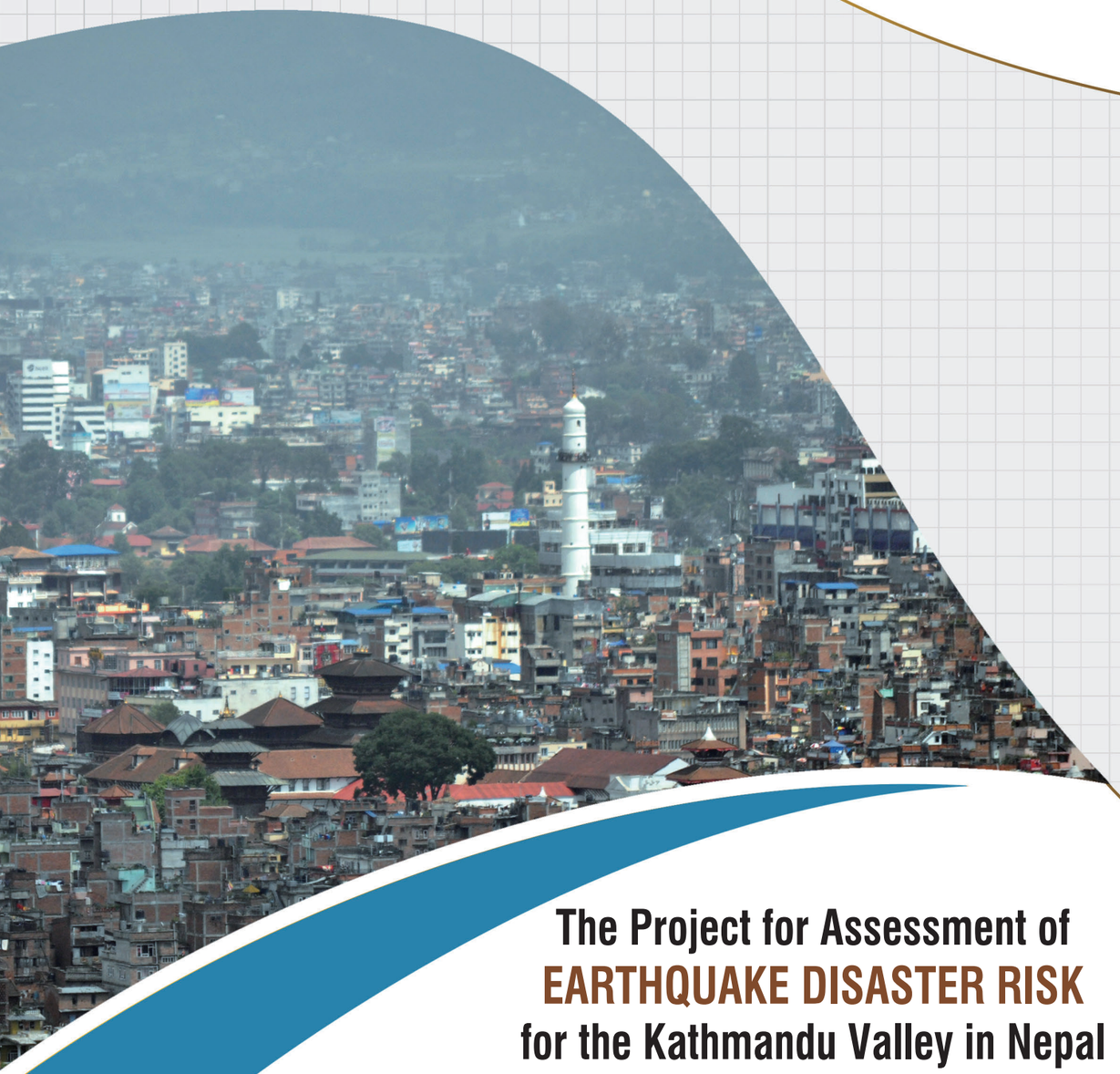
MINISTRY OF URBAN DEVELOPMENT (MoUD)
MINISTRY OF HOME AFFAIRS (MoHA)
MINISTRY OF FEDERAL AFFAIRS AND LOCAL DEVELOPMENT (MoFALD)
DEPARTMENT OF MINES AND GEOLOGY (DMG)
FEDERAL DEMOCRATIC REPUBLIC OF NEPAL

FINAL REPORT
VOLUME 3: MAP BOOK

KATHMANDU VALLEY



The Project for Assessment of EARTHQUAKE DISASTER RISK for the Kathmandu Valley in Nepal

Japan International Cooperation Agency
Oriental Consultants Global Co., Ltd.
OYO International Corporation

APRIL 2018

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MINISTRY OF URBAN DEVELOPMENT (MoUD)
MINISTRY OF HOME AFFAIRS (MoHA)
MINISTRY OF FEDERAL AFFAIRS AND LOCAL DEVELOPMENT (MoFALD)
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FINAL REPORT
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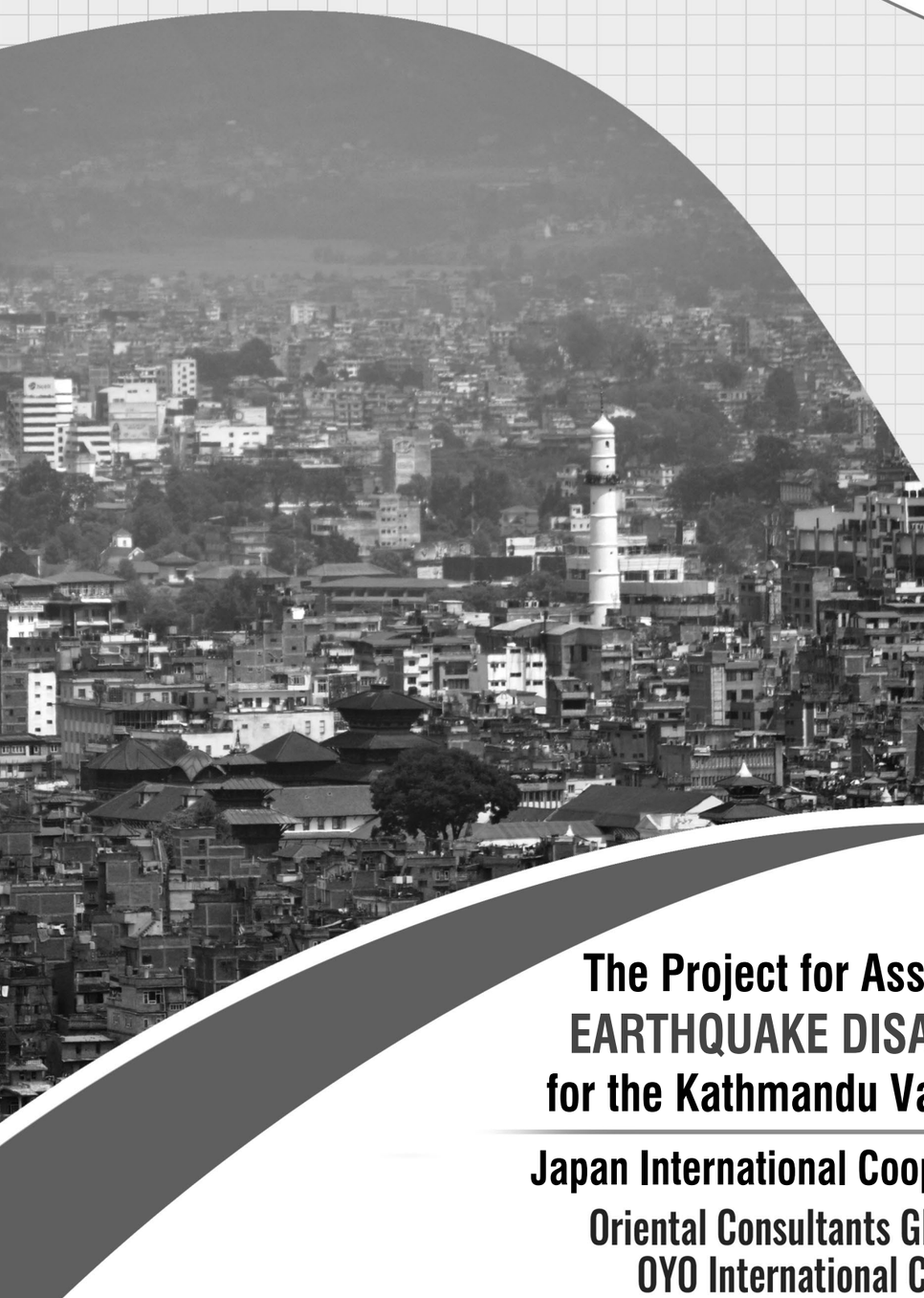

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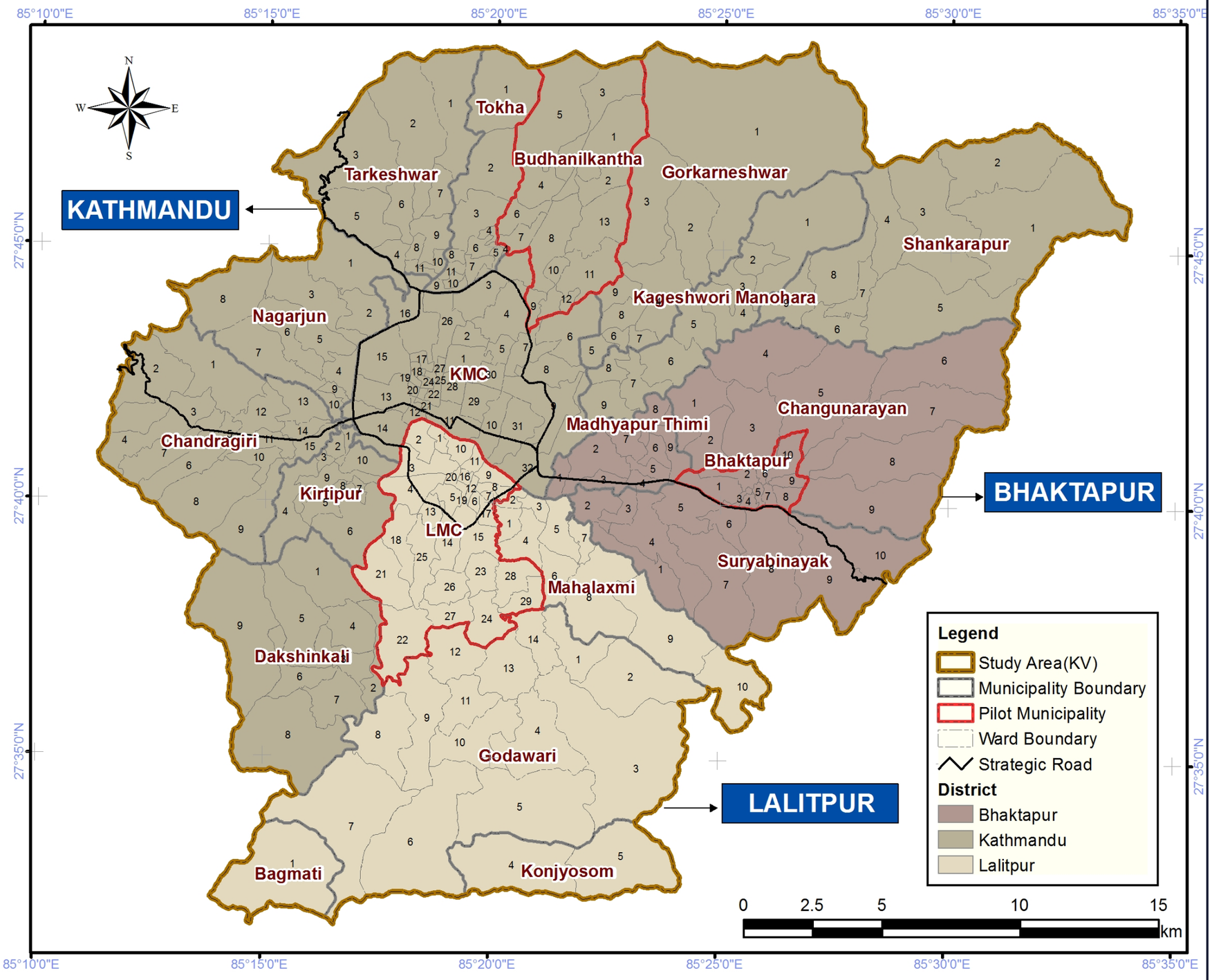
Contents of Map Book

A. Basic Conditions



A-1

Study Area and Pilot Municipalities

Note:

- The study area is the entire Kathmandu valley consisting of 2 Metropolitan Cities, 16 Municipalities and parts of 2 Rural Municipalities, covering a total of 232 wards, in 2017. In case of Rural Municipalities, only ward 4 and 5 of Konjyosom Rural Municipality and ward 1 of Bagmati Rural Municipality lies within the study area.
- Seismic hazard assessment has been conducted based on scenario earthquakes and detailed ground model have been prepared for this study area; seismic risk evaluation for a variety of socio-economic impacts due to scenario earthquakes such as damage of buildings and infrastructures, human and economic loss has been carried out.
- Lalitpur Metropolitan City, Bhaktapur Municipality and Budhanilkantha Municipality were selected as pilot municipalities for formulation of BBB Recovery and Reconstruction Plan utilizing results of Seismic Hazard Assessment, Disaster Risk Reduction and Management (DRRM) plans based on the results of Seismic risk assessment , formulation of SOP for emergency response after an earthquake disaster and implementation of Community Based Disaster Risk Reduction and Management (CBDRRM) activities.

Source:

- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River network: 2002 JICA Project, UN OCHA Project

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Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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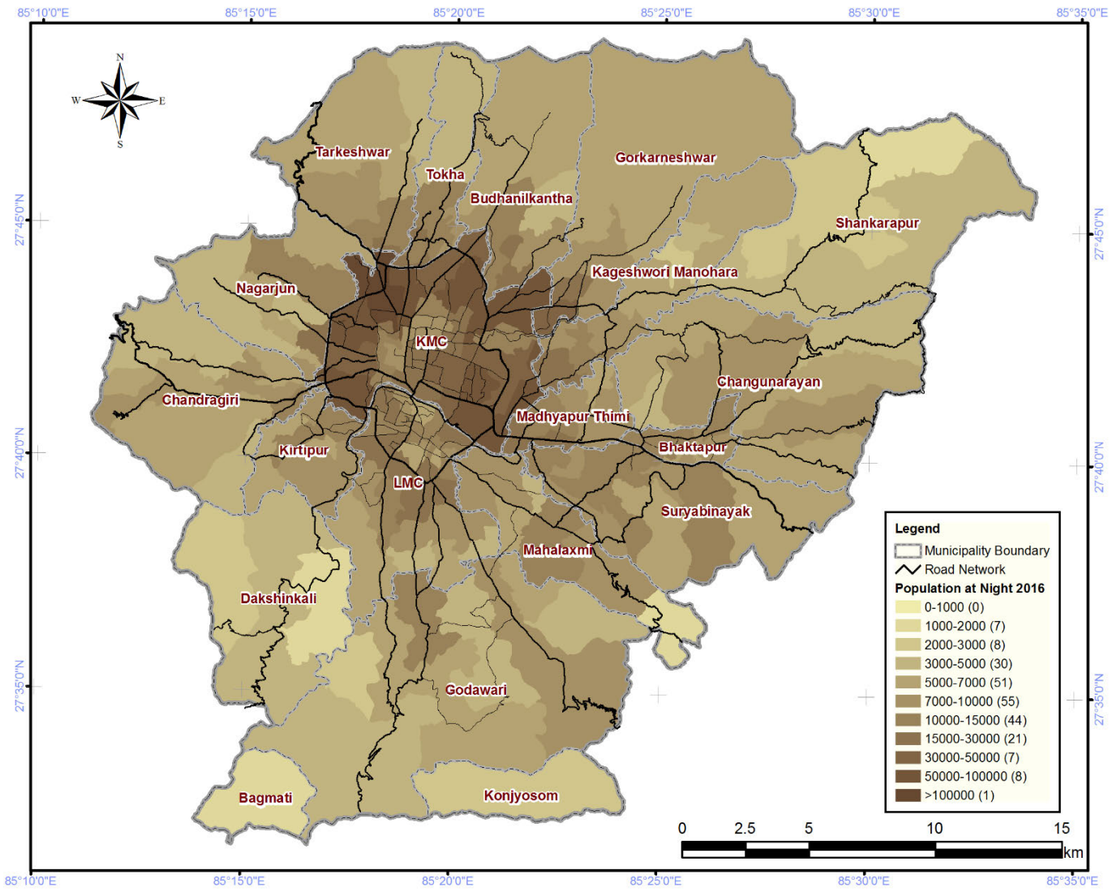
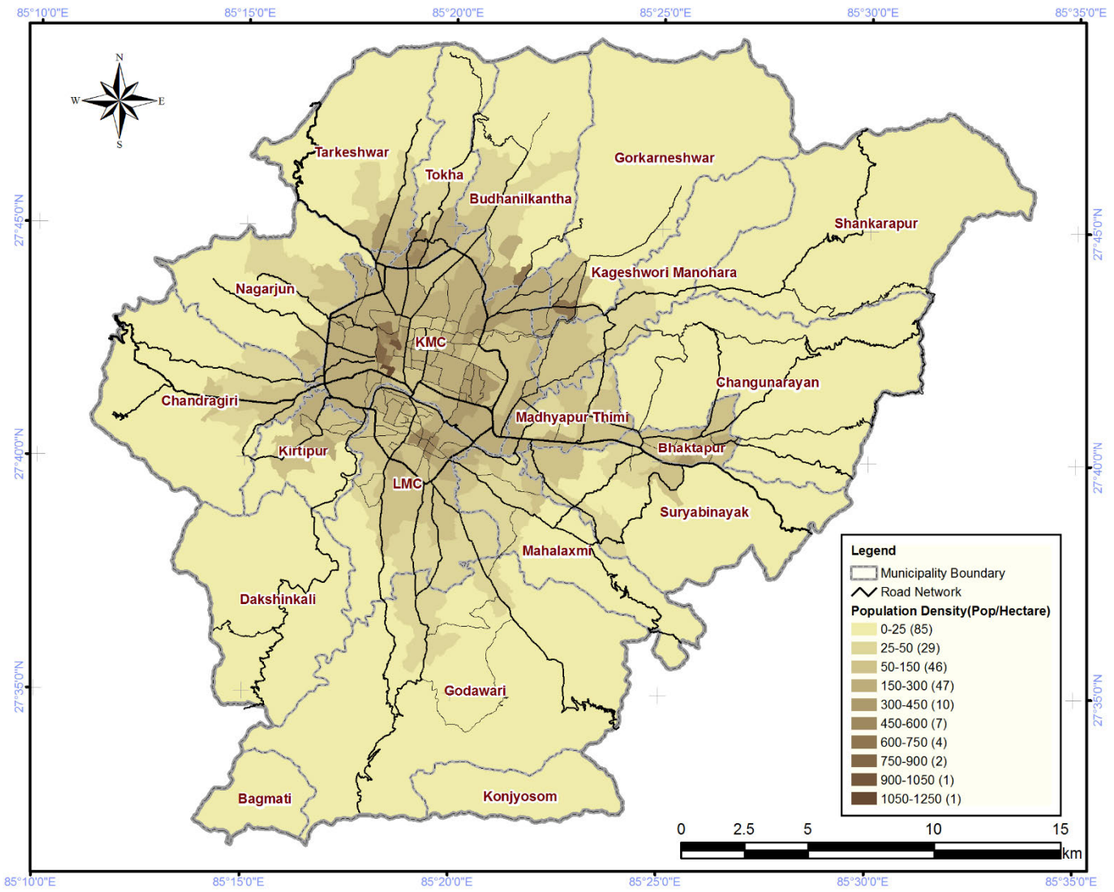
A-2
Distribution of Population in 2016 at Night

Population



Population Density



Note:

- The total population of the study area was estimated to be 2,786,929 in 2016.
- The estimation of ward-wise population in 2016 was carried out by JICA Project Team for the purpose of human casualty estimation based on the scenario earthquakes. The population in 2001 and 2011 according to National Censuses by CBS, the forecast result of the annual population growth rates by district every half-decade by 2016 and the result of prospective analysis for the decennial urbanization process by ward from 1990 to 2016 were used for this prediction.

Source:

- Ward wise predicted population in 2016: ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
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false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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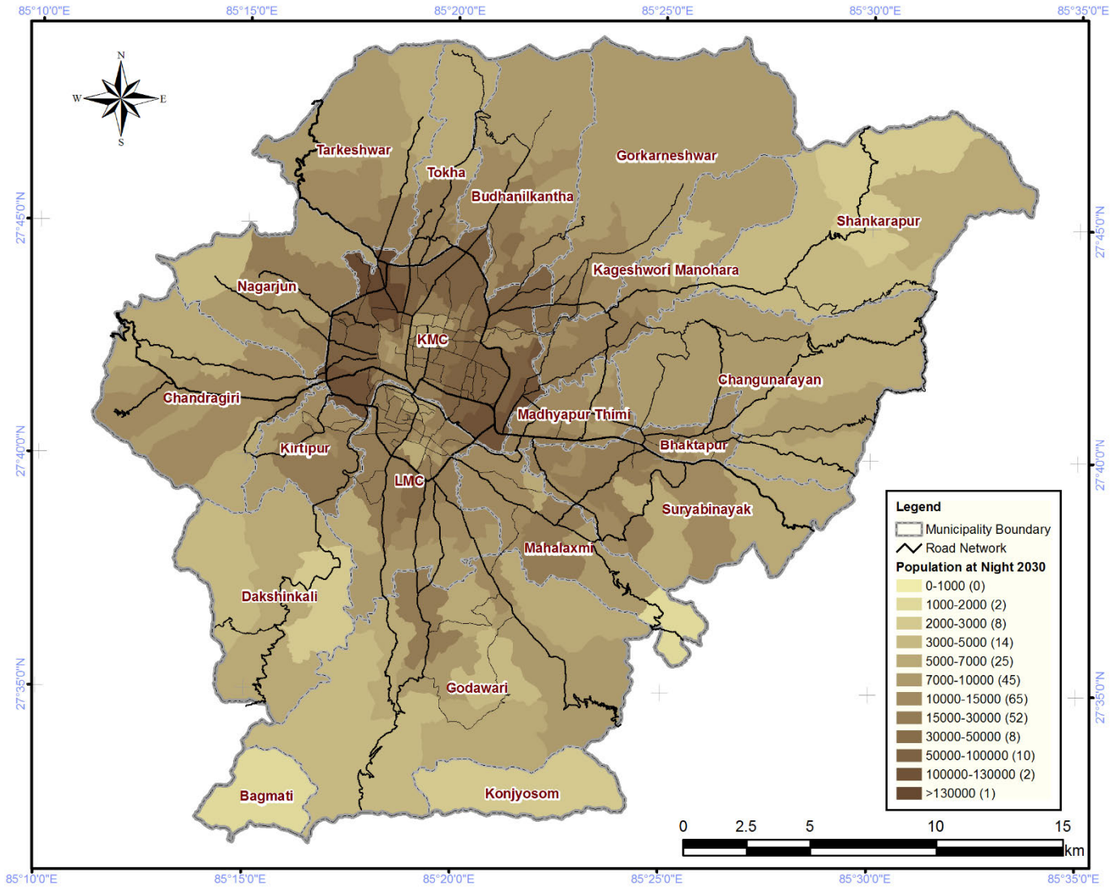
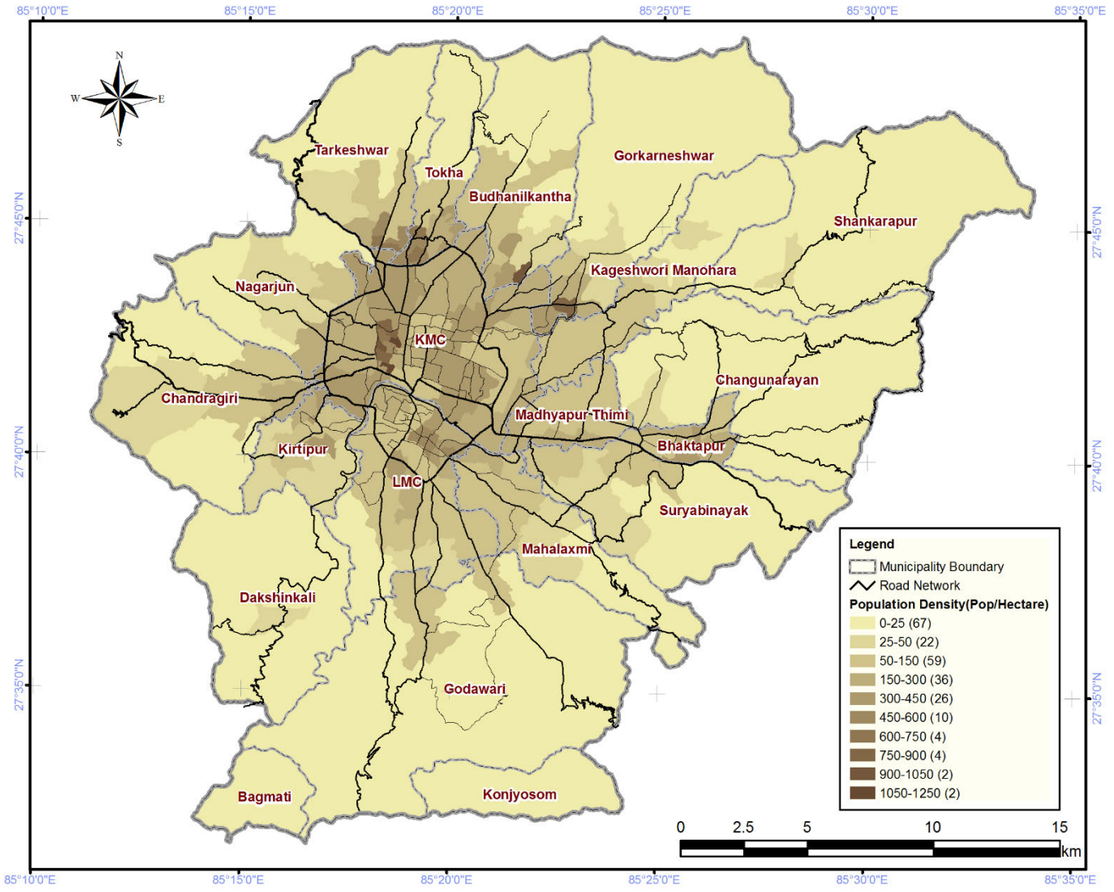
A-3
Distribution of Estimated Population in 2030 at Night

Population



Population Density



Note:

- The total population in the study area in 2030 was estimated at 3,805,926.
- The estimation of the ward-wise population in 2030 was carried out by JICA Project Team for the purpose of human casualty estimation based on the scenario earthquakes. The population in 2001 and 2011 according to National Censuses by CBS, the forecast result of the annual population growth rates by district every half-decade by 2031 and the result of prospective analysis for the decennial urbanization process by ward from 1990 to 2030 were used for this prediction.

Source:

- Ward wise predicted future population in 2030: ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

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central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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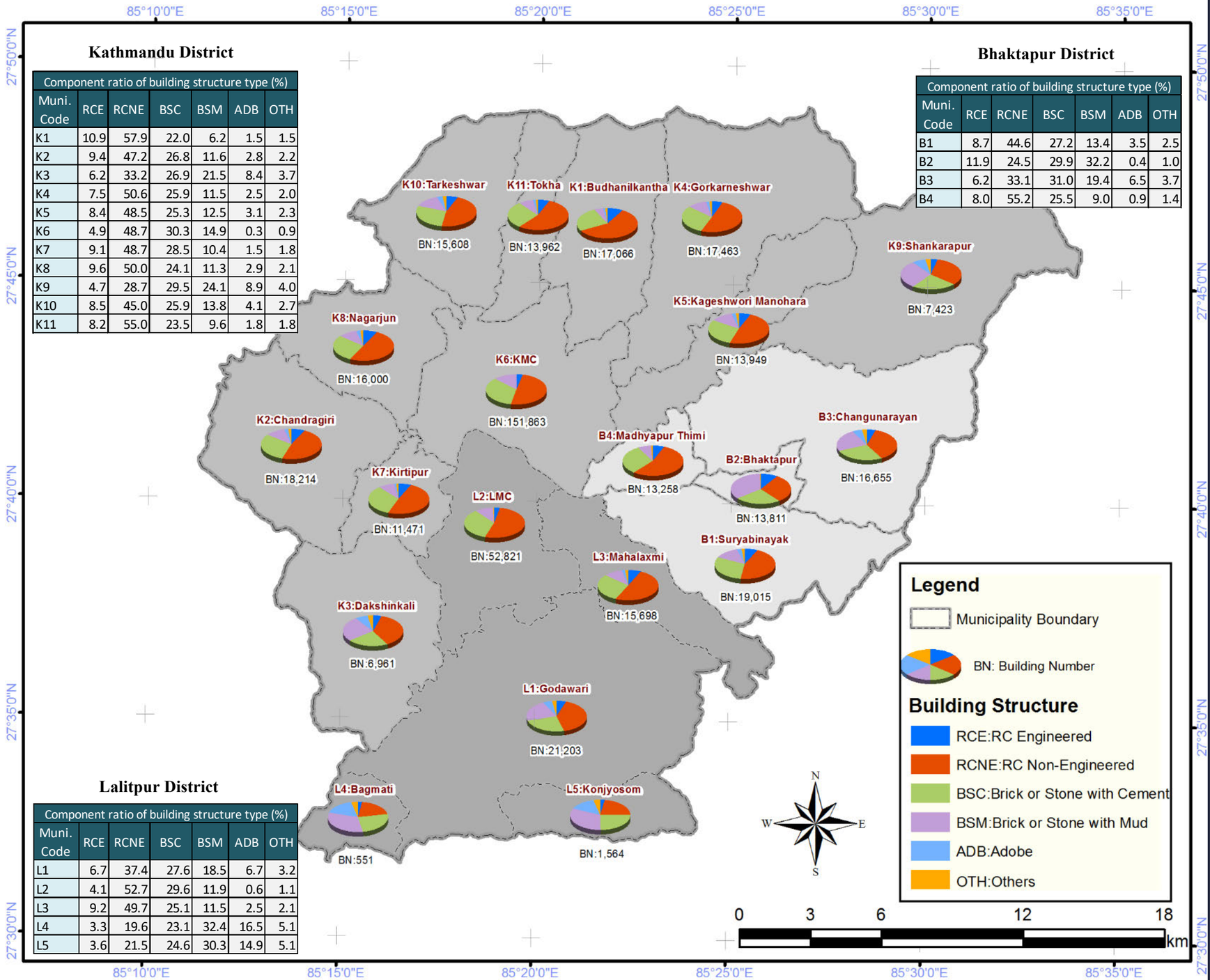

Kathmandu District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
K1	10.9	57.9	22.0	6.2	1.5	1.5
K2	9.4	47.2	26.8	11.6	2.8	2.2
K3	6.2	33.2	26.9	21.5	8.4	3.7
K4	7.5	50.6	25.9	11.5	2.5	2.0
K5	8.4	48.5	25.3	12.5	3.1	2.3
K6	4.9	48.7	30.3	14.9	0.3	0.9
K7	9.1	48.7	28.5	10.4	1.5	1.8
K8	9.6	50.0	24.1	11.3	2.9	2.1
K9	4.7	28.7	29.5	24.1	8.9	4.0
K10	8.5	45.0	25.9	13.8	4.1	2.7
K11	8.2	55.0	23.5	9.6	1.8	1.8

Bhaktapur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
B1	8.7	44.6	27.2	13.4	3.5	2.5
B2	11.9	24.5	29.9	32.2	0.4	1.0
B3	6.2	33.1	31.0	19.4	6.5	3.7
B4	8.0	55.2	25.5	9.0	0.9	1.4

Lalitpur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
L1	6.7	37.4	27.6	18.5	6.7	3.2
L2	4.1	52.7	29.6	11.9	0.6	1.1
L3	9.2	49.7	25.1	11.5	2.5	2.1
L4	3.3	19.6	23.1	32.4	16.5	5.1
L5	3.6	21.5	24.6	30.3	14.9	5.1

Legend

- Municipality Boundary
- BN: Building Number

Building Structure

- RCE:RC Engineered
- RCNE:RC Non-Engineered
- BSC:Brick or Stone with Cement
- BSM:Brick or Stone with Mud
- ADB:Adobe
- OTH:Others

A-4

Building Distribution in 2016

Note:

- The total building number in the study area was estimated to be 444,554 in 2016.
- The building distribution in 2016 was estimated on the basis of the following assumption:

  Heavily damaged buildings due to Gorkha Earthquake were reconstructed of Brick Masonry with Cement mortar or RC Engineered.
- As the first step of estimation of building distribution in 2016, the building distribution at the time of the Gorkha earthquake was estimated using several types of source data such as the result of building inventory & damage survey after Gorkha earthquake, the detailed building footprint map and the land use classification maps.
- Estimated heavily damaged buildings based on Gorkha earthquake model was approx. 39,000, and the proportion of heavily damaged buildings to total number of buildings was 8.8%.
- The summarized component ratio of building structure type and the building number by municipality in 2016 are shown in the map.
- The 250m gird wise building distribution in 2016 was estimated by the JICA Project Team only for the purpose of Building Damage Estimation based on the scenario earthquakes.

Source:

- Building Distribution in 2016: ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
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false_northing: 0.0
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latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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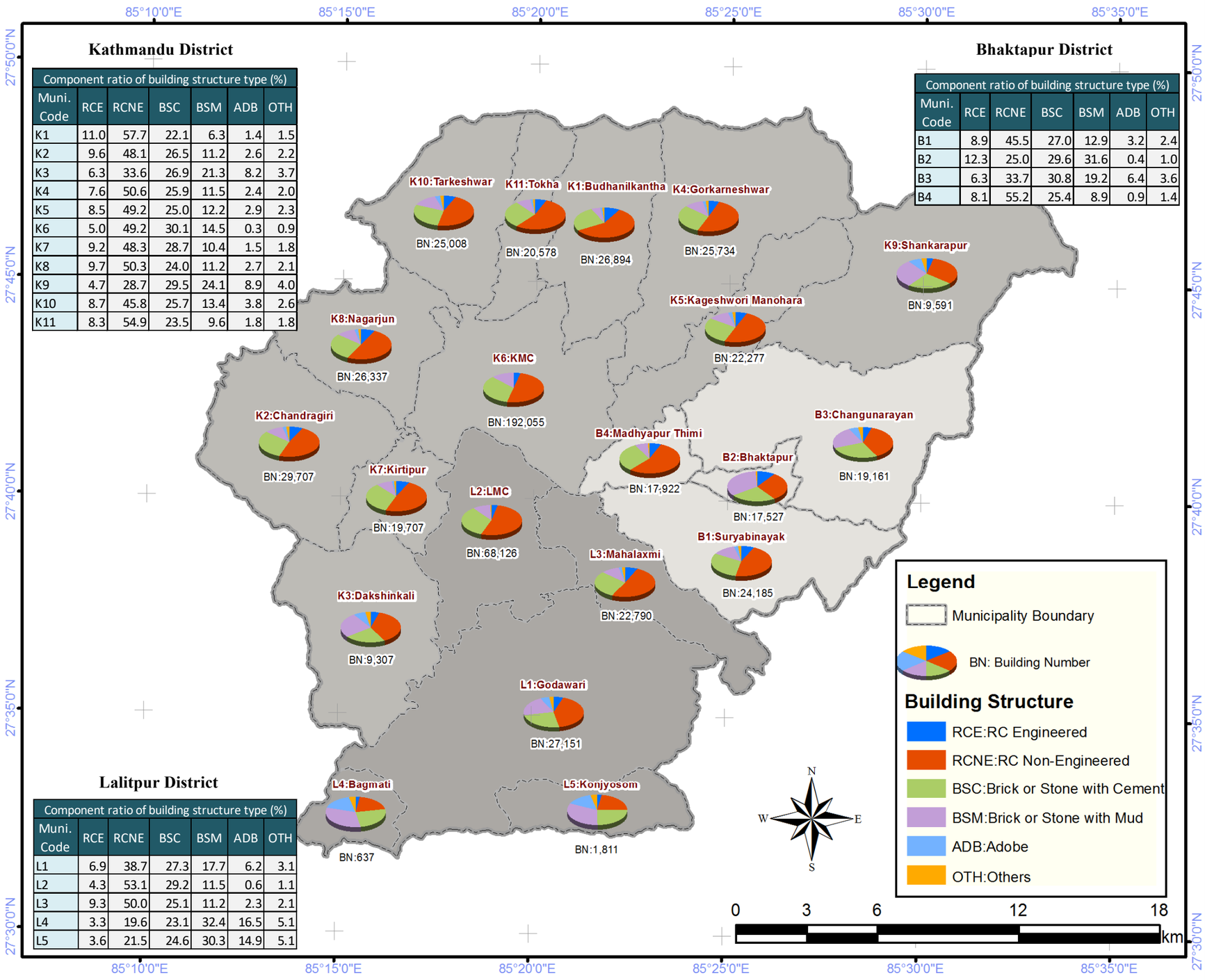

Kathmandu District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
K1	11.0	57.7	22.1	6.3	1.4	1.5
K2	9.6	48.1	26.5	11.2	2.6	2.2
K3	6.3	33.6	26.9	21.3	8.2	3.7
K4	7.6	50.6	25.9	11.5	2.4	2.0
K5	8.5	49.2	25.0	12.2	2.9	2.3
K6	5.0	49.2	30.1	14.5	0.3	0.9
K7	9.2	48.3	28.7	10.4	1.5	1.8
K8	9.7	50.3	24.0	11.2	2.7	2.1
K9	4.7	28.7	29.5	24.1	8.9	4.0
K10	8.7	45.8	25.7	13.4	3.8	2.6
K11	8.3	54.9	23.5	9.6	1.8	1.8

Bhaktapur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
B1	8.9	45.5	27.0	12.9	3.2	2.4
B2	12.3	25.0	29.6	31.6	0.4	1.0
B3	6.3	33.7	30.8	19.2	6.4	3.6
B4	8.1	55.2	25.4	8.9	0.9	1.4

Lalitpur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
L1	6.9	38.7	27.3	17.7	6.2	3.1
L2	4.3	53.1	29.2	11.5	0.6	1.1
L3	9.3	50.0	25.1	11.2	2.3	2.1
L4	3.3	19.6	23.1	32.4	16.5	5.1
L5	3.6	21.5	24.6	30.3	14.9	5.1

A-5

Estimated Building Distribution in 2030 without BSPS

BSPS: Promotion on Building Seismic Performance Strengthening

Note:

- The total building number in the study area was estimated at 606,506 buildings in 2030. The estimated total building number increased by 36.4% from 2016.
- The rate of increase in building number from 2016 to 2030 by 250m-mesh grid defined as a minimum unit for seismic risk assessment in the project was estimated considering the future population growth rates (CBS) and the result of projection for future built-up area distribution (KVDA/UNDP).
- The building distribution in 2030 without BSPS was estimated on the basis of the following assumptions:

  The building component ratio by 250m-mesh grid is same as 2016.
- The summarized component ratio of building structure type and the building number by municipality are shown in the map.
- The 250m gird wise building distribution in 2030 without BSPS was estimated by the JICA Project Team only for the purpose of building Damage Estimation based on the scenario earthquakes.

Source:

- Building Distribution in 2030 without BSPS: ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD

WGS_1984_UTM_Zone_45N

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false_northing: 0.0
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scale_factor: 0.9996
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Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
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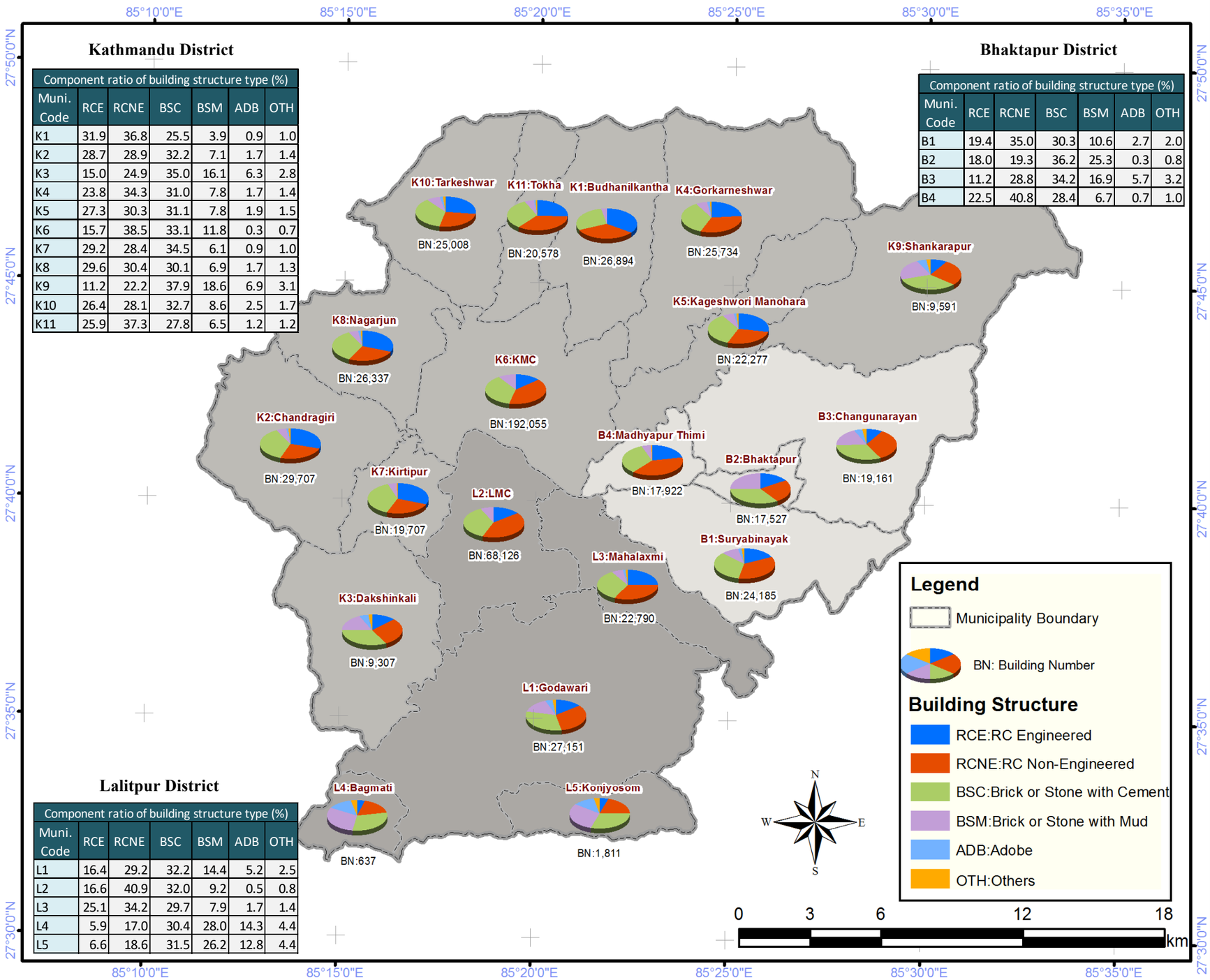
The Project for Assessment of EARTHQUAKE DISASTER RISK for the Kathmandu Valley in Nepal



Kathmandu District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
K1	31.9	36.8	25.5	3.9	0.9	1.0
K2	28.7	28.9	32.2	7.1	1.7	1.4
K3	15.0	24.9	35.0	16.1	6.3	2.8
K4	23.8	34.3	31.0	7.8	1.7	1.4
K5	27.3	30.3	31.1	7.8	1.9	1.5
K6	15.7	38.5	33.1	11.8	0.3	0.7
K7	29.2	28.4	34.5	6.1	0.9	1.0
K8	29.6	30.4	30.1	6.9	1.7	1.3
K9	11.2	22.2	37.9	18.6	6.9	3.1
K10	26.4	28.1	32.7	8.6	2.5	1.7
K11	25.9	37.3	27.8	6.5	1.2	1.2

Bhaktapur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
B1	19.4	35.0	30.3	10.6	2.7	2.0
B2	18.0	19.3	36.2	25.3	0.3	0.8
B3	11.2	28.8	34.2	16.9	5.7	3.2
B4	22.5	40.8	28.4	6.7	0.7	1.0

Lalitpur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
L1	16.4	29.2	32.2	14.4	5.2	2.5
L2	16.6	40.9	32.0	9.2	0.5	0.8
L3	25.1	34.2	29.7	7.9	1.7	1.4
L4	5.9	17.0	30.4	28.0	14.3	4.4
L5	6.6	18.6	31.5	26.2	12.8	4.4

A-6

Estimated Building Distribution in 2030 with BSPS Case-1

BSPS: Promotion on Building Seismic Performance Strengthening

Note:

- The total building number in the study area was estimated at 606,506 buildings in 2030. The estimated total building number increased by 36.4% from 2016.
- The rate of increase in building number from 2016 to 2030 by 250m-mesh grid, defined as the minimum unit for seismic risk assessment in the project, was estimated considering the future population growth rates (CBS) and the result of projection for future built-up area distribution (KVDA/UNDP).
- The building distribution in 2030 with BSPS case-1 was estimated on the basis of the following assumptions:

  *The buildings of Brick Masonry with Cement (BMC) and RC Engineered (RCE) will be constructed as new buildings during the period from 2016 to 2030. The ratio of BMC and RCE for new buildings assumes same as the ratio of building number between Masonry[*1] and RC[*2] in 2016.*

  **1: Masonry structures include Adobe, Stone with Mud & Cement, Brick Masonry with Mud or Cement and Other materials.*
  **2: RC structures include RC Non-Engineered and RC Engineered.*
- The summarized component ratio of building structure type and the building number by municipality are shown in the map.
- The 250m gird wise building distribution in 2030 with BSPS Case-1 was estimated by JICA Project Team only for the purpose of building Damage Estimation based on the scenario earthquakes.

Source:

- Building Distribution in 2030 with BSPS C-1: ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD

WGS_1984_UTM_Zone_45N

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Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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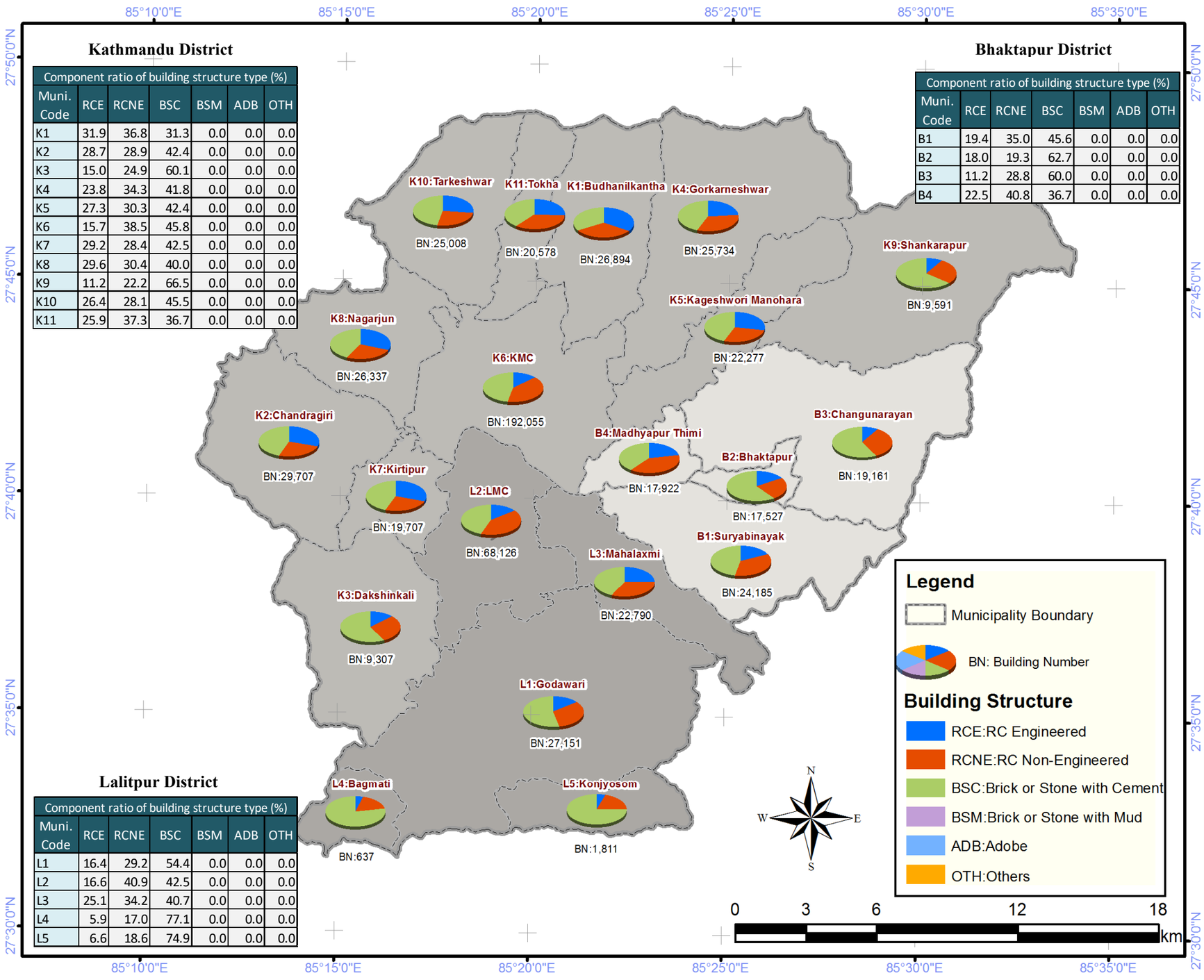

Kathmandu District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
K1	31.9	36.8	31.3	0.0	0.0	0.0
K2	28.7	28.9	42.4	0.0	0.0	0.0
K3	15.0	24.9	60.1	0.0	0.0	0.0
K4	23.8	34.3	41.8	0.0	0.0	0.0
K5	27.3	30.3	42.4	0.0	0.0	0.0
K6	15.7	38.5	45.8	0.0	0.0	0.0
K7	29.2	28.4	42.5	0.0	0.0	0.0
K8	29.6	30.4	40.0	0.0	0.0	0.0
K9	11.2	22.2	66.5	0.0	0.0	0.0
K10	26.4	28.1	45.5	0.0	0.0	0.0
K11	25.9	37.3	36.7	0.0	0.0	0.0

Bhaktapur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
B1	19.4	35.0	45.6	0.0	0.0	0.0
B2	18.0	19.3	62.7	0.0	0.0	0.0
B3	11.2	28.8	60.0	0.0	0.0	0.0
B4	22.5	40.8	36.7	0.0	0.0	0.0

Lalitpur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
L1	16.4	29.2	54.4	0.0	0.0	0.0
L2	16.6	40.9	42.5	0.0	0.0	0.0
L3	25.1	34.2	40.7	0.0	0.0	0.0
L4	5.9	17.0	77.1	0.0	0.0	0.0
L5	6.6	18.6	74.9	0.0	0.0	0.0

A-7

Estimated Building Distribution in 2030 with BSPS Case-2

BSPS: Promotion on Building Seismic Performance Strengthening

Note:

- The total building number in the study area was estimated at 606,506 buildings in 2030. The estimated total building number increased by 36.4% from 2016.
- The rate of increase in building number from 2016 to 2030 by 250m-mesh grid, defined as the minimum unit for seismic risk assessment in the project, was estimated considering the future population growth rates (CBS) and the result of projection for future built-up area distribution (KVDA/UNDP).
- The building distribution in 2030 with BSPS case-2 was estimated on the basis of the following assumptions:

  The buildings of Brick Masonry with Cement (BMC) and RC Engineered (RCE) will be constructed as new buildings during the period from 2016 to 2030. The ratio of BMC and RCE for new buildings assumes same as Case-1.

  Existing buildings made of Adobe, Brick Masonry with Mud and Other materials in 2016 will be reconstructed by Brick Masonry with Cement.
- The summarized component ratio of building structure type and the building number by municipality are shown in the map.
- The 250m gird wise building distribution in 2030 with BSPS Case-2 was estimated by JICA Project Team only for the purpose of building Damage Estimation based on the scenario earthquakes.

Source:

- Building Distribution in 2030 with BSPS C-2: ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD

WGS_1984_UTM_Zone_45N

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false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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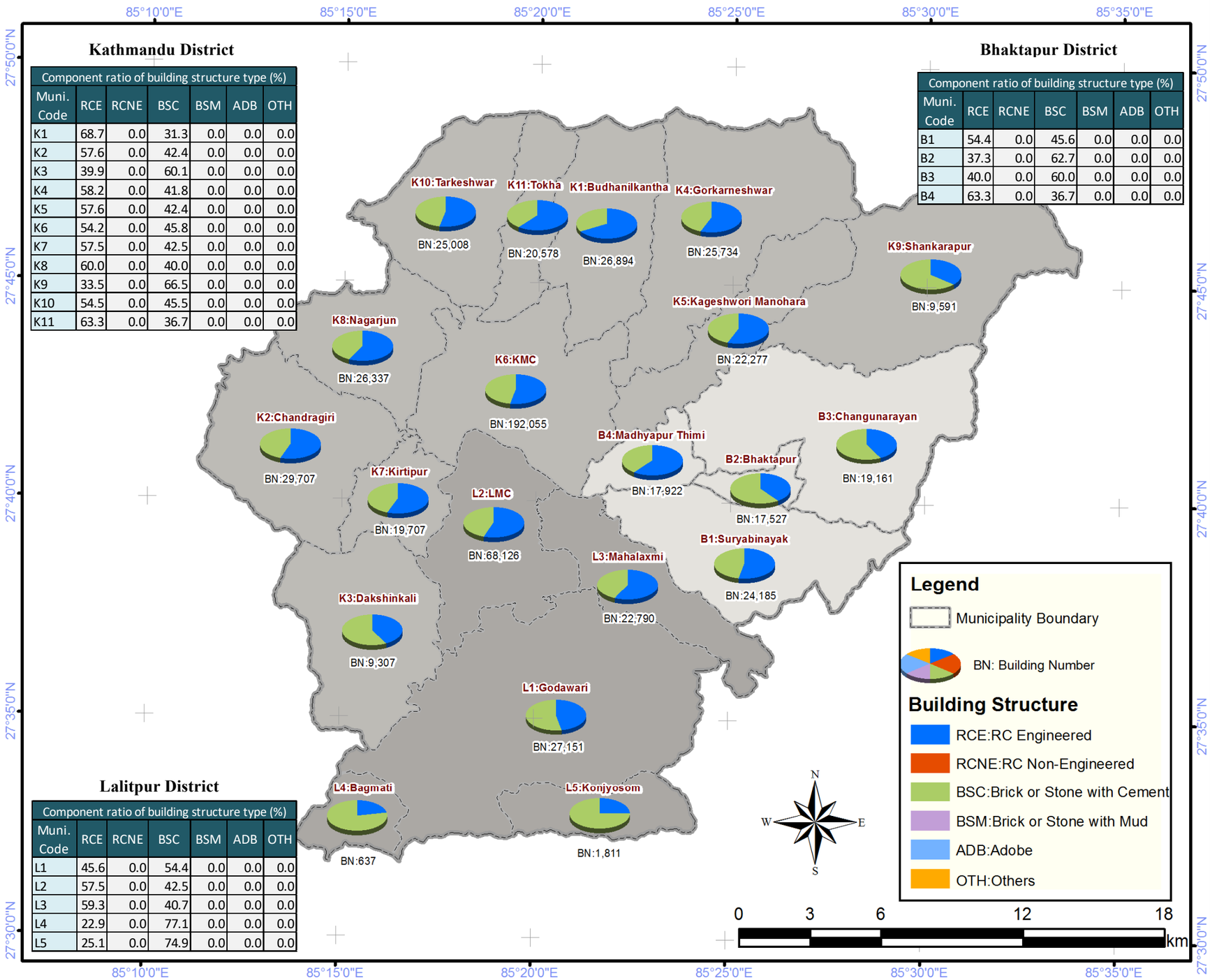

Component ratio of building structure type (%) — Kathmandu District

Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
K1	68.7	0.0	31.3	0.0	0.0	0.0
K2	57.6	0.0	42.4	0.0	0.0	0.0
K3	39.9	0.0	60.1	0.0	0.0	0.0
K4	58.2	0.0	41.8	0.0	0.0	0.0
K5	57.6	0.0	42.4	0.0	0.0	0.0
K6	54.2	0.0	45.8	0.0	0.0	0.0
K7	57.5	0.0	42.5	0.0	0.0	0.0
K8	60.0	0.0	40.0	0.0	0.0	0.0
K9	33.5	0.0	66.5	0.0	0.0	0.0
K10	54.5	0.0	45.5	0.0	0.0	0.0
K11	63.3	0.0	36.7	0.0	0.0	0.0

Component ratio of building structure type (%) — Bhaktapur District

Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
B1	54.4	0.0	45.6	0.0	0.0	0.0
B2	37.3	0.0	62.7	0.0	0.0	0.0
B3	40.0	0.0	60.0	0.0	0.0	0.0
B4	63.3	0.0	36.7	0.0	0.0	0.0

Component ratio of building structure type (%) — Lalitpur District

Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
L1	45.6	0.0	54.4	0.0	0.0	0.0
L2	57.5	0.0	42.5	0.0	0.0	0.0
L3	59.3	0.0	40.7	0.0	0.0	0.0
L4	22.9	0.0	77.1	0.0	0.0	0.0
L5	25.1	0.0	74.9	0.0	0.0	0.0

A-8

Estimated Building Distribution in 2030 with BSPS Case-3

BSPS: Promotion on Building Seismic Performance Strengthening

Note:

- The total building number in the study area was estimated at 606,506 buildings in 2030. The estimated total building number increased by 36.4% from 2016.
- The rate of increase in building number from 2016 to 2030 by 250m-mesh grid, defined as the minimum unit for seismic risk assessment in the project, was estimated considering the future population growth rates (CBS) and the result of projection for future built-up area distribution (KVDA/UNDP).
- The building distribution in 2030 with BSPS case-3 was estimated on the basis of the following assumptions:

  The buildings of Brick Masonry with Cement (BMC) and RC Engineered (RCE) will be constructed as new buildings during the period from 2016 to 2030. The ratio of BMC and RCE for new buildings assumes same as Case-1.

  Existing buildings made of Adobe, Brick Masonry with Mud and Other materials in 2016 will be reconstructed by Brick Masonry with Cement.

  Existing buildings of RC Non-Engineered at 2016 will be reconstructed by RC Engineered.
- The summarized component ratio of building structure type and the building number by municipality are shown in the map.
- The 250m gird wise building distribution in 2030 with BSPS Case-3 was estimated by the JICA Project Team only for the purpose of building Damage Estimation based on the scenario earthquakes.

Source:

- Building Distribution in 2030 with BSPS C-3: ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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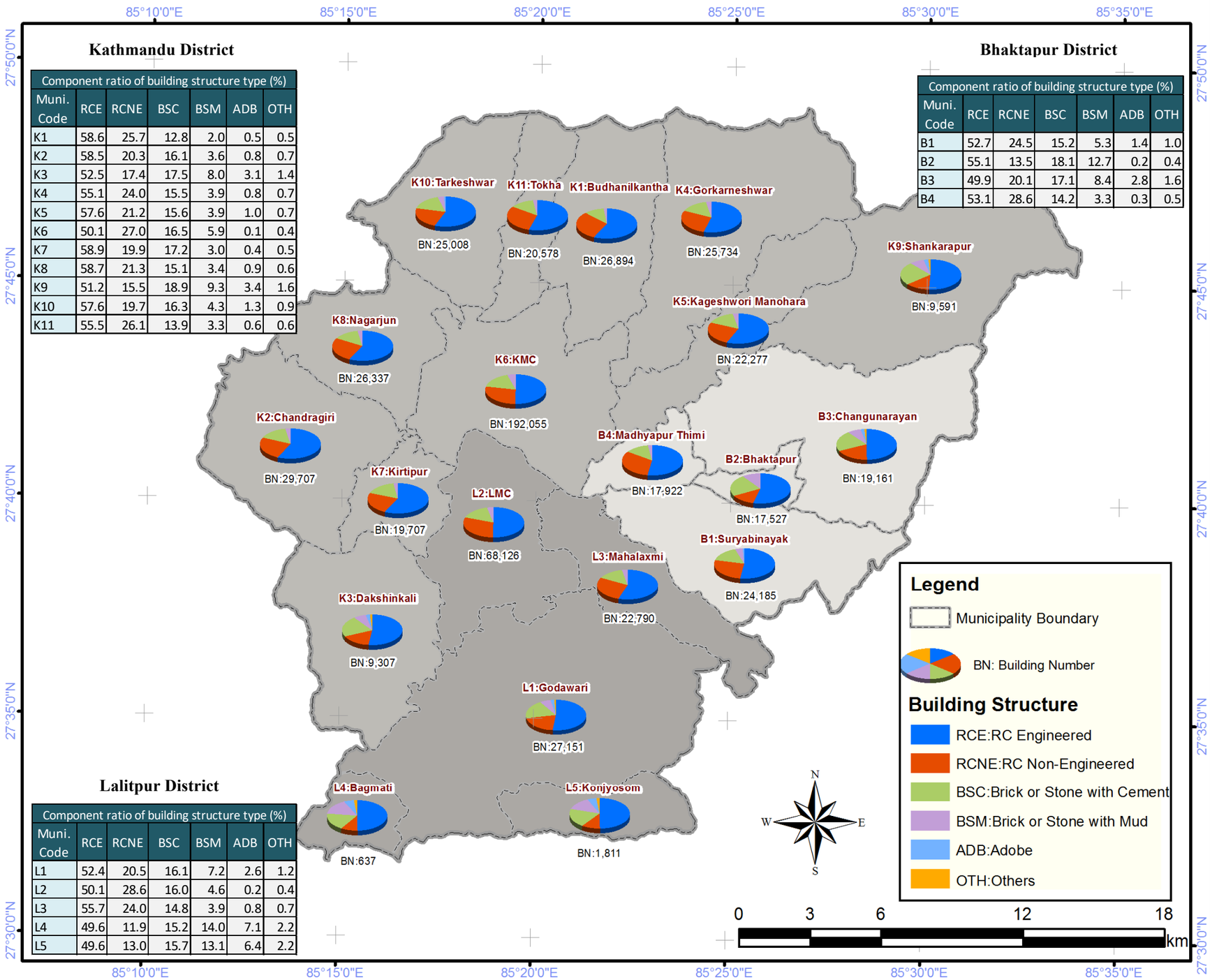

Kathmandu District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
K1	58.6	25.7	12.8	2.0	0.5	0.5
K2	58.5	20.3	16.1	3.6	0.8	0.7
K3	52.5	17.4	17.5	8.0	3.1	1.4
K4	55.1	24.0	15.5	3.9	0.8	0.7
K5	57.6	21.2	15.6	3.9	1.0	0.7
K6	50.1	27.0	16.5	5.9	0.1	0.4
K7	58.9	19.9	17.2	3.0	0.4	0.5
K8	58.7	21.3	15.1	3.4	0.9	0.6
K9	51.2	15.5	18.9	9.3	3.4	1.6
K10	57.6	19.7	16.3	4.3	1.3	0.9
K11	55.5	26.1	13.9	3.3	0.6	0.6

Bhaktapur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
B1	52.7	24.5	15.2	5.3	1.4	1.0
B2	55.1	13.5	18.1	12.7	0.2	0.4
B3	49.9	20.1	17.1	8.4	2.8	1.6
B4	53.1	28.6	14.2	3.3	0.3	0.5

Lalitpur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
L1	52.4	20.5	16.1	7.2	2.6	1.2
L2	50.1	28.6	16.0	4.6	0.2	0.4
L3	55.7	24.0	14.8	3.9	0.8	0.7
L4	49.6	11.9	15.2	14.0	7.1	2.2
L5	49.6	13.0	15.7	13.1	6.4	2.2

Legend

- Municipality Boundary
- BN: Building Number

Building Structure

- RCE:RC Engineered
- RCNE:RC Non-Engineered
- BSC:Brick or Stone with Cement
- BSM:Brick or Stone with Mud
- ADB:Adobe
- OTH:Others

A-9

Estimated Building Distribution in 2030 with BSPS Case-4

BSPS: Promotion on Building Seismic Performance Strengthening

Note:

- The total building number in the study area was estimated at 606,506 buildings in 2030. The estimated total building number increased by 36.4% from 2016.
- The building distribution in 2030 with BSPS case-4 was estimated on the basis of the following assumptions:

  *The buildings of Brick Masonry with Cement (BMC) and RC Engineered (RCE) will be constructed as new buildings during the period from 2016 to 2030. The ratio of BMC and RCE for new buildings assumes same as the ratio of building number between 50% of Masonry*1, and RC*2 plus 50% of Masonry*1 in 2016.*

  *50% of existing buildings of Masonry*1 in 2016 will be reconstructed of RC Engineered by 2030.*

  30% of existing buildings of RC Non-Engineered in 2016 will be reconstructed of RC Engineered by 2030.

  **1: Masonry structures include Adobe, Stone with Mud & Cement, Brick Masonry with Mud or Cement and Other materials.*
  **2: RC structures include RC Non-Engineered and RC Engineered.*

- The summarized component ratio of building structure type and the building number by municipality are shown in the map.
- The 250m gird wise building distribution in 2030 with BSPS Case-4 was estimated by the JICA Project Team only for the purpose of building Damage Estimation based on the scenario earthquakes.

Source:

- Building Distribution in 2030 with BSPS C-4: ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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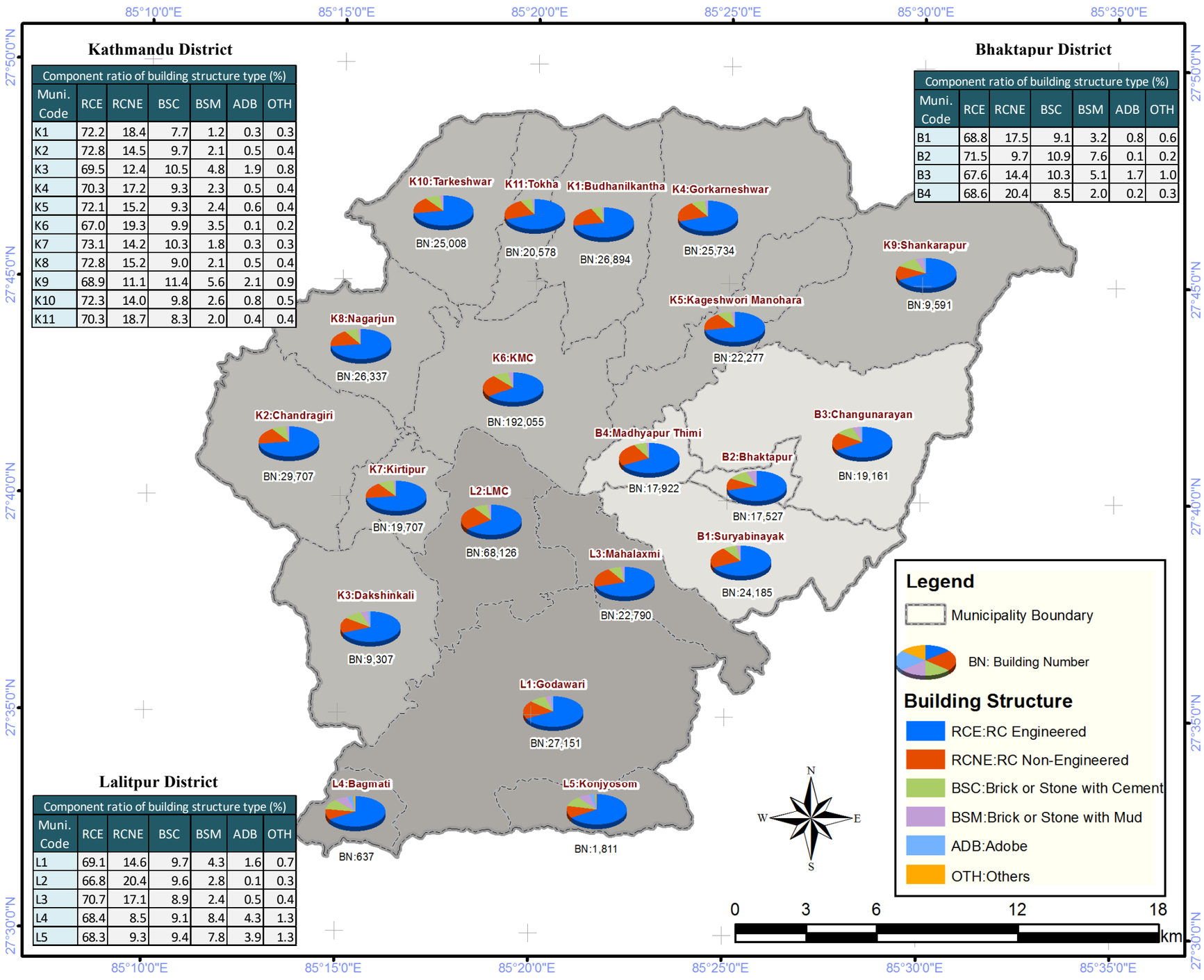

Kathmandu District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
K1	72.2	18.4	7.7	1.2	0.3	0.3
K2	72.8	14.5	9.7	2.1	0.5	0.4
K3	69.5	12.4	10.5	4.8	1.9	0.8
K4	70.3	17.2	9.3	2.3	0.5	0.4
K5	72.1	15.2	9.3	2.4	0.6	0.4
K6	67.0	19.3	9.9	3.5	0.1	0.2
K7	73.1	14.2	10.3	1.8	0.3	0.3
K8	72.8	15.2	9.0	2.1	0.5	0.4
K9	68.9	11.1	11.4	5.6	2.1	0.9
K10	72.3	14.0	9.8	2.6	0.8	0.5
K11	70.3	18.7	8.3	2.0	0.4	0.4

Bhaktapur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
B1	68.8	17.5	9.1	3.2	0.8	0.6
B2	71.5	9.7	10.9	7.6	0.1	0.2
B3	67.6	14.4	10.3	5.1	1.7	1.0
B4	68.6	20.4	8.5	2.0	0.2	0.3

Lalitpur District

Component ratio of building structure type (%)						
Muni. Code	RCE	RCNE	BSC	BSM	ADB	OTH
L1	69.1	14.6	9.7	4.3	1.6	0.7
L2	66.8	20.4	9.6	2.8	0.1	0.3
L3	70.7	17.1	8.9	2.4	0.5	0.4
L4	68.4	8.5	9.1	8.4	4.3	1.3
L5	68.3	9.3	9.4	7.8	3.9	1.3

Legend

- Municipality Boundary
- BN: Building Number

Building Structure

- RCE:RC Engineered
- RCNE:RC Non-Engineered
- BSC:Brick or Stone with Cement
- BSM:Brick or Stone with Mud
- ADB:Adobe
- OTH:Others

A-10

Estimated Building Distribution in 2030 with BSPS Case-5

BSPS: Promotion on Building Seismic Performance Strengthening

Note:

- The total building number in the study area was estimated at 606,506 buildings in 2030. The estimated total building number increased by 36.4% from 2016.
- The building distribution in 2030 with BSPS case-5 was estimated on the basis of the following assumptions:

  *The buildings of Brick Masonry with Cement (BMC) and RC Engineered (RCE) will be constructed as new buildings during the period from 2016 to 2030. The ratio of BMC and RCE for new buildings assumes same as the ratio of building number between 30% of Masonry[*1], and RC[*2] plus 70% of Masonry[*1] in 2016.*

  *70% of existing buildings of Masonry[*1] at 2016 will be reconstructed of RC Engineered by 2030.*

  50% of existing buildings of RC Non-Engineered at 2016 will be reconstructed of RC Engineered by 2030.

  **1: Masonry structures include Adobe, Stone with Mud & Cement, Brick Masonry with Mud or Cement and Other materials.*
  **2: RC structures include RC Non-Engineered and RC Engineered.*
- The summarized component ratio of building structure type and the building number by municipality are shown in the map.
- The 250m gird-wise building distribution in 2030 with BSPS Case-5 was estimated by JICA Project Team only for the purpose of building Damage Estimation based on the scenario earthquakes.

Source:

- Building Distribution in 2030 with BSPS C-5: ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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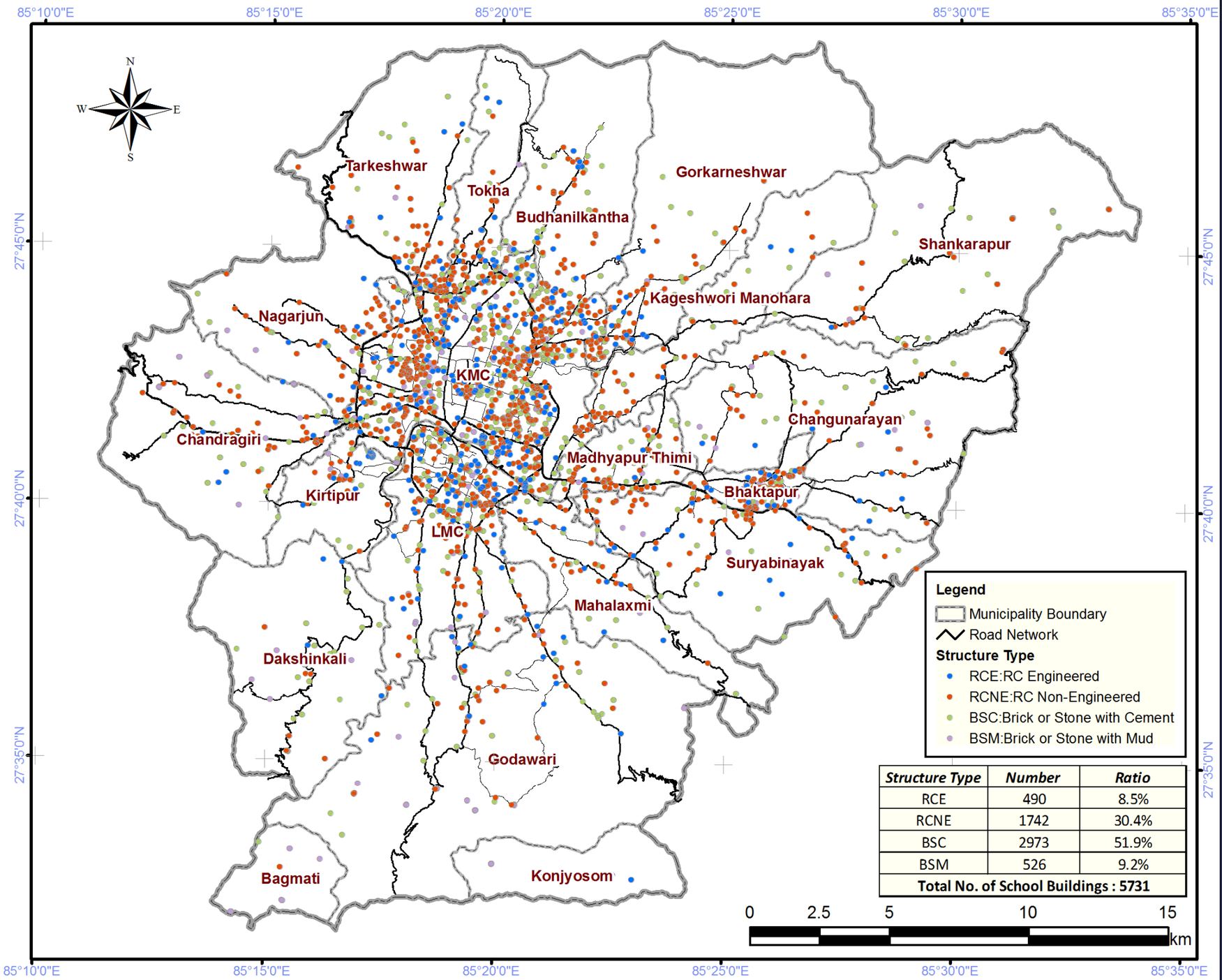


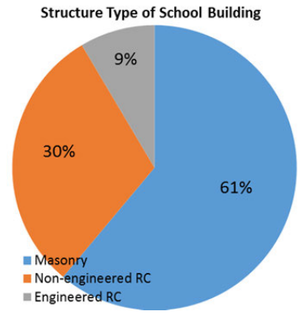
Structure Type	Number	Ratio
RCE	490	8.5%
RCNE	1742	30.4%
BSC	2973	51.9%
BSM	526	9.2%
Total No. of School Buildings : 5731		

A-11

Distribution of School Building

Note:

- There are a total of 2,115 schools in the study area targeted for the seismic risk assessment. These are classified into Primary, Lower secondary, Secondary, Higher secondary, College, University and others. The total number of school buildings is 5,731.
- The component ratio of structure type of school buildings in the study area is as follows:



Source:

- School inventory data: DoE, Flagship 1 of NRRC.
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
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false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
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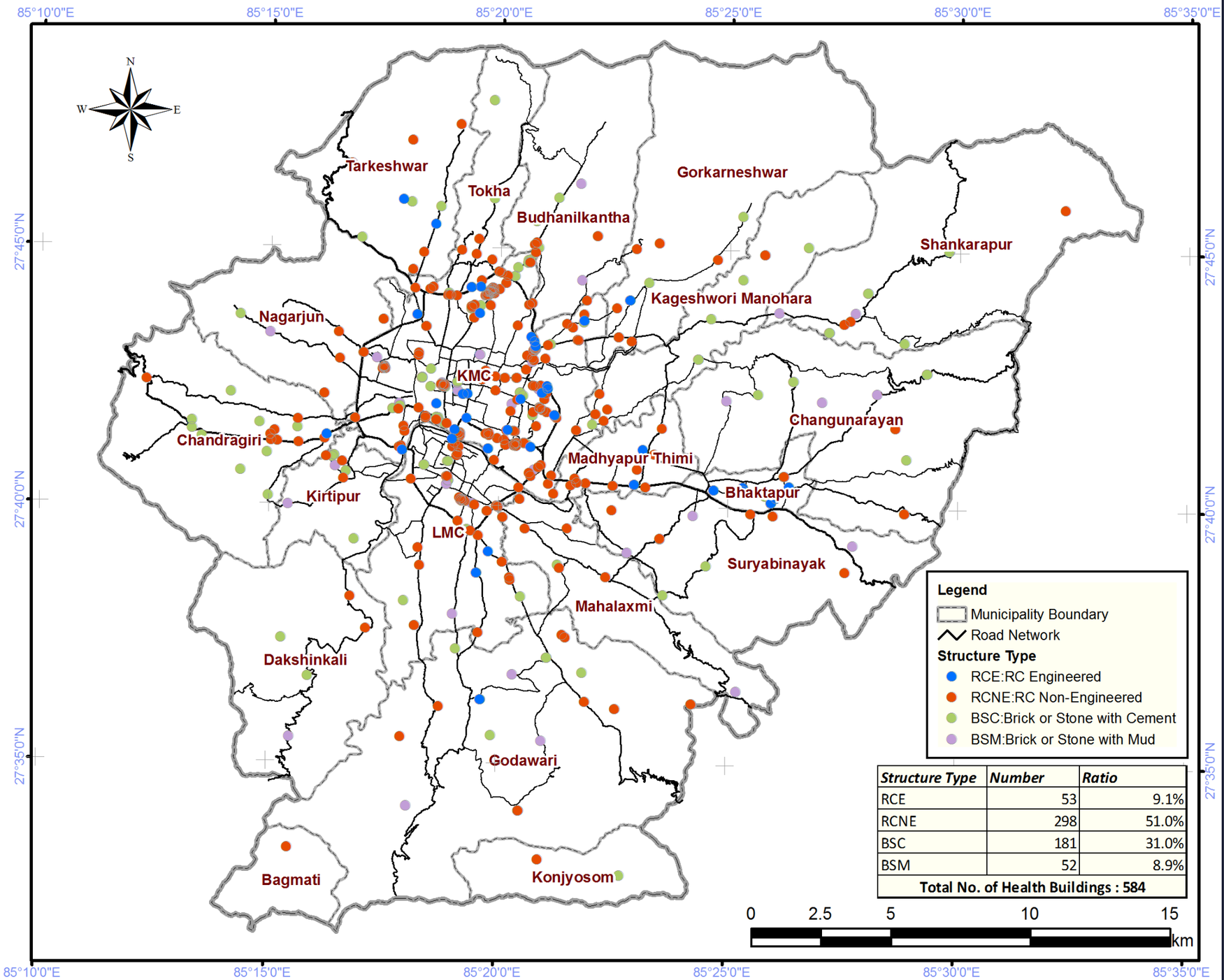


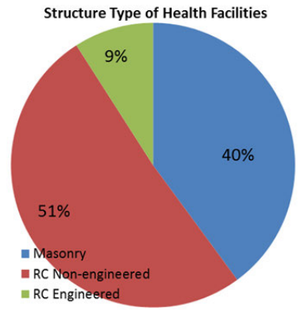
Structure Type	Number	Ratio
RCE	53	9.1%
RCNE	298	51.0%
BSC	181	31.0%
BSM	52	8.9%
Total No. of Health Buildings : 584		

A-12

Distribution of Health Facility Building

Note:

- There are a total of 363 health facilities in the study area targeted for seismic risk assessment. These are classified into Hospital,,, PHCC, Health post and others which operators are divided into Government, Private and Community. The total number of health facilities' buildings is 584.
- The component ratio of structure type of health facilities buildings in the study area is as follows:



Source:

- Health Facility inventory data: DoH, Flagship 1 of NRRC.
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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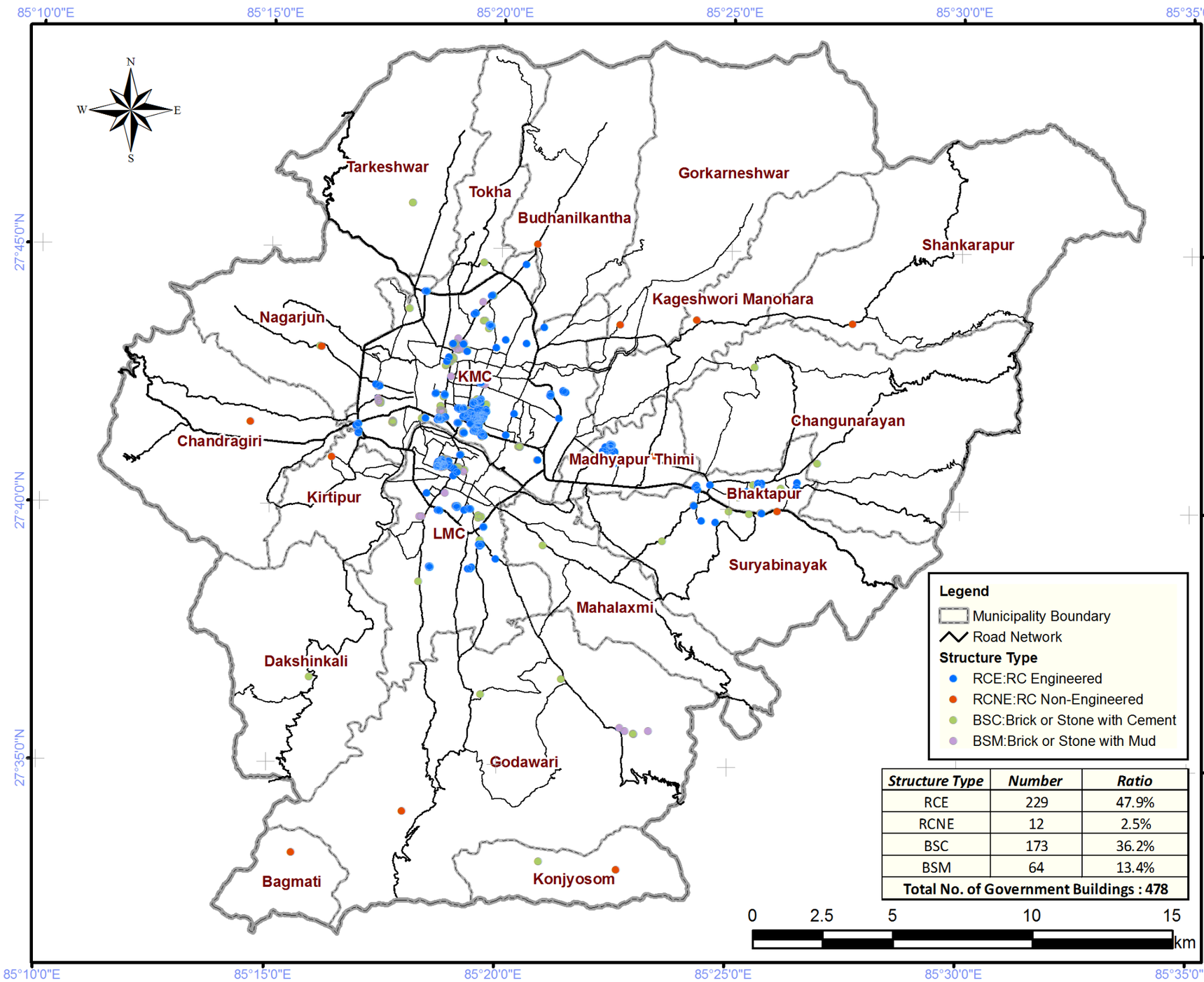
for the Kathmandu Valley in Nepal



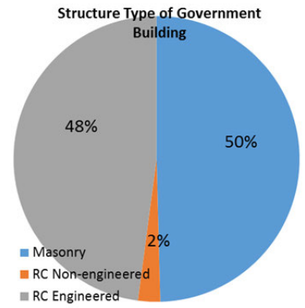
Structure Type	Number	Ratio
RCE	229	47.9%
RCNE	12	2.5%
BSC	173	36.2%
BSM	64	13.4%
Total No. of Government Buildings : 478		

A-13

Distribution of Government Building

Note:

- There are a total of 478 government buildings in the study area targeted for seismic risk assessment. The targeted buildings are classified into Ministry and Department offices, Municipality offices, Library, Laboratory and others.
- The component ratio of each structure types of government buildings in the study area is as follows:



Source:

- Government building inventory data: DUDBC, ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
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false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
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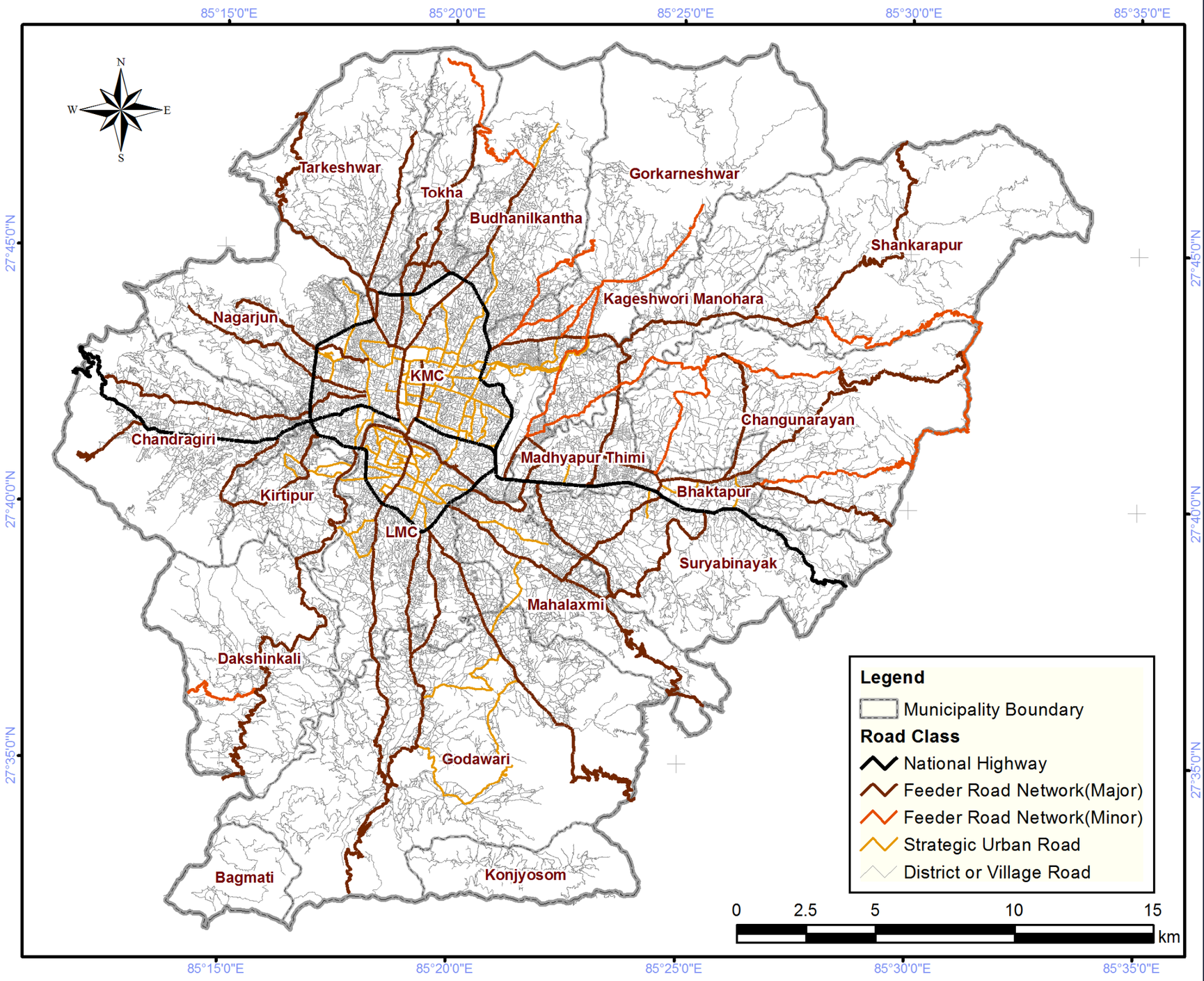

A-14

Road Network

Note:

- According to the SSRN2015-2016 (Statistics of Strategic Road Network 2015-16) published by DoR and Highway Management Information System (HMIS) managed by DoR, the total length of strategic road network (SRN) for the three districts is as follows:

District	Class of Road	Road Length (Km)
Kathmandu	NH	39.85
	FRN	207.85
	SUR	78.35
Lalitpur	NH	18.00
	FRN	113.39
	SUR	56.61
Bhaktapur	NH	14.12
	FRN	110.94
	SUR	7.60

NH: National Highway
FRN: Feeder Road Network
SUR: Strategic Urban Road

Source:

- Road Network: DoR, DoLIDAR
- Boundary of Municipality and Ward: DoS, MoFALD

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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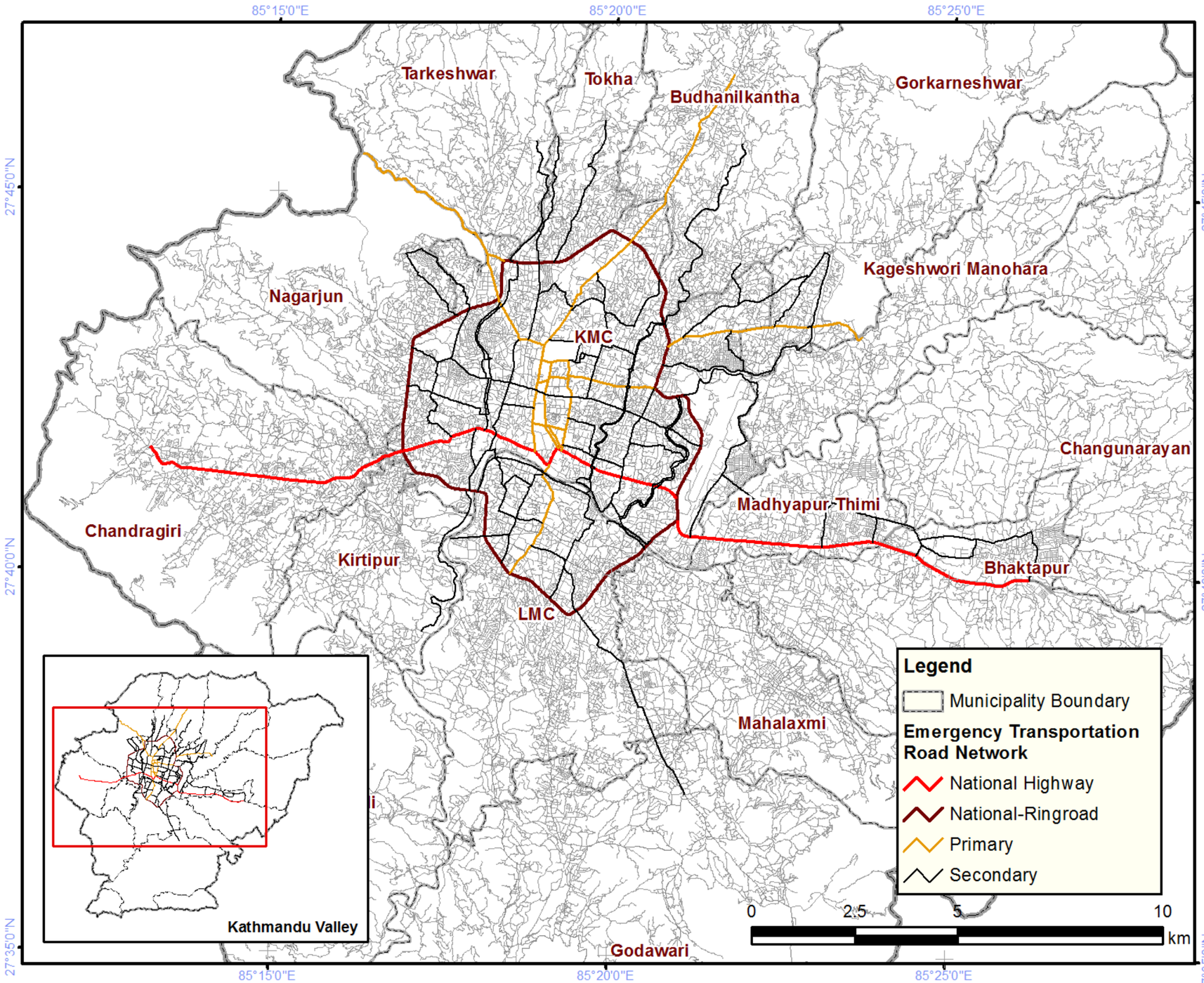

A-15

Emergency Transportation Road Network (ETRN) Proposed by JICA RRNE

RRNE: Rehabilitation and Recovery from Nepal Earthquake

Note:

- The Emergency Transportation Road Network (ETRN) in Kathmandu valley was proposed by the Project on Rehabilitation and Recovery from Nepal Earthquake (RRNE) through collaboration with the project on Urban Transport Improvement for Kathmandu Valley.
- ETRN was selected in consideration of locations of critical sites and facilities for disaster response and recovery such as government offices, major hospitals, evacuation places and other important facilities.
- National highway and Ring-road were designated for ETRN. And a part of strategic road network and district road network at the central Kathmandu valley were selected as primary or secondary of ETRN.

Source:

- Emergency Transportation Road Network: RRNE2017
- Road Network: DoR, DoLIDAR
- Boundary of Municipality and Ward: DoS, MoFALD
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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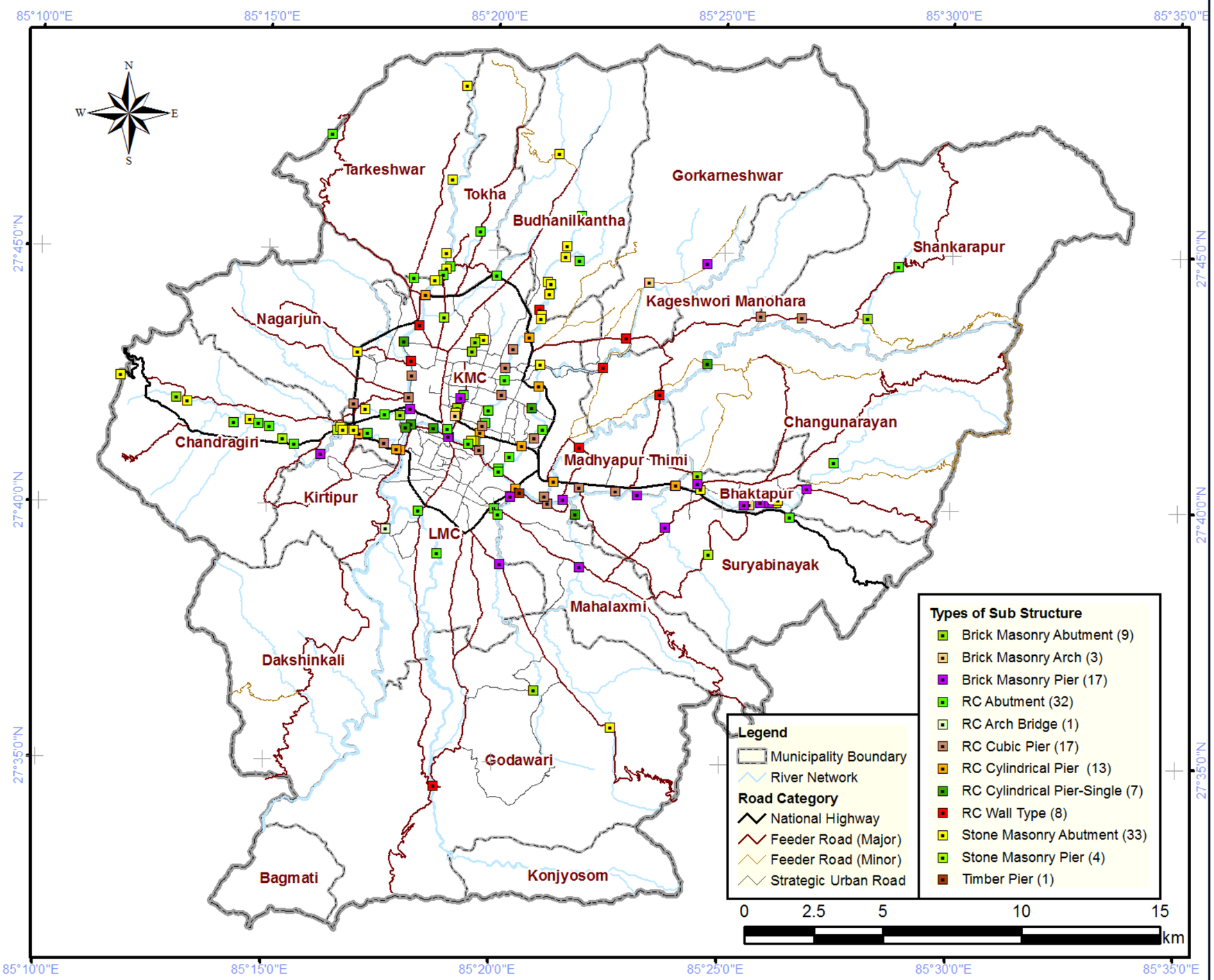

A-16

Distribution of Bridge

Note:

- There are a total of 145 bridges in the study area targeted for seismic risk assessment.
- Targeted bridges are mainly located on the Strategic Road Network (SRN) but some bridges are located on district or village road network.
- The exact location of the bridges and structure types for each bridge were identified by visiting each bridge based on the inventory of the Bridge Management System (BMS), operated by DoR, and other available data.

The structure types of bridges are divided as follows:

Structure	Multi-Span (72)	Single-Span (73)
RC	47	31
Masonry	24	42
Timber	1	0

Source:

- Bridge Inventory Data: DoR, ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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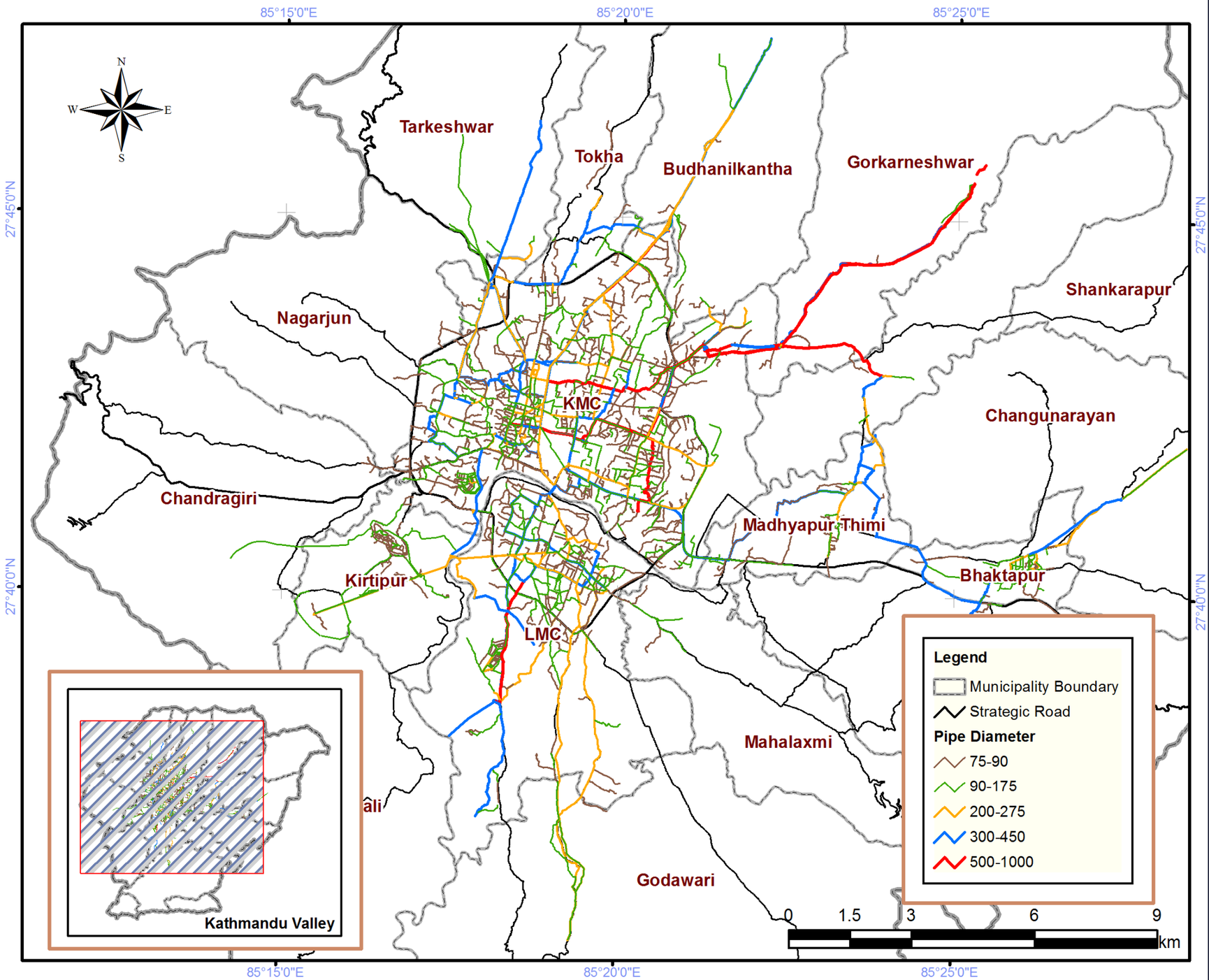

A-17

Distribution of Water Supply Network (Existing)

Note:

- According to the annual report published in 2015 by Kathmandu Upatyaka Khanepani Limited (KUKL), the water supply service area in the Kathmandu Valley covers 235 wards in 21 municipalities out of the 427 wards in 22 municipalities and four VDCs. The amount of water supply is 119MLD (Millions of Litters per Day), while on the other hand, the amount of water demand is 375MLD, which is three times the amount of water supply in 2014 to 2015.
- The spatial data of existing water supply distribution network was received from KUKL. This data contains the types of pipe materials, diameter of pipes (mm) and construction years by pipe node as attribute information.
- The six types of pipe materials such as cast-iron pipe (CI), ductile cast-iron pipe (DI), galvanized iron pipe (GI), high density polyethylene pipe (HDPE), polyvinyl chloride pipe (PVC), and stainless iron pipe (SI) are used for existing water supply distribution network.
- Existing water supply distribution network is shown in the map with color coding according to pipe diameter class.

Source:

- Existing Water Supply Distribution Network: KUKL
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

The Project for Assessment of
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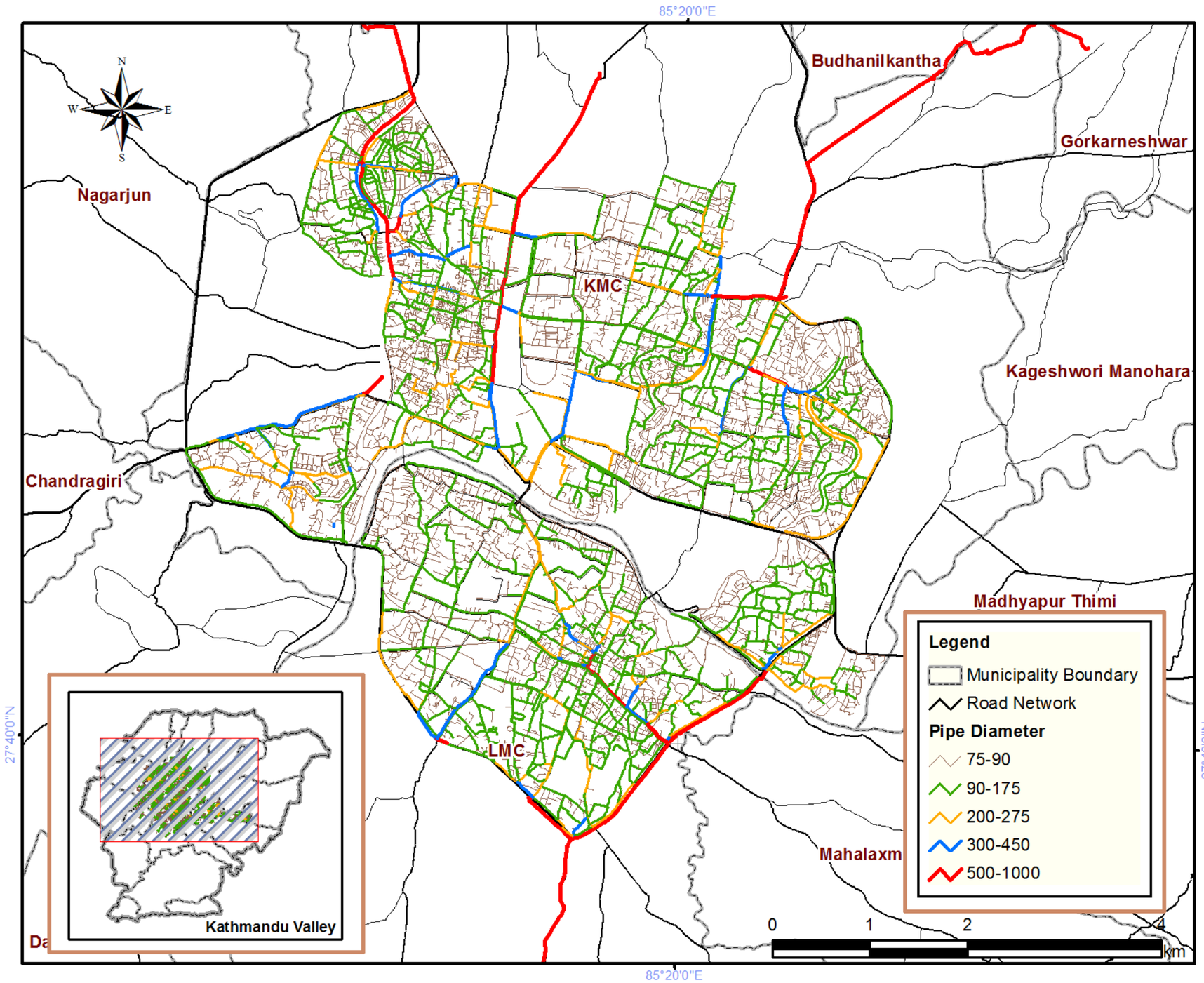
for the Kathmandu Valley in Nepal



A-18

Distribution of Water Supply Network (Planned)

Note:

- In order to improve the water supply capacity, the Kathmandu Valley Water Supply Improvement Project has been carried out as a loan assistance project by the Asian Development Bank (ADB). According to the Project Implementation Directorate (PID) of that project under KUKL, as the first phase of the project, there is a plan to start an operation of new water supply network in eleven areas located inside the Ring-road by 2018.
- It should be noted that, after the new water supply network is brought into operation, the existing water distribution network will be abandoned leaving only the existing distribution reservoir. In addition, two types of pipes such as ductile cast-iron pipe (DI) and high density polyethylene pipe (HDPE), as major materials, are supposed to be installed, which is expected to improve the seismic capacity of pipe lines as compared to the existing one.
- Planned water supply distribution network is shown in the map with color coding according to pipe diameter class.

Source:

- Planned Water Supply Distribution Network: KUKL
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

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Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
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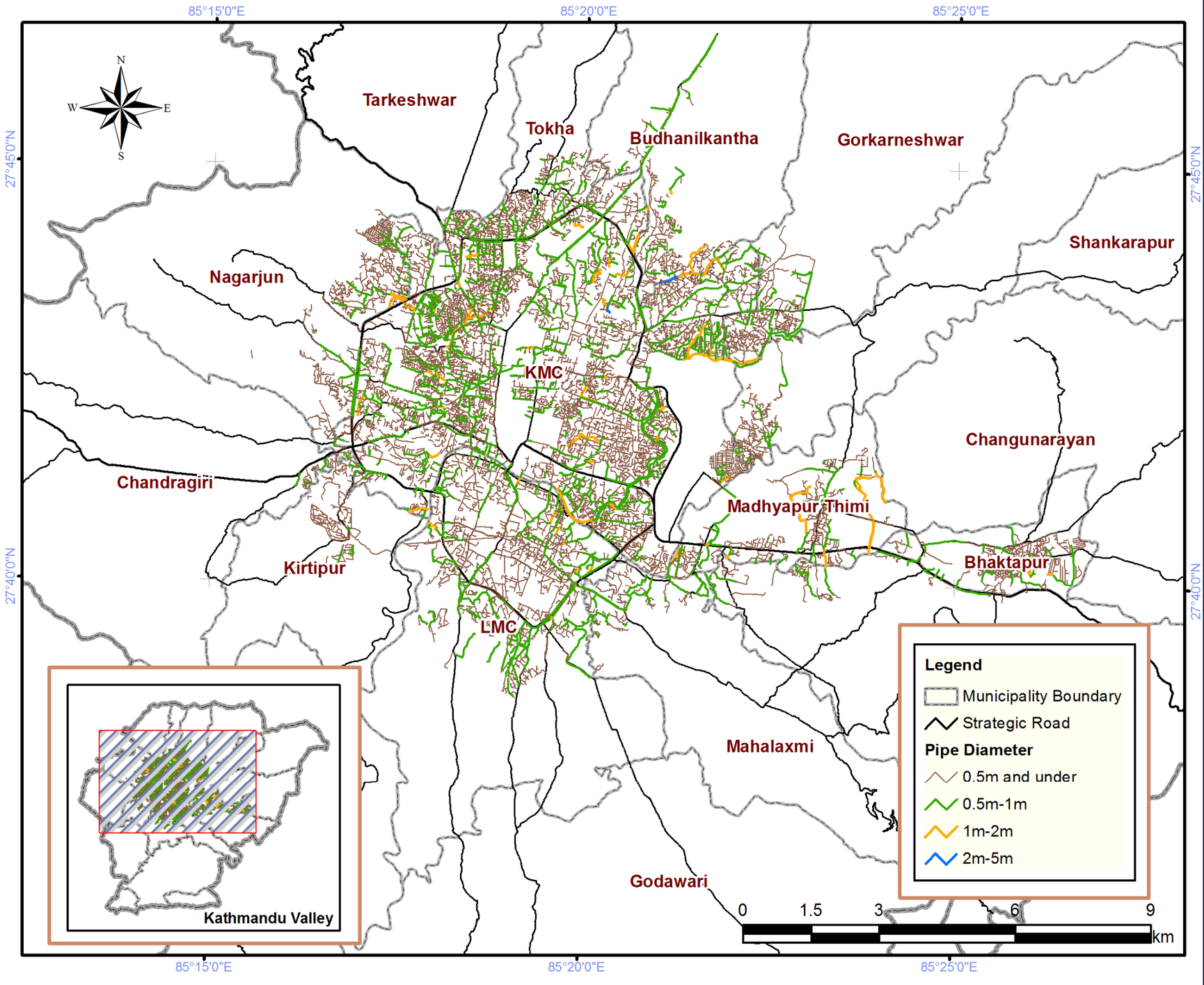

A-19

Distribution of Sewage Network

Note:

- According to the annual report published by KUKL in 2015, the service area of the sewage network covers 110 wards in five municipalities of Kathmandu, Lalitpur, Bhaktapur, Madhayapur Thimi and Kritipur. The service area is concentrated in the central area of the Kathmandu Valley and is limited compared to the service area for the water supply. The operation and maintenance of the water sewage system is conducted by KUKL, and at times, the construction of the system is implemented by municipalities or other organizations.
- The spatial data of existing sewage distribution network was received from KUKL. This data contains the types of pipe materials, pipes diameter (mm), depth of burial (mm) and construction years by pipe node as attribute information. The reinforced concrete is mainly used as the pipe material.
- Existing sewage distribution network is shown in the map with color coding according to pipe diameter class.

Source:

- Existing Sewage Distribution Network: KUKL
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
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false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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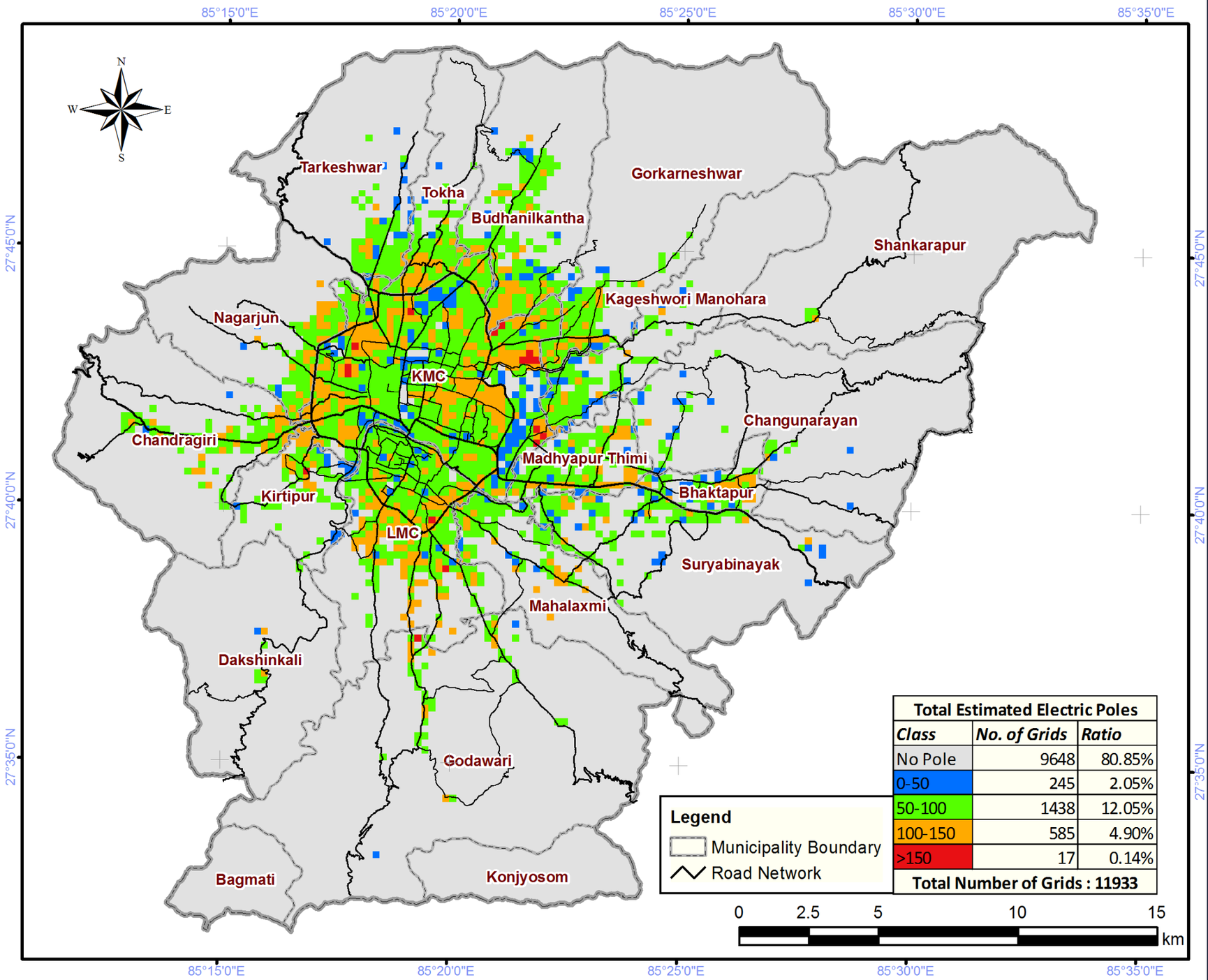

Total Estimated Electric Poles		
Class	*No. of Grids*	*Ratio*
No Pole	9648	80.85%
0-50	245	2.05%
50-100	1438	12.05%
100-150	585	4.90%
>150	17	0.14%
Total Number of Grids : 11933		

A-20

Estimated Power Pole Distribution

Note:

- In this project, the ratio of electricity power outage due to electricity pole failures was supposed to be estimated as the risk assessment of electricity network, but a detail distribution network data is required as an input data for this estimation. However, there is no detail spatial data for the distribution network with locations of power poles such as GIS data. Therefore, JICA Project Team proposed an estimation approach to estimate the density of distribution lines and power poles using existing road network distribution as alternative method.
- According to Annual Summary Report of 2072/073 prepared by Kathmandu Regional Office of Nepal Electricity Authority (NEA), the total length of distribution network is 5,749km. On the other hand, the length of detailed road network located inside the urbanized area is 2533km. From both values and average distance between the poles, which was identified as 30.13m based on field survey for distribution poles installation in the study area, a formula to calculate pole number by 250m-mesh grid was defined as follows:

Pole Number per 250m-mesh gird =
*Total road length per 250m-mesh gird * 2.27/30.13*

- As a result, the total length of distribution network and power poles were estimated as 5,750km and 190,851 units in the study area.
- 250m-mesh grid wise estimated power pole distribution is shown in the map.

Source:

- Estimated Power Pole Distribution: ERAKV 2017
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
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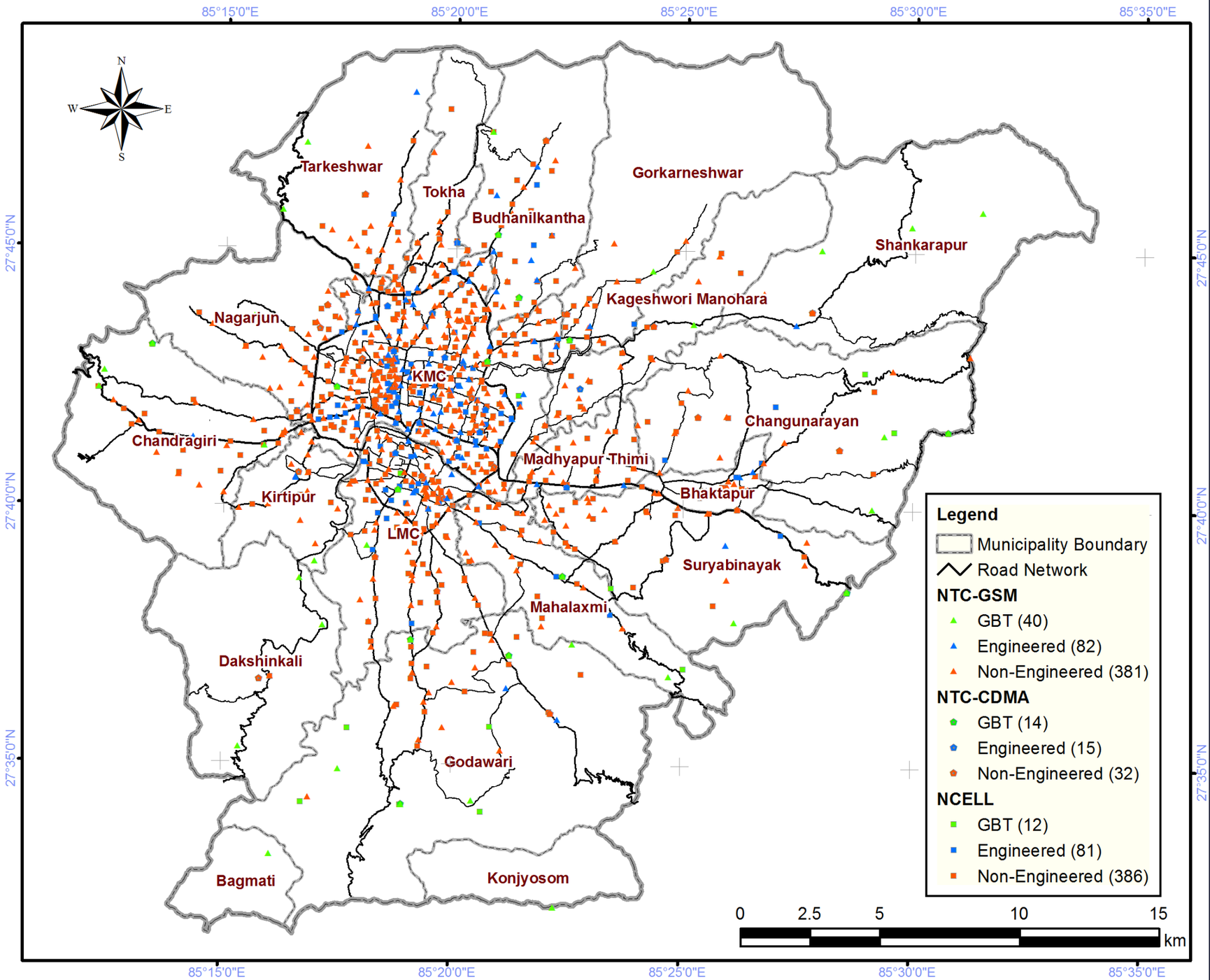
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

The Project for Assessment of
EARTHQUAKE DISASTER RISK
for the Kathmandu Valley in Nepal



A-21

Distribution of Mobile BTS Tower

Note:

- Currently, mobile communication is the common telecommunication system in Nepal, with a total number of mobile subscribers exceeding 90% of the total telecommunication facility users. More than 90% share in the mobile communication market is taken by NTC (Nepal Telecom) and Ncell.
- Given the existing status of the telecommunication environment in Nepal, the damage assessment of the mobile telecommunication network is an important component of the earthquake risk assessment. In this project, it was decided to focus on the vulnerability assessment of the Base Transceiver Stations (BTS) which connects each mobile phone and mobile communication networks.
- With the cooperation of Nepal Telecommunication Authority (NTA), the latest data for locations of BTSs has been received from NTC and Ncell.
- The location map of current BTSs managed by NTC and Ncell in the study area is shown in the map.

Source:

- BTS distribution Data: NTA, NTC, Ncell
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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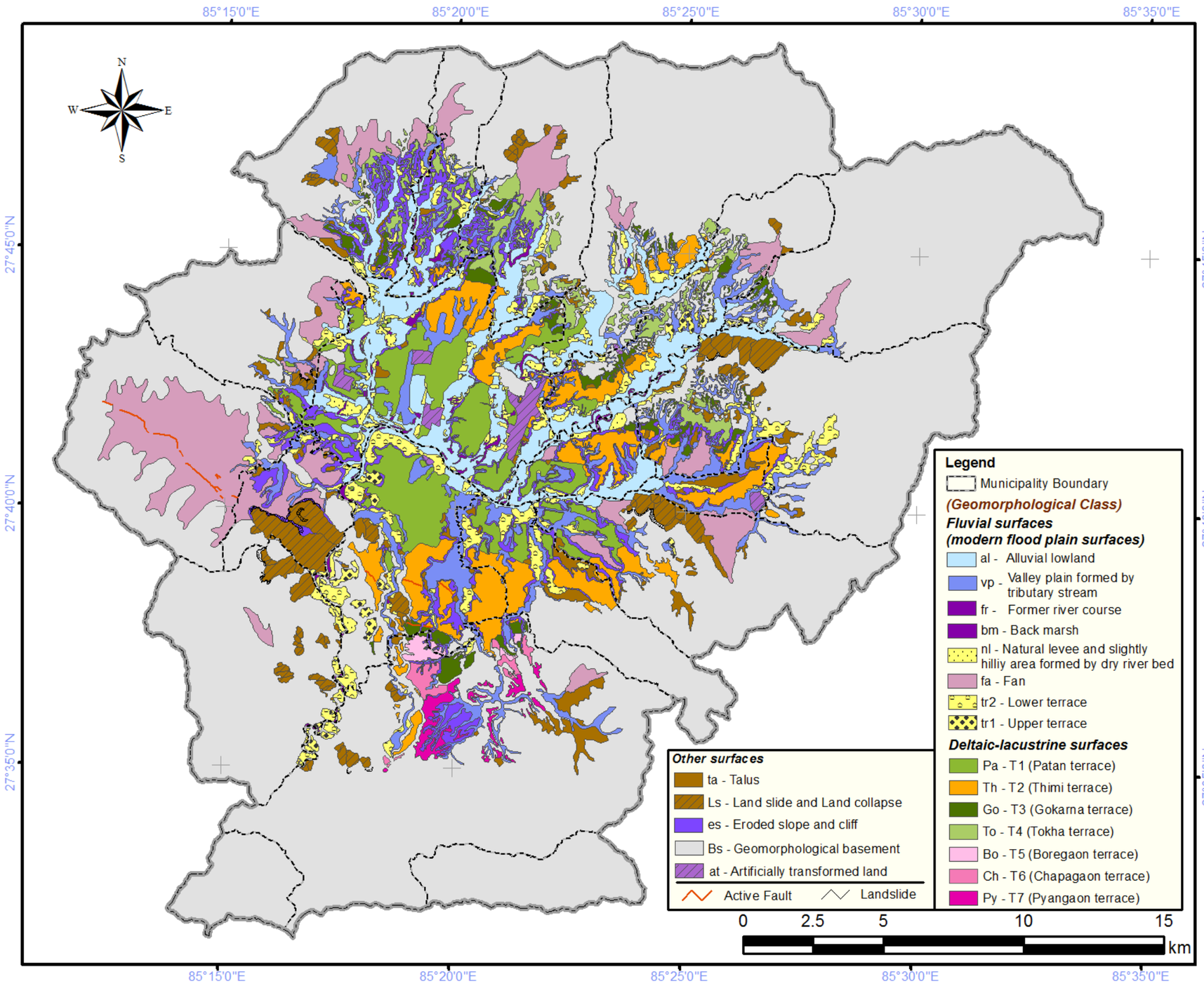
for the Kathmandu Valley in Nepal

B. Seismic Hazard Assessment



B-1

Geomorphological Map

Note:

- For ground modelling, along with geological information, drilling data and topographical materials, geomorphological map which reflects detailed depositional environment plays an important role. Geomorphological interpretation and site reconnaissance survey were implemented, and a new detailed geomorphological map was prepared with DMG participation. Still site survey has not yet perfect, which will be supplemented by DMG, and then, DMG will be supposed to publicize after some further analysis.
- The detailed geomorphological classification was carried out by stereo-view of large-scale aerial photographs taken in December 1998 (scale about 1:15,000, by Department of Survey). Most areas of the Kathmandu Valley are covered by these aerial photographs taken in 1998, while large-scale photographs are not available in the western to southwestern margin of the Kathmandu Valley. Therefore, we used complementary small-scale aerial photographs taken in 1992 (scale about 1: 50,000, by Department of Survey).

Source:

- Geomorphological Map: ERAKV 2016
- Boundary of Municipality: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
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latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
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Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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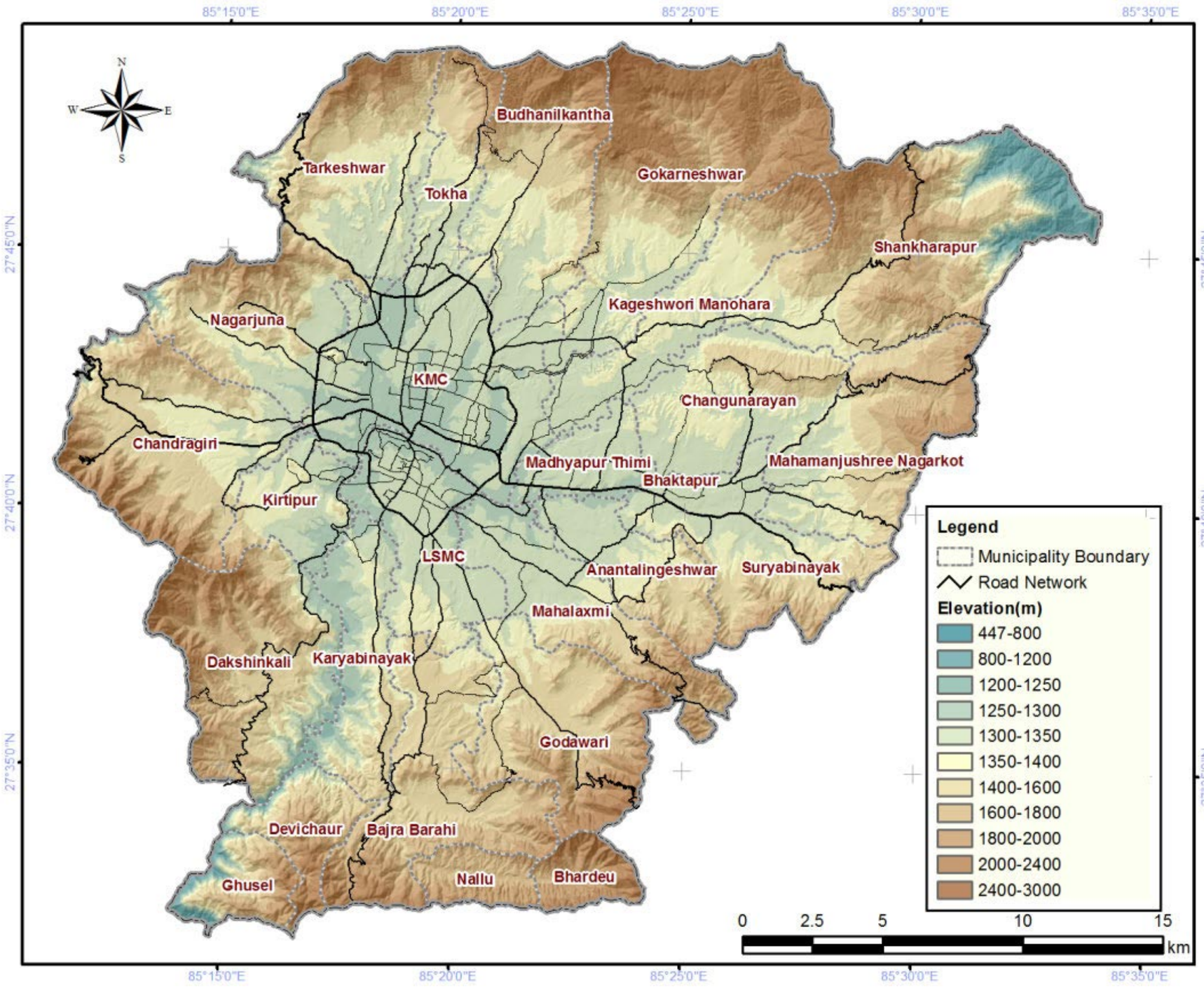
for the Kathmandu Valley in Nepal



B-2

Altitude Distribution Map

Note:

- As one of ground information, altitude data were collected. The altitude data was obtained as a DEM (Digital Elevation Model) derived from recent satellite imagery data from UNDP.

Source:

- Digital Elevation Model: UNDP
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
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Spheroid: .....WGS_1984

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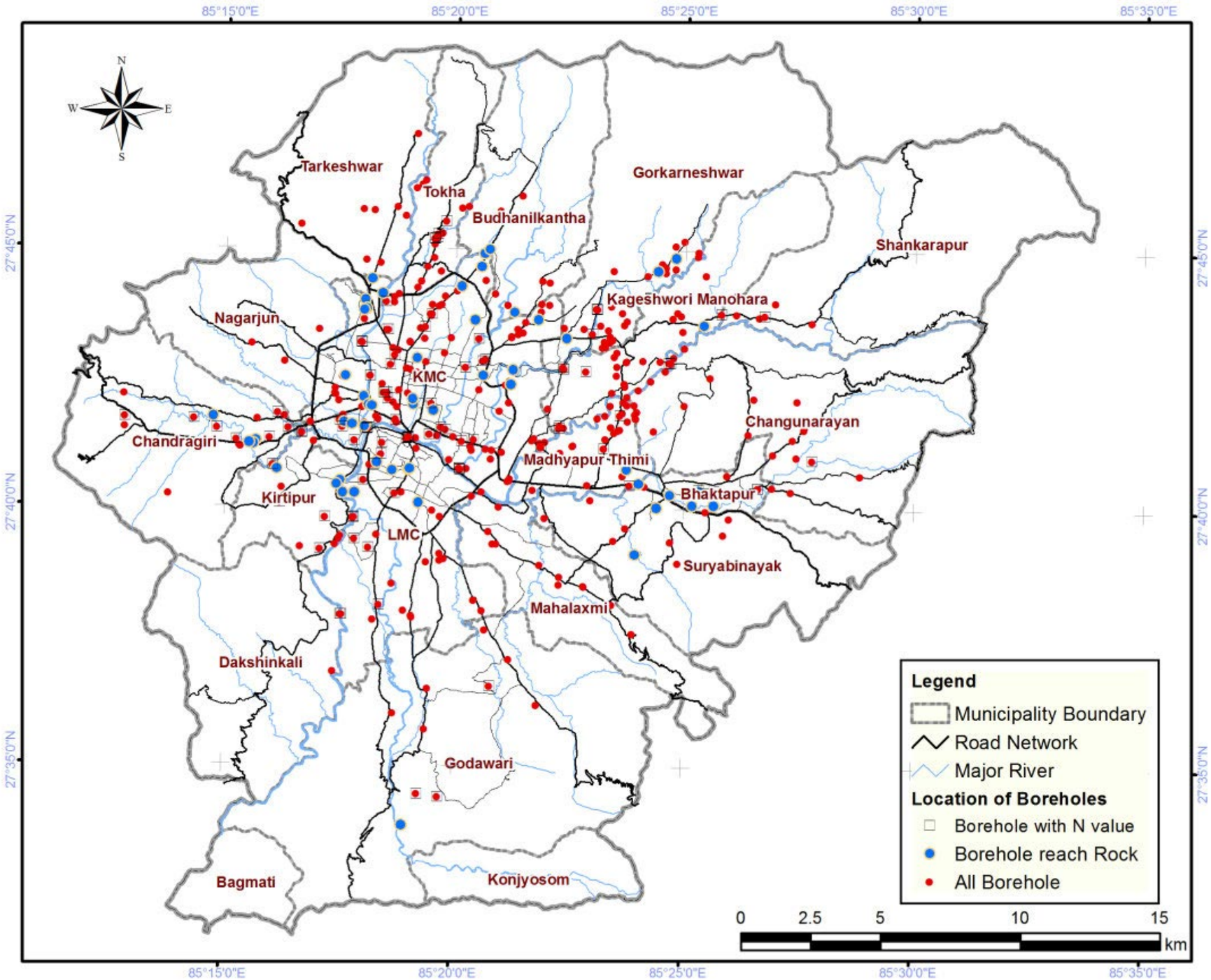

B-3

Distribution of Collected Borehole Data

Note:

- In total 449 drilling data were collected. Collection sources were 2002 JICA Project, UNDP, DoR, KUKL and so on.
- Among them, 124 boreholes have N values, within those only 36 are 20m or more in depth. 56 boreholes reach rock. And soil tests were carried out at 24 holes. In addition, out of 449 boreholes, depths shallower than 50m are 236, 100m or deeper are around 200 boreholes.

Source:

- Borehole Data: 2002 JICA Project, UNDP, DoR, KUKL
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
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false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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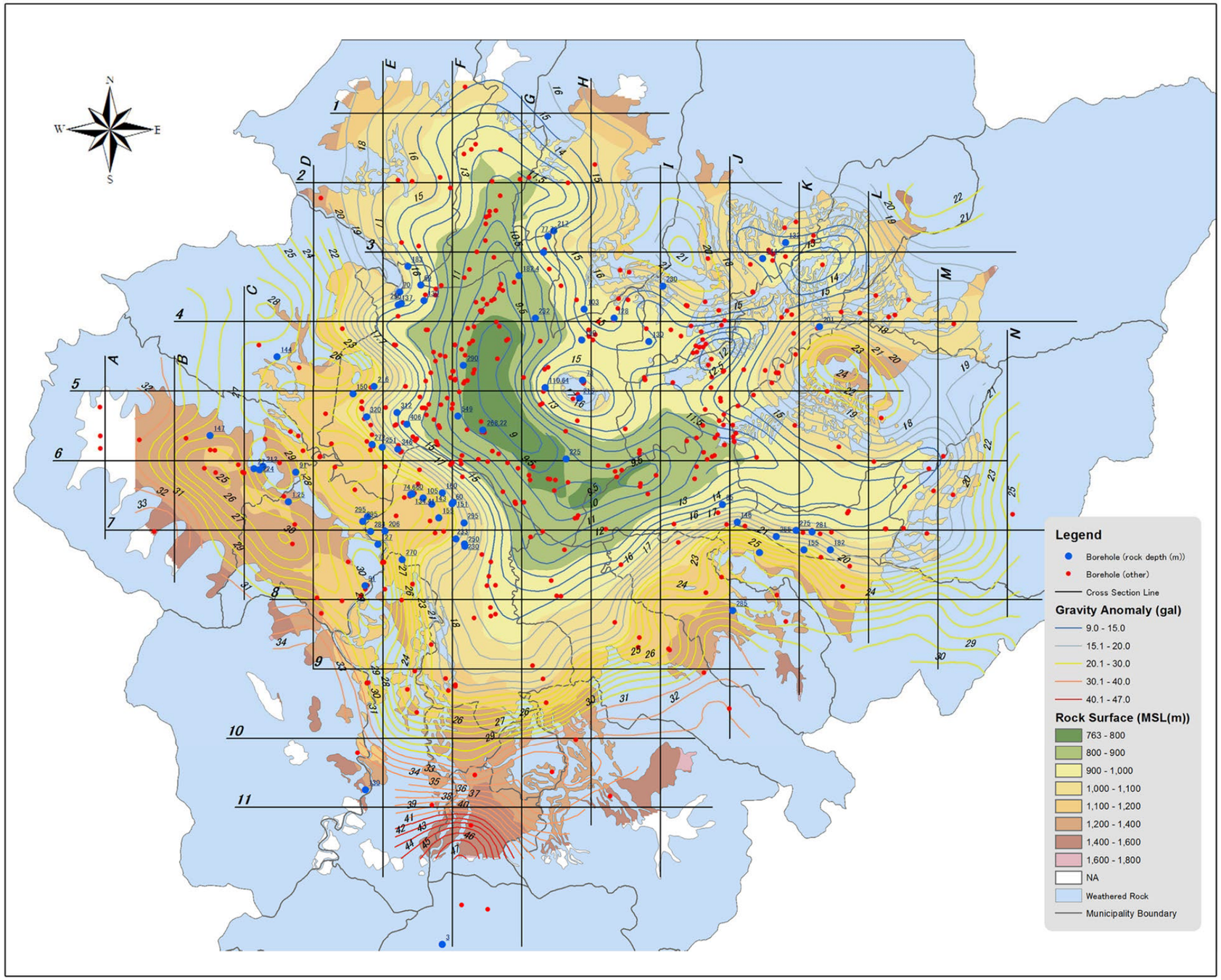


B-4

Rock Depth Distribution and Location of Borehole

Note:

- Since the drilling information as point data that reach rock layer is in limited number of 56, in order to clarify the distribution or contour of rock depth, the gravity anomaly exploration results (Moribayashi and Maruo, 1980) was utilized. In other words, the relation between the gravity anomaly distribution and rock depth by drilling data was found. Then, together with rock depth (altitude) by drilling, geomorphological map, geological map etc., the rock depth distribution was developed.
- According to the map, it is easily identified that the internal soil structure variation of the valley is not simple. It should be reflected with the process of the formation of the valley, that the past mountain areas with ridges and valleys settled, next the old lake was produced, and soils were flown in and deposited in the lake from surrounding slopes, as a result the terrace layer was formed along changes of water level of the old lake. Overall, the topography is quite complex.
- Though the maximum depth of rock is more than 500m at the central region, there are situations where a face of the rock is exposed at the ground surface and can be observed. Deeper portion of the ground is across the centre of Kathmandu City from north to south, southern extension hits Lalitpur Sub-Metropolitan City, bypasses to the east, and is divided into southwest and east portions. East oriented portion passes through the Thimi (Madhyapur) City to Bhaktapur City. In the north of Tribhuvan International Airport there is Pashupatinath, west of Kathmandu there is Swayambhunath, and in Lalitpur and Kirtipur bedrock appears on the ground surface or at shallow depth.

Source:

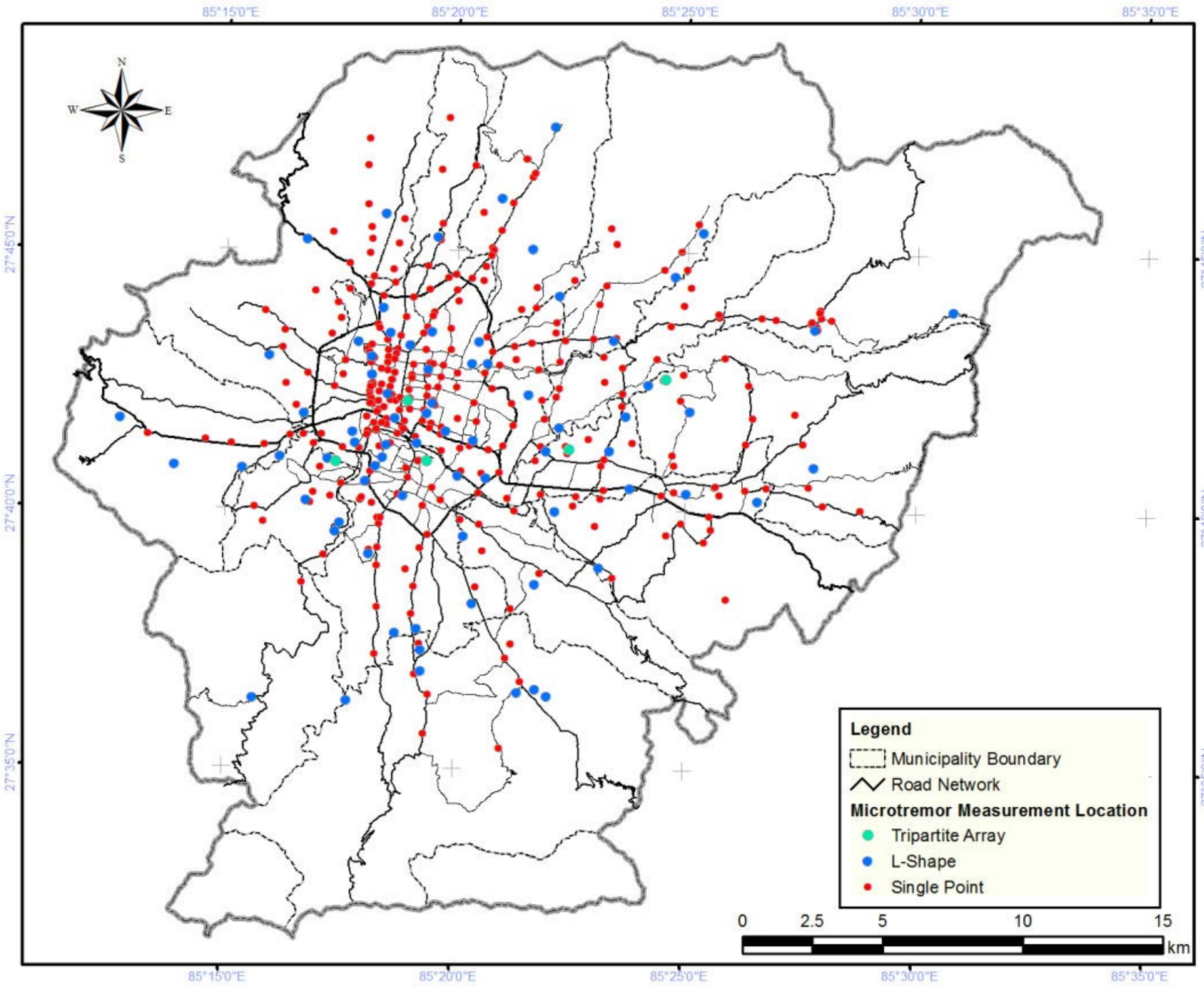
- Rock Depth Distribution: ERAKV 2016
- Borehole Data: 2002 JICA Project, UNDP, DoR, KUKL

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

The Project for Assessment of
EARTHQUAKE DISASTER RISK
for the Kathmandu Valley in Nepal



B-5

Location of Microtremor Measurement

Note:

- The outline of ground structure and its distribution can be estimated by geological map, geological cross section, geomorphology map and rock depth studied in this project and existing data, which are shown in clause 4.3 of the main text. The other necessary information to assess the amplification by response analysis is the physical property of the soil layer. Microtremor measurement was selected as the method of ground survey. Three types of microtremor measurement were conducted for separate purposes. Tripartite Microtremor Measurement was conducted to know the S-wave velocity structure of deep grounds up to several 100 metres. The purpose of the L-shape Array Microtremor was to know the S-wave velocity structure of shallow ground up to 50 metres. Single Microtremor Measurement was conducted to know the predominant period of the point and used for the confirmation of the ground model.
- It should be noted that the results of this survey may include an error of more or less 10% due to the inaccuracy of installation, observation and analysis. Also, the limitation of the measurement derives from the balance of power of microtremor and resolution of measuring instruments which is different in time and place. As there was less power of especially longer period of microtermor than expected, the accuracy of the S-wave velocity (Vs) of deeper geology is not necessarily sufficient.

Source:

- **Location of Microtremor Measurement:** ERAKV 2016
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
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false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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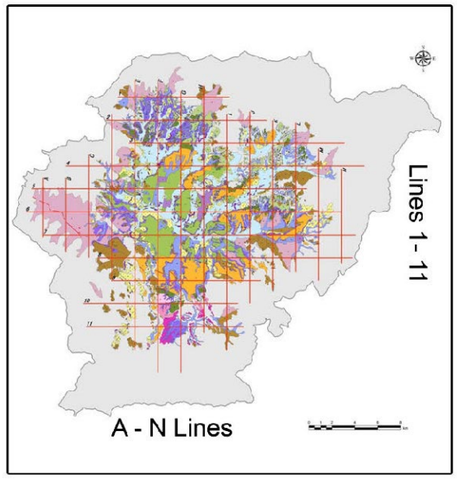

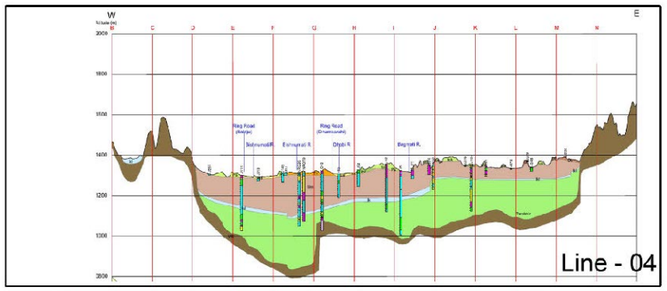

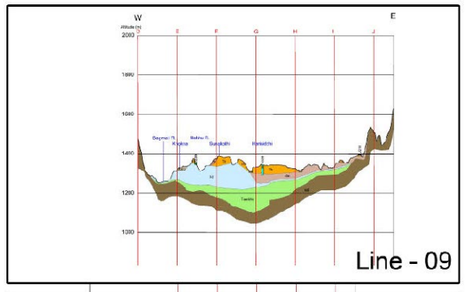

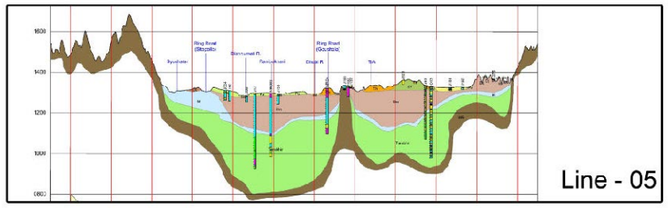

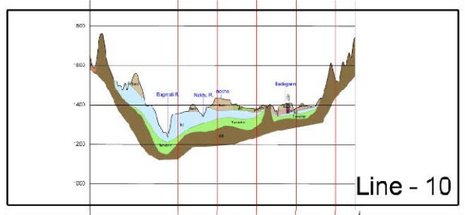

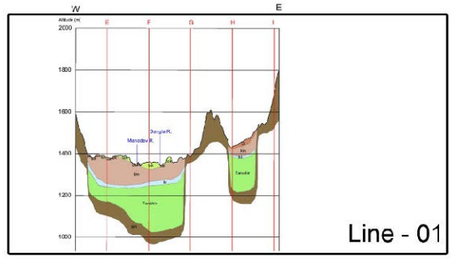

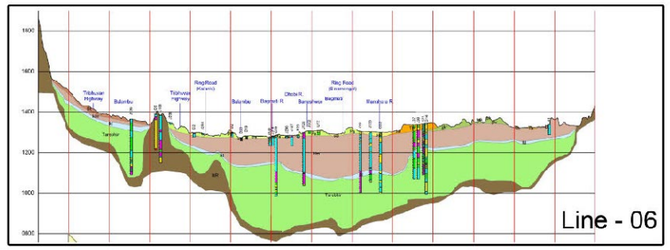

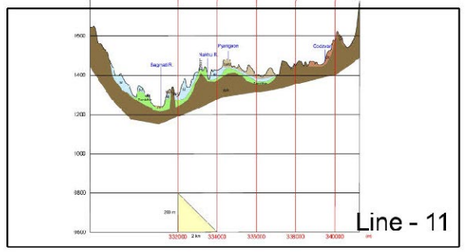

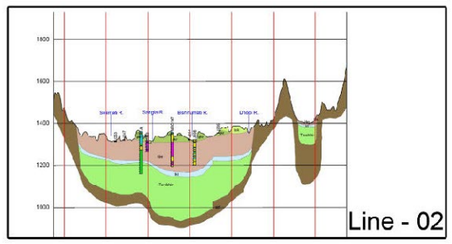

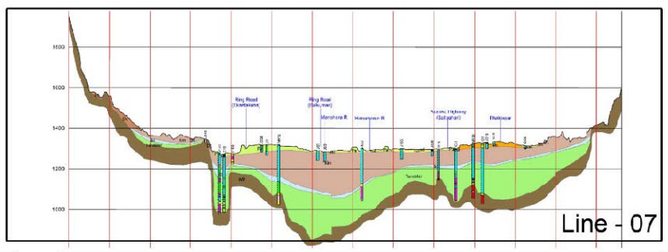

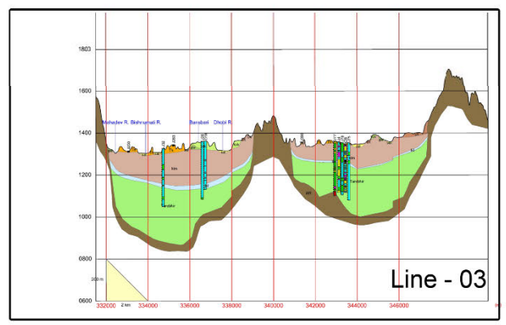

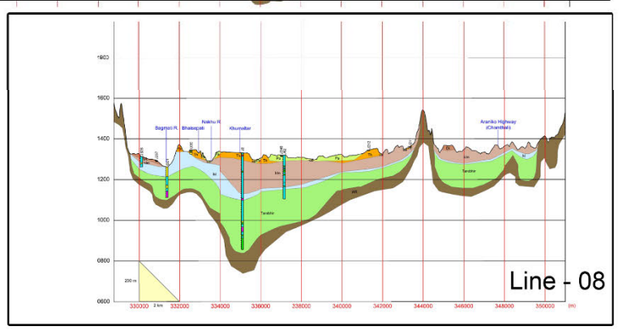

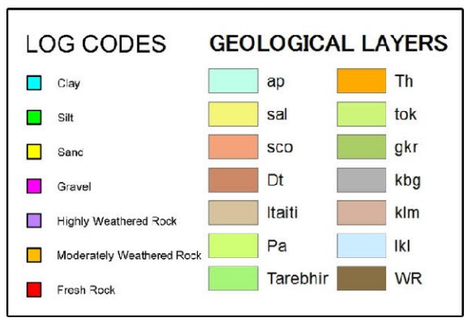

Formation Codes

ap : Alluvial Plain	Th : Thimi formation
Sal : Recent alluvial Soil	tok : Tokha formation
sco : Colluvial Soil	gkr : Gokarna formation
Dt : Talus deposit	kbg : Kobgaon formation
Itaiti : Itaiti formation	klm : Kalimati formation
Pa : Patan formation	lkl : Lukundol formation
Tarebhir : Tarebhir formation	WR : Wheathered rock

B-6

Geological Cross-Section EW

Note:

- The geological cross-section is inevitable for soil modelling, so, a new one has been developed for this project. They are a total of 25 sections (14 north-south and 11 east-west) at 2km intervals. Still the information is insufficient, and it is necessary to supplement and improve it in the future. Basically, the fundamental structure of the geological layers is as following. Referring to the existing geological documentation, under the top soil layers the somewhat thick Kalimati layer mainly composed of relatively soft lacustrine clay was found, under Kalimati the somewhat rigid, thin Lukundol layer (mainly lacustrine clay) and thick Tarebhir layer (lacustrine) were found. This is the main configuration of the cross-section.
- However, since the material information is not sufficient, assumptions have to be often adopted during the determination of strata, interpolation between the layers and materials, etc. Although the ground modelling in this project have used these cross-sections, in the future, it is expected to prepare more detailed geological cross-sections which can suggest important clues to obtain more accurate ground characteristics, by enriching the ground information.

Source:

- Geological Cross-Section: ERAKV 2016

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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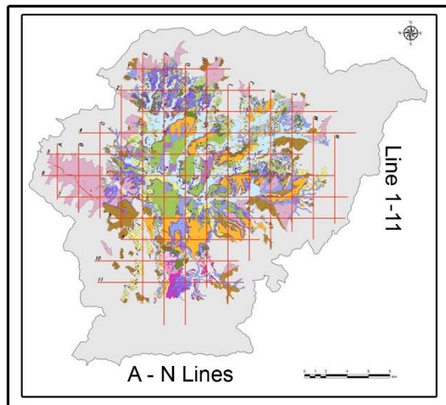

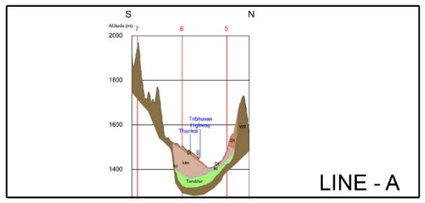

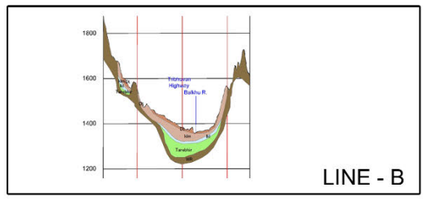

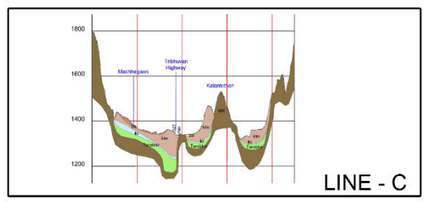

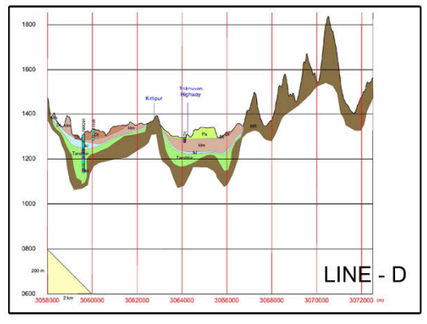

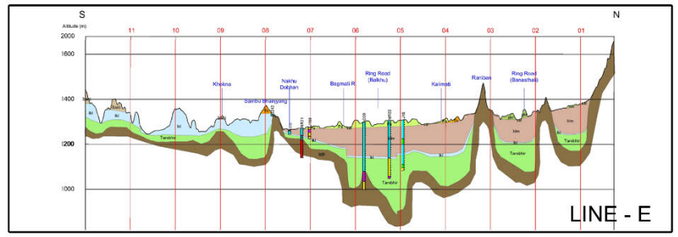

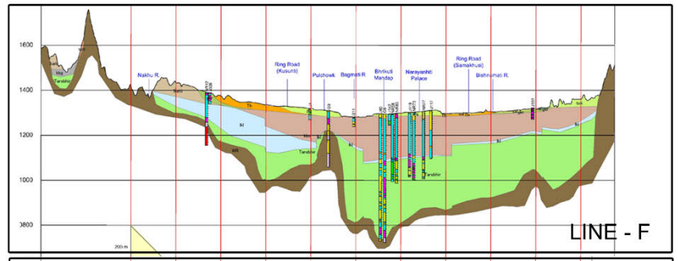

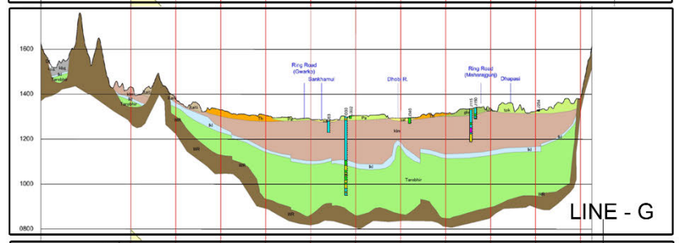

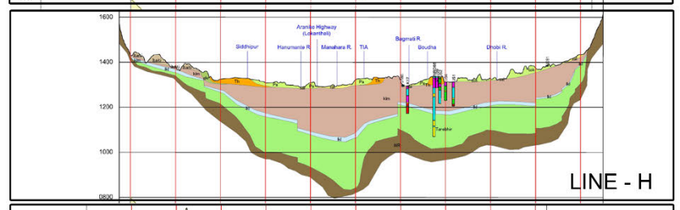

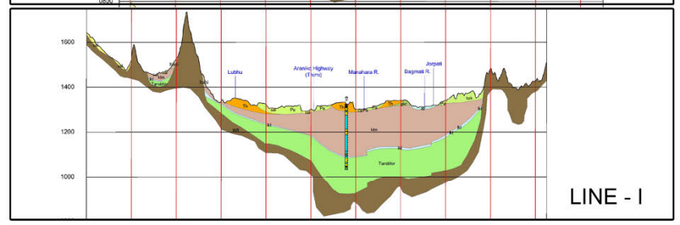

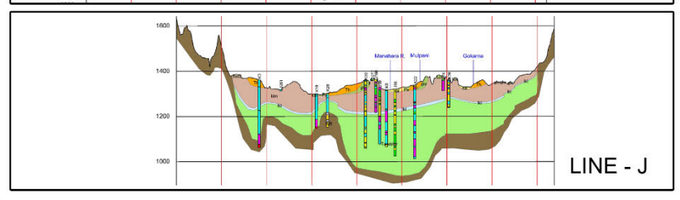

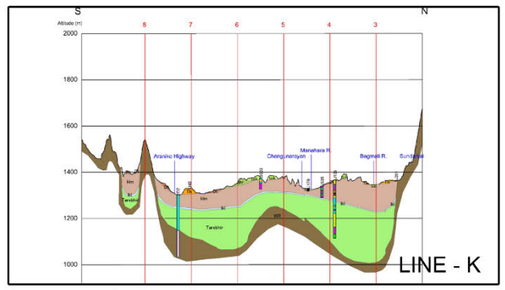

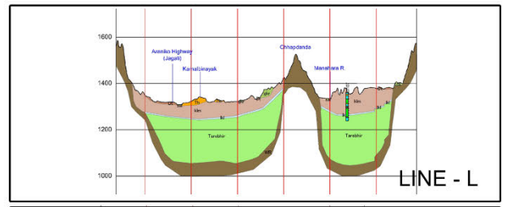

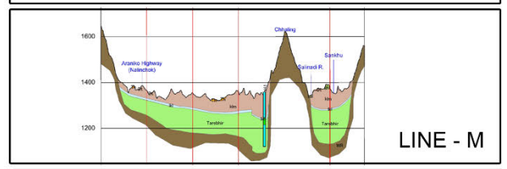

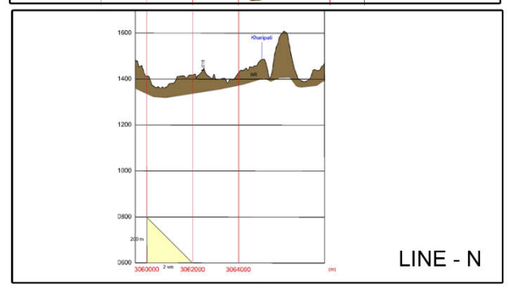

LOG CODES

- Clay
- Silt
- Sand
- Gravel
- Highly Weathered Rock
- Moderately Weathered Rock
- Fresh Rock

GEOLOGICAL LAYERS

ap	Th
sal	tok
sco	gkr
Dt	kbg
Itaitl	klm
Pa	lkl
Tarebhir	WR

Formation Codes

ap : Alluvial Plain	Th : Thimi formation
Sal : Recent alluvial Soil	tok : Tokha formation
sco : Colluvial Soil	gkr : Gokarna formation
Dt : Talus deposit	kbg : Kobgaon formation
Itaiti : Itaiti formation	klm : Kalimati formation
Pa : Patan formation	lkl : Lukundol formation
Tarebhir : Tarebhir formation	WR : Wheathered rock

B-7

Geological Cross-Section NS

Note:

- The geological cross-section is inevitable for soil modelling, so, a new one has been developed for this project. They are a total of 25 sections (14 north-south and 11 east-west) at 2km intervals. Still the information is insufficient, and it is necessary to supplement and improve it in the future. Basically, the fundamental structure of the geological layers is as following. Referring to the existing geological documentation, under the top soil layers the somewhat thick Kalimati layer mainly composed of relatively soft lacustrine clay was found, under Kalimati the somewhat rigid, thin Lukundol layer (mainly lacustrine clay) and thick Tarebhir layer (lacustrine) were found. This is the main configuration of the cross-section.
- However, since the material information is not sufficient, assumptions have to be often adopted during the determination of strata, interpolation between the layers and materials, etc. Although the ground modelling in this project have used these cross-sections, in the future, it is expected to prepare more detailed geological cross-sections which can suggest important clues to obtain more accurate ground characteristics, by enriching the ground information.

Source:

- Geological Cross-Section: ERAKV 2016

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin: 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree ..... (0.0174532925199433)
Prime Meridian: ..... Greenwich (0.0)
Datum: ..... D_WGS_1984
Spheroid: ..... WGS_1984

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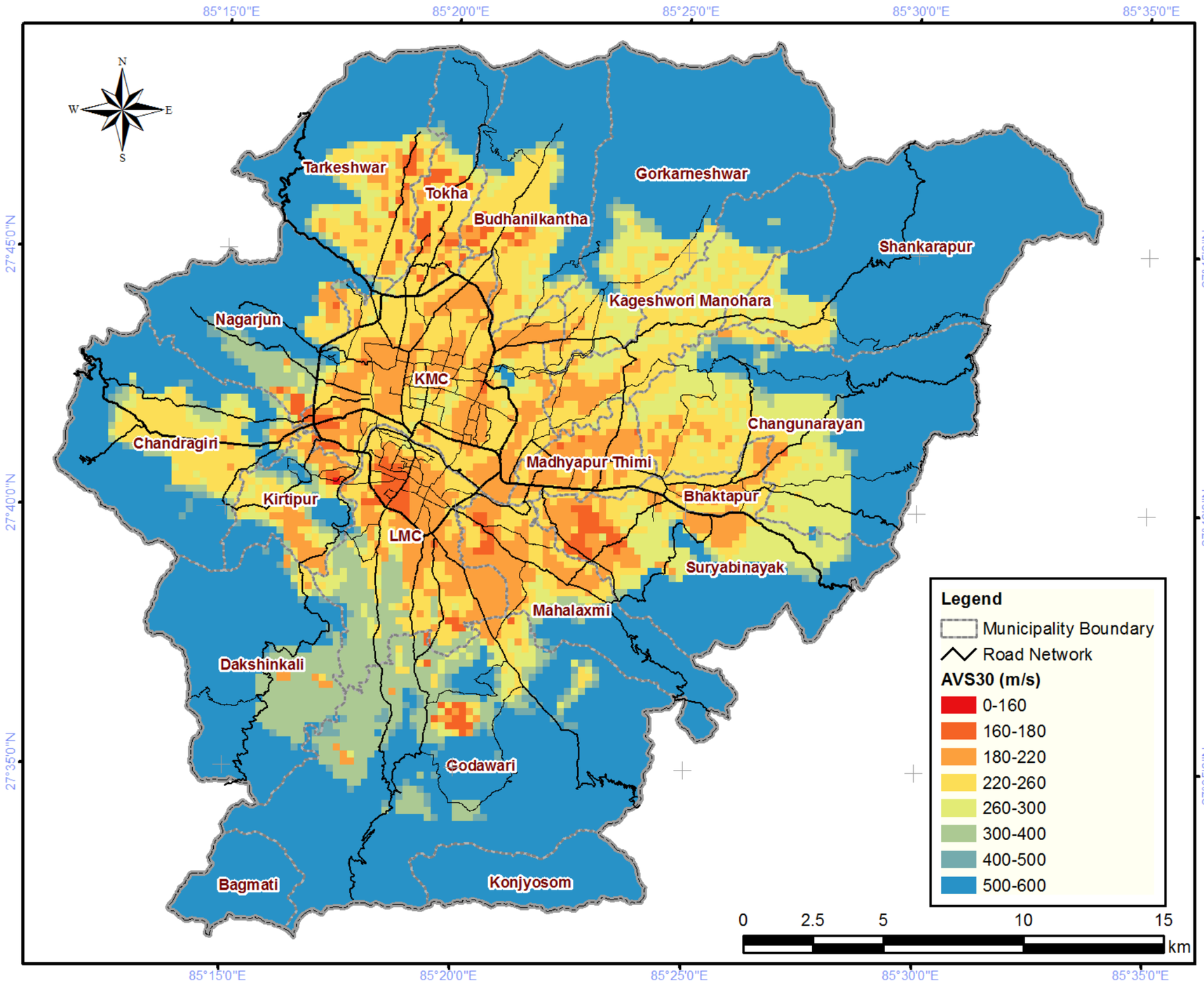

B-8

Estimated AVS30 from Ground Model

Note:

- The AVS30 (Average Vs over 30m from surface) of the ground are calculated from the ground model which is developed in this study.

Source:

- AVS30 Data: ERAKV 2016
- Road Network: DoR, DoLIDAR
- Road Network: Boundary of Municipality and Ward: DoS, MoFALD

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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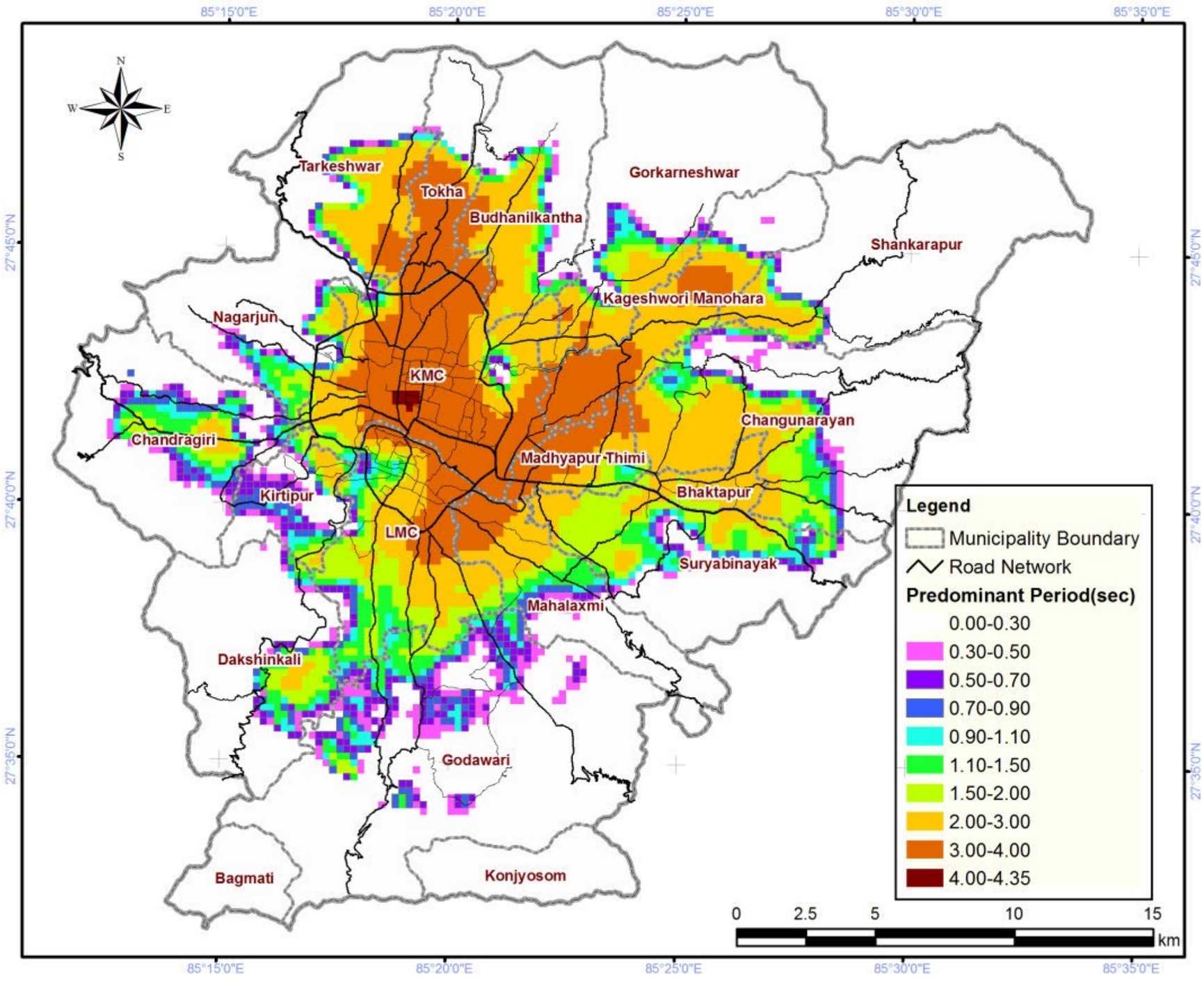
for the Kathmandu Valley in Nepal



B-9

Predominant Period of Ground

Note:

- The predominant period of the ground can be calculated from the ground model. The map shows the 1st peak of the transfer function by SH wave multiple reflection response analysis.

Source:

- Predominant period: ERAKV 2016
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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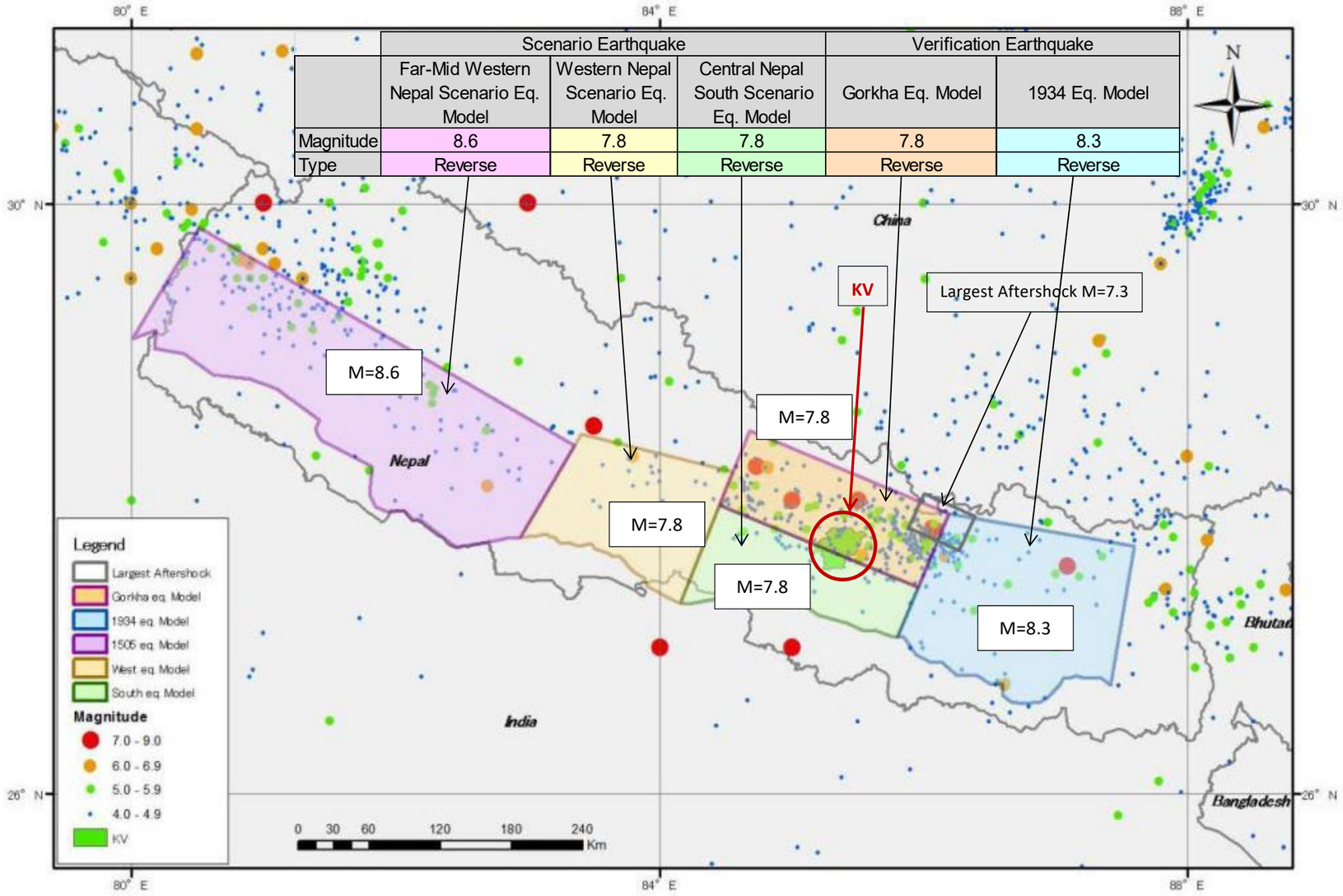
for the Kathmandu Valley in Nepal



B-10

Fault Model of Scenario Earthquake

Note:

- The scenario earthquakes were finalized and formally approved in 2nd JWG (April 11, 2016) and 3rd JCC (May 10, 2016), referring to the comments by SATREPS and National Scientific Community. The scenario earthquakes are three scenario earthquakes such as; “Far-Mid Western Scenario Earthquake”, “Western Nepal Scenario Earthquake” and “Central Nepal South Scenario Earthquake” and two earthquakes for verification; the 1934 Bihar-Nepal Earthquake and the 2015 Gorkha Earthquake including largest aftershock.

Source: ERAKV 2016

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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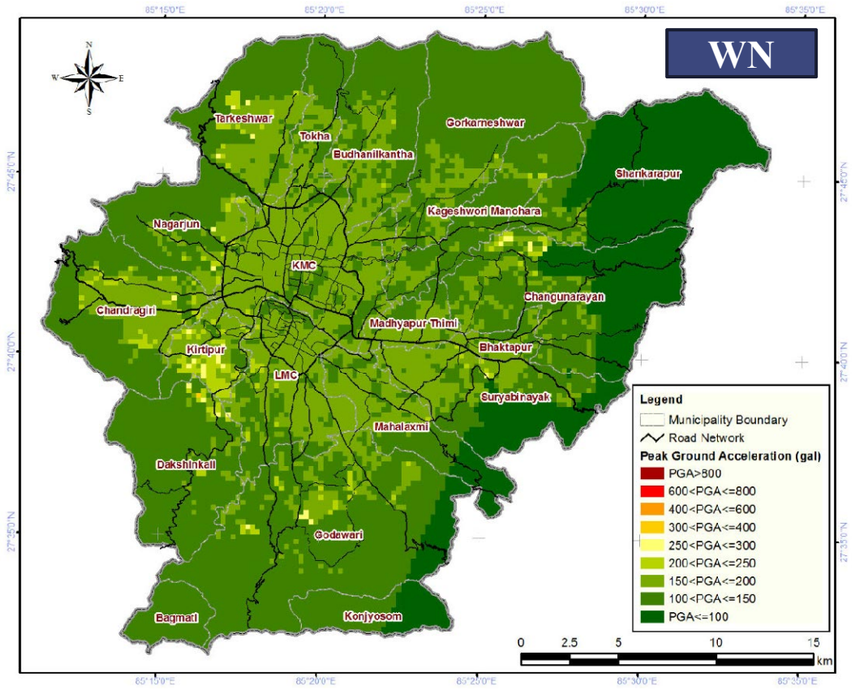

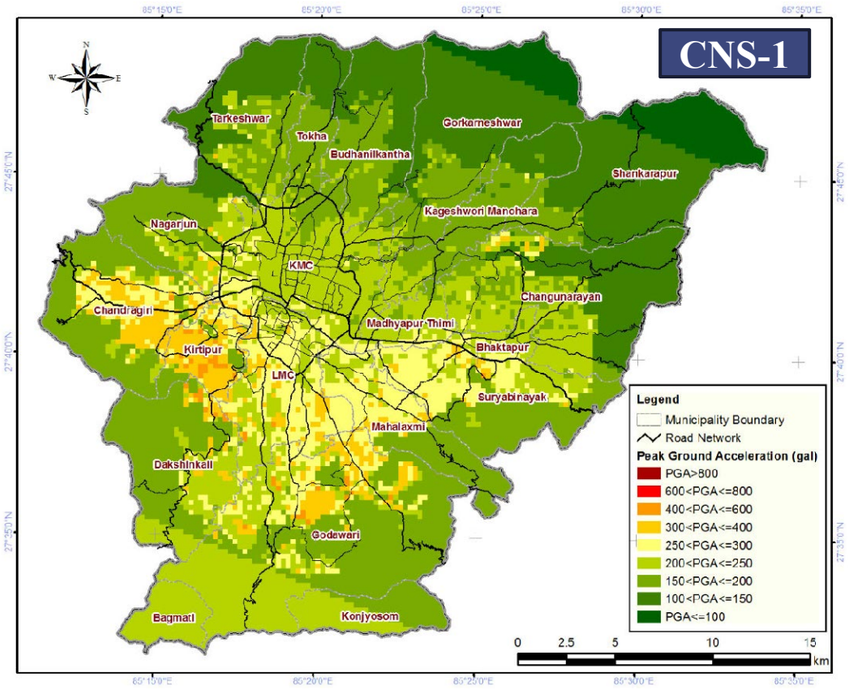

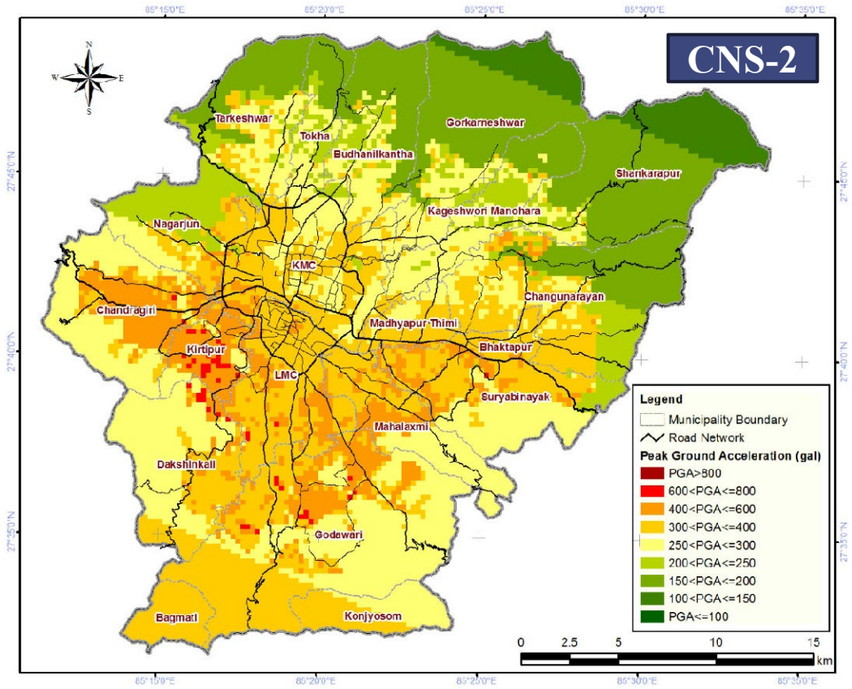

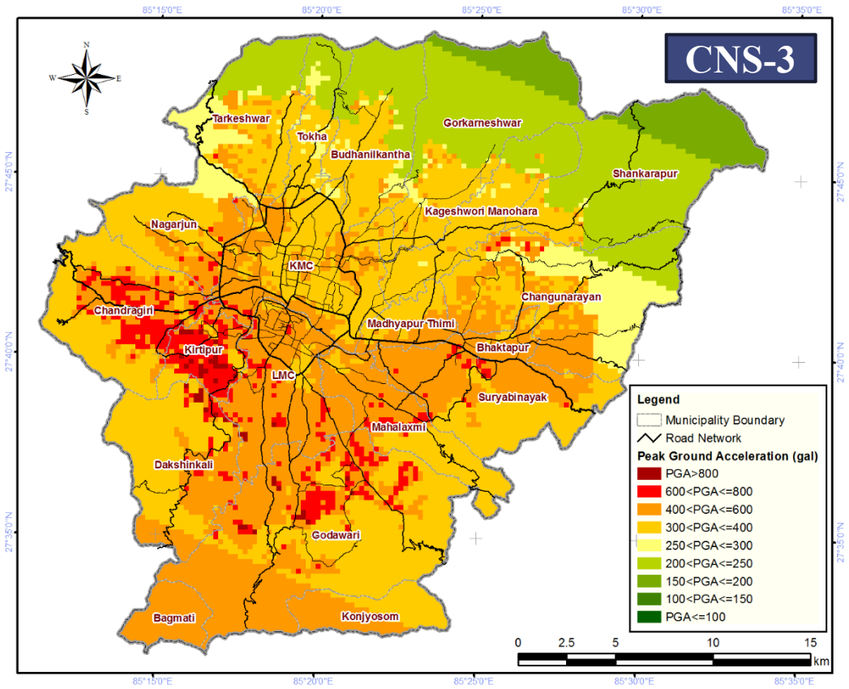

B-11

Peak Ground Acceleration Distribution

Note:

- First, the earthquake motion of scenario earthquake at bedrock (Vs=600m/sec) was calculated using existing Ground Motion Prediction Equation.
- Second, ground model for response analysis is constructed by drilling log, geomorphology map, microtremor survey, etc. in this project.
- Then, amplification of the ground is evaluated by one dimensional response analysis (SHAKE), based on the ground model above.
- PGA (Peak Ground Acceleration) is calculated by multiplying the bedrock motion by scenario earthquake and amplification of surface ground.

Source:

- Peak Ground Acceleration: ERAKV 2016
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:..... 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: ..... Greenwich (0.0)
Datum: ..... D_WGS_1984
Spheroid: ..... WGS_1984

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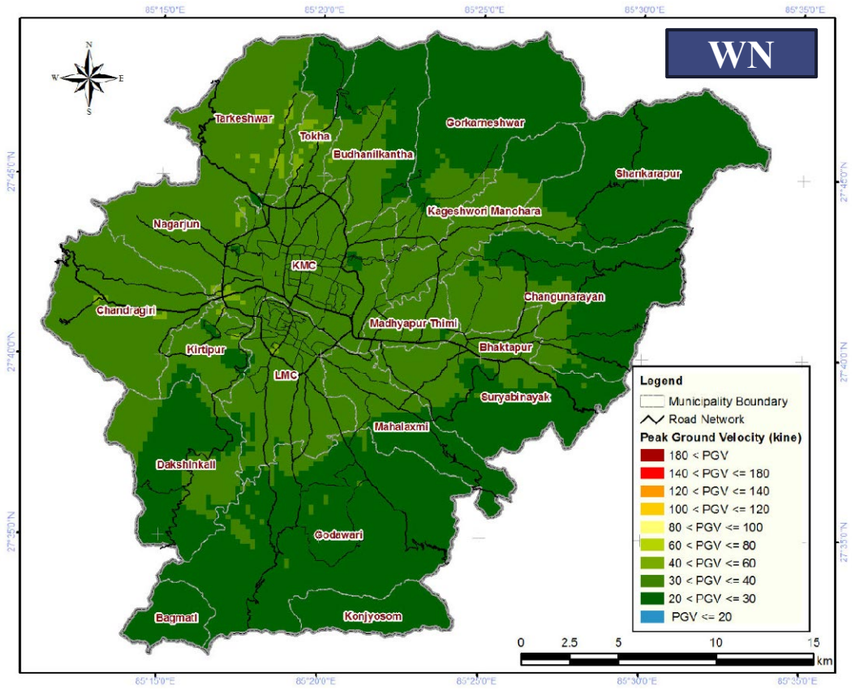

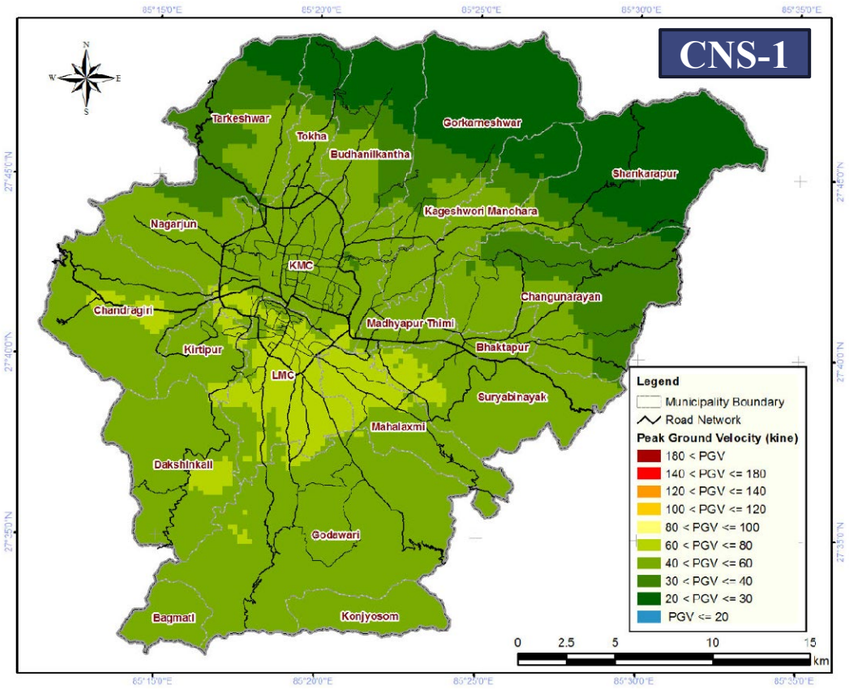

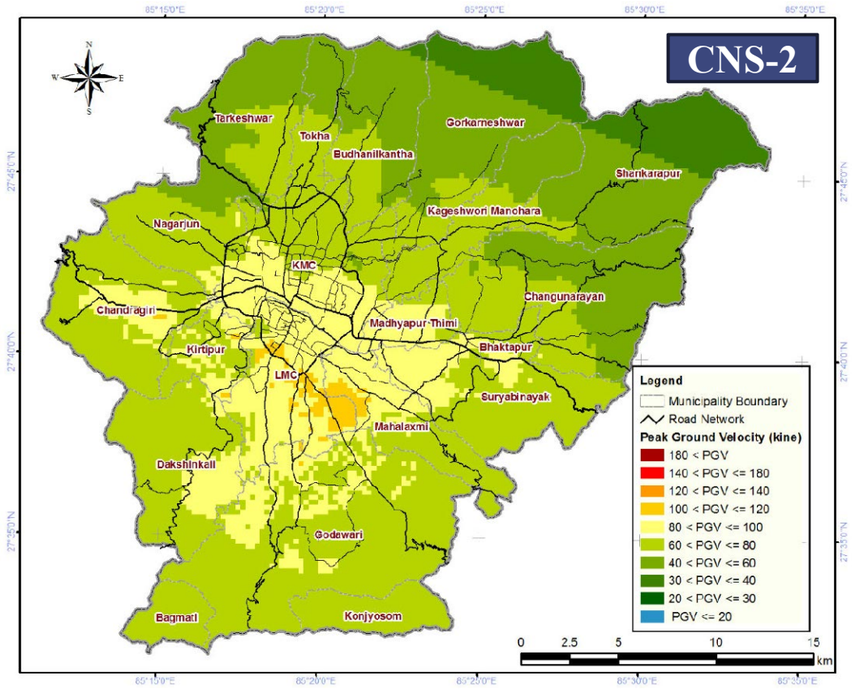

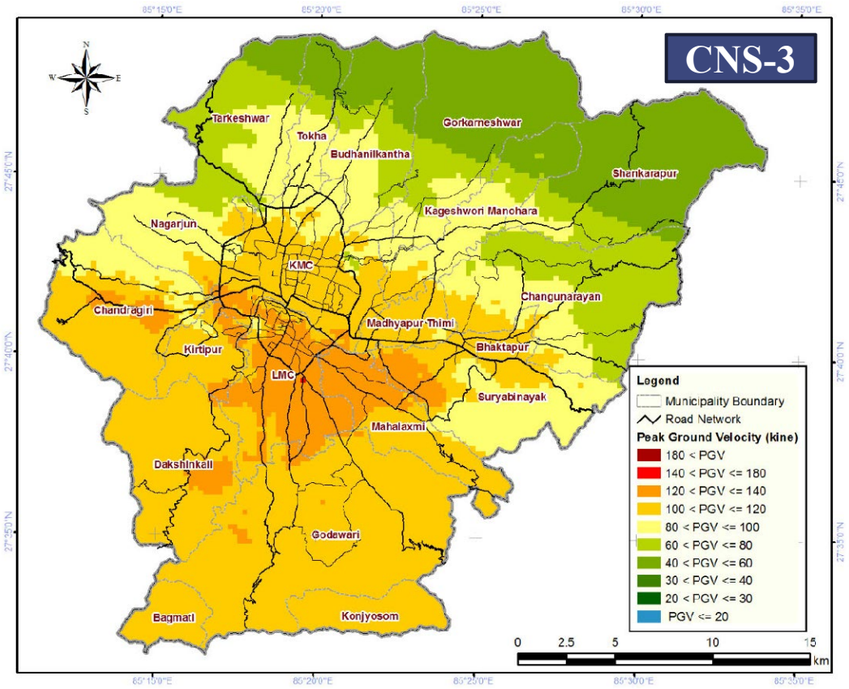

B-12

Peak Ground Velocity Distribution

Note:

- First, the earthquake motion of scenario earthquake at bedrock (Vs=600m/sec) was calculated using existing Ground Motion Prediction Equation.
- Second, ground model for response analysis is constructed by drilling log, geomorphology map, microtremor survey, etc. in this project.
- Then, amplification of the ground is evaluated by one dimensional response analysis (SHAKE), based on the ground model above.
- PGV (Peak Ground Velocity) is calculated by integrating the surface acceleration waveform by response analysis.

Source:

- Peak Ground Velocity: ERAKV 2016
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin: 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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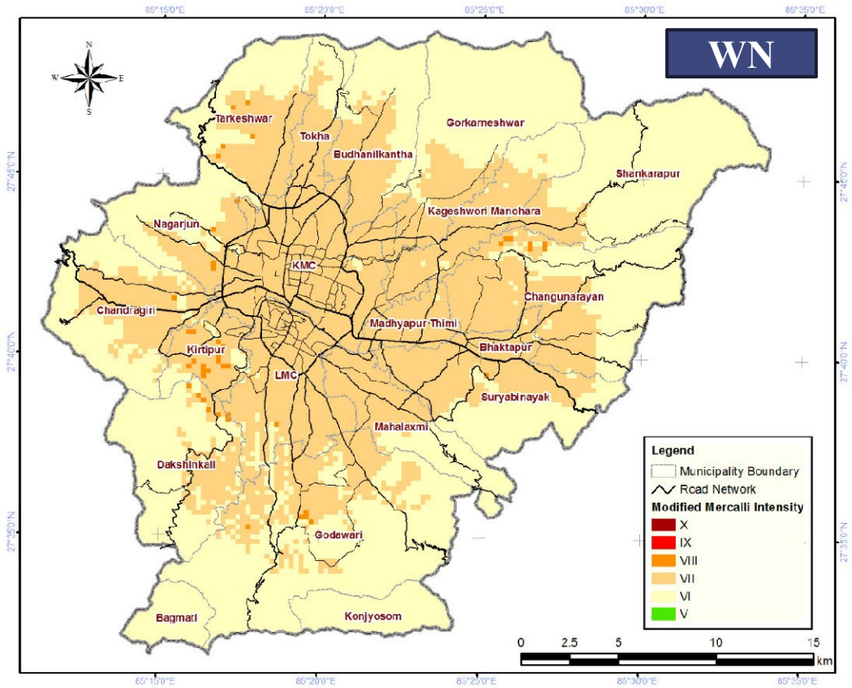

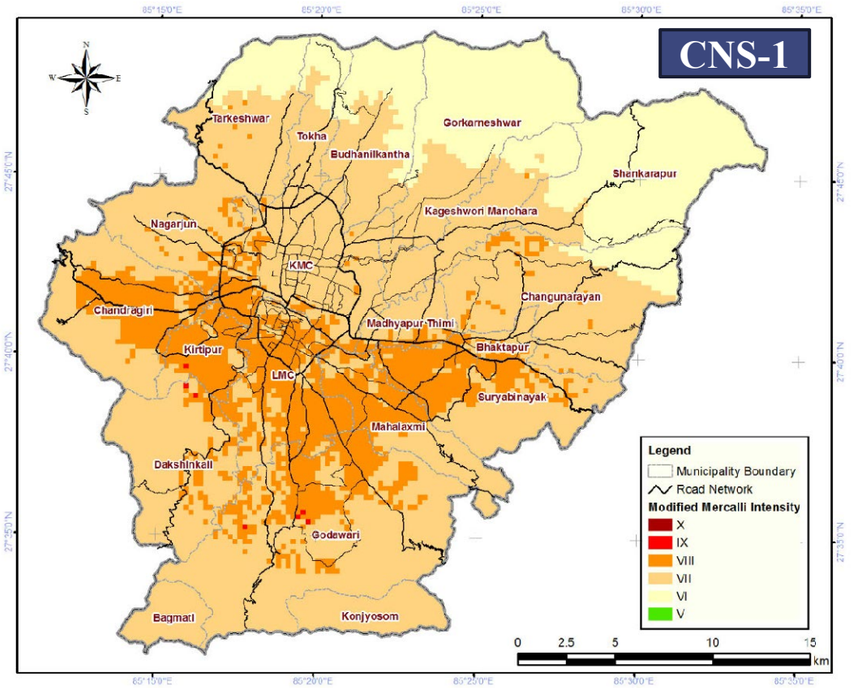

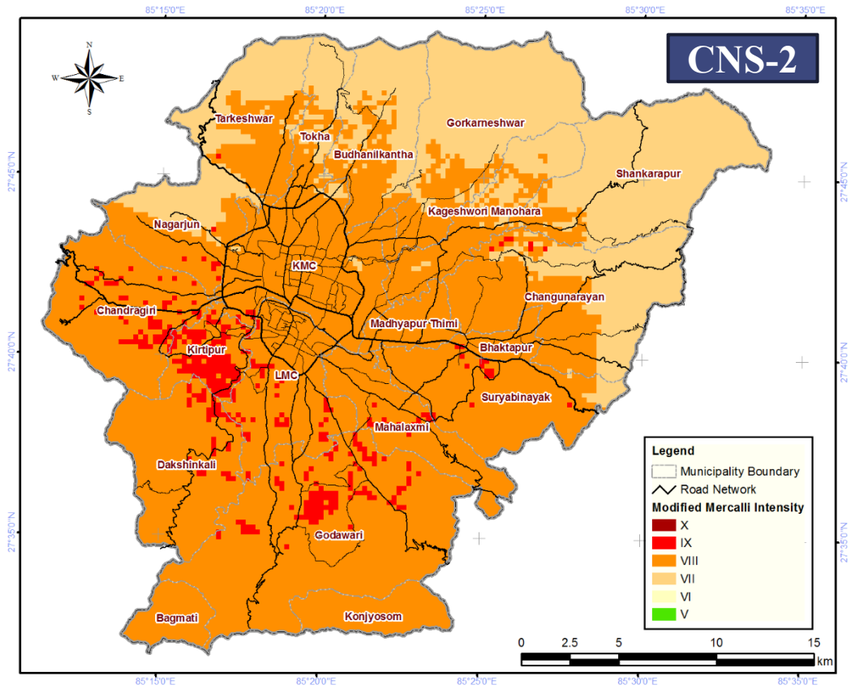

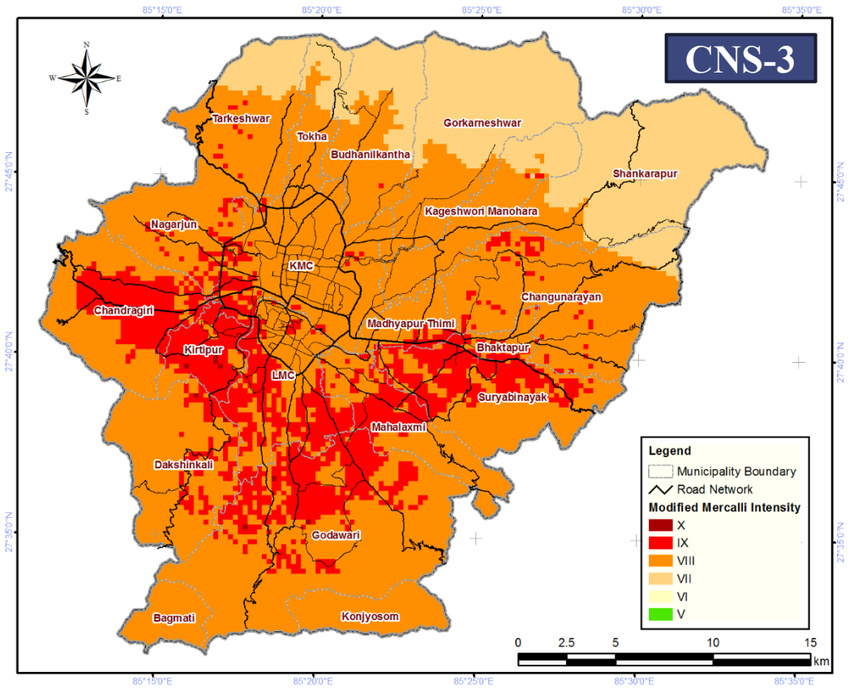

B-13

Seismic Intensity (MMI) Distribution

Note:

- First, the earthquake motion of scenario earthquake at bedrock (Vs=600m/sec) was calculated using existing Ground Motion Prediction Equation.
- Second, ground model for response analysis is constructed by drilling log, geomorphology map, microtremor survey, etc. in this project.
- Then, amplification of the ground is evaluated by one dimensional response analysis (SHAKE), based on the ground model above.
- Seismic Intensity in the MMI scale is estimated from existing empirical relation with PGA.

Source:

- Seismic Intensity (MMI): ERAKV 2016
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin: 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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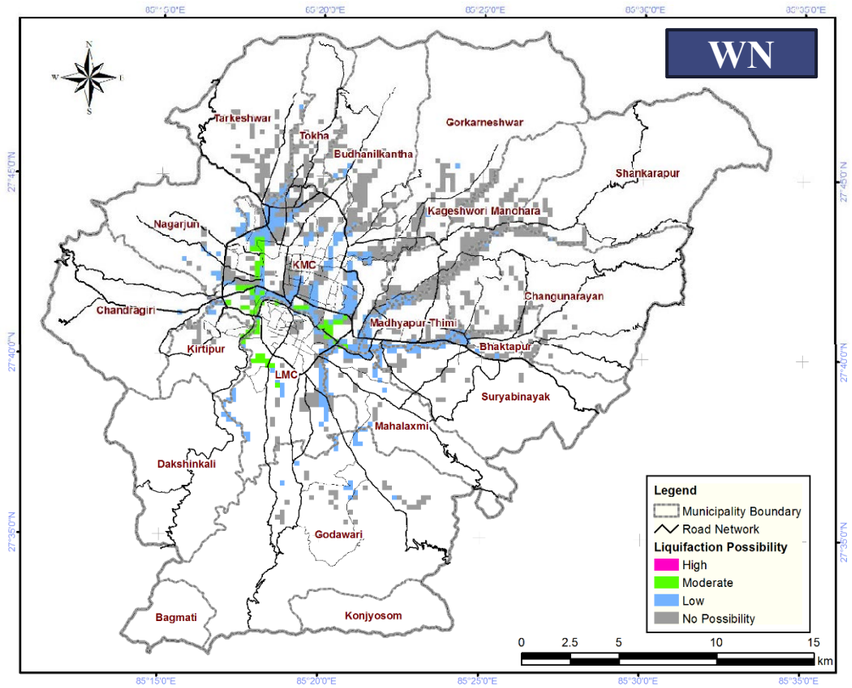
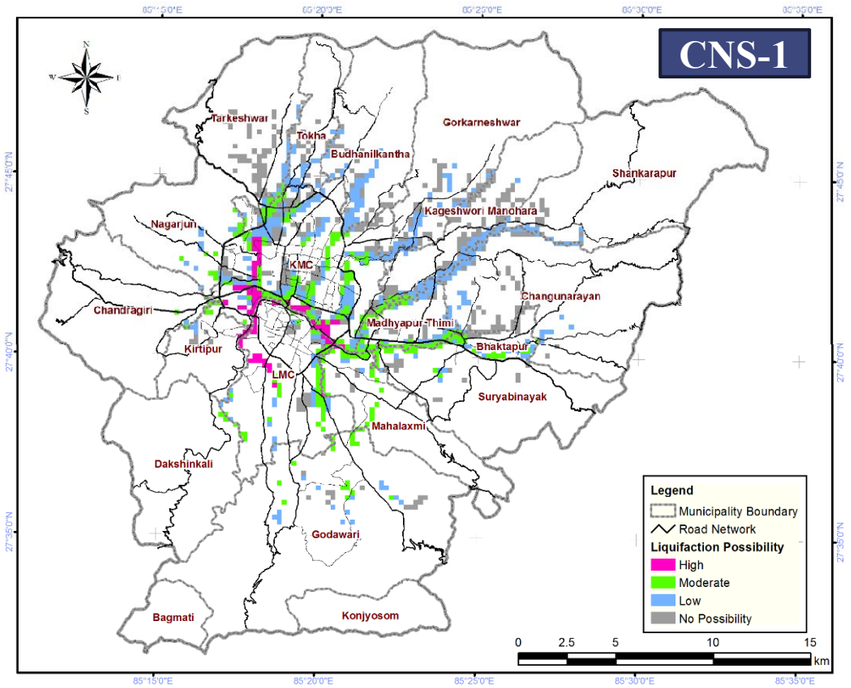
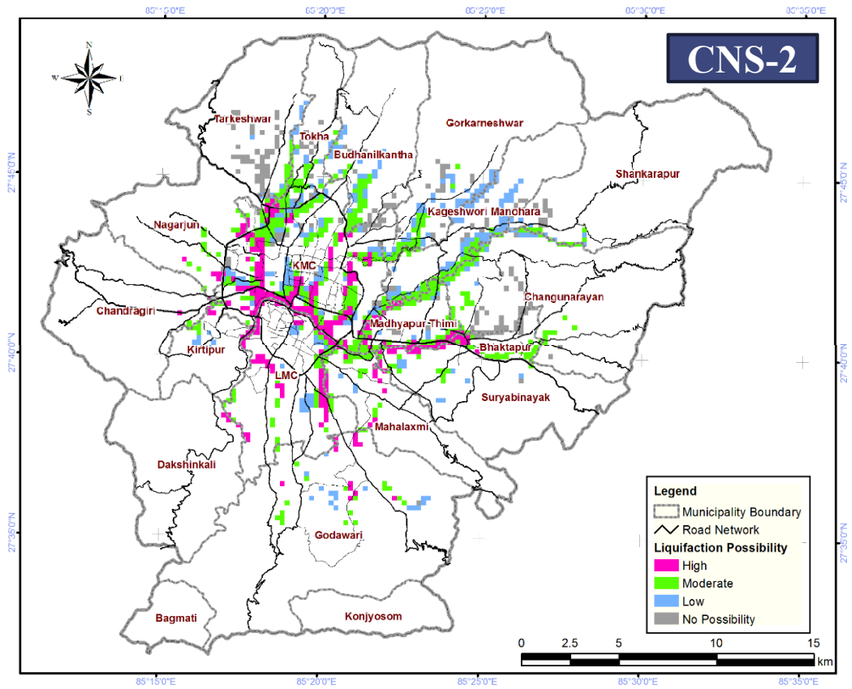
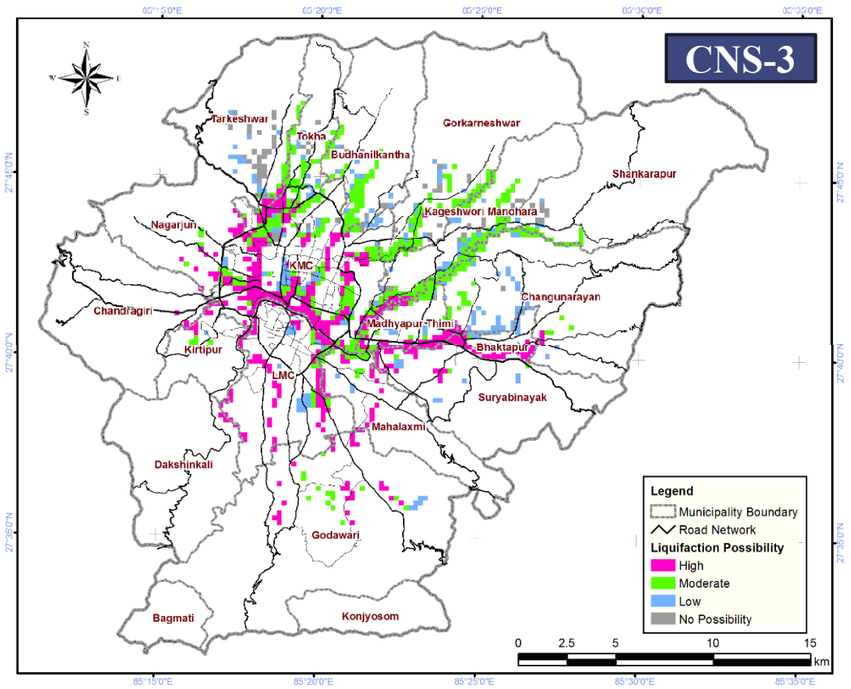
for the Kathmandu Valley in Nepal









B-14

Distribution of Estimated Liquefaction in Rainy Season

Note:

- The liquefaction was evaluated using geomorphological map, boreholes with N values, groundwater level, and results of J-RAPID, and also taking into consideration of the history of liquefaction.
- These maps show the liquefaction possibility in Rainy Season, namely ground water level is high.

Source:

- Assessment Result of Liquefaction: ERAKV 2016
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin: 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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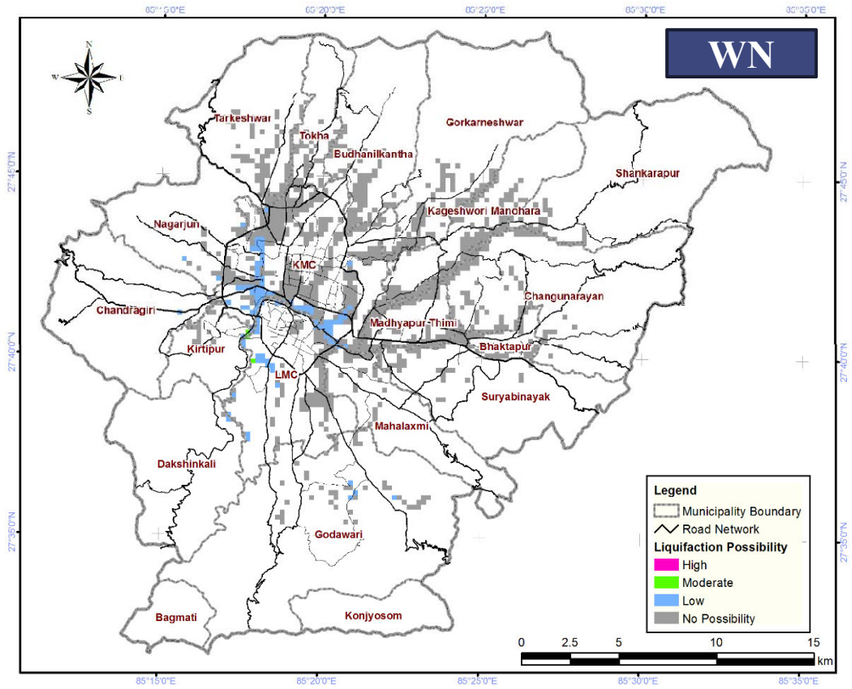
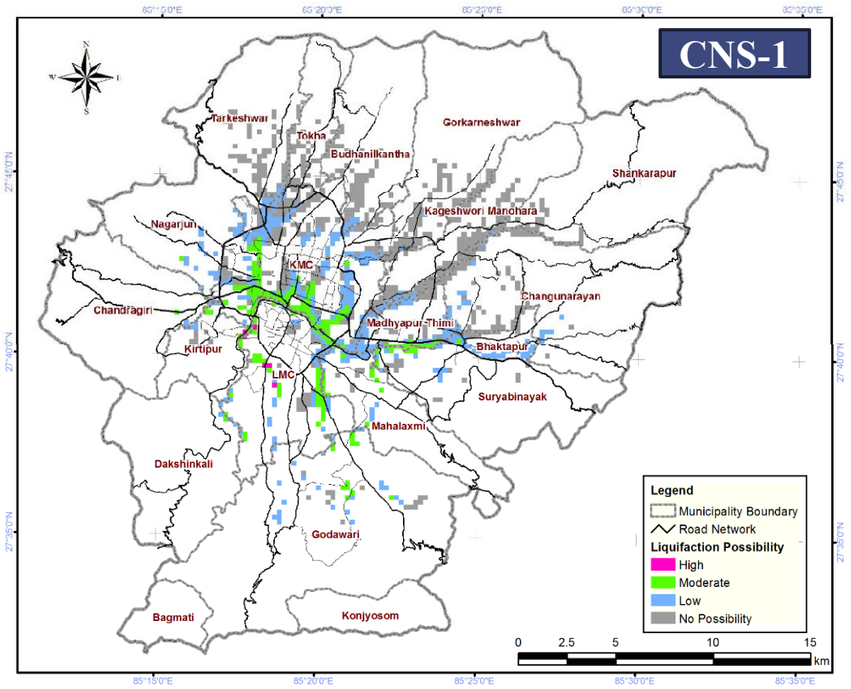
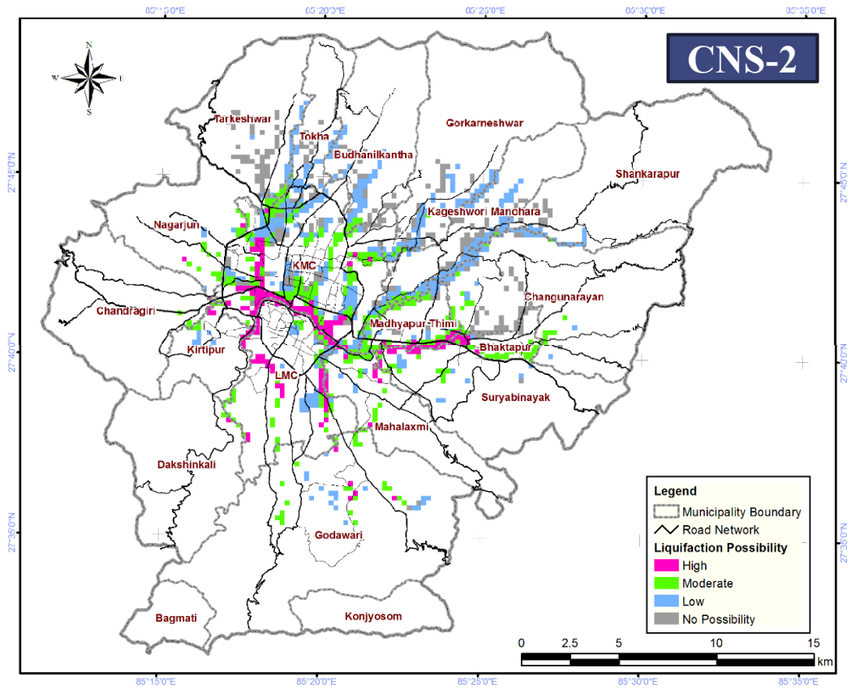
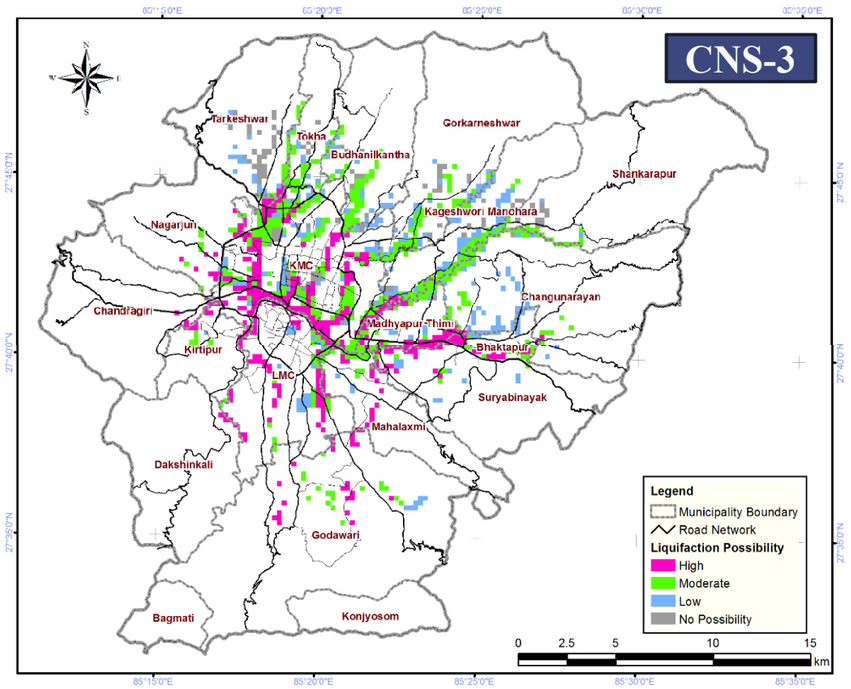
for the Kathmandu Valley in Nepal









B-15

Distribution of Estimated Liquefaction in Dry Season

Note:

- The liquefaction was evaluated using geomorphological map, boreholes with N values, groundwater level, and results of J-RAPID, and also taking into consideration of the history of liquefaction.
- These maps show the liquefaction possibility in Dry Season, namely ground water level is low.

Source:

- Assessment Result of Liquefaction: ERAKV 2016
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin: 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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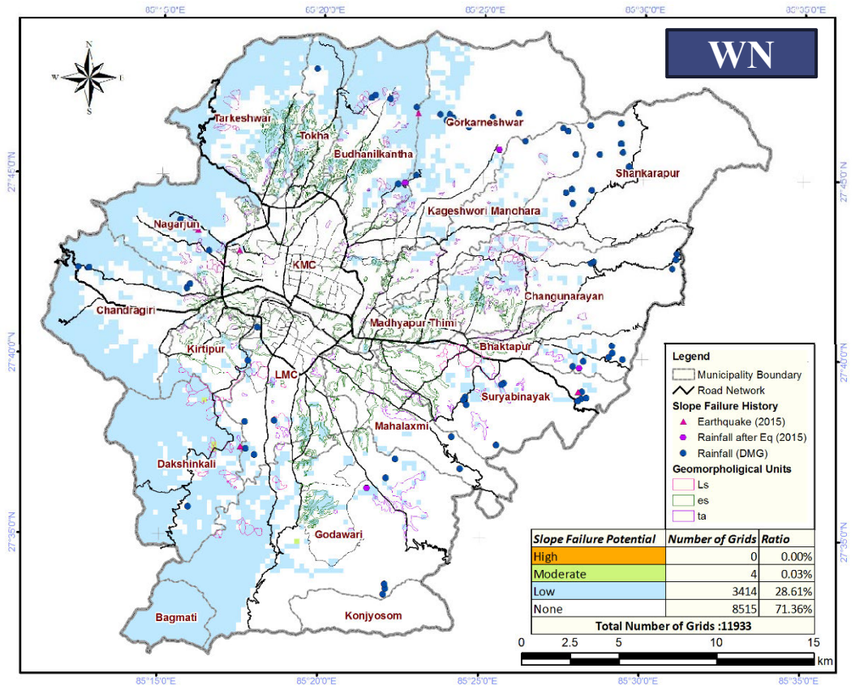

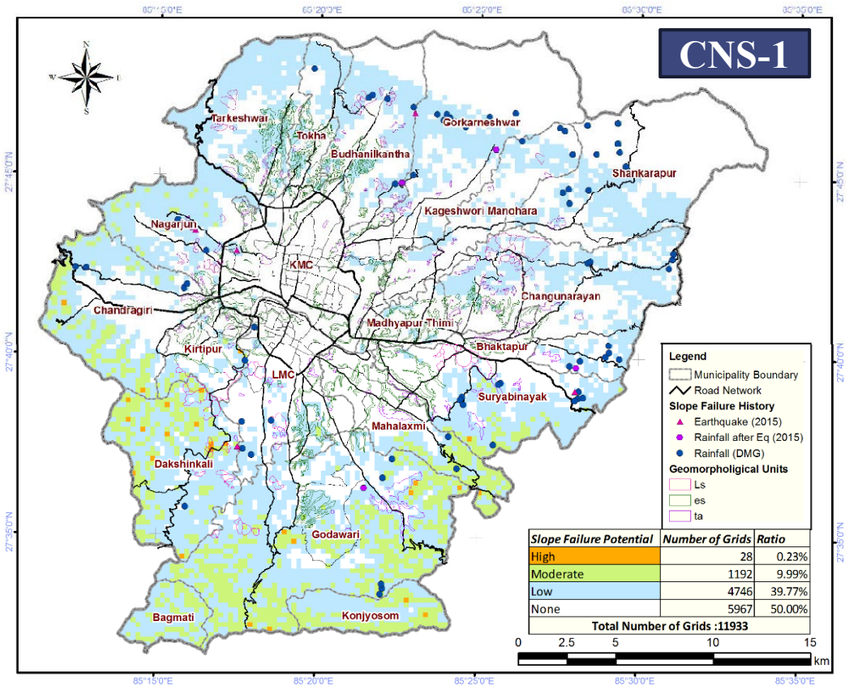

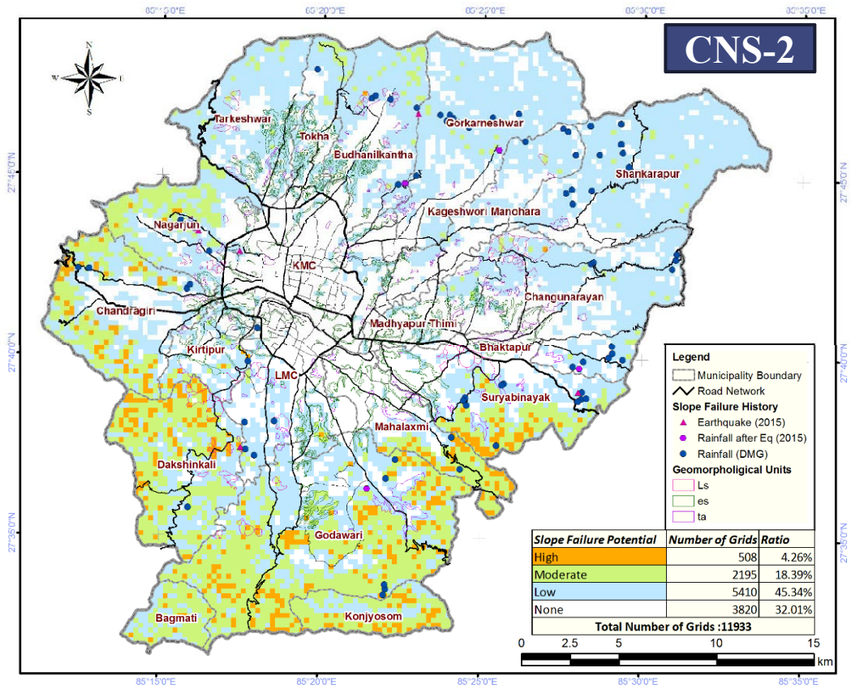

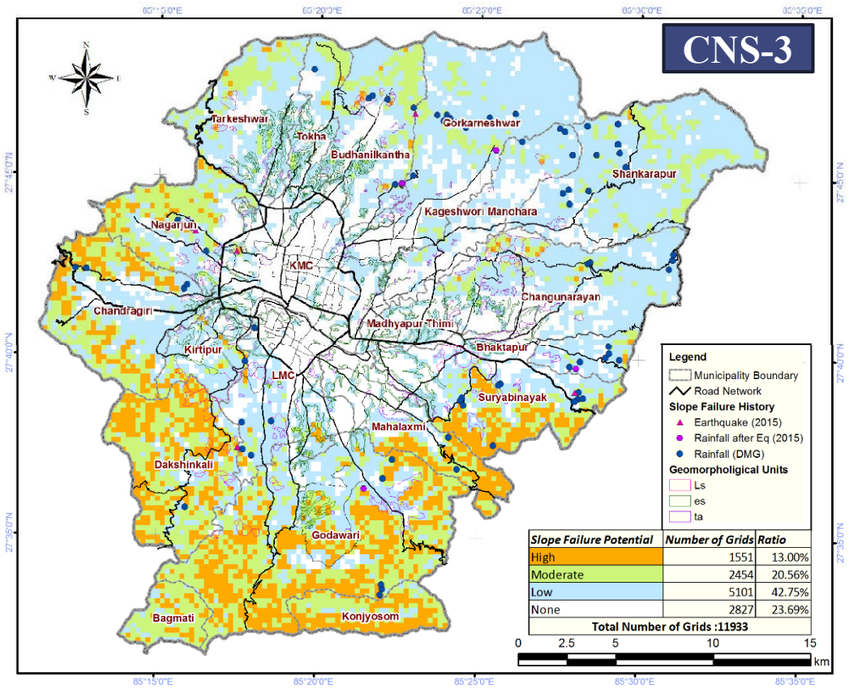

B-16

Distribution of Estimated Earthquake Induced Slope Failure

Note:

- For the evaluation of the earthquake induced slope failure, slope angle, geology, history of slope failure are taken into consideration and the peak ground acceleration is used. The physical soil properties of slopes are estimated.

Source:

- Assessment Result of Slope Failure: ERAKV 2016
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin: 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
Prime Meridian: .....Greenwich (0.0)
Datum: .....D_WGS_1984
Spheroid: .....WGS_1984

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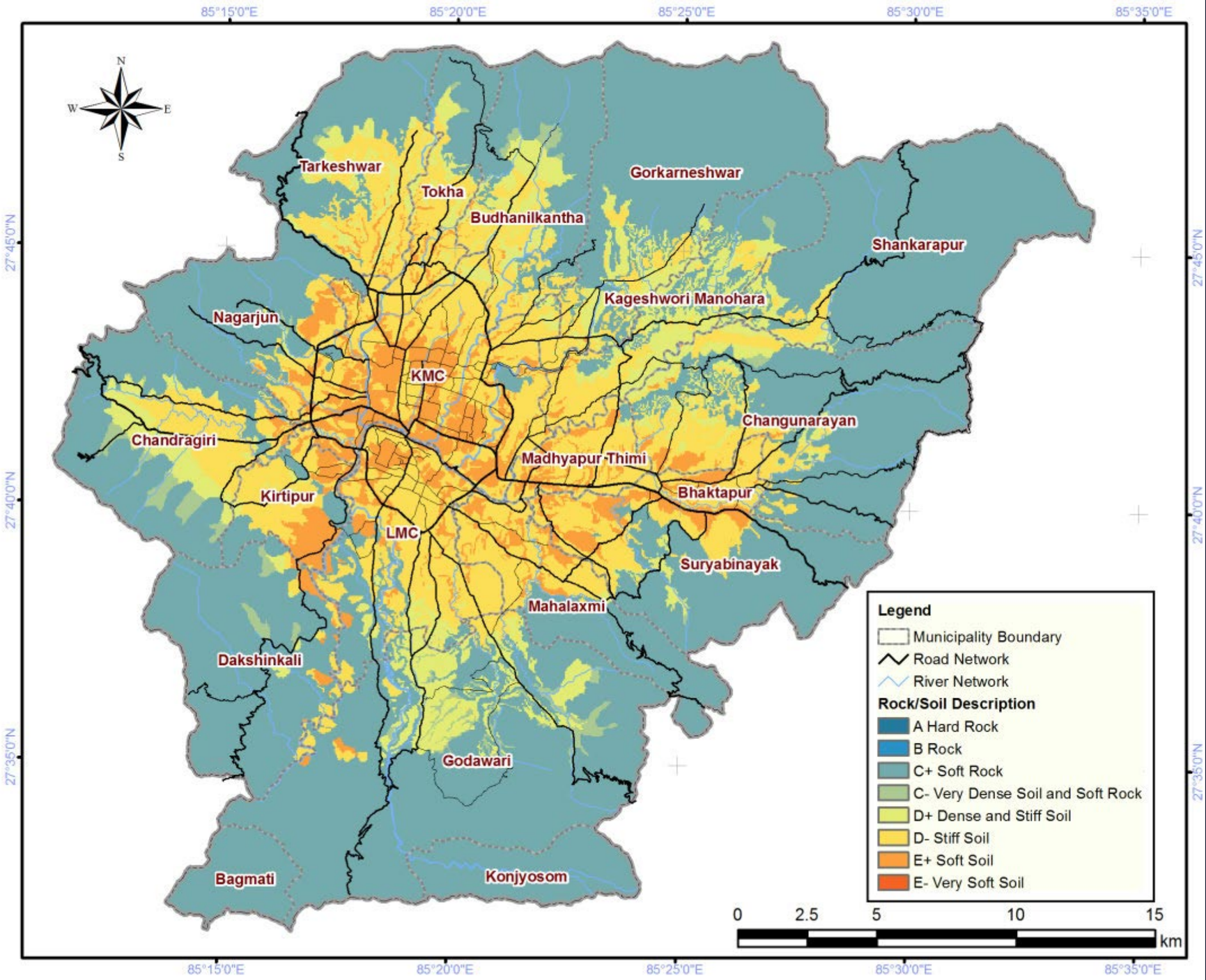

B-17

AVS30 Map based on Geomorphological Unit

Note:

- The geomorphological map has significantly contributed not only to the ground modelling, but also to the understanding of origin, process and distribution of ground formation. In this project, by combining the geomorphological map and a variety of survey results, the maps were developed that show the softness of ground, vulnerability related to liquefaction and slope failure.
- Specifically, to organize the results of AVS30 obtained from the L-shaped array measurement of microtremor described below (where AVS30 is the average value of the S-wave velocity to a depth of 30m from the surface) for each geomorphological unit, together with the relationship with altitude, AVS30 map or the surface soil softness map, namely “Shakability” map, was developed.

Source:

- AVS30 map base on geomorphological unit: ERAKV 2016
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin:.....0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree .....(0.0174532925199433)
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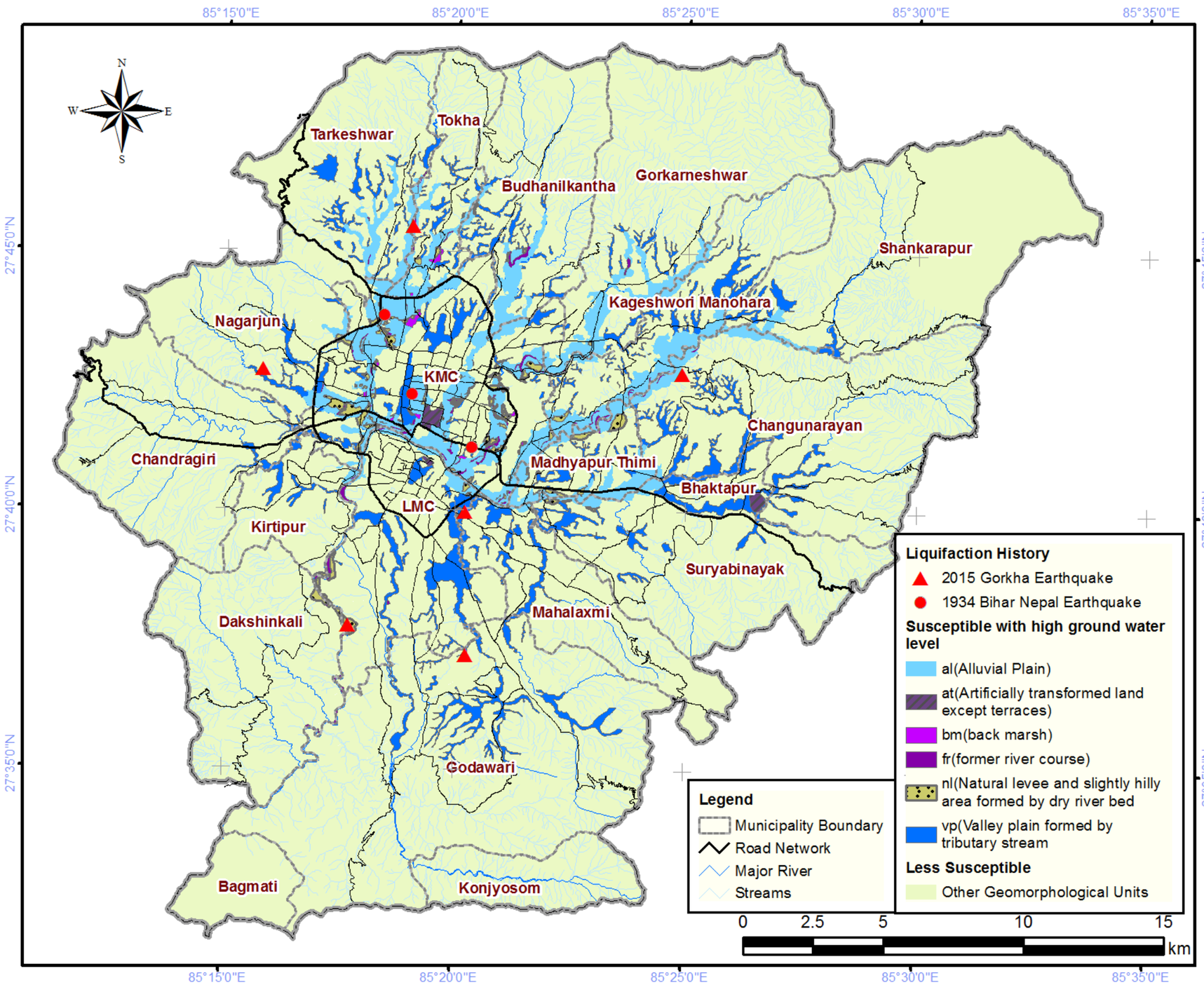

B-18

Liquefaction Susceptibility Map

Note:

- The geomorphological map has significantly contributed not only to the ground modelling, but also to the understanding of origin, process and distribution of ground formation. In this project, by combining the geomorphological map and a variety of survey results, the maps were developed that show the softness of ground, vulnerability related to liquefaction and slope failure.
- The liquefaction susceptibility map with the past liquefaction history was prepared. This susceptibility map should be valid map for taking advantage as basic information at the time of grasping the ground situation of the entire Valley, or development planning, setting land use unit.

Source:

- Liquefaction Susceptibility Map: ERAKV 2016
- Boundary of Municipality and Ward: DoS, MoFALD
  Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin: 0.0
Linear Unit: Meter (1.0)

Geographic Coordinate System: GCS_WGS_1984
Angular Unit: Degree ..... (0.0174532925199433)
Prime Meridian: ..... Greenwich (0.0)
Datum: ..... D_WGS_1984
Spheroid: ..... WGS_1984

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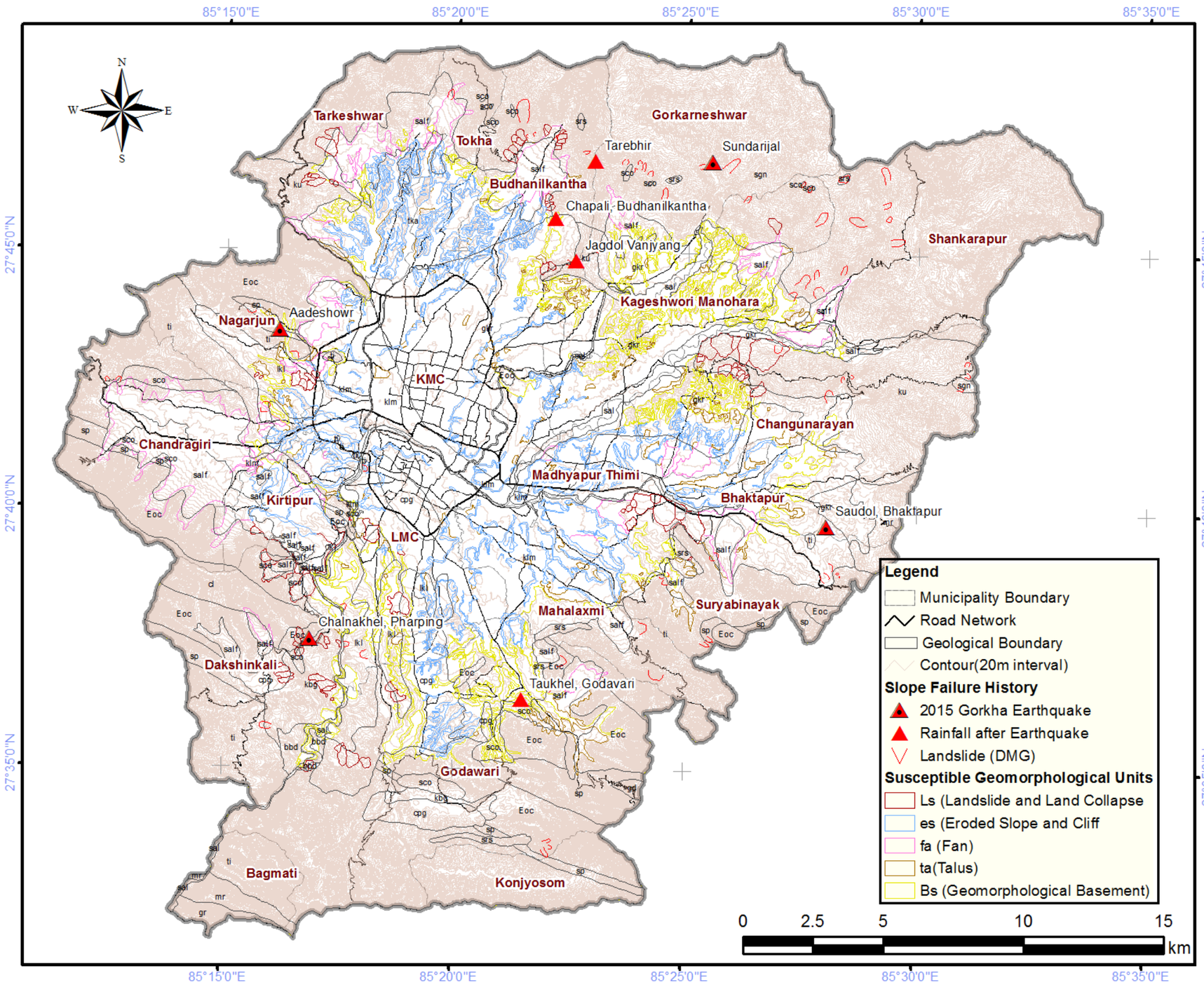

B-19

Earthquake Induced Slope Failure Susceptibility Map

Note:

- The geomorphological map has significantly contributed not only to the ground modelling, but also to the understanding of origin, process and distribution of ground formation. In this project, by combining the geomorphological map and a variety of survey results, the maps were developed that show the softness of ground, vulnerability related to liquefaction and slope failure.
- Earthquake induced slope failure susceptibility map considering slope angle, geomorphological unit, the history of slope failure and the inclination was developed. This susceptibility map should be valid map for taking advantage as basic information at the time of grasping the ground situation of the entire Valley, or development planning, setting land use unit.

Source:

- Earthquake induced slope failure Susceptibility Map: ERAKV 2016
- Boundary of Municipality and Ward: DoS, MoFALD
- Road Network: DoR, DoLIDAR
- River Network: 2002 JICA Project, UN OCHA Project

WGS_1984_UTM_Zone_45N

Projection: Transverse_Mercator
false_easting: 500000.0
false_northing: 0.0
central_meridian: 87.0
scale_factor: 0.9996
latitude_of_origin: 0.0
Linear Unit: Meter (1.0)

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