in the "High" category. Data available in the field, such as rock mass strength and degree of weathering, are not included in the analysis. If available, these field data can help refine the results of this study.

4.34 In the modified MGB criteria, areas considered highly susceptible to rain-induced landslides include those having steep to very steep slopes (>35 degrees). In terms of ground stability, evident active landslides, relative high density of lineaments or scarps or both over an area of interest, and bulges are considered. Areas where inactive landslides are evident, such as old landslide debris deposits and collapsed sinkholes, are also included.

4.35 In the remotely sensed image, the terrain appears “deformed” in appearance due to lineaments and scarps that cut it. Actively worked mining areas with their steep walls are considered highly susceptible too. Instances where high erosion along the riverbanks threatens infrastructures and development projects are considered highly susceptible to landslides even though the more accurate description would be riverbank erosion or mass wasting along riverbanks.

4.36 For the "Moderate" landslide susceptibility category, slopes having 18-35 degrees are considered. Generally, some lineaments and scarps are observed as well but their relative density is low compared to the high density lineaments and scarps in the "High" susceptibility category. The terrain appears relatively not deformed in terms of landslide scars and lineaments that cut it.

4.37 The "Low" landslide susceptibility category includes those areas with slopes below 18 degrees. In accordance with the MGB criteria, these areas have no identified landslide scars--whether old, recent or active.

4.38 Lineaments and landslide scarps interpreted from the remotely sensed data were plotted on map layers. Polygons were drawn to cover areas having a relatively high density of lineaments and landslide scarps or both over an area of interest (see Figure 4.2.10). If available, data on active landslides in the area were plotted. This, together with old and recent landslide scarps and lineaments, help determine the areas highly susceptible to landslides. The whole analysis was performed in an integrated GIS and image processing environment.

4.39 Figure 4.2.10 helps determine areas with high susceptibility to landslides. Colored polygons indicate the highly susceptible areas. Interpreted lineaments (lines) also pose hazards to properties.

Source: JICA Study Team (GIS 2014)

Figure 4.2.10 Data on Active Landslides, Landslide Scarps and Lineaments

4.40 In the actual analysis, the first areas identified are those with active landslides, high density of lineaments and scarps, old landslide debris complexes, collapsed sinkholes, and active mining quarries, all belonging to the "High" susceptibility to landslides category. Wetlands in lowland areas suspected to be sinkholes are included in the same category. However, these same areas may equally be included in the "High" susceptibility to flooding category. Areas with slopes from 18 degrees and above ended up being included in the "Moderate" susceptibility category even though the design was to have those areas with slopes greater than 35 degrees in the "High" susceptibility category.

4.41 To improve the present analysis, four categories of susceptibility can be used. Areas with high slopes (greater than 35 degrees) although without scarps or lineaments cutting across them can be separated from the "Moderate" category to form the "High" susceptibility to landslides category. Following that, the current "High" susceptibility can be upgraded to "Very High" category because they already have evidences of landslides and collapsed structures.

4.42 It is important to note the difference between degrees and gradient. Table 4.2.9 shows a conversion of degrees to gradient. Only important values are shown. This study used degrees during the analysis.

Table 4.2.9 Selected Values of Degrees and Conversions to % Grade

Slope (in Degrees)	Gradient		% Grade
	x	Y	
0.1	1	573.0	0.17
1	1	57.29	1.75
5	1	11.43	8.75
10	1	5.671	17.6
11	1	5.145	19.4
15	1	3.732	26.8
18	1	3.078	32.5
20	1	2.747	36.4
25	1	2.145	46.6
30	1	1.732	57.7
35	1	1.428	70.0
40	1	1.193	83.9
45	1	1.000	100.0

Source: JICA Study Team.

4.43 The following discussion of results uses only the planned three categories bearing in mind that areas with high slopes were included in the Moderate susceptibility category.

(3) Results

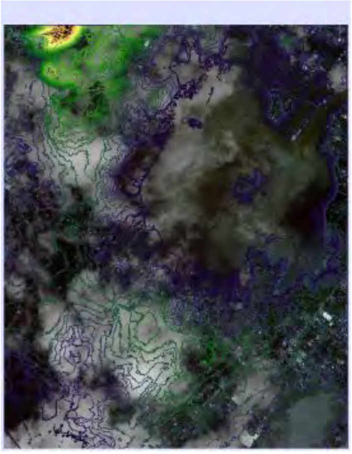
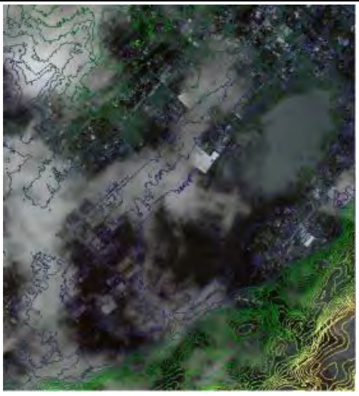
4.44 In Metro Cebu, areas identified to be highly susceptible to landslides include old landslide debris deposits, collapsed sinkholes, and old landslide complexes. While these areas may have stabilized to some degree, intense rain or strong earthquake or a combination thereof may remobilize old landslide debris causing new landslide events. Lineaments with related or nearby fresh landslide scarps are definitely highly susceptible to further landslides. Areas with a relatively high density of lineaments and scarps are also highly susceptible.

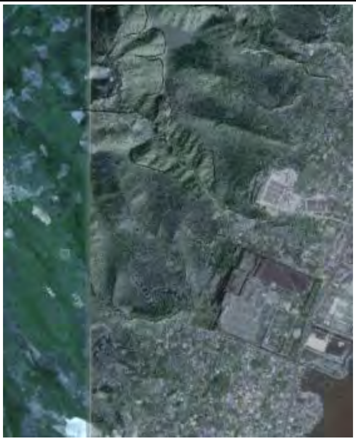
4.45 Major lineaments in Cebu Province trend NE-SW in agreement with the mapping done by MGB and PHIVOLCS. This study found smaller lineaments trending NW-SE that may prove important to development projects being planned.

4.46 The succeeding figures which illustrate the various characteristics of areas susceptible to landslides are summarized and briefly described in Table 4.2.10.

Table 4.2.10 Characteristics of Landslide Hazards

Hazard Level	Identified Landslide Hazards	Examples
Moderate	(a) Rolling Hills with Moderate Susceptibility to Landslides: From the eastern coast of northern Cebu, rolling hills stand out in sharp contrast to the narrow, relatively flat lowland. Further west, the hills rise to mountain areas. The hills, underlain by limestone, form elongated features whose axes generally trend at some angle towards the east. These hills have moderate susceptibility to landslides.	
High	(b) Active Landslide Areas: Some hill areas are highly susceptible to landslides. The figure at the right shows that landslides affected the road at least twice. An older landslide scarp (in blue), together with the more recent scarps (in yellow and red) reveal that the area is landslide-prone. Two landslides are close to each other in Compostela. The big landslide (yellow) left some rocks hanging on the wall. The smaller one (right) seems to be a remobilized portion of an earlier bigger landslide (in blue). The site is just north of the boundary with Liloan, about 1.5 km west of the National Highway.	
High	(c) Bulging Areas on Slopes: In some instances, bulging areas on slopes indicate either an area that moved or is likely to suddenly move given the right trigger such as intense rain or an earthquake of sufficient magnitude. The figure at the right shows a bulging area that already moved down and can move down further. This bulging area on a slope indicates high landslide susceptibility. The scarp at the top of the bulge reveals that the mass has already moved down. With the right trigger such as intense rainfall or high magnitude earthquake, this mass could collapse. This bulge is located about 2.3 km northwest from the center of Silot Bay.	

Hazard Level	Identified Landslide Hazards	Examples
High	(d) Suspect Subsidence Areas: Some features identified are suspect subsidence areas. For example, this semi-circular feature (about 800 meters long and 500 meters wide) in Liloan could be an incipient sinkhole, or area of land subsidence, or simply a topographic low. This area needs further data, analysis, and ground verification. The site is about 2 km west northwest of the center of Silot Bay near the boundary of Consolacion.	
High	(e) Silot Bay: Silot Bay in Liloan is connected to the sea. On the way out to the sea past the bridge, the waters from Silot Bay swirl into small whirlpools. This river outlet is the only river in the study area where the waters swirl a lot as they exit to the sea. The figure at the right shows Silot Bay and its surroundings. The bay measures about 1.4 km long and 1.2 km wide. The contour lines (5 meters interval) draped over the image show that Silot Bay is roughly circular and the slopes around it are steep. If we imagine submerging the whole bay area including the surrounding ridge under water, it would likely appear like a circular blue hole. This study proposes that Silot Bay is a cave formation whose roof collapsed. This feature is more commonly called a collapsed sinkhole. Notice the closely-spaced contours that reveal the roughly circular shape of the bay and the steep slopes around it. The ridge surrounding the bay is about 25 m above sea level. These ridge areas around the bay are highly susceptible to landslides. The lower areas near the waters are soft and are susceptible to differential ground settlement.	
High	(f) Wetland in Lowlands: Large wetlands in lowland areas with no surface outlets towards the sea were identified as collapsed sinkholes. The low elevation of these wetlands allow freshwater to accumulate. These wetlands may have underground passageways that allow freshwater to drain to the sea. The figure shows a large wetland in Liloan about one km from the coast with no surface creek or river that serves as outlet to the sea.	
High	(g) Actively Worked Mines: Actively worked mining areas are considered highly susceptible to landslides. Development of these areas requires extreme caution and rigid implementation of safety procedures. Before abandoning the mine, the quarry slopes must be stabilized for the safety of the general public. Since mining activity over an area is a temporary land use, it is worth considering what future land use these quarries will be after its closure and abandonment. Shown on the figure is a site in Naga.	

Hazard Level	Identified Landslide Hazards	Examples
High	(h) Developments Very Close to Hillsides and Rivers: Developments very close to hillsides and rivers can create dangerous situations. In the case of Naga City (figure at the right), upstream in the headwaters are wide scarps between 100 m to 200 m in width. The total length of the scarp series is about 1 km long. The scarp face itself is steep between 30 and 45 degrees. The series of scarps, arranged in semi-round configuration, made the catchment area wider at the top, thus catching more rainwater. If debris temporarily dams the narrow creek that drains the place, the upstream area may flood. If the temporary dam breaches, large amounts of water rushing downwards can trigger landslides and flash floods downstream and affect communities and development projects near its path.	
High	(i) Old Landslide Debris Deposits Area: An old landslide debris deposit with communities built on top was recognized. Features like these might be difficult to recognize at ground level. The steep slopes with little vegetation at the scarp face are susceptible to rock falls that may hit residents and motorists below. At the same time, the old debris deposit with the river water passing beside could have differential settling, causing damage to properties and the road. This site is in Naga City near the boundary with Minglanilla.	
	(j) Hill Development Settings that Need Engineering Intervention: The figure at the right shows a hill development setting in Naga City that needs good engineering study and intervention. In the figure, a barren slope on the west is directly above some impounded water body of unknown volume. Further below to the east is a building. The barren slope might fail and hit the water body and building below. A few other danger variant scenarios are possible in this setting.	
High	(k) Areas with Lineaments Need Buffer Spaces: There are many lineaments observed in the remotely sensed images covering the study area. Lineaments are zones of weakness on the ground. While many may not presently indicate evidences of motion, ground shaking due to strong earthquakes can cause these lineaments to move, thus damaging the structure situated on top of the feature. The figure shows an example of a development project in Talisay City that needs to observe some buffer spaces from the lineaments. An open space at least 5 meters on both sides of the lineament is recommended.	

Hazard Level	Identified Landslide Hazards	Examples
High	(l) **Active Landslide Areas:** In some parts of Cebu City and Talisay City, active landslide areas were identified. This particular area, transected by a lineament and marked by a landslide scarp, is highly unstable. Vegetation's inability to grow along a slope is indication of the high potential for landslide susceptibility. The figure shows an area in Brgy. Sinsin, Cebu City with high erosion and active slumping transected by a NW-trending lineament that cuts across the road. This area is highly unstable. When landslides are closely spaced, along with other evidences of ground instability, they may form a large zone that has high susceptibility to landslides.	
High	(m) **Areas Situated at the Confluence of Streams and Trajectories of Landslides:** Areas situated at the confluence of streams and trajectories of landslides are areas with high susceptibility to landslides. These areas, called landslide debris depositional areas, are also at risk to flash floods. Landslide debris may come from afar and move down at great speed. Areas in the path of the debris are in danger. Shown here is an area in Talisay City near the boundary with Cebu City.	
High	(n) **Areas with High Slopes:** Areas with very high slopes are considered to have high susceptibility to landslides. High slopes could be due to road cuts, scarp faces or deep gully erosion. Shown on the right is a site in Carcar City 1.2 km near the boundary with San Fernando.	
High	(o) **Series of Old Landslide Scarps:** Old landslide scarps identified in some hillsides of South Metro Cebu (boundary area between San Fernando on the lower left, and Naga City on the upper right). measure up to 300 m across, suggesting either a single large landslide event in the past or a series of adjacent small landslides that created the present large scarp. In some instances, the series of adjacent scarps are evident, stretching up to 1.5 km in length. While active landslides and fresh scarps are the main indicators of high susceptibility to landslides, the relatively high density of scarps (large number of scarps present over a given area) points to the area as being highly susceptible to landslides. The occurrence of new fresh landslides in the area is very likely.	

Hazard Level	Identified Landslide Hazards	Examples
High	(p) Old Landslide Debris Deposits: Houses built on some old landslide debris deposits areas where debris have stabilized to some degree are at risk to debris remobilization caused by heavy rains, earthquake ground shaking, or both acting singly or together within a short period. The figure shows an old landslide debris deposit with communities on it located in Carcar City.	
High	(q) Large Sinkholes–Collapsed Cave Formation: The figure shows an area in Naga City with large collapsed sinkholes measuring about 800 m long and 680 m wide.	
High	(r) High Erosion and Slumping along River Banks near Development Areas: In the urbanized areas near active rivers, some development areas are at risk to riverbank erosion and slumping. Engineering interventions are needed to protect such development projects. The site shown is in San Fernando near Carcar City, about 750 m from the coast.	

Source: JICA Study Team.

(4) Conclusions

4.47 The above findings show that Metro Cebu has many areas highly susceptible to landslides. These areas include active landslide areas/ high erosion, collapsed sinkholes / collapsed cave formations, old landslide debris depositional areas, actively mined areas, and mountain areas with very steep slopes. The hill areas are moderately susceptible to landslides.

4.48 The use of remotely sensed data provided a synoptic view of Metro Cebu and enabled the recognition and identification of large hazard features such as collapsed sinkholes, old landslide debris depositional areas, and long lineaments that are difficult to recognize at ground level.

4.49 Several existing development areas in Metro Cebu need engineering interventions to reduce the hazards that may affect them. The results of this study can be refined by site visits and integration of ground data and information. Identified hazardous areas with development projects, existing and proposed, will need more detailed ground survey.

5 ATLAS FOR NORTHERN CEBU

5.1 In parallel with the mapping works for Metro Cebu, another digital mapping for the northern areas of the Province of Cebu was conducted to prepare a topographic map in 1:25,000 scale and several hazard maps. Northern Cebu is frequently traversed by tropical typhoons. It already experienced heavy damages during the Typhoon Yolanda in 2013. Therefore, the output maps from this study should be utilized for overall topographical analysis, land use analysis and hazard mapping. This Atlas contains many outputs of the GIS-processed information. A visual presentation of the study area in the mentioned aspects could afford various interpretation for a planning development framework.

5.1 Physical, Environmental and Socio-economic Features of Northern Cebu

5.2 Utilizing the digitized topographic maps, a series of thematic maps were prepared. These maps were utilized as bases for detailed analyses on existing land use, disaster hazard analyses, and urban services conditions. Table 5.1.1 is an index of thematic maps prepared and shown in this Atlas covering Northern Cebu. The target LGUs are 17 with the administrative boundaries shown on the satellite imageries depicted in Figure 5.1.1.

5.3 The secondary sources of the maps processed in this compilation are from MGB, PPDO of Cebu, NAMRIA, PhilGIS, PHIVOLCS-DOST, BSWM, PEZA, and NSO.

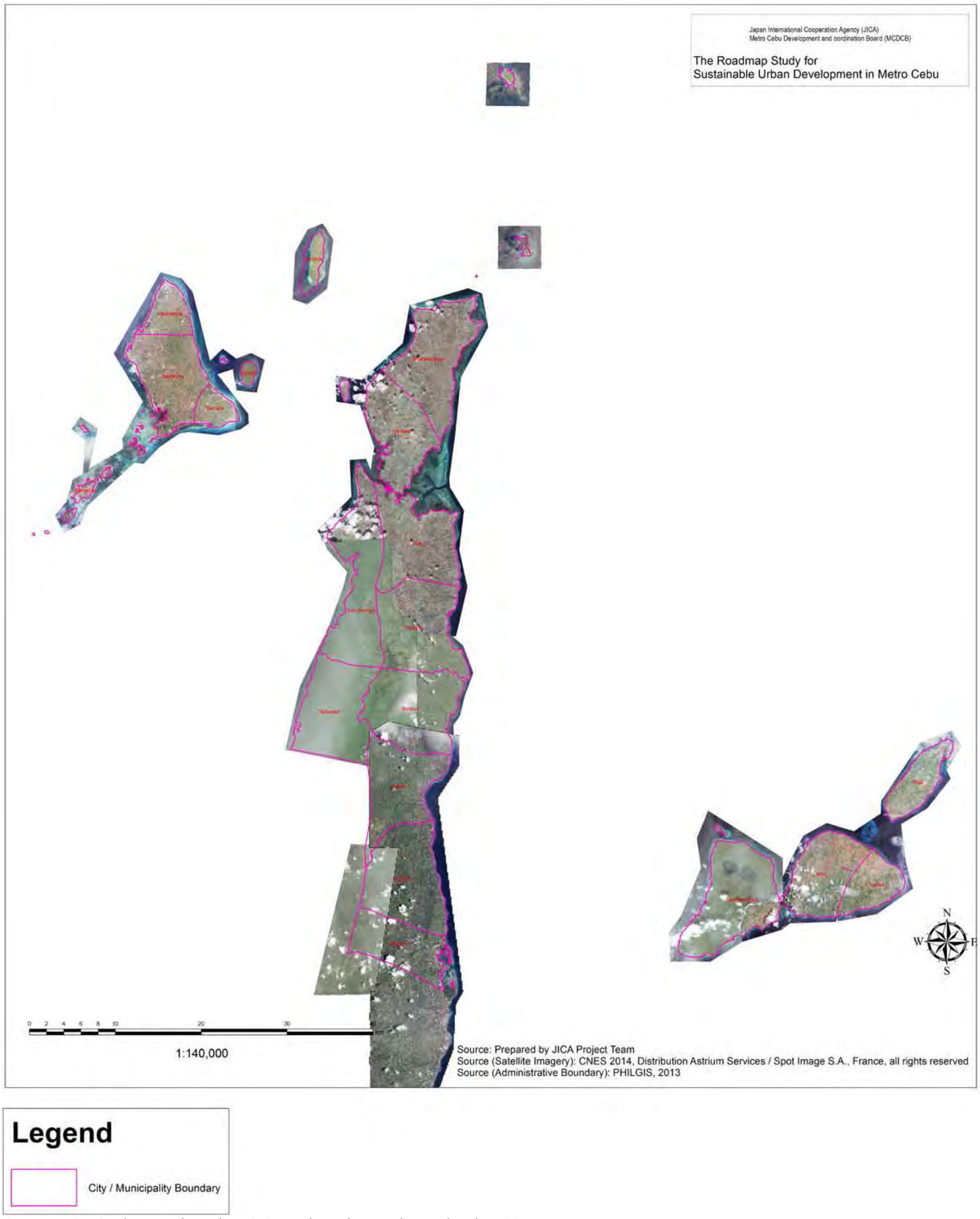
Table 5.1.1 List of Thematic Maps for Northern Cebu

Category		Figure No.	Theme	Remarks
1) Base Map		5.1.1	Satellite Imagery	
		5.1.2	Topography	
2) Natural Condition		5.1.3	Elevation	
		5.1.4	Rivers and River Basins	
		5.1.5	Geology	MGB, DNER
3) Reservation Areas		5.1.6	NIPAS	Republic Act 7586
4) Hazardous Areas	(1) Identified by National Agencies	5.1.7	Geology by Softness	MGB, DNER
		5.1.8	Active Faults and Liquefaction	PHIVOLCS, DOST
		5.1.9	Susceptibility to Earthquake-triggered Landslide	PHIVOLCS, DOST
		5.1.10	Tsunami-Prone Areas	PHIVOLCS, DOST
	(2) Identified based on Topographic Map in 1:10,000	5.1.11	Lowland Hazard Area (less than 2m)	Less than 2m area using detail contour is identified as lowland hazard areas
		5.1.12	Slope Hazard Area	Slope is calculated based on detail contours and Digital Terrain Model (DTM)
		5.1.13	Flood Hazard Area	Identified by flood simulation using available rainfall and river data.
		5.1.14	Landslide Hazard Area	Identified with the aid of remote sensing technology.
		5.1.15	Typhoon Yolanda Affected Areas	Identified through field survey, interviews and GPS .
5) Land Use		5.1.16	Existing Land Use	Identified and digitized based on satellite images.
		5.1.17	Development Suitable Area and Urbanization	Defined as the area without constraints and hazards
6) Urban Transport		5.1.18	Transport System	Road network is identified by topographic map and linked with inventorial information
		5.1.19	Existing Road Network by Width of Carriage Way	
7) Urban Services		5.1.20	Location of City Hall and Barangay Hall	Location is identified by GPS
		5.1.21	Location of Church	

Category	Figure No.	Theme	Remarks
	5.1.22	Location of Hospital	
	5.2.23	Location of School	

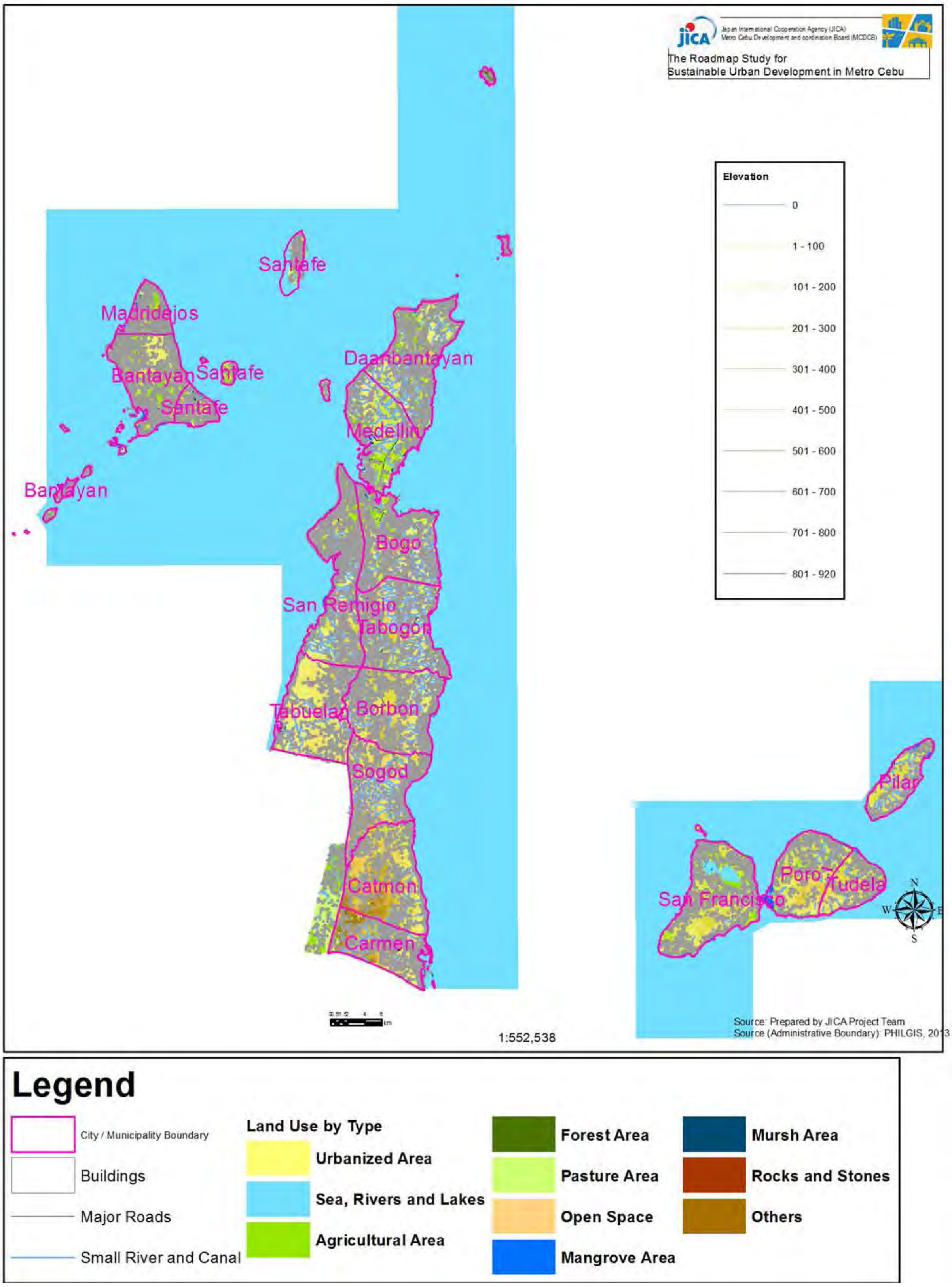
Source: JICA Study Team.

1) Base Map



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

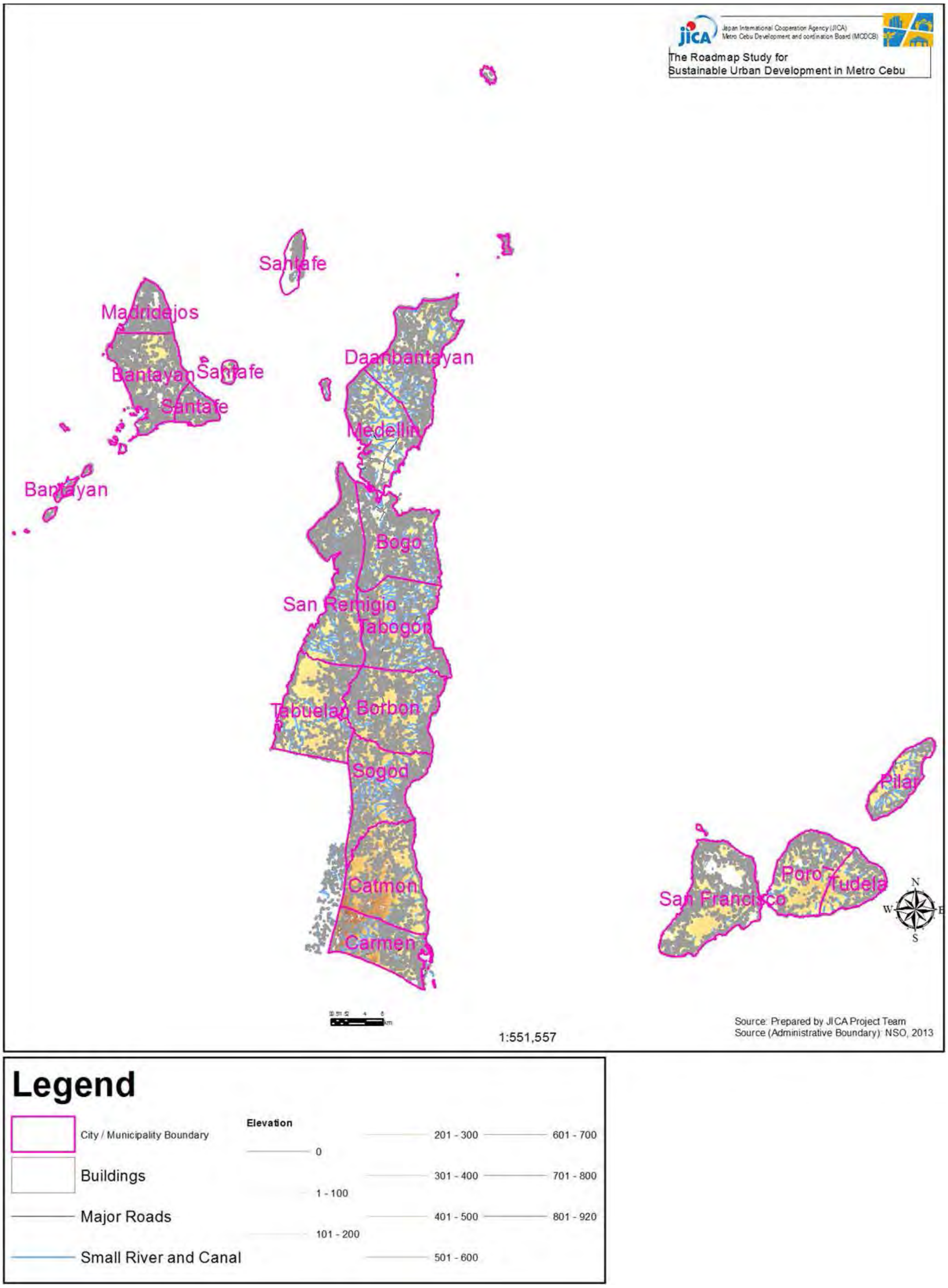
Figure 5.1.1 Satellite Imagery



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

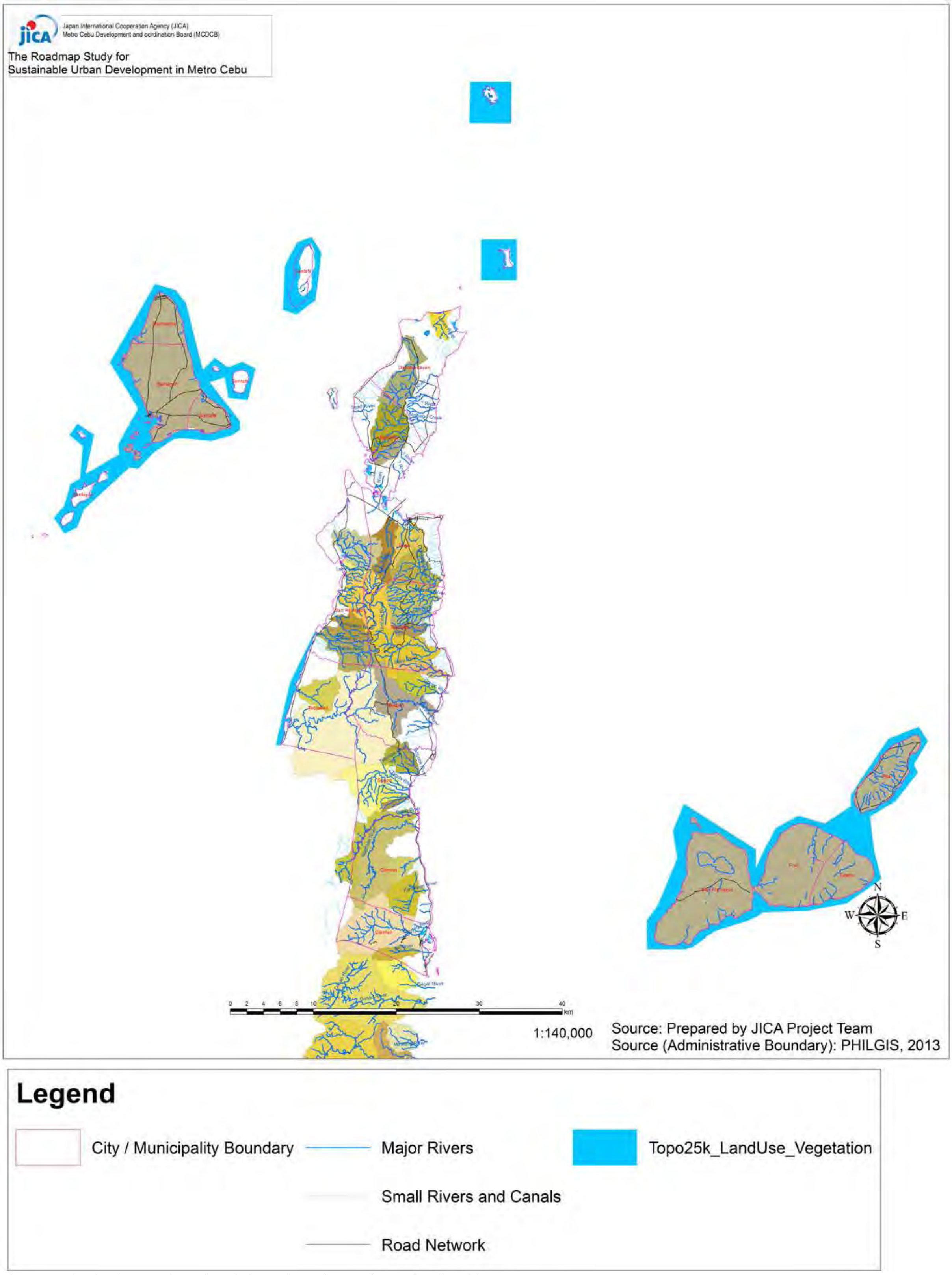
Figure 5.1.2 Topography

2) Natural Conditions



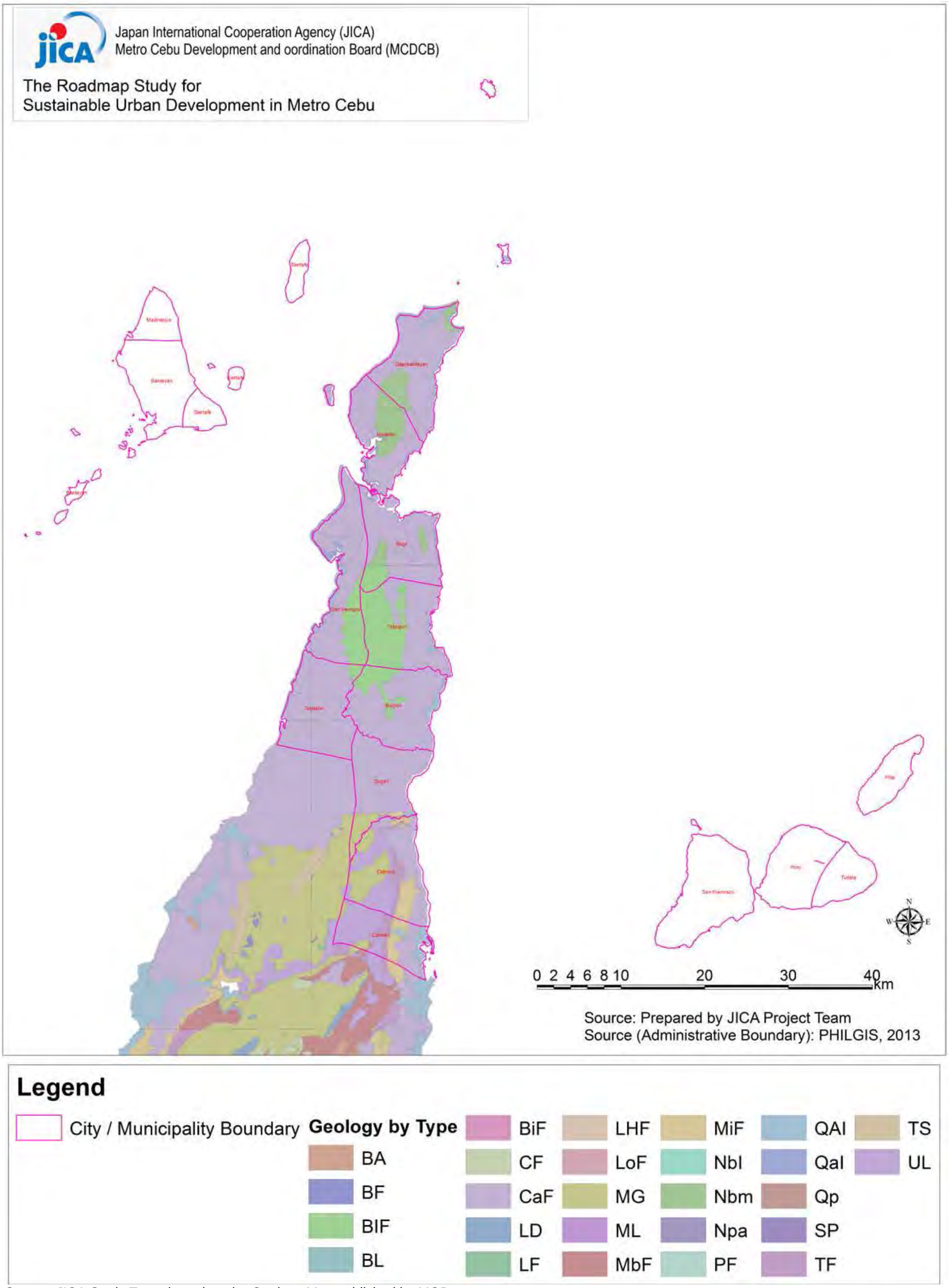
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 5.1.3 Elevation



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

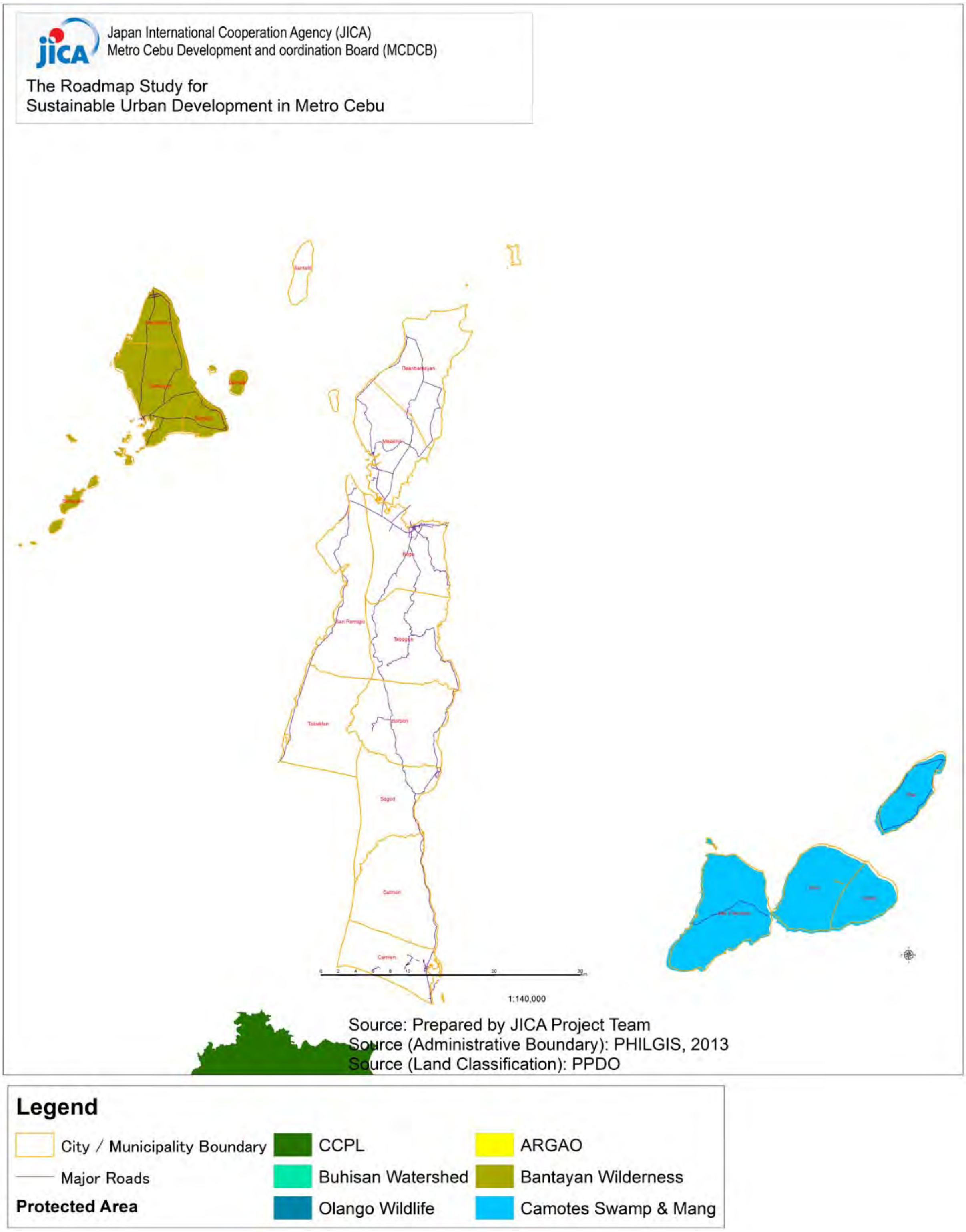
Figure 5.1.4 Rivers and River Basins



Source: JICA Study Team based on the Geology Map published by MGB.

Figure 5.1.5 Geology

3) Reservation Areas

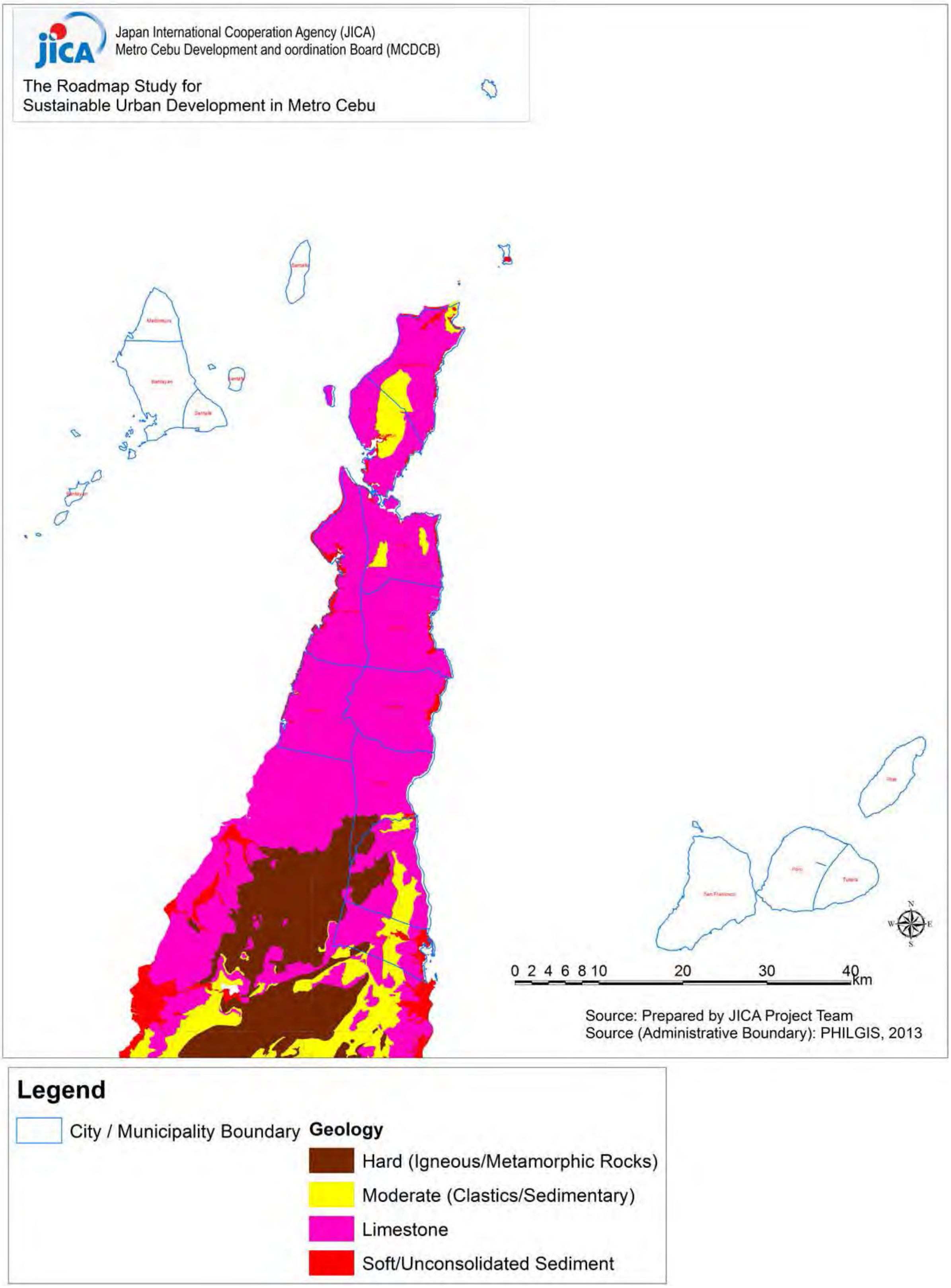


Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 5.1.6 National Integrated Protected Areas System (NIPAS) Areas

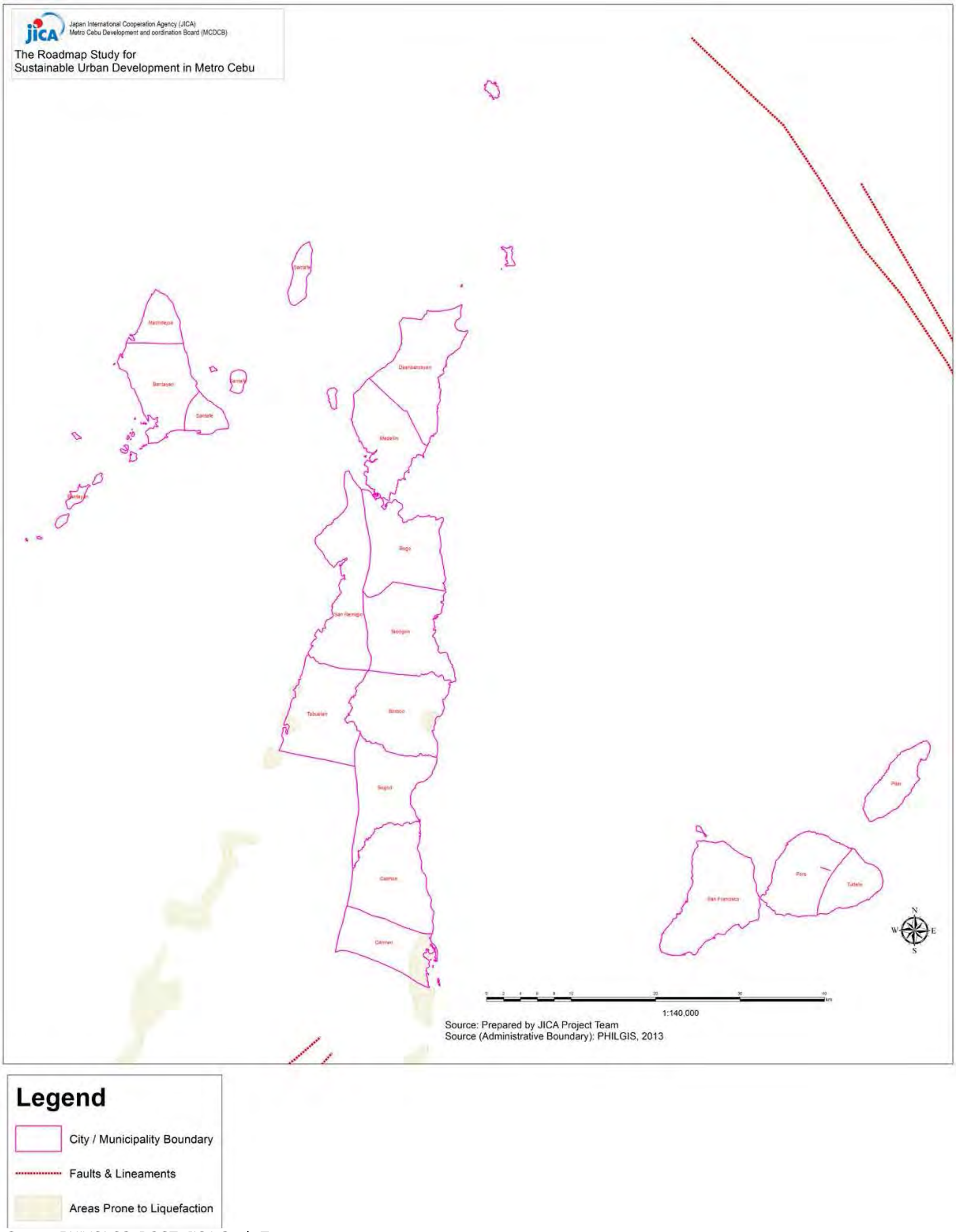
4) Hazardous Areas

(1) Identified by National Agencies



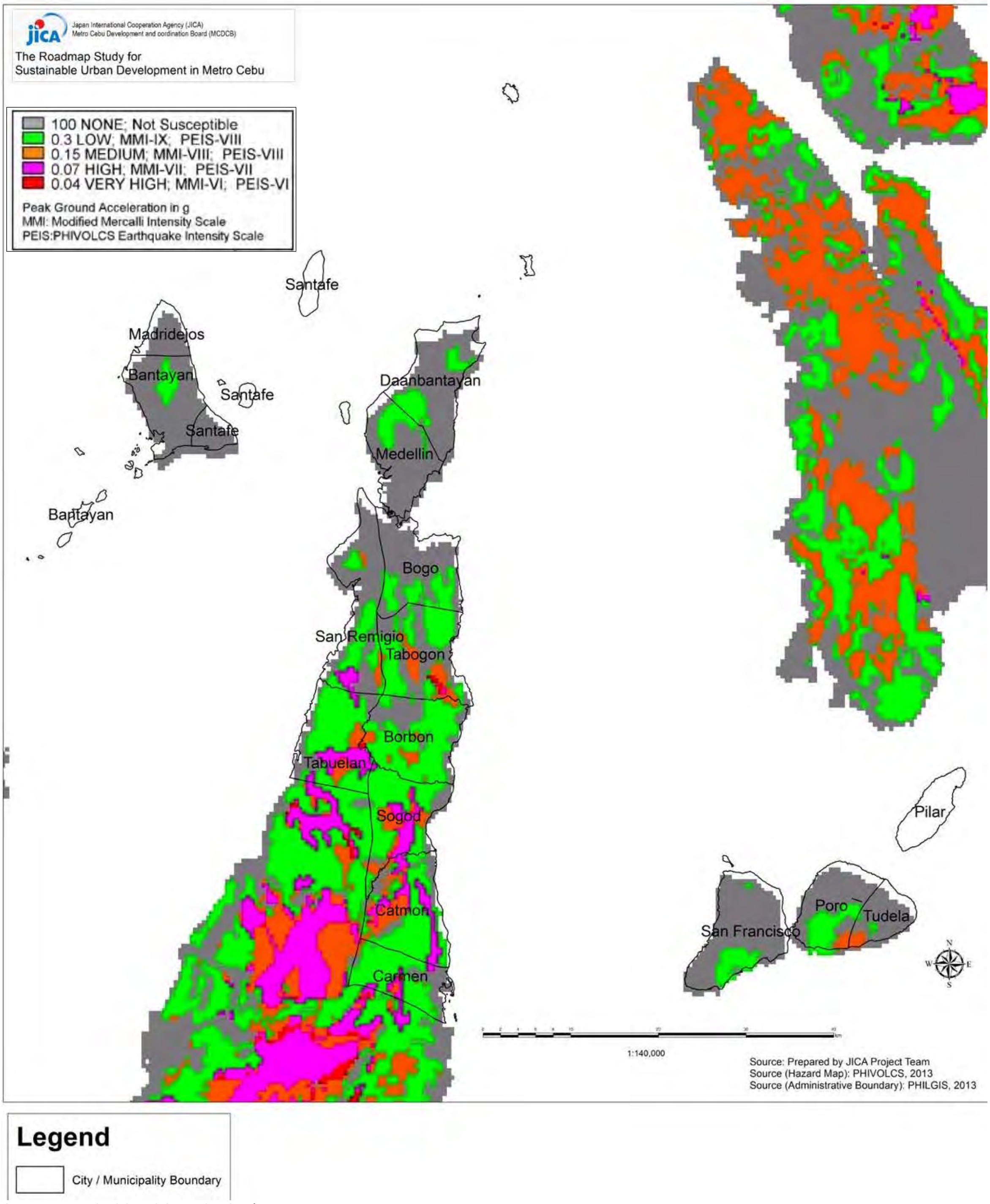
Source: MGB, DENR, JICA Study Team.

Figure 5.1.7 Geology Classified by Softness



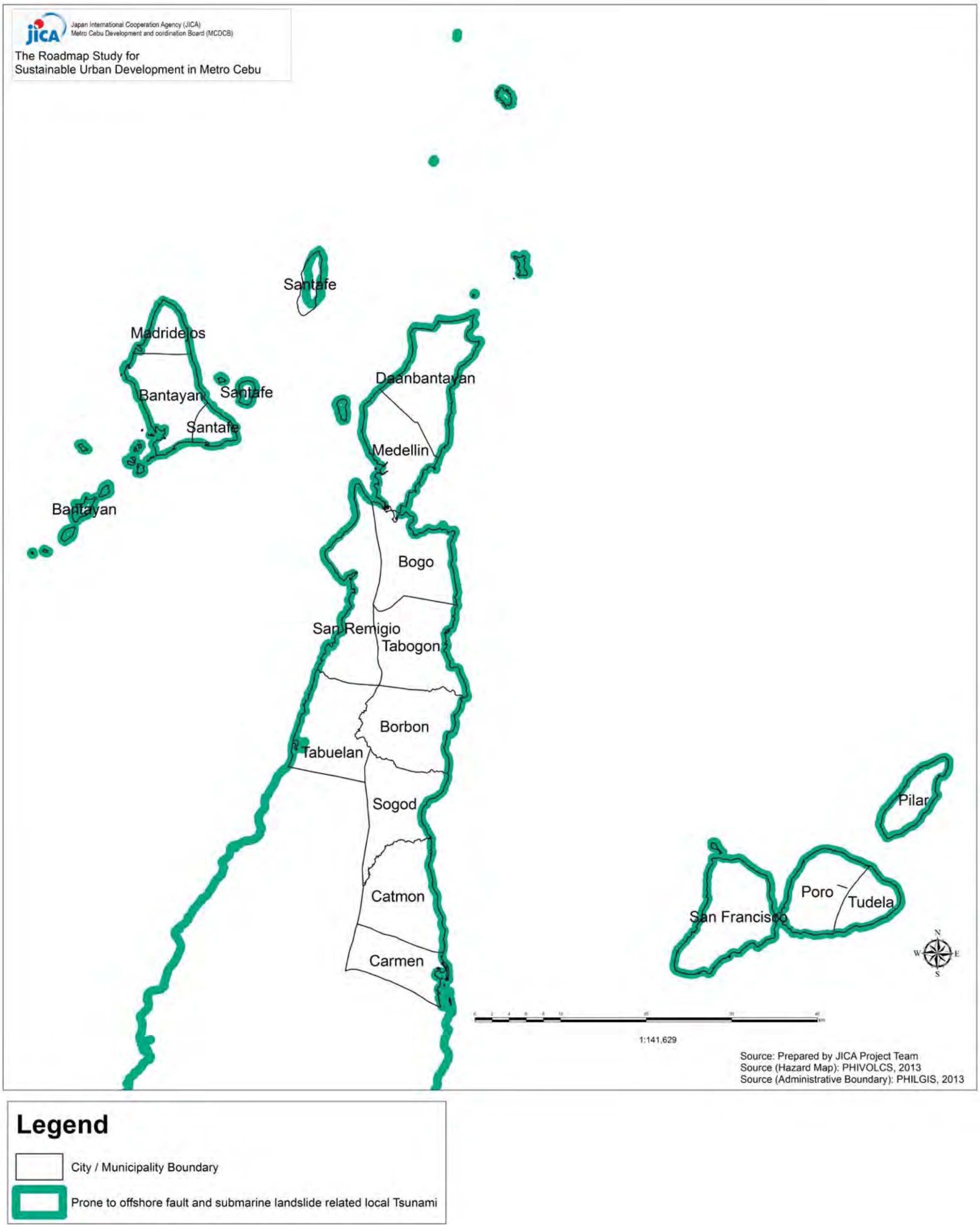
Source: PHIVOLCS, DOST, JICA Study Team.

Figure 5.1.8 Active Faults and Liquefaction



Source: PHIVOLCS, DOST, JICA Study Team.

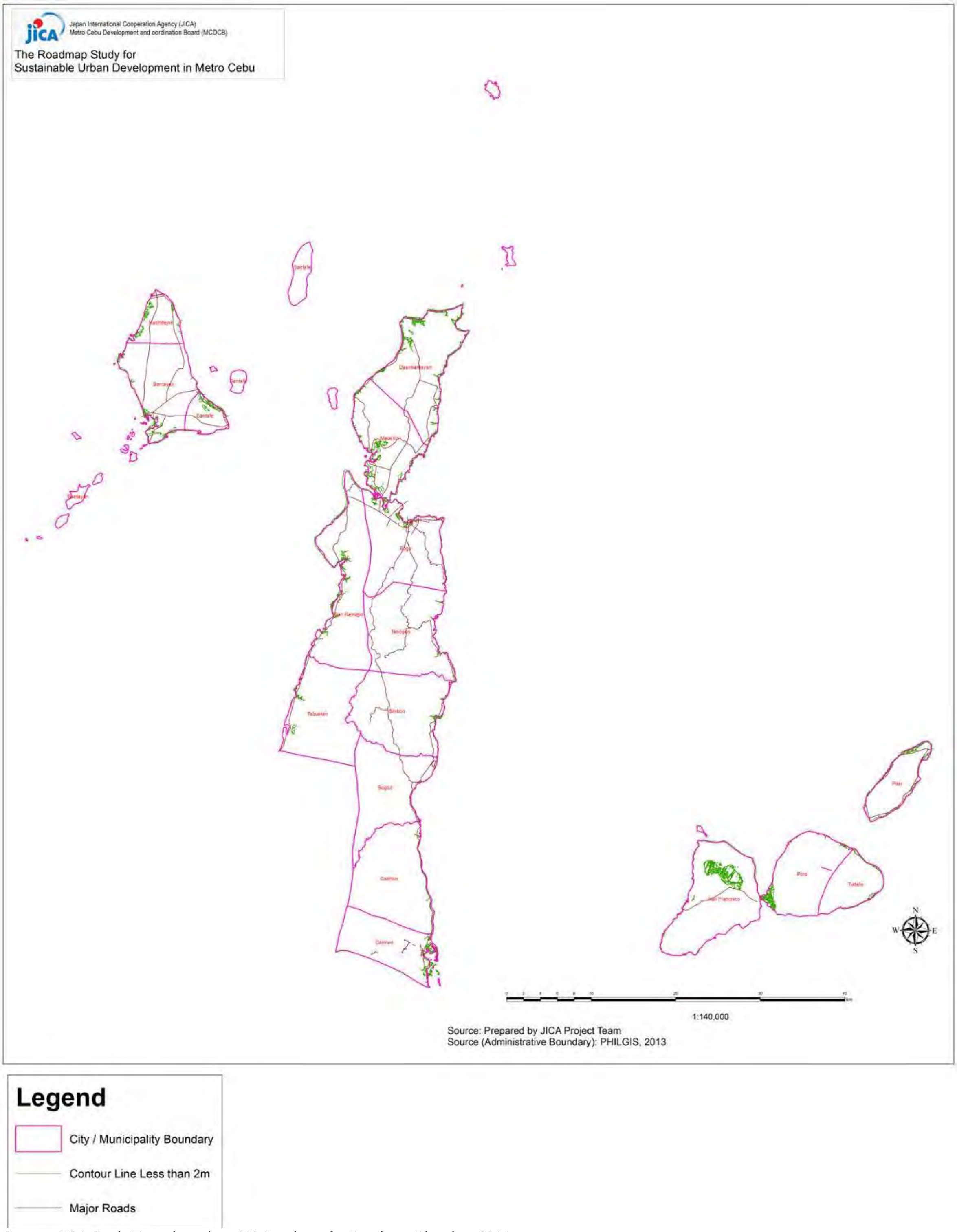
Figure 5.1.9 Susceptibility to Earthquake-triggered Landslide



Source: PHIVOLCS, DOST, JICA Study Team.

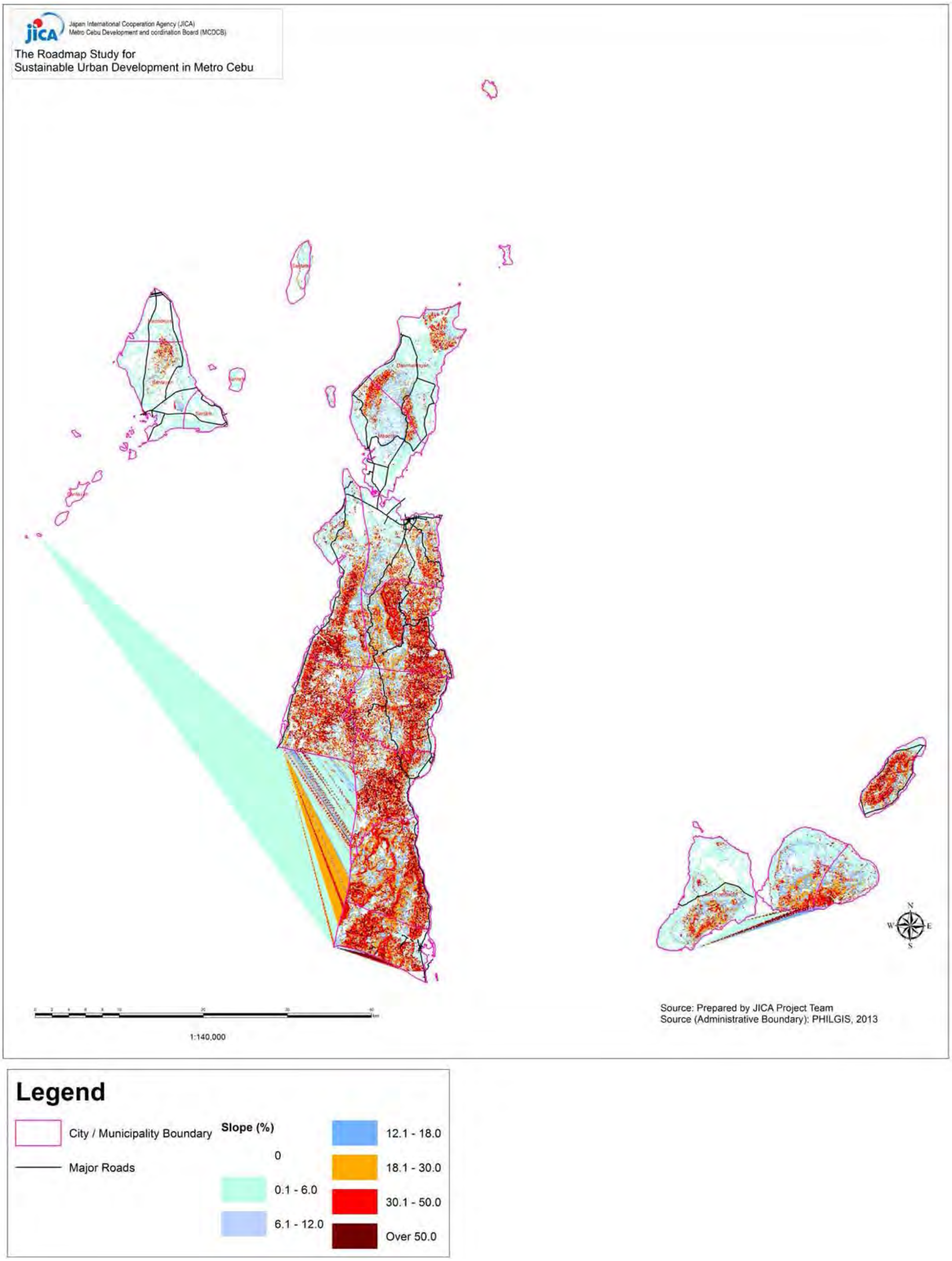
Figure 5.1.10 Tsunami-Prone Areas

(2) Identified Based on Topographic Map in 1:10,000



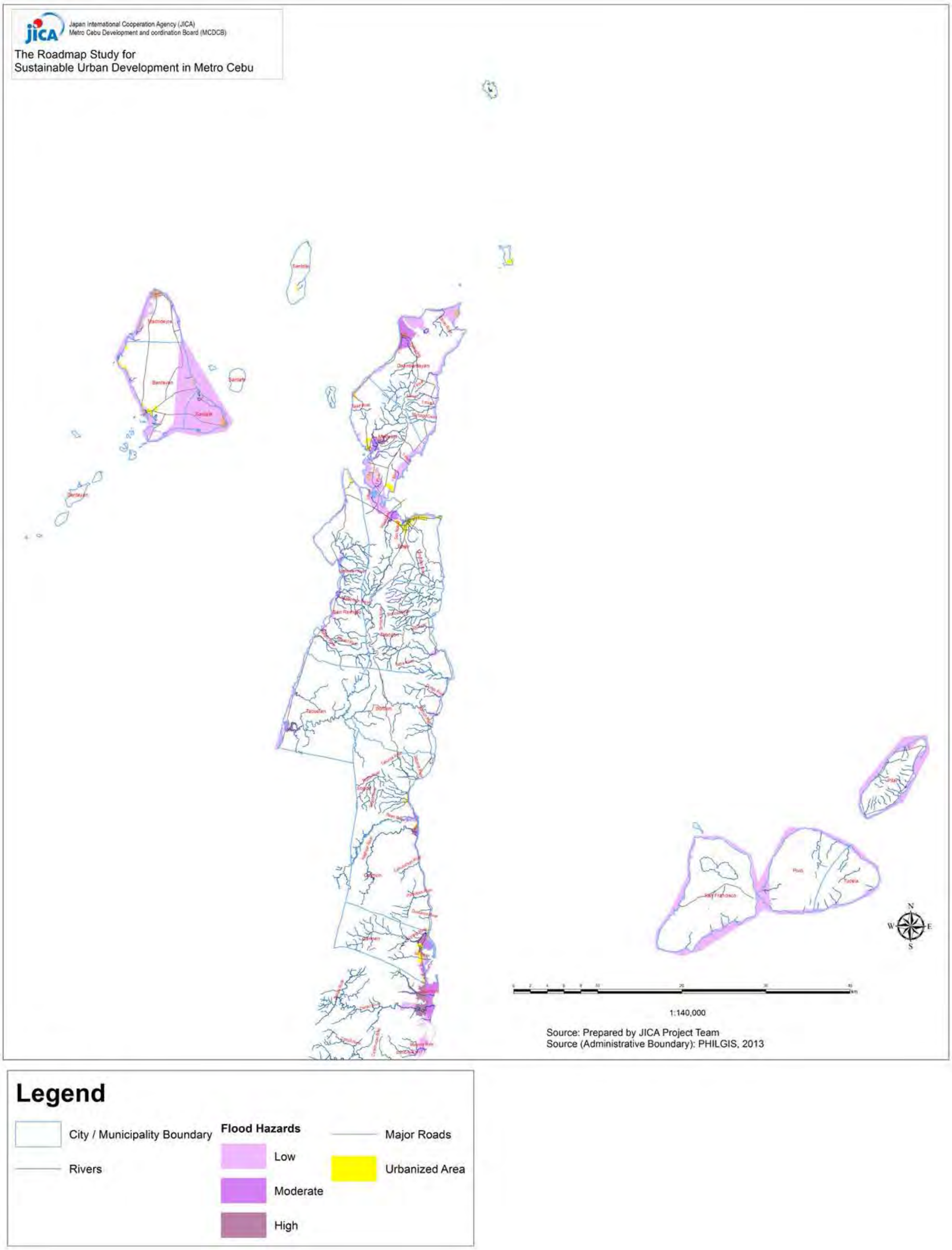
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 5.1.11 Lowland Hazard Area (Less than 2 m)



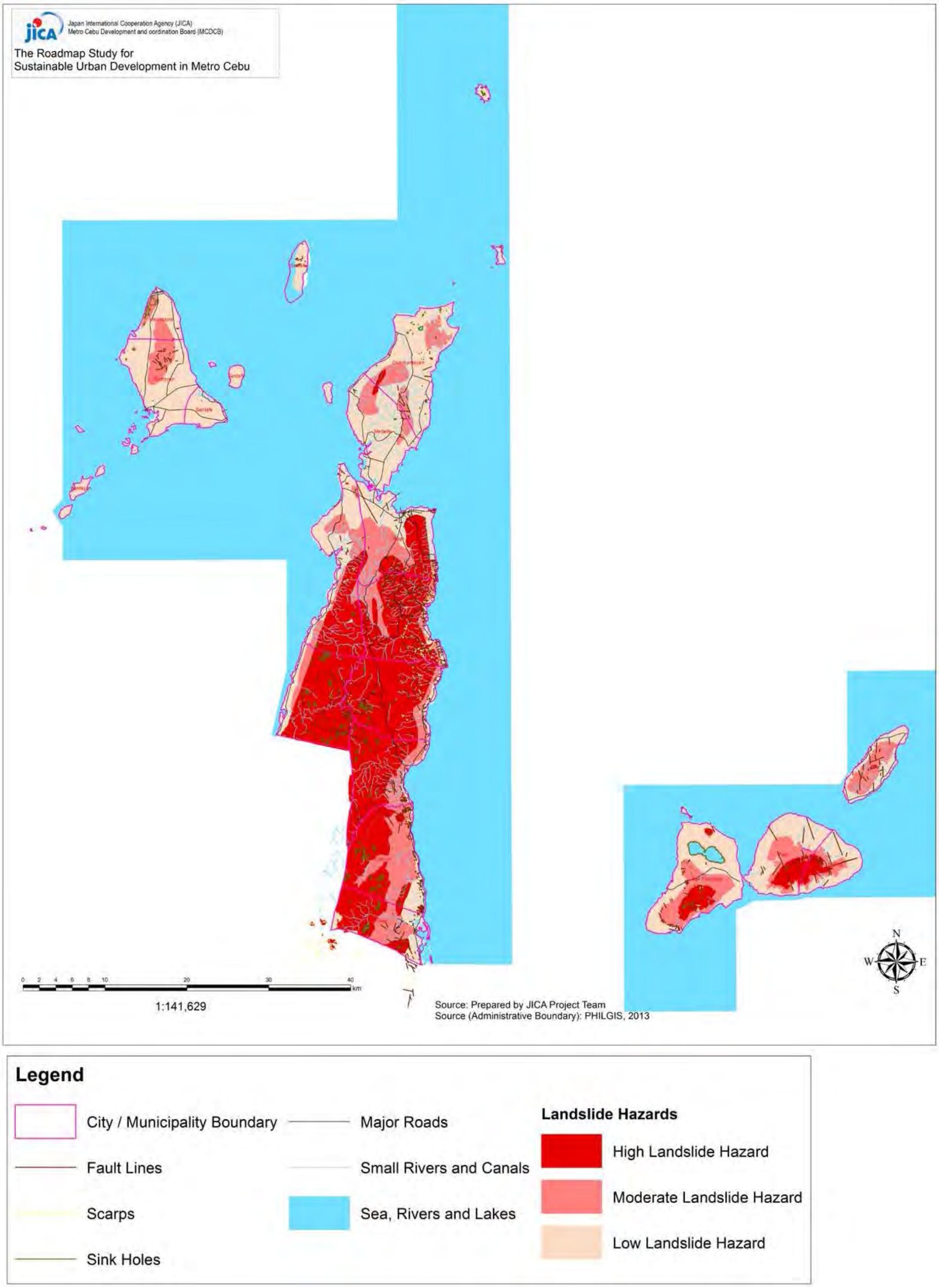
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 5.1.12 Slope Hazard Area



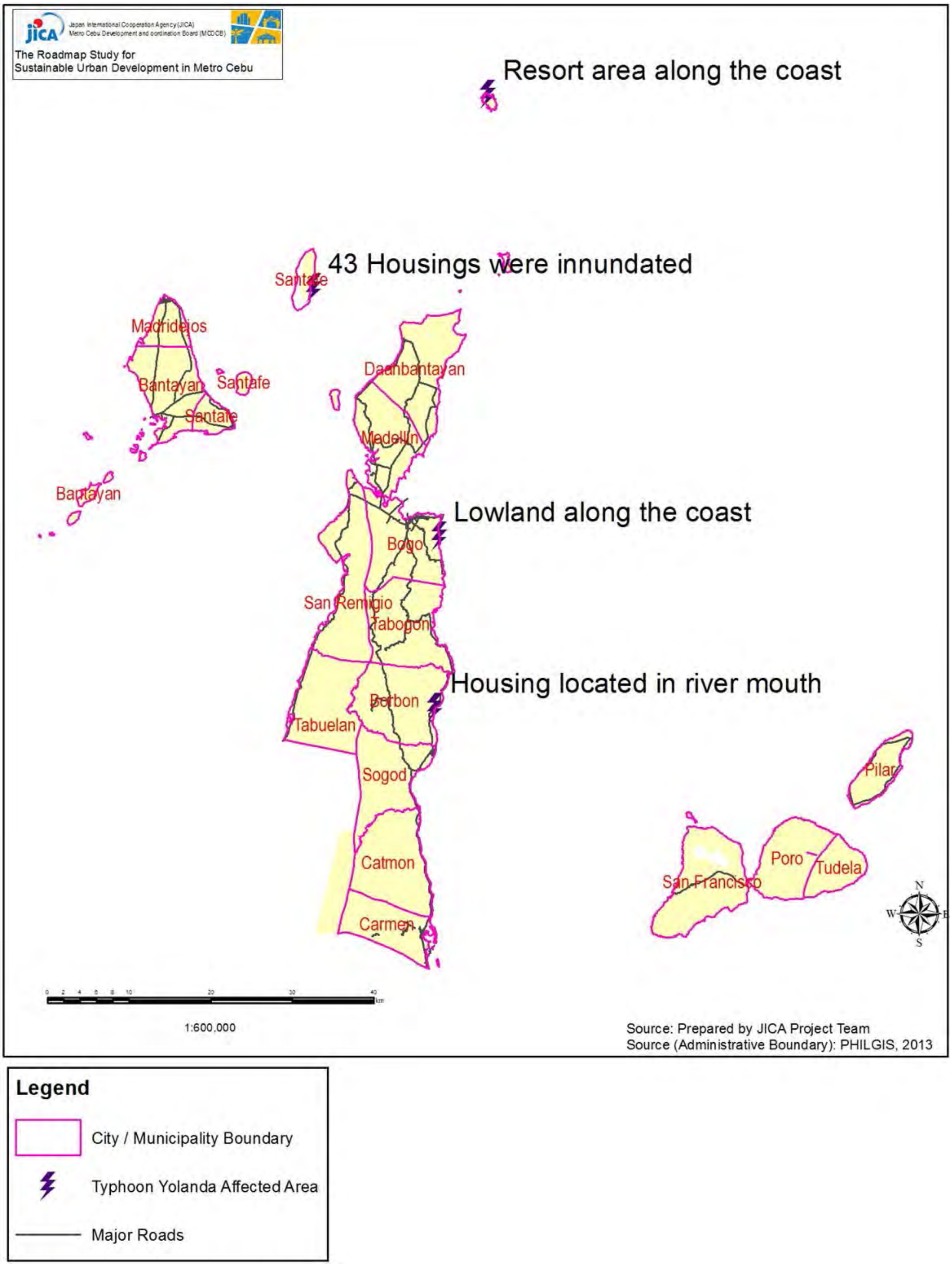
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 5.1.13 Flood Hazard Area



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

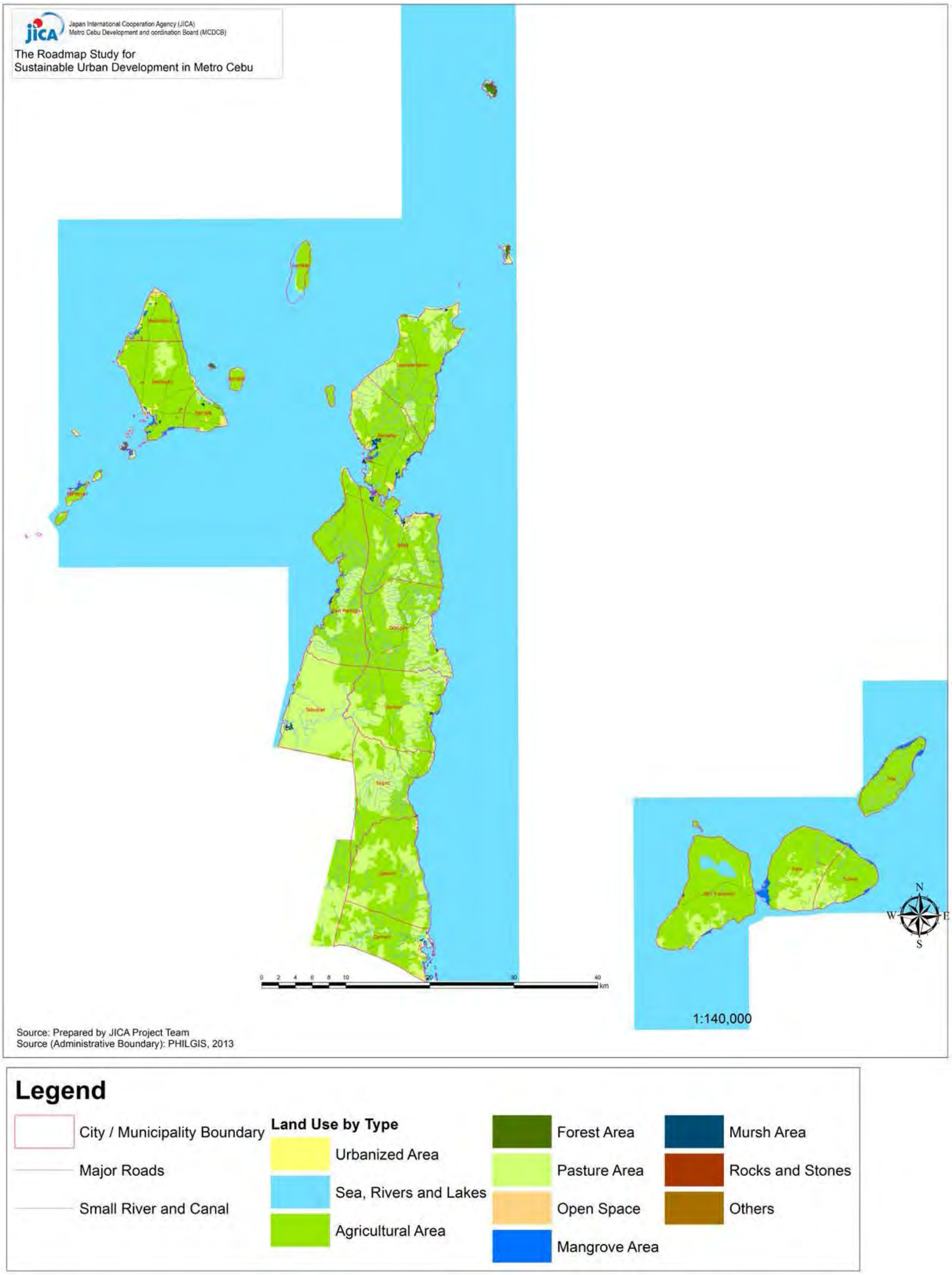
Figure 5.1.14 Landslide Hazard Area



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

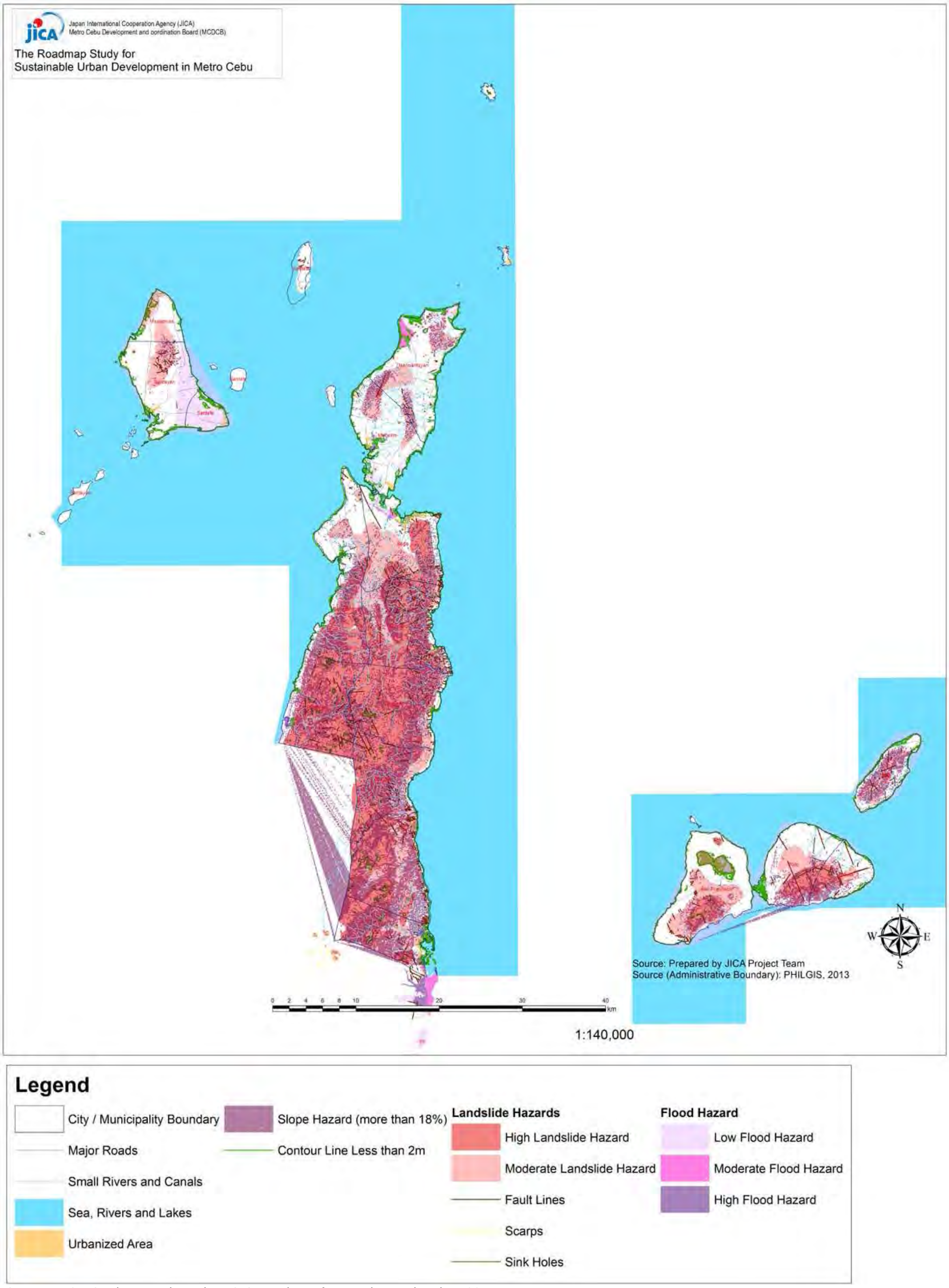
Figure 5.1.15 Typhoon Yolanda Affected Area

5) Land Use



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

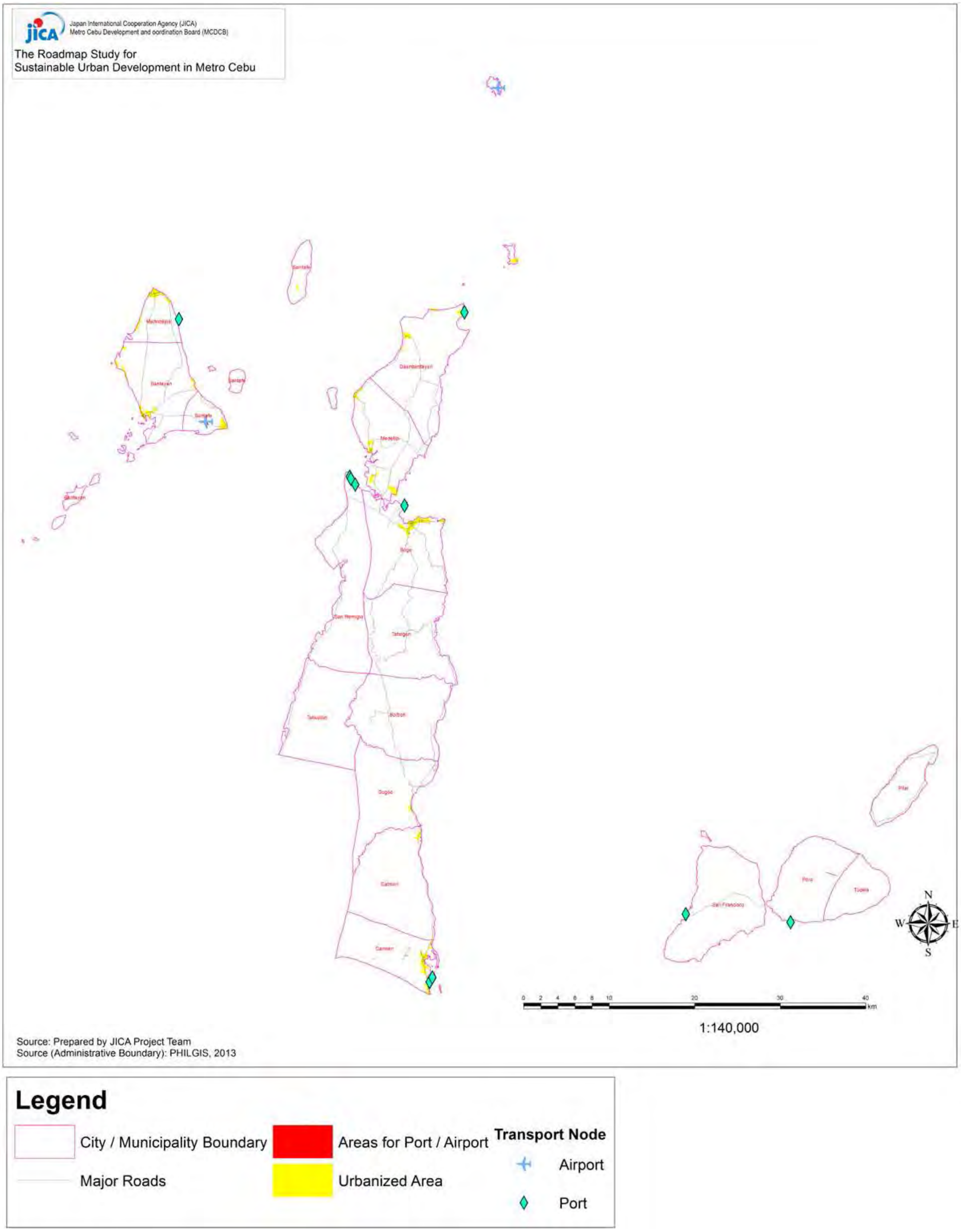
Figure 5.1.16 Existing Land Use



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

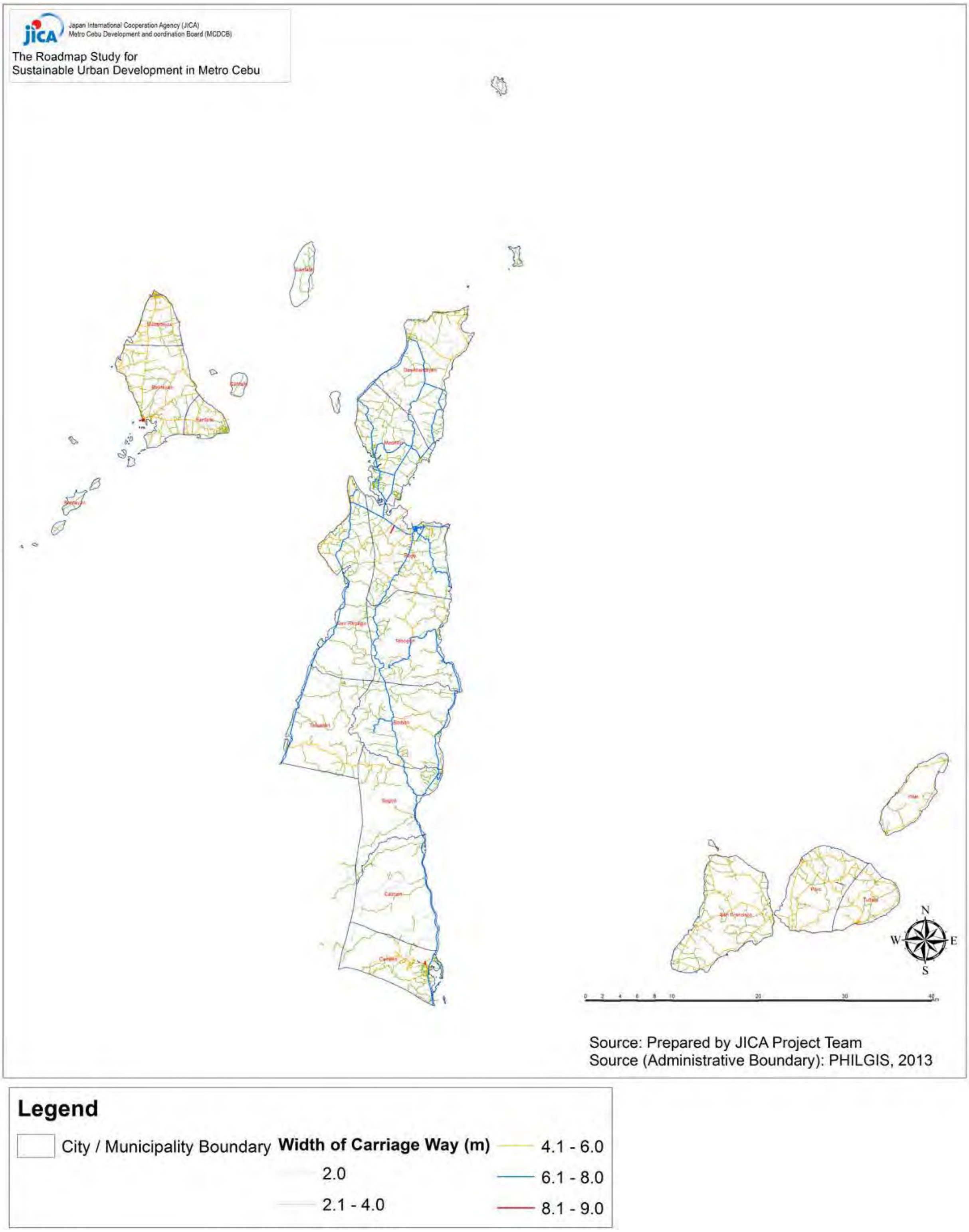
Figure 5.1.17 Development Suitable Area and Urbanization

6) Urban Transport



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

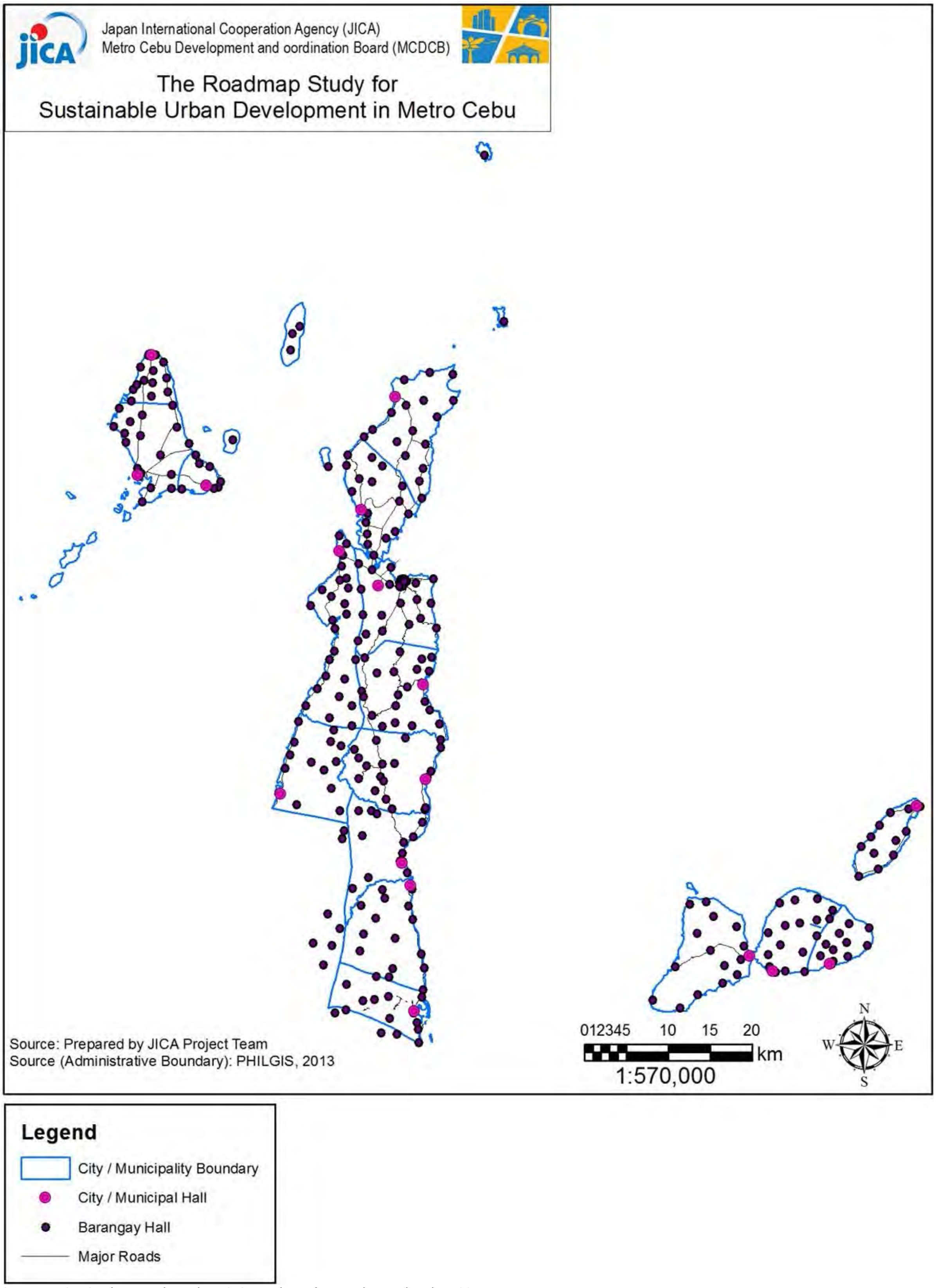
Figure 5.1.18 Transport System



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

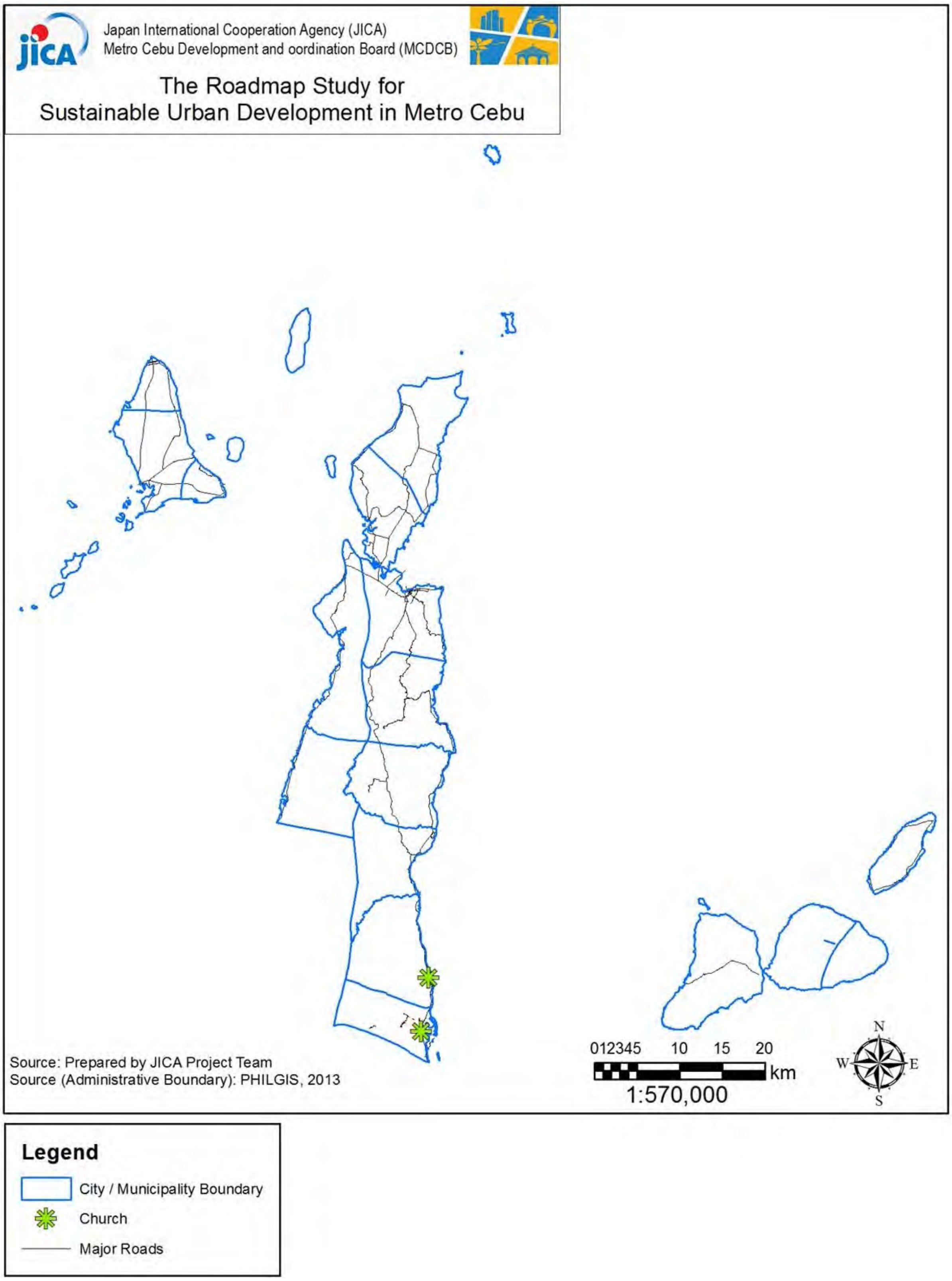
Figure 5.1.19 Existing Road Network by Width of Carriage Way

7) Urban Services



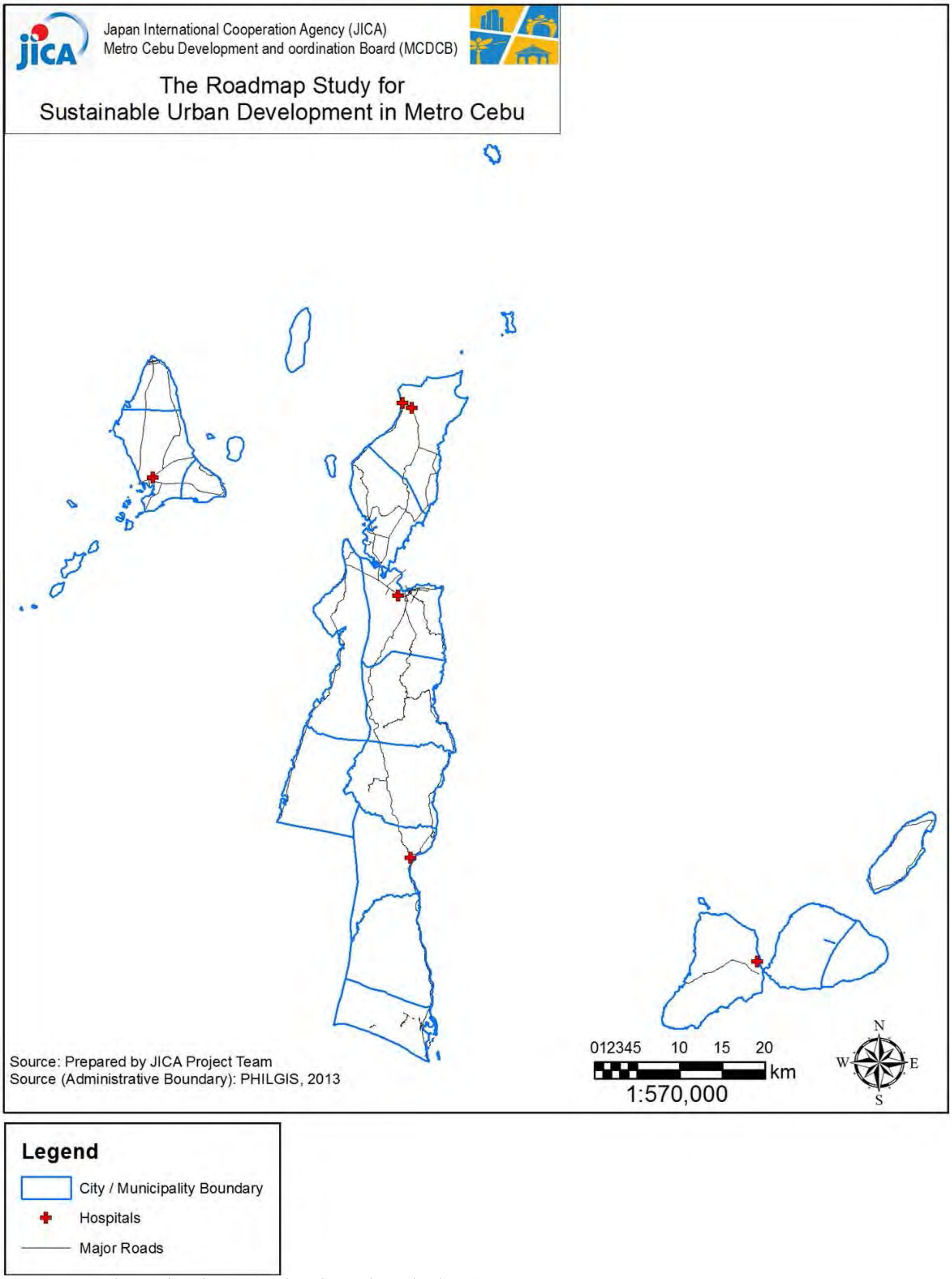
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 5.1.20 Location of City Hall and Barangay Hall



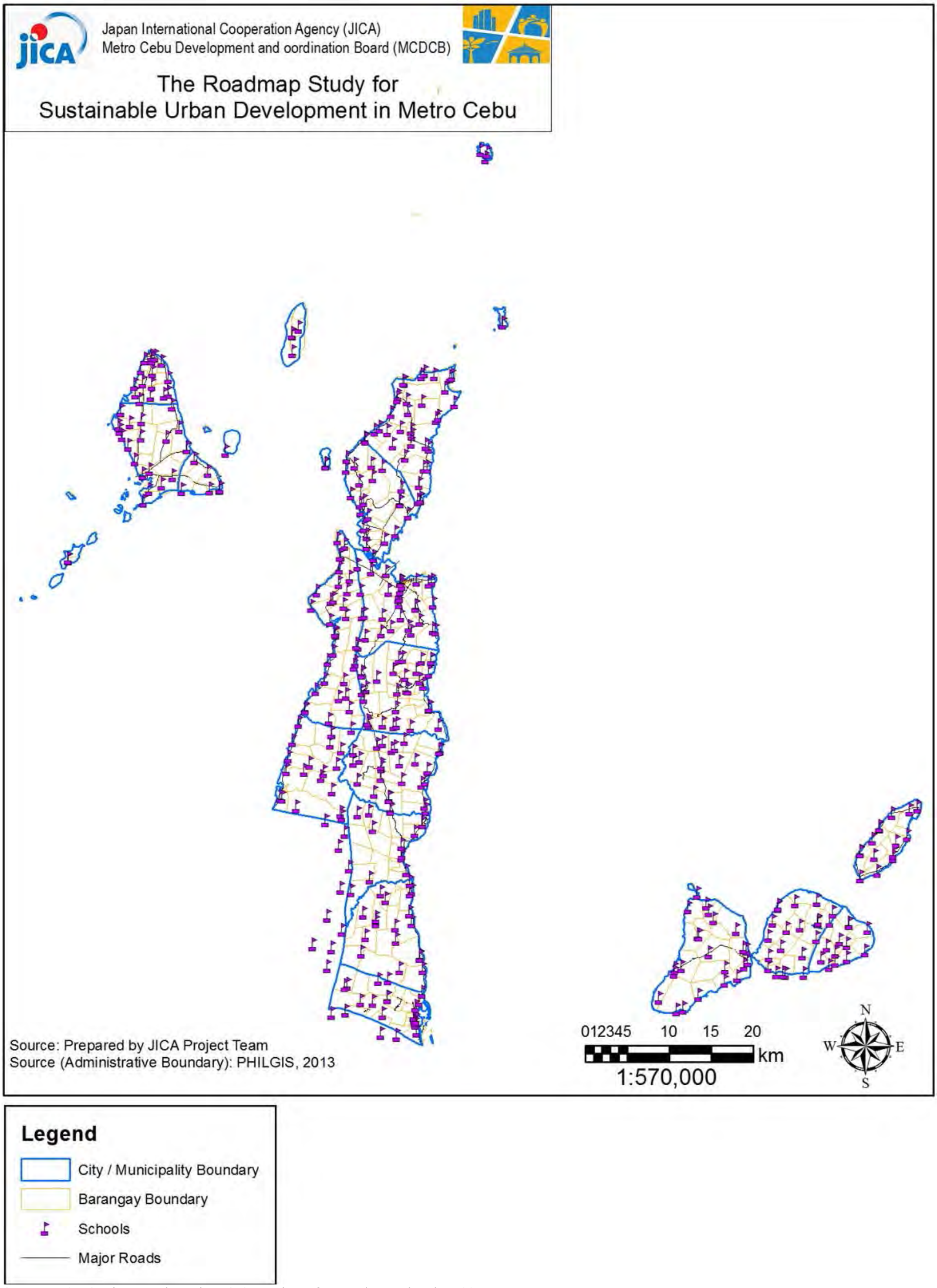
Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 5.1.21 Location of Church



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 5.1.22 Location of Hospital



Source: JICA Study Team based on GIS Database for Roadmap Planning, 2014.

Figure 5.1.23 Location of Schools

5.2 Methodology to Identify Hazard Areas

5.4 The methodologies to identify the hazards of flood and landslide are described in Section 4.2 Methodology to Identify Hazard Areas of Chapter 4 Atlas for Metro Cebu of this report. This section describes the methodology to identify the affected areas of Typhoon Yolanda.

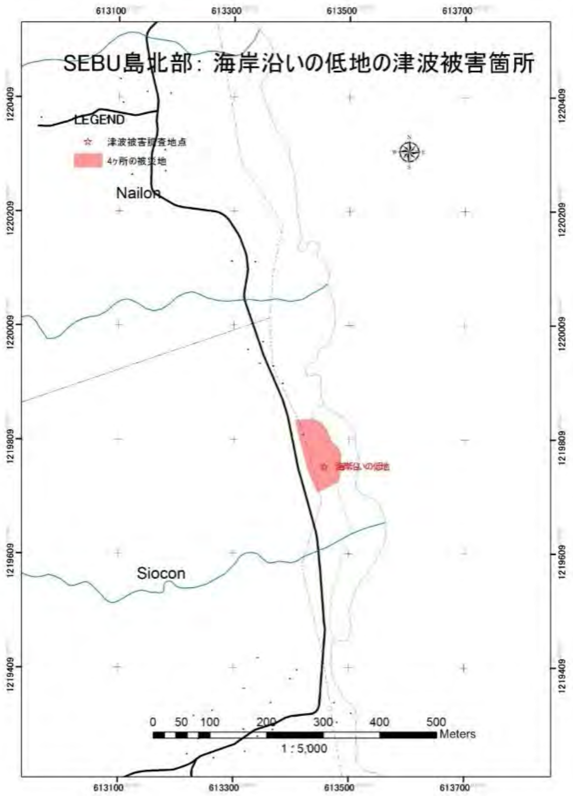
1) Typhoon Yolanda Affected Areas

5.5 Recently, a major disaster struck the Visayas region on November 10, 2013 which caused serious damages to the area. This was the Typhoon Yolanda (international code name: Haiyan). The typhoon damages in the Province of Cebu were mostly found in the northern areas, which affected housing and livelihood in the agricultural and fishery sectors.

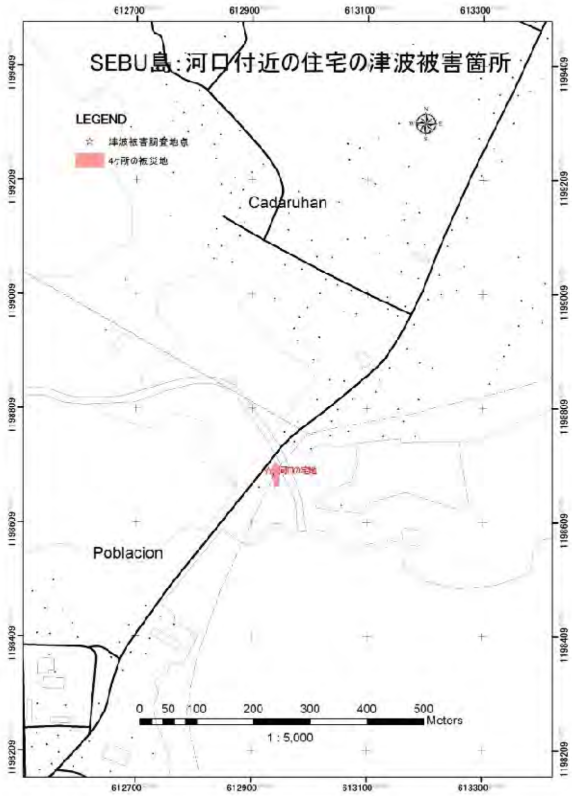
5.6 The Study conducted a field survey in the 20 sites which were affected by high tide caused by the typhoon in northern Cebu. It sought to identify the damages mostly on the populated areas. Interviews were conducted with the residents along the coastal areas to ascertain their condition and extent of the damages. The location of the affected areas were identified by GPS and depicted on the GIS map. Figure 5.2.1 shows the sites and damage conditions identified based on this survey.

5.7 The results clarified that the sea level rise was lower than the high tide level because the typhoon passed over northern Cebu during low tide. However, the following four sites were sprayed by the waves:

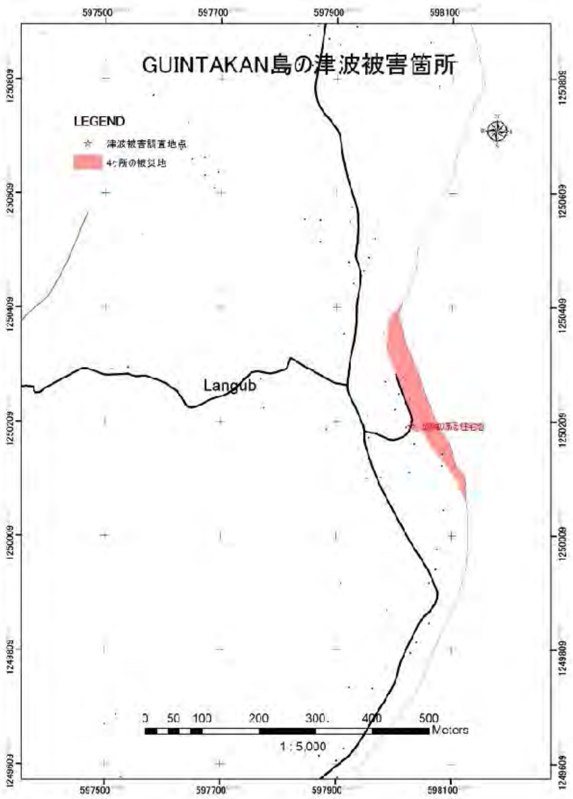
(i) Lowland area along the coast in Bogo;
(ii) Housing at the mouth of the river in Borbon;
(iii) Community where 43 houses were inundated in Guntakan Island; and
(iv) Resort area by the sea in Carinaza Island.



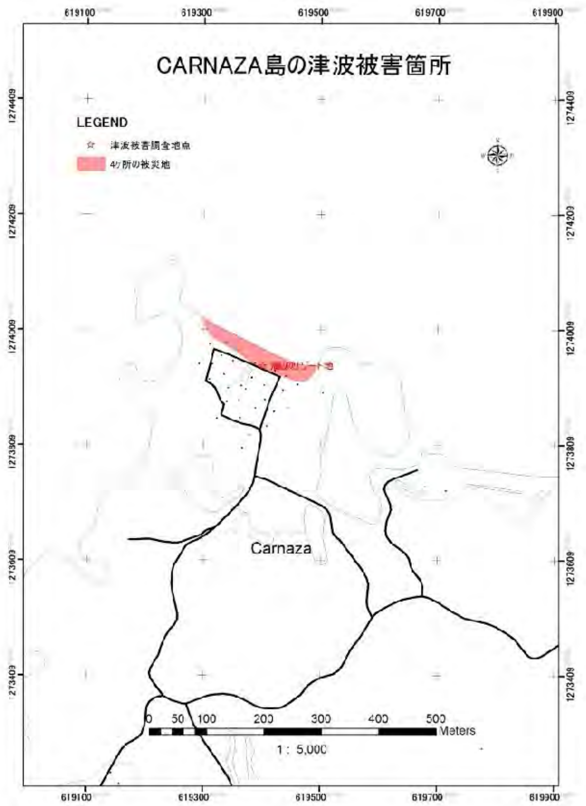
(a) Lowland Area along the Coast



(b) Housing in the River Mouth



(c) Community where 43 Houses were Inundated



(d) Resort Area by the Sea

Source: JICA Study Team based on Field Survey, 2014.

Figure 5.2.1 Typhoon Yolanda Affected Area