Ministry of Disaster Management and Relief

ATLAS

SEISMIC RISK ASSESSMENT OF BANGLADESH

For Bogra, Dinajpur, Mymensingh, Rajshahi, Rangpur and Tangail City Corporation/ Paurashava Areas, Bangladesh

Ministry of Disaster Management and Relief (MoDMR)

Atlas
Seismic Risk Assessment of Bangladesh
for Bogra, Dinajpur, Mymensingh, Rajshahi, Rangpur and Tangail
City Corporation / Paurashava Areas, Bangladesh

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MESSAGE

Due to the geological set-up Bangladesh is under tremendous threat of impending devastating earthquake that could be generated from any of the regional active faults, located within the country and/or its immediate vicinity. Rapidly growing of urban population, proliferation of high density unplanned urban agglomerations and, ill designed and poorly constructed urban dwellings and infrastructure are having compounding effects on the urban disaster vulnerability landscape to a great extent. In the backdrop of such a situation, it is a very timely initiative by CDMP II, a programme of Ministry of Disaster Management and Relief, to commission earthquake risk assessment of major cities and paurashavas of Bangladesh and publishing this Atlas on "Seismic Risk Assessment of Bangladesh" compiling outputs of the assessments undertaken in this regard.

In Bangladesh our response towards any imminent earthquake disaster mainly would be to increase our preparedness to a level so that vulnerabilities of city dwellers and city infrastructure are reduced, and resilience of individuals, communities and above all local government institutions are increased. These can be achieved through information sharing, awareness raising and capacity building of relevant institutions.

CDMP's investment in generating scientific information on earthquake risk assessment had been substantial over the years and the sheer amount of information generated had been tremendous. This Atlas, a compiled handy form of information generated, could be used for ready references in decision making, planning and designing of risk reduction interventions, in scientific research, in city and infrastructure management, and above all in the awareness building of city dwellers. All of these would lead to the building of resilient urban space and also of resilient urban communities.

I would like to take this opportunity to thank both national and international professionals who worked relentlessly to publish this very valuable document for the country.

Mesbah ul Alam
Secretary
Ministry of Disaster Management and Relief (MoDMR)

MESSAGE

It is really very pleasing to know that Comprehensive Disaster Management Programme (CDMP II), has taken initiative to publish an Atlas on "Seismic Risk Assessment in Bangladesh" compiling results of the assessments undertaken in 6 major cities and paurashavas of Bangladesh. This is in fact the first of its kind in Bangladesh produced from very comprehensive scientific studies conducted over last four years.

Bangladesh is an earthquake prone country, due its proximity to major regional faults and underlying physical, social and economic vulnerabilities. Risk of any impending earthquake is increasing for the urban centers of the country in every passing moment. Taking appropriate preparedness measures to minimize the devastating effects of any impending earthquake is high on the agenda of the Government of Bangladesh. However, in designing and implementing appropriate interventions on earthquake risk reduction the necessity of having scientific information had been a long overdue. CDMP's current initiative of publishing this atlas therefore could be viewed as a right step towards a right direction.

Department of Disaster Management is one of the implementing arms of the Ministry of Disaster Management and Relief for dealing with disaster management activities in Bangladesh. The department has a network of professionals working across the country. This very important knowledge product will definitely help its professionals to take risk- informed decisions in their everyday businesses. Besides, since DDM is the safe depository of disaster management related knowledge products and documents, and, is the institutional memory for MoDMR, this valuable document will be an important inclusion which could be used for a ready reference for the researchers and professionals.

I would encourage planners, development professionals and all concerned citizens to make best use of this atlas, so that, working together we can make our cities and towns more resilient.

I express my heartfelt thanks to UNDP and other development partners for supporting CDMP II to conduct various high quality studies, and specially, on earthquake risk assessment of 6 very vulnerable cities and paurashavas of Bangladesh and to publish this very valuable Atlas.

Mohammad Abdul Wazed
Director General(Additional Secretary)
Department of Disaster Management (DDM)

PREFACE

Bangladesh is recognized as one of the most vulnerable countries of the world with regard to earthquake disaster due to its geographical location, unabated and unplanned growth of urban settlements and infrastructure, and ever increasing urban population. Current trend of urbanization is likely to increase earthquake vulnerability of the country, specifically to major urban centers, located very close to the major active faults of the region to many folds.

Comprehensive Disaster Management Programme of Ministry of Disaster Management and Relief for the first time in the country initiated comprehensive earthquake risk assessment during its phase I and continued the endeavor in phase II which is designed and being implemented to reduce Urban Disaster Risks. A wide range of high quality scientific studies, including earthquake Hazard Identification, Risk and Vulnerability Assessment, Risk Informed Landuse and Contingency Planning have been conducted by the eminent national and international professionals, and well reputed agencies from home and abroad. The Atlas on "Seismic Risk Assessment in Bangladesh" for 6 highly vulnerable cities/ paurashavas of Bangladesh is a consolidated output of all these efforts.

The Atlas has been developed with the intention of assisting the policy makers, government officials, planners at various Ministries and Departments, academicians and researchers, house owners and developers to understand the earthquake vulnerabilities of respective cities and paurashavas of the country, which would enable them to take risk informed decisions for planning, designing and constructing urban infrastructure to reduce urban disaster risk to a great extent.

I firmly believe this Atlas would contribute immensely to the existing national knowledge pool on seismic hazard and related vulnerabilities in Bangladesh. Besides, at practitioners' level it would help in taking pro-active and targeted preparedness initiatives, which are needed to achieve our much cherished dream of 'paradigm shift' (from response to risk reduction) in disaster management of the country.

I congratulate the professionals working in CDMP and other agencies for the sincere efforts they put together for publishing this Atlas.

Mohammad Abdul Qayyum
Additional Secretary &
National Project Director
Comprehensive Disaster Management Programme (CDMP II)

ACKNOWLEDGEMENT

Comprehensive Disaster Management Programme II (CDMP II) acknowledges the contribution and wonderful spirit of cooperation from all concerned strategic partners of CDMP II, particularly the Asian Disaster Preparedness Center (ADPC) for the successful completion of the Atlas on "Seismic Risk Assessment in Bangladesh" describing the underlying threat, vulnerability, risk and potential damage due to earthquake in Rajshahi, Rangpur city corporation and Bogra, Dinajpur, Mymensingh, and Tangail Paurashava areas.

Special thanks are due to Mohammad Abdul Qayyum, Additional Secretary and the National Project Director of CDMP II, and, the Urban Risk Reduction Team of CDMP II for their continuous following up, guidance and advice to ensure that the Atlas is of a high standard.

The Atlas development process was inspired by MoDMR. Continuous encouragement from UNDP had always been there. Technical guidance from the Technical Advisory Group, and contribution of a good number of national and international professionals, who worked hard on the assignment, had been very instrumental in the development and publishing of this Atlas, and, is appreciated. CDMP II also recognizes the contribution and support from respective City Corporations and Paurashavas.

It is important to note that this Atlas is a living document, and, therefore, there is an expectation of further improvement in future based on continuous research in many relevant disciplines.

It is now hoped and expected that intended end user of the atlas, the planners, engineers and developers, working in these six cities will apply the knowledge in pursuit of a safer Bangladesh.

Peter Medway
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FROM EDITOR'S DESK

Urbanization has a great influence on the role disaster risk plays across the world. In the low and lower-middle income countries, new urban development is increasingly more likely to occur on hazard prone land, namely, in floodplains and other low-lying areas, along fault lines, and on steep slopes. In addition to settling in hazard prone areas, much of the building construction that occurs is unregulated and unplanned, placing vulnerable populations, who settle on hazard prone land, at increased risk. Bangladesh is no exception to these trends. Since the country is projected to experience rapid urbanization over the next several decades, it is imperative for the policy makers and urban managers to plan for new urban developments with proper integration of disaster risk information and pertinent risk management options into the urban planning and construction processes. In recent years, Bangladesh has made significant progress in integrated flood management throughout the country. There is however, increasing disaster risk for other hazards like Earthquakes. Since most of the major cities in Bangladesh are growing rapidly without proper development control, the anticipated risk for the people and infrastructure are gradually increasing. It is within this context the MoDMR along with the project partners of CDMP II saw the need to develop a Seismic Risk Assessment for growing urban areas in Bangladesh. The project, Seismic Risk Assessment for the Six Major Cities and Municipalities (i.e. Bogra, Dinajpur, Mymensingh, Rajshahi, Rangpur and Tangail) in Bangladesh is the first major step towards identifying the potential earthquake risks for the major cities and devise possible planning and preparedness initiatives towards Disaster Risk Reduction (DRR). The project has several outputs including earthquake hazard, vulnerability and risk assessment; earthquake scenario development; scenario based spatial Contingency Plan preparation; capacity building of different stakeholders, and community development for earthquake preparedness. This Atlas mainly presents the summary of the assessments findings of different components under the project. Main objective of the Atlas is to provide decision makers, and, city planners and managers with a compiled and handy set of information on the existing situation of the respective sectors in the cities in terms of vulnerability and risk to facilitate more informed and effective development decision making.

Current initiative of Seismic Risk Assessment includes a comprehensive and scientific assessment of seismic hazard that is looming on to these cities, their vulnerabilities and risks, and above all, portraying of probable damage scenario that could be experienced by these cities in case of any impending earthquake. These assessments are expected to help in reducing underlying risk factors for these cities, promoting the preparedness initiatives and enhancing emergency response capabilities of the key GOB organizations, humanitarian aid agencies, development partners, decision makers, and above all, in increasing awareness of city dwellers. The assessment results are expected to be further integrated into the physical planning process of these cities in future, and would also provide useful inputs into construction regulation and practices in order to develop risk resilient built environment. State of the Art technologies and methodologies have been used to assess the seismic hazard, vulnerabilities and risks of the cities and municipalities under the current project. In order to perform rigorous seismic hazard analysis, all available knowledge of the historical earthquake, tectonic environment, and instrumental seismic data were gathered to predict the strong ground shaking in future earthquakes. This was done to determine appropriate earthquake ground motion parameters for seismic mitigation. In this study probabilistic assessment of two ground motion parameters, namely, horizontal Peak Ground Acceleration (PGA) and Spectral Acceleration (SA) values at 0.2 and 1.0 s with the return periods of 43, 475, and 2475 years were conducted. However, in this Atlas Scenario of 475 year return period, which is recommended as design base for National Building Code, is presented. A good number of geotechnical and Geophysical investigations were conducted for preparation of Engineering Geological Map, soil liquefaction maps for seismic hazard Assessment and for damage and loss estimation. The investigations include Boreholes with SPT, PS Logging, MASW and SSM, Microtremor Array and Single Microtremor.

Damage and risk assessment for seismic hazard provide forecasts of damage and human and economic impacts that may result from earthquake. Risk assessments of general building stock, essential facilities (hospitals, emergency operation centers, schools) and lifelines (transportation and utility systems) using the HAZUS software package were conducted in this study. HAZUS was developed by the United States' Federal Emergency Management Agency (FEMA) and National Institute of Building Sciences (NIBS). It is a powerful risk assessment software program for analyzing potential losses from disasters on a regional basis. For risk assessment analyses of the six City Corporation /Paurashava areas, defaults databases for the United States were replaced with Bangladesh databases of the 6 cities/municipalities. Reputed experts from both home and abroad, under the guidance of very well-known and reverend group of professionals of the country in the Technical Advisory Group for the project, worked relentlessly for years to generate scientific information required for these assessments. Information generated were duly cross checked and scientifically verified. This atlas contains altogether 5 Chapters. Unlike traditional atlases, a brief description on natural disasters in Bangladesh and a general over view of disaster management of the country, discussed in chapter one would help readers to understand seismic risk assessment and management in context of entire gamut of disaster management of the country. Geological setting, seismic hazard and history of seismicity in Bangladesh-issues described in chapter two would provide readers with a clear view of seismic activities, their origins and hazard potentials in and around the country. Chapter three, the major part of the atlas, presents seismic vulnerability and risk assessment results of 6 cities/ municipalities along with a brief discussion on Initiatives taken so far on seismic research in Bangladesh and methodology adopted in the current study for seismic hazard, vulnerability and risk assessment. Chapter four presents different preparedness initiatives, like preparation of Spatial Contingency Plan, simulation drill, capacity building initiatives, so far been taken by the Government of Bangladesh. These would help raising awareness among local government officials, change agents, CBOs and the communities on preparedness initiatives and devising right kind of interventions to be taken for any impending seismic disaster. Chapter Five describes the way forward for future initiatives with regard to seismic preparedness for the country.

Along with this Atlas a good number of different reports have been produced under the current initiative of CDMP II. All these reports are available at e-library of CDMP II and available at its website (www.dmic.org.bd/e-library). Maps presented in this document can be used as reference only, for more detail, it is however, recommended to consult main reports.

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INFORMATION ABOUT THE PROJECT

The project "Seismic Risk Assessment in Bangladesh" was initiated by the Comprehensive Disaster Management Programme (CDMP) under the Ministry of Disaster Management and Relief (MoDMR) of the Government of the Peoples' Republic of Bangladesh. The Programme is funded by the United Nations Development Program (UNDP), European Union (EU), Norwegian Embassy, UKaid, Swedish Sida and Australian Aid. The overall study has been implemented in two phases respectively during CDMP I (2007-2009) and CDMP II (2012-2014). Main objectives of the project had been to understand the prevailing Earthquake Hazard in the national context, to understand the vulnerability and risk related to earthquake for the major cities of the country and to undertake initiatives for earthquake preparedness and capacity building in accordance with requirements at four different levels, viz., National, City, Community and Agency levels. The project specifically addressed following issues:

- Earthquake hazard, vulnerability and risk assessment for the major cities in Bangladesh.
- Preparation of earthquake Contingency Plan for National, City, Agency and Community levels based-on the scenarios developed from risk assessment results.
- Training and capacity building activities focusing different target groups like student and teachers, mason and bar binders, religious leaders, decision makers, first responding agencies in different cities in Bangladesh.
- Development of Risk Communication Strategy based on the risk assessment case studies, carried out for different cities using modern technologies and approaches.

PROJECT PARTNERS

The Project was implemented by the Asian Disaster Preparedness Center (Center) Thailand in association with OYO International Corporation Japan, Asian Institute of Technology (AIT) Thailand, National Society for Earthquake Technology (NSET) Nepal and Data Experts Limited (datEx) Bangladesh. The project was also supported by the Department of Disaster Management (DDM), Geological Survey of Bangladesh (GSB), Urban Development Directorate (UDD), Bangladesh Fire Service and Civil Defense (BFSCD), Dhaka University, Bangladesh University of Engineering and Technology (BUET), Chittagong University of Engineering and Technology (CUET), Rajshahi University of Engineering and Technology (RUET), Dhaka North City Corporation (DNCC), Dhaka South City Corporation (DSCC), Chittagong City Corporation (CCC), Sylhet City Corporation (SCC), Rajshahi City Corporation (RCC), Rajshahi Development Authority (RDA), Rangpur City Corporation (RpCC), Mymensingh Paurashava, Dinajpur Paurashava, Tangail Paurashava and Bogra Paurashava.

adpc   datEx DATA EXPERTS   OYO   NSET

ABOUT THE ATLAS

This atlas contains basic information on the hazards and disaster management system in Bangladesh. Main focus of the atlas is on the Earthquake history in the country and the region, earthquake hazard in context of the country, earthquake vulnerability and risk with regard to population, infrastructure, building, emergency facilities in six major cities / Paurashavas with potential damage and loss estimation.

Main objective of the Atlas is to facilitate the decision makers with the information on the existing situation of the respective sectors in the cities in terms of vulnerability and risk. The study on Seismic Hazard assessment considered Probabilistic Assessment in terms of PGA at 43, 475, and 2475 year return periods. Two Scenarios have been developed for each of the return period. However, for this Atlas Scenarios of 475 year return period, which is recommended as design base for Building Code, has been presented. Different type of exposure Maps have been developed for all the cities under the project. Scenario maps (i.e.; concrete & masonry building damage, liquefaction susceptibility, infrastructure damage maps etc.) have been developed based on the risk assessment tools used for the project. Besides, different initiatives for earthquake risk reduction and enhance disaster preparedness in case of any imminent earthquake, taken so far through CDMP II of MoDMR, have also been briefly discussed in this Atlas.

This Atlas will assist the government departments for taking preparation for the improvement of Earthquake Risk Management system in the respective cases. It will also provide useful input to the formulation of policies and regulations to relevant sectors and their proper implementation.

List of Abbreviations

ADPC	Asian Disaster Preparedness Center
AFD	Armed Forces Division
AIT	Asian Institute of Technology
ASCE	American Society of Civil Engineers
BDRCS	Bangladesh Red Crescent Society
BFSCD	Bangladesh Fire Service and Civil Defence
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CCC	Chittagong City Corporation
CCDMC	City Corporation Disaster Management Committee
CDMP	Comprehensive Disaster Management Programme
CHTDF	Chittagong Hill Tracts Development Facility
CPPIB	Cyclone Preparedness Programme Implementation Board
CPP	Cyclone Preparedness Programme
CSDDWS	Committee for Speedy Dissemination of Disaster Related Warning/Signals
DatEx	Data Experts Limited
DDM	Department of Disaster Management
DDMC	District Disaster Management Committee
DFID	Department for International Development
DMTATF	Disaster Management Training and Public Awareness Building Task Force
DM&RD	Disaster Management & Relief Division
DNCC	Dhaka North City Corporation
DSCC	Dhaka South City Corporation
ECRRP	Emergency 2007 Cyclone Recovery and Restoration Project
EPAC	Earthquake Preparedness and Awareness Committee
ESRI	Environmental Systems Research Institute
EU	European Union
FEMA	Federal Emergency Management Agency
FPOCG	Focal Points Operational Co-ordination Group
GIS	Geographic Information System
GoB	Government of Bangladesh
GSB	Geological Survey of Bangladesh
HAZUS	Hazards United States
HFT	Himalayan Frontal Thrust
IMDMCC	Inter-Ministerial Disaster Management Coordination Committee
IPCC	Intergovernmental Panel on Climate Change
LGED	Local Government Engineering Department
MASW	Multichannel Analysis of Surface Waves
MoFDM	Ministry of Food and Disaster Management
MoDMR	Ministry of Disaster Management and Relief
NDMAC	National Disaster Management Advisory Committee
NDMC	National Disaster Management Council
NGOCC	NGO Coordination Committee
NIBS	National Institute of Building Sciences
NPDM	National Plan for Disaster Management
NPDRR	National Platform for Disaster Risk Reduction
NSET	National Society for Earthquake Technology-Nepal
OIC	OYO International Corporation
PDMC	Pourashava Disaster Management Committee
PGA	Peak Ground Acceleration
PGD	Permanent Ground Deformation
PWD	Public Works Department
RCC	Rajshahi City Corporation
RDA	Rajshahi Development Authority
RpCC	Rangpur City Corporation
RTK-GPS	Real Time Kinematic – Global Positioning System
RUET	Rajshahi University of Engineering and Technology
SA	Spectral Acceleration
SCC	Sylhet City Corporation
SOB	Survey of Bangladesh
SOD	Standing Orders on Disaster
SPT	Standard Penetration Test
SSMM	Small Scale Microtremor Measurements
SUST	Shahjalal University of Science and Technology
UDD	Urban Development Directorate
UDMC	Union Disaster Management Committee
UNDP	United Nations Development Programme
USGS	U. S. Geological Survey
UTC	Temps Universel Coordonné
UzDMC	Upazila Disaster Management Committee

Contents

CHAPTER - 01
GENERAL INTRODUCTION

1.1 Introduction

Over the past decades, urbanization in Bangladesh has been rapidly taking place without proper guidance. As a result many of the urban centers have developed haphazardly. These urban centers are fast growing and influence the economic developments of the country. It is therefore, essential to have a realistic understanding on the nature, severity and consequences of likely damage/loss that a possible event of earthquake could cause. A strong earthquake affecting major urban centers may result in damage and destructions of massive proportions and may have disastrous consequences for the entire naton.

Considering this reality, the Comprehensive Disaster management Programme (CDMP) being implemented by the Ministry of Disaster Management and Relief (MoDMR) of the Government of Bangladesh (GoB) and supported by United Nations Development Program (UNDP), European Union (EU), Norwegian Embassy, UKaid from the Department for International Development (DFID), Swedish Sida and Australian Aid, is designed to strengthen the Bangladesh Disaster Management System, and more specifically, to achieve a paradigm shift from reactive response to a proactive risk reduction culture. Asian Disaster Preparedness Center (ADPC) has been given responsibility for implementation of Seismic Risk Assessment for Major Cities in Bangladesh.This atlas presents the seismic risk assessment of Bogra, Dinajpur, Mymensingh, Rajshahi, Rangpur and Tangail Municipal Areas. Chapter one describes the project background, brief on the natural disasters and disaster management system in Bangladesh. Chapter two presents seismic hazard assessment in the country followed by the seismic vulnerability, risk assessment methodology, different scenarios and assessment results of different cities presented in Chapter Three. The results of risk assessment include: direct earthquake damage, induced earthquake damage, casualties, and economic losses to the components at risk. Chapter four describes the preparedness initiatives at different levels under this project. Chapter Five describes the way forward for future initiatives with regard to seismic preparedness for Bangladesh.

1.2 Bangladesh and Natural Disaster

Due to geographical setting Bangladesh has to receive and drain-out huge volume of upstream waters. The flows of mighty rivers the Meghna, Padma and Brhammaputra, originated from the Himalayans, drain-out in the Bay of Bengal flowing through-out the country. In the summer, from May to August, the melting of glaciers in the Himalayans makes the rivers in Bangladesh live. The rainy season, which is strongly influenced by monsoon wind from the South-West, also sets on at the same period and causes huge precipitation. Therefore, the combined effect of upstream flows, precipitation and terrestrial run-off resulted to over flooding, causing water logging and prolonged flood almost every year.

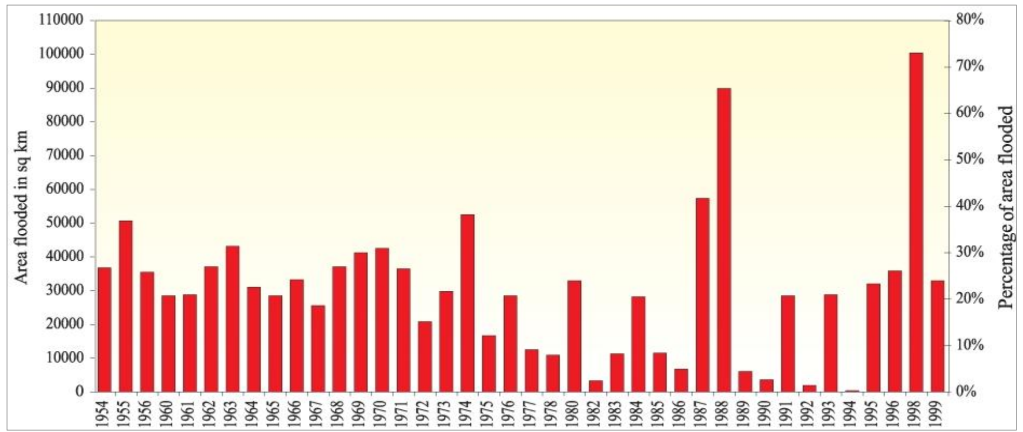


Figure 1: Intensity of floods in Bangladesh from 1954 to 1999 (Banglapedia, 2014)

On the other hand, rising sea level is causing water level rise in the rivers and thereby accelerating risks of flood and water logging. Again, as the elevation of coastal plain of Bangladesh is only 3-5 meter from the mean sea level, a vast coastal area, approximately 18% of total land, would submerge by 1 meter sea level rise according to the IPCC 4th Assessment Report (IPCC, 2007). The major reasons behind these assumptions are; a) no defense mechanism for the protection of coastal plain land and b) sea level will rise following the contour line. The problem of water logging might be more dangerous than flooding. Already many coastal places, where sustainable drainage network system has not developed, are facing water logging problem and the intensity of problem is appearing as a catastrophe day by day.

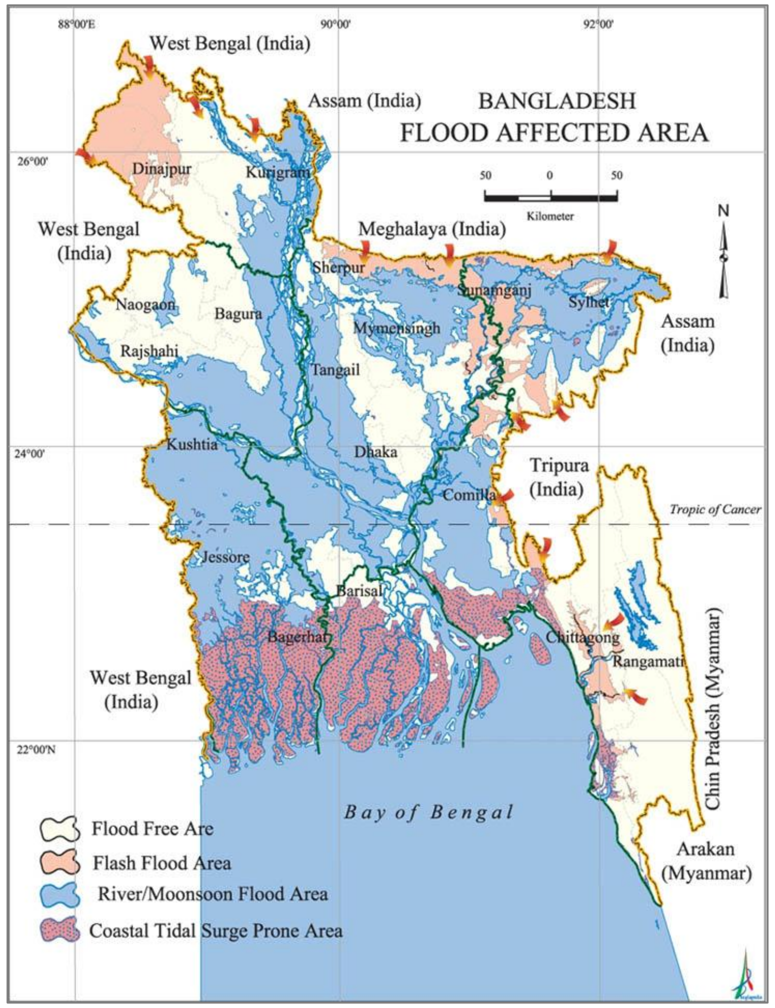


Figure 2: Bangladesh flood affected areas (Banglapedia, 2014)

The entire coastal zone is prone to violent storm and tropical cyclones during pre-monsoon and post-monsoon season. Therefore, the Bangladesh coastal zone could be termed a geographical 'death trap' due to its extreme vulnerability to cyclones and storm surges. Nearly one million people have been killed in Bangladesh by cyclones since 1820. As many as 10 percent of the world's cyclone develop in the Indian Ocean but they cause 85 percent of the world's cyclonic havoc (Gray, 1968).

The good lesion is that, death tolls due to cyclone is decreasing over the last decade due to the cyclone preparedness progeamme including warning dissemination active volunteerism and cyclone Shelters. According to UNDP (2004) among the Asian countries Bangladesh is highly prone to cyclonic disaster. The report also says, during 1980 to 2000 cyclone caused death of 250 thousand people worldwide, of which 60 percent were in Bangladesh. Although, the Philippine is more vulnerable to cyclone than Bangladesh but cyclonic death is 10 times more in Bangladesh than the Philippines.

Extreme and non-extreme weather or climate events affect vulnerability to future extreme events by modifying resilience, coping capacity, and adaptive capacity (IPCC, 2012). In particular, the cumulative effects of disasters at local or sub-national levels can substantially affect livelihood options and resources and the capacity of societies and communities to prepare for and respond to future disasters.

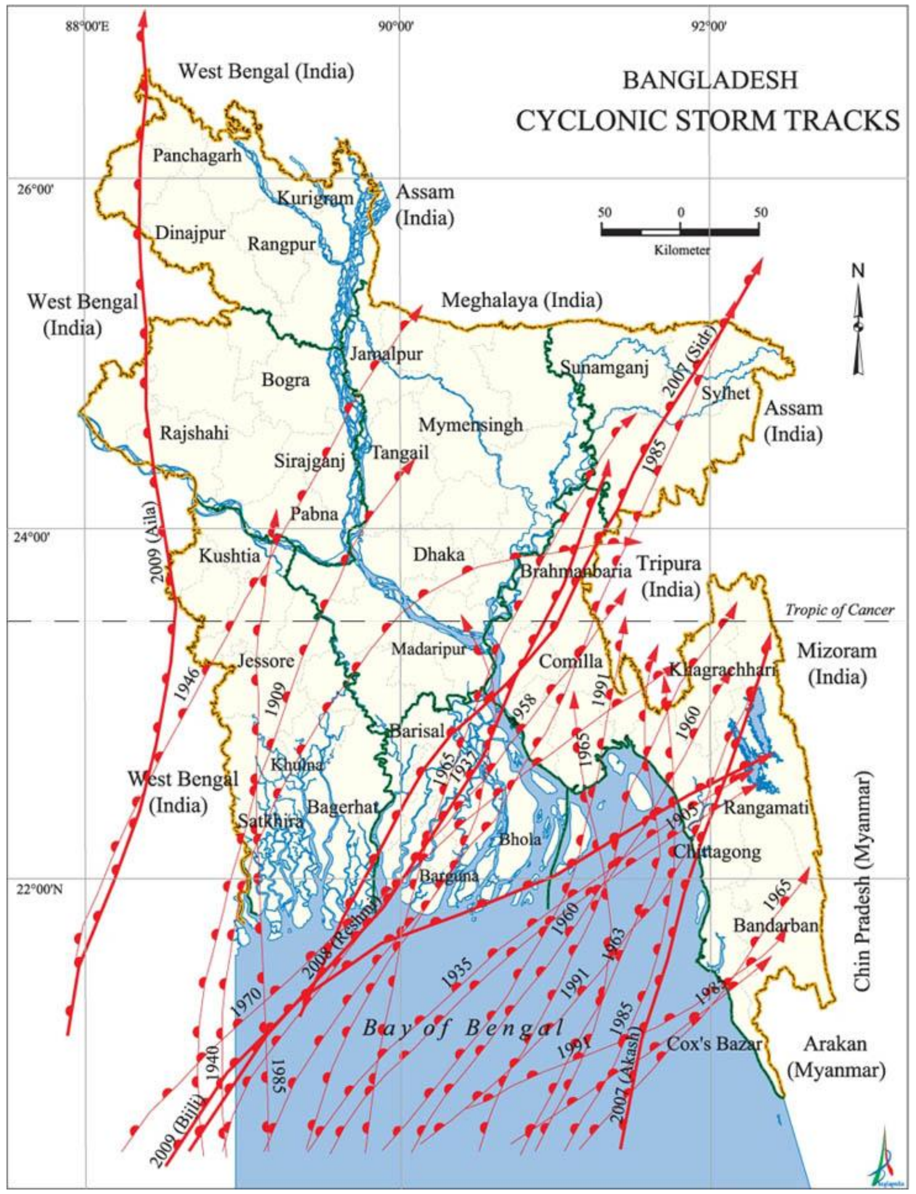


Figure 3: Historical cyclonic storm track (Banglapedia, 2014)

A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events.

Landslide in the south-eastern hilly region is another major disaster for the country. These areas have a long history of instability. Although written records of landslide incidents are very rare, they have been a hazard to people ever since they have been living there. In fact, every year especially in the rainy season landslides take place in both natural and man-induced slopes. The cause is often infiltration of water that makes the swelling soils more fluid. Major processes that cause landslides in Bangladesh are 1) removal of lateral support: (a) erosion by rivers, (b) previous slope movements such as slumps that create new slopes, (c) human modifications of slopes such as cuts, pits, and canals; 2) addition of weight to the slope: (a) accumulation of rain, (b) increase in vegetation, (c) construction of fill, (d) weight of buildings and other structures, (e) weight of water from leaking pipelines, sewers, canals, and reservoirs; 3) earthquakes ; 4) regional tilting; 5) removal of underlying support: (a) undercutting by rivers and waves; (b) swelling of clays; 6) anthropogenic activities as jhum cultivation.

Drought, a prolonged, continuous period of dry weather along with abnormal insufficient rainfall, is also another frequent disaster in Bangladesh especially for the north-west region of the country. It occurs when evaporation and transpiration exceed the amount of precipitation for a reasonable period. Drought causes the earth to parch and a considerable hydrologic (water) imbalance resulting water shortages, wells to dry, depletion of groundwater and soil moisture, stream flow reduction, crops to wither leading to crop failure and scarcity in fodder for livestock. Drought is a major natural hazard faced by communities directly dependent on rainfall for drinking water, crop production, and rearing of animals. Drought has become a recurrent natural phenomenon of northwestern Bangladesh (i.e. Barind Tract) in recent decades. Barind Tract covers most parts of the greater Dinajpur, Rangpur, Pabna, Rajshahi, Bogra, Joypurhat and Naogaon districts of Rajshahi division. Rainfall is comparatively less in Barind Tract than the other parts of the country. The average rainfall is about 1,971 mm, which mainly occurs during the monsoon. Rainfall varies aerially as wells as yearly. For instance, rainfall recorded in 1981 was about 1,738 mm, but in 1992 it was 798 mm. The distribution of rainfall is rather variable from one place to another. Thus this region has already been known as drought prone area of the country. The average highest temperature of the Barind region ranges from 35°C to 25°C for the hottest season and 12°C to 15°C for the coolest season. Generally this particular region of the country is rather hot and considered as a semi-arid region. In summer, some hottest days experience the temperature of about 45°C or even more in the Rajshahi area, particularly at Lalpur. Again in the winter the temperature even falls at 5°C in some places of Dinajpur and Rangpur districts. So this older alluvium region experiences the two extremities that clearly contrast with the climatic condition of the rest of the country. Meteorologically drought can be classified into three types: permanent drought - characterized by arid climate; seasonal drought - caused by irregularities in recognized rainy and dry seasons; and contingent drought - caused by irregular rainfall. In Bangladesh, the last two types are more prevalent.

Drought mostly affects Bangladesh in pre-monsoon and post-monsoon periods. From 1949 to 1979 drought conditions had never affected the entire country. The percentage of drought affected areas were 31.63% in 1951, 46.54% in 1957, 37.47% in 1958, 22.39% in 1961, 18.42% in 1966, 42.48% in 1972 and 42.04% in 1979. During 1981 and 1982 droughts affected the production of the monsoon crops only. During the last 50 years, Bangladesh suffered about 20 drought conditions. The drought condition in northwestern Bangladesh in recent decades had led to a shortfall of rice production of 3.5 million tons in the 1990s. If other losses, such as, to other crops (all rabi crops, sugarcane, wheat, etc.) as well as to perennial agricultural resources, such as, bamboo, betel nut, fruits like litchi, mango, jackfruit, banana etc. are considered, the loss will be substantially much higher.

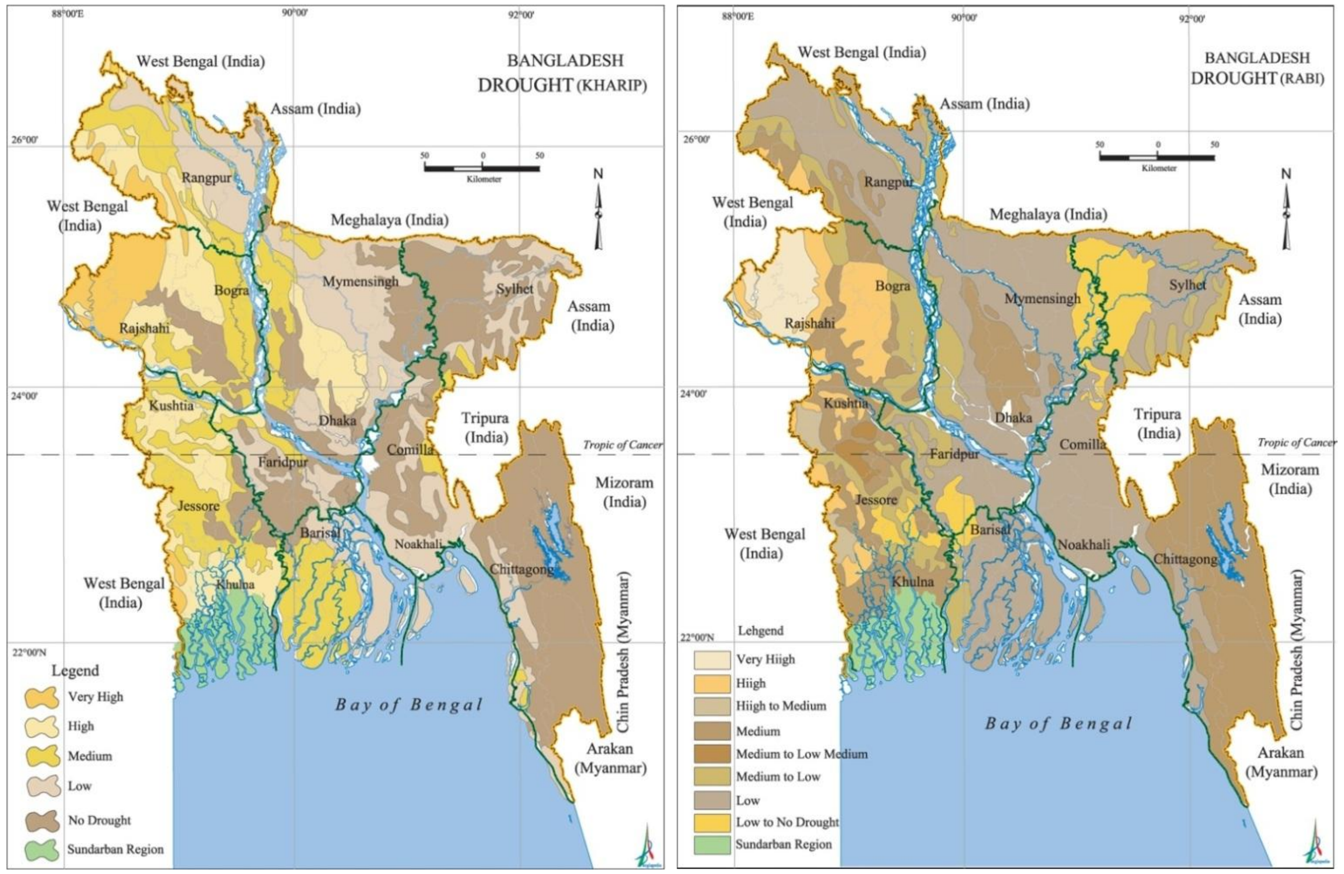


Figure 4: Meteorological Drought for Kharip and Rabi (Banglapedia, 2014)

Earthquake means trembling or shaking movement of the earth's surface. Most earthquakes are minor tremors, while larger earthquakes usually begin with slight tremors, rapidly take the form of one or more violent shocks, and end in vibrations of gradually diminishing force called aftershocks. Earthquake is a form of energy of wave motion, which originates in a limited region and then spreads out in all directions from the source of disturbance. It usually lasts for a few seconds to a minute. Earthquakes originate due to various reasons, which fall into two major categories viz non-tectonic and tectonic. The origin of tectonic earthquakes is explained with the help of 'elastic rebound theory'. Earthquakes are distributed unevenly on the globe. However, it has been observed that most of the destructive earthquakes originate within two well-defined zones or belts namely, 'the circum-Pacific belt' and 'the Mediterranean-Himalayan seismic belt'.

Bangladesh is extremely vulnerable to seismic activity. Accurate historical information on earthquakes is very important in evaluating the seismicity of Bangladesh in close coincidences with the geotectonic elements. Information on earthquakes in and around Bangladesh is available for the last 250 years. The earthquake record suggests that since 1900 more than 100 moderate to large earthquakes occurred in Bangladesh, out of which more than 65 events occurred after 1960. This brings to light an increased frequency of earthquakes in the last 30 years. This increase in earthquake activity is an indication of fresh tectonic activity or propagation of fractures from the adjacent seismic zones. Detail about earthquake in Bangladesh is described in Chapter 2.

1.3 Disaster Risk Management in Bangladesh

Due to the geographic location and settlement, Bangladesh has its long history of being affected from Natural Disaster. It is estimated that between 1980 to 2008 the country faced a damage of 16 Billion USD from about 200 events. As a developing country, Bangladesh had to depend very much on the relief mostly assisted by the donor agencies and foreign countries. After devastating flood in 1988 Flood Action Plan was initiated as a culture of Disaster Management and Risk reduction. Catastrophic cyclone in 1991 urged the necessity of establishing institution based disaster management in the country and Disaster Management Bureau (current DDM) was established in 1993. From early 2000 with a view to shifting from the traditional relief and rehabilitation approach to the more holistic disaster risk reduction approach, initiative was taken for Comprehensive Disaster Management Program for disaster preparedness at all levels of the country. Currently the Ministry of Disaster Management and Relief of the Government of Bangladesh is the responsible ministry for coordinating national disaster management efforts across all agencies. The Ministry for the first time issued the Standing Orders on Disaster (SOD) in January 1997 (updated in 2010) to guide and monitor disaster management activities in Bangladesh.

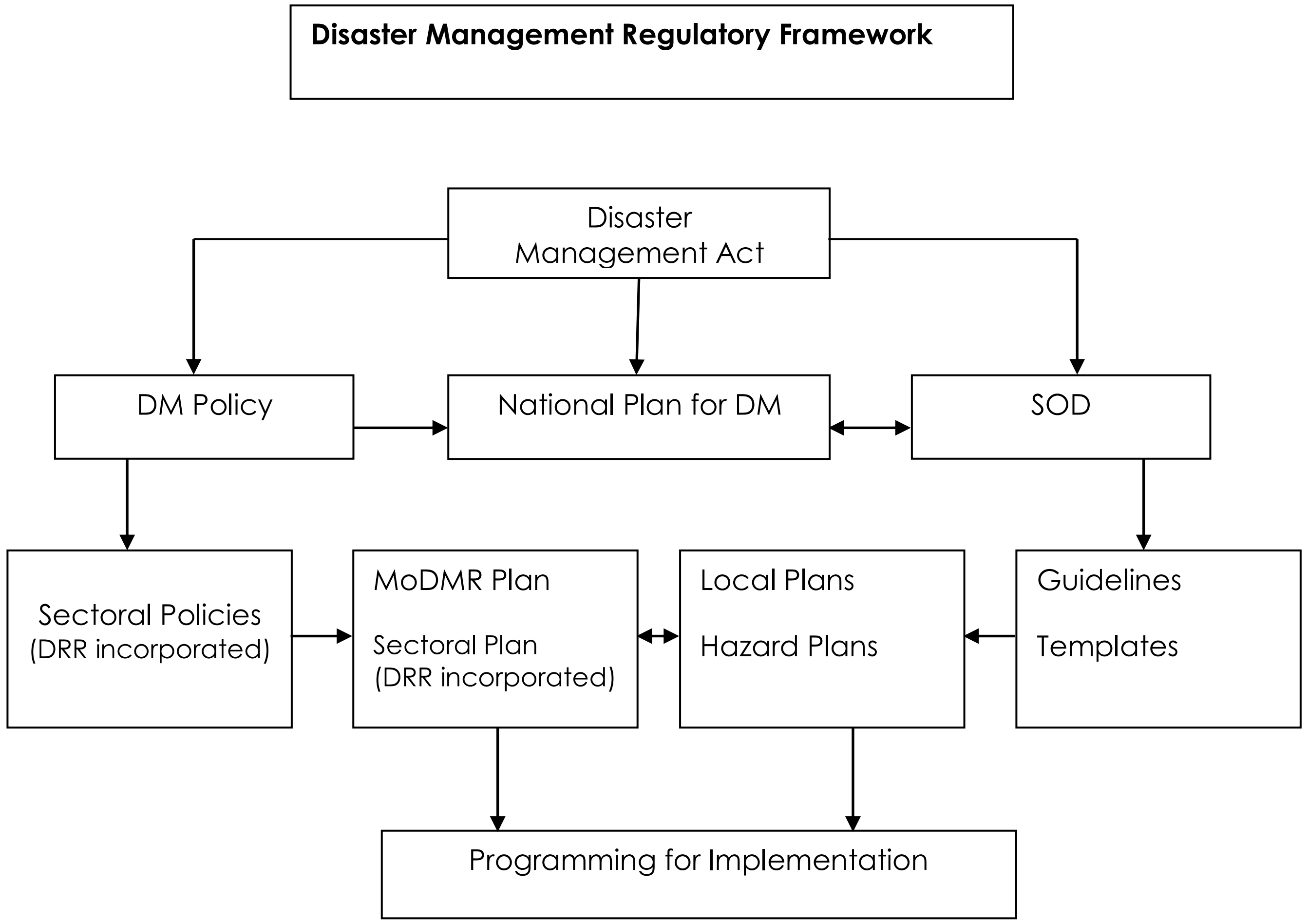


Figure 5: Disaster Management Regulatory Framework in Bangladesh (NPDM- 2010-2015)

The main objective of the SOD is to make the concerned persons understand their duties and responsibilities regarding disaster management at all levels, and accomplish accordingly. All Ministries, Divisions/Departments and Agencies shall prepare their own Action Plans in respect of their responsibilities under the Standing Orders for efficient implementation. The National Disaster Management Council (NDMC) and Inter-Ministerial Disaster Management Coordination Committee (IMDMCC) are to ensure coordination of disaster related activities at the National level. Coordination at District, Thana and Union levels are to be done by the respective District, Thana and Union Disaster Management Committees. The Department of Disaster Management is to render all assistance to them by facilitating the process (NPDM, 2010).

Inter-related institutions, at both national and sub-national levels have been created to ensure effective planning and coordination of disaster risk reduction and emergency response management. Following is the list of National and Sub-national level institutions respectively.

At National levels

1. National Disaster Management Council (NDMC) headed by the Honorable Prime Minister to formulate and review the disaster management policies and issue directives to all concerns.
2. Inter-Ministerial Disaster Management Co-ordination Committee (IMDMCC) headed by the Hon'ble Minister in charge of the Disaster Management and Relief Division (DM&RD) to implement disaster management policies and decisions of NDMC / Government.
3. National Disaster Management Advisory Committee (NDMAC) headed by an experienced person having been nominated by the Honorable Prime Minister.
4. National Platform for Disaster Risk Reduction (NPDRR) headed by Secretary, DM&RD and DG, DDM functions as the member secretary. This platform shall coordinate and provide necessary facilitation to the relevant stakeholders.
5. Earthquake Preparedness and Awareness Committee (EPAC) headed by Honorable minister for MoFDM and DG, DDM act as member secretary.
6. Cyclone Preparedness Program Implementation Board (CPPIB) headed by the Secretary, Disaster Management and Relief to review the preparedness activities in the face of initial stage of an impending cyclone.
7. Cyclone Preparedness Programme (CPP) Policy Committee headed by Honorable Minister, MoFDM and Secretary, DM&RD act as member secretary. Disaster Management Training and Public Awareness Building Task Force (DMTATF) headed by the Director General of Department of Disaster Management (DDM) to coordinate the disaster related training and public awareness activities of the Government, NGOs and other organizations.
8. Focal Point Operation Coordination Group of Disaster Management (FPOCG) headed by the Director General of DDM to review and coordinate the activities of various departments/agencies related to disaster management and also to review the Contingency Plan prepared by concerned departments.
9. NGO Coordination Committee on Disaster Management (NGOCC) headed by the Director General of DDM to review and coordinate the activities of concerned NGOs in the country.
10. Committee for Speedy Dissemination of Disaster Related Warning/ Signals (CSDDWS) headed by the Director General of DDM to examine, ensure and find out the ways and means for the speedy dissemination of warning/ signals among the people.

At sub-national levels

1. District Disaster Management Committee (DDMC) headed by the Deputy Commissioner (DC) to coordinate and review the disaster management activities at the District level.
2. Upazila Disaster Management Committee (UZDMC) headed by the Upazila Nirbahi Officer (UNO) to coordinate and review the disaster management activities at the Upazila level.
3. Union Disaster Management Committee (UDMC) headed by the Chairman of the Union Parishad to coordinate, review and implement the disaster management activities of the concerned Union.
4. Paurashava Disaster Management Committee (PDMC) headed by Chairman of Pourashava (Paurashava) to coordinate, review and implement the disaster management activities within its area of jurisdiction.
5. City Corporation Disaster Management Committee (CCDMC) headed by the Mayor of City Corporations to coordinate, review and implement the disaster management activities within its area of jurisdiction.

Earthquake Preparedness and Awareness Committee (EPAC)

The Government of Bangladesh has formed a committee on Earthquake Preparedness and Awareness, in order to prepare the nation for earthquake risk management (SOD, 2010). Following is the Earthquake Preparedness and Awareness Committee is formed by the Government.

- Minister, Ministry of Food and Disaster Management;
- Secretary, Ministry of Home Affairs;
- Secretary, Finance Division, Ministry of Finance;
- Secretary, DM&RD, MoFDM,;
- Secretary, Roads and Railways Division;
- Secretary, Ministry of Information;
- Secretary, Ministry of Health and Family Planning Affairs;
- Secretary, Ministry of Defence;
- Secretary, Ministry of Foreign Affairs;
- Secretary, Economic Relations Divisions;
- Secretary, Housing and Public Works Ministry;
- Secretary, energy and Mineral Resource Division;
- Secretary, Ministry of Education;

- Secretary, Primary and Mass Education Ministry;
- Secretary, Local Government Division;
- Chief Engineer, Roads and Highways Department;
- Chief Engineer, Engineering Education Department;
- Chief Engineer, Local Government Engineering Department (LGED);
- Chief engineer, Public Works Department (PWD);
- Director General, Geological Survey of Bangladesh (GSB);
- Director General, Health Services;
- Director General, Fire Services and Civil Defence Department;
- Representative, Department of Geology, University of Dhaka;
- Representative, Department of Geography and Environment, Jahangirnagar University;
- Representative, Civil Engineering Department, BUET;
- Representative, Department of Geography and Environment, University of Chittagong;
- Representative, Civil and Environmental Engineering, SUST;
- Director, BMD;
- Director, Armed Forces Division (AFD);
- Chairman, Bangladesh Red Crescent Societies (BDRCS);
- Representative CARE;
- Representative Oxfam;
- Representative BRAC;
- Representative CARITAS;
- Representative Action Aid;
- Representative Save The Children USA;
- Representative World Vision;
- Representative Islamic Relief UK;
- Director General, Department of Disaster Management (DDM) as member secretary.

Functionally The Committee is supposed to meet twice a year, the Chairman may call additional meetings, if needed. Sub-Committee: Sub committees may be formed for contingency planning and aspect of earthquake risk reduction. Responsibilities of the committee are to (1) Review national earthquake preparedness and awareness programme and recommend suggestion for concerned organizations. (2) Review the list of Search and Rescue equipment for earthquake. (3) Prepare and recommend a list of equipment for earthquake risk reduction and search and rescue programme after an earthquake.

CHAPTER - 02
SEISMIC HAZARD IN BANGLADESH

2.1 Geological Settings

Tectonically, Bangladesh lies in the northeastern Indian plate near the edge of the Indian craton and at the junction of three tectonic plates – the Indian plate, the Eurasian plate and the Burmese microplate. These form two boundaries where plates converge– the India-Eurasia plate boundary to the north forming the Himalaya Arc and the India-Burma plate boundary to the east forming the Burma Arc. The Indian plate is moving ~6 cm/yr in a northeast direction and subducting under the Eurasian (@ 45 mm/yr) and the Burmese (@ 35 mm/yr) plates in the north and east, respectively (Sella et al., 2002; Bilham, 2004; Akhter, 2010).

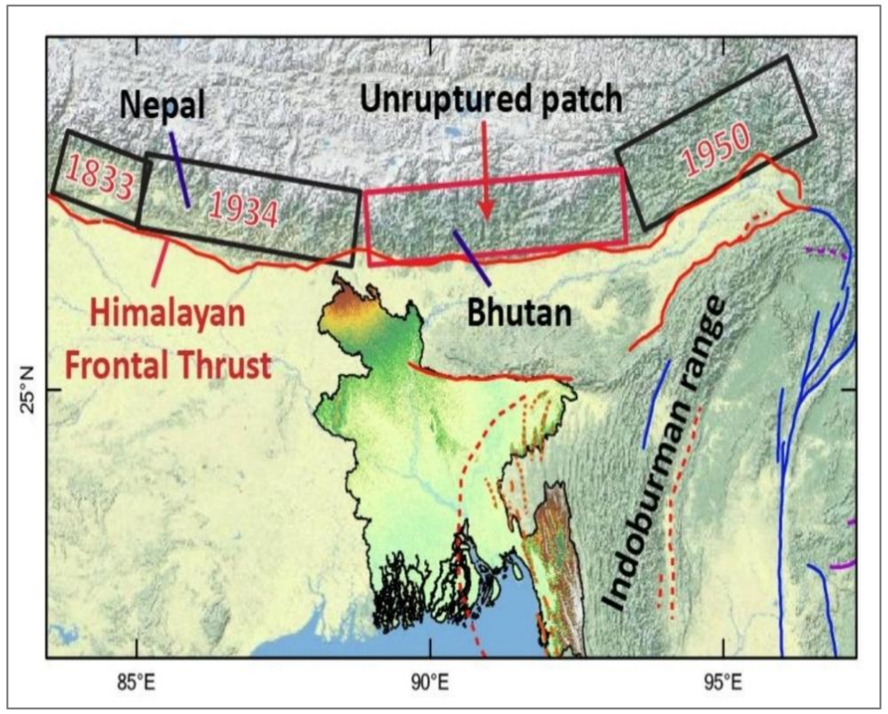


Figure 6: Historical earthquakes along the Himalayan Frontal Thrust fault (CDMP,2013)

To the north, the collision between the Indian and Eurasian plates has created the spectacular Himalayan Mountains, bounded along their southern flank by the Himalayan Frontal Thrust (HFT), along which continental lithosphere of the Indian plate under thrusts the Eurasian plate. This great north-dipping thrust fault runs more than 2,000 km from Pakistan to Assam and has produced many large continental earthquakes over the past millennium, some greater than M 8. The 500-km long section just 60 km north of Bangladesh, however, has not produced a great earthquake in the past several hundred years (Kumar et al. 2010).

The other major active tectonic belt of Bangladesh appears along the country's eastern side. The Arakan subduction-collision system involves oblique convergence of the Indian and Burma plates. It has produced the N-S trending Indoburman range and a broad belt of folds along the western edge of the Bay of Bengal [Curray, 2005; Wang and Sieh, 2013]. These lie above a mega thrust that dips moderately eastward beneath the Indoburman range but is nearly flat-lying beneath the folds. Beneath the 500-km long fold belt the mega thrust is also referred to as a decollement, because it is parallel or nearly parallel to sediment bedding within the Ganges Brahmaputra delta. As we will describe below, many of the folds within the western 100 to 200 km of the fold belt appear to be actively growing, which implies that the underlying decollement is relaying slip onto thrust faults beneath these folds as it dies out westward toward a poorly defined deformation front.

2.2 Seismic Hazard and Bangladesh

Bangladesh is located in the tectonically active Himalayan orogenic belt that developed by the collision among the Indian, Arabian, and Eurasian plates over the last 30-40 million years (Ma), (Aitchinson et al.2007). Moderate to large earthquake magnitudes are common in this region and will continue to occur as long as the tectonic deformation continues. Some of these earthquakes caused serious damage to buildings and infrastructures through strong ground shaking and also, in some cases, faults rupturing the ground surface. The destructive and deadly hazards associated with earthquakes pose a real and serious threat to the life of people, property damage, economic growth and development of the country. A proper understanding of the distribution and level of seismic hazard throughout the country is therefore necessary. In order to perform rigorous seismic hazard analysis, all available knowledge of the historical earthquake, tectonic environment, and instrumental seismic data are required to predict the strong ground shaking in future earthquakes. However, until now, investigation of the seismic potential of Bangladesh tectonic elements is still in its infancy (Wang and Sieh, 2013). The main objective of this work is to determine appropriate earthquake ground motion parameters for seismic mitigation based on current existing data and most recent geological data interpretation. These ground motion parameters include: horizontal Peak Ground Acceleration (PGA) and Spectral Acceleration (SA) values at 0.2 and 1.0 s with the return periods of 43, 475, and 2475 years.

The study team has considered Probabilistic Seismic Hazard Assessment in terms of PGA at 43, 475, and 2475 year return periods and Spectral Acceleration (SA) at 0.2s and 1.0s at 43, 475, and 2475 year return periods In general, at short return period, i.e. 43 years, the observed seismicity in and around Bangladesh controls the hazard for most considered structural periods. However, at long return period, i.e. 2,475 years, the seismic hazard of all structural period is controlled by major tectonic structures, and these results confirm the importance of further study of active tectonic structures in Bangladesh. For the 475 year return period PGA hazard map, the hazard is fairly well correlated with the seismicity pattern shown in figure 10a. The effect of major active tectonic structures in and around Bangladesh on seismic hazard is not clear on this map excepting from area near Dauki fault.

Ground motion across Bangladesh represented by PGA is in the range of 0.1–0.6g, corresponding to the 475 year return period and in the range of 0.1–1.0 g, corresponding to the 2,475 year return period. The effect of high-slip-rate of Duaki fault could be observed as the largest seismic hazard zone in Bangladesh. From, the PGA and SA at 0.2 and 1.0s at 475 and 2,475 year return period for six cities (i.e. Bogra, Dinajpur, Mymensingh, Rajshahi, Rangpur and Tangail), included in CDMP phase II are shown. Out of these six cities, Bogra, Mymensingh, and Rangpur have by far the greatest seismic hazard. The estimated PGA value of 0.5g at 2,475 year return period is comparable to the seismically active region of the intermountain west in the United States (Petersen et al., 2008). This is primarily due to its proximity to the potentially fast-moving Duaki fault with augmented from high rate of background seismicity. The seismic hazard of Rajshahi is the lowest about 0.4g at 2,475 year return period, largely because it is far removed from Dauki active fault and Arakan blind mega thrust. In addition, Rajshahi is the one location in Bangladesh where previous analysis based on instrumental seismicity may underestimate what might be expected from the Martin and Szeliga's (2010) historical earthquake catalogue, where there are two events have been located with earthquake magnitude between 7.3 and 6.1 on 11 November 1842 and 22 June 1897, respectively.

2.3 Seismic History in Bangladesh

Although in the recent past Bangladesh has not been affected by any big earthquake, but the evidence of large scale earthquake in the region reminds the possibilities of big earthquake in the future. The past major earthquake in and around Bangladesh includes 1548 earthquake that hit Sylhet and Chittagong region, 1642 earthquake in Sylhet District with damage to build structure, 1762 earthquake hit most part of Bangladesh including Dhaka & Chittagong caused loss of life and properties, 1897 Known as the Great India Earthquake with a magnitude of 8.7 hit the region. This earthquake caused serious damage to buildings in Sylhet town where the death toll rose to 545. In Mymensingh, many public buildings including the Justice House collapsed wrecked. Heavy damage was done to the bridges on the Dhaka - Mymensingh railway and traffic was suspended for about a fortnight. The river communication of the district was seriously affected. Loss of life was not great, but loss of property was estimated at five million Rupees. Rajshahi suffered severe shocks, especially on the eastern side, and 15 persons died. In Dhaka damage to property was heavy. In Tippera masonry buildings and old temples suffered a lot and the total damage was estimated at Rs. 9,000, 1918 earthquake Known as the Srimangal Earthquake is occurred on 18 July with a magnitude of 7.6 and epicenter at Srimangal, Maulvi Bazar.

1897 Great Indian Earthquake, M=8.7

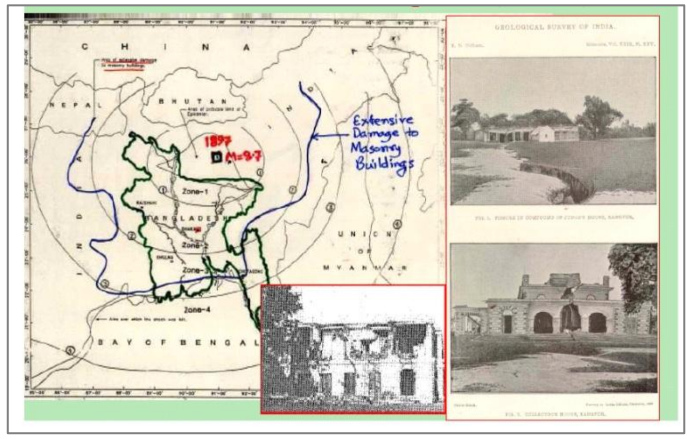
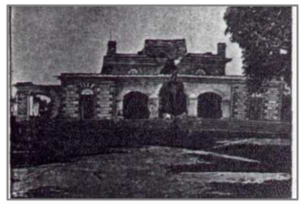


Figure 7: Effect of 1897 Great Indian Earthquake (Oldham and Richard, 1899, http://images.rgs.org and http://nisee.berkeley.edu)


Rail Track at Rangpur


Collapse of building in Armanitola Dhaka


Damage at Rangpur, 1897 earthquake


Court – Kachari Building Collapsed at Mymensingh


Damage at Sirajganj 1897 Earthquake (http://www.world-housing.net)

Figure 8: Effect of 1997 Earthquake, Bangladesh (The Daily Star, 2005)


LAKER'S PUBLIC SCHOOL, RANGAMATI


HEALTH COMPLEX, KALABUNIA, RANGAMATI


BDR CLUB, KALABUNIA, RANGAMATI


BDR CAMP, KALABUNIA, RANGAMATI

Figure 9: Effect of 2003 Rangamati Earthquake (Ansary et al. 2003)

The 1997 Chittagong earthquake, or the 1997 Bandarban earthquake, occurred on November 21, 1997 at 11:23 UTC in the Bangladesh-India-Myanmar border region. It had a magnitude of Mw 6.1 (USGS, 2014). The epicenter was located in southern Mizoram, India. While no fatalities were reported in Mizoram, India, however, 23 people were killed when a 5-storey building collapsed in Chittagong, Bangladesh (ASC, 2008).

An earthquake occurred on 22 July, 1999 at Maheshkhali Island with the epicenter in the same place, a magnitude of 5.2. Severely felt around Maheshkhali Island and the adjoining sea. Houses cracked and in some cases collapsed.

Borkol earthquake, occurred in the early morning of 27 July 2003 at 5:18:17.96 am local time, killed three people, injured 25 people and damaged about 500 buildings in Chittagong and the Chittagong Hill Tracts. Power supply to some areas was cut as a transformer exploded at the Modunaghat Grid Sub-station in Hathazari, Chittagong. The epicenter was situated217 km southeast of Dhaka at the eastern bank of Kaptai reservoir. It had a magnitude measured Mw 5.7. Dhaka shook with MM intensity IV. Many people were awakened, especially residents of upper floors of high rise buildings.

Seismic Hazard Map of Different Return Periods

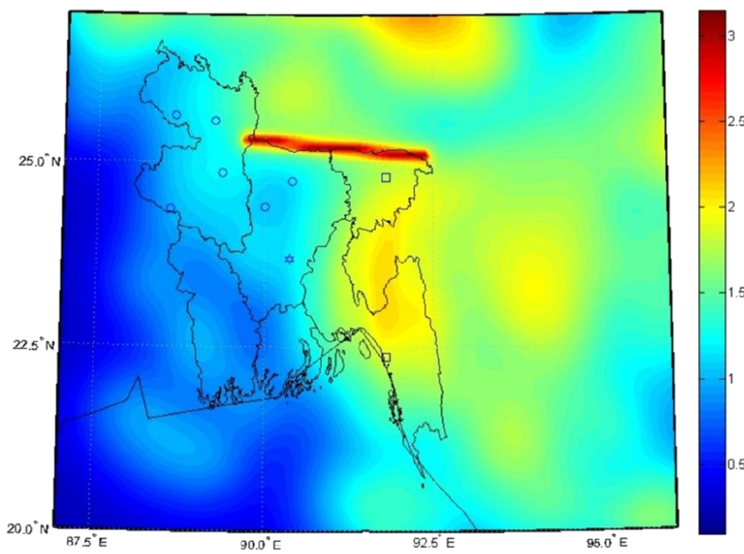


Figure 10a: Bangladesh Hazard Map for Spectral accelleration at 0.2s Structural Period Corrosponding to 2475 Years Return Period

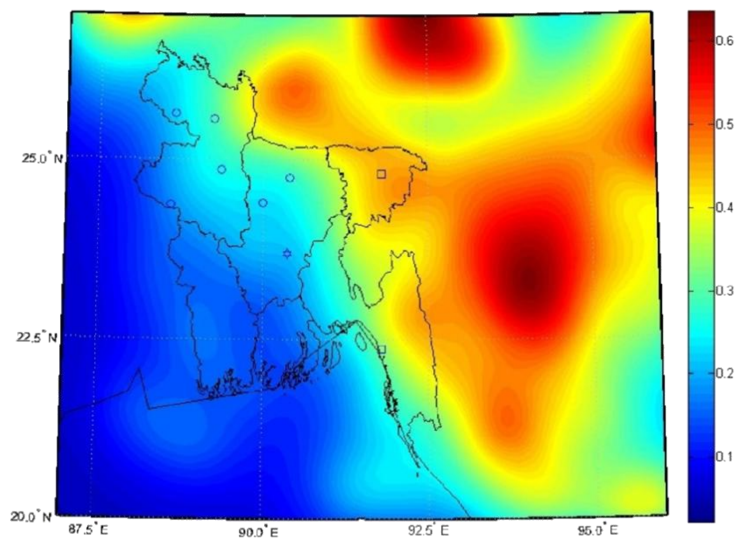


Figure 10b: Bangladesh Hazard Map for Spectral accelleration at 0.2s Structural Period Corrosponding to 43 Years Return Period Period

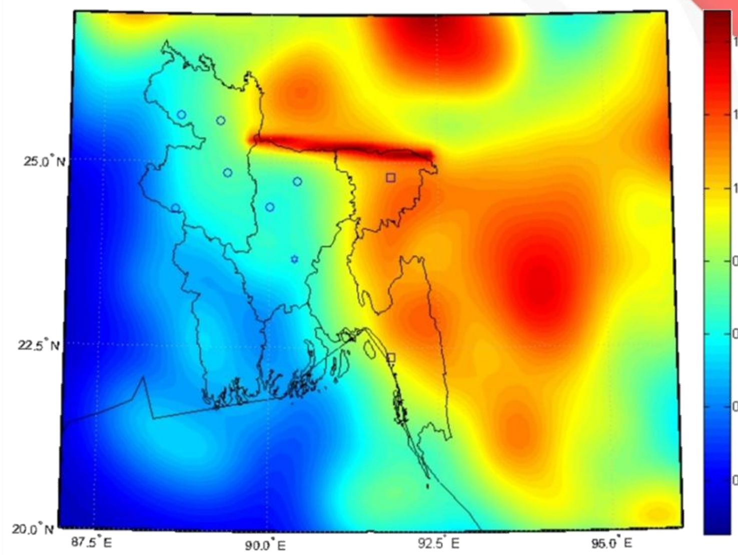


Figure 10c: Bangladesh Hazard Map for Spectral accelleration at 0.2s Structural Period Corrosponding to 475 Years Return Period

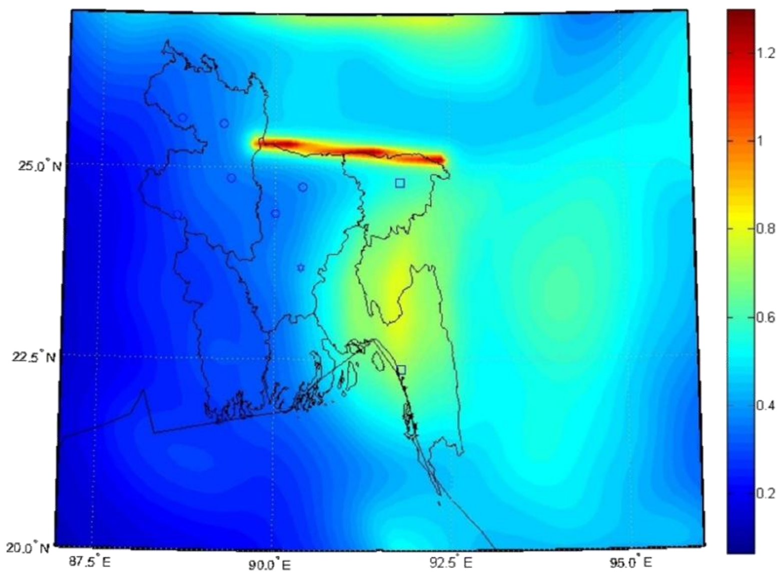


Figure 10d: Bangladesh Hazard Map for Spectral accelleration at 1.0s Structural Period Corrosponding to 2475 Years Return Period

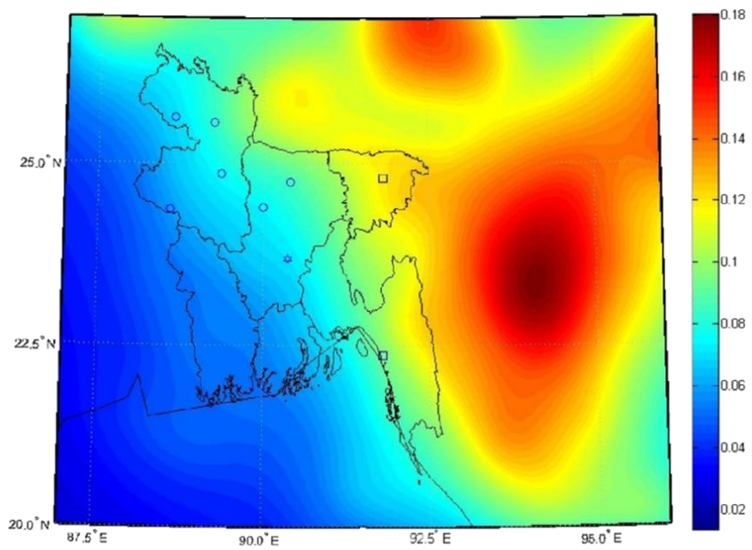


Figure 10e: Bangladesh Hazard Map for Spectral accelleration at 1.0s Structural Period Corrosponding to 43 Years Return Period

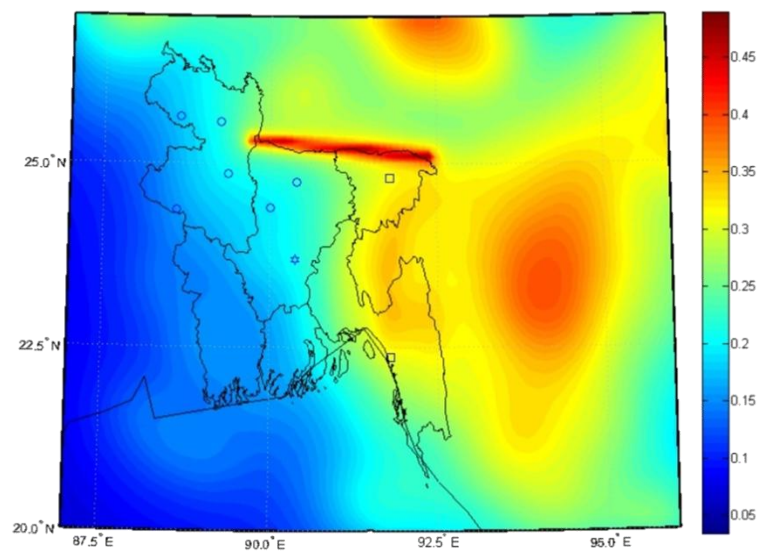


Figure 10f: Bangladesh Hazard Map for Spectral accelleration at 1.0s Structural Period Corrosponding to 475 Years Return Period

CHAPTER - 03
SEISMIC VULNERABILITY AND RISK ASSESSSMENT INITIATIVES IN BANGLADESH

3.1 Initiatives for Seismic Preparedness in Bangladesh

Realizing the earthquake vulnerability and risk in Bangladesh, a number of initiatives have been taken by the Government, research institutes, donor agencies, International NGOs and National NGOs regarding Earthquake Preparedness and Management. Most of the initiated projects are focusing in three thematic areas like Hazard & Risk Assessment, Awareness & Capacity Building and Formulation of Plan & Preparedness. Following is the brief on the activities initiated by different agencies in the respective areas regarding earthquake preparedness and Management.

Hazard & Risk Assessment and Research

Department of Disaster Management (DDM) under the ministry of Disaster Management and Relief is the focal agency in Bangladesh for Disaster Risk Reduction and Disaster Risk Management. Since its inception in 1993 DDM has taken several initiatives for Disaster Management Activities. Currently DDM (2011-2015) is implementing a project named "Multi Hazard Risk and Vulnerability Assessment and Mapping" for the whole country. This nationwide assessment will cover the hazards like flood, earthquake, drought, cyclone, storm surge etc. The assessment would act as the guidance for the disaster preparedness initiatives in Bangladesh. The hazard and vulnerability mapping will be updated with the course of time and will be useful for the emergency preparedness guide.

Geological Survey of Bangladesh (GSB) under Ministry of Energy and Mineral Resources of the Government of Bangladesh plays vital role in earthquake research across the country. The main activities of the organization are to deal with the technical and scientific aspects of earthquake. As a part of that GSB check the land formation change, change in river course, undulation in land etc. immediately after any earthquake. Earthquake fault zone is also identified by Geological Survey of Bangladesh as a part of regular activities.

As a part of earthquake preparedness, GSB has installed Earthquake accelerometer at 20 points across the country. The reading of these stations is useful for building code revision in the context of different parts of the country. In the recent time, GSB has conducted geological investigation at Purbachal and Jhilmil residential areas. These results of the investigation will be handed over to the respective agency which can be used for building code implementation in these areas.

Comprehensive Disaster Management Programme (CDMP) under the ministry of Disaster Management and Relief has launched major earthquake preparedness programs in Bangladesh. The initiatives started in 2008 with the earthquake risk assessment of Dhaka, Chittagong and Sylhet City Corporation areas. This earthquake assessment also identified the active faults across the country that is the sources for major possible earthquake. CDMP II also initiated for (2012-2014) earthquake risk assessment, training & awareness development and city, agency and ward level Contingency Plan preparation for the cities of Bogra, Dinajpur, Mymensingh, Rajshahi, Rangpur and Tangail.

Chittagong Hill Tracts Development Facilities (CHTDF)-UNDP is a special program for the three hill districts of Bangladesh. Under one of the regional programs named ECRRP, CHTDF-UNDP had taken initiatives for conducting earth hazard and risk assessment for the paurashavas of Rangamati, Bandarban and Khagrachari. The project was implemented from the year 2009 to 2010. Under this initiative, detail base maps, seismic hazard map, building & lifeline vulnerability assessment were conducted for the municipal towns of Rahnagati, Bandarban and Khagrachari. During the implementation of the project a number of professionals from these three towns were also provided with training on earthquake risk assessment methodology and techniques.

Bangladesh University of Engineering and Technology (BUET) had several earthquake preparedness and research studies over the years. The research projects include Seismic Micro Zonation in Cox's Bazar, School Safety program in Dhaka and arrangements of training regarding earthquake research. Apart from this the Civil Engineering Department of the institute has enhance its capacity through earthquake research programs as initiated over the years. Moreover, Bangladesh Network for Urban Safety (BNUS) was initiated by BUET with the collaboration from ICUS, Japan. BUET also has expertise in the areas of structural engineering, geotechnical engineering, and preparation of seismic hazard maps and in seismic micro-zonation of urban areas in Bangladesh. It has already established National Centre for Earthquake Engineering (NCEE) in 2002. BUET is currently overseeing a seismic instrumentation project for the five kilometer long Bridge (Jamuna multipurpose bridge, Bangladesh). It has also procured sixty SMAs from USGS recently. A two year linkage project with Virginia Polytech Institute and State University, USA has been established on seismic vulnerability of Bangladesh.

Earth observatory under the Department of Geology, University of Dhaka being established in 2003, is working in Bangladesh for scientific research on Geologic setup and tectonic setting. Currently, the center has 23 GPS to monitor the 3D movement of the earth crust. Active fault study and mapping is the one of the major field to be emphasized in near future by the center.

3.2 Risk Assessment Process and Methodology

The seismic risk assessment describes the scale and the extent of damage and disruption that may result from potential earthquakes. Damage and risk assessment for seismic hazard provide forecasts of damage and human and economic impacts that may result from earthquake. The scope of work covers the risk assessment of general building stock, essential facilities (hospitals, emergency operation centers, schools) and lifelines (transportation and utility systems). For CDMP-I & CDMP II the risk assessment is executed using the HAZUS software package. HAZUS was developed by the United States' Federal Emergency Management Agency (FEMA) and National Institute of Building Sciences (NIBS). It is a powerful risk assessment software program for analyzing potential losses from disasters on a regional basis. This risk assessment scheme can be used primarily by local, regional, and central government officials to plan and stimulate efforts to reduce risks from earthquakes and to prepare for emergency response and recovery.

HAZUS operates through a Geographic Information System (GIS) application i.e. ESRI ArcGIS platform. For risk assessment analyses of the nine city corporation areas and paurashavas, defaults databases for the United States are replaced with Bangladesh databases of the 9 cities/Towns. Ground shaking is characterized quantitatively using peak ground accelerations and spectral response accelerations. HAZUS methodology aggregates the general building stocks on a cluster basis, but is site-specific for essential facilities and lifelines. The transportation and utility lifeline losses are combined in one package with losses associated with the general building stock and essential facilities.

The framework of the HAZUS risk assessment methodology includes six major modules shown in Figure 11 as indicated by the arrows in the figure, the modules are interdependent with the output of one module acting as input to another. Explanation of every module is given as follows.

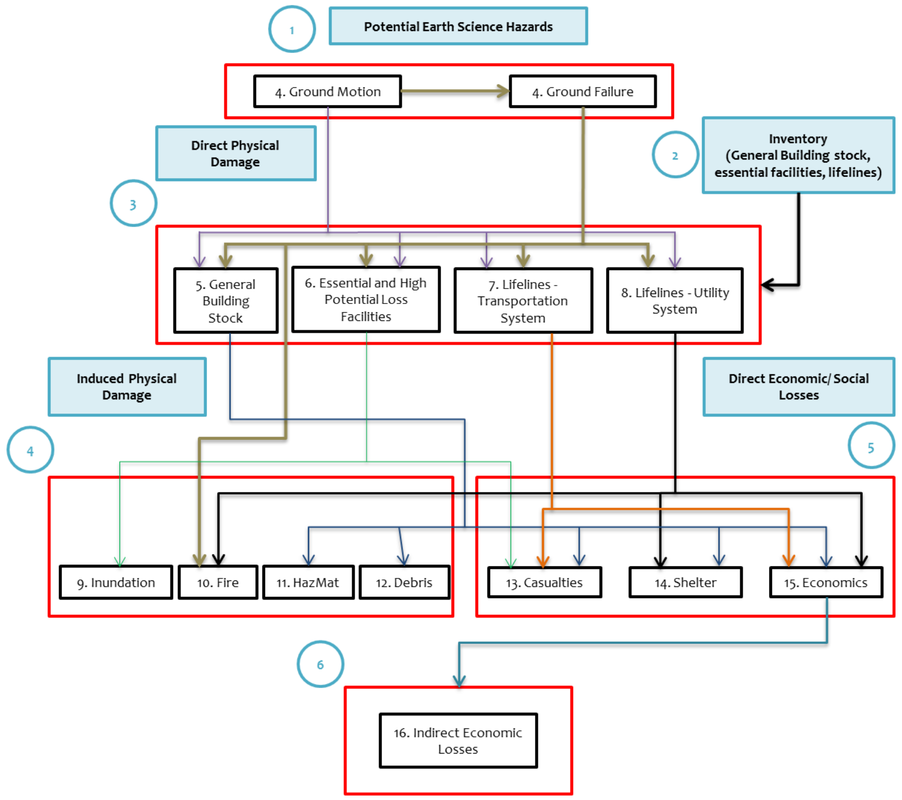


Figure 10: Flowchart of HAZUS Earthquake Risk Assessment Methodology

1. Potential Earth Science Hazards (PESH)

PESH module estimates ground motion and ground failure. Ground motion demands, for example, peak ground acceleration (PGA) and spectral acceleration, are estimated based on earthquake source parameters, attenuation relations and geological data. Ground failure which is caused by landslides, liquefaction and surface fault rupture are quantified by permanent ground deformation (PGD). This PGD is determined based on topological data, geological data and ground water depth.

2. Inventory

The inventory contains tools for describing the physical infrastructure and demographics of the study areas. It uses standardized classification systems for the groups of components at risk: (a) general building stock, (b) essential facilities, (c) transportation system components, and (d) utility system components. These groups are defined to address distinct inventory and modeling characteristics. An extensive amount of GIS database is utilized to develop dataset for these groups.

The general building stock is classified by occupancy (residential, commercial, etc.) and by model building type (structural system and material, height). Characteristic relationships between occupancy and structure types are developed based on building survey data. Population data is derived from the average of building occupants per unit building, which is obtained from the building survey. Estimates for building exposure are based on for building replacement costs (dollars per square foot) for each model building type and occupancy class that has been modified to Bangladesh cost. Dataset of essential facilities lifelines are developed from GIS database and secondary sources (service provider authority), clarified and verified through the field survey.

3. Direct Physical Damage

This module provides damage estimates in terms of probabilities of occurrence for specific damage states given in a specified level of ground motion and ground failure. Estimates also include loss of function to essential facilities and lifelines and the anticipated service outages for potable water and electric power.

For buildings, the capacity-demand spectrum method as implied by HAZUS is utilized for the estimation of seismic demand. The estimated seismic demand is, thus, used to determine the probability of being in a particular damage state through fragility functions. However, the seismic performance of buildings in Bangladesh is different from that of United States. As a result, a new set of building capacity spectrum and fragility functions were developed based on the field survey data and comprehensive numerical analyses.

For both essential facilities and general building stock, damage state probabilities are determined for each facility or structural class. Damage is expressed in terms of probabilities of occurrence of specific damage states, given a level of ground motion and ground failure. Five damage states are identified - none, slight, moderate, extensive and complete.

For lifeline, the methodology focuses on estimating damage and restoration times for every system of transportation (highway, railway, bus, and ferry) and utility (potable water, waste water, natural gas, electric power, communication). Overall fragility curves for a system are evaluated using fault tree logic to combine components fragility curves. The hazard is typically represented by Peak Ground Acceleration (PGA) and Permanent Ground Deformation (PGD). Utilizing overall fragility curves, damage state probabilities are calculated for the lifeline components. Restoration times are evaluated from very simplified rules, relating to degree of damage and size of component.

4. Induced Physical Damage

Once direct physical damage is available, induced damage can be evaluated. Induced damage is defined as the secondary consequences of a natural hazard other than damage due to the primary hazard (earthquake) that led to losses. Here, the methodology calculates damage due to fire following an earthquake and tonnage of debris generation. For estimation of the impacts from the fires that follow an earthquake, HAZUS methodology utilizes Monte Carlo simulation techniques to assess the potential impacts and separated the module into 3 major elements: fire ignition, spread, and suppression. Number of fire ignition is estimated from the size and type of building inventory and the ground motion to which it is subjected. Spread is a function of the density of the construction, the presence of wind, fire breaks (e.g. lakes, wide streets) and low fuel areas (e.g. parks, cemeteries). Suppression is a function of the available firefighting capabilities. The spread and suppression modules use damage and loss function out of the essential facilities and lifelines modules to determine the response capabilities and effectiveness of the fire-fighting personnel. For debris, HAZUS methodology estimates 2 different types of debris. The first type is debris that fall in large pieces like steel members or reinforced concrete elements, which require special treatment to break into smaller pieces before they are hauled away. The second one is smaller and more easily moved with bulldozers, such as brick, wood, glass, building contents, etc.

5. Direct Economic/Social Losses

Both direct and induced damage can lead to direct losses. There are 2 types of losses evaluated in the methodology: economic and social losses. The economic losses quantify the cost of repair and replacement of structures and lifeline systems that are damaged as a consequence of the earthquake. Structural and non-structural damage and also losses to contents inside buildings are included. To compute the direct economic losses, damage information from the direct damage module is combined with economic data of the study area, particularly construction/replacement cost of buildings and lifeline systems. Social losses are quantified in terms of casualties. To quantify the casualties, HAZUS methodology combines the output from direct damage module with building inventory and population data. Estimation is carried out for two times of day: 2:00PM (day time) and 2:00AM (night time).

6. Indirect Economic Losses

This module assesses the broad and long-term implications of the direct impacts (direct damage and losses) mentioned before. Examples of indirect economic impacts are changes in employment and personal income. This module is not included in this work due to inexistence of complete data of income and employment.

3.3 Base Map and Database Development

Spatial databases have been developed for the study cities and used as base maps to assist hazard and vulnerability assessment. All important physical features of these cities are considered during the database development. Based upon the availability of existing database and information of the respective cities, an appropriate methodology was developed to acquire missing information by conducting physical feature survey and attribute information collection.

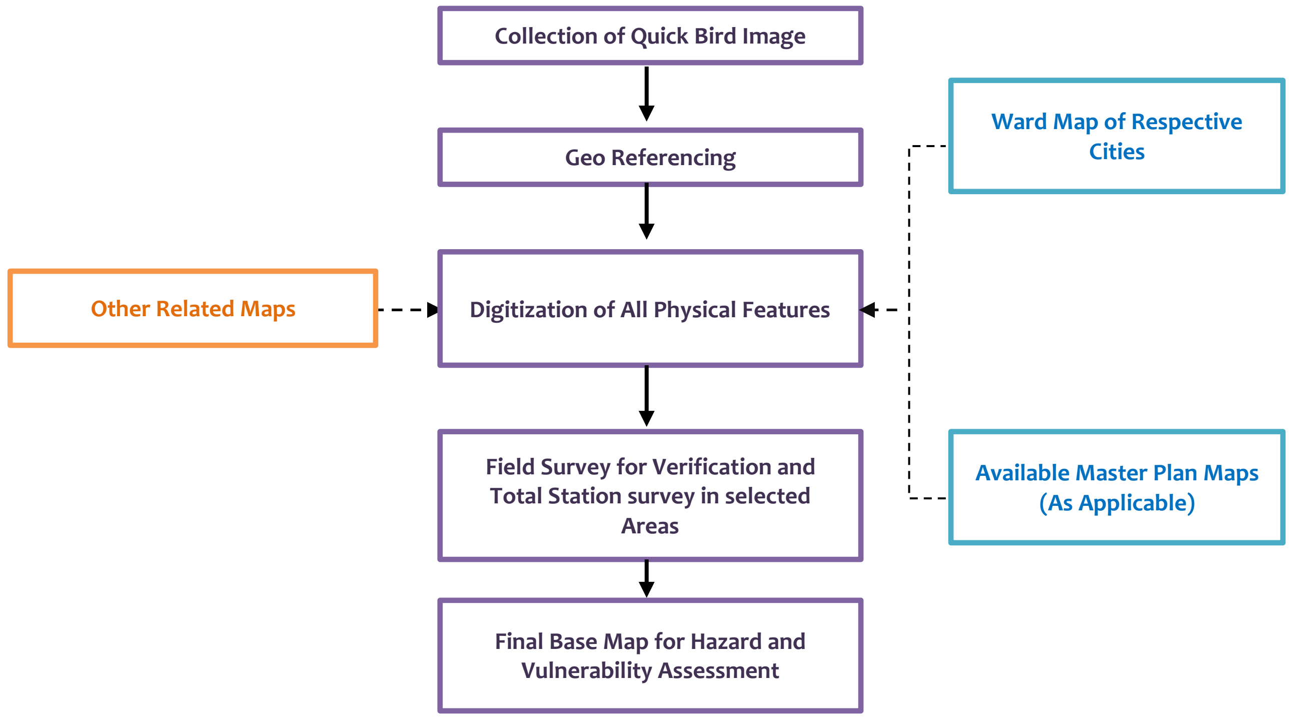


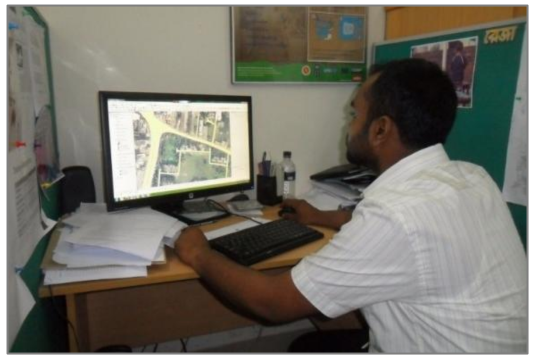
Figure 11: Flow-chart of Base Map Development Process

For preparation of Base Map, Satellite (Quickbird) images were collected. Ground Control Points were selected on the image at suitable locations for geo-referencing. Established Bench Marks like SOB, PWD, BWDB, and JICA were used as referencing point to do geo referencing. RTK-GPS and Total station was used for image geo-referencing. After geo-referencing of the image physical features like road alignment, building outline, water body boundary, river boundary etc. were digitized. After completion of digitization, maps were printed for field verification. During field verification a preset list of items were followed to collect attribute information against each of the digitized features. After completion of attribute information collection and feature verification, collected information had been added against the each surveyed features and base map was prepared for use. Following is the detail of the steps followed during base map preparation.

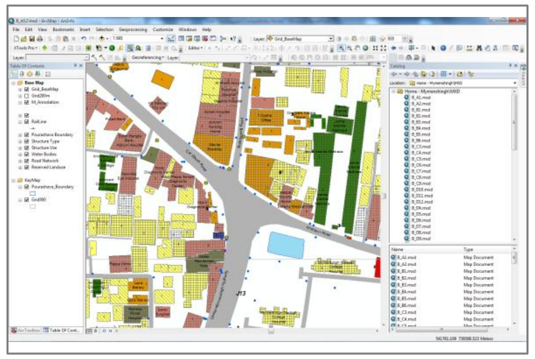
Quickbird Images of Rajshahi

Geo-Referencing of Image using RTK GPS

Image of a part of Rajshahi City after Geo-referencing

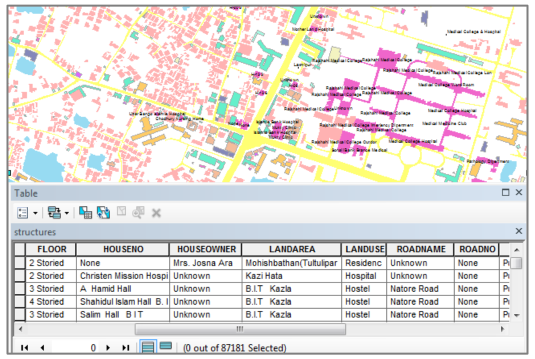


On Screen Digitization

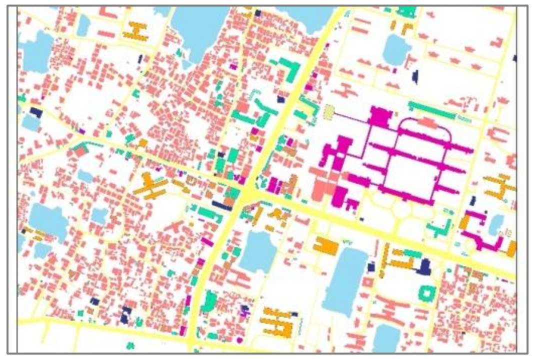


Physical Features after digitization

Field Verification and Attribute Information Collection



Attribute Information added in the Database



Base Map

Figure 12: Steps of Base Map Preparation

Table 1: List of Physical Features and Information incorporated in the Base Map

No.	Physical Features	Attribute Information
1.	Building	Building use, land use, structure type, storey number, structure name
2.	Road	Pavement material, width, number of lane, length
3.	Railway	Type
4.	Water body	Type (river, lake, khal, dighi, pond, marshy land)
5.	Open Space	Type (eidghah, playground, park, graveyard)

Building Inventory Development

To properly assess the seismic vulnerability of existing building stock, it is required to know the building structural type, the building occupancy class, the number of building occupants during the day and the night, the total floor area, the number of stories, the cost of the building and its contents inside, the seismic vulnerability characteristics of building, etc.

To acquire the missing information, it is not necessary to survey each and every building in the cities—which is impossible under the scope of budget and time frame. Instead, a series of well-designed comprehensive building surveys have been carried out in this study. The surveys were classified into 3 levels: Level-1, level-2, and level-3 surveys.

Level 01: Building Survey

In the level 01 building survey, side walk and questionnaire surveys were carried out. The average time required for this survey by a 2-member team was about 8-10 minutes for one building. The building attributes collected at this survey level were:

Number of stories; Occupancy class; Structural type; Number of occupants during the day and the night (Based on no. of Apartment); Age of the building(range); Presence of soft story (yes/no); Presence of heavy overhangs (yes/no); Shape of the building in plan view (rectangular, narrow rectangular, irregular); Shape of the building in elevation view (regular, setback, and narrow tall); Pounding possibility (yes/no); Building in slope land (yes/no); Visible ground settlement (yes/no); Presence of short columns (yes/no); Visible physical condition (poor/average/good)

Table 2 shows the list of number and types of buildings surveyed in Six Cities

Table 2: Total number of Structure in Six Cities

City Corporation/Pourashava	Number of Buildings
Bogra Paurashava	92830
Dinajpur Paurashava	41955
Mymensingh Paurashava	45033
Rajshahi City Corporation	93885
Rangpur City Corporation (Old Pourashava Area)	76444
Tangail Paurashava	68348

Level 02: Building Survey

About 10 percent of the level 01 surveyed buildings were chosen for the Level 02 survey on a random basis. In addition to the attributes acquired in the Level-1 survey, measurements of the building ground floor were taken. A sketch of the building plan at the ground story was made, and the dimensions of columns, concrete and masonry walls were measured. The main objective of this survey was to acquire more detailed information for more in-depth seismic vulnerability assessment of typical buildings. It took on an average about two and a half hours for a 2-member team to complete the Level 02 survey on one building.

For concrete buildings, the building attributes acquired during the Level-2 survey are:

- Torsional irregularity (non-rectangular shape, unsymmetrical infill, unsymmetrical shear wall)
- Short column (less than 25% of floor height, 25-50% of floor height, more than 50% of floor height)
- Diaphragm discontinuity (mezzanine floor, floor opening)
- Slab system (cast insitu, pre-cast)
- Key dimensions (plan dimensions, typical column size, no. of bays, span length, shear wall dimensions)

For masonry buildings, the building attributes acquired during the Level 02 survey are:

- Wall Thickness
- Maximum unsupported length of wall
- Corner separation (yes/no)
- Anchorage of wall to floor (yes/no)
- Anchorage of roof with wall (yes/no)
- Wall to wall anchorage (yes/no)
- Bracing of flexible floor/roof (yes/no)
- Existence of gable wall (yes/no)
- Horizontal band (yes/no)
- Vertical post (yes/no)

Level 03: Building Survey

For dynamic measurement was conducted on few selected buildings in three cities. Main objective of this survey is to understand the behavior of different types of buildings during earthquake. For dynamic measurement of RCC Buildings, Micro tremor, Schmidt Hammer, Ferro Scanner, Vibration shaker were used. For masonry building Shear strength test of binding mortar of masonry walls was done using Hydraulic Jack with Deflection Meter.

Geotechnical and Geophysical Investigations

A number of geotechnical & Geophysical investigations were conducted for preparation of Engineering Geological Map, soil liquefaction maps for seismic hazard Assessment and for damage and loss estimation. The investigations include Boreholes with SPT, PS Logging, MASW and SSM, Microtremor Array and Single Microtremor. Table 3 shows the brief description on the number and type of Geotechnical & Geophysical Investigation.

Table 3: Description on the number and type of Geotechnical & Geophysical Investigation

Name of the City	Name and number of the Investigation				
	Borelog with SPT	PS Logging	MASW and SSMM	Microtremor Array	Single Microtremor
Bogra	25	15	18	03	25
Dinajpur	20	15	18	03	25
Mymensingh	25	15	18	03	25
Rajshahi	20	15	18	04	25
Rangpur	70	20	30	05	100
Tangail	20	15	18	03	25

The number of tests conducted had been selected depending on the surface geology (geomorphology) of the city. As a sample case, Mymensingh town example has been provided in the following figure. Number of the tests were selected in such a fashion that, each of the geomorphic unit contains adequate number of tests for the analysis.

Figure 13: Geological Investigations

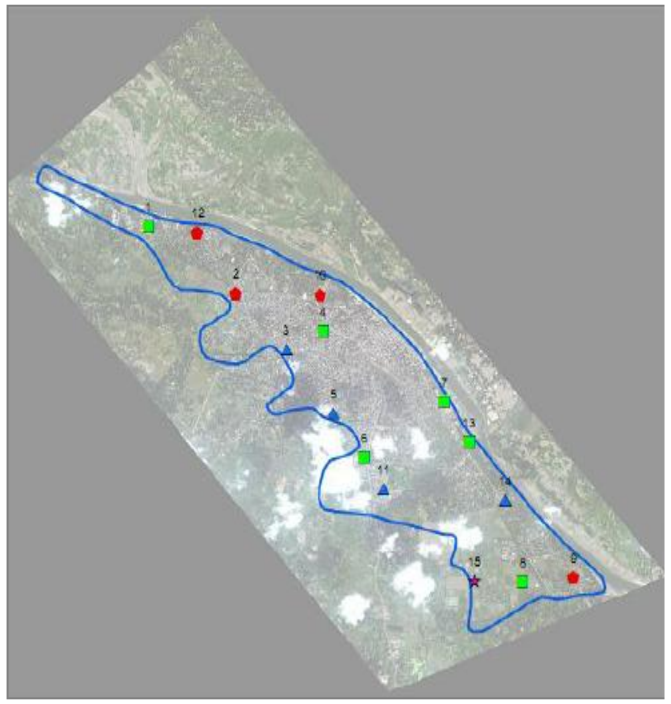


Figure 14: Test Locations in Mymensingh Paurashava

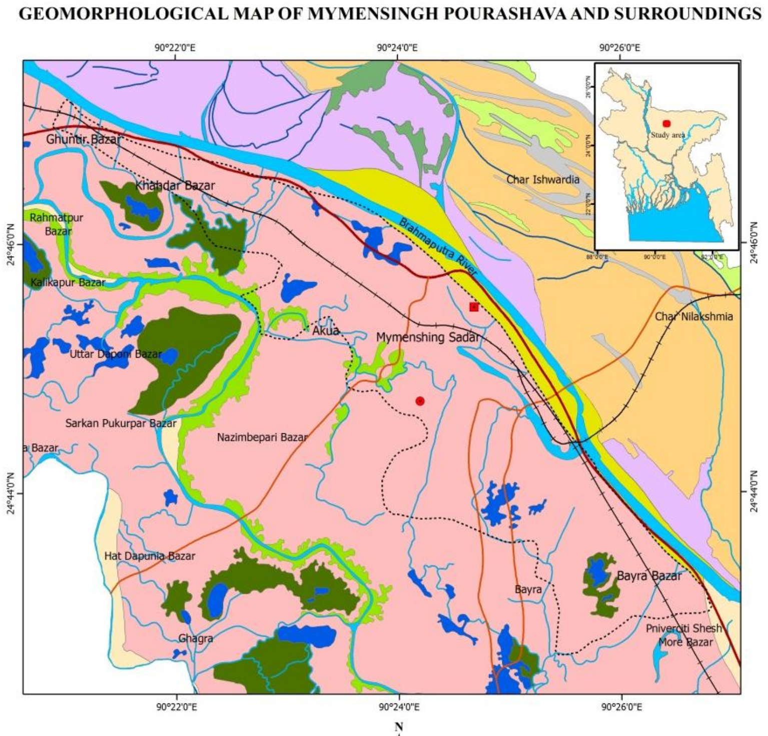


Figure15: Geomorphology (Surface Geology) of Mymensingh Paurashava

Earthquake Scenario 3 (475-yr Return Period) of Mymensingh

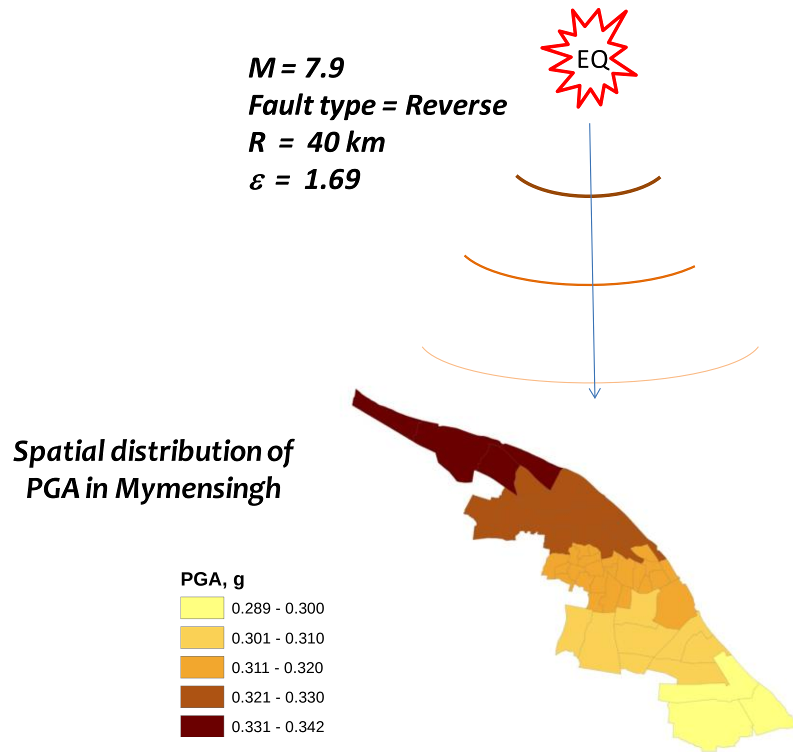


Figure 16: Peak Ground Acceleration Computation at Bed Rock level

All tests were conducted to measure the shear wave velocities at 30 m depth Vs30 at the specific sites, which was utilized to comprehend the soil characteristics of the site. Peak Ground Acceleration at bed rock level was calculated from the source characteristics as well as the attenuation characteristics. Table 4 shows the empirical relationship between SPT N value and Vs30.

Table 4: Relations between shear wave velocities and SPT N-values of soils

Years	Researchers	Equations	Units	Soil types	Locations
1973	Ohsaki , Iwasaki	$V_s = 81.686\,N^{0.39}$	m/s	All	Japan
1982	Imai, Tonuchi	$V_s = 96.926\,N^{0.341}$	m/s	All	Japan
1978	Ohta, Goto	$V_s = 85.344\,N^{0.341}$	m/s	All	Japan
1983	Seed, Idriss, Arango	$V_s = 56.388\,N^{0.5}$	m/s	Sand	Japan
1983	Sykora, Stokoe	$V_s = 100.584\,N^{0.29}$	m/s	Sand	Japan
1994	Dickenson	$V_s = 88.392(N+1)^{0.30}$	m/s	Sand	San Francisco

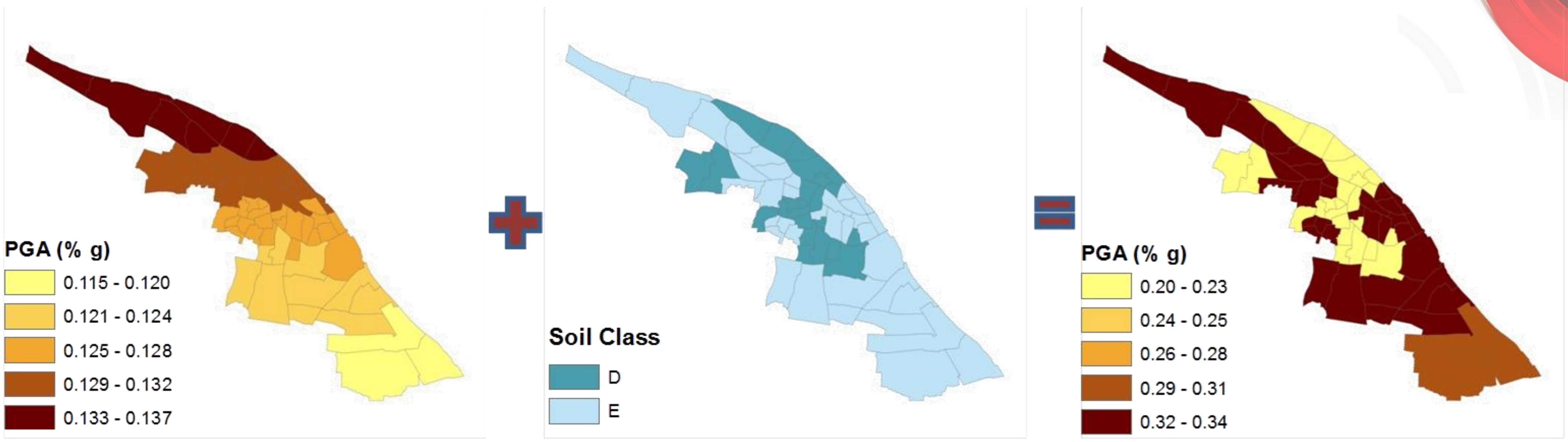
The PGA will be amplified or de-amplified depending on the soil under the site. For the cities, the average shear wave velocities were calculated to illustrate the soil classification as shown in table 5. The soil has been classified according to table 5 as follows. For most of the cities under the study, the soil class was either D or E, which corresponds to soft and very soft soil.

Table 5: Soil Class Classification

Site Class	Shear Wave Velocity at 30 m depth [Vs30 (m/s)]	Soil Type
A	>1500	Hard Rock
B	760-1500	Rock
C	360-760	Very dense soil and soft rock
D	180-360	Dense/ Stiff Soil
E	<180	Loose/ Soft Soil

Source: ASCE-7

With the soil classification, the amplification maps for different cities can be derived as following figure (the example is given for Mymensingh Paurashava):



The distribution of PGA can be utilized to calculate the Liquefaction Probability of the soil, utilizing the liquefaction susceptibility of the site. The process is shown for Mymensingh Paurashava as follows:

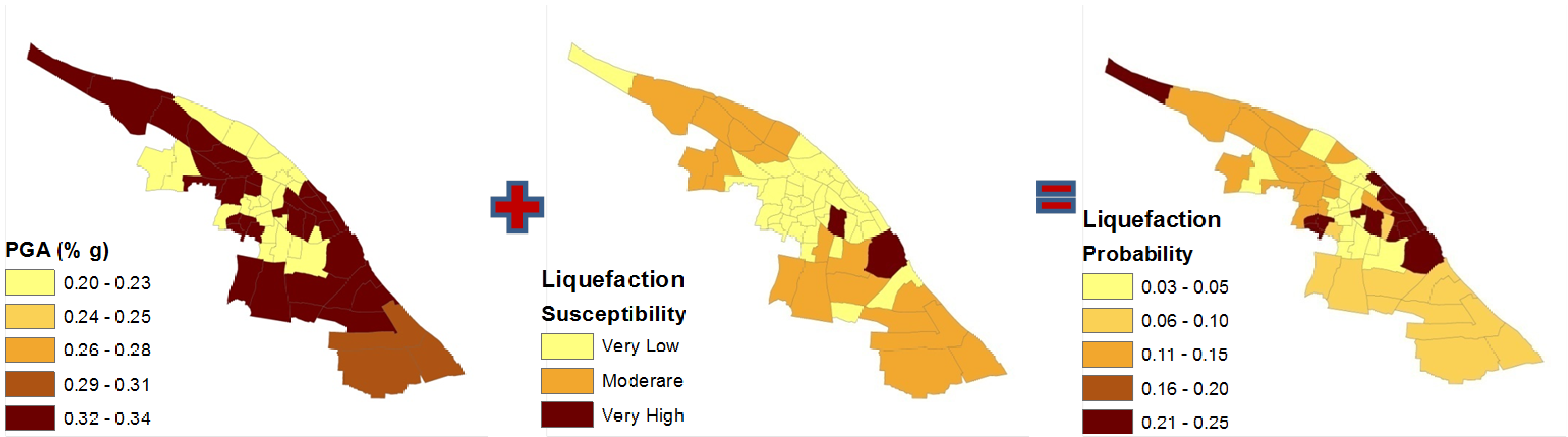


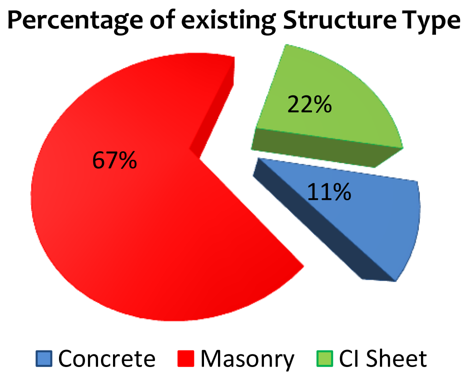
Figure 17: Process of constructing liquefaction potential maps

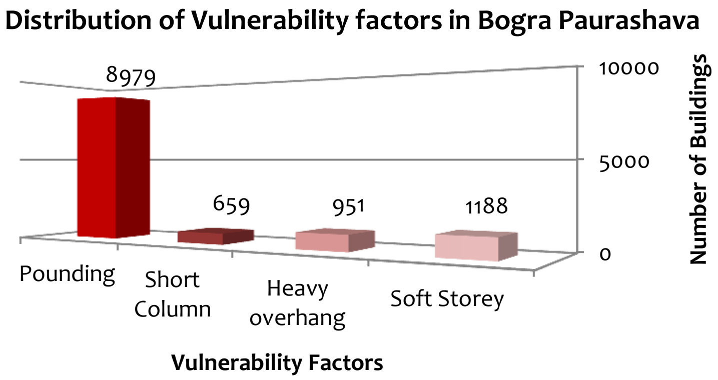
3.4 Seismic Risk and Vulnerability Assessment

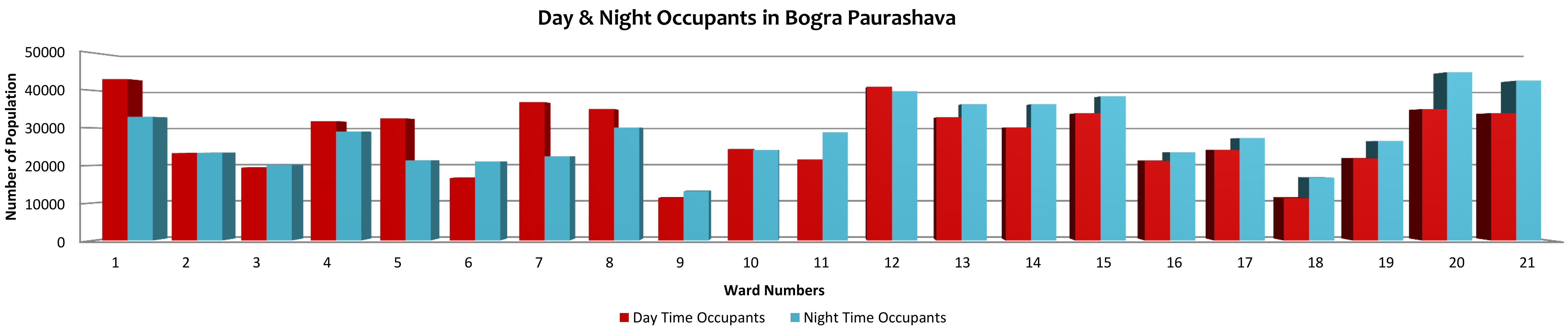
Bogra Paurashava

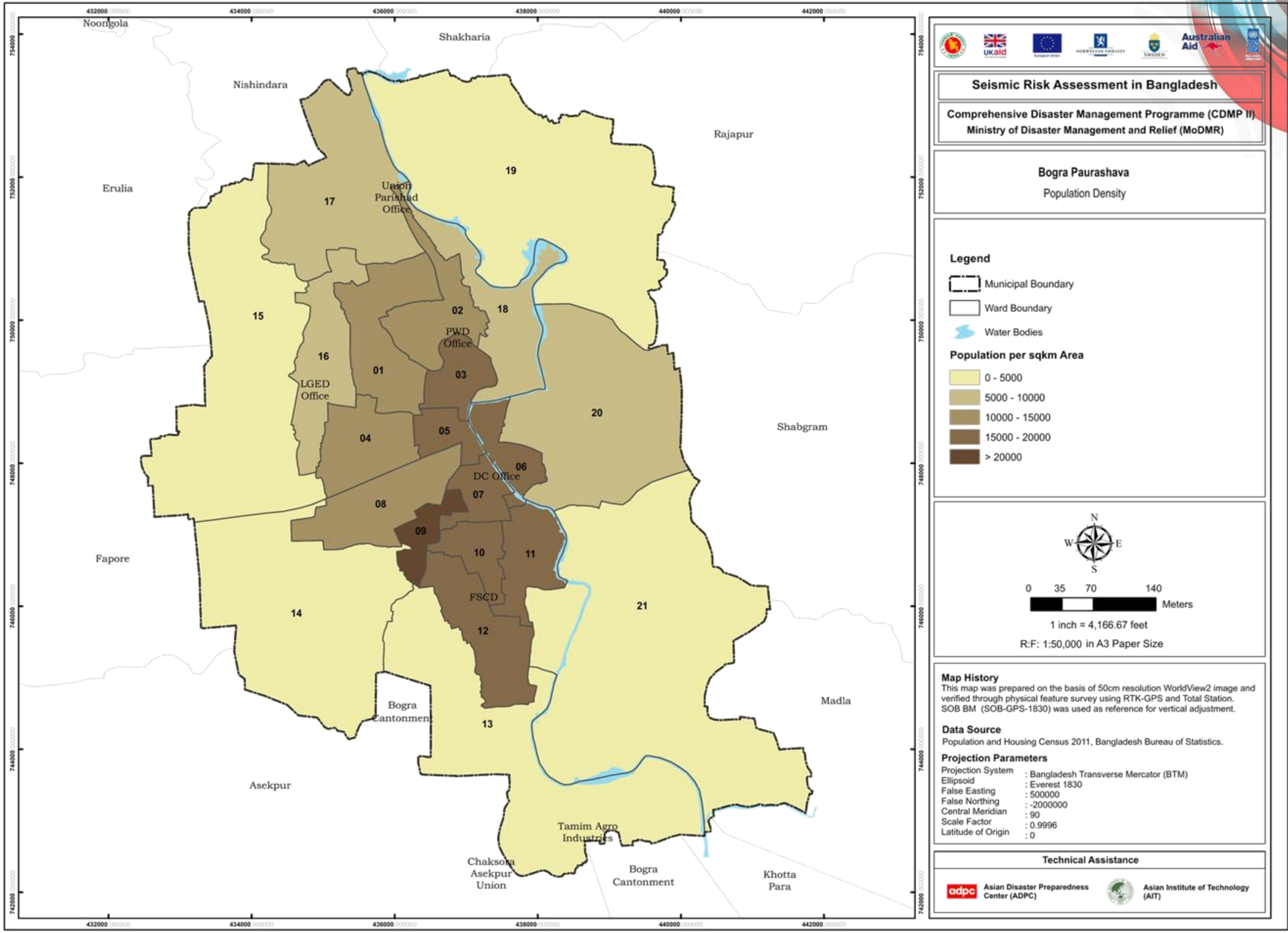
Bogra was founded as a Town in 1850. Later Bogra Paurashava was established in 1884. It consists of 21 wards and 46 mahallas with total area of 64.97 sq. km. The Total population of the paurashava is about 400983 (male 53.20%, female 46.80%). The literacy rate among the town people is about 63%. The main occupations of the city consist of: Agriculture (29.95%), agricultural labor (12.53%), wage labor (2.2%), commerce (18.11%), service (15.62%), transport (6.66%), and others (14.93%).

Brief Information of the City	
Name of the City	Bogra
Name of the Paurashava	Bogra Pourashava
Year of Establishment	1884
Total Area	64.97 sq.km
Number of Wards	21
Total Population	400983 (Male-210093, Female- 190890)
Population Growth Rate (2011)	1.20%
Road Network	802.54 km
Railways	8.5 km
Water Ways	1.14 sq km or 629.95 acre
Natural Water Bodies	2.54 sq km or 629.95 acre
Open Space	5.698 sq. km or 280 acr3
Education Institutions	421
Health Facilities	69
Re-fueling Stations	29
Fire Station	1
Police Station	1








Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Population Density
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Population per sqkm Area
0 - 5000
5000 - 10000
10000 - 15000
15000 - 20000
> 20000
N
W
E
S
0 35 70 140
Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-1830) was used as reference for vertical adjustment.
Data Source
Population and Housing Census 2011, Bangladesh Bureau of Statistics.
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Noongola
Shakharia
Nishindara
Rajapur
Erulia
Shabgram
Fapore
Madla
Asekpur
Bogra Cantonment
Tamim Agro Industries
Chaksota Asekpur Union
Khotta Para
Union Parishad Office
PWD Office
LGED Office
DC Office
FSCD
01
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432000
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748000
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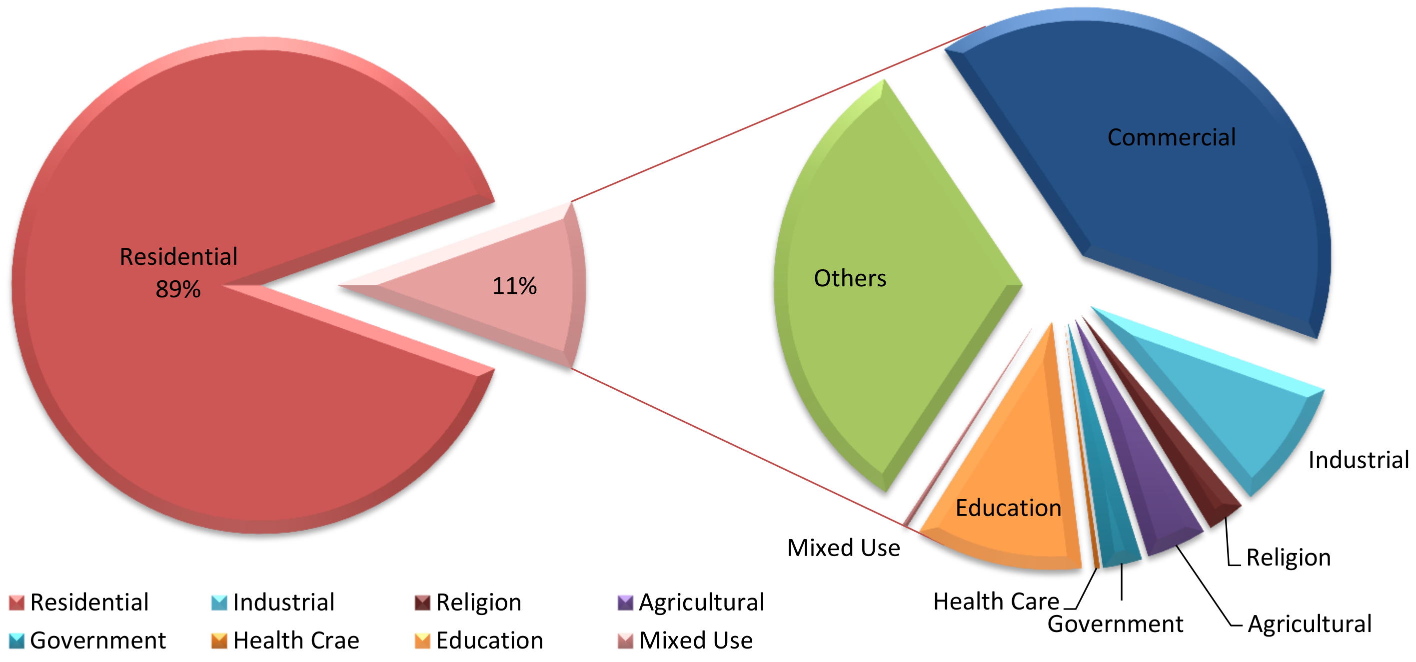
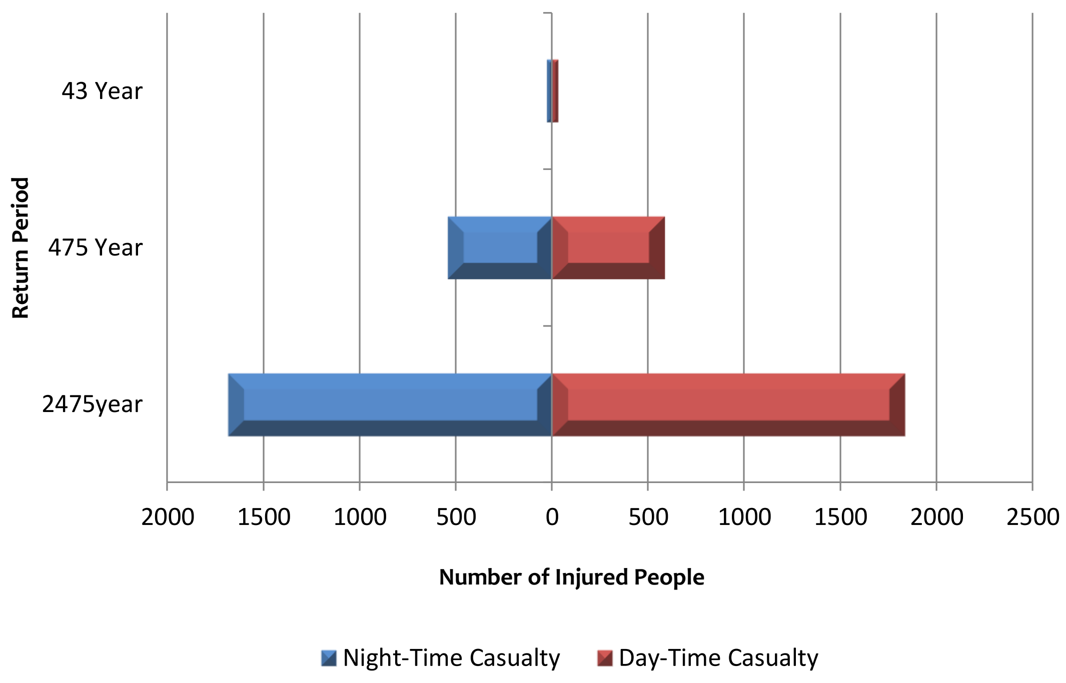
742000

Distribution of Different Occupancy Classes in Bogra Paurashava



Expected Casualties in Bogra Paurashava



EXPECTED PHYSICAL DAMAGE STATES

Table 6: Expected physical damage states of buildings for different scenario cases

Scenarios	Total Structure	Concrete Structure					Masonry Structure					Informal Structures				
		Total Concrete Structure	Moderate Damage		Complete Damage		Total Masonry Structure	Moderate Damage		Complete Damage		Total Zinc Shed and Bamboo Structure	Moderate Damage		Complete Damage	
			No.	%	No.	%		No.	%	No.	%		No.	%	No.	%
Scenario 1 Case 1	91344	9829	128	1.30%	0	0.00%	61288	756	1.23%	0	0.00%	20227	229	1.13%	0	0.00%
Scenario 2 Case 2	91344	9829	244	2.48%	0	0.00%	61288	405	0.66%	0	0.00%	20227	109	0.54%	0	0.00%
Scenario 3 Case 1	91344	9829	2288	23.28%	2	0.02%	61288	17557	28.65%	58	0.09%	20227	4426	21.88%	0	0.00%
Scenario 4 Case 2	91344	9829	1750	17.80%	213	2.17%	61288	16334	26.65%	3666	5.98%	20227	2036	10.07%	0	0.00%
Scenario 5 Case 1	91344	9829	4213	42.86%	36	0.37%	61288	28390	46.32%	645	1.05%	20227	8581	42.42 %	3	0.01%
Scenario 6 Case 2	91344	9829	2247	22.86%	823	8.37%	61288	12131	19.79%	19726	32.19%	20227	3751	18.54%	0	0.00%

Debris Generation

Table 7: Expected debris generation for different scenario cases

Earthquake Scenario	Amount of Debris (million tons)	% of Concrete and Steel materials	% of Brick and Wood materials
Scenario 1 Case 1	0.020	16%	84%
Scenario 2 Case 2	0.020	25%	75%
Scenario 3 Case 1	0.430	50%	50%
Scenario 4 Case 2	1.050	65%	35%
Scenario 5 Case 1	1.320	65%	35%
Scenario 6 Case 2	3.850	73%	27%

Damage to utility systems

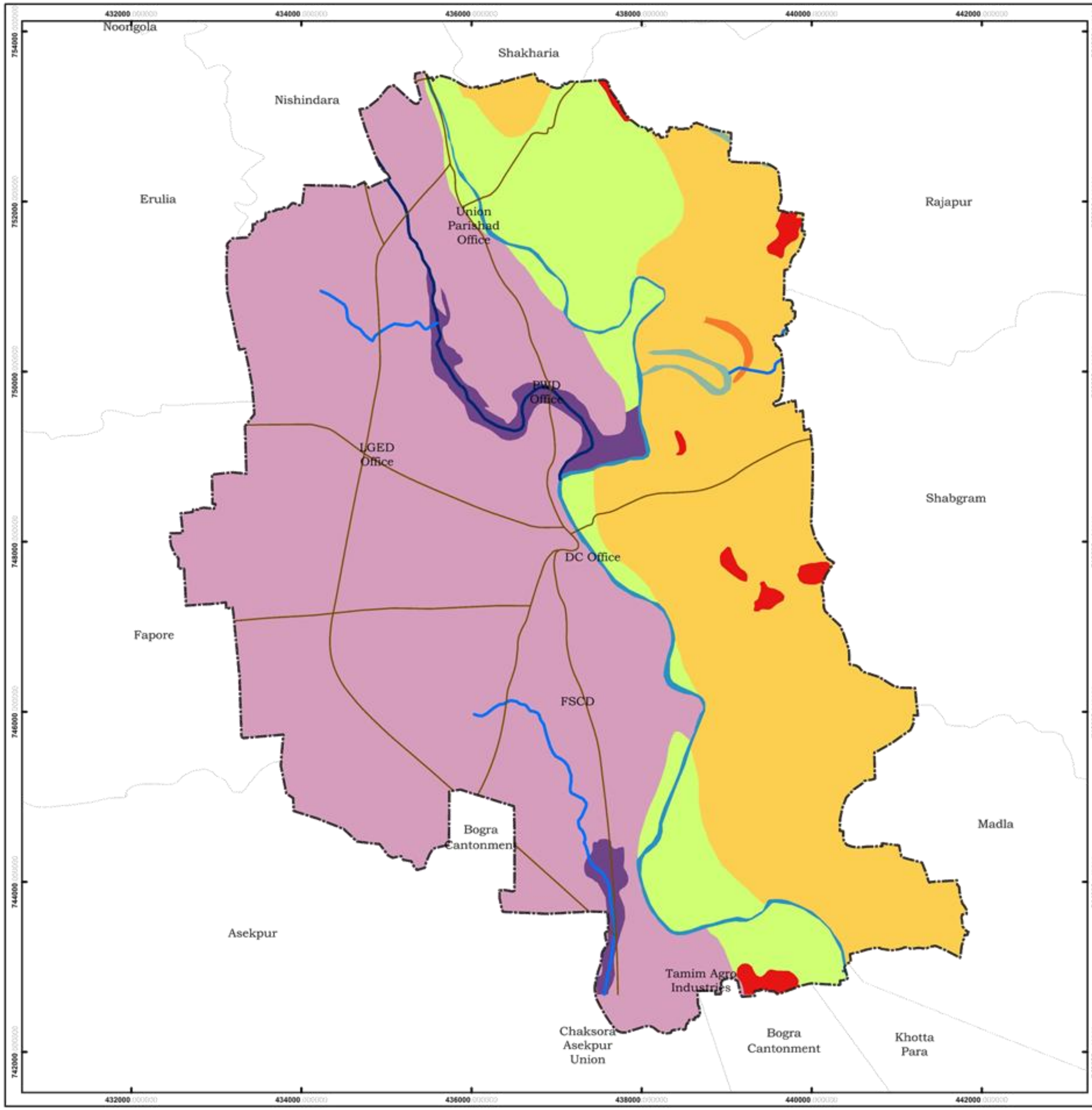
Table 8: Expected damage to utility systems for different scenario cases

System	Total Length Pipelines (km)	No. of Leaks						No. of Breaks					
		Scenario 1 Case 1	Scenario 2 Case 2	Scenario 3 Case 1	Scenario 4 Case 2	Scenario 5 Case 1	Scenario 6 Case 2	Scenario 1 Case 1	Scenario 2 Case 2	Scenario 3 Case 1	Scenario 4 Case 2	Scenario 5 Case 1	Scenario 6 Case 2
Potable Water	124	1	2	8	19	24	41	0	1	2	5	6	10

Damage of Utility and Lifelines

Table 9: Expected damage to lifelines for scenario 3 case 1

System	Component	Total	Moderate Damage	Complete Damage	At least 50% Functional	
					Day 1	Day 7
Highway	Segments	6644	0	0	6644	6644
	Bridges	37	0	0	37	37
	Facilities	70	1	0	69	70
Railway	Segments	10	0	0	10	10
	Bridges	2	0	0	2	2
	Facilities	4	0	0	4	4



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Bogra Paurashava
Geology

Legend

- Municipal Boundary
- Major Road Network
- Intermittent Channel

Barind Tract Deposits

- Barind Clay Residuum
- Valley Deposits

Jamuna - Karatoya Floodplain Deposits

- Active Channel Deposits
- Abandoned Channel Deposits
- Bar Deposits
- Flood Plain Deposits
- Meander Scar Deposits
- Back Swamp Deposits

N W E S

0 35 70 140 Meters

1 inch = 4,166.67 feet

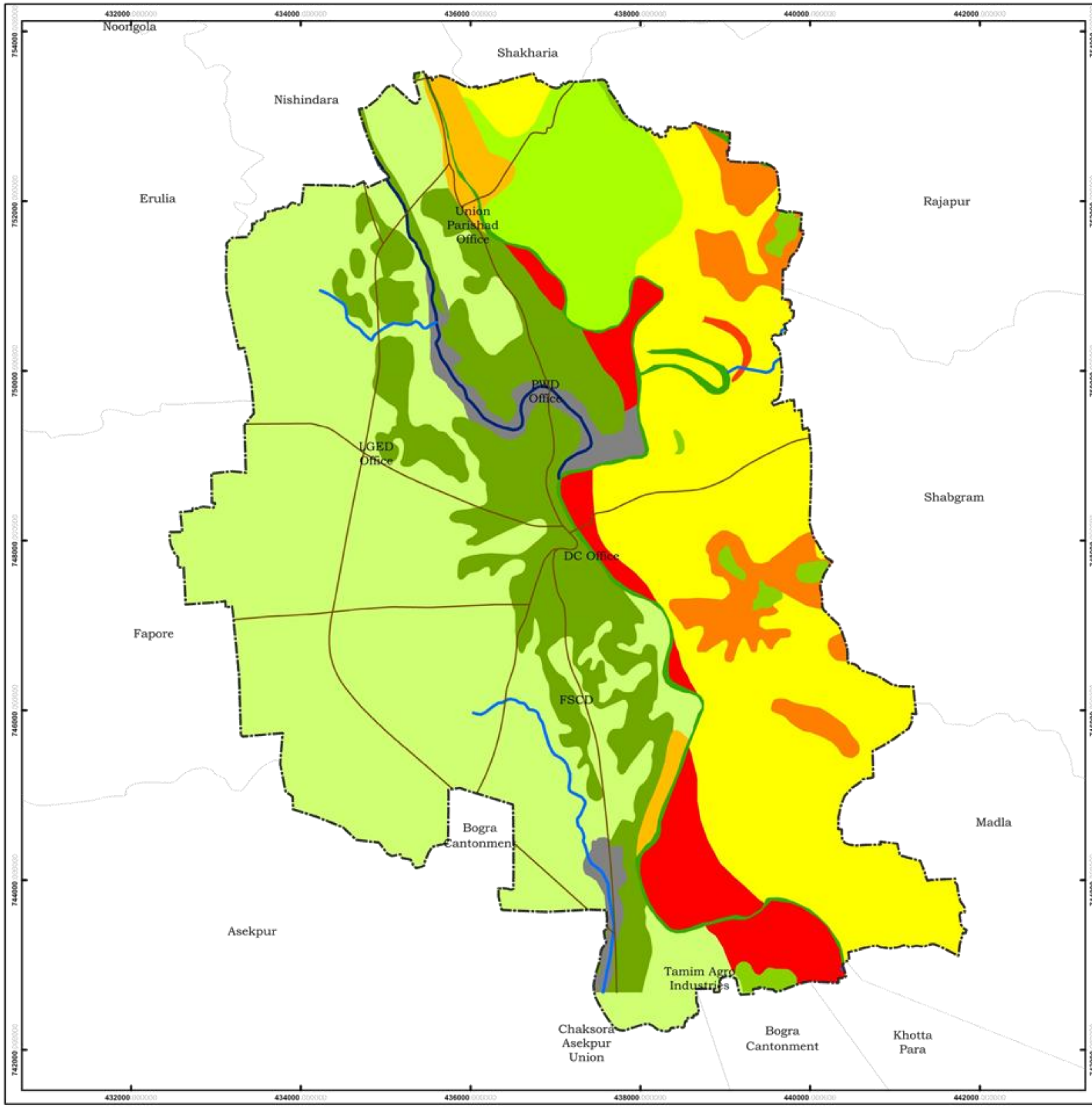
R:F: 1:50,000 in A3 Paper Size

Barind Tract Deposit	
Barind clay residuum	Grey (10YR 5/1) to greyish brown (10YR 5/2) mottled clay, clayey silt and silty clay
Valley deposits	Dark greyish brown (10YR 4/2) to grey (10YR 5/1) silty clay and sandy silt
Jamuna-Karatoya Floodplain deposits	
Active channel	Light grey (10YR 7/1) to grey (10YR 5/1) coarse to medium sand and silt
Abandoned channel deposits	Dark grey (10YR 4/1) to dark greyish brown (10YR 4/2), fine to medium sand with silt
Bar deposits	Dark grey (10YR 4/1) to grey (10YR 5/1), sandy silt and silt
Flood plain deposits	Light brownish grey (10YR 6/2) to greyish brown (10YR 5/2) silty sand, sand and clayey silt
Meander scar deposits	Greyish brown (10YR 5/2) to grey (10YR 5/1) clayey silt, fine to medium sand
Back swamp deposits	Dark grey (10YR 4/1) to dark greyish brown (10YR 4/2) clayey silt, clay and sandy silt

Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0

Technical Assistance

Geological Survey of Bangladesh (GSB)
Asian Disaster Preparedness Center (ADPC)



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Bogra Paurashava
Geomorphology

Legend

- Municipal Boundary
- Major Road Network
- Intermittent Channel

Barind Tract

- Higher Barind Terrrace
- Lower Barind Terrrace
- Barind Fill

Jamuna - Karatoya Floodplain

- Abandoned Channel
- Active Channel
- Back Swamp
- Scroll bar
- Higher Flood Plain
- Lateral Bar
- Lower Flood Plain
- Meander Scar
- Point Bar

N W E S

0 35 70 140 Meters

1 inch = 4,166.67 feet

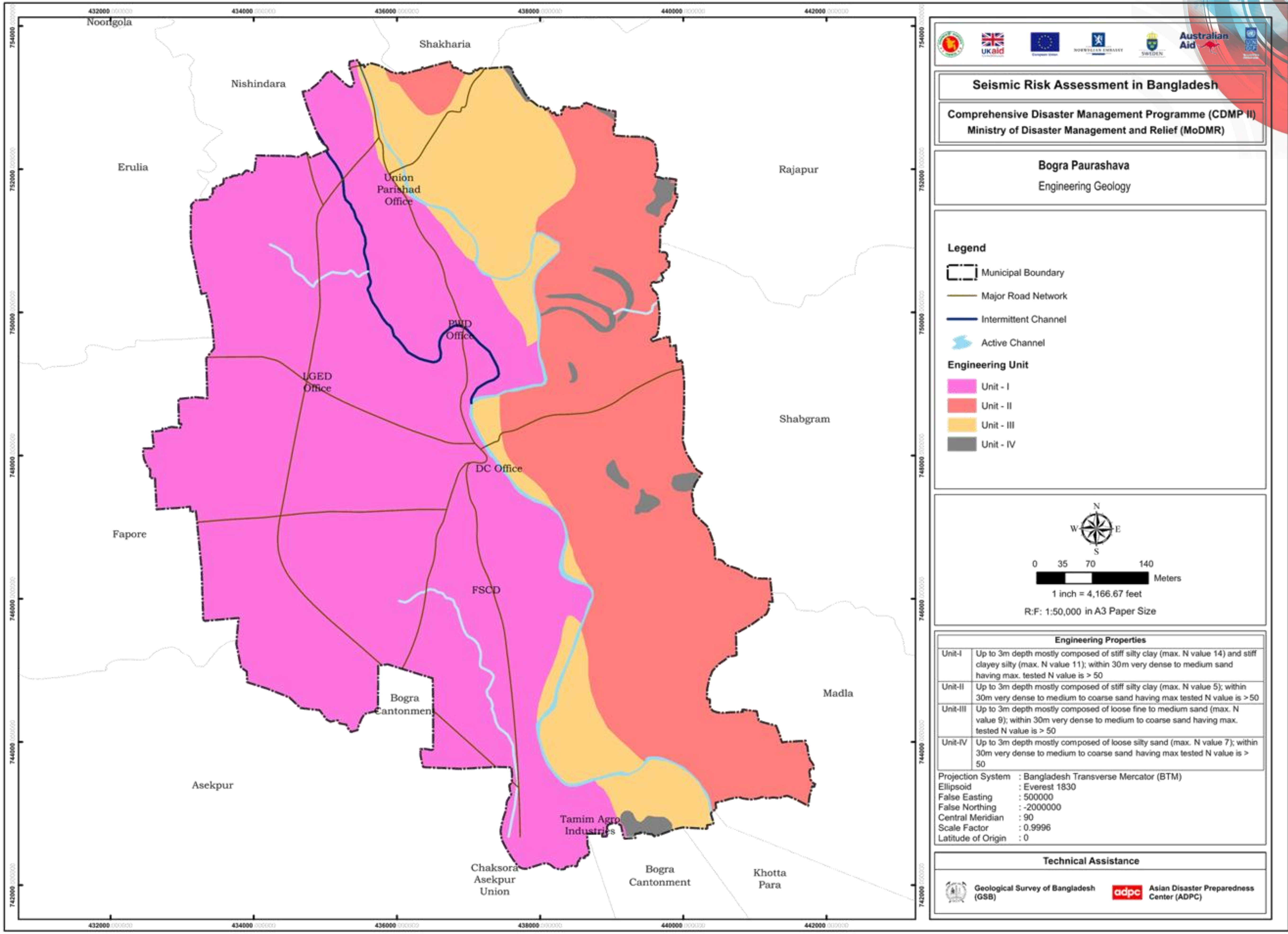
R.F: 1:50,000 in A3 Paper Size

Barind Tract	
High barind terrace	Irregular elevated landform in the Barind tract consisting of clay, clayey silt and silty clay
Lower barind terrace	Modereately elevated table like landform within barind tract consisting of clay, clayey silt and silty clay
Braind Valley	Irreguar narrow landform within higher and lower barind tract consisting of silty clay and sandy silt
Jamuna – Korotoya Floodplain	
Abandoned Channel	Elongated narrow channels without flowing water formed by the shifting of stream courses later filled by fine to medium sand
Active channel	Channel with perennial water having loose sand as bed loads
Back swamp	Irregular shaped depressed part within the floodplain consisting of clayey silt, clay and sandy silt
Scroll bar	Irregular shaped accumulation of sand consisting of ridges and swales
Higher floodplain	Elevated part of Jamuna-Karatoya floodlain above normal flooding level, consisting of silty sand, sand and clay silt
Lateral bar	Elongated accumulation of sand found along the south of Karatoya River
Lower floodplain	Part of Jamuna-Karatoya perennially flooded, consist of silty sand, sand and clayey silt
Meander scar	Crescent shaped sandy remnant of mender channels within the floodplain formed by the channel neck cut off
Point Bar	Crescent shaped accumulation of sand along the Karatoya River

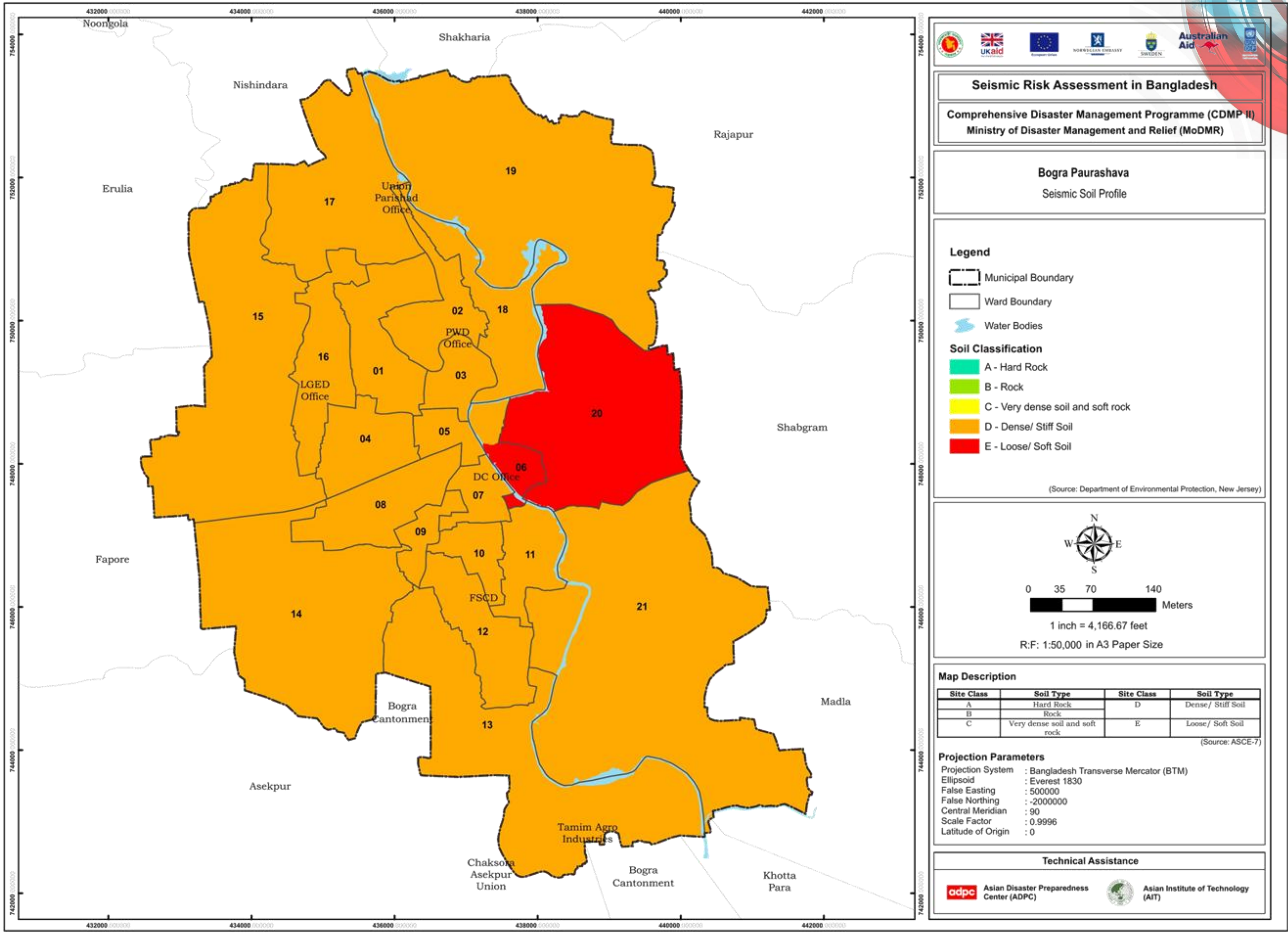
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0

Technical Assistance

Geological Survey of Bangladesh (GSB)
Asian Disaster Preparedness Center (ADPC)



Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Engineering Geology
Legend
Municipal Boundary
Major Road Network
Intermittent Channel
Active Channel
Engineering Unit
Unit - I
Unit - II
Unit - III
Unit - IV
N
W
E
S
0 35 70 140
Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Engineering Properties
Unit-I Up to 3m depth mostly composed of stiff silty clay (max. N value 14) and stiff clayey silty (max. N value 11); within 30m very dense to medium sand having max. tested N value is > 50
Unit-II Up to 3m depth mostly composed of stiff silty clay (max. N value 5); within 30m very dense to medium to coarse sand having max tested N value is > 50
Unit-III Up to 3m depth mostly composed of loose fine to medium sand (max. N value 9); within 30m very dense to medium to coarse sand having max. tested N value is > 50
Unit-IV Up to 3m depth mostly composed of loose silty sand (max. N value 7); within 30m very dense to medium to coarse sand having max tested N value is > 50
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Geological Survey of Bangladesh (GSB)
Asian Disaster Preparedness Center (ADPC)
Noongola
Shakharia
Nishindara
Erulia
Rajapur
Union Parishad Office
PWD Office
LGED Office
DC Office
Shabgram
Fapore
FSCD
Bogra Cantonment
Madla
Asekpur
Tamim Agro Industries
Chaksora Asekpur Union
Bogra Cantonment
Khotta Para


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Seismic Soil Profile
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Soil Classification
A - Hard Rock
B - Rock
C - Very dense soil and soft rock
D - Dense/ Stiff Soil
E - Loose/ Soft Soil
(Source: Department of Environmental Protection, New Jersey)
N
S
E
W
0 35 70 140
Meters
1 inch = 4,166.67 feet
R.F: 1:50,000 in A3 Paper Size
Map Description
Site Class | Soil Type | Site Class | Soil Type
A | Hard Rock | D | Dense/ Stiff Soil
B | Rock
C | Very dense soil and soft rock | E | Loose/ Soft Soil
(Source: ASCE-7)
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Noongola
Shakharia
Nishindara
Rajapur
Erulia
Shabgram
Fapore
Madla
Asekpur
Bogra Cantonment
Chaksora Asekpur Union
Khotta Para
Tamim Agro Industries
Union Parishad Office
PWD Office
LGED Office
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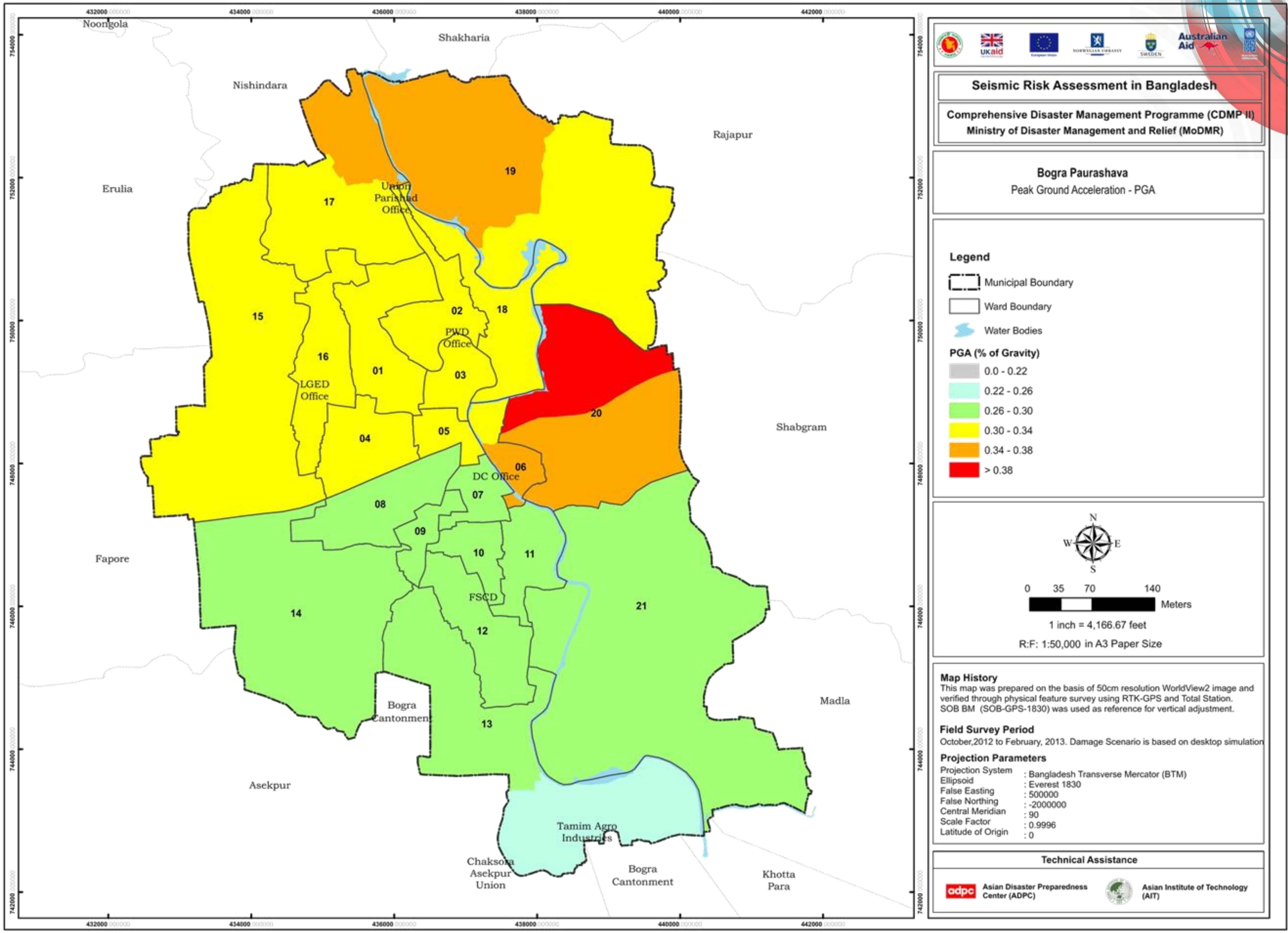
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Peak Ground Acceleration - PGA
Legend
Municipal Boundary
Ward Boundary
Water Bodies
PGA (% of Gravity)
0.0 - 0.22
0.22 - 0.26
0.26 - 0.30
0.30 - 0.34
0.34 - 0.38
> 0.38
0 35 70 140 Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-1830) was used as reference for vertical adjustment.
Field Survey Period
October,2012 to February, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Noongola
Shakharia
Nishindara
Rajapur
Erulia
Shabgram
Fapore
Madla
Asekpur
Chaksora Asekpur Union
Bogra Cantonment
Khotta Para
Tamim Agro Industries
Union Parishad Office
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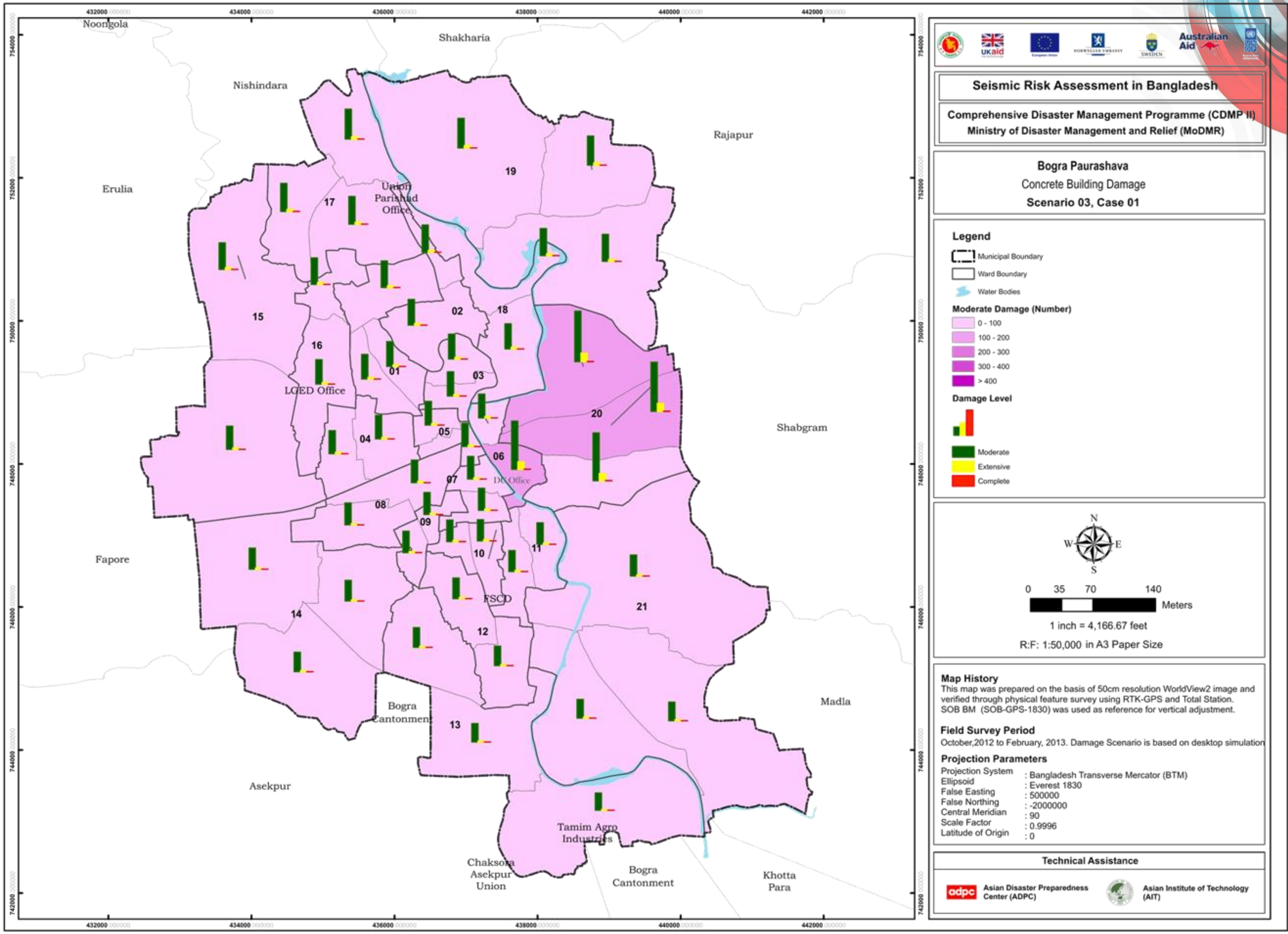

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Concrete Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Moderate Damage (Number)
0 - 100
100 - 200
200 - 300
300 - 400
> 400
Damage Level
Moderate
Extensive
Complete
N
W
E
S
0 35 70 140
Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
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Field Survey Period
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Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Noongola
Shakharia
Nishindara
Rajapur
Erulia
Shabgram
Fapore
Madla
Asekpur
Bogra Cantonment
Chaksora Asekpur Union
Khotta Para
Tamim Agro Industries
Union Parishad Office
LGED Office
DC Office
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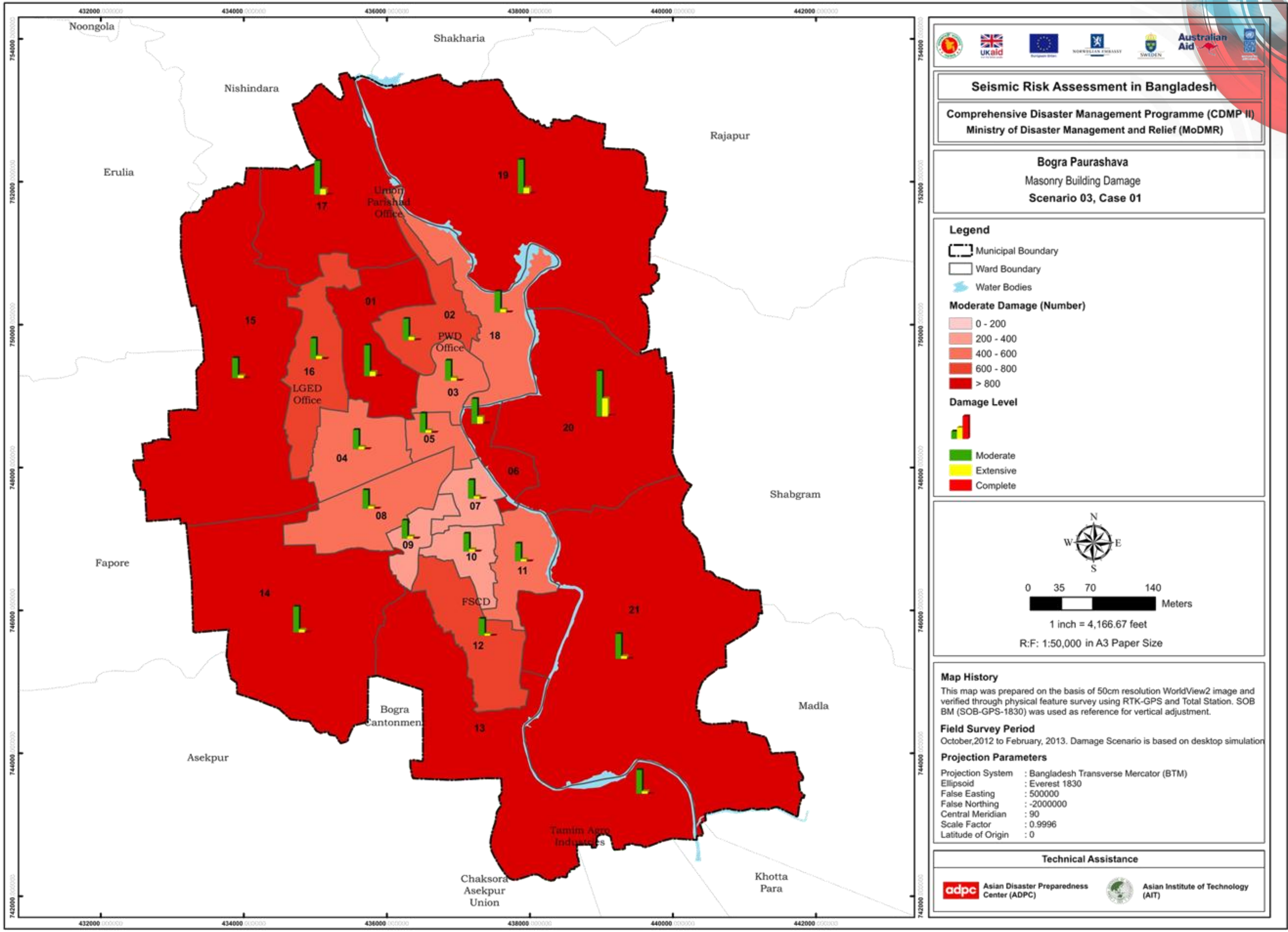

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Masonry Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Moderate Damage (Number)
0 - 200
200 - 400
400 - 600
600 - 800
> 800
Damage Level
Moderate
Extensive
Complete
N
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0
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70
140
Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
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Field Survey Period
October,2012 to February, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
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Nishindara
Rajapur
Erulia
Union Parishad Office
PWD Office
LGED Office
FSCD
Shabgram
Fapore
Madla
Bogra Cantonment
Asekpur
Tamim Agro Industries
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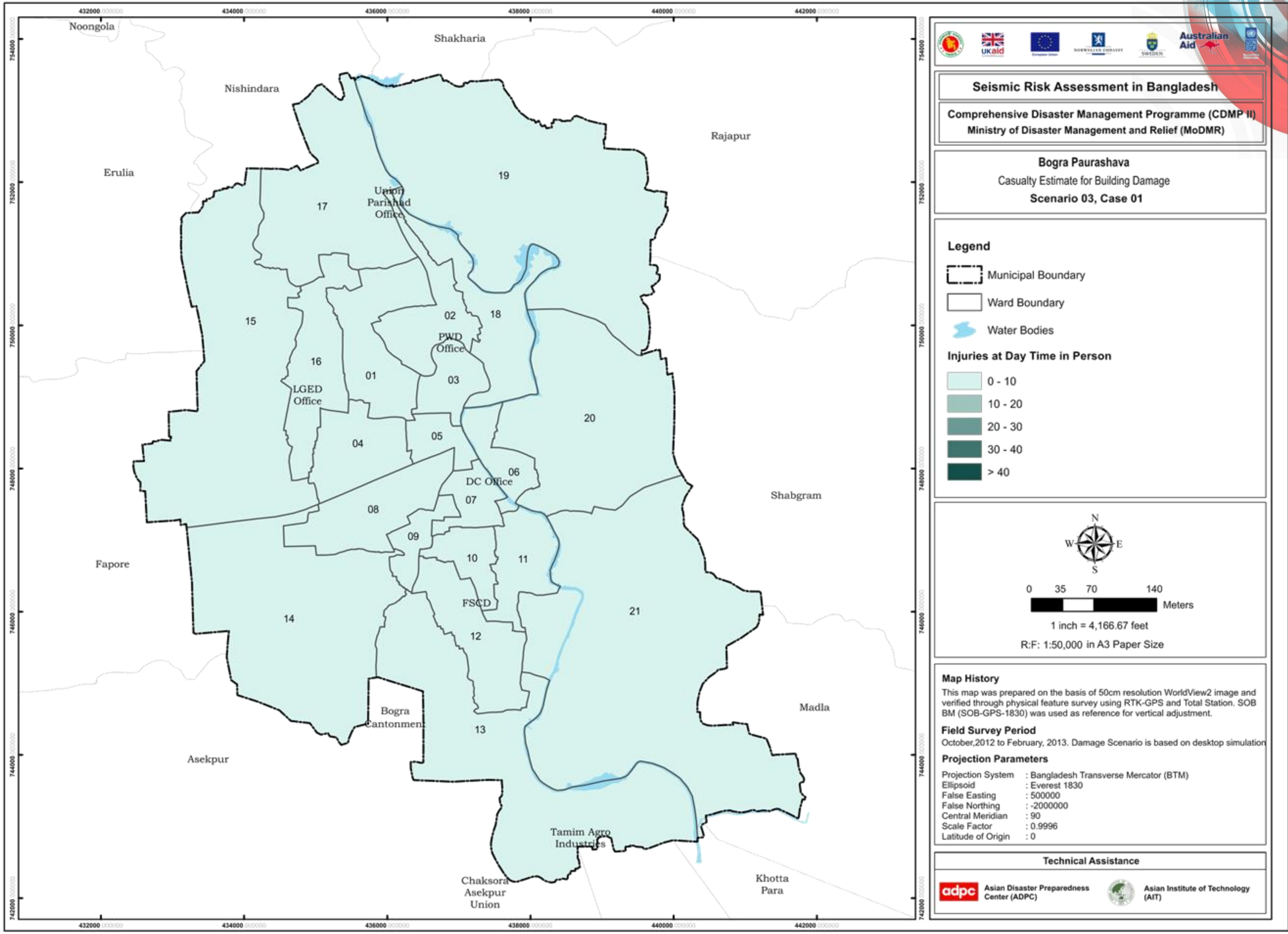
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Casualty Estimate for Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Injuries at Day Time in Person
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
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140
Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
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Projection System : Bangladesh Transverse Mercator (BTM)
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False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Noongola
Shakharia
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Union Parishad Office
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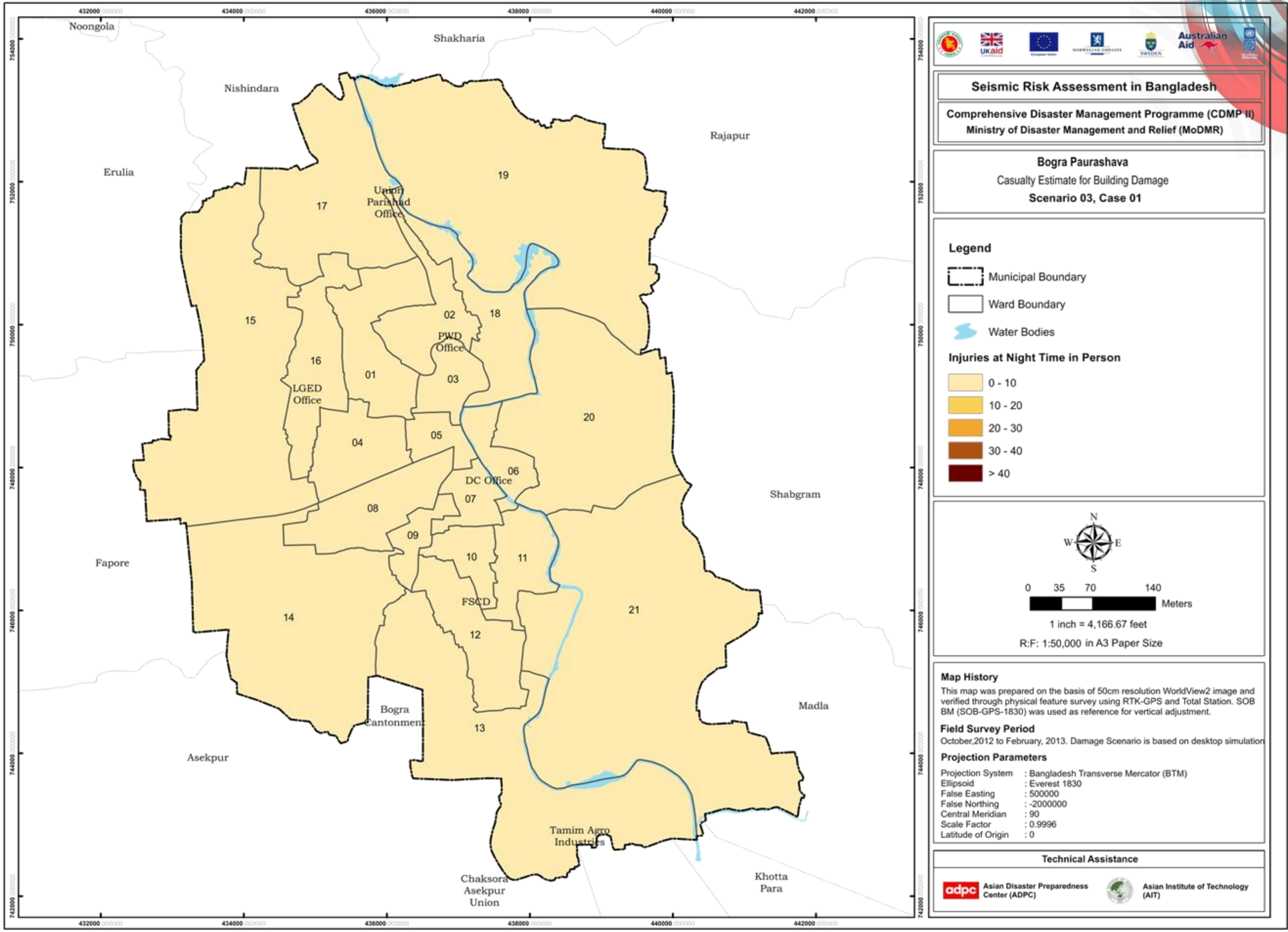
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Casualty Estimate for Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Injuries at Night Time in Person
0 - 10
10 - 20
20 - 30
30 - 40
> 40
0 35 70 140
Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
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October,2012 to February, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Noongola
Shakharia
Nishindara
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Bogra Cantonment
Chaksora Asekpur Union
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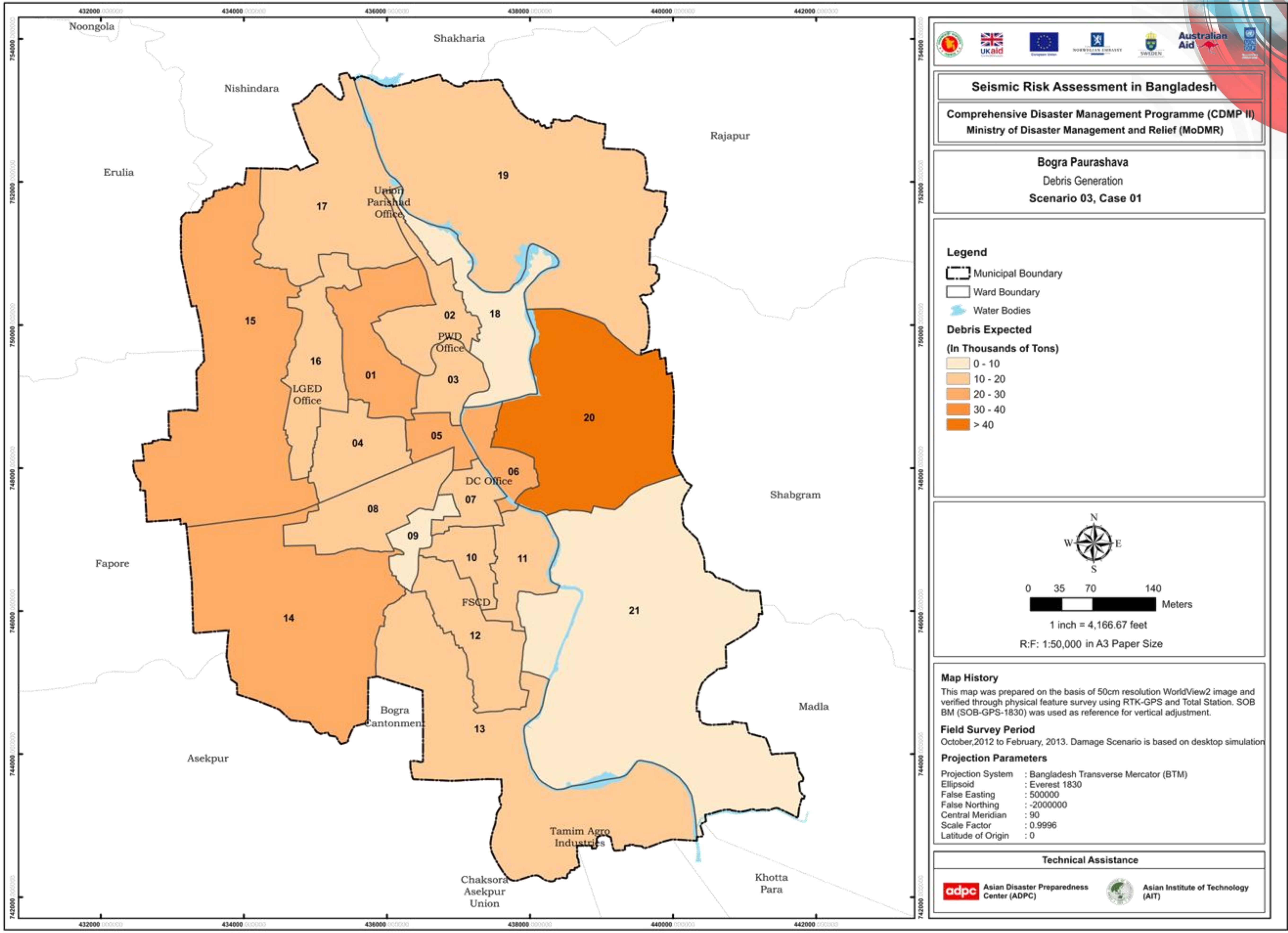
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Debris Generation
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Debris Expected
(In Thousands of Tons)
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
W
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S
0 35 70 140
Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-1830) was used as reference for vertical adjustment.
Field Survey Period
October,2012 to February, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Noongola
Shakharia
Nishindara
Rajapur
Erulia
Union Parishad Office
PWD Office
LGED Office
DC Office
FSCD
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Madla
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Chaksora Asekpur Union
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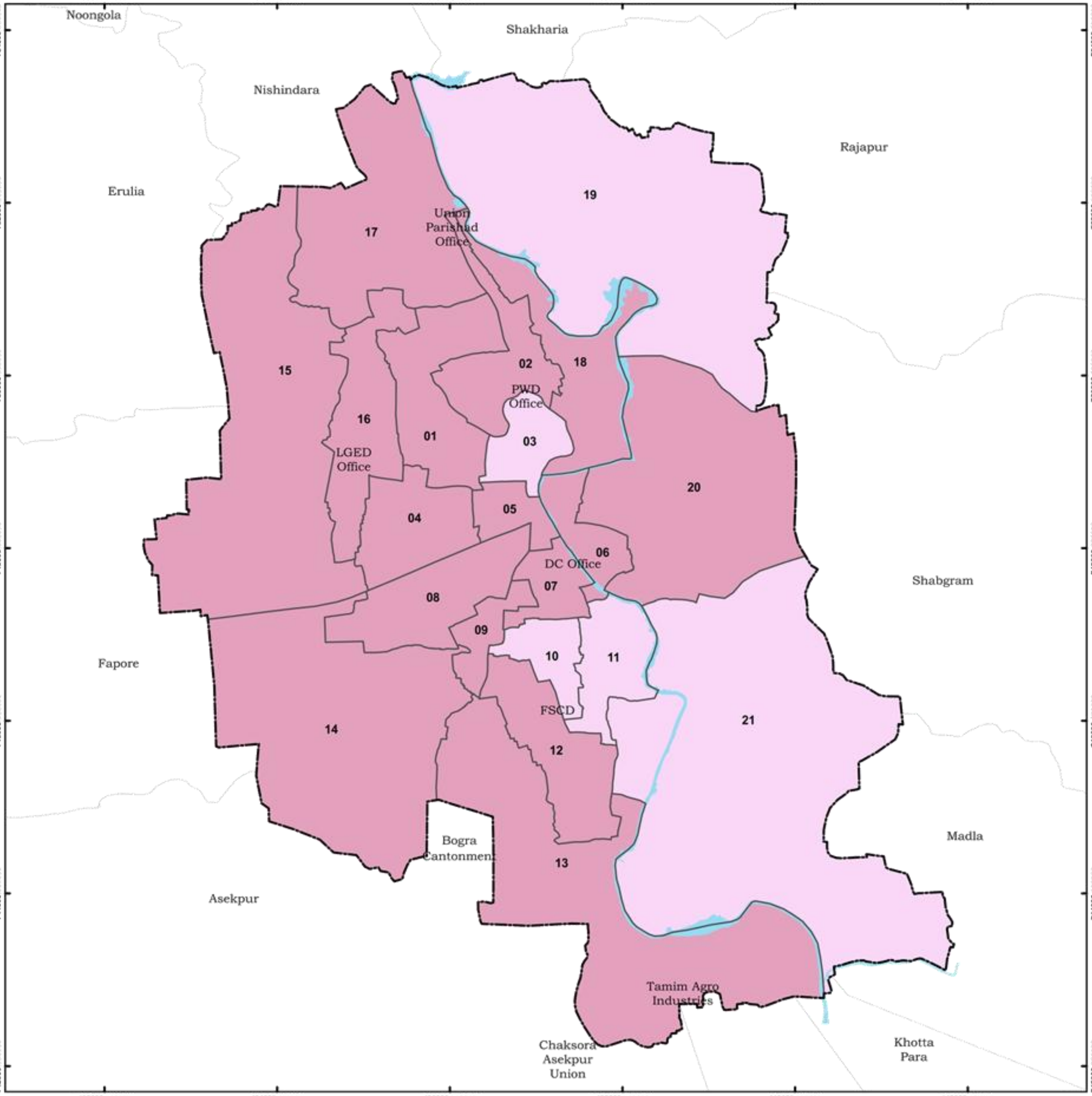


Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Bogra Paurashava
Fire Following Earthquake
Scenario 03, Case 01

Legend

Municipal Boundary
Ward Boundary
Water Bodies

Number of Ignitions

0
1
2
3
> 3

N S W E

0 35 70 140 Meters

1 inch = 4,166.67 feet

R:F: 1:50,000 in A3 Paper Size

Map History

This map was prepared on the basis of 50cm resolution WorldView2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-1830) was used as reference for vertical adjustment.

Field Survey Period

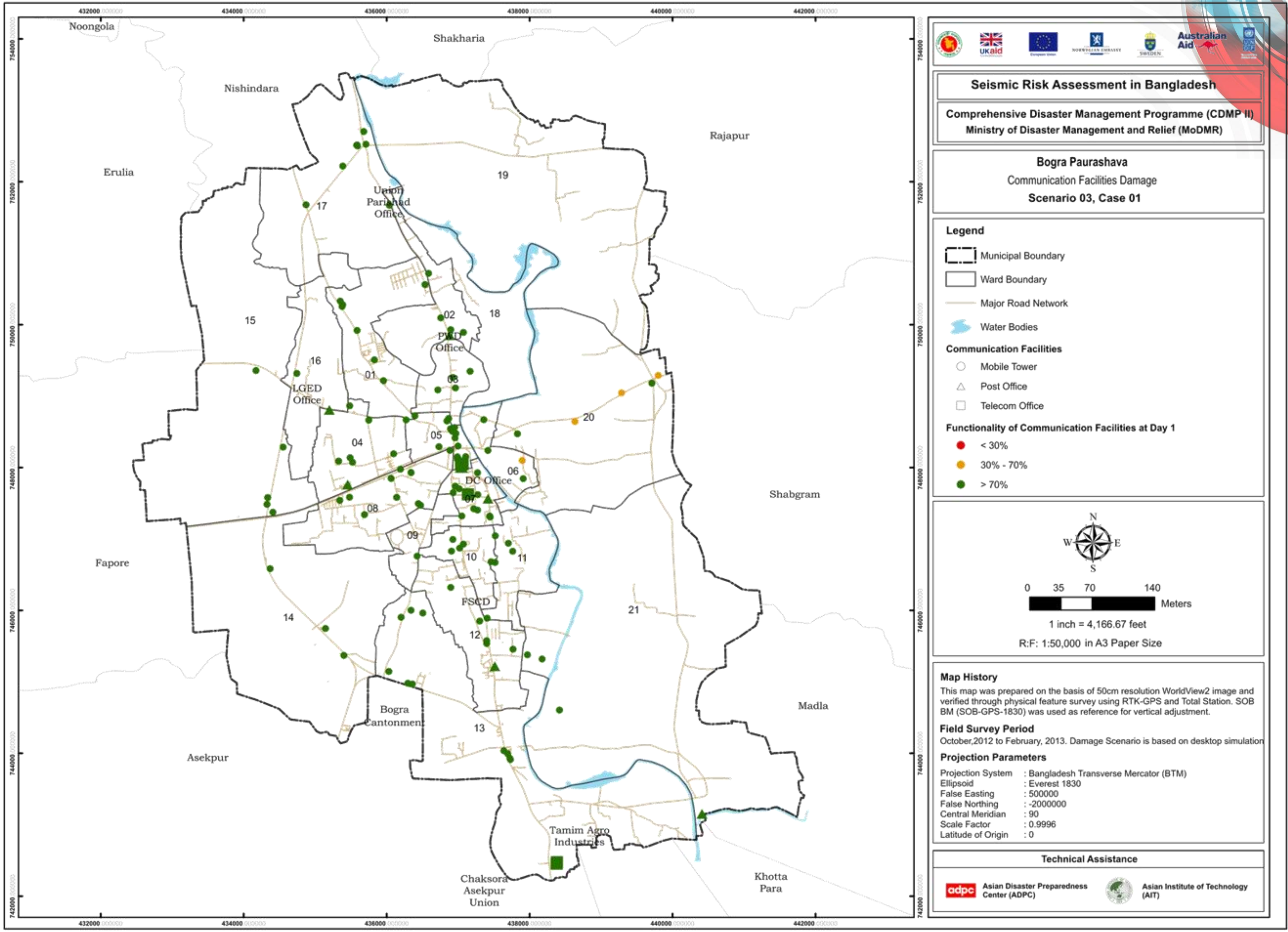
October,2012 to February, 2013. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)



Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Communication Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Communication Facilities
Mobile Tower
Post Office
Telecom Office
Functionality of Communication Facilities at Day 1
< 30%
30% - 70%
> 70%
N
E
S
W
0 35 70 140
Meters
1 inch = 4,166.67 feet
R.F: 1:50,000 in A3 Paper Size
Map History
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Field Survey Period
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Ellipsoid : Everest 1830
False Easting : 500000
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Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Noongola
Shakharia
Nishindara
Rajapur
Erulia
Union Parishad Office
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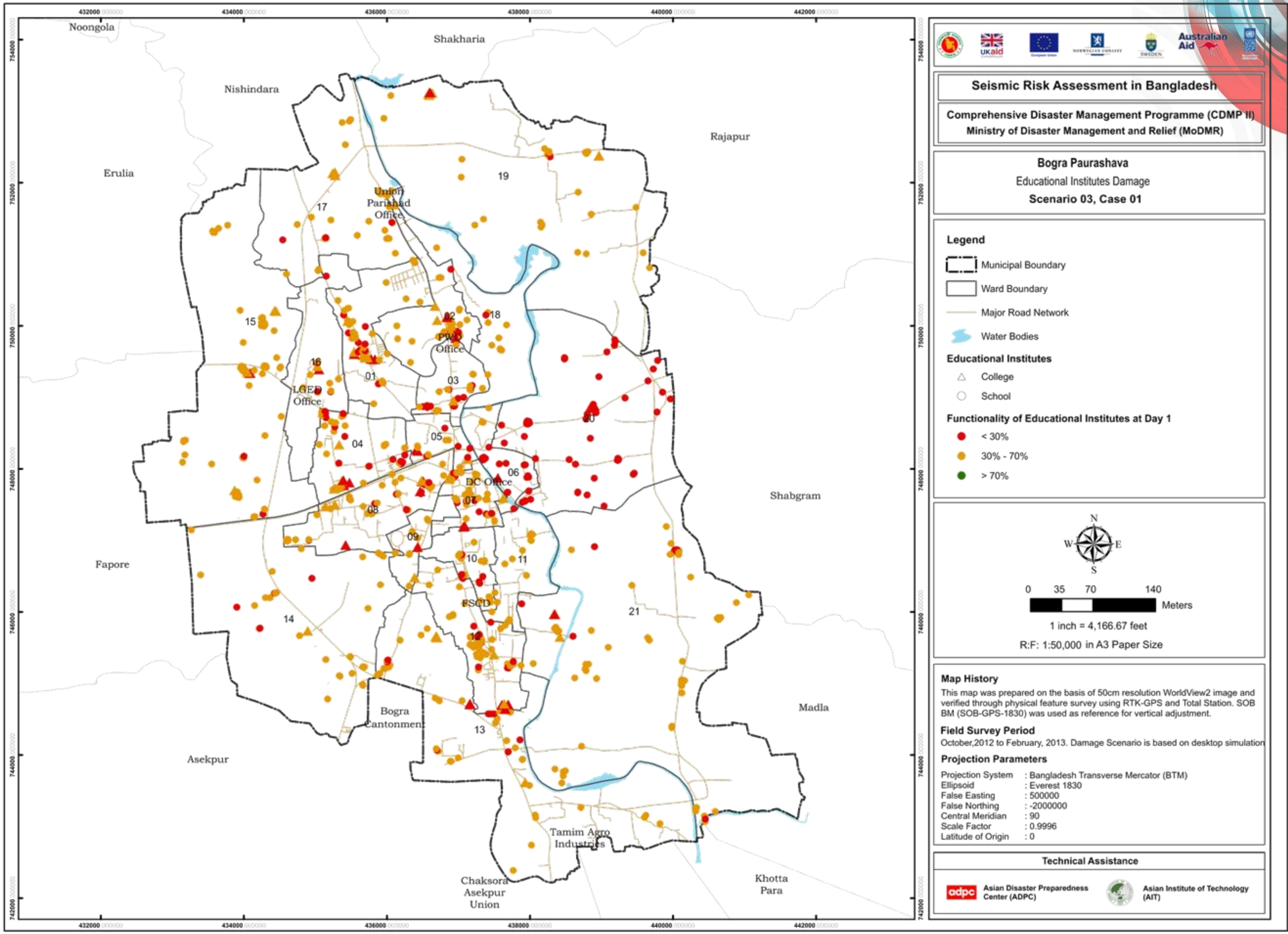
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Educational Institutes Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Educational Institutes
College
School
Functionality of Educational Institutes at Day 1
< 30%
30% - 70%
> 70%
N
S
E
W
0 35 70 140
Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-1830) was used as reference for vertical adjustment.
Field Survey Period
October,2012 to February, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Noongola
Shakharia
Nishindara
Rajapur
Erulia
Union Parishad Office
PWD Office
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Chaksora Asekpur Union
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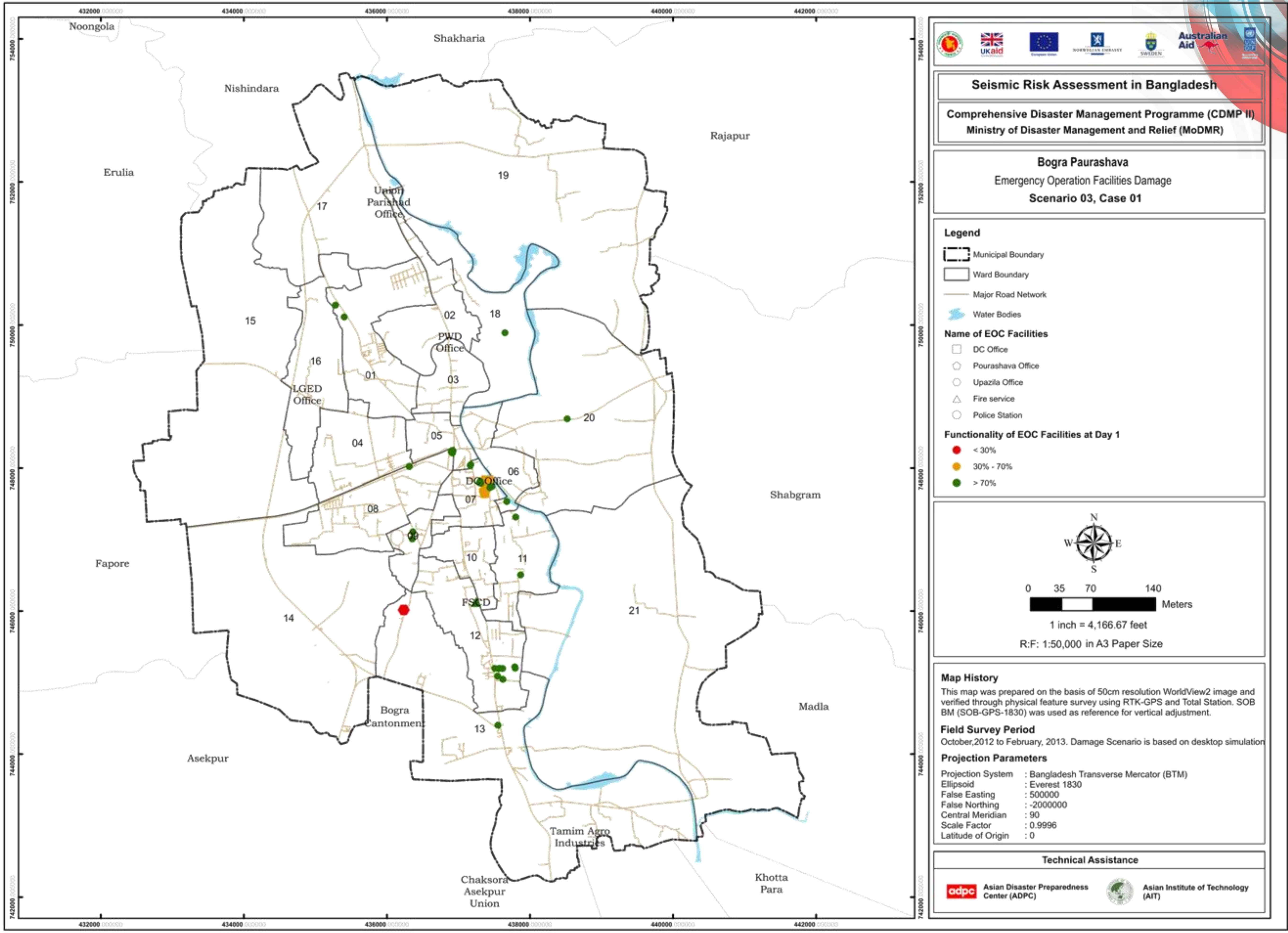
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Emergency Operation Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Name of EOC Facilities
DC Office
Pourashava Office
Upazila Office
Fire service
Police Station
Functionality of EOC Facilities at Day 1
< 30%
30% - 70%
> 70%
N
W
E
S
0 35 70 140
Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
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Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Noongola
Shakharia
Nishindara
Rajapur
Erulia
Union Parishad Office
PWD Office
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Bogra Cantonment
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Asekpur
Tamim Agro Industries
Chaksora Asekpur Union
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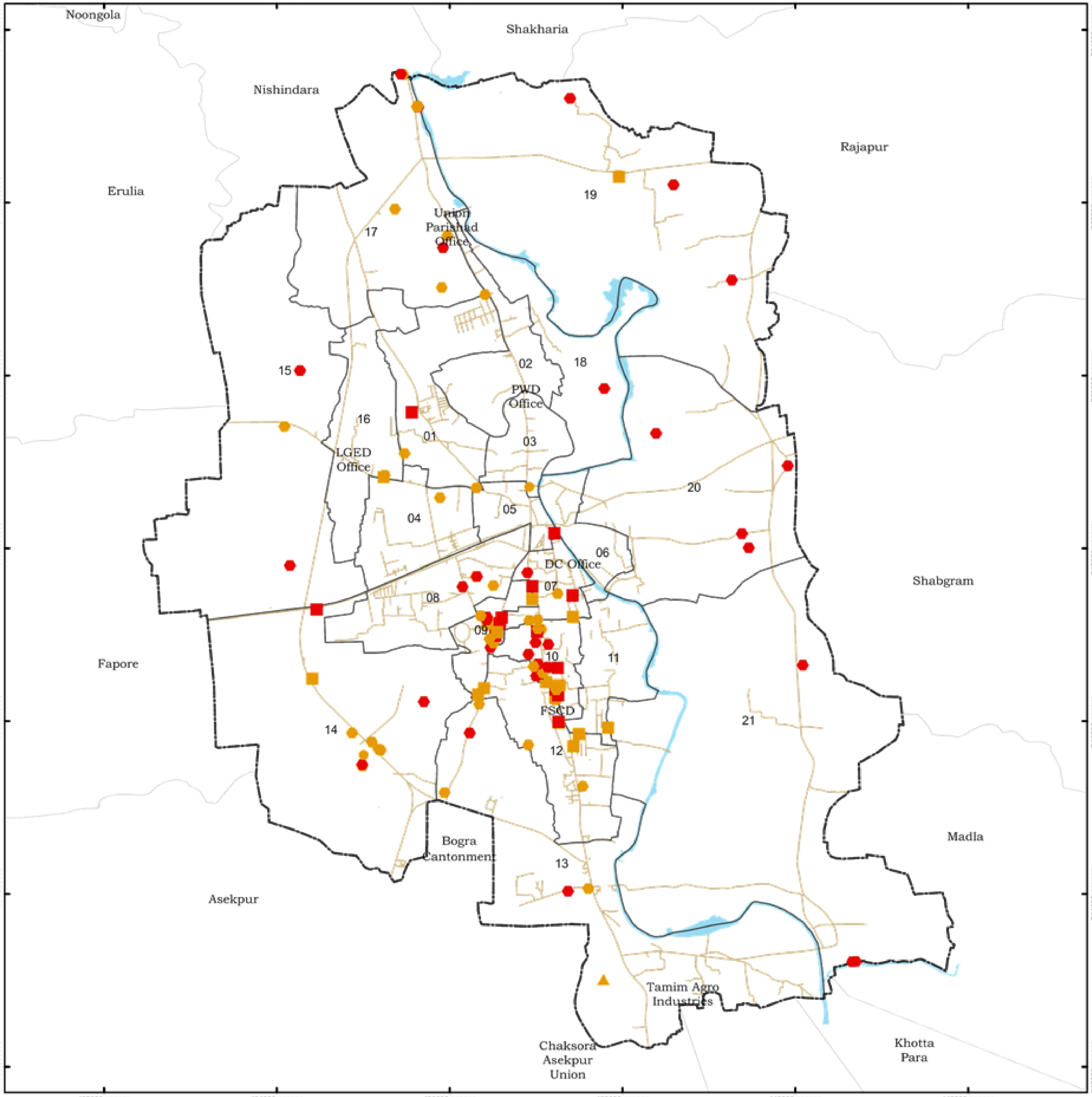

UKaid
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Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
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Bogra Paurashava
Medical Care Facilities Damage
Scenario 03, Case 01

Legend

- Municipal Boundary
- Ward Boundary
- Major Road Network
- Water Bodies

Medical Care Facilities

- Large Hospital
- Medium Hospital
- Small Hospital
- Medical Clinic

Functionality of Medical Care Facilities at Day 1

- < 30%
- 30% - 70%
- > 70%

N
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0 35 70 140
Meters

1 inch = 4,166.67 feet

R:F: 1:50,000 in A3 Paper Size

Map History

This map was prepared on the basis of 50cm resolution WorldView2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-1830) was used as reference for vertical adjustment.

Field Survey Period

October,2012 to February, 2013. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

adpc Asian Disaster Preparedness Center (ADPC)
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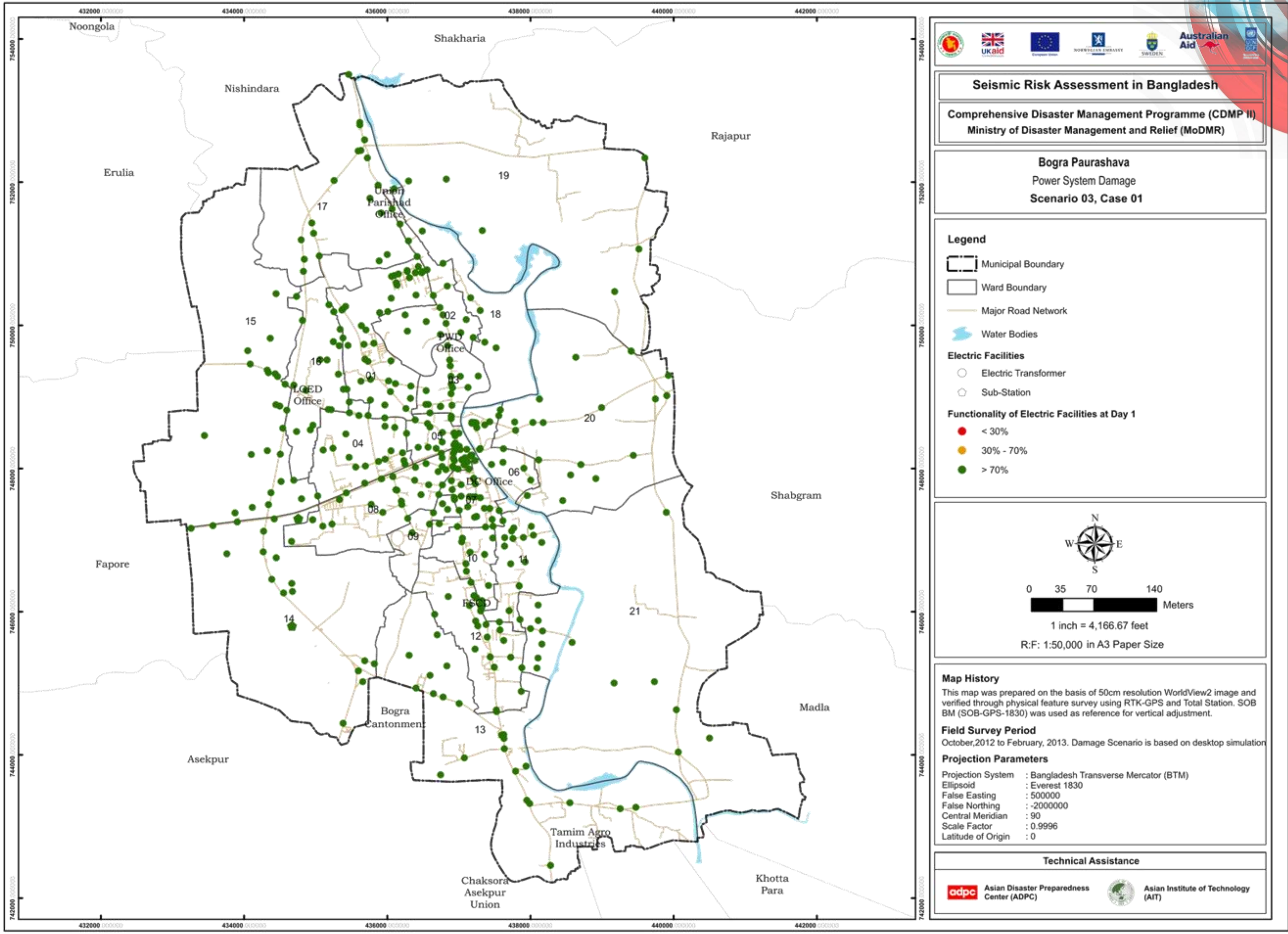
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
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Power System Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Electric Facilities
Electric Transformer
Sub-Station
Functionality of Electric Facilities at Day 1
< 30%
30% - 70%
> 70%
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Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
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False Easting : 500000
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Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
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Nishindara
Rajapur
Erulia
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Madla
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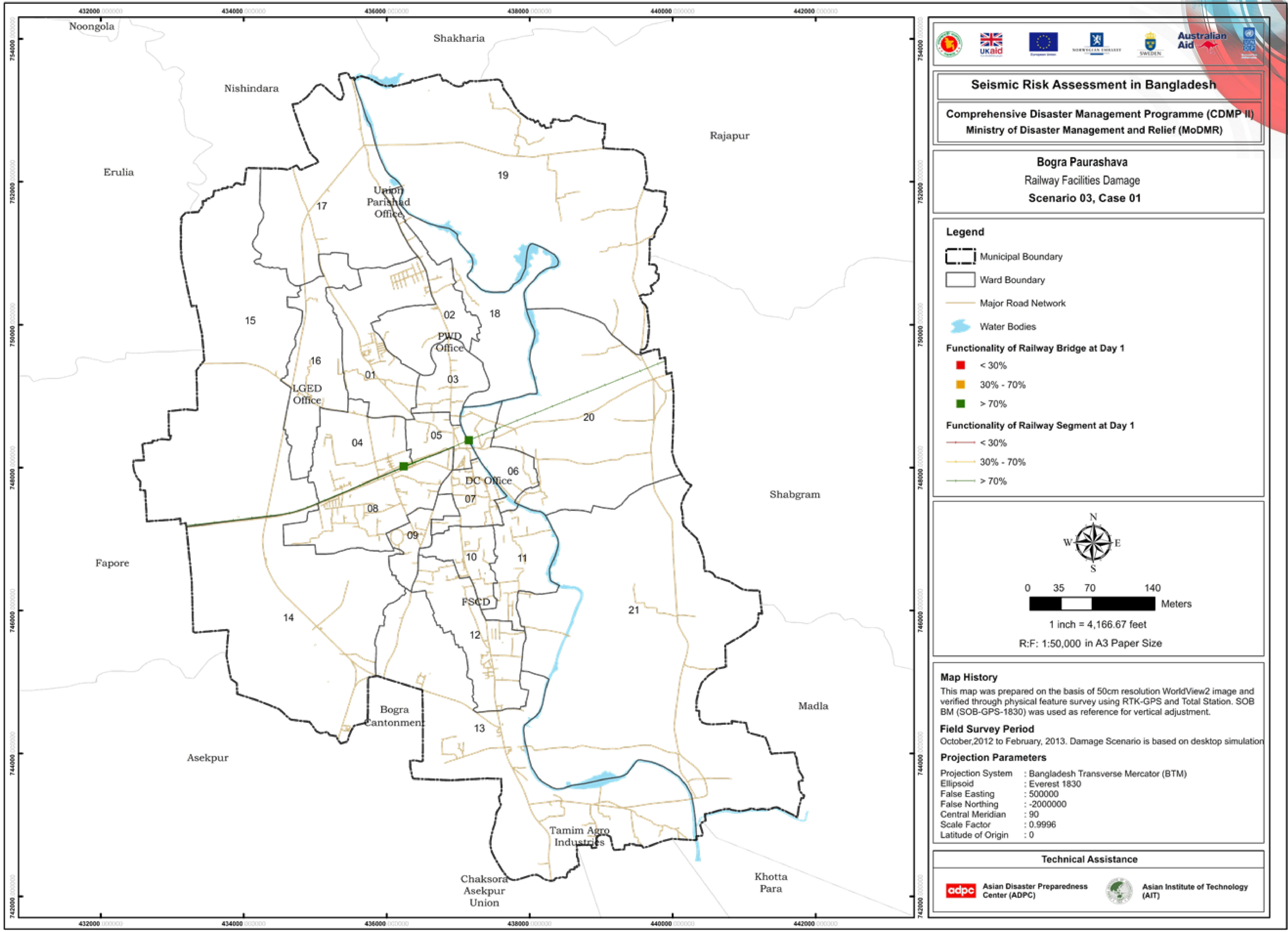

Seismic Risk Assessment in Bangladesh
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Bogra Paurashava
Railway Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Functionality of Railway Bridge at Day 1
< 30%
30% - 70%
> 70%
Functionality of Railway Segment at Day 1
< 30%
30% - 70%
> 70%
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Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
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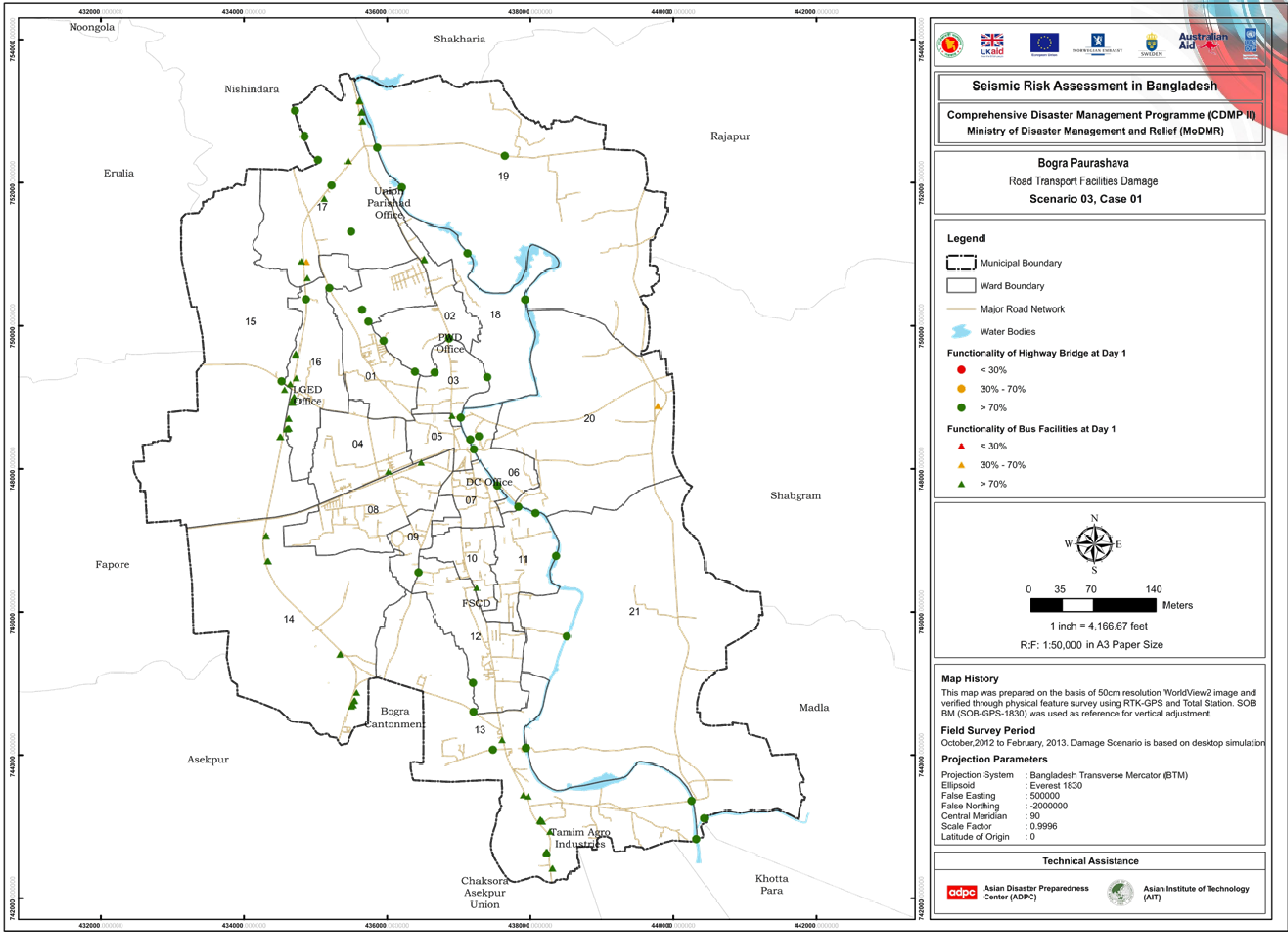
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
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Road Transport Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Functionality of Highway Bridge at Day 1
< 30%
30% - 70%
> 70%
Functionality of Bus Facilities at Day 1
< 30%
30% - 70%
> 70%
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Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
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Field Survey Period
October,2012 to February, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
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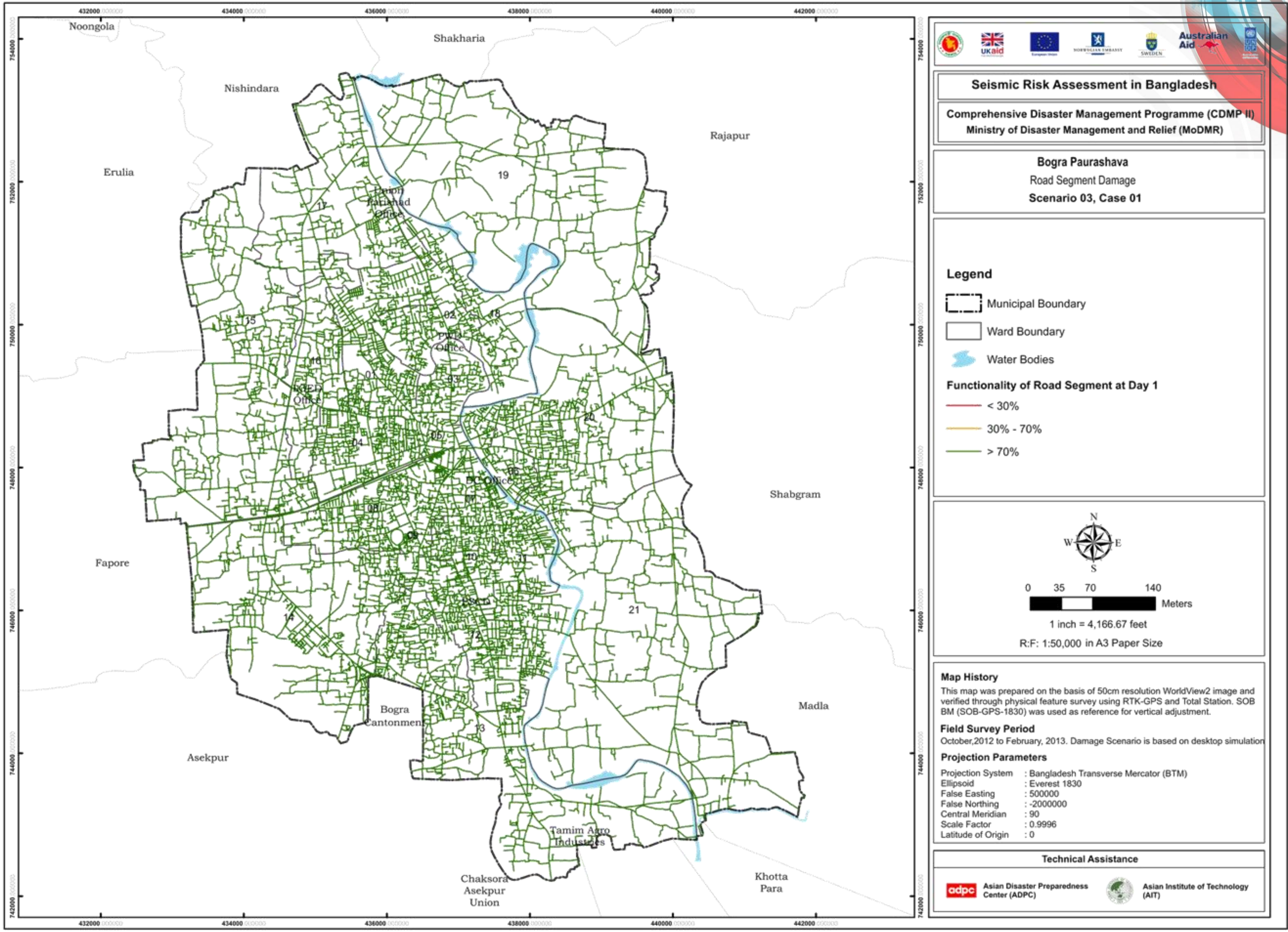
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Road Segment Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Functionality of Road Segment at Day 1
< 30%
30% - 70%
> 70%
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Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
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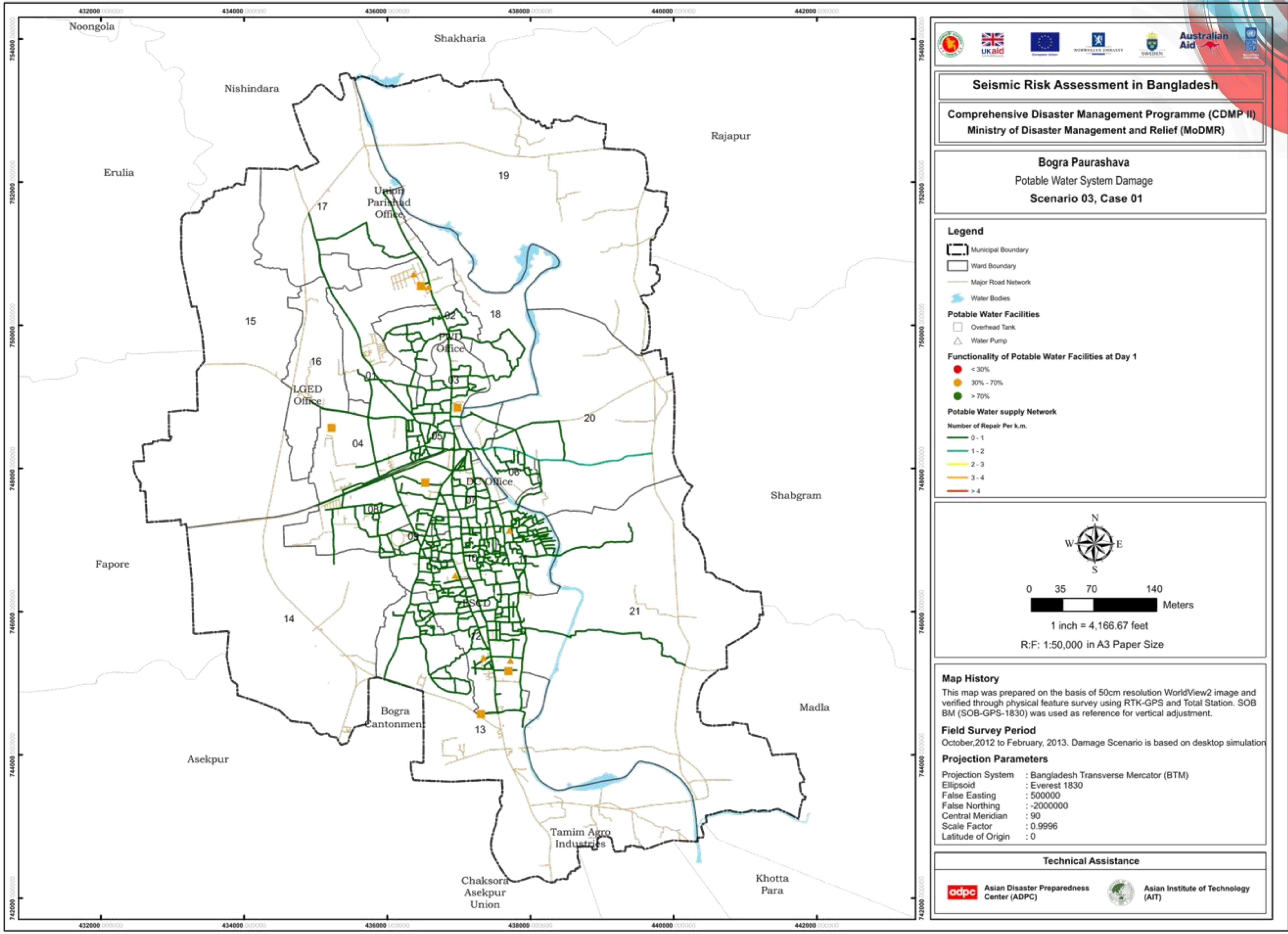
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Potable Water System Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Potable Water Facilities
Overhead Tank
Water Pump
Functionality of Potable Water Facilities at Day 1
< 30%
30% - 70%
> 70%
Potable Water supply Network
Number of Repair Per k.m.
0 - 1
1 - 2
2 - 3
3 - 4
> 4
N
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0 35 70 140
Meters
1 inch = 4,166.67 feet
R.F: 1:50,000 in A3 Paper Size
Map History
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Field Survey Period
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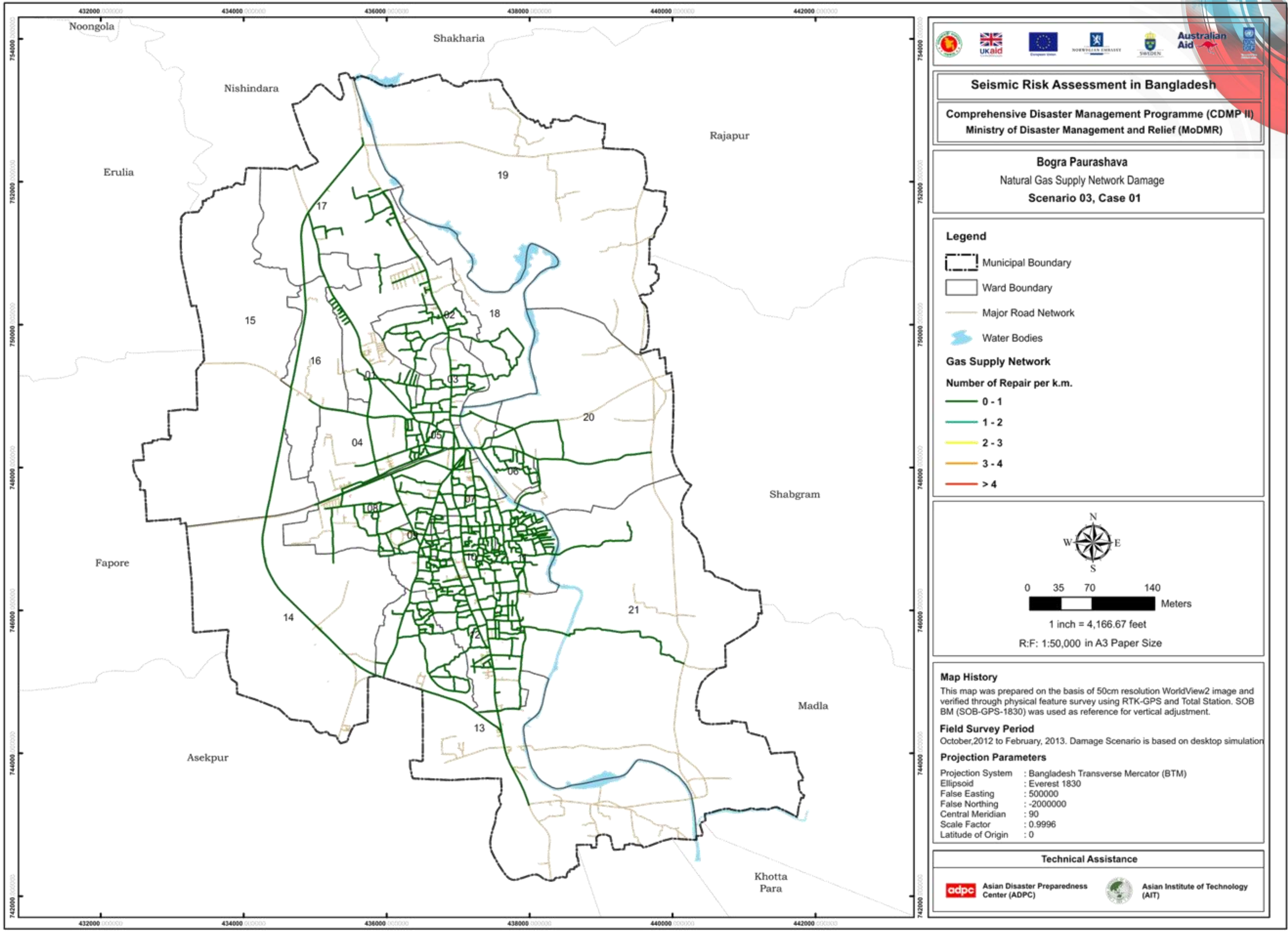
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Bogra Paurashava
Natural Gas Supply Network Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Gas Supply Network
Number of Repair per k.m.
0 - 1
1 - 2
2 - 3
3 - 4
> 4
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Meters
1 inch = 4,166.67 feet
R:F: 1:50,000 in A3 Paper Size
Map History
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Field Survey Period
October,2012 to February, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
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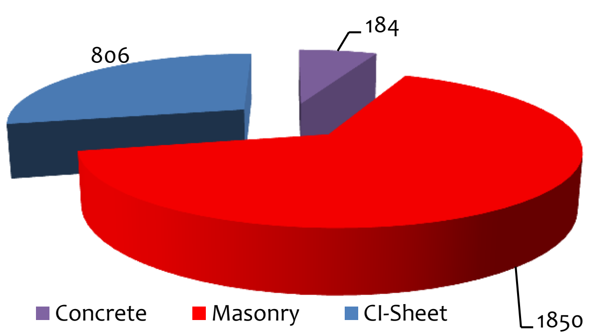
Dinajpur Paurashava

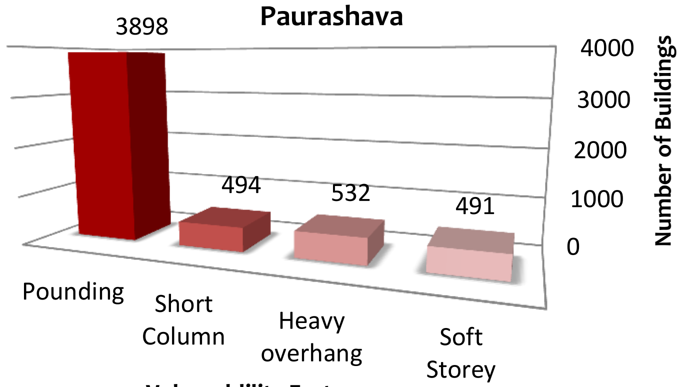
Dinajpur Paurashava was founded in 1887 Total number of ward of the paurashava is 12 with a total area of 20.6 sq km. The Total population of the paurashava is about 186727 (male 51.48%, female 48.51%). The literacy rate among the town people is about 75.4%. The main occupations of the town consist of: Agriculture (33.23%), agricultural labor (3.32%), wage labor (3.17%), commerce (16.02%), service (14.73%), transport (6.01%), and others (23.52%).

Archaeological heritage and relics namely kantanagar temple, Rajbari, Dinajpur Museum, Ramsagar, the tombs of Chehel Gazi and Gora Shahid, Sitar Kuthuri, Habra Zamindar Bari, Gour Gabindha, Baraduari, Shingha Darwaza Palace, Nayabad mosque, Aowkar Mosque are main tourist attractions of the area.

Exixting Structural type in Dinajpur Pourashava

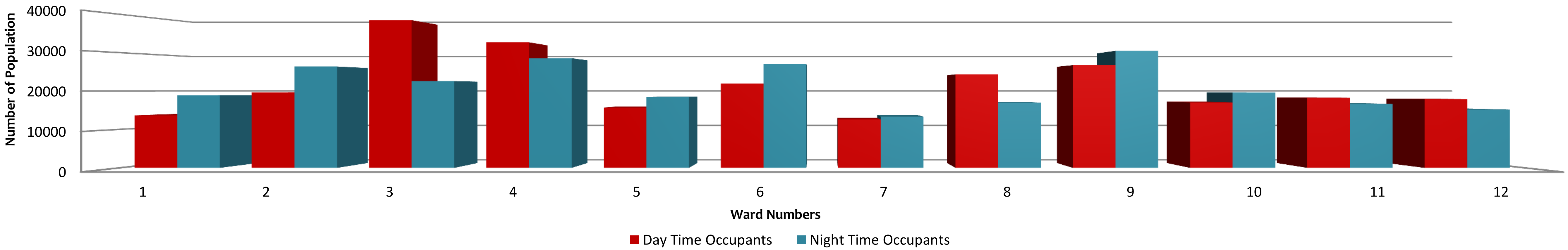


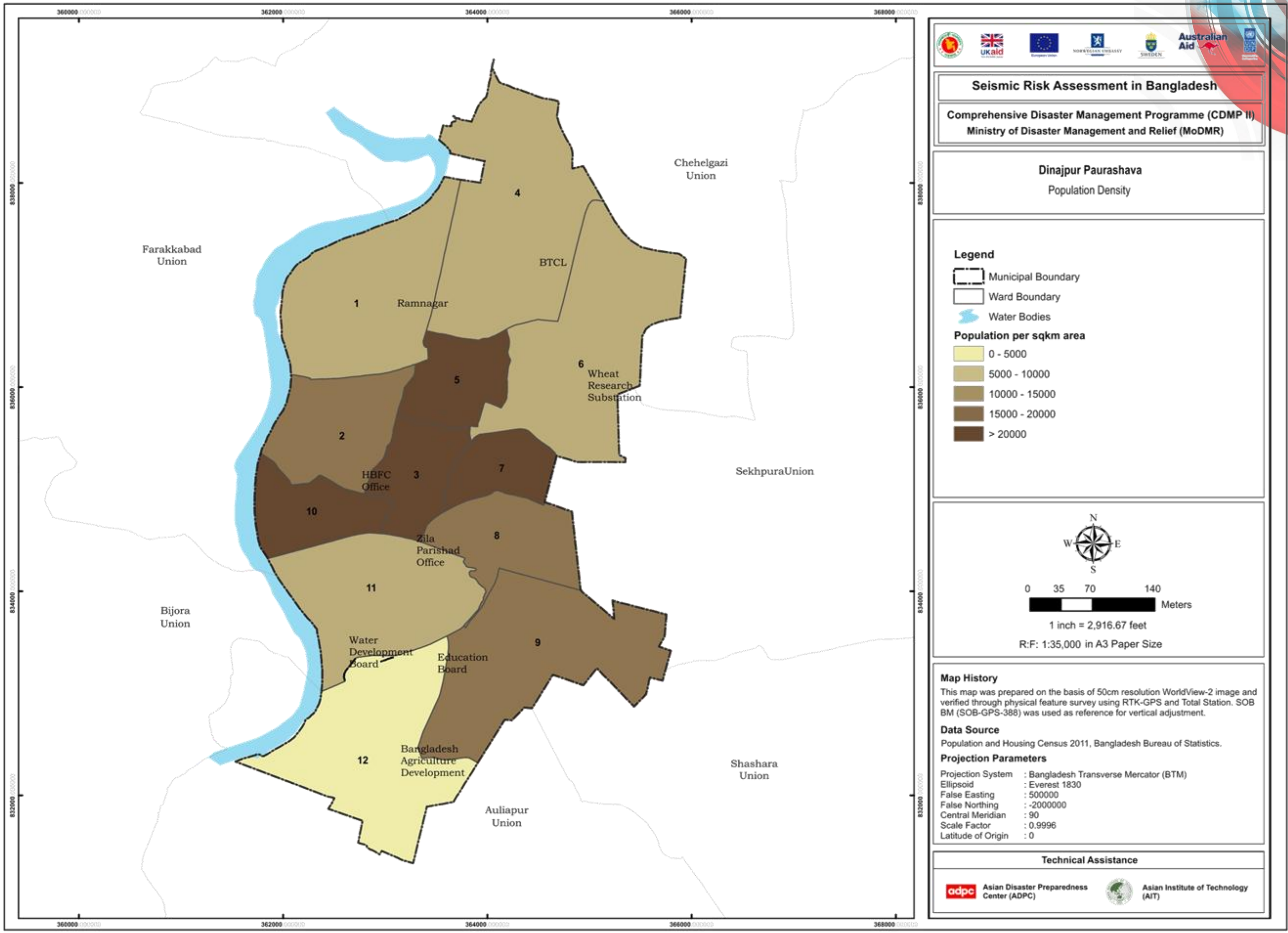
Distribution of Vulnerability Factors in Rangpur Paurashava



Brief Information of the City	
Name of the City	Dinajpur
Name of the Paurashava	Dinajpur Pourashava
Year of Establishment:	1887
Total Area	20.6 sq. km
Number of Wards	12
Total Population	186727(Male-96139, Female-90588)
Population Growth Rate (2011)	1.22%
Road Network	322.78 km
Railways	6.14 km
Water Ways	1.55 sq. km or 383.8 Acre
Natural Water Bodies	1.11 sq.km or 274.2 Acre
Open Space	59.232
Education Institutions	205
Health Facilities	47
Re-fueling Stations	10
Fire Station	1
Police Station	2

Day & Night Occupants in Rangpur Paurashava




Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Population Density
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Population per sqkm area
0 - 5000
5000 - 10000
10000 - 15000
15000 - 20000
> 20000
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140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Data Source
Population and Housing Census 2011, Bangladesh Bureau of Statistics.
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
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Farakkabad Union
SekhpuraUnion
Bijora Union
Shashara Union
Auliapur Union
Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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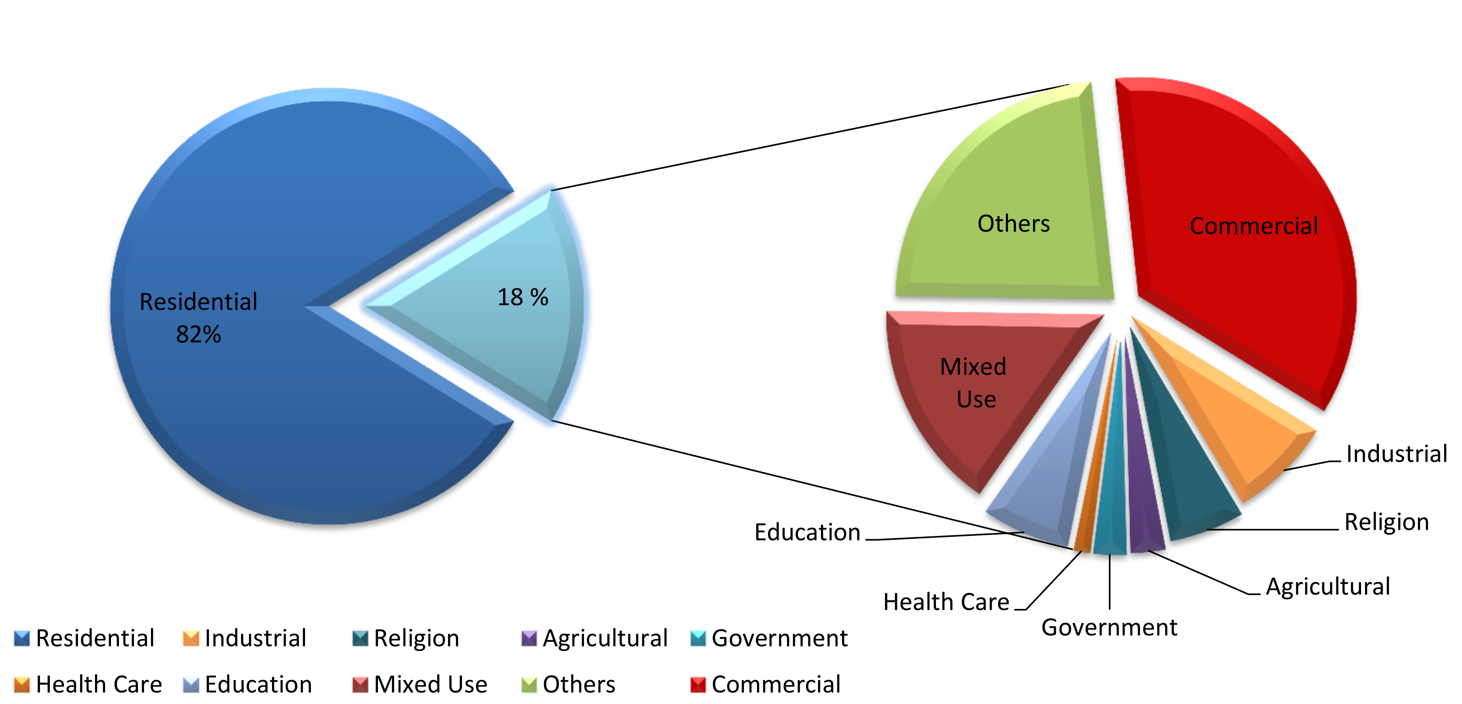
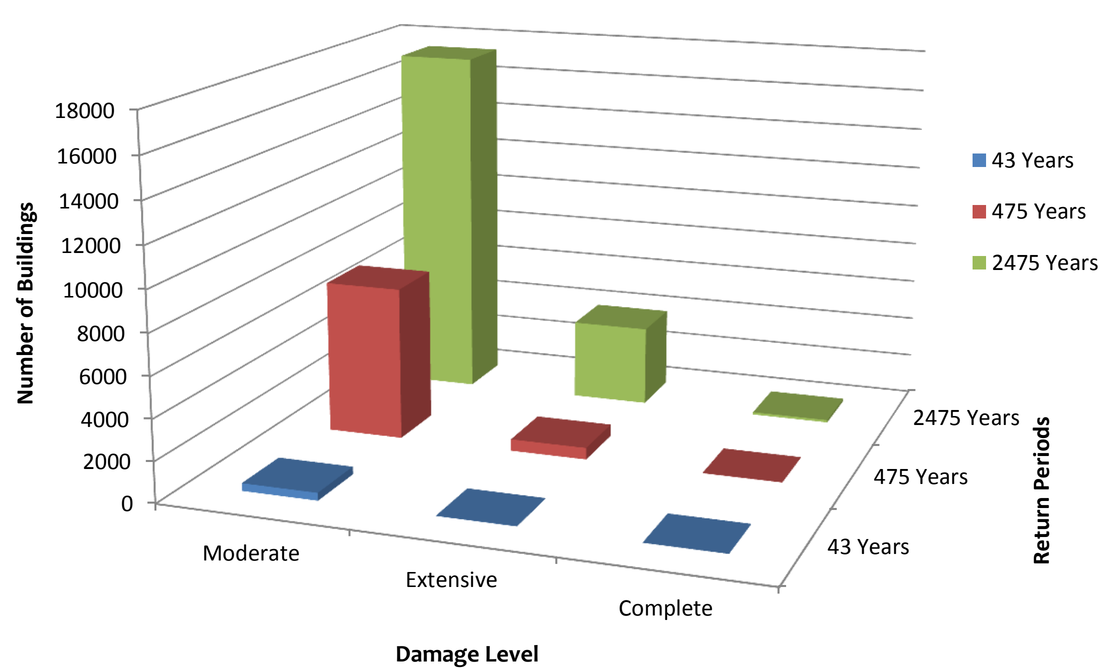
Distribution of Different Occupancy Classes in Dinajpur Paurashava



Number of Damage Buildings in Dinajpur Paurashava



EXPECTED PHYSICAL DAMAGE STATES

Table 10: Expected physical damage states of buildings for different scenario cases

Scenarios	Total Structure	Concrete Structure						Masonry Structure						Tin Shed and Bamboo Structure					
		Total Concrete Structure	Moderate Damage		Complete Damage			Total Masonry Structure	Moderate Damage		Complete Damage			Total Zinc Shed and Bamboo Structure	Moderate Damage		Complete Damage		
			No.	%	No.	%			No.	%	No.	%			No.	%	No.	%	
Scenario 1 Case 1	40304	3929	39	0.99%	0	0.00%		28318	261	0.92%	0	0.00%		8057	58	0.72%	0	0.00%	
Scenario 2 Case 2	40304	3929	37	0.94%	0	0.00%		28318	88	0.31%	0	0.00%		8057	16	0.20%	0	0.00%	
Scenario 3 Case 1	40304	3929	631	16.06%	3	0.01%		28318	5580	19.70 %	37	0.13%		8057	1126	13.98%	9	0.08%	
Scenario 4 Case 2	40304	3929	502	12.78%	10	0.25%		28318	4866	17.18%	41	0.14%		8057	434	5.39%	2	0.02%	
Scenario 5 Case 1	40304	3929	1520	38.69%	13	0.33%		28318	12507	44.17%	198	0.70%		8057	2887	35.83%	27	0.34%	
Scenario 6 Case 2	40304	3929	972	22.74%	70	1.78%		28318	7278	25.70%	4703	16.61%		8057	1167	14.48%	8	0.10%	

Debris Generation

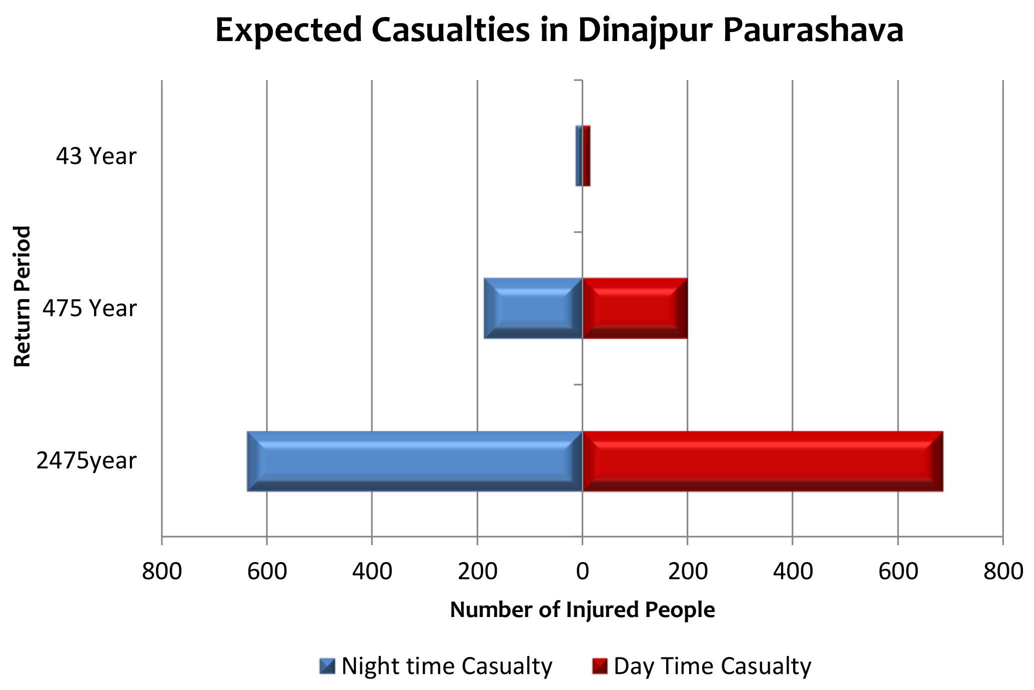
Table 11: Expected debris generation for different scenario cases

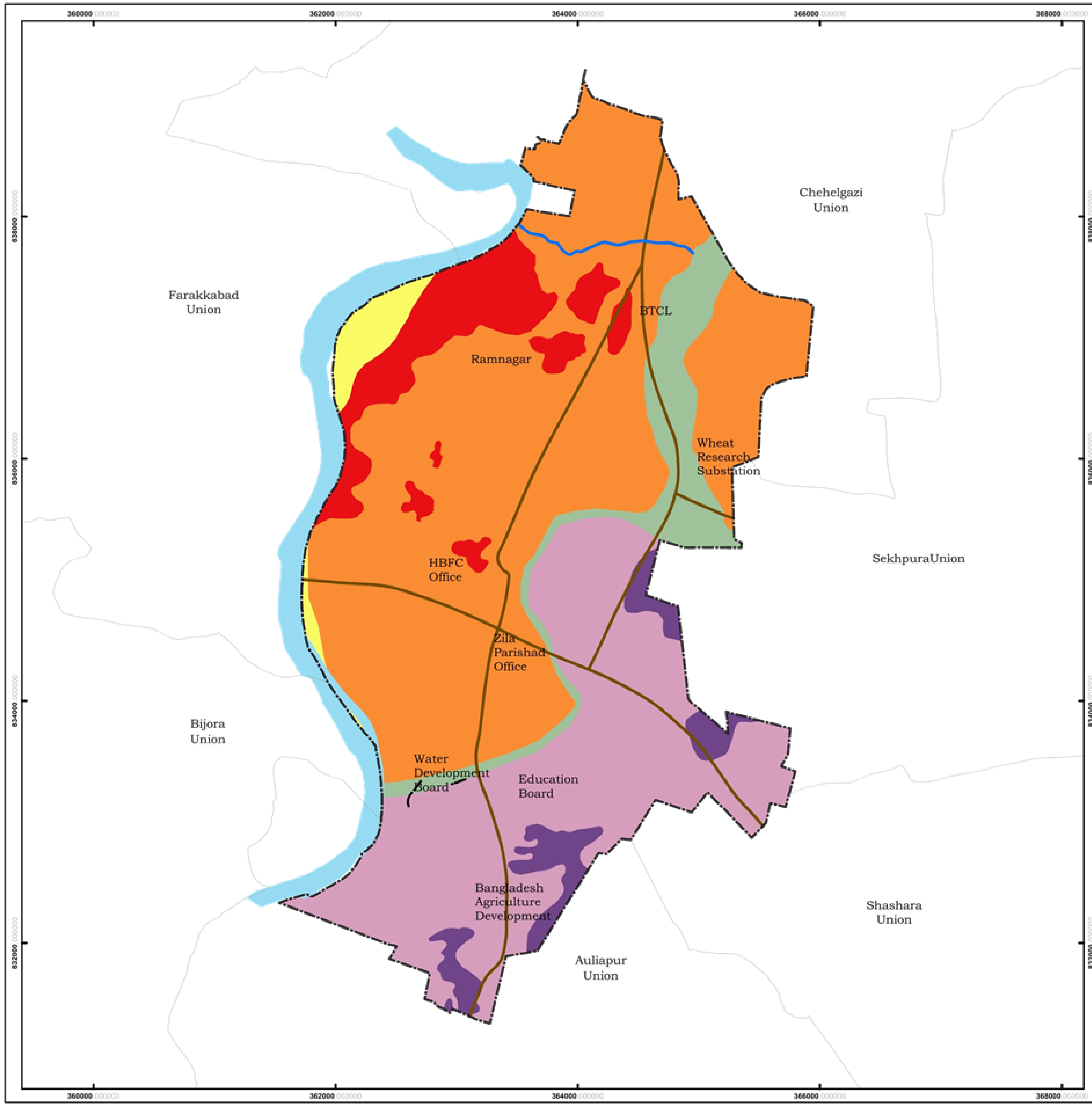
Earthquake Scenario	Amount of Debris (million tons)	% of Concrete and Steel materials	% of Brick and Wood materials
Scenario 1 Case 1	0.010	13%	87%
Scenario 2 Case 2	0.010	16%	84%
Scenario 3 Case 1	0.011	35%	65%
Scenario 4 Case 2	0.140	50%	50%
Scenario 5 Case 1	0.0410	56%	44%
Scenario 6 Case 2	1.390	75%	25%

Damage of Lifelines

Table 12: Expected damage to lifelines for scenario 3 Case 1

System	Component	Total	Moderate Damage	Complete Damage	At least 50% Functional	
					Day 1	Day 7
Highway	Segments	2745	0	0	2745	2745
	Bridges	20	0	0	20	20
	Facilities	14	0	0	14	14
Railway	Segments	9	0	0	9	9
	Bridges	1	0	0	1	1
	Facilities	3	0	0	3	3





Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Dinajpur Paurashava

Geology

Legend

- Municipal Boundary
- Major Road Network
- Active Channel

Barind Deposits

- Barind Clay Residuum
- Depression Deposits

Tista Alluvium Fan Deposits

- Active Channel Deposits
- Abandoned Channel Deposits
- Bar Deposits
- Tista Fan Deposits
- Back Swamp Deposits

N, W, E, S

0 35 70 140 Meters

1 inch = 2,916.67 feet

R:F: 1:35,000 in A3 Paper Size

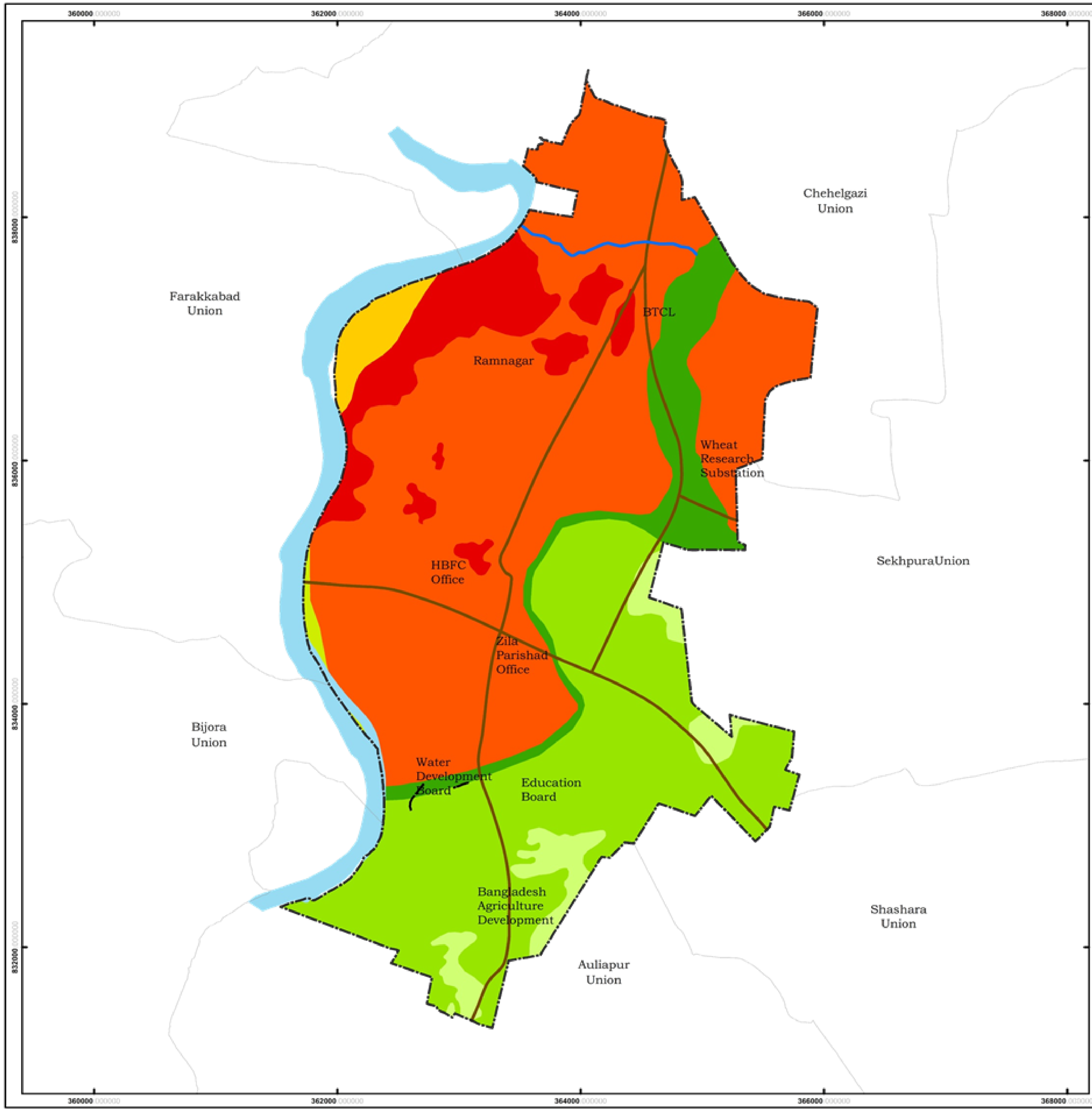
Barind Deposit	
Barind clay residuum	Dull yellowish brown (10YR 5/3) and dark brown (10YR 3/4) silt and clayey silt
Depression deposits	Grey (10YR 5/1) to light brownish grey (10YR 6/2) silt and silty clay with minor amount of sand
Tista Alluvium Fan Deposits	
Active channel deposits	Light brownish grey (10YR 6/2) to grey (10YR 5/1) medium to fine very loose sand
Abandoned channel deposits	Bluish grey (5B 5/1) to grey (10YR 5/1) and light brownish grey (10YR 6/2) clayey silt, sandy silt and fine sand
Bar deposits	Dark brown (10YR 3/4) grey (10YR 5/1) clayey silt and fine sand
Tista fan deposits	Brownish grey (10YR 5/1) to greyish olive (7.5Y 6/2) and grey (5Y 6/1) silty clay and fine sand
Back swamp deposits	Dark brown(7.5YR 3/3) to dull yellow (2.5Y 6/3) and light yellow (2.5Y 6/3) to yellow brown (2.5Y 5/4) clayey silt and very fine to fine sand

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Geological Survey of Bangladesh (GSB)

Asian Disaster Preparedness Center (ADPC)



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Dinajpur Paurashava
Geomorphology

Legend

- Municipal Boundary
- Major Road Network
- Active Channel

Barind Tract
- Barind Terrace
- Depression

Tista Fan
- Active Channel
- Abandoned Channel
- Younger Point Bar
- Old Point Bar
- Alluvial Plain
- Back Swamp

N S W E

0 35 70 140 Meters

1 inch = 2,916.67 feet

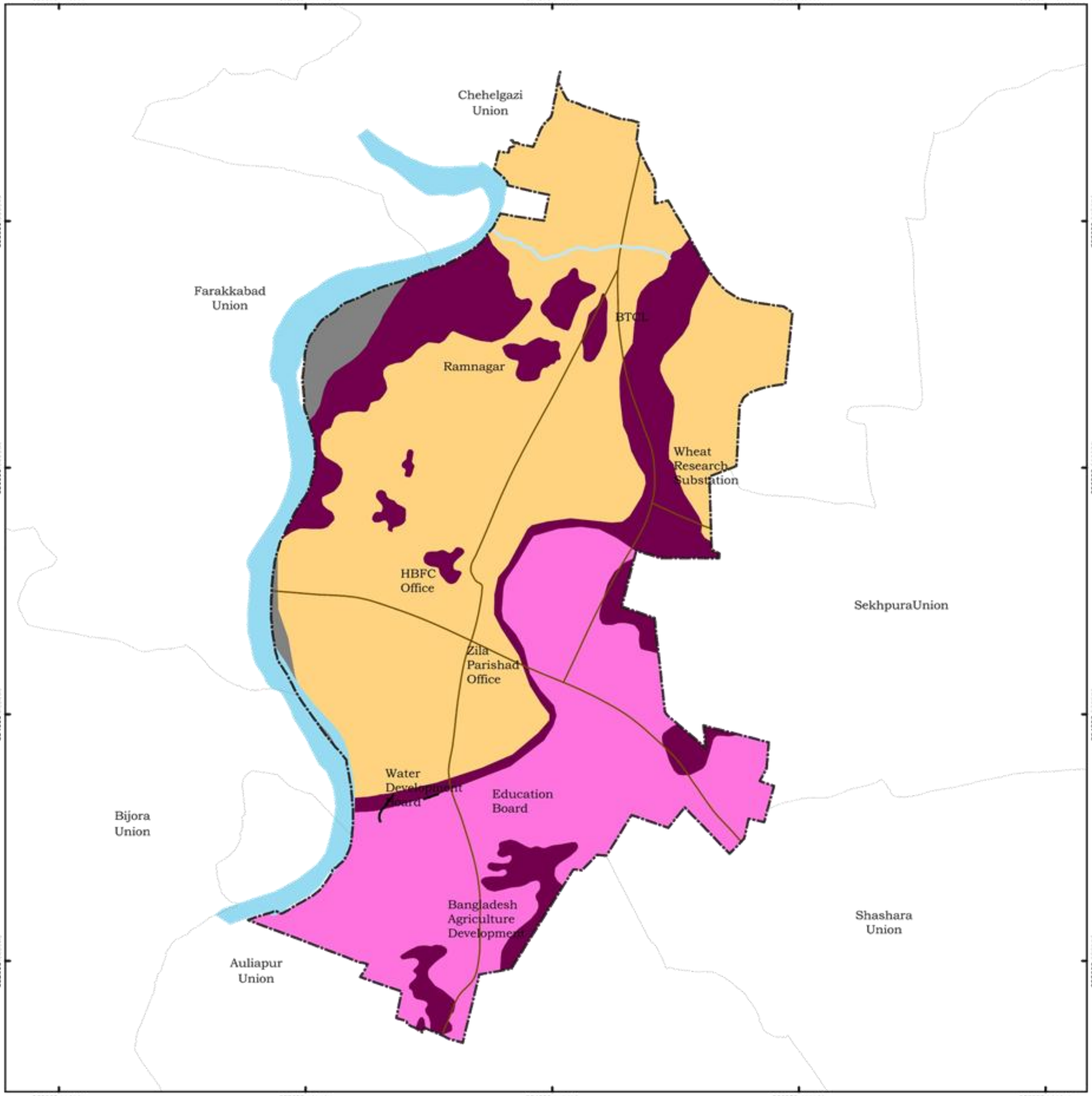
R:F: 1:35,000 in A3 Paper Size

Barind terrace	
Barind terrace	Elevated highly oxidized table like landform in the south of the Tista Fan consists of silt and clayey silt
Barind valley	Irregular shaped narrow as well as broad erosional landform within the Barind terrace consists silt and silty clay
Depression	Irregular shaped water bodies within the Barind tract consists of silty clay
Tista Fan	
Active channel	Channel with flowing water consist of medium to fine sand
Intermittent channel	Channels having seasonal flow of water consist of sandy silt and silty sand
Abandoned channel	Elongated wide as well as narrow channels without water formed the shifting of strea courses and filled by sandy and silty sand
Young point bar	Crescent shaped recent accumulation of sand along the meandering channels deposited at the western side of the area
Old point bar	Crescent shaped older accumulation of sand along the meandering channels deposited at the western side of the area
Natural levee	Elongated irregular over bank deposit along the abandoned channel at the north-east corner of the area consists of silt and medium to fine sand
Alluvial plain	Distal part of the Tista Fan having southward gentle slope consisted of silty clay and fine sand
Back swamp	Irregular shape depressed areas in the Tista Fan consists of clayey silt and very fine to fine sand

Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0

Technical Assistance

Geological Survey of Bangladesh (GSB)
Asian Disaster Preparedness Center (ADPC)



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Dinajpur Paurashava
Engineering Geology

Legend

Municipal Boundary
Major Road Network
Active Channel

Engineering Units

Unit - I
Unit - II
Unit - III
Unit - IV
Unit - V

N
W E
S

0 35 70 140 Meters

1 inch = 2,916.67 feet

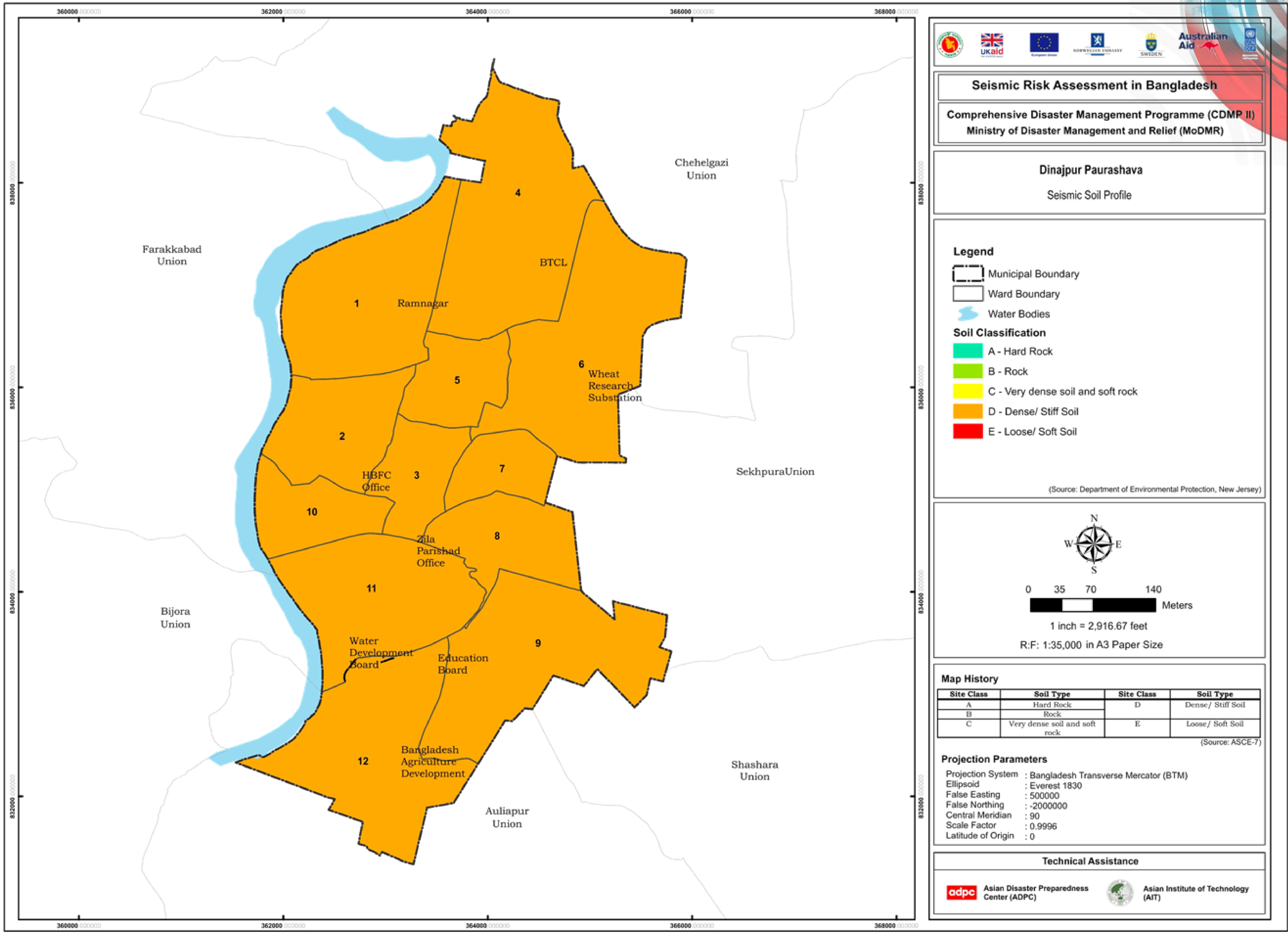
R:F: 1:35,000 in A3 Paper Size

Engineering Properties	
Unit-I	Up to 3m depth mostly composed of stiff silty clay (max. N value 15) and loose to medium dense sandy silty (max. N value 11); within 30m very dense fine sand having max. tested N value is > 50
Unit-II	Up to 3m depth mostly composed of medium stiff to silty clay (max. N value 15); within 30m very dense fine sand having max tested N value is >50
Unit-III	Up to 3m depth mostly composed of medium dense sandy silt and fine sand (max. N value 18); within 30m very silty sand having max. tested N value is > 50
Unit-IV	Up to 3m depth mostly composed of medium dense to loose fine sand (max. N value 10). Within 30m dense silty sand having max tested N value is 43
Unit-V	Up to 3m depth mostly composed of medium dense sandy silt (max. N value 26) and, fine sand and sandy silt (max. N value 18). Within 30m dense silty sand having max. tested N value is 40

Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0

Technical Assistance

Geological Survey of Bangladesh (GSB)
Asian Disaster Preparedness Center (ADPC)


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Seismic Soil Profile
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Soil Classification
A - Hard Rock
B - Rock
C - Very dense soil and soft rock
D - Dense/ Stiff Soil
E - Loose/ Soft Soil
(Source: Department of Environmental Protection, New Jersey)
N
W
E
S
0 35 70 140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
Site Class | Soil Type | Site Class | Soil Type
A | Hard Rock | D | Dense/ Stiff Soil
B | Rock
C | Very dense soil and soft rock | E | Loose/ Soft Soil
(Source: ASCE-7)
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Farakkabad Union
Chehelgazi Union
SekhpuraUnion
Bijora Union
Shashara Union
Auliapur Union
1
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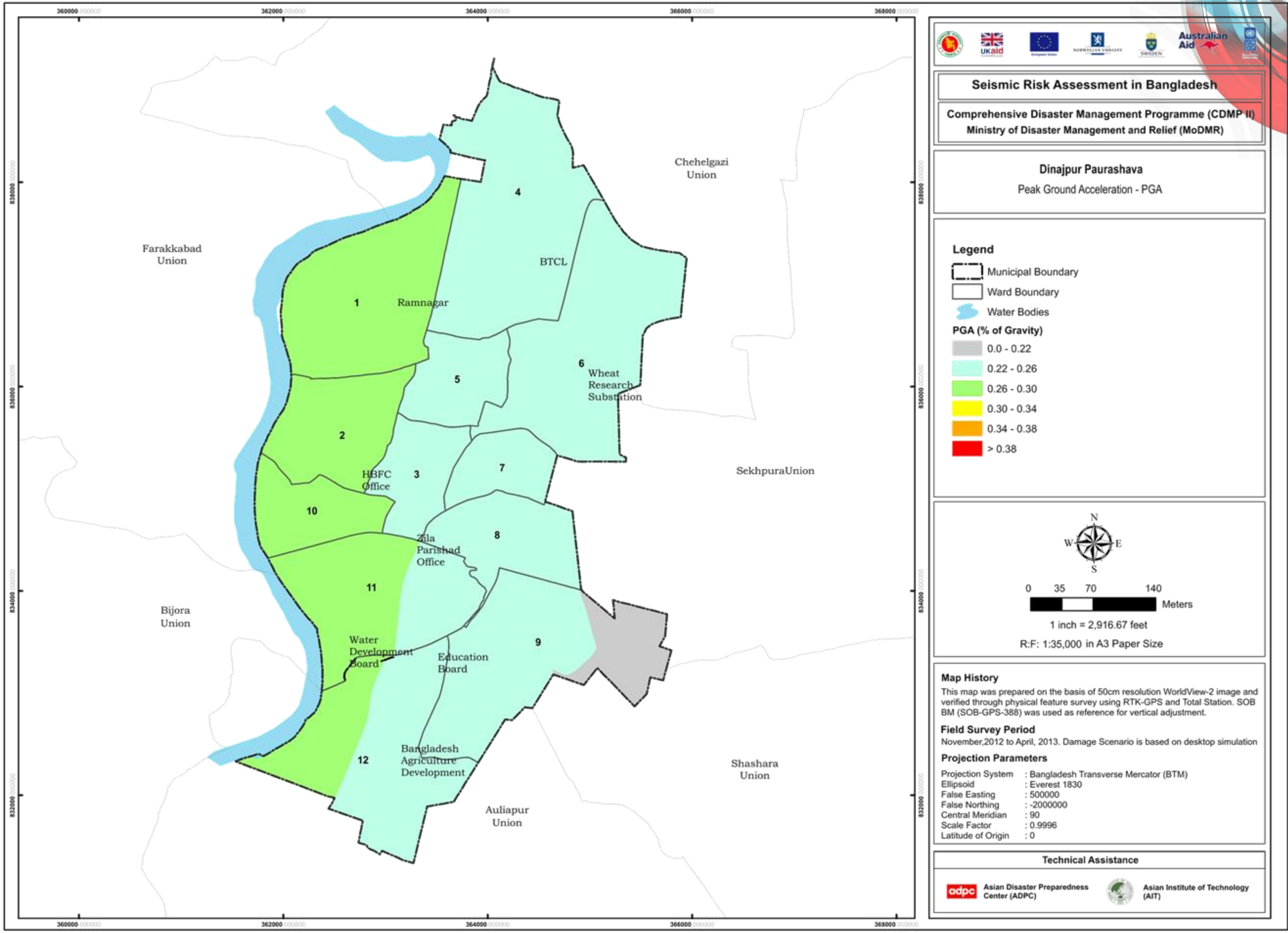
Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
360000
362000
364000
366000
368000
832000
834000
836000
838000


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Peak Ground Acceleration - PGA
Legend
Municipal Boundary
Ward Boundary
Water Bodies
PGA (% of Gravity)
0.0 - 0.22
0.22 - 0.26
0.26 - 0.30
0.30 - 0.34
0.34 - 0.38
> 0.38
N
W
E
S
0
35
70
140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Chehelgazi Union
Farakkabad Union
Bijora Union
SekhpuraUnion
Shashara Union
Auliapur Union
BTCL
Ramnagar
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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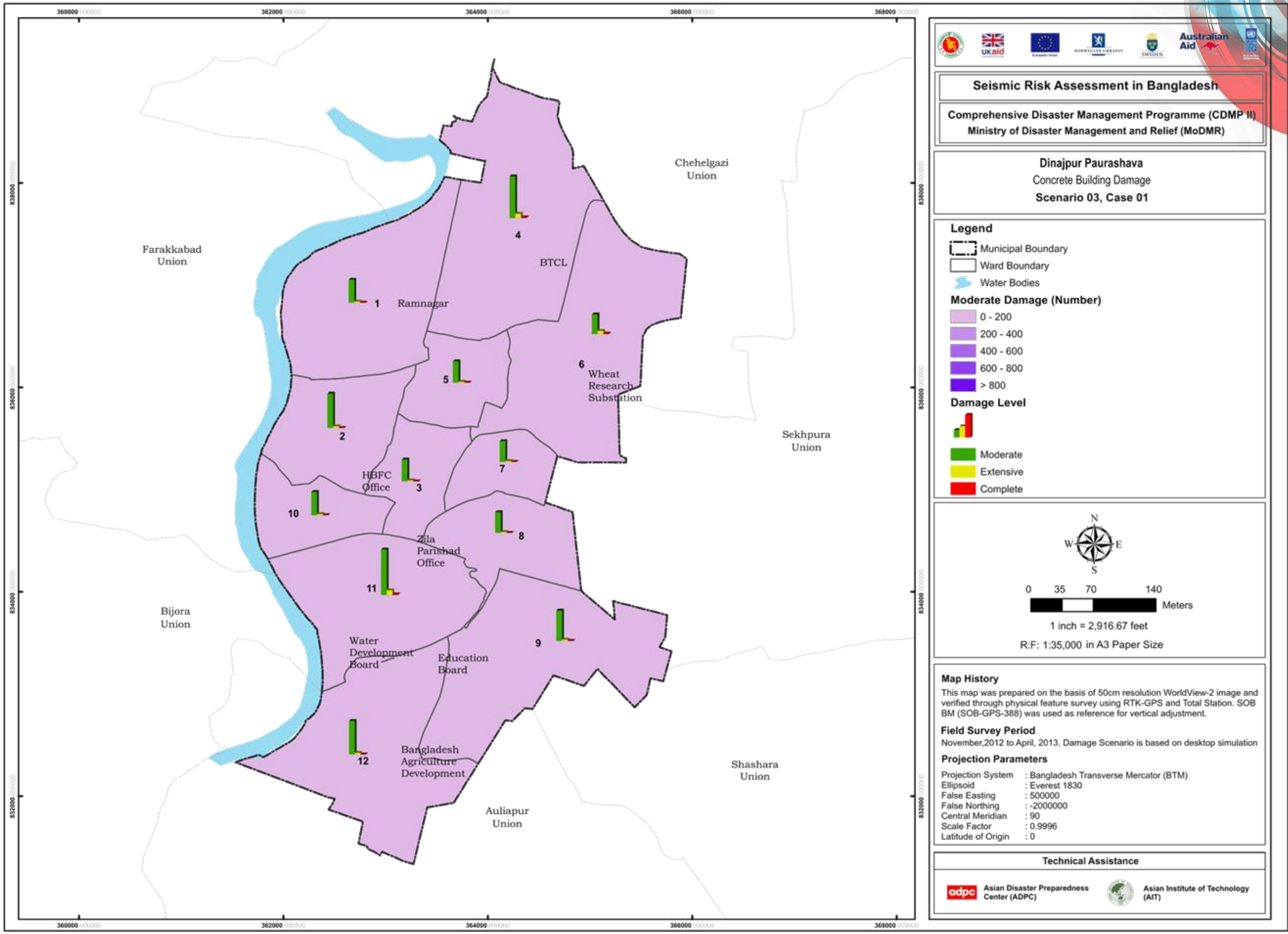

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Concrete Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Moderate Damage (Number)
0 - 200
200 - 400
400 - 600
600 - 800
> 800
Damage Level
Moderate
Extensive
Complete
N
S
E
W
0
35
70
140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Chehelgazi Union
Farakkabad Union
Sekhpura Union
Bijora Union
Shashara Union
Auliapur Union
BTCL
Ramnagar
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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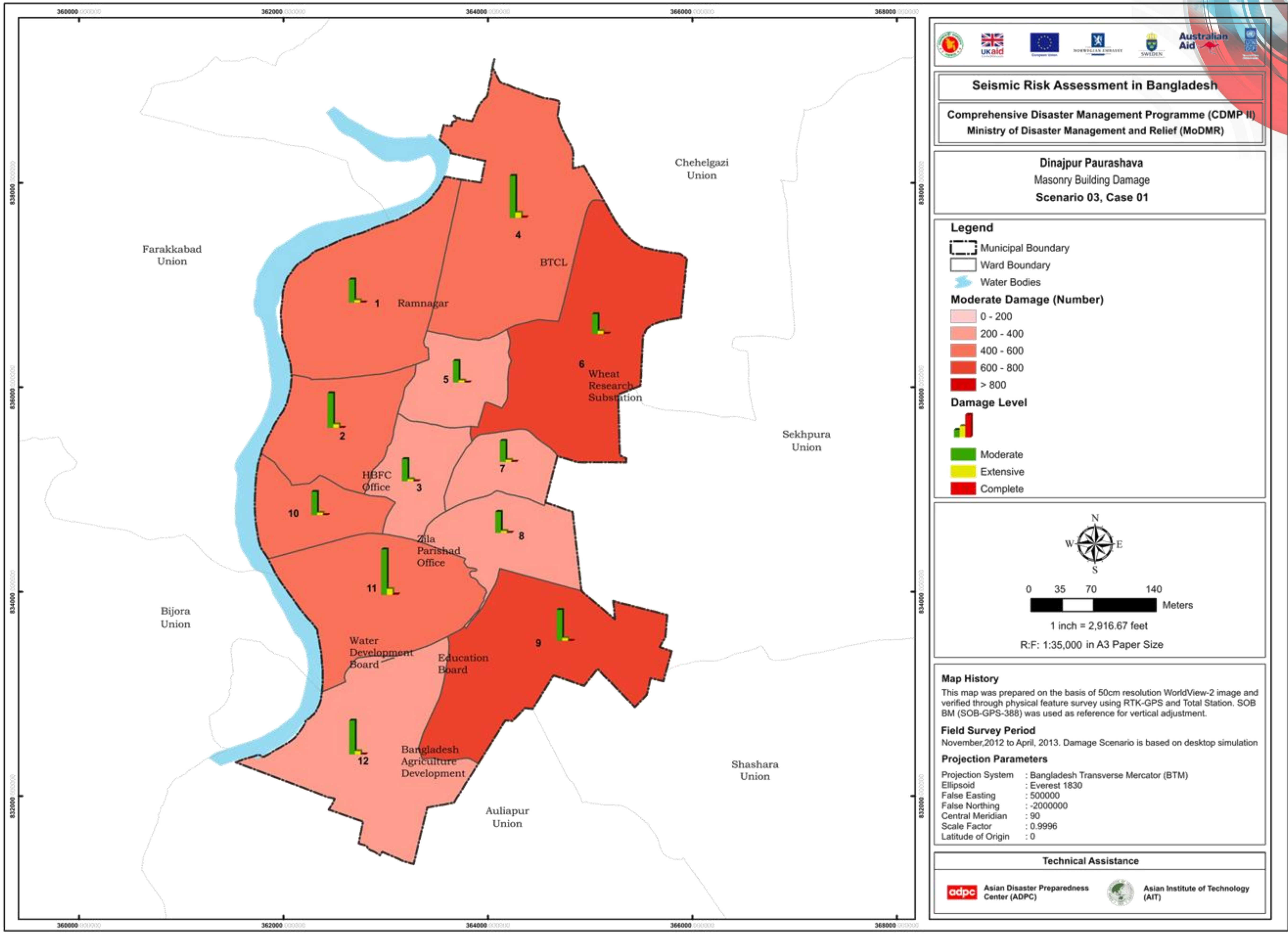
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Masonry Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Moderate Damage (Number)
0 - 200
200 - 400
400 - 600
600 - 800
> 800
Damage Level
Moderate
Extensive
Complete
N
S
E
W
0 35 70 140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Chehelgazi Union
Farakkabad Union
Sekhpura Union
Bijora Union
Shashara Union
Auliapur Union
Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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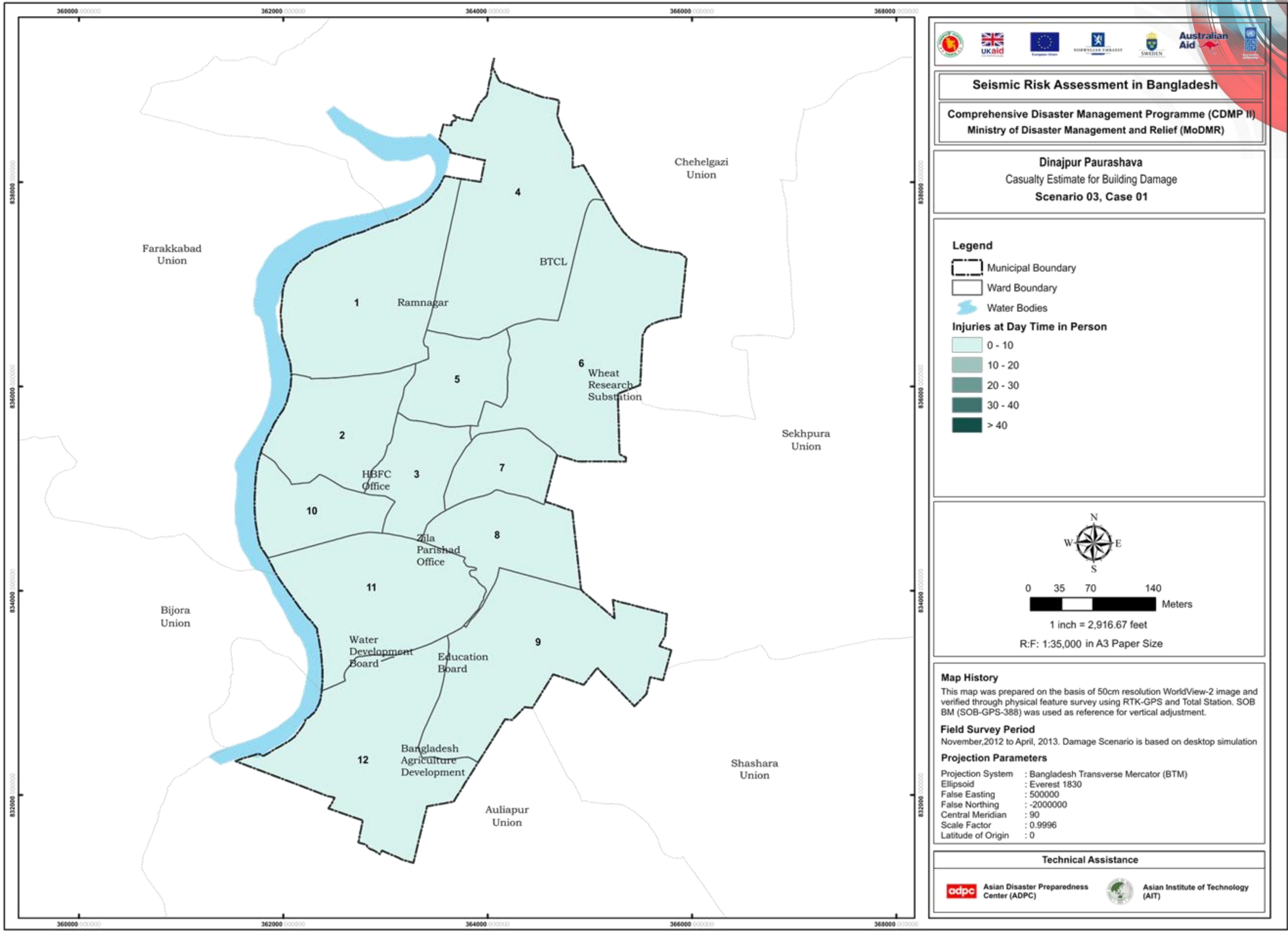
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Casualty Estimate for Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Injuries at Day Time in Person
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
W
E
S
0
35
70
140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Farakkabad Union
Chehelgazi Union
Sekhpura Union
Bijora Union
Shashara Union
Auliapur Union
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Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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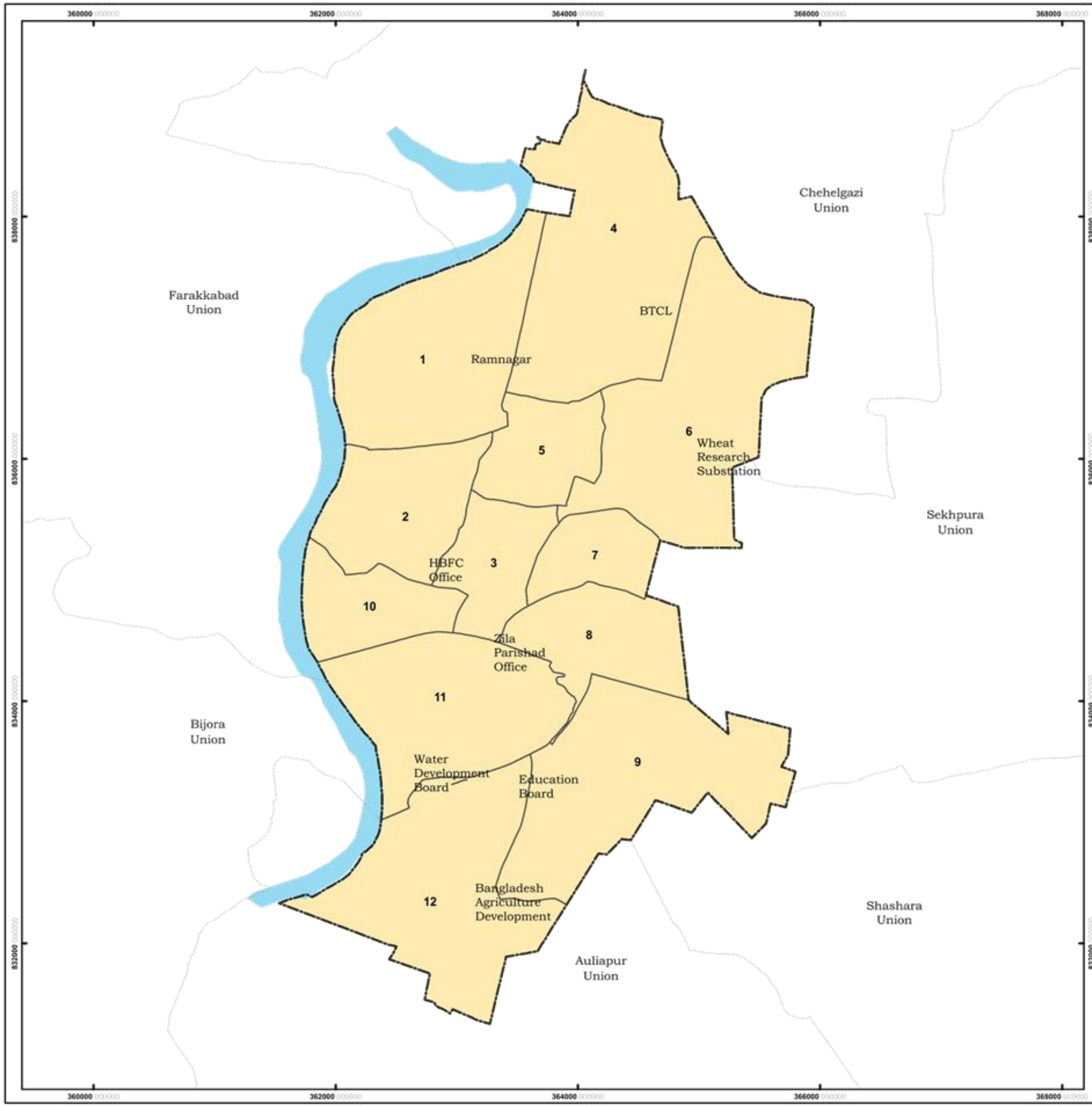


Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Dinajpur Paurashava
Casualty Estimate for Building Damage
Scenario 03, Case 01

Legend

- Municipal Boundary
- Ward Boundary
- Water Bodies

Injuries at Night Time in Person

- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- > 40

N
W E
S

0 35 70 140 Meters

1 inch = 2,916.67 feet

R:F: 1:35,000 in A3 Paper Size

Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.

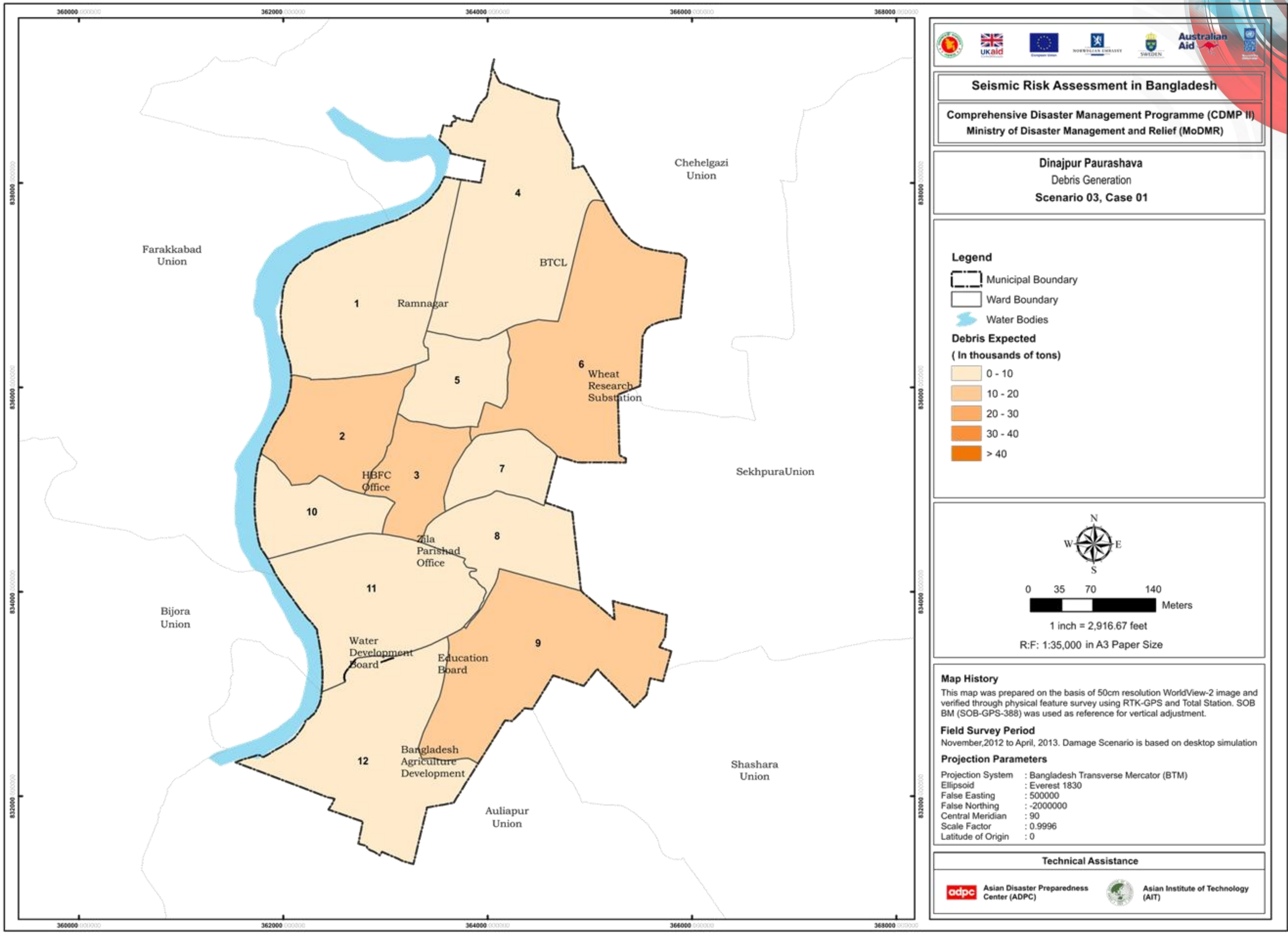
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Debris Generation
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Debris Expected
(In thousands of tons)
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
W
E
S
0
35
70
140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Farakkabad Union
Chehelgazi Union
SekhpuraUnion
Bijora Union
Shashara Union
Auliapur Union
Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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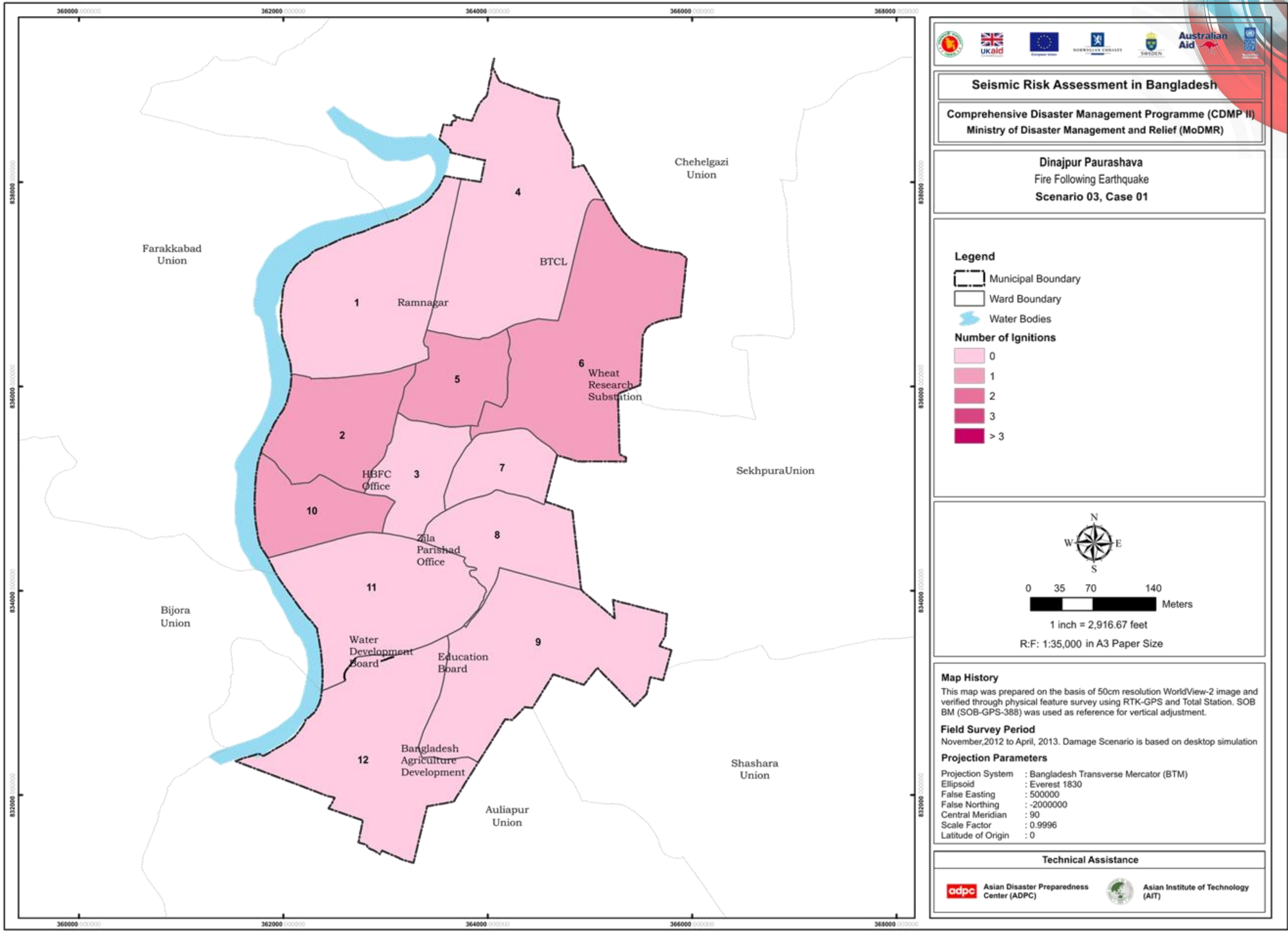

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Fire Following Earthquake
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Number of Ignitions
0
1
2
3
> 3
N
W
E
S
0 35 70 140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Farakkabad Union
Chehelgazi Union
SekhpuraUnion
Bijora Union
Shashara Union
Auliapur Union
Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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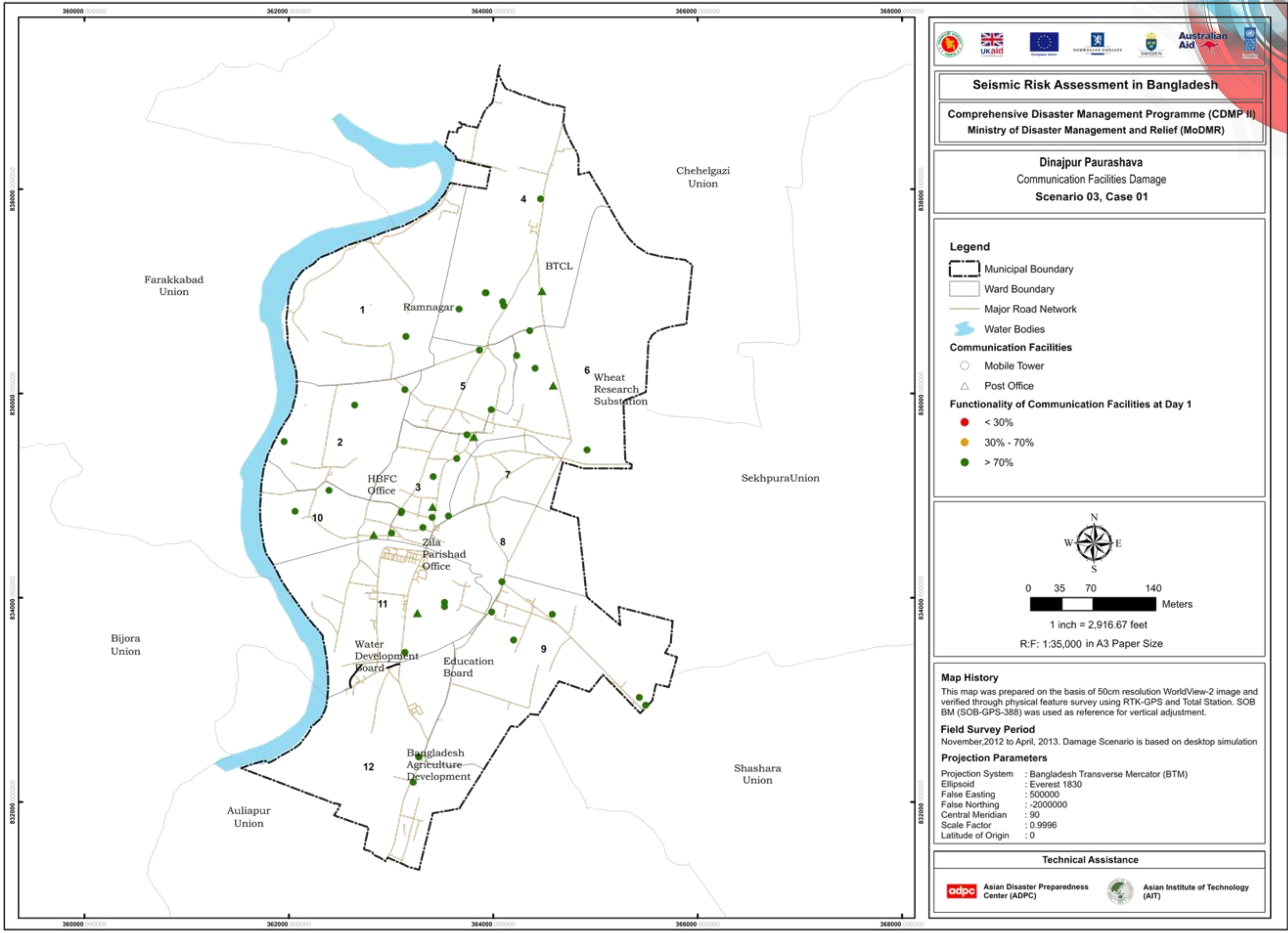
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Communication Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Communication Facilities
Mobile Tower
Post Office
Functionality of Communication Facilities at Day 1
< 30%
30% - 70%
> 70%
N
S
E
W
0 35 70 140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Farakkabad Union
Chehelgazi Union
Sekhpura Union
Bijora Union
Auliapur Union
Shashara Union
Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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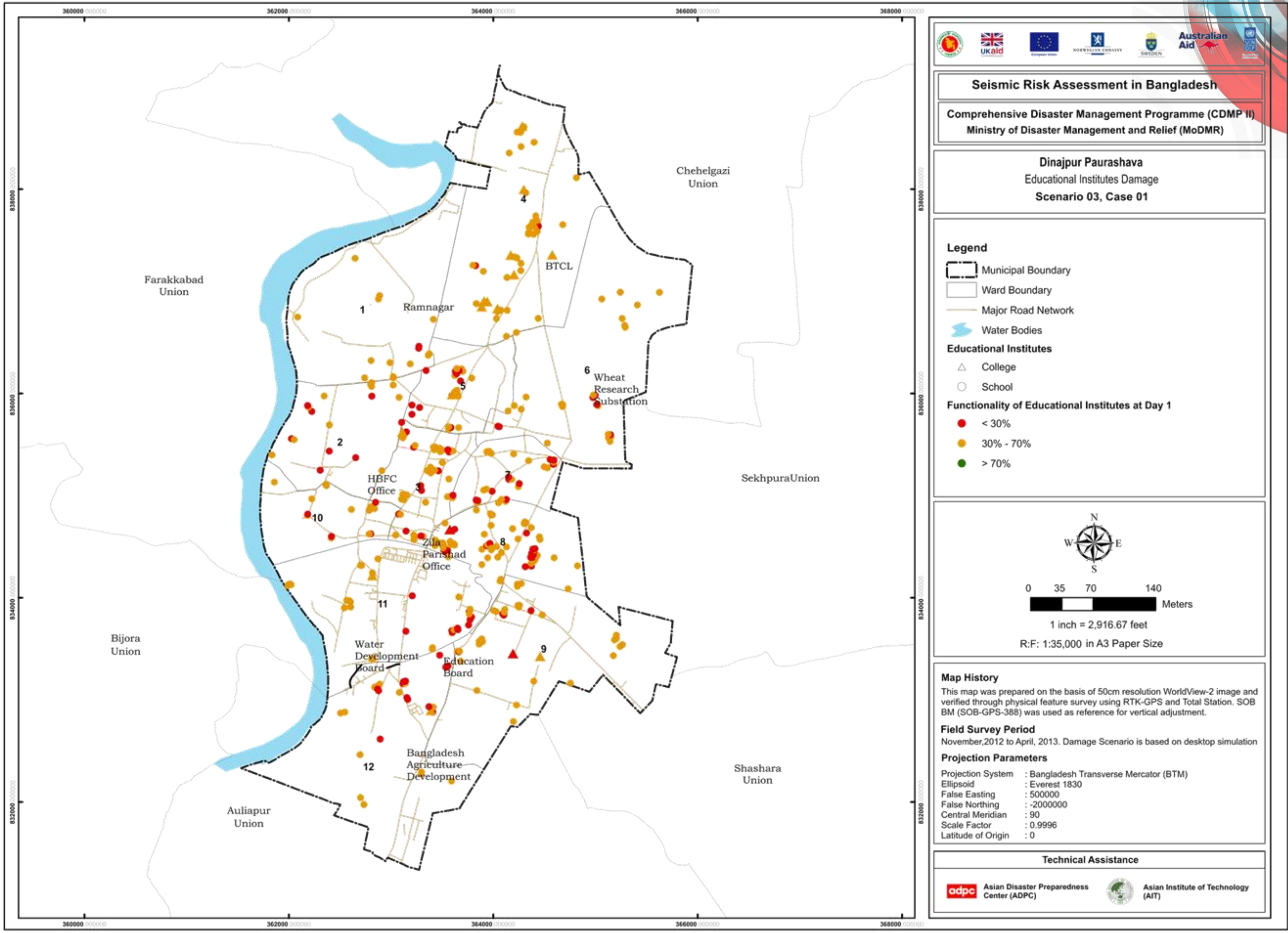
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Educational Institutes Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Educational Institutes
College
School
Functionality of Educational Institutes at Day 1
< 30%
30% - 70%
> 70%
N
W
E
S
0 35 70 140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Farakkabad Union
Chehelgazi Union
SekhpuraUnion
Bijora Union
Auliapur Union
Shashara Union
Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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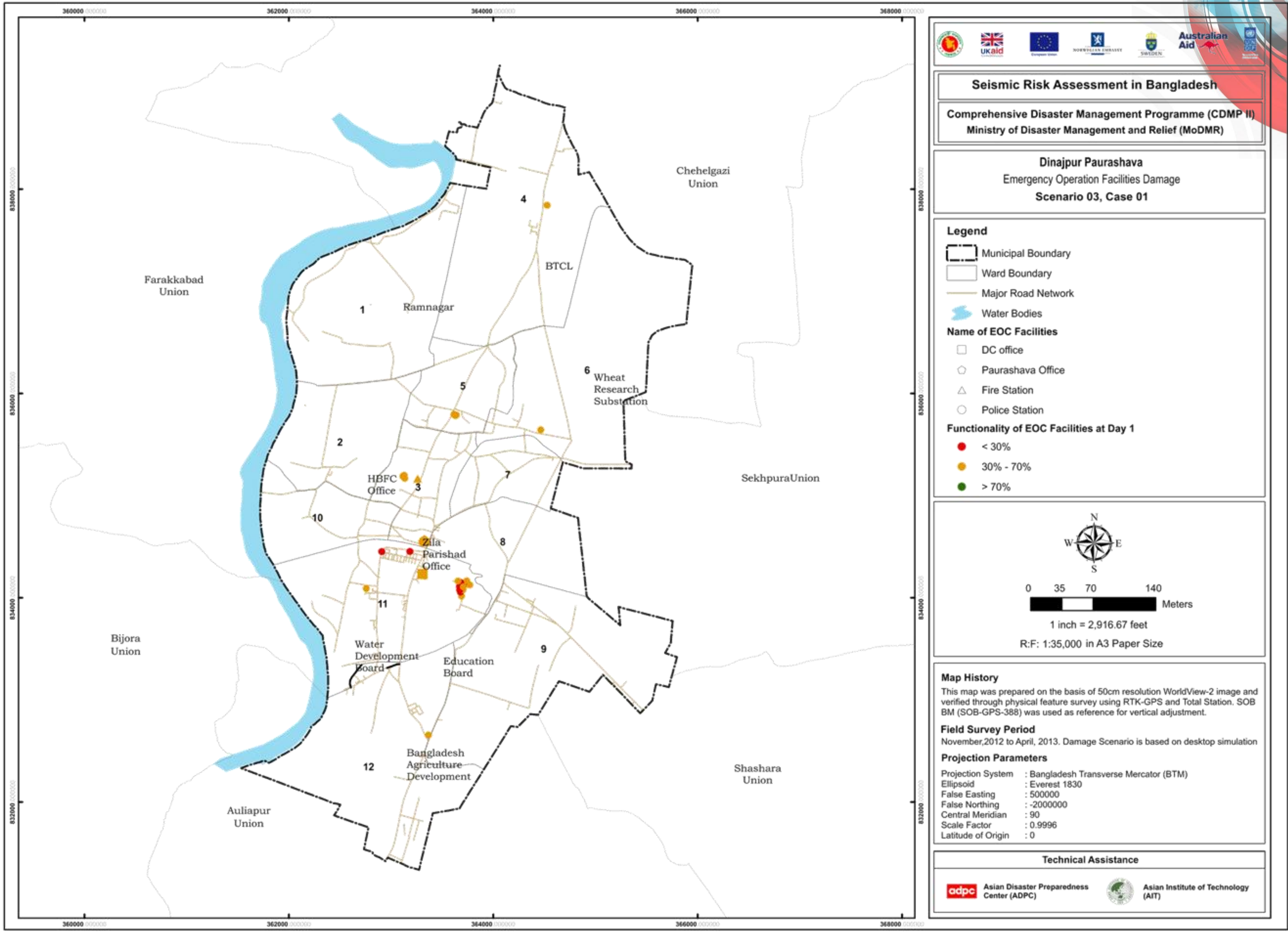
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Emergency Operation Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Name of EOC Facilities
DC office
Paurashava Office
Fire Station
Police Station
Functionality of EOC Facilities at Day 1
< 30%
30% - 70%
> 70%
N
W
E
S
0
35
70
140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Chehelgazi Union
Farakkabad Union
Bijora Union
Auliapur Union
Shashara Union
SekhpuraUnion
BTCL
Ramnagar
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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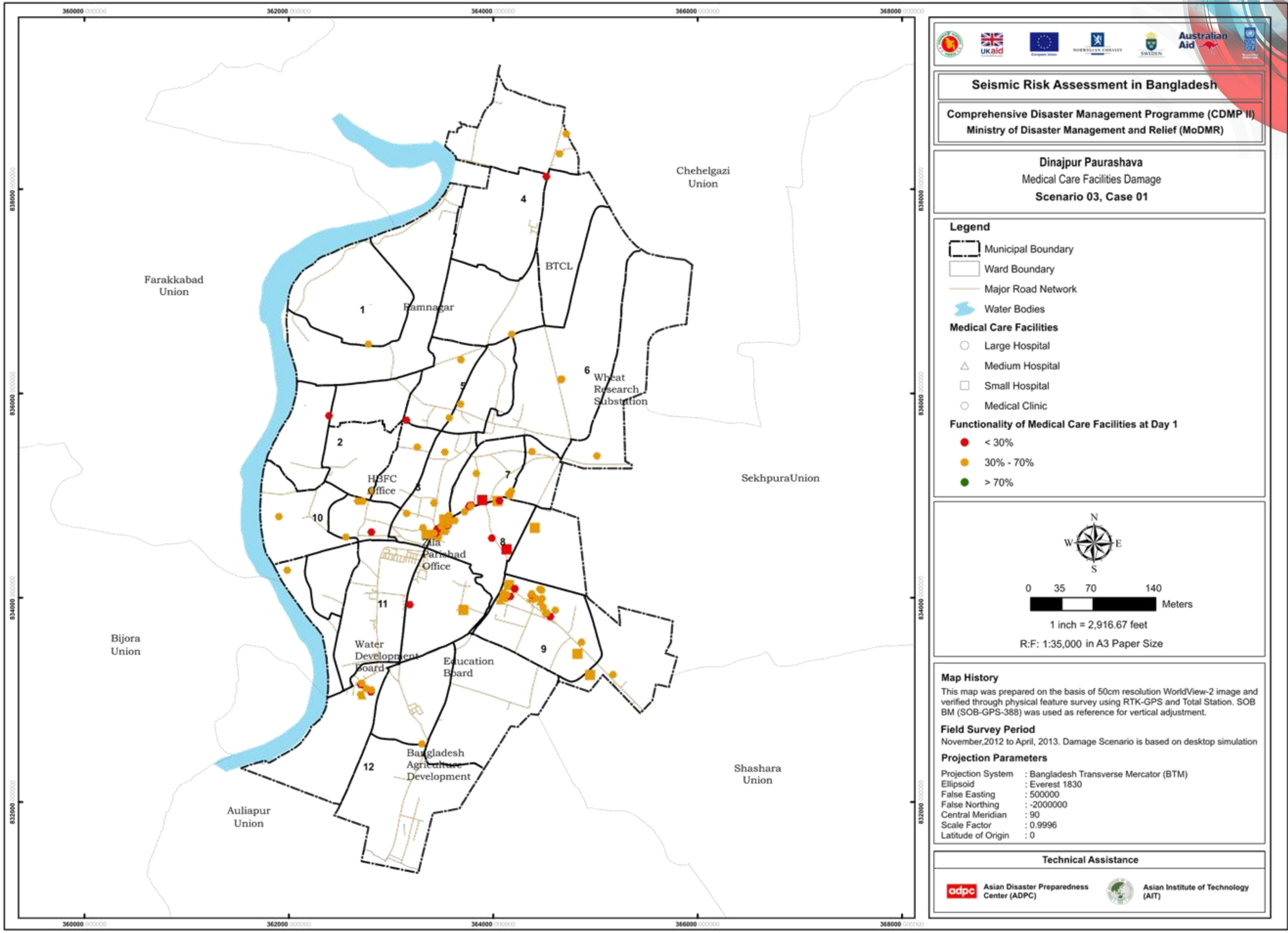
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Medical Care Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Medical Care Facilities
Large Hospital
Medium Hospital
Small Hospital
Medical Clinic
Functionality of Medical Care Facilities at Day 1
< 30%
30% - 70%
> 70%
N
W
E
S
0 35 70 140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Farakkabad Union
Chehelgazi Union
Sekhpura Union
Bijora Union
Auliapur Union
Shashara Union
BTCL
Ramnagar
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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366000
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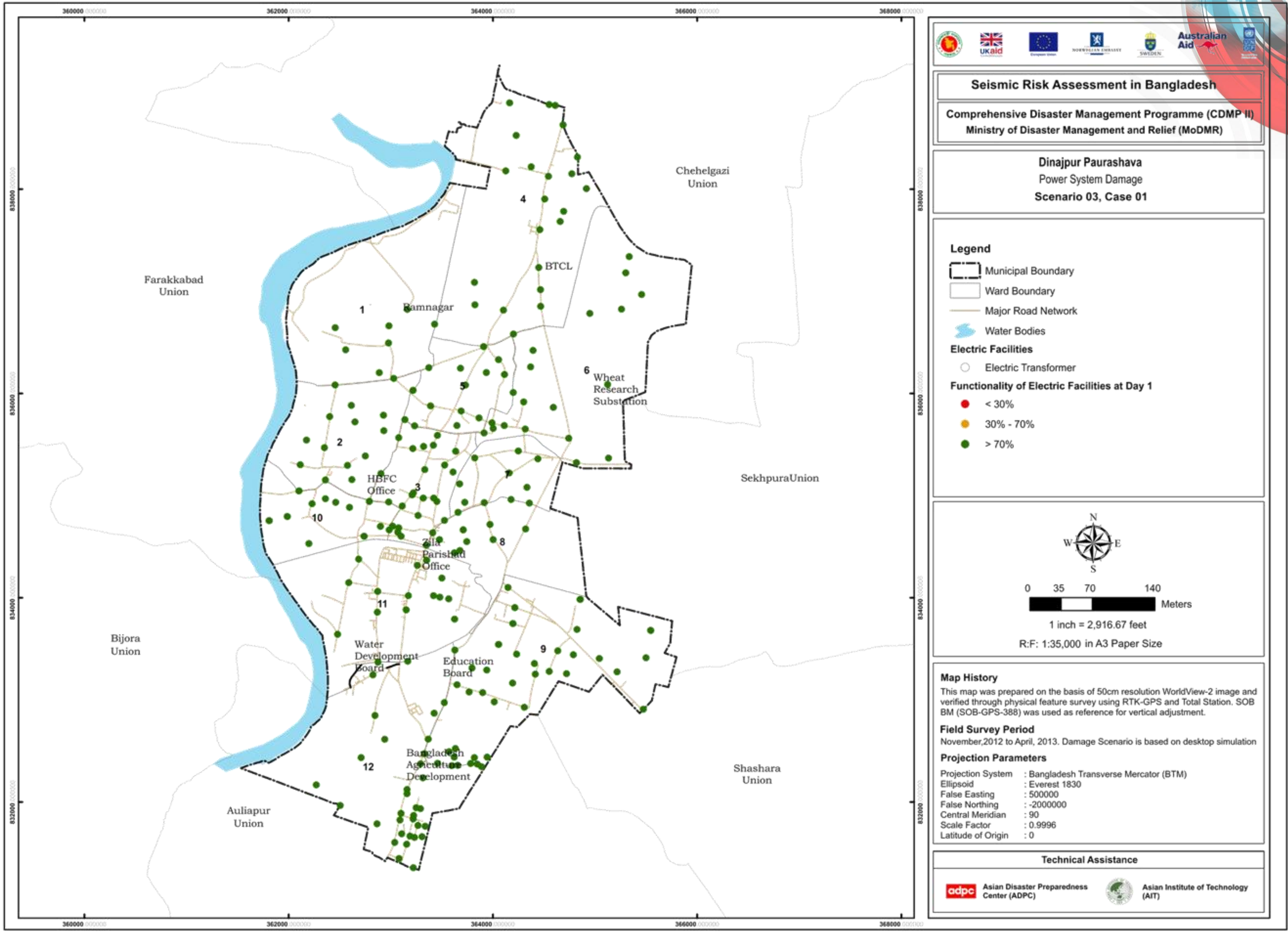

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Power System Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Electric Facilities
Electric Transformer
Functionality of Electric Facilities at Day 1
< 30%
30% - 70%
> 70%
N
W
E
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0
35
70
140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Farakkabad Union
Chehelgazi Union
SekhpuraUnion
Bijora Union
Shashara Union
Auliapur Union
Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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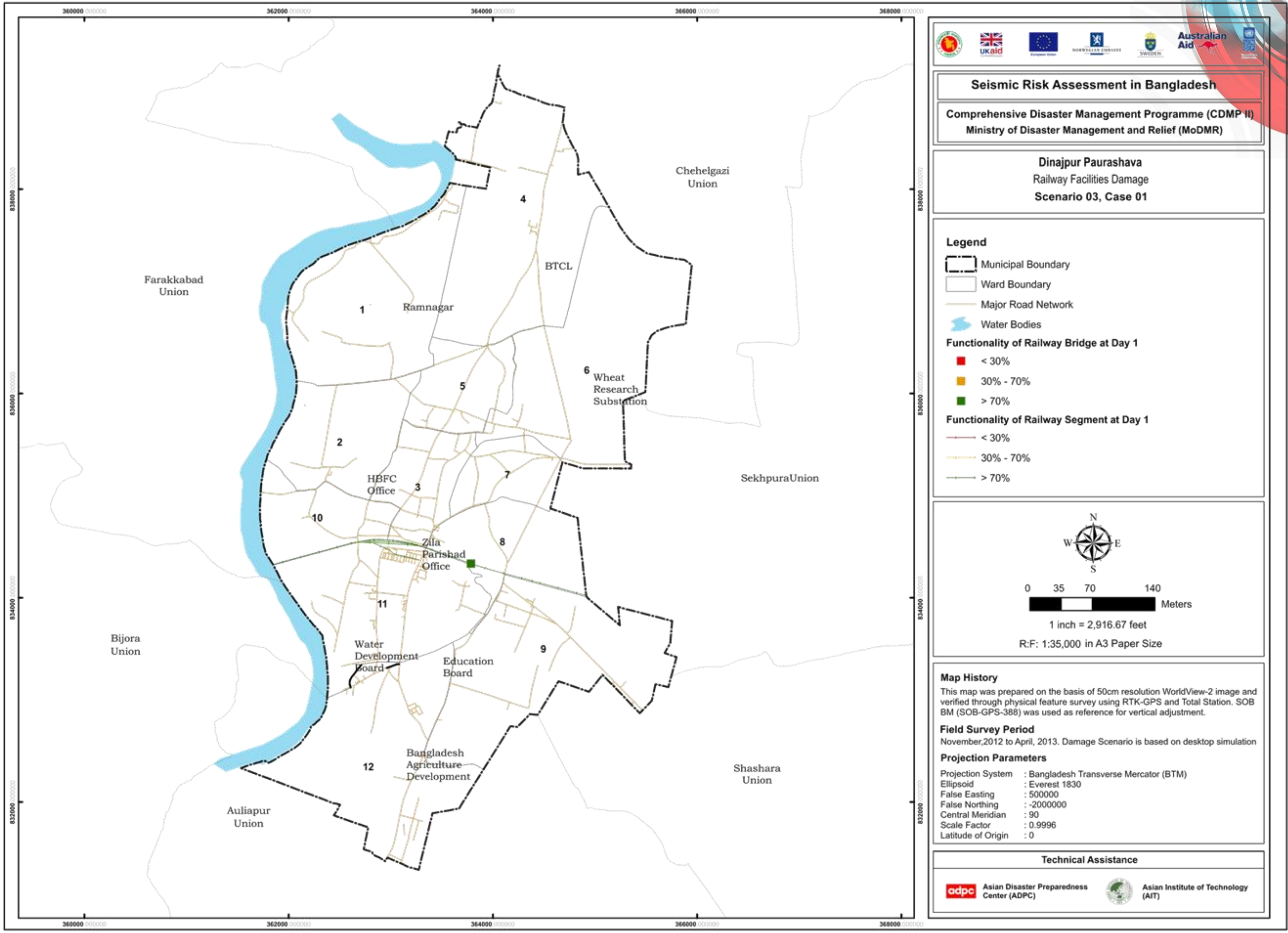
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Railway Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Functionality of Railway Bridge at Day 1
< 30%
30% - 70%
> 70%
Functionality of Railway Segment at Day 1
< 30%
30% - 70%
> 70%
N
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0 35 70 140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
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Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
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Farakkabad Union
Chehelgazi Union
SekhpuraUnion
Bijora Union
Auliapur Union
Shashara Union
Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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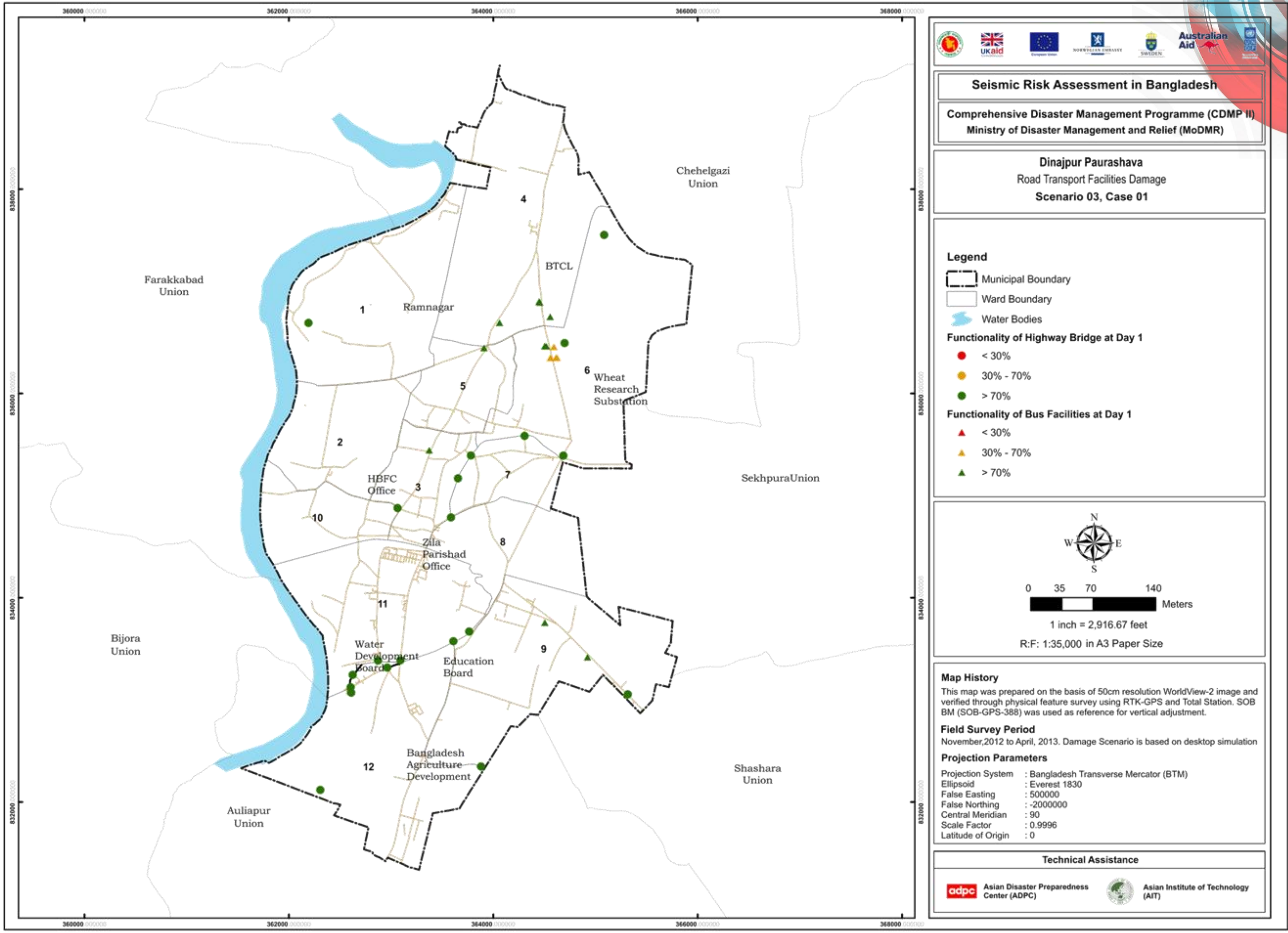
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Road Transport Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Functionality of Highway Bridge at Day 1
< 30%
30% - 70%
> 70%
Functionality of Bus Facilities at Day 1
< 30%
30% - 70%
> 70%
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Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
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November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
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Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Chehelgazi Union
Farakkabad Union
Ramnagar
BTCL
Wheat Research Substation
SekhpuraUnion
HBFC Office
Zila Parishad Office
Bijora Union
Water Development Board
Education Board
Bangladesh Agriculture Development
Shashara Union
Auliapur Union
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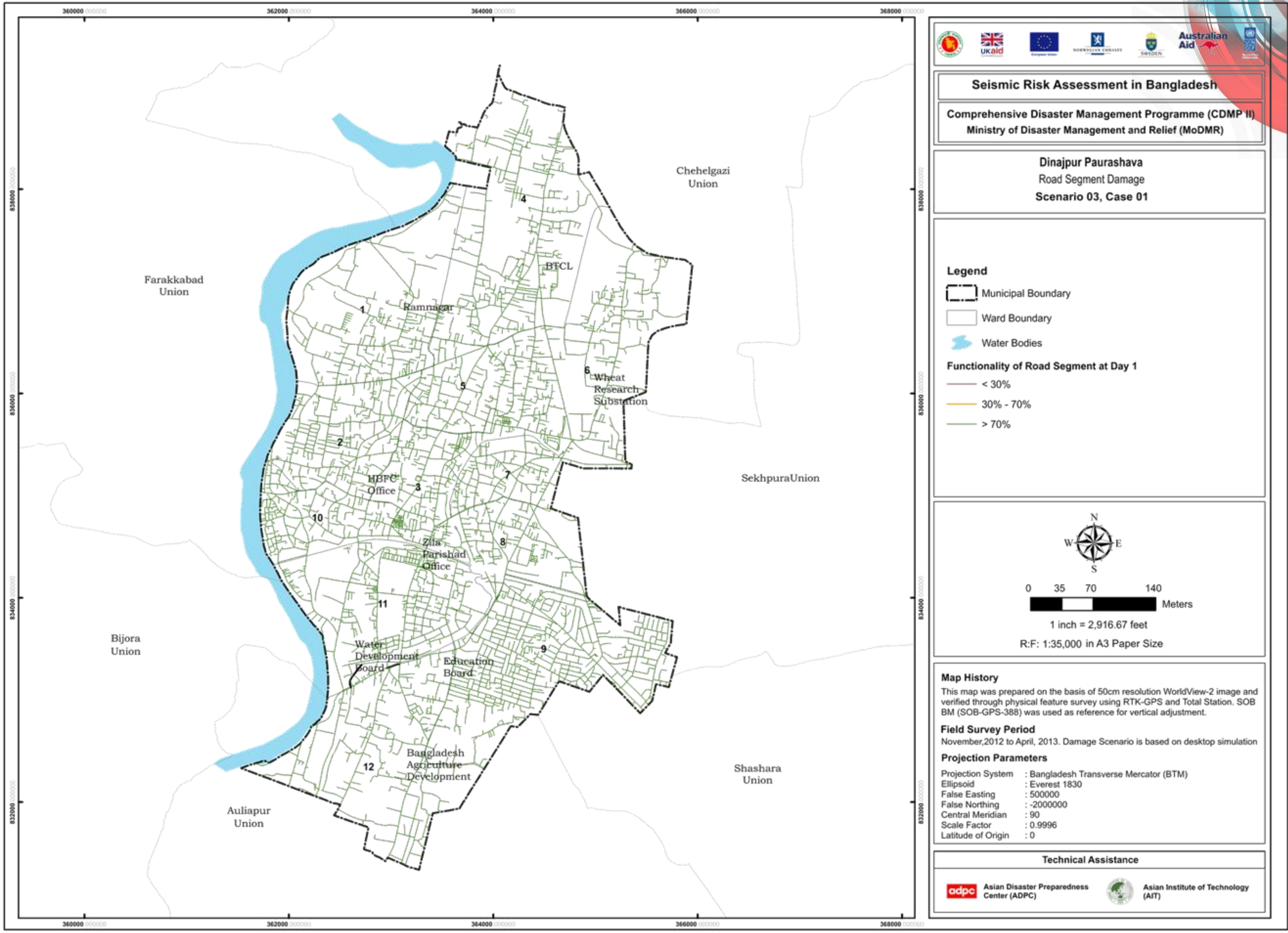
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Road Segment Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Functionality of Road Segment at Day 1
< 30%
30% - 70%
> 70%
N
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140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
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Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
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Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Chehelgazi Union
Farakkabad Union
SekhpuraUnion
Bijora Union
Shashara Union
Auliapur Union
Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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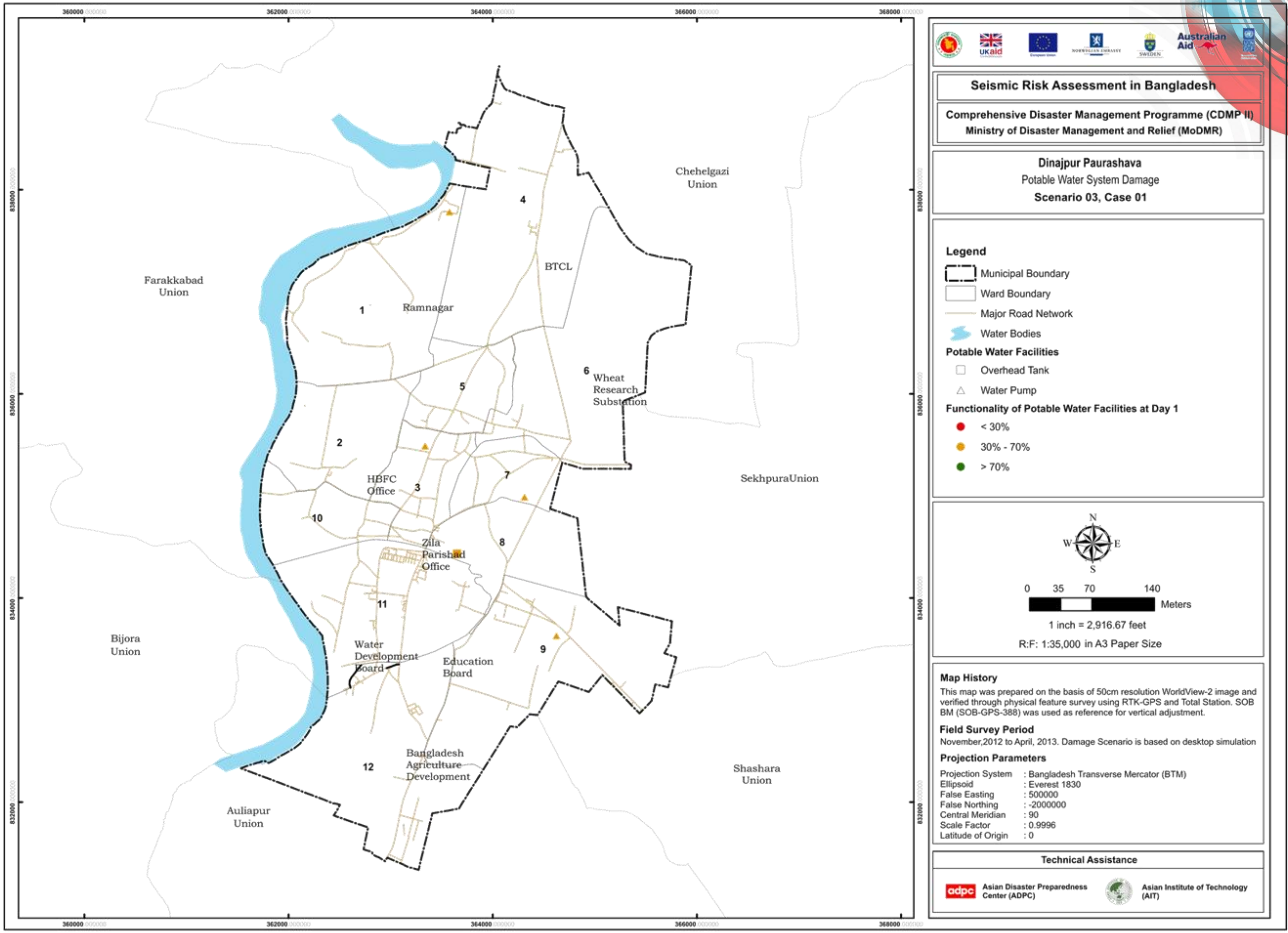
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Dinajpur Paurashava
Potable Water System Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Potable Water Facilities
Overhead Tank
Water Pump
Functionality of Potable Water Facilities at Day 1
< 30%
30% - 70%
> 70%
N
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0 35 70 140
Meters
1 inch = 2,916.67 feet
R:F: 1:35,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-388) was used as reference for vertical adjustment.
Field Survey Period
November,2012 to April, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Farakkabad Union
Chehelgazi Union
Sekhpura Union
Bijora Union
Auliapur Union
Shashara Union
Ramnagar
BTCL
Wheat Research Substation
HBFC Office
Zila Parishad Office
Water Development Board
Education Board
Bangladesh Agriculture Development
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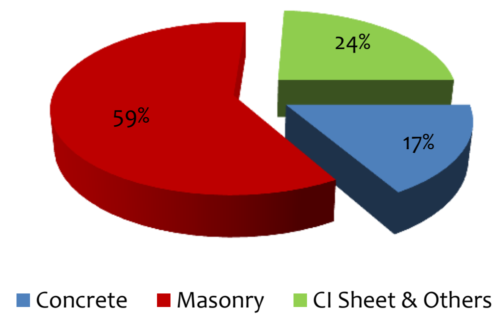
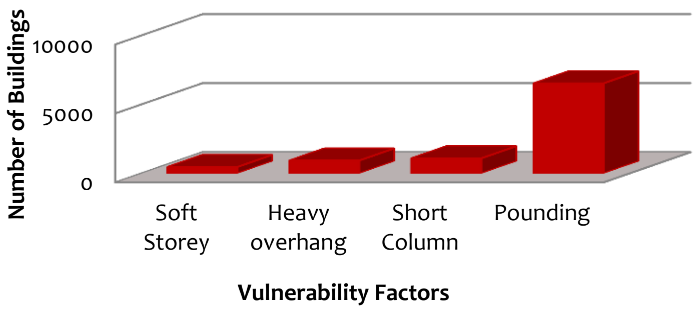
MYMENSINGH PAURASHAVA

Mymensingh town, earlier known as Nasirabad, is placed on the west bank of Brahmaputra River. The paurashava was founded in 1869. The town consists of 21 wards and 85 mahallas. It is home to the Bangladesh Agricultural University, a huge bridge on the Brahmaputra River, 2 medical colleges (Mymensingh Medical College and Community Based Medical College), 8 high schools, Raj bari, and naturally beautiful farm lands among other assets. Mymensingh is one of the most suitable places to live in Bangladesh. The area of the town is 21.73 sq. km. The population of the town is around 2,58,040 (male 51.20%, female 48.80%) and the literacy rate is about 73.9% (male 76.7% , Female 71.0%). The main attractive sites in Mymensingh Town are the castle of the Jamindar Family: Shoshi Lodge, Alexandra Castle, Raj Rajjeshwari Water Works, Robindra Botomul, Mymensingh Museum, Jainul Abedin Museum, Shomvuganj Bridge, BAU campus, City park, Bipin park and the river front of the Brahmaputra River.

Structural type in Mymenshingh Paurashava

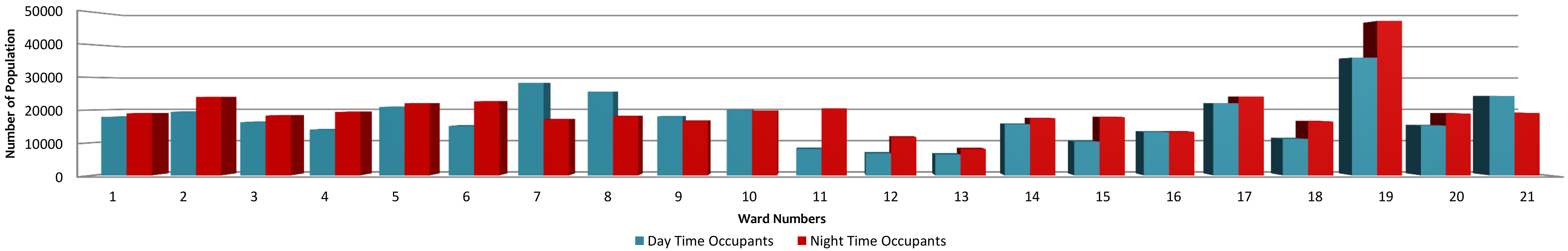


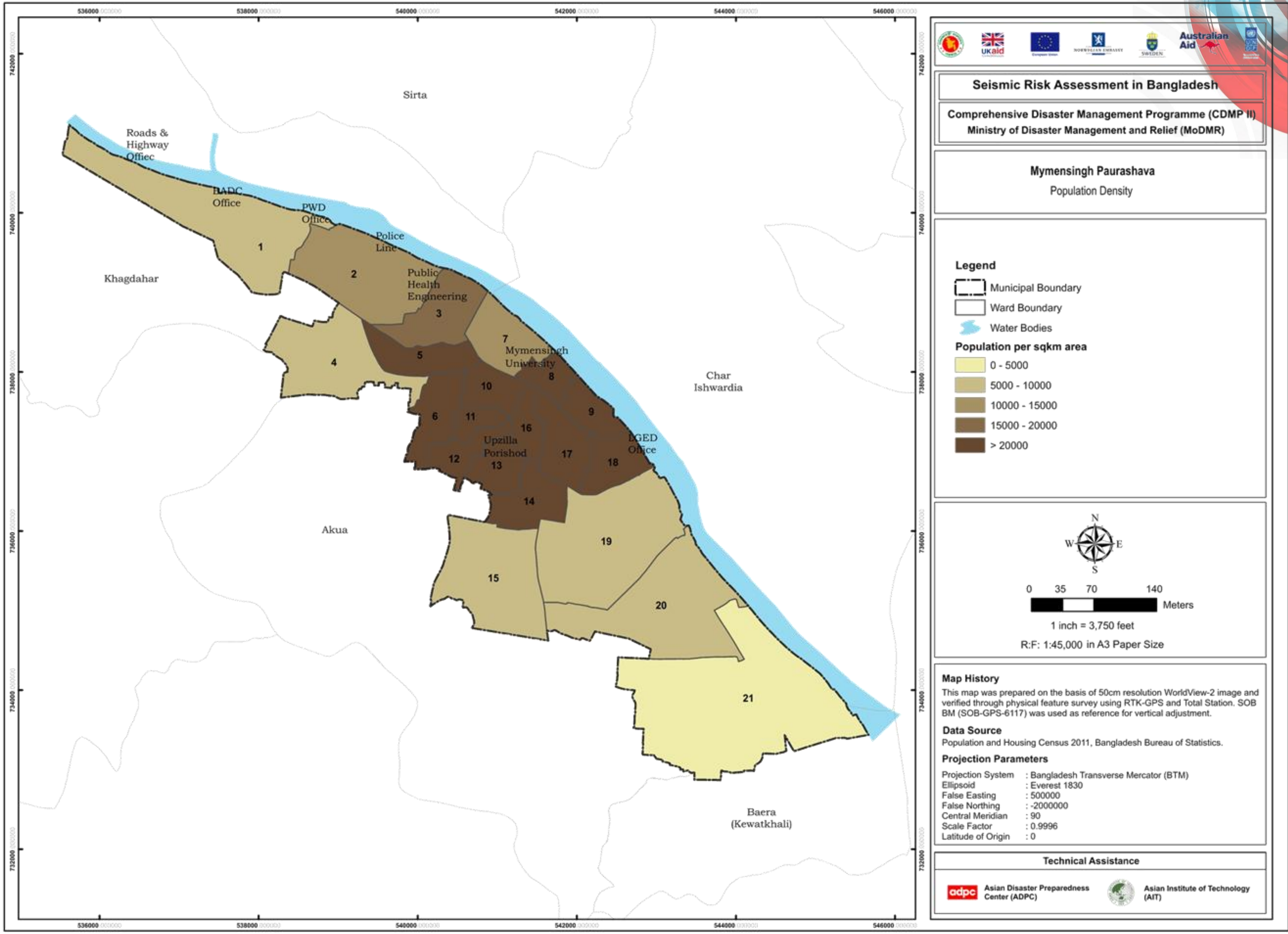
Vulnerability factors in Mymenshingh Paurashava



Brief Information of the City	
Name of the City	Mymensingh
Name of the Paurashava	Mymensingh Pourashava
Year of Establishment	1869
Total Area	21.73 sq. km
Number of Wards	21
Total Population	258040(Male-132123, Female-125917)
Population Growth Rate (2011)	1.82%
Road Network	325.50 km
Railways	26.92 km
Water Ways	3.23 sq. km or 797 acre
Natural Water Bodies	1.87 km or 465.63 acre
Open Space	63.06 acre
Education Institutions	193
Health Facilities	64
Re-fueling Stations	6
Fire Station	1
Police Station	1

Day & Night Occupants in Mymensingh Paurashava




Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Population Density
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Population per sqkm area
0 - 5000
5000 - 10000
10000 - 15000
15000 - 20000
> 20000
N
W
E
S
0
35
70
140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-6117) was used as reference for vertical adjustment.
Data Source
Population and Housing Census 2011, Bangladesh Bureau of Statistics.
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Sirta
Roads & Highway Officc
BADC Office
PWD Office
Police Line
Public Health Engineering
Mymensingh University
Khagdahar
Char Ishwardia
Upzilla Porishod
LGED Office
Akua
Baera (Kewatkhali)
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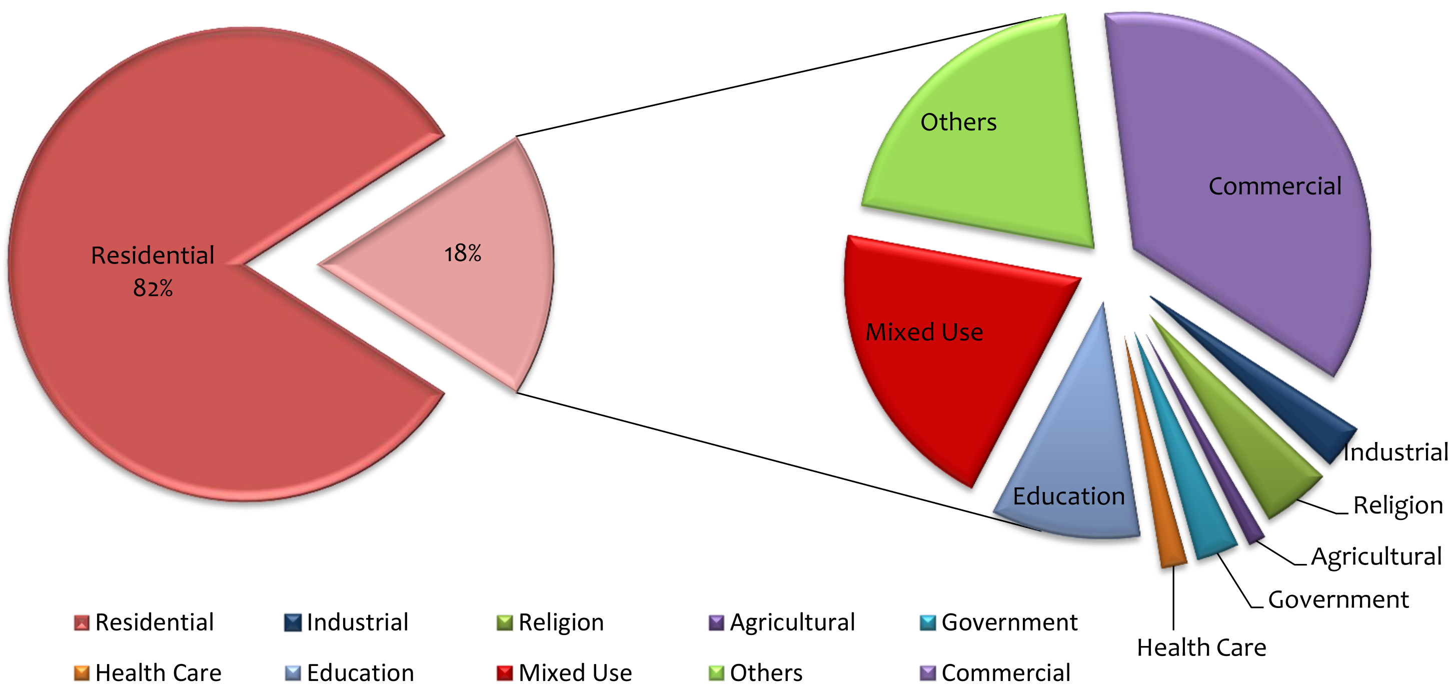
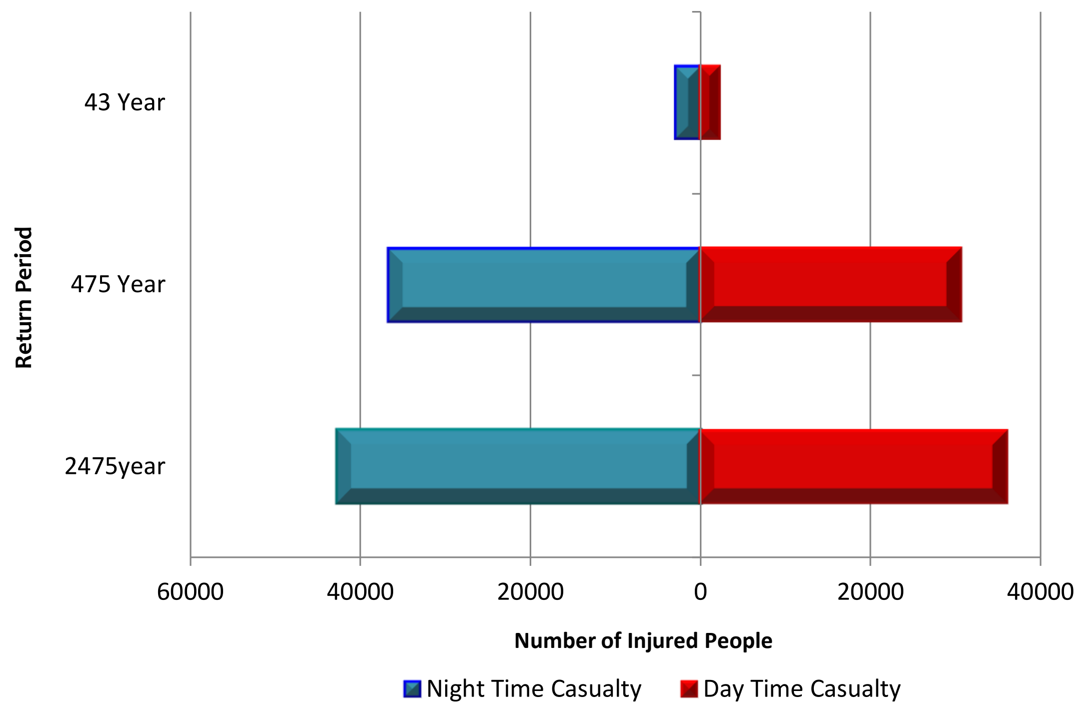
742000
740000
738000
736000
734000
732000

Distribution of Different Occupancy Classes in Mymensingh Paurashava



Expected Casualties in Mymensingh Paurashava



EXPECTED PHYSICAL DAMAGE STATES

Table 13: Expected physical damage states of buildings for different scenario cases

Scenarios	Total Structure	Concrete Structure					Masonry Structure					Tin Shed and Bamboo Structure				
		Total Concrete Structure	Moderate Damage		Complete Damage		Total Masonry Structure	Moderate Damage		Complete Damage		Total Zinc Shed and Bamboo Structure	Moderate Damage		Complete Damage	
			No.	%	No.	%		No.	%	No.	%		No.	%	No.	%
Scenario 1 Case 1	45033	7703	2846	36.94%	427	5.54%	26789	10361	38.68%	284	1.06%	10541	943	8.94%	249	0.59%
Scenario 2 Case 2	45033	7703	2770	35.96%	411	5.33%	26789	9907	36.98%	313	1.17%	10541	727	6.90%	43	0.41%
Scenario 3 Case 1	45033	7703	208	2.70%	6472	83.99%	26789	2007	7.49%	15411	57.53%	10541	5312	50.39%	249	2.36%
Scenario 4 Case 2	45033	7703	115	1.49%	6945	90.12%	26789	1199	4.48%	19061	71.15%	10541	4174	39.60%	135	1.28%
Scenario 5 Case 1	45033	7703	84	1.09%	7092	92.06%	26789	915	3.42%	20048	74.84%	10541	5379	51.03%	401	3.80%
Scenario 6 Case 2	45033	7703	45	0.58%	7533	97.77%	26789	152	0.57%	24583	91.77%	10541	4043	38.36%	165	1.57%

Debris Generation

Table 14: Expected debris generation for different scenario cases

Earthquake Scenario	Amount of Debris (million tons)	% of Concrete and Steel materials	% of Brick and Wood materials
Scenario 1 Case 1	0.860	67%	33%
Scenario 2 Case 2	0.860	67%	33%
Scenario 3 Case 1	4.370	72%	28%
Scenario 4 Case 2	4.370	72%	28%
Scenario 5 Case 1	4.370	72%	28%
Scenario 6 Case 2	4.550	70%	30%

Damage to Utility Systems

Table 15: Expected damage to utility systems for different scenario cases

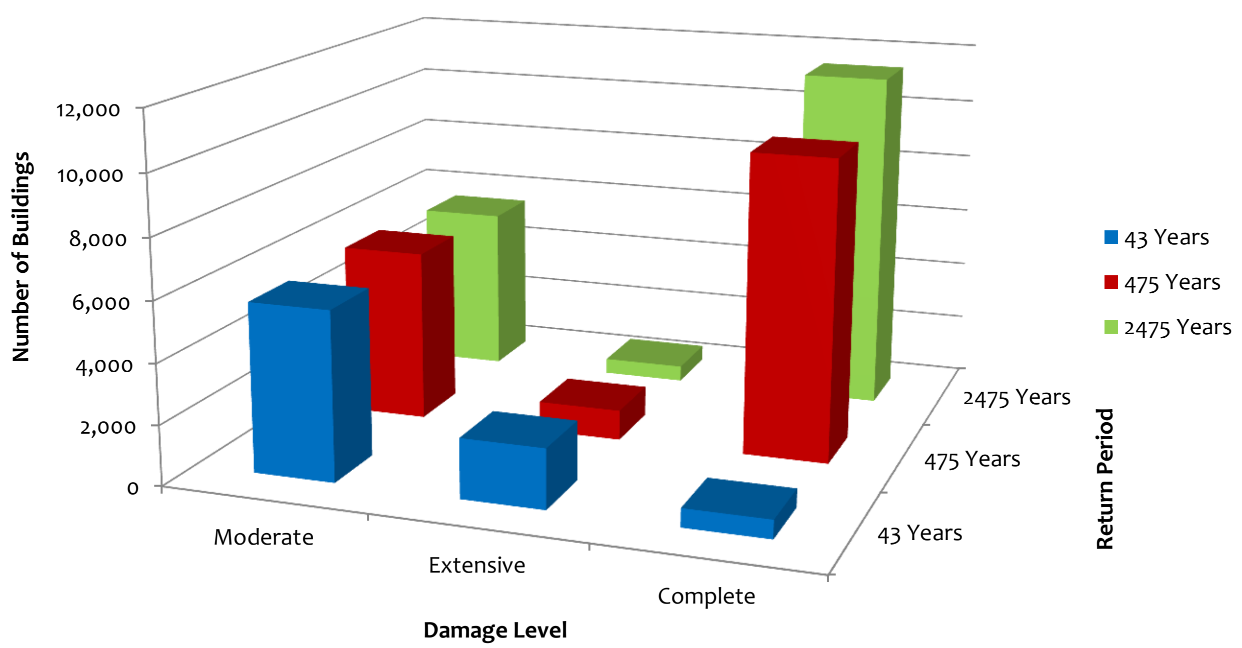
System	Total Length Pipelines (km)	No. of Leaks						No. of Breaks					
		Scenario 1 Case 1	Scenario 2 Case 2	Scenario 3 Case 1	Scenario 4 Case 2	Scenario 5 Case 1	Scenario 6 Case 2	Scenario 1 Case 1	Scenario 2 Case 2	Scenario 3 Case 1	Scenario 4 Case 2	Scenario 5 Case 1	Scenario 6 Case 2
Potable Water	129	35	26	150	121	274	206	66	52	175	129	231	186

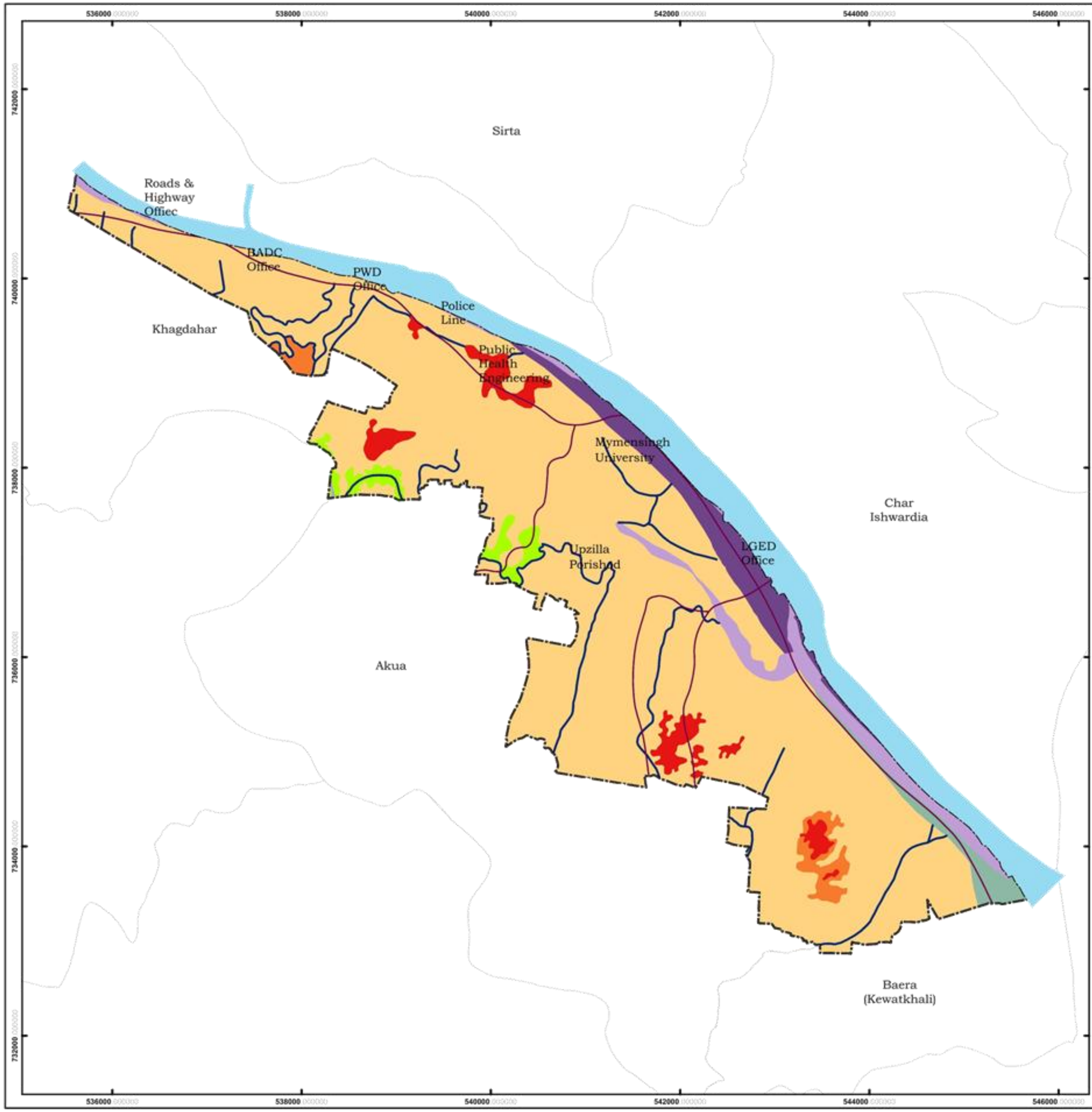
Damage of Lifeline Facilities

Table 16: Expected damage to lifelines for scenario 3 case 1

System	Component	Total	Moderate Damage	Complete Damage	At least 50% Functional	
					Day 1	Day 7
Highway	Segments	2936	0	0	2927	2927
	Bridges	4	4	0	0	3
	Facilities	8	8	5	0	0
Railway	Segments	22	0	0	22	22
	Bridges	8	8	5	0	0

Number of Damage Buildings in Mymensingh Paurashava





Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Mymensingh Paurashava
Geology

Legend

- Municipal Boundary
- Major Road Network
- Active Channel

Young Flood Plain Deposits

- Active Channel Deposits
- Bar Deposits

Old Flood Plain Deposits

- Abandoned Channel Deposits
- Bar Deposits
- Natural Levee Deposits
- Flood Plain Deposits
- Flood Basin Deposits
- Depression Deposits

N W E S

0 35 70 140 Meters

1 inch = 3,750 feet

R:F: 1:45,000 in A3 Paper Size

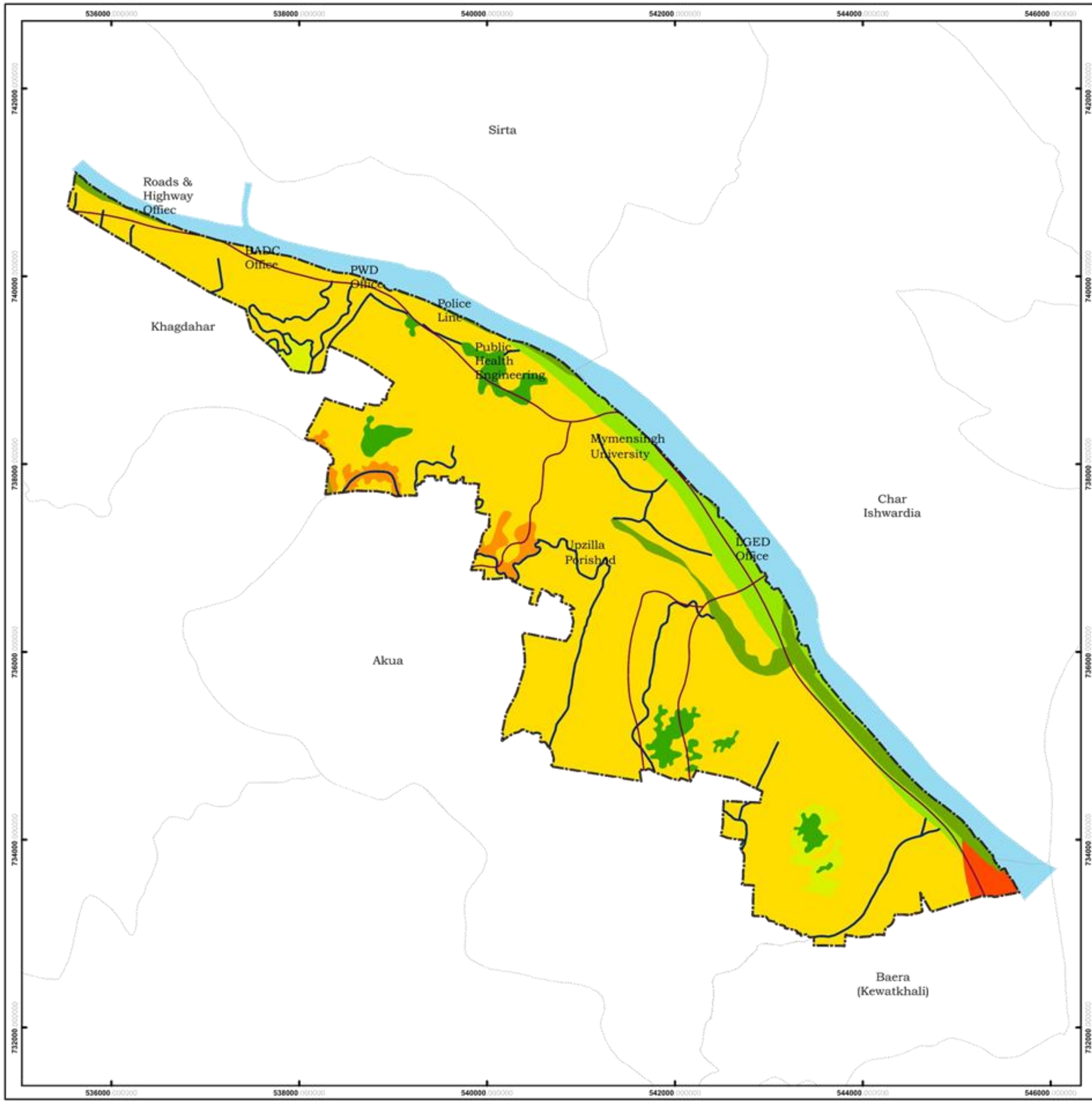
Young Flood Plain Deposits	
Active channel	Grey (N3) to light grey (N7) fine to medium sand
Bar deposits	Light olive grey (5Y 4/1) micaceous very fine to medium sand
Old Flood Plain Deposits	
Abandoned channel deposits	Greenish black (5GY 2/1), moderate yellowish brown (10YR 5/4) to greenish grey (5GY 6/1) sandy silt and micaceous fine to medium sand
Bar deposits	Light olive grey (5Y 4/1) very fine to medium sand with micas
Natural levee deposits	Olive brown (5Y 6/6), greenish black (5G 2/1) and light bluish grey (5B 7/1) fine sand and silty clay
Flood plain deposits	Light olive grey (5Y 5/2) to reddish brown (10R 4/6) silty clay with olive grey (5Y 5/2) to dark greenish grey (5GY 4/1) micaceous sand
Flood basin deposits	Bluish grey (5B 51) to grey (10Y R51) clayey silt and grey (10Y R51) to yellowish brown (10YR 5/4) silty clay with organic matters
Depression deposits	Moderately olive brown (5Y 4/4) to greenish black (5G 2/1) clay and very fine to medium sand with silty clay

Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0

Technical Assistance

Geological Survey of Bangladesh (GSB)

Asian Disaster Preparedness Center (ADPC)



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Mymensingh Paurashava
Geomorphology

Legend

- Municipal Boundary
- Major Road Network
- Active Channel

Young Flood Plain
- Active Channel
- Lateral Bar

Old Flood Plain (Mymensingh Terrace)
- Depression
- Flood Basin
- Flood Plain
- Natural Levee
- Point Bar
- Ox-bow Lake

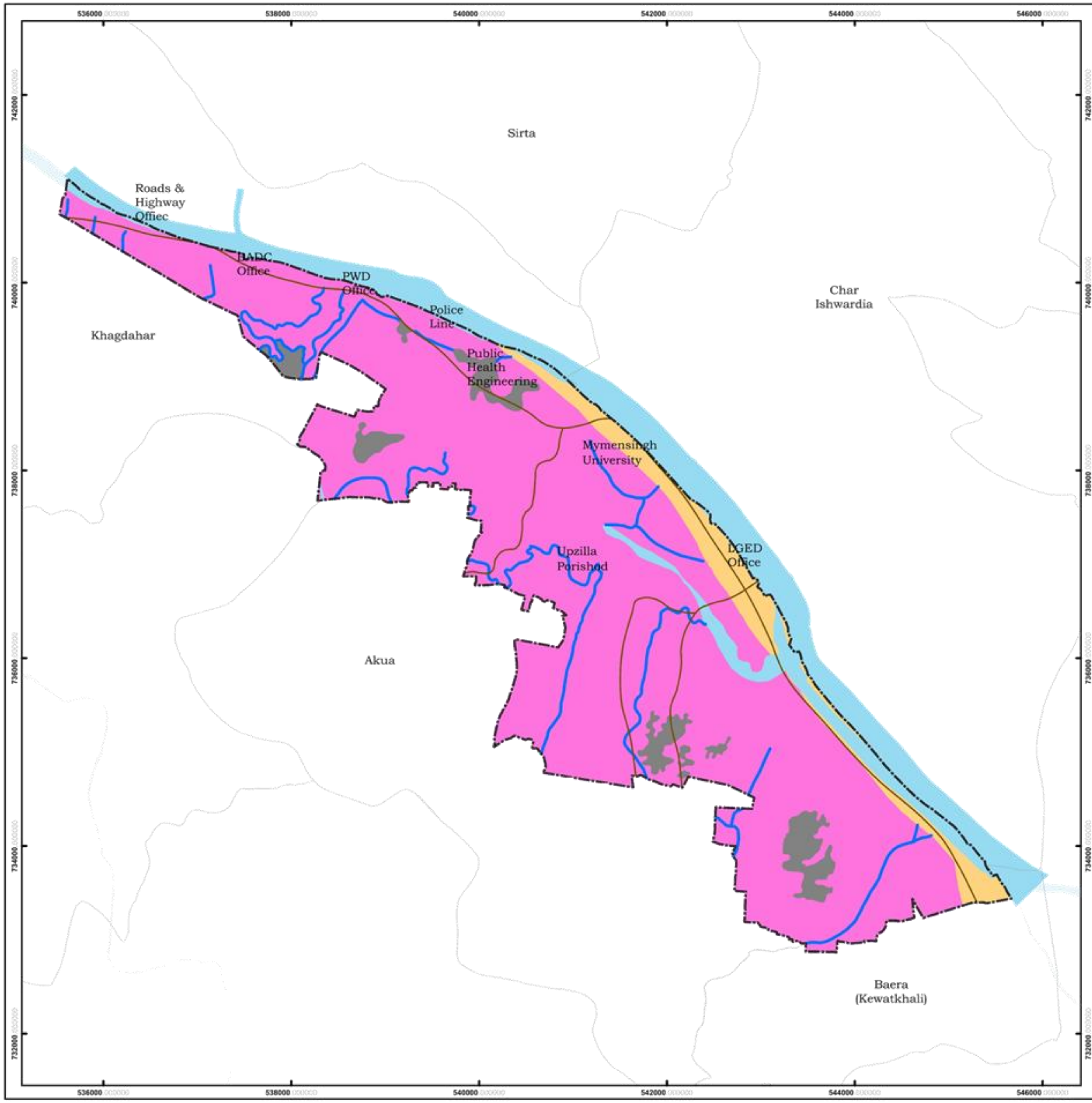
N W E S
0 35 70 140 Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size

Young Flood Plain	
Active channel	Broad, straight Old Bramhmaputra channel with flowing water consist of sand
Lateral Bar	Elongated active accumulation of sand along the bank of river consist of medium of fine sand
Old Flood Plain	
Depression	Irregular shaped deepest areas within the flood plain and flood basins having permanent water bodies consisting of sticky clay with organic matter
Flood Basin	Irregular shaped deepest areas within the floodplain and flood basins having permanent water bodies consisting of sticky clay with organic matter
Flood plain	Broad flat areas extended from the river remain above normal flood level consisted of red to reddish brown colored silty clay and clayey silt
Natural Levee	Irregular shaped accumulation of sediments along the bank and sloping away from either side towards the flood plain consists of silty clay
Point bar	Crescent shaped accumulation of sand along the channel deposited at older flood plain
Ox-bow-lake	Ox-bow-shaped body of water that formed by neck cut of meander channels consist of sandy silt and sand

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Geological Survey of Bangladesh (GSB)
Asian Disaster Preparedness Center (ADPC)



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Mymensingh Paurashava

Engineering Geology

Legend

- Municipal Boundary
- Major Road Network
- Active Channel

Engineering Unit

- Unit - I
- Unit - II
- Unit - III
- Unit - IV

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0 35 70 140 Meters

1 inch = 3,750 feet

R:F: 1:45,000 in A3 Paper Size

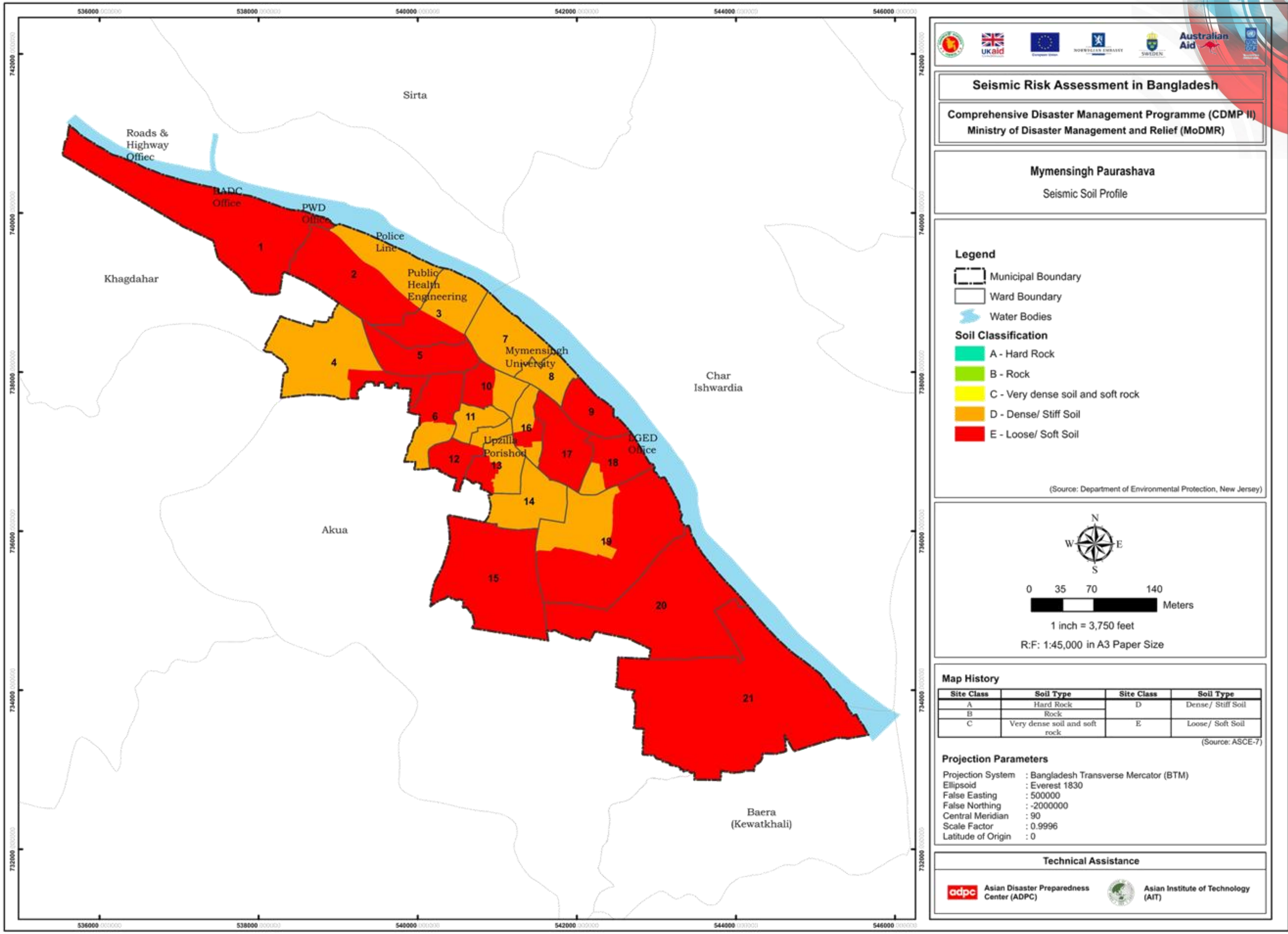
Engineering Properties	
Unit-I	Up to 3m depth mostly composed of stiff clay (max. N value 12), loose silt (max. N value 9), very loose sand (max. N value 4). Within 39m very dense silty sand having max. tested N value is > 50
Unit-II	Up to 3m depth mostly composed of loose sand (max. N value 6). Within 30m dense sand having max tested N value is 40
Unit-III	Up to 3m depth mostly composed of loose to medium sand (max. N value 11). Within 30m dense silty sand having max. tested N value is 35
Unit-IV	Up to 3m mostly composed of loose sand and sandy silt (max. N value 9). Within 30m dense sand having max tested N value is> 50

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Geological Survey of Bangladesh (GSB)

Asian Disaster Preparedness Center (ADPC)



Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Seismic Soil Profile
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Soil Classification
A - Hard Rock
B - Rock
C - Very dense soil and soft rock
D - Dense/ Stiff Soil
E - Loose/ Soft Soil
(Source: Department of Environmental Protection, New Jersey)
N
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E
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0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
Site Class | Soil Type | Site Class | Soil Type
A | Hard Rock | D | Dense/ Stiff Soil
B | Rock
C | Very dense soil and soft rock | E | Loose/ Soft Soil
(Source: ASCE-7)
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Sirta
Roads & Highway Offiec
BADC Office
PWD Office
Police Line
Public Health Engineering
Khagdahar
Mymensingh University
Char Ishwardia
Upzilla Porishod
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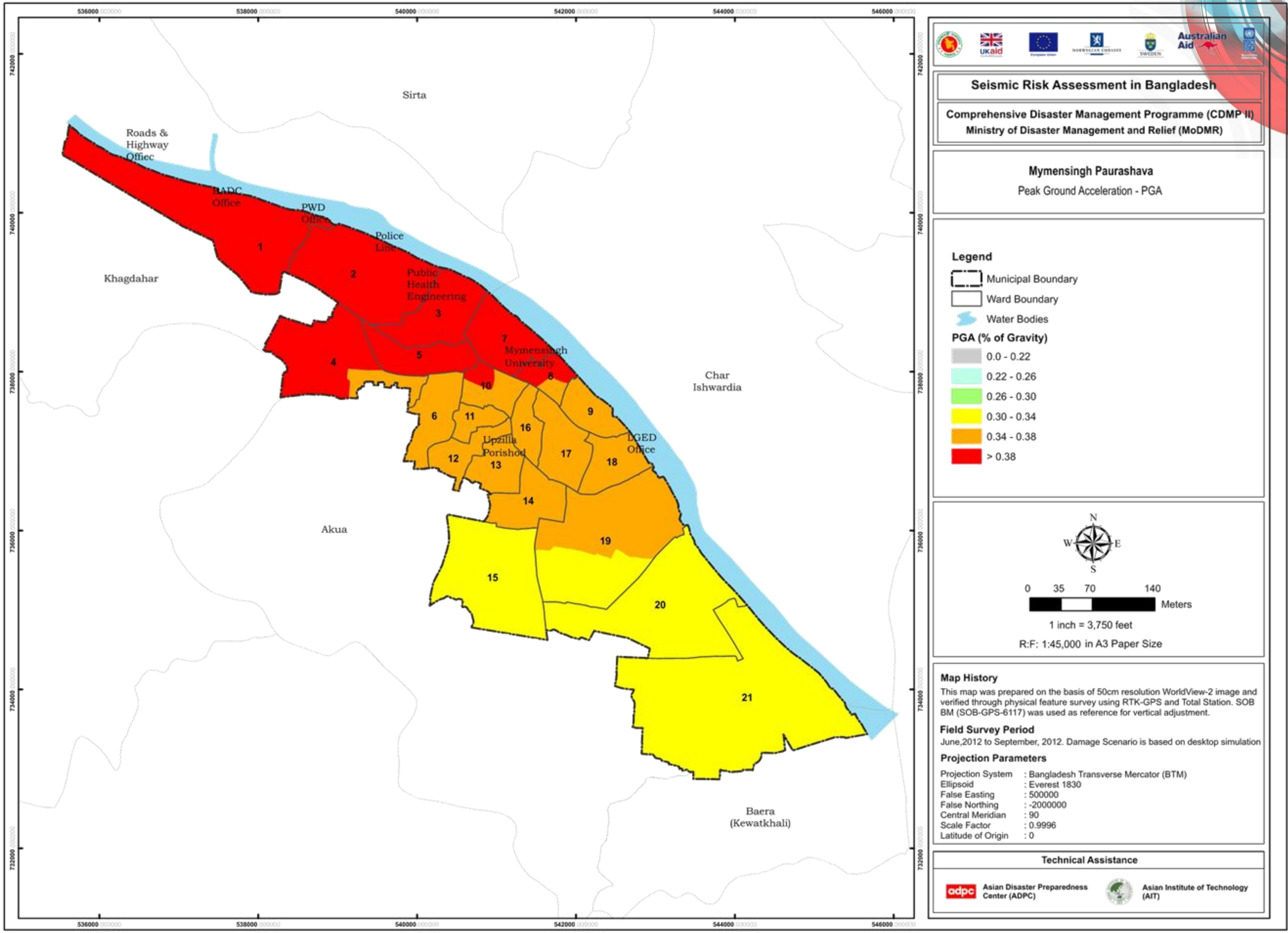
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Peak Ground Acceleration - PGA
Legend
Municipal Boundary
Ward Boundary
Water Bodies
PGA (% of Gravity)
0.0 - 0.22
0.22 - 0.26
0.26 - 0.30
0.30 - 0.34
0.34 - 0.38
> 0.38
N
W
E
S
0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-6117) was used as reference for vertical adjustment.
Field Survey Period
June,2012 to September, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
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Roads & Highway Offiec
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Public Health Engineering
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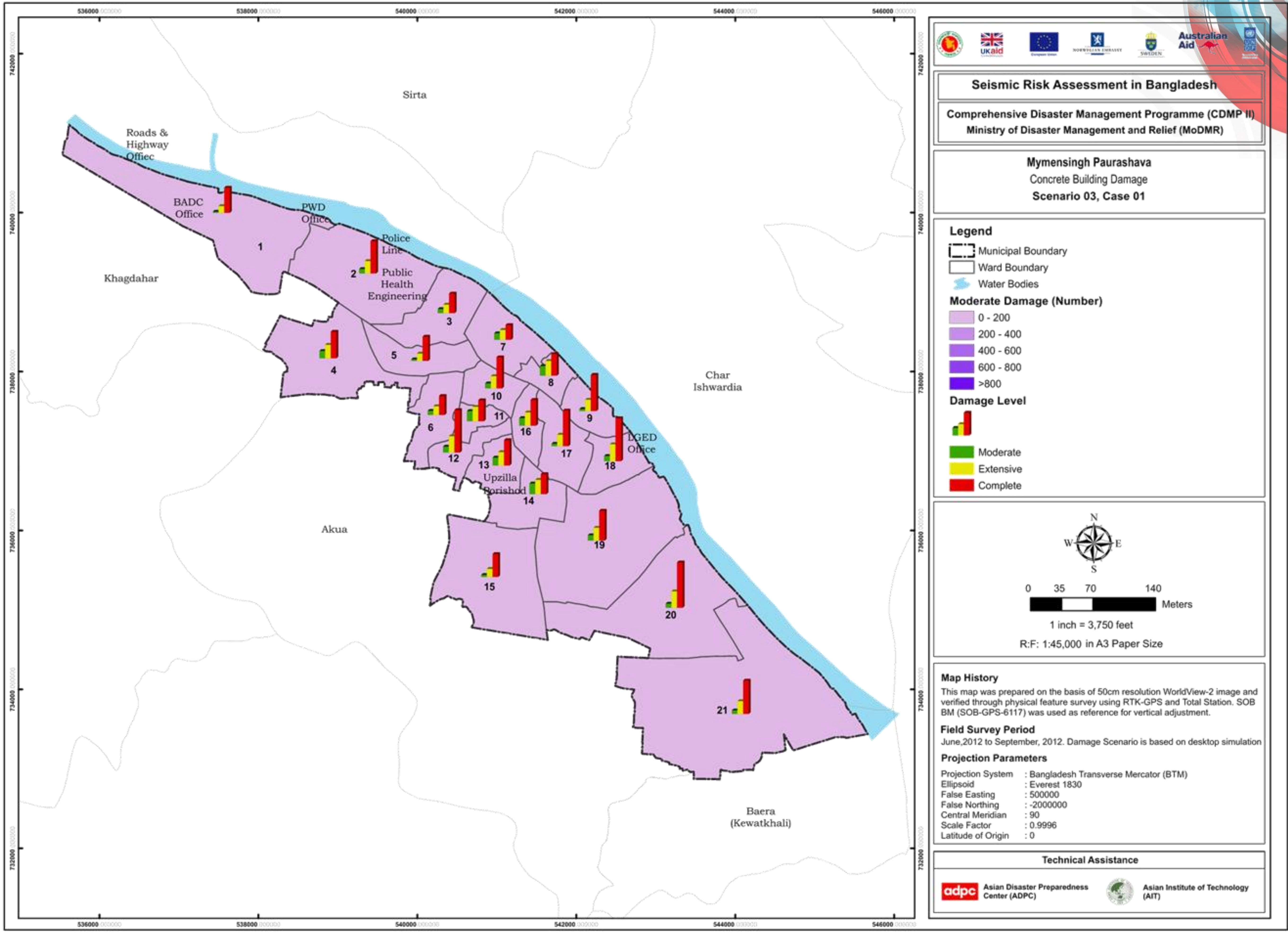
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Concrete Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Moderate Damage (Number)
0 - 200
200 - 400
400 - 600
600 - 800
>800
Damage Level
Moderate
Extensive
Complete
N
W
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S
0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
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June,2012 to September, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
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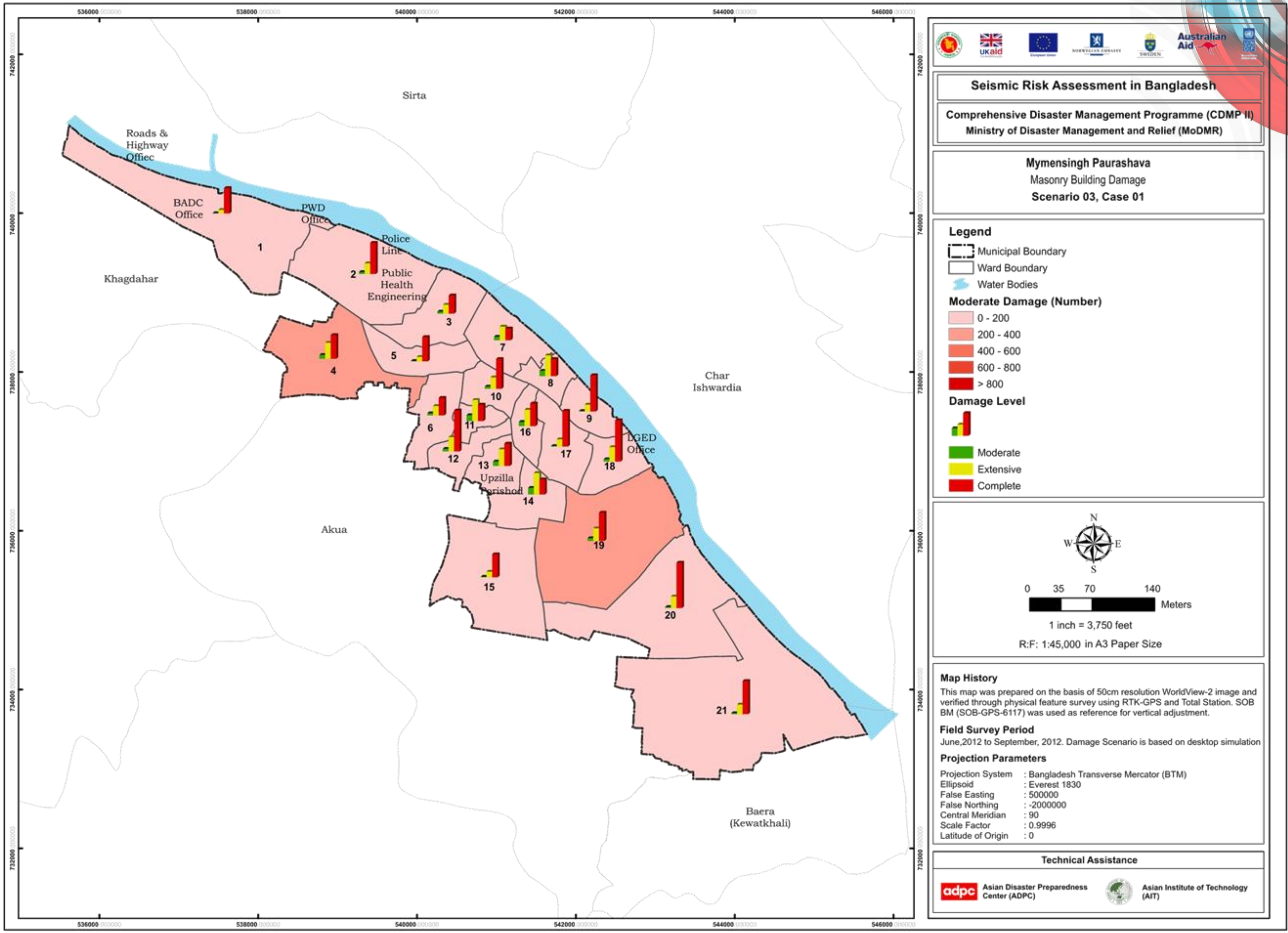
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Masonry Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Moderate Damage (Number)
0 - 200
200 - 400
400 - 600
600 - 800
> 800
Damage Level
Moderate
Extensive
Complete
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0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
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June,2012 to September, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
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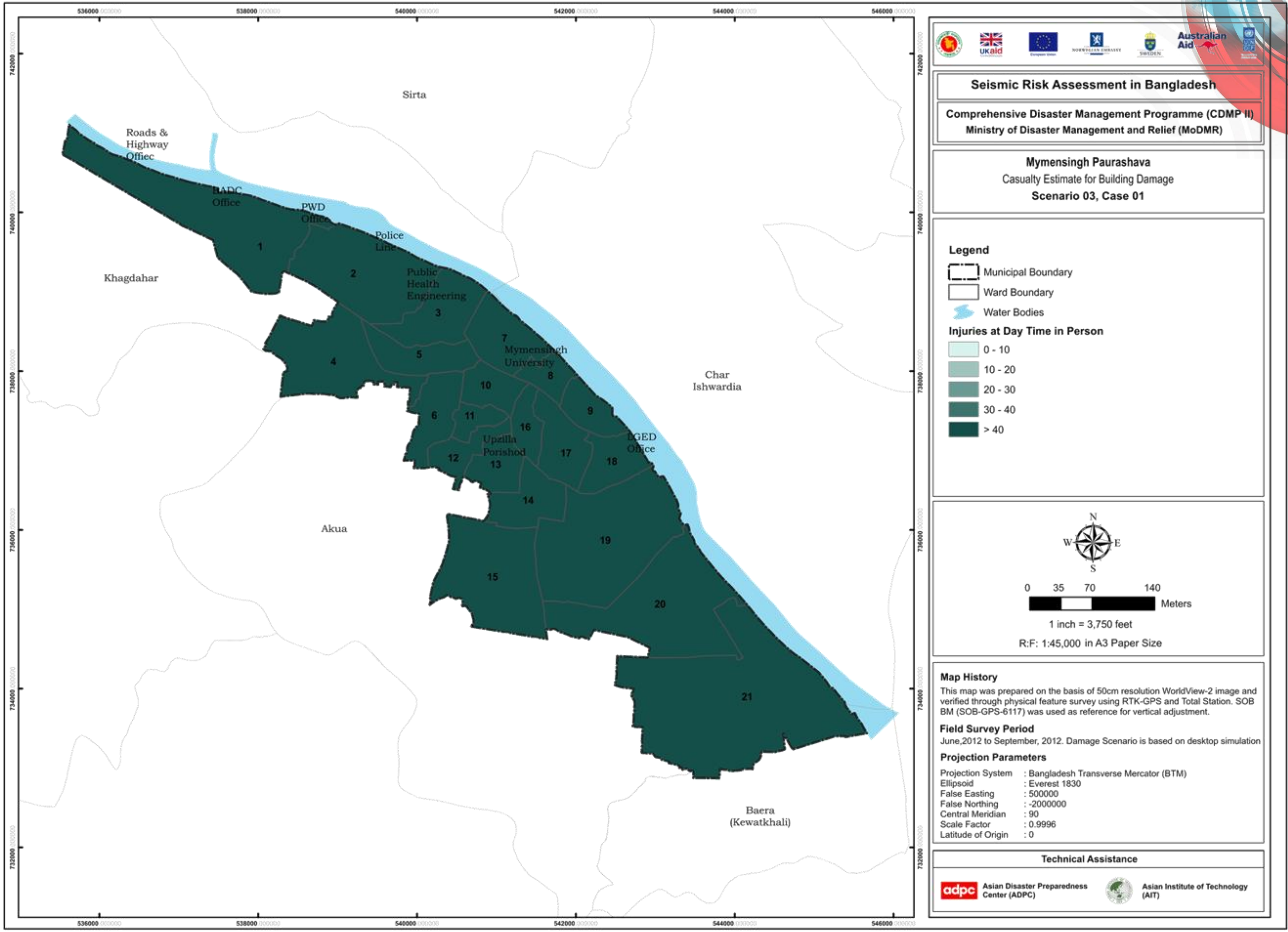

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Casualty Estimate for Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Injuries at Day Time in Person
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
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W
0 35 70 140
Meters
1 inch = 3,750 feet
R.F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-6117) was used as reference for vertical adjustment.
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June,2012 to September, 2012. Damage Scenario is based on desktop simulation
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Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Sirta
Roads & Highway Offiec
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Public Health Engineering
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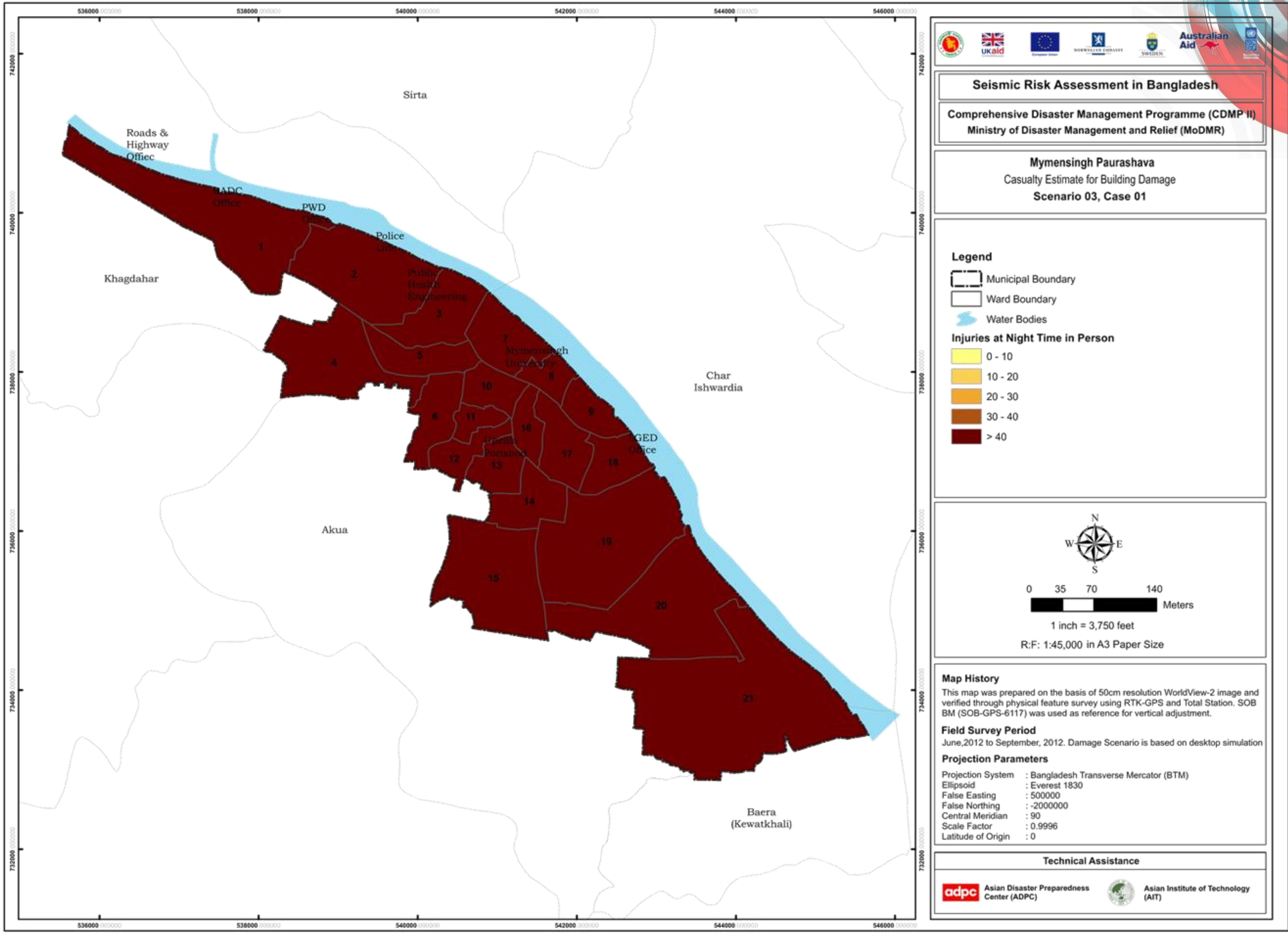
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Casualty Estimate for Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Injuries at Night Time in Person
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
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Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
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Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Sirta
Roads & Highway Offiec
PWD Office
Police Line
Khagdahar
Mymensingh University
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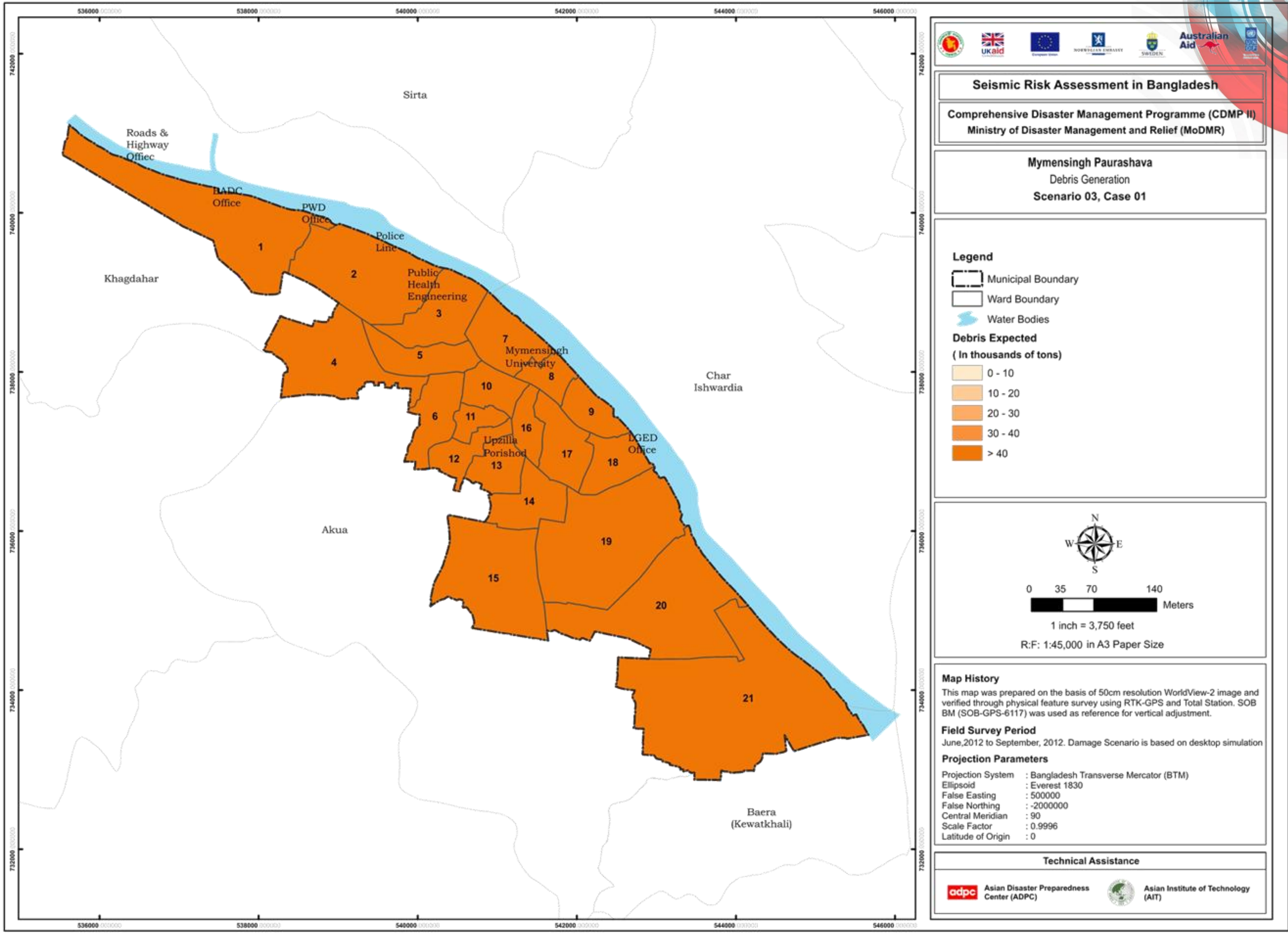
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Debris Generation
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Debris Expected
(In thousands of tons)
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
W
E
S
0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-6117) was used as reference for vertical adjustment.
Field Survey Period
June,2012 to September, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Sirta
Roads & Highway Offiec
BADC Office
PWD Office
Police Line
Public Health Engineering
Khagdahar
Mymensingh University
Char Ishwardia
Upzilla Porishod
LGED Office
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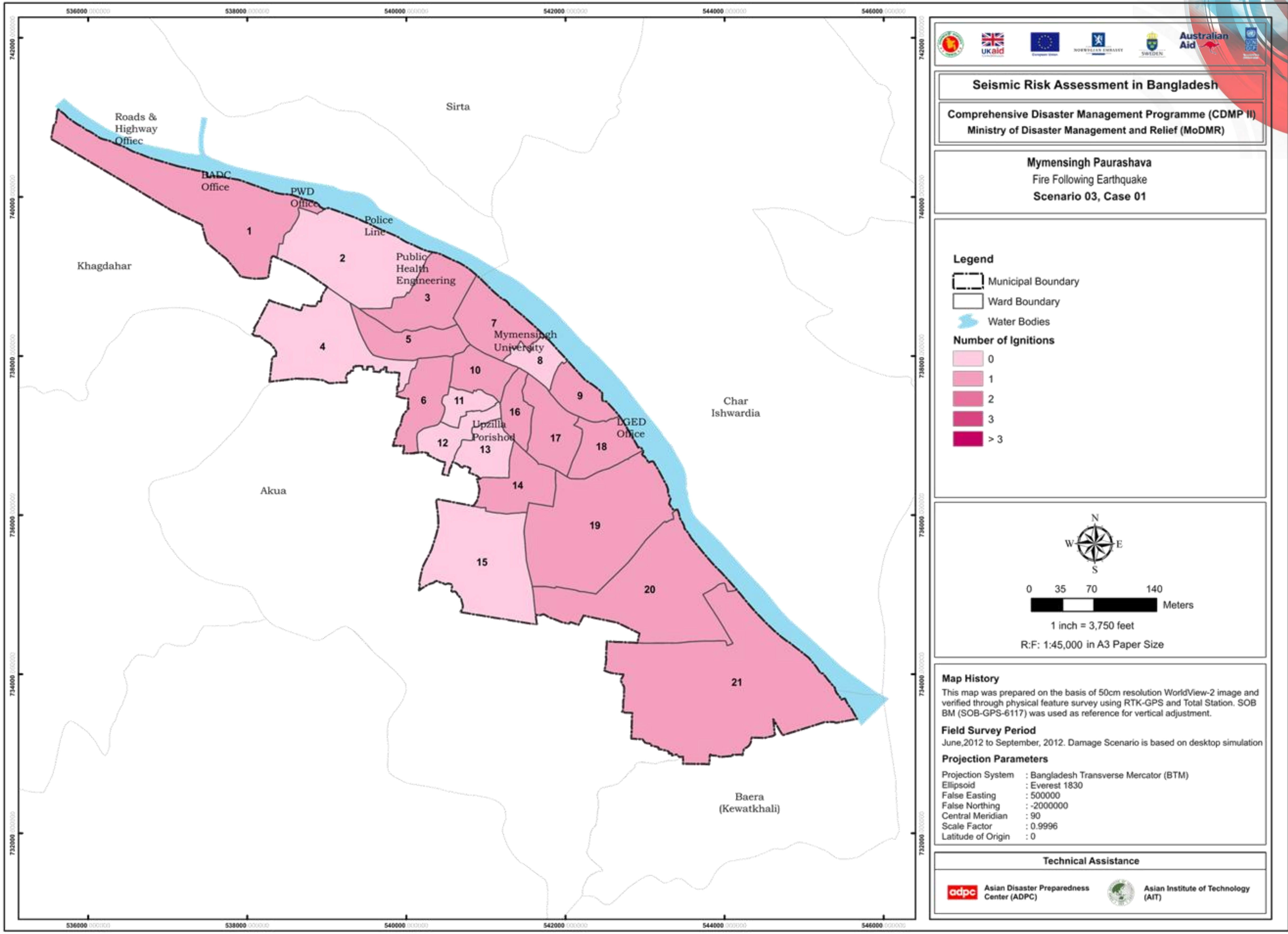

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Fire Following Earthquake
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Number of Ignitions
0
1
2
3
> 3
N
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W
0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-6117) was used as reference for vertical adjustment.
Field Survey Period
June,2012 to September, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Australian Aid
UKaid
Roads & Highway Offiec
BADC Office
PWD Office
Police Line
Public Health Engineering
Mymensingh University
Upzilla Porishod
LGED Office
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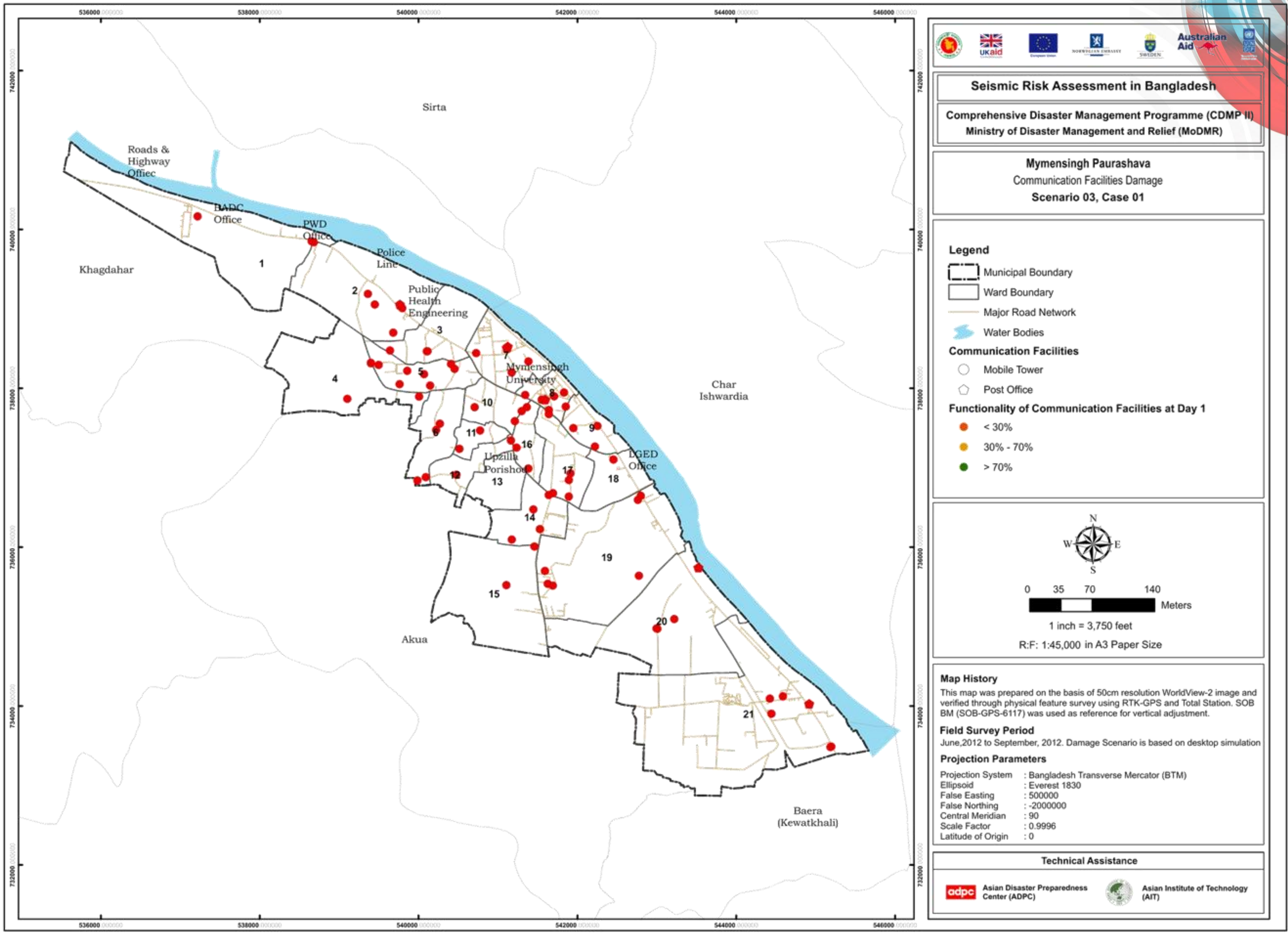
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Communication Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Communication Facilities
Mobile Tower
Post Office
Functionality of Communication Facilities at Day 1
< 30%
30% - 70%
> 70%
N
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0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
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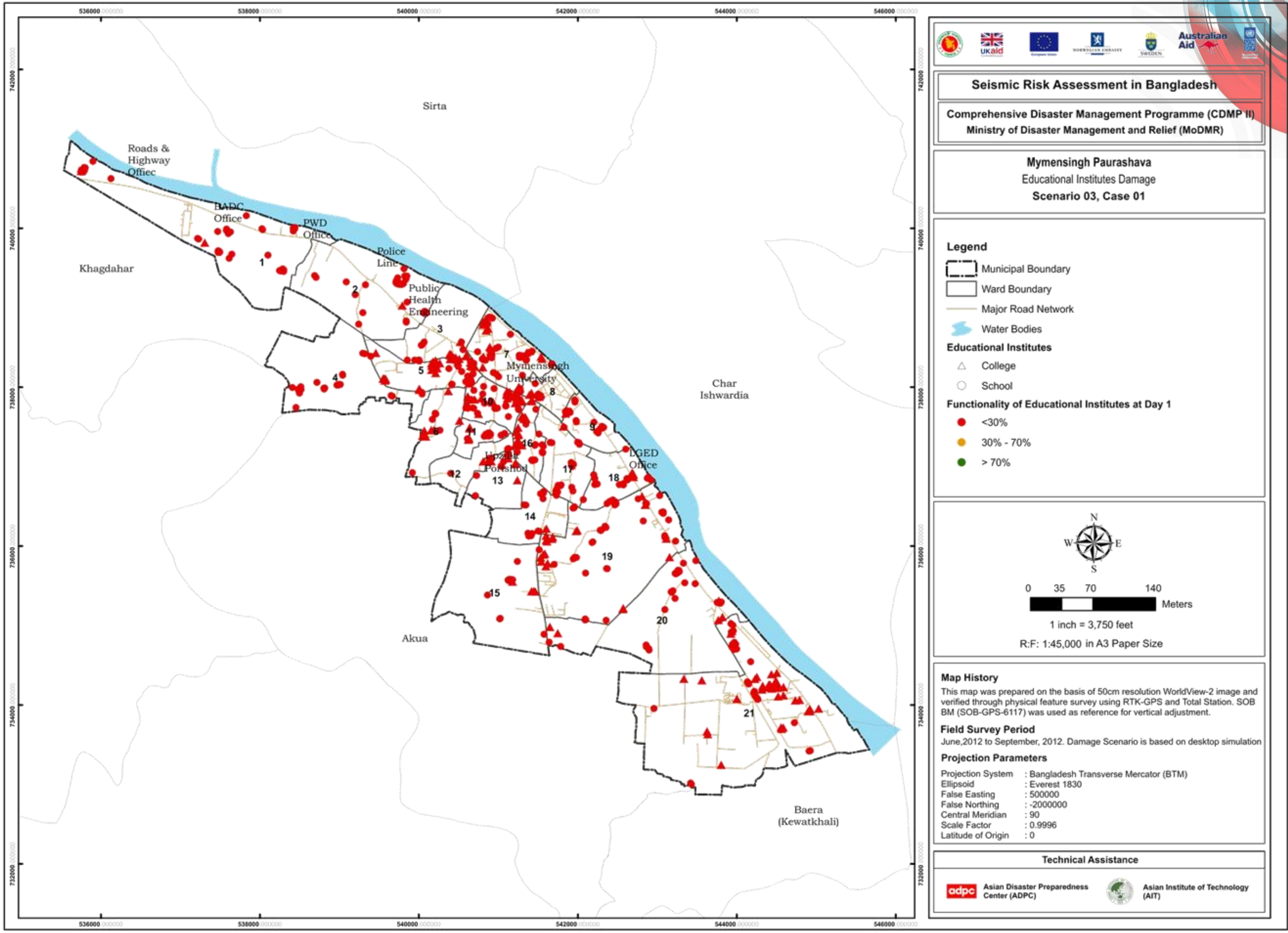
Field Survey Period
June,2012 to September, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Sirta
Roads & Highway Offiec
BADC Office
PWD Office
Police Line
Public Health Engineering
Khagdahar
Mymensingh University
Char Ishwardia
Upzilla Porishod
LGED Office
Akua
Baera (Kewatkhali)



Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Educational Institutes Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Educational Institutes
College
School
Functionality of Educational Institutes at Day 1
<30%
30% - 70%
> 70%
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0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-6117) was used as reference for vertical adjustment.
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Projection System : Bangladesh Transverse Mercator (BTM)
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False Easting : 500000
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Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Sirta
Khagdahar
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Roads & Highway Offiec
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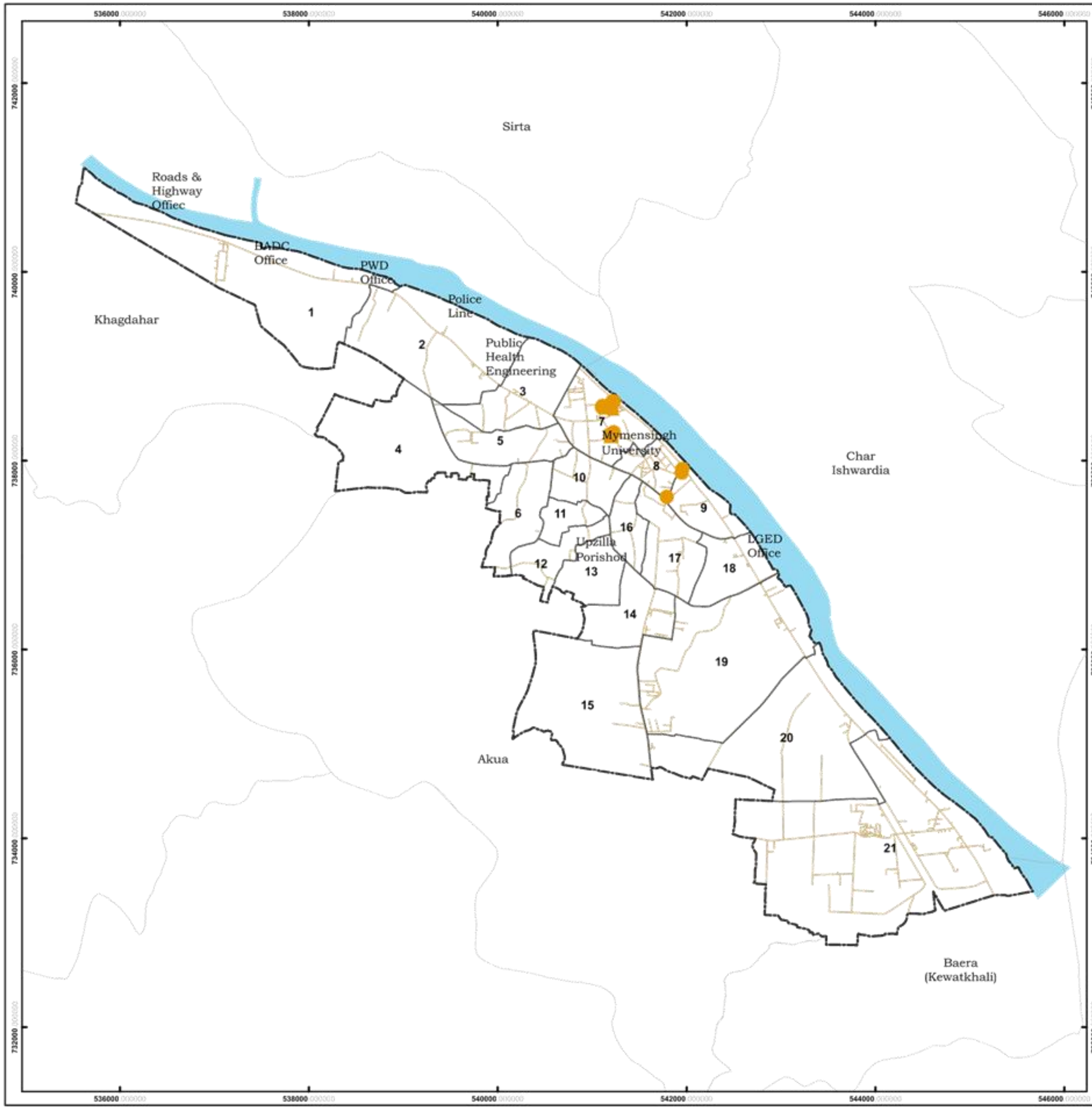

Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Mymensingh Paurashava
Emergency Operation Facilities Damage
Scenario 03, Case 01

Legend

Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies

Name of EOC Facilities

FSCD
Paurashava Office
Police Super Office
Qutoali Model Thana

Functionality of EOC Facilities at Day 1

< 30%
30% - 70%
> 70 %

N
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0 35 70 140 Meters

1 inch = 3,750 feet

R:F: 1:45,000 in A3 Paper Size

Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-6117) was used as reference for vertical adjustment.

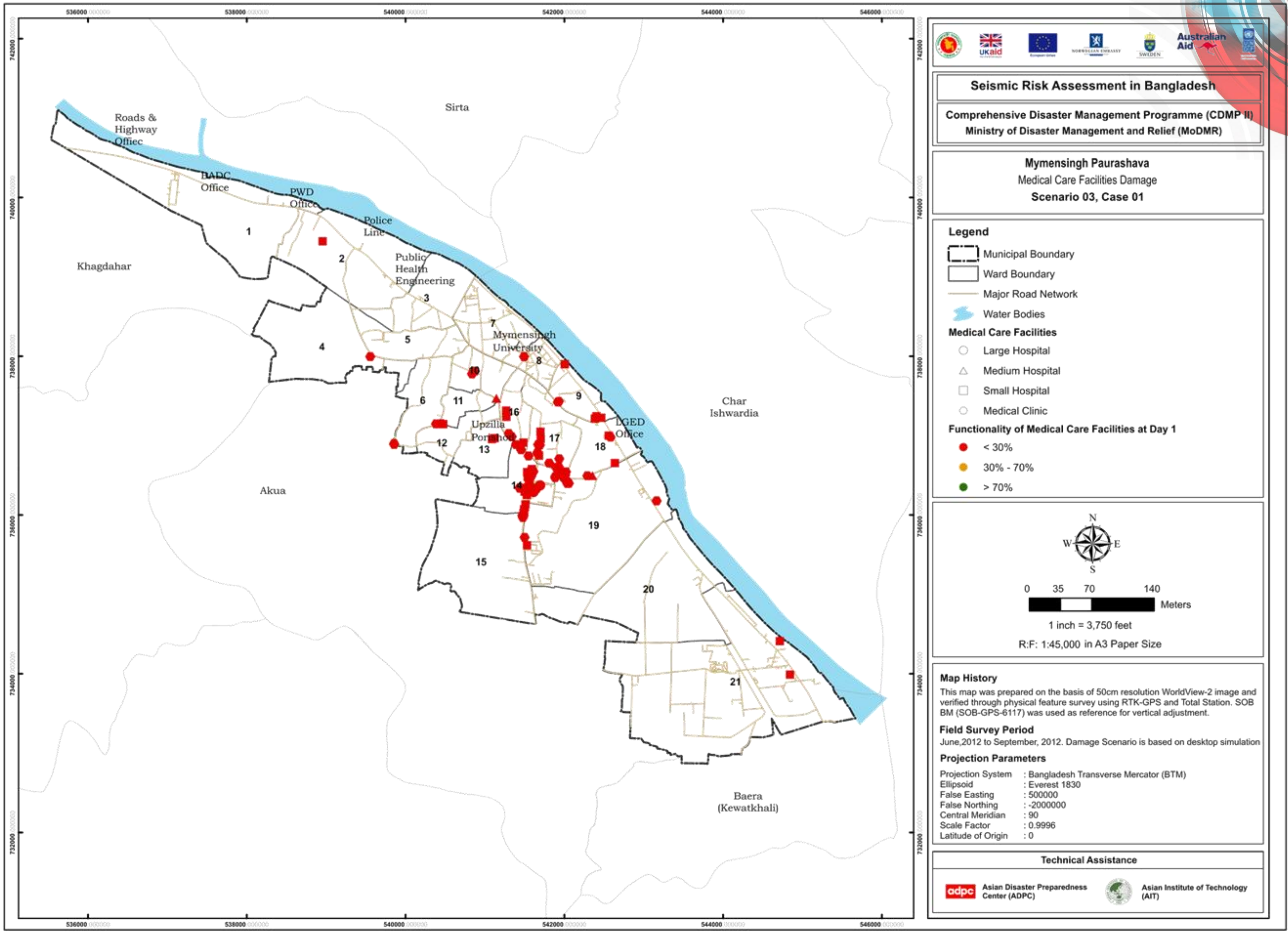
Field Survey Period
June,2012 to September, 2012. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Medical Care Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Medical Care Facilities
Large Hospital
Medium Hospital
Small Hospital
Medical Clinic
Functionality of Medical Care Facilities at Day 1
< 30%
30% - 70%
> 70%
N
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0 35 70 140
Meters
1 inch = 3,750 feet
R.F: 1:45,000 in A3 Paper Size
Map History
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Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Roads & Highway Offiec
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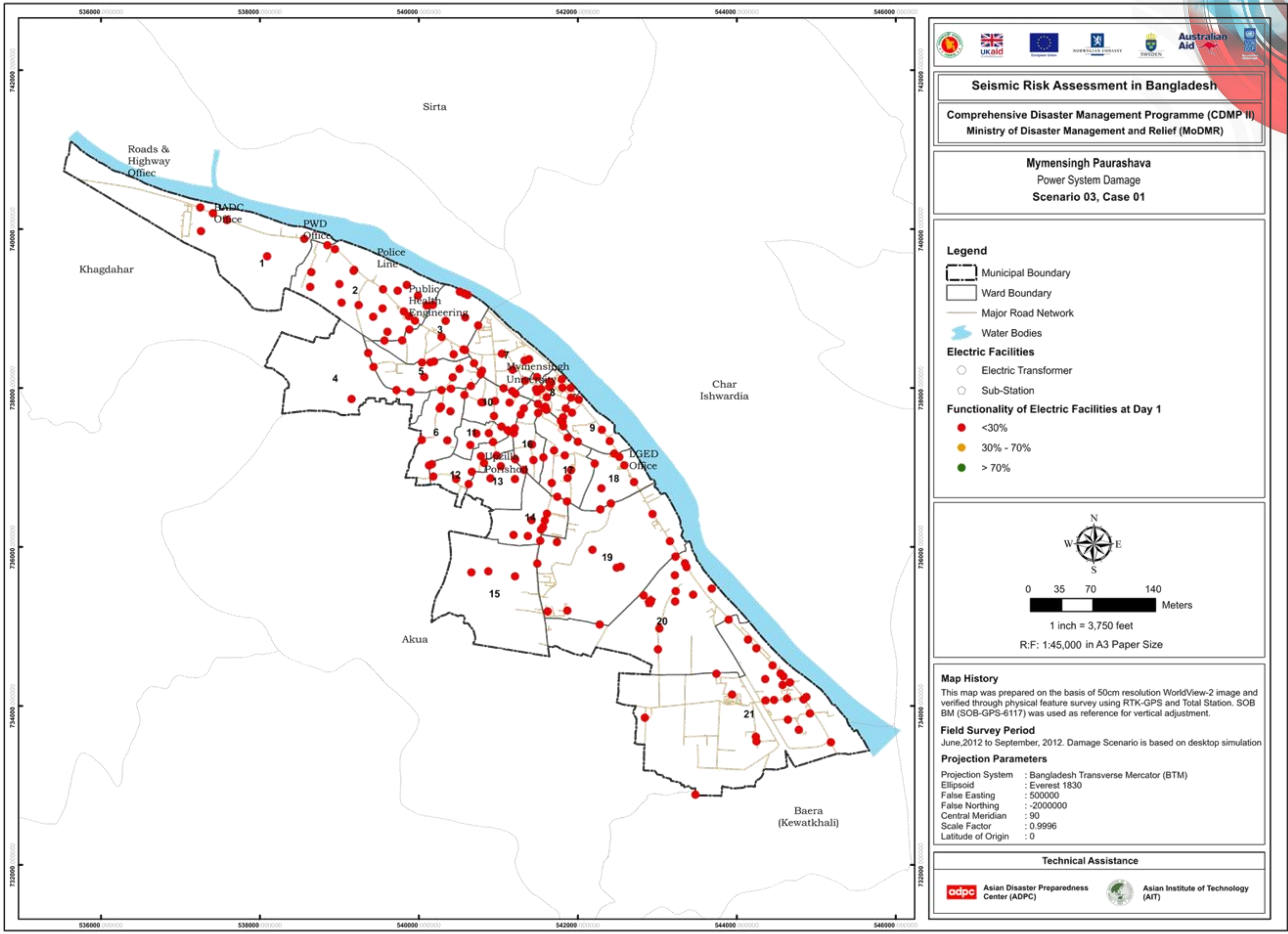
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Power System Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Electric Facilities
Electric Transformer
Sub-Station
Functionality of Electric Facilities at Day 1
<30%
30% - 70%
> 70%
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Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
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Field Survey Period
June,2012 to September, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Australian Aid
UKaid
Sirta
Roads & Highway Offiec
BADC Office
PWD Office
Police Line
Public Health Engineering
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Mymensingh University
Char Ishwardia
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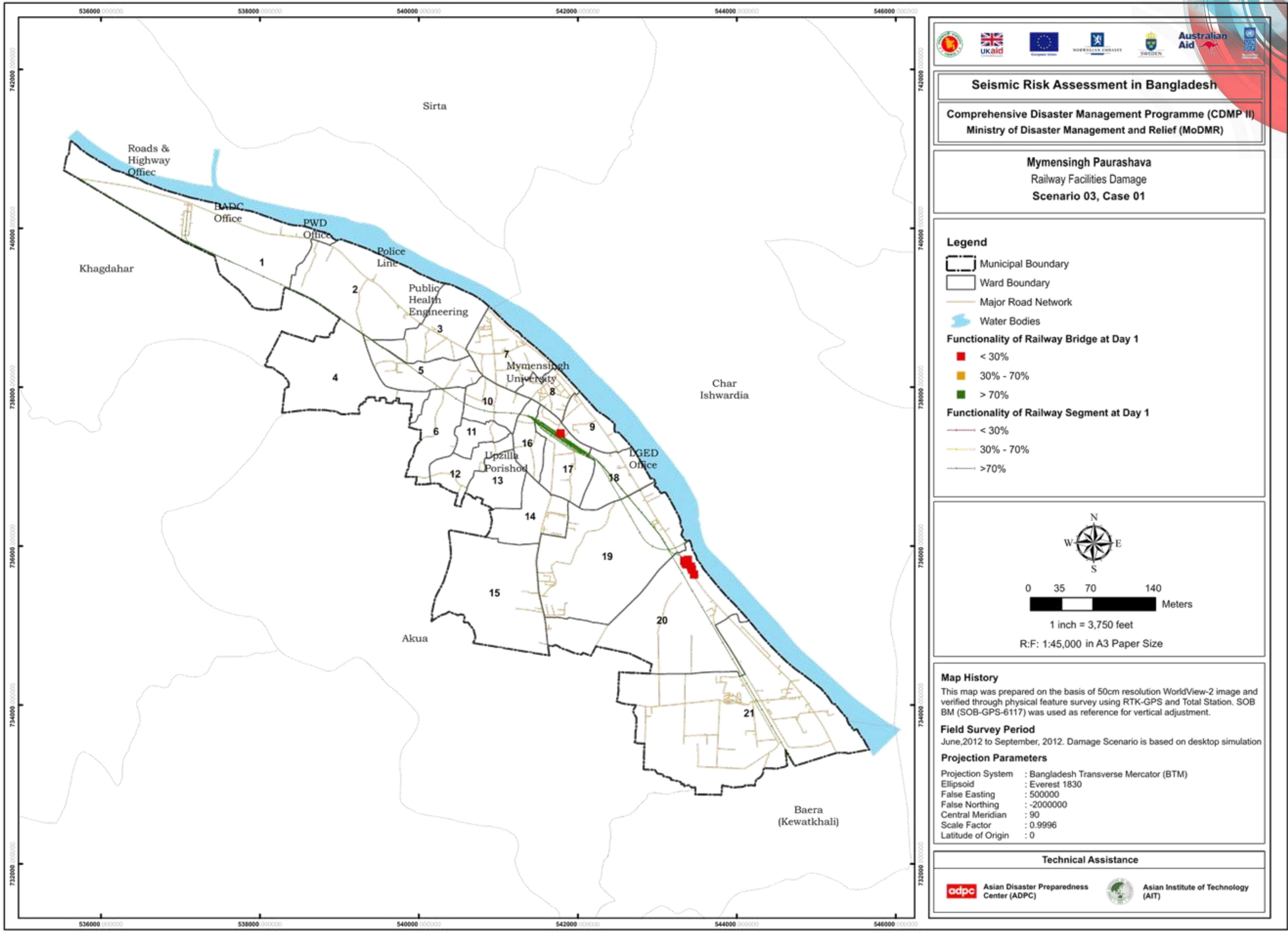
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Railway Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Functionality of Railway Bridge at Day 1
< 30%
30% - 70%
> 70%
Functionality of Railway Segment at Day 1
< 30%
30% - 70%
>70%
N
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0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-6117) was used as reference for vertical adjustment.
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Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
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Sirta
Roads & Highway Offiec
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PWD Office
Police Line
Public Health Engineering
Khagdahar
Mymensingh University
Char Ishwardia
Upzilla Porishod
LGED Office
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Baera (Kewatkhali)
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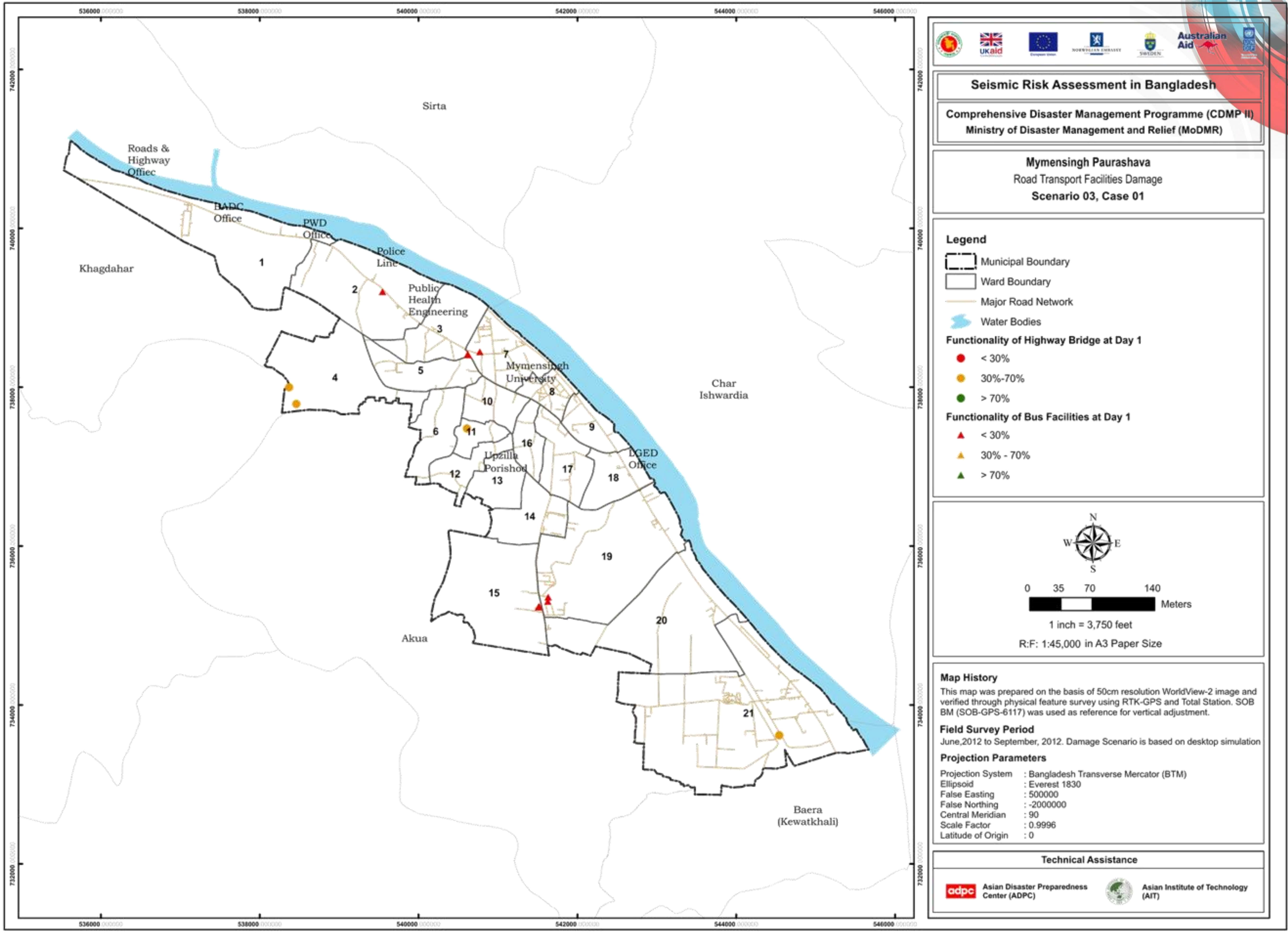
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Road Transport Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Functionality of Highway Bridge at Day 1
< 30%
30%-70%
> 70%
Functionality of Bus Facilities at Day 1
< 30%
30% - 70%
> 70%
N
W
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S
0
35
70
140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-6117) was used as reference for vertical adjustment.
Field Survey Period
June,2012 to September, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Sirta
Roads & Highway Offiec
BADC Office
PWD Office
Police Line
Public Health Engineering
Khagdahar
Mymensingh University
Char Ishwardia
Upzilla Porishod
LGED Office
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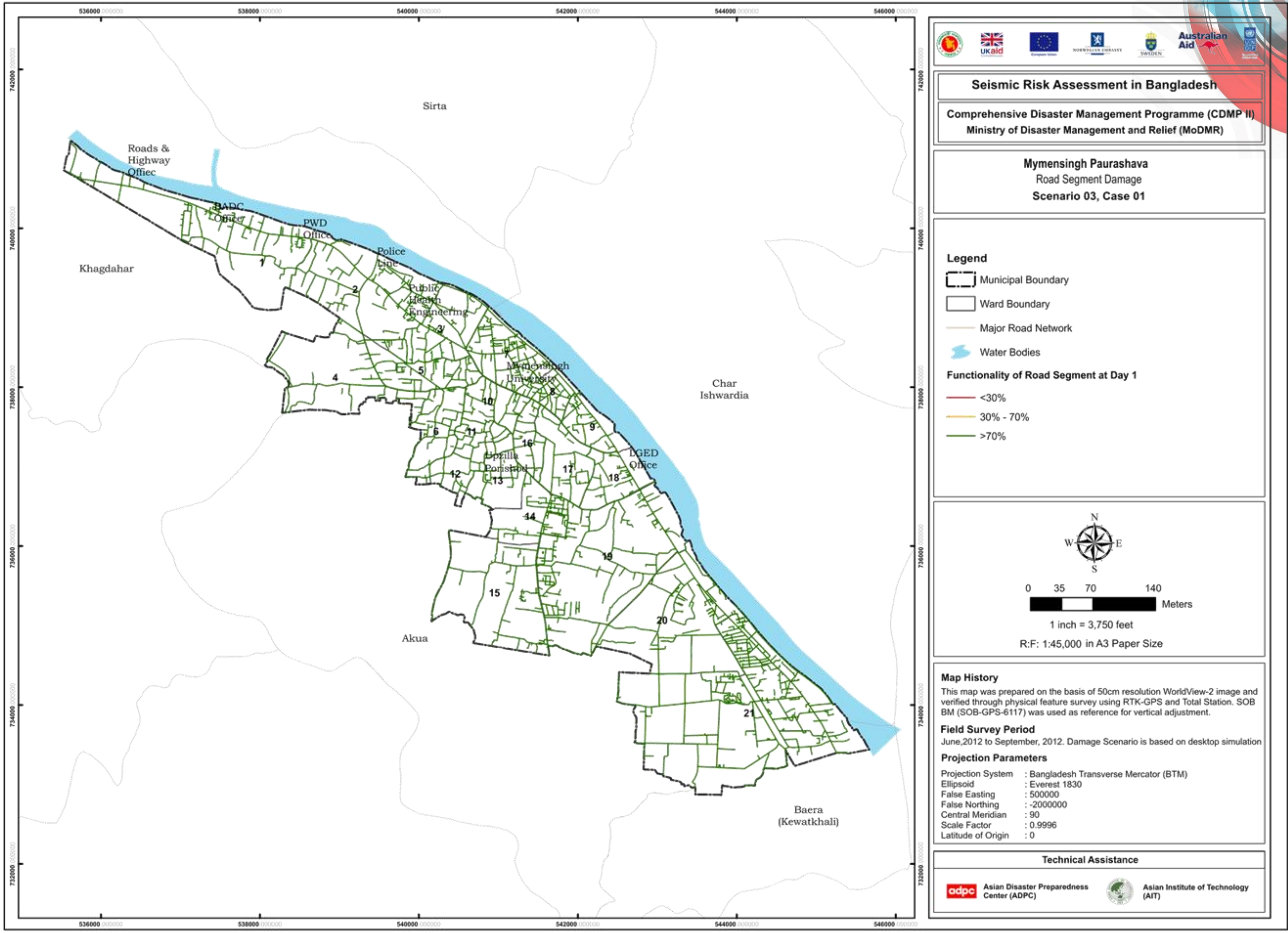
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Road Segment Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Functionality of Road Segment at Day 1
<30%
30% - 70%
>70%
N
W
E
S
0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
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Central Meridian : 90
Scale Factor : 0.9996
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Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Sirta
Roads & Highway Offiec
BADC Office
PWD Office
Police Line
Khagdahar
Public Health Engineering
Mymensingh University
Char Ishwardia
LGED Office
Upzilla Porishod
Akua
Baera (Kewatkhali)
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736000
734000
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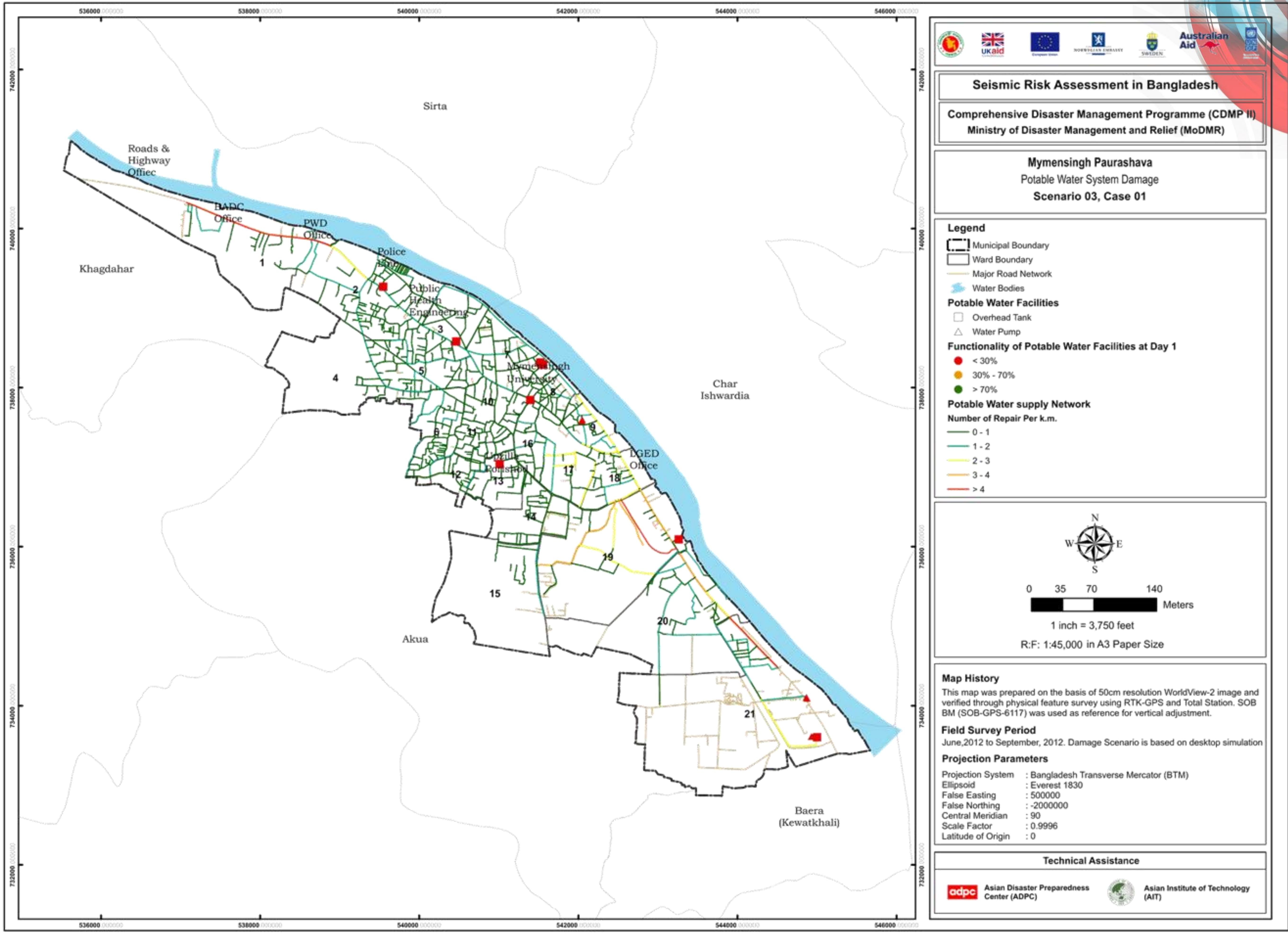
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Mymensingh Paurashava
Potable Water System Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Potable Water Facilities
Overhead Tank
Water Pump
Functionality of Potable Water Facilities at Day 1
< 30%
30% - 70%
> 70%
Potable Water supply Network
Number of Repair Per k.m.
0 - 1
1 - 2
2 - 3
3 - 4
> 4
N
W
E
S
0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
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June,2012 to September, 2012. Damage Scenario is based on desktop simulation
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Scale Factor : 0.9996
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Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Sirta
Roads & Highway Offiec
BADC Office
PWD Office
Police Line
Public Health Engineering
Mymensingh University
LGED Office
Khagdahar
Char Ishwardia
Akua
Baera (Kewatkhali)
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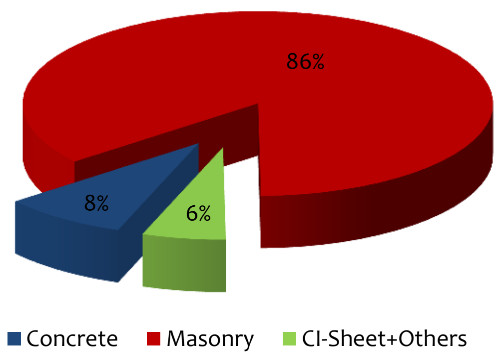
RAJSHAHI CITY CORPORATION

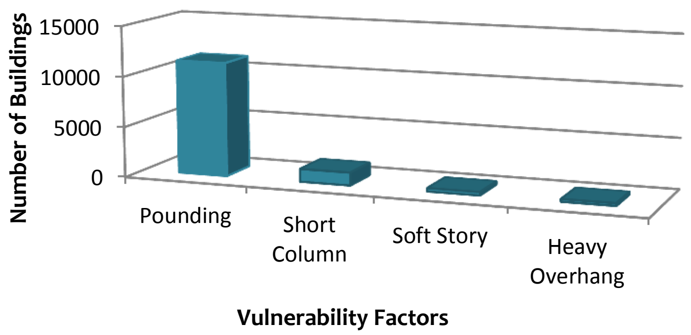
The city of Rajshahi is the divisional headquarter of Rajshahi division. Rajshahi Paurashava, which was one of the first paurashavas in Bangladesh, was established in 1876 as Rajshahi Pourashava, and finally, Rajshahi Pourashava was declared Rajshahi City Corporation in 1991.

The estimated population of the city is around 449756 (BBS, 2011) of which 51.80%% are male and 48.20%% are female. Its total area is 96.69 sq.km (37.33 sq m) and is situated on the northern banks of the river Padma. Rajshahi City Corporation consists of 4 Thanas, 30 Wards and 175 Mahallahs. Besides, the city corporation, Rajshahi Unnayan Kortripokhkho (Rajshahi Development Authority-RDA) is responsible for planning the development of the city and coordinates all development related work.

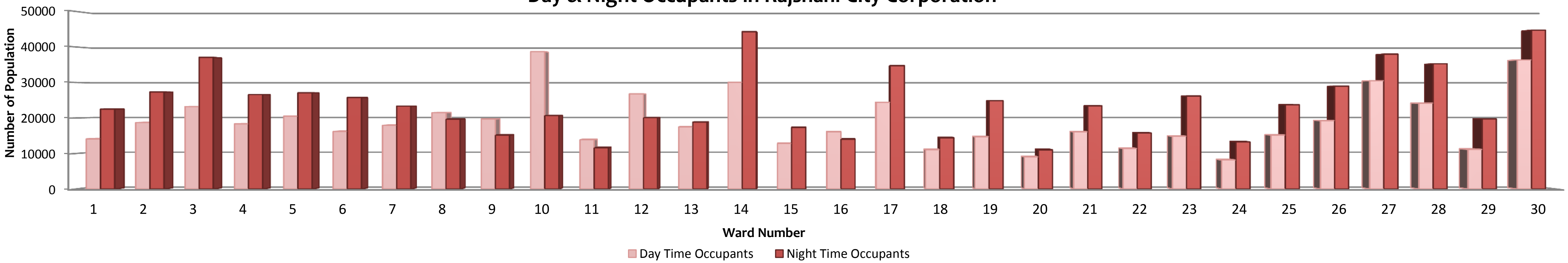
Structural type of Rajshahi City Corporation



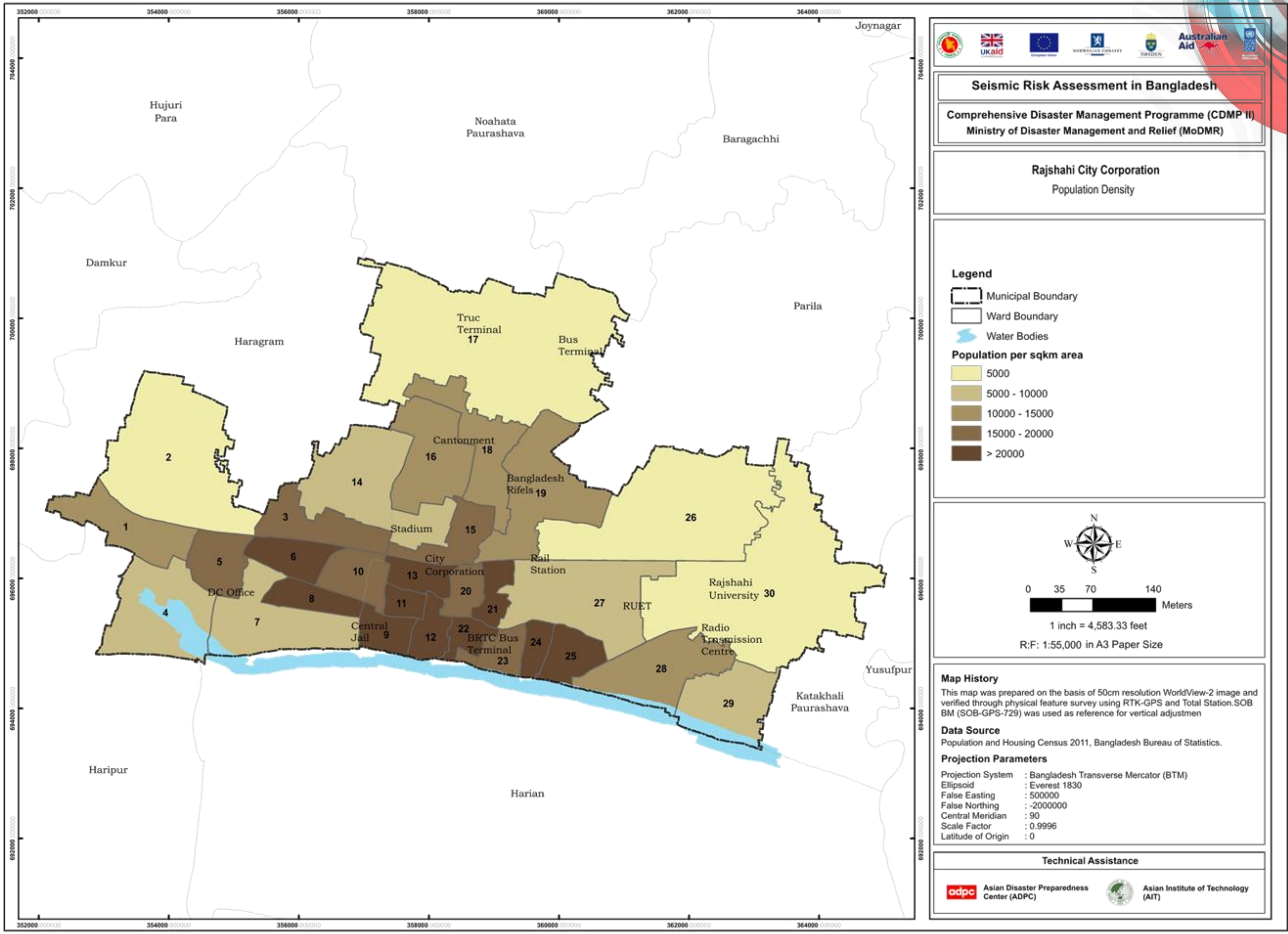
Vulnerability Factors in Rajshahi City Corporation



Day & Night Occupants in Rajshahi City Corporation



Brief Information of the City	
Name of the City	Rajshahi
Name of the Paurashava	Rajshahi City Corporation
Year of Establishment	Rajshahi Paurashava Established in 1876.The Paurashava upgrade to Rajshahi City Corporation in 1991.
Total Area	96.69 sq. km.
Number of Wards	30 Wards
Total Population	449756(Male-232974, Female-216782)
Population Growth Rate (2011)	1.25%
Road Network	500.63 km
Railways	69.59 km
Water Ways	2.66 sq.km or 658.4 acre
Natural Water Bodies	1.65 sq.km or 407 acre
Open Space	421398 sqm or 104.13 acre
Education Institutions	116
Health Facilities	90
Re-fueling Stations	7
Fire Station	1
Police Station:	4



Joynagar
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Haragram
Parila
Truc Terminal 17
Bus Terminal
Cantonment 18
16
14
2
Bangladesh Rifels 19
3
1
Stadium
15
26
5
6
City Corporation
Rail Station
10
13
20
DC Office
8
11
21
27
RUET
Rajshahi University 30
4
7
Central Jail 9
12
22
BRTC Bus Terminal 23
24
25
Radio Trnsmission Centre
28
Yusufpur
29
Katakhali Paurashava
Haripur
Harian
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Population Density
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Population per sqkm area
5000
5000 - 10000
10000 - 15000
15000 - 20000
> 20000
N
W
E
S
0 35 70 140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station.SOB BM (SOB-GPS-729) was used as reference for vertical adjustmen
Data Source
Population and Housing Census 2011, Bangladesh Bureau of Statistics.
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)

Expected physical damage states

Table 17: Expected physical damage states of buildings for different scenario cases

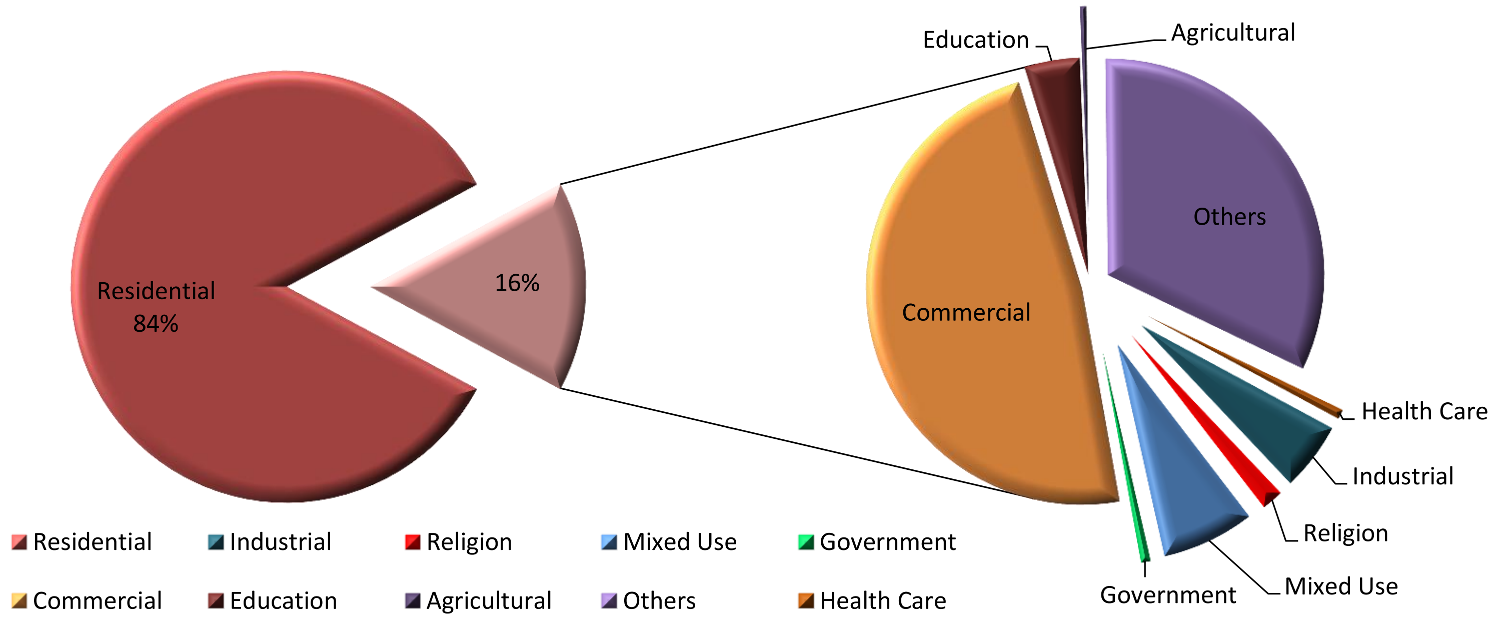
Scenarios	Total Structure	Concrete Structure					Masonry Structure					Tin Shed and Bamboo Structure				
		Total Concrete Structure	Moderate Damage		Complete Damage		Total Masonry Structure	Moderate Damage		Complete Damage		Total Zinc Shed and Bamboo Structure	Moderate Damage		Complete Damage	
			No.	%	No.	%		No.	%	No.	%		No.	%	No.	%
Scenario 1 Case 1	93742	7982	132	1.65%	0	0.00%	80618	1498	1.86%	2	0.00%	5142	68	1.32%	0	0.00%
Scenario 2 Case 2	93742	7982	74	0.93%	0	0.00%	80618	264	0.33%	0	0.00%	5142	9	0.18%	0	0.00%
Scenario 3 Case 1	93742	7982	1505	18.85%	8	0.10%	80618	18915	23.46%	139	0.17%	5142	867	16.86%	6	0.12%
Scenario 4 Case 2	93742	7982	1126	14.11%	32	0.40%	80618	9490	11.77%	583	0.72%	5142	240	4.67%	1	0.02%
Scenario 5 Case 1	93742	7982	3318	41.57%	49	0.61%	80618	36248	44.96%	1108	1.37%	5142	1928	37.50%	18	0.35%
Scenario 6 Case 2	93742	7982	1904	23.85%	688	8.62%	80618	23967	29.73%	15187	18.84%	5142	929	18.07%	7	0.14%

Debris Generation

Table 18: Expected debris generation for different scenario cases

Earthquake Scenario	Amount of Debris (million tons)	% of Concrete and Steel materials	% of Brick and Wood materials
Scenario 1 Case 1	0.020	12%	88%
Scenario 2 Case 2	0.010	10%	90%
Scenario 3 Case 1	0.200	37%	63%
Scenario 4 Case 2	0.200	57%	43%
Scenario 5 Case 1	0.700	56%	44%
Scenario 6 Case 2	1.610	68%	32%

Distribution of Differents Occupancy Classes in Rajshahi City Corporation



Damage of Lifelines

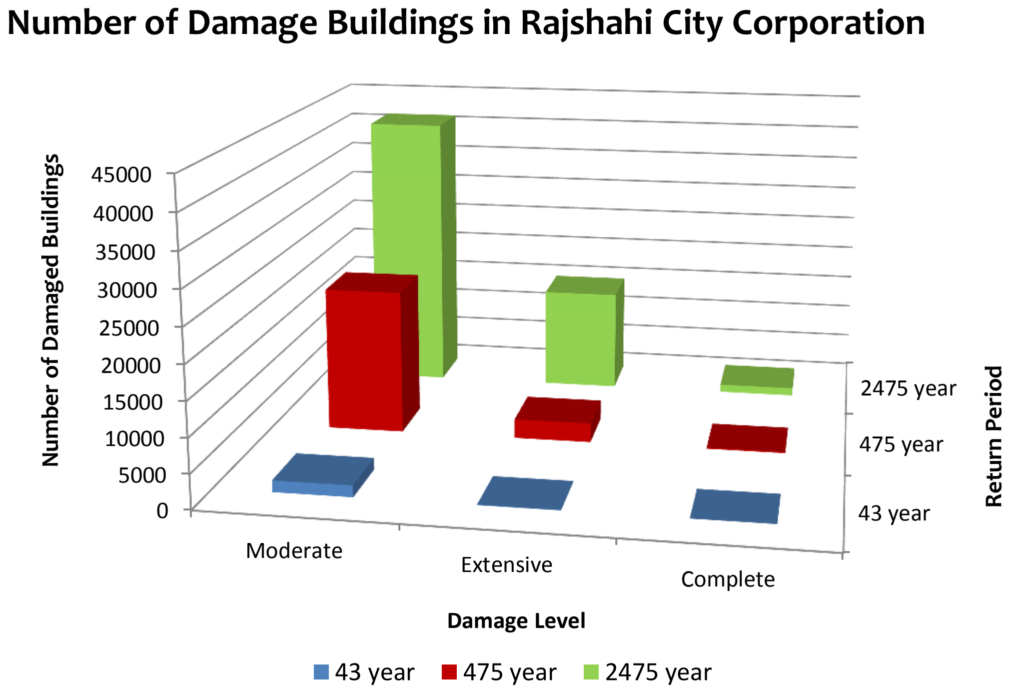
Table 19: Expected damage to lifelines for scenario 3 case 1

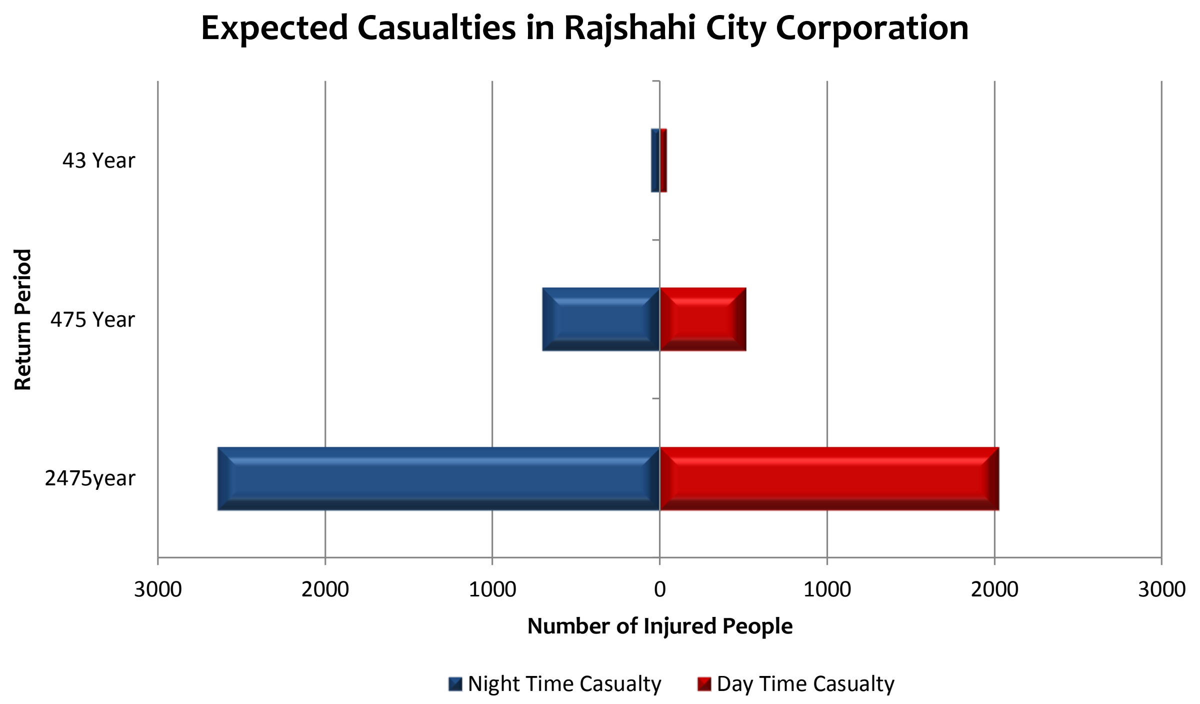
System	Component	Total	Moderate Damage	Complete Damage	At least 50% Functional	
					Day 1	Day 7
Highway	Segments	7819	0	0	7819	7819
	Bridges	1	0	0	1	1
Railway	Segments	57	0	0	57	57
	Facilities	5	0	0	5	5
Bus	Facilities	9	2	0	8	9

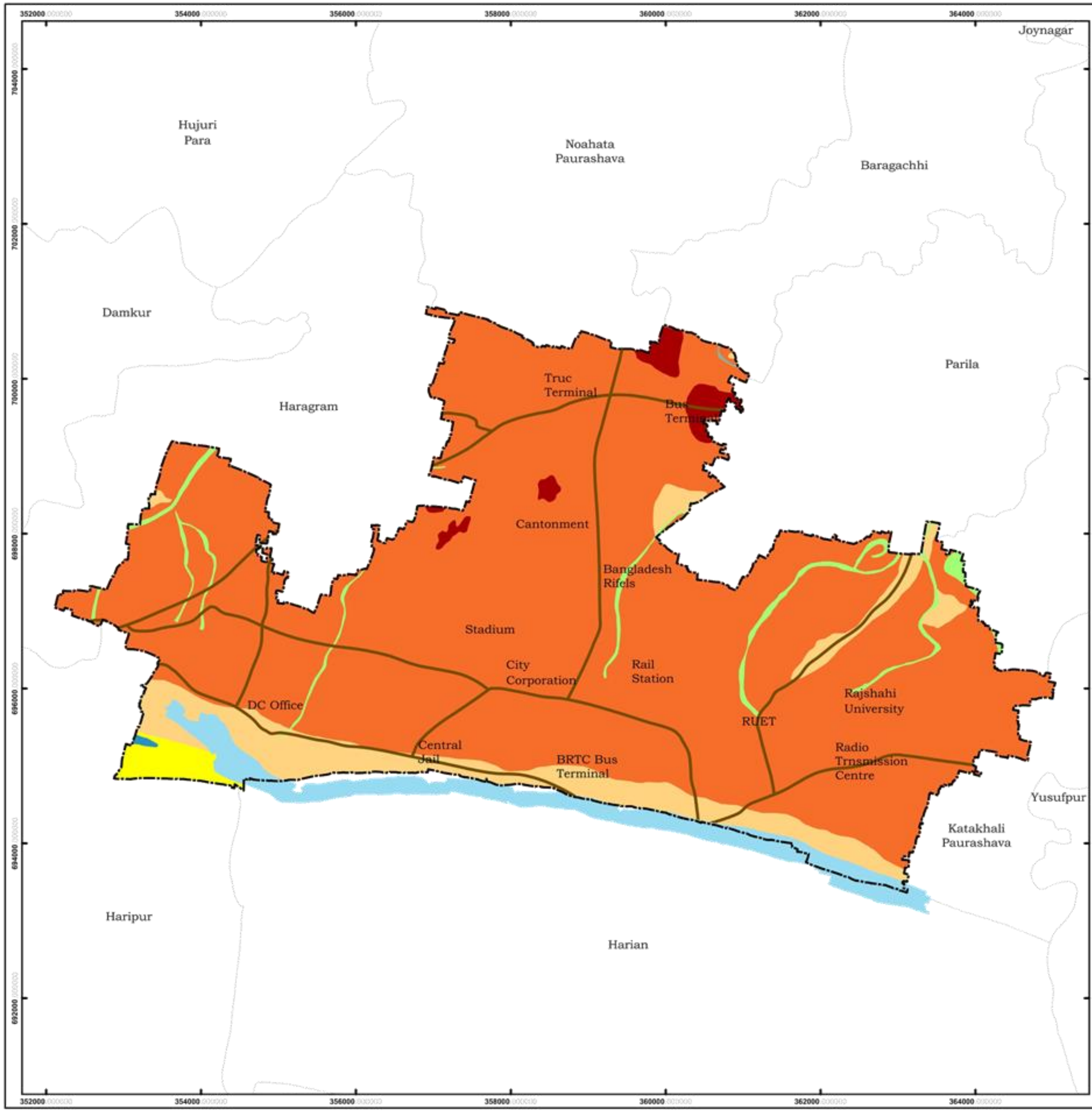
Damage to Utility Systems

Table 20: Expected damage to utility systems for different scenario cases

System	Total Length Pipelines (km)	No. of Leaks						No. of Breaks					
		Scenario 1 Case 1	Scenario 2 Case 2	Scenario 3 Case 1	Scenario 4 Case 2	Scenario 5 Case 1	Scenario 6 Case 2	Scenario 1 Case 1	Scenario 2 Case 2	Scenario 3 Case 1	Scenario 4 Case 2	Scenario 5 Case 1	Scenario 6 Case 2
Potable Water	170	02	02	12	16	32	43	01	01	13	06	30	20







Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rajshahi City Corporation
Geology

Legend

- Municipal Boundary
- Major Road Network
- Active Channel

Ganges Flood Plain Deposits

- Active Channel Deposits
- Intermittent Channel Deposits
- Abandoned Channel Deposits
- Bar Deposits
- Natural Levee Deposits
- Flood Plain Deposits
- Back Swamp Deposits

N W E S

0 35 70 140 Meters

1 inch = 4,583.33 feet

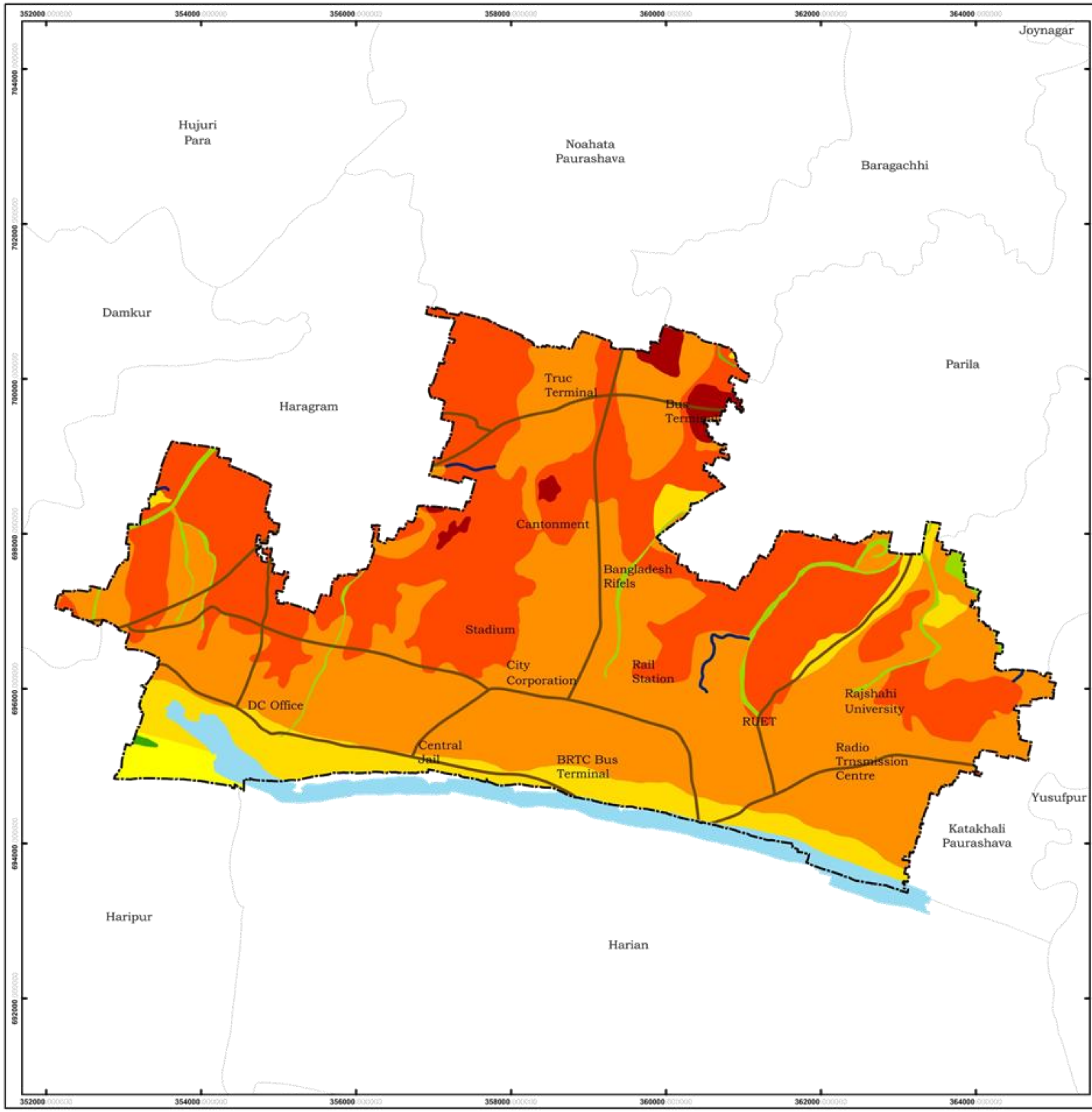
R:F: 1:55,000 in A3 Paper Size

Ganges Flood Plain Deposits	
Active channel deposits	Light grey (10YR 7/1) to grey (10YR 5/1) medium to coarse grained sand with silt
Intermittent channel deposit	Grey (10YR 5/1) to light brownish grey (10YR 6/2) clayey to sandy silt and silty sand
Abandoned Channel deposits	Grey (10YR 5/1) to light brownish grey (10YR 6/2) fine sand to clayey silt
Bar deposits	Light grey (10YR 7/1) to grey (10YR 5/1), medium to coarse sand
Natural leeve deposits	Grey (10YR 5/1) to light brownish grey (10YR 6/2) silty sand and sandy silt
Flood plain deposits	Grey (10YR 5/1), light grey (10YR 7/1) to light brownish grey (10YR 6/2) sandy silt and clay
Back swamp deposits	Grey (10YR 5/1), bluish grey (5B 5/1) to dark grey (10YR 4/1) sticky clay with high organic material

Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0

Technical Assistance

Geological Survey of Bangladesh (GSB)
Asian Disaster Preparedness Center (ADPC)



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rajshahi City Corporation
Geomorphology

Legend

- Municipal Boundary
- Major Road Network
- Active Channel

Ganges Flood Plain

- Active Channel
- Intermittent Channel
- Abandoned Channel
- Lateral Bar
- Natural Levee
- Higher Flood Plain
- Lower Flood Plain
- Back Swamp

N W E S

0 35 70 140 Meters

1 inch = 4,583.33 feet

R:F: 1:55,000 in A3 Paper Size

Ganges Flood Plain	
Active channel	Channel with perennial water flow having medium grained sand with silt as bed loads
Intermittent channel	Channels having ephemeral flow of water having clayey to sandy silt and silty sand
Abandoned channel	Elongated narrow channels without flowing water formed by the cut off from main stream later filled by fine sand to clayey silt
Channel bar	Irregular shaped accumulation of sand within the Padma river deposited by the river flow
Lateral bar	Oval shaped accumulation of sand along the bank of the Padma river deposited by the river flow
Natural levee	Elongated linear accumulation of sediments on either banks of the river consists of silty sand and sandy silt
Higher flood plain	Wide plain land extended from the river above normal flooding consists of sandy silt and clay
Lower flood plain	Plain land within the higher flood plain under normal flooding consists of sandy silt and clay
Back swamp	Irregular shaped depressed areas within the floodplain consist of sticky clay

Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
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False Northing : -2000000
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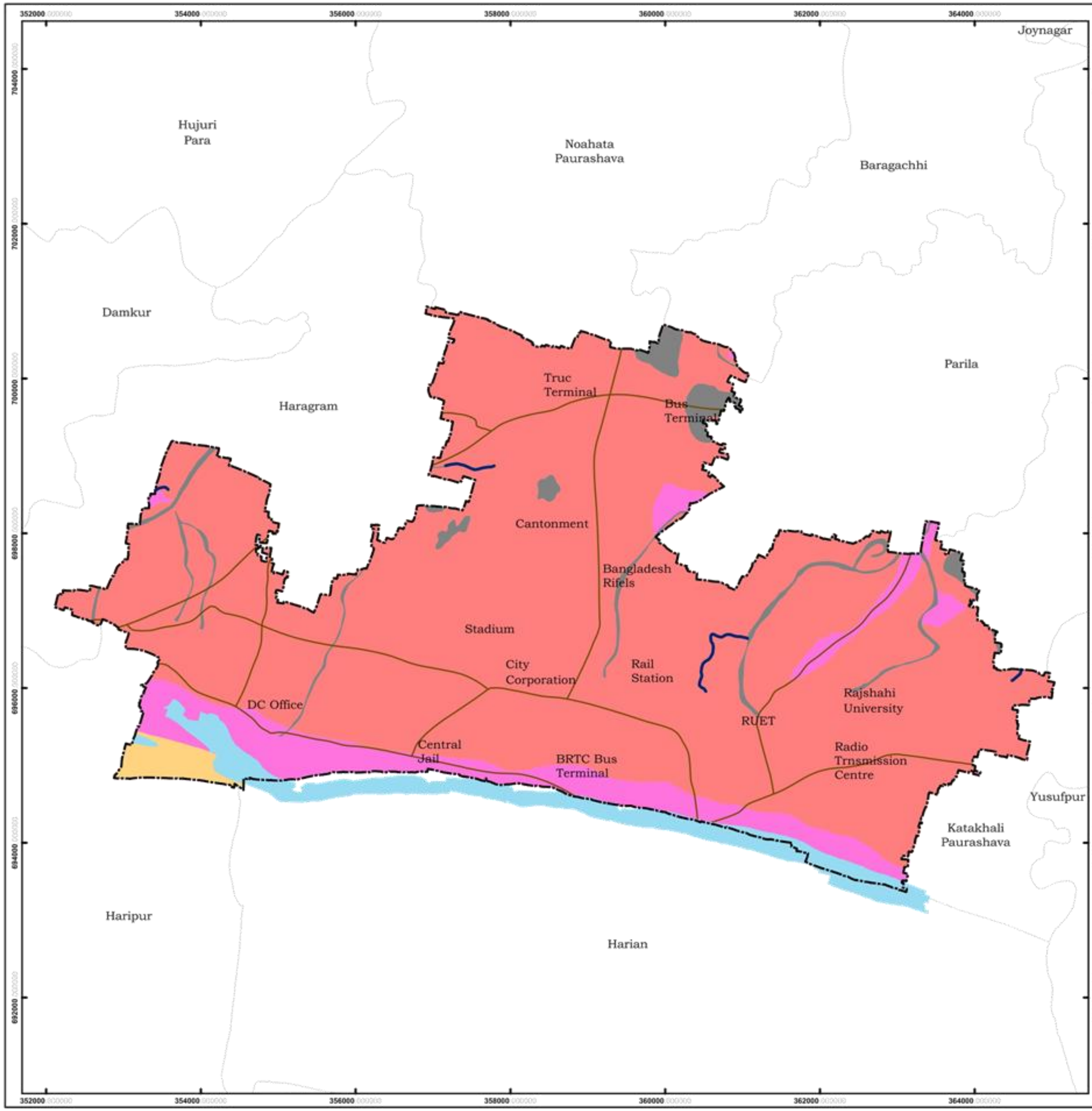
Scale Factor : 0.9996
Latitude of Origin : 0

Technical Assistance

Geological Survey of Bangladesh (GSB)
Asian Disaster Preparedness Center (ADPC)



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rajshahi City Corporation
Engineering Geology

Legend

- Municipal Boundary
- Major Road Network
- Abandoned Channel
- Active Channel

Engineering Unit

- Unit - I
- Unit - II
- Unit - III
- Unit - IV

N W E S

0 35 70 140 Meters

1 inch = 4,583.33 feet

R:F: 1:55,000 in A3 Paper Size

Engineering Properties	
Unit-I	Up to 3m depth mostly composed of medium dense stiff clay (max. N value 12). Within 39m dense fine to medium sand having max. tested N value is 30
Unit-II	Up to 3m depth mostly composed of loose to medium dense sandy silt (max. N value 11) and stiff clayey silt (max. N values 10). Within 30m very dense silty sand having max tested N value is> 50
Unit-III	Up to 3m depth mostly composed of medium to fine very loose to loose sand (max. N value 10). N value increase with depth
Unit-IV	Up to 3m mostly composed of loose silty sand (max. N value 5). Within 30m dense sandy silt having max tested N value is> 50

Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
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False Northing : -2000000
Central Meridian : 90
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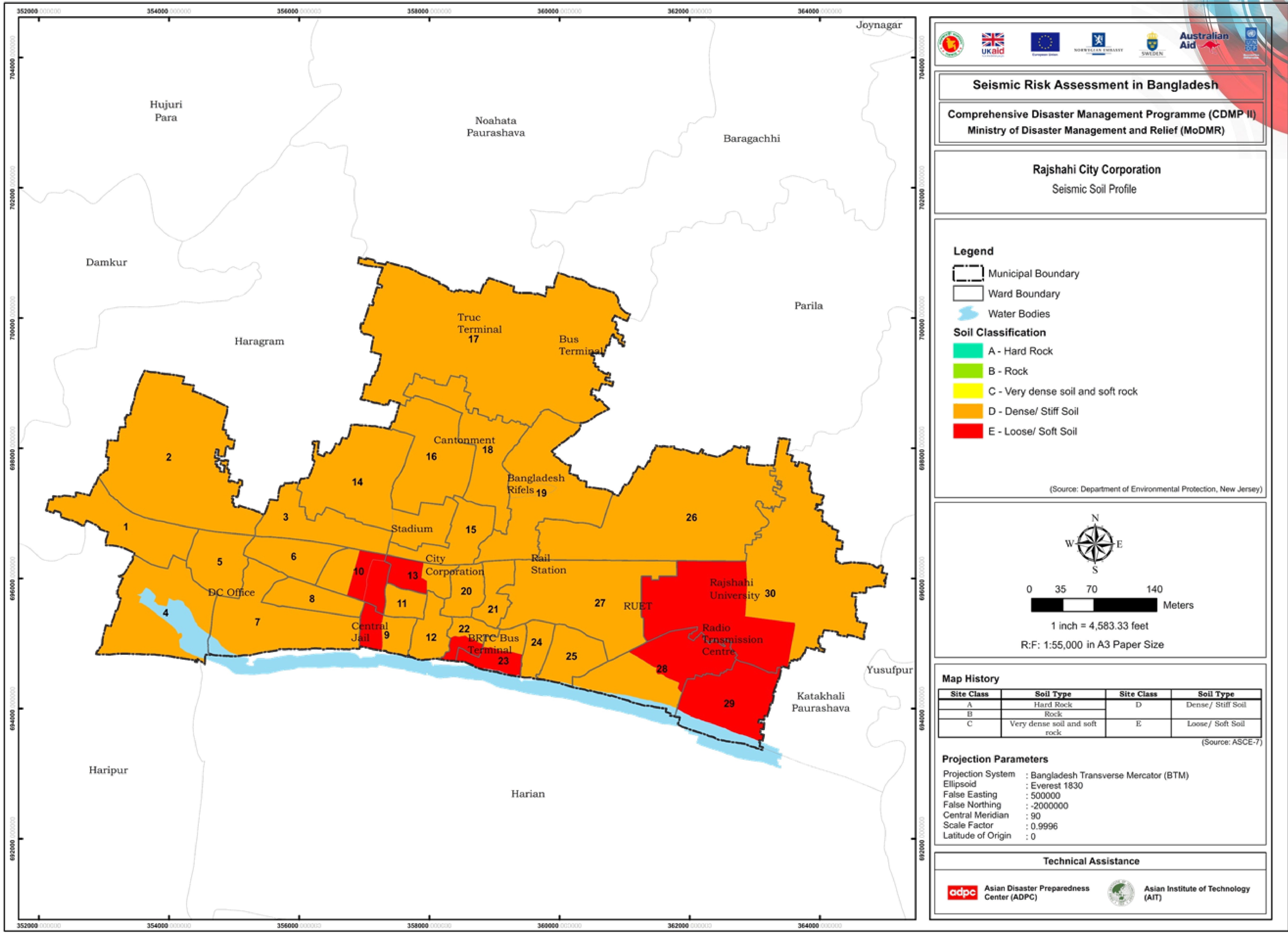
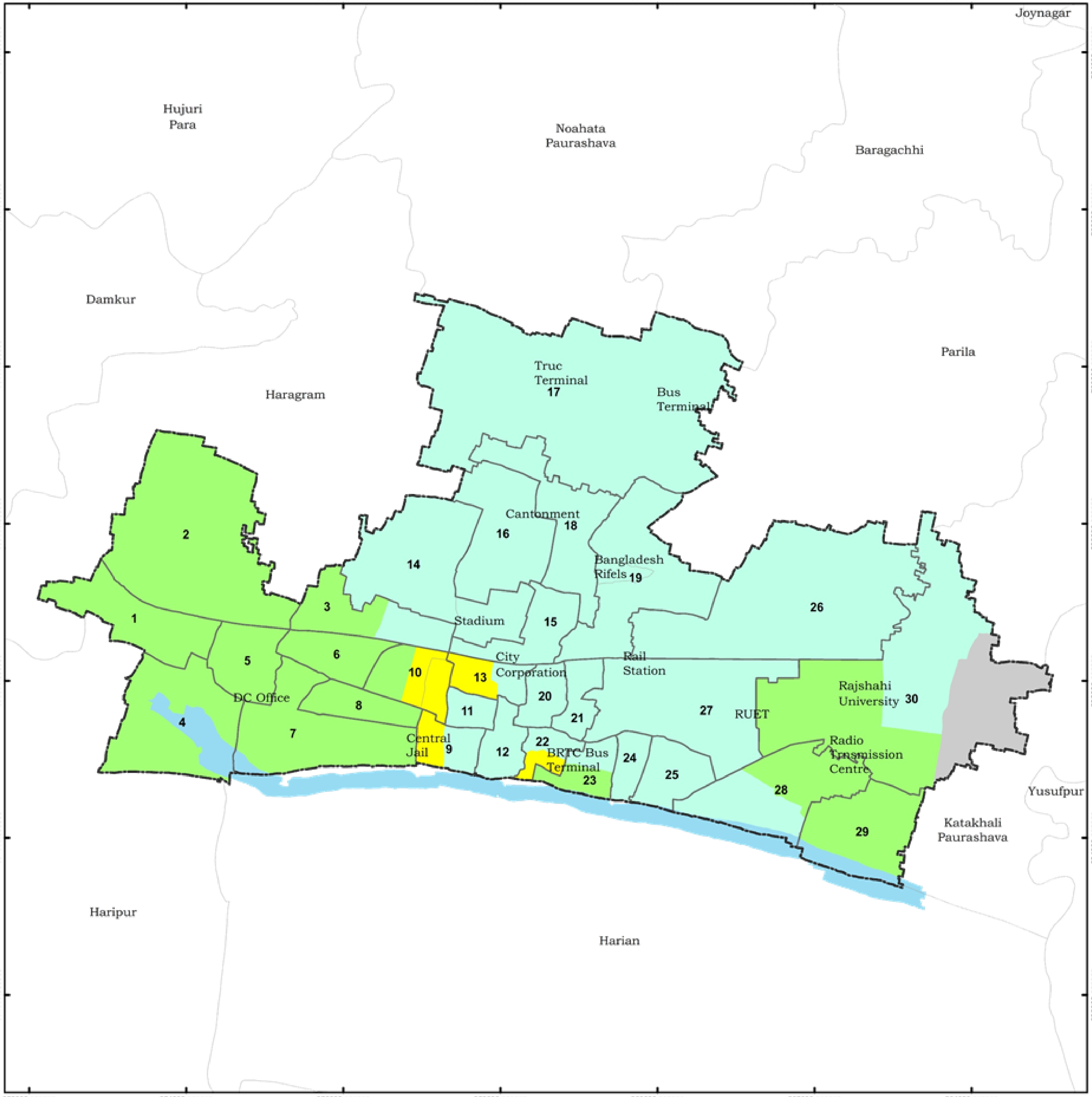
Latitude of Origin : 0

Technical Assistance

Geological Survey of Bangladesh (GSB)
Asian Disaster Preparedness Center (ADPC)



Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Seismic Soil Profile
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Soil Classification
A - Hard Rock
B - Rock
C - Very dense soil and soft rock
D - Dense/ Stiff Soil
E - Loose/ Soft Soil
(Source: Department of Environmental Protection, New Jersey)
N
W
E
S
0 35 70 140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
Map History
Site Class | Soil Type | Site Class | Soil Type
A | Hard Rock | D | Dense/ Stiff Soil
B | Rock
C | Very dense soil and soft rock | E | Loose/ Soft Soil
(Source: ASCE-7)
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Joynagar
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Haragram
Parila
Truc Terminal
Bus Terminal
Cantonment
Bangladesh Rifels
Stadium
City Corporation
Rail Station
DC Office
Central Jail
BRTC Bus Terminal
RUET
Rajshahi University
Radio Transmission Centre
Yusufpur
Katakhali Paurashava
Haripur
Harian



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rajshahi City Corporation
Peak Ground Acceleration - PGA

Legend
- Municipal Boundary
- Ward Boundary
- Water Bodies

PGA (% of Gravity)
- 0.0 - 0.22
- 0.22 - 0.26
- 0.26 - 0.30
- 0.30 - 0.34
- 0.34 - 0.38
- > 0.38

N S W E

0 35 70 140 Meters

1 inch = 4,583.33 feet

R:F: 1:55,000 in A3 Paper Size

Map History
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Field Survey Period
February,2013 to July, 2013. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
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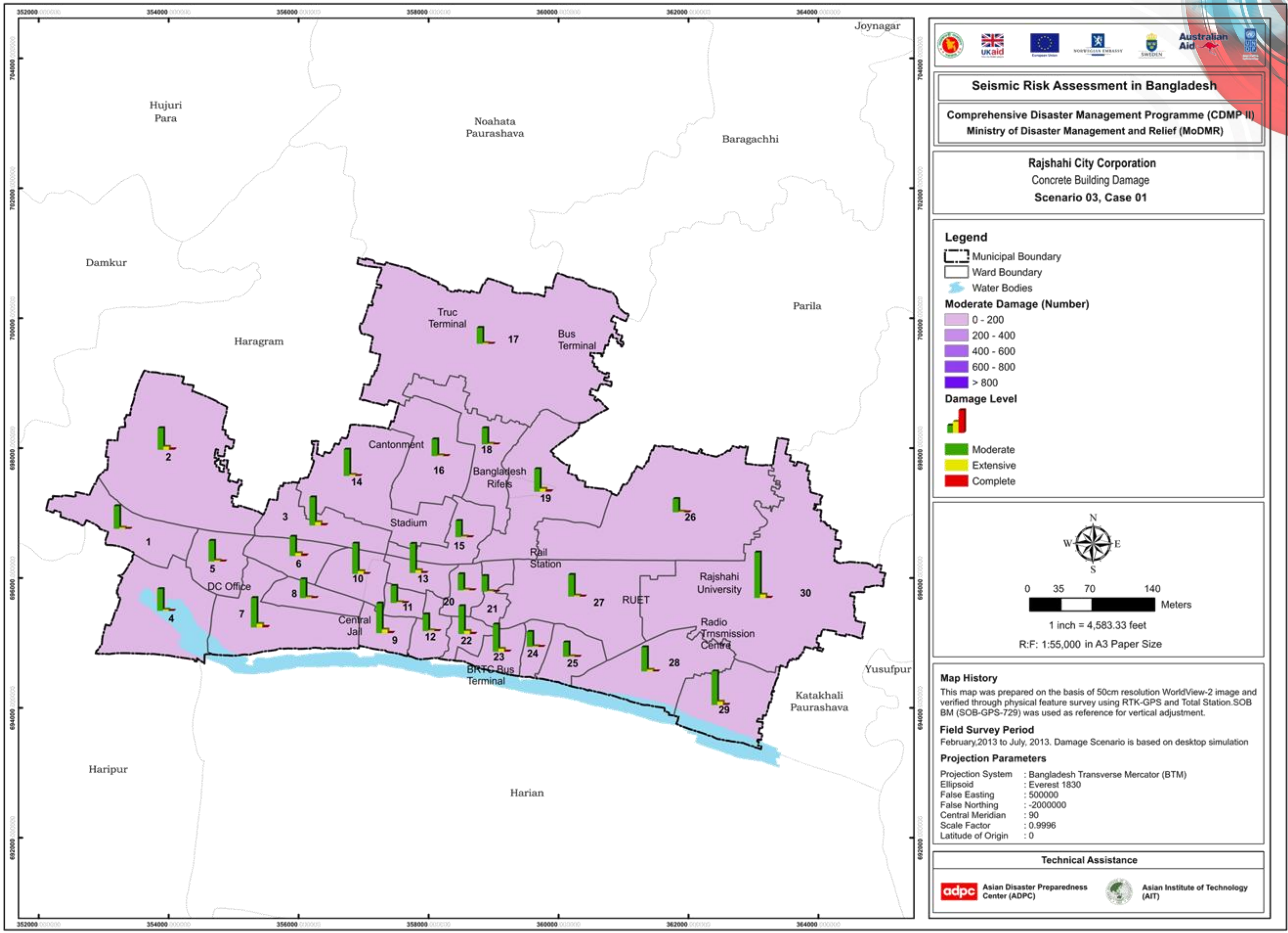
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Concrete Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Moderate Damage (Number)
0 - 200
200 - 400
400 - 600
600 - 800
> 800
Damage Level
Moderate
Extensive
Complete
N
W
E
S
0 35 70 140
Meters
1 inch = 4,583.33 feet
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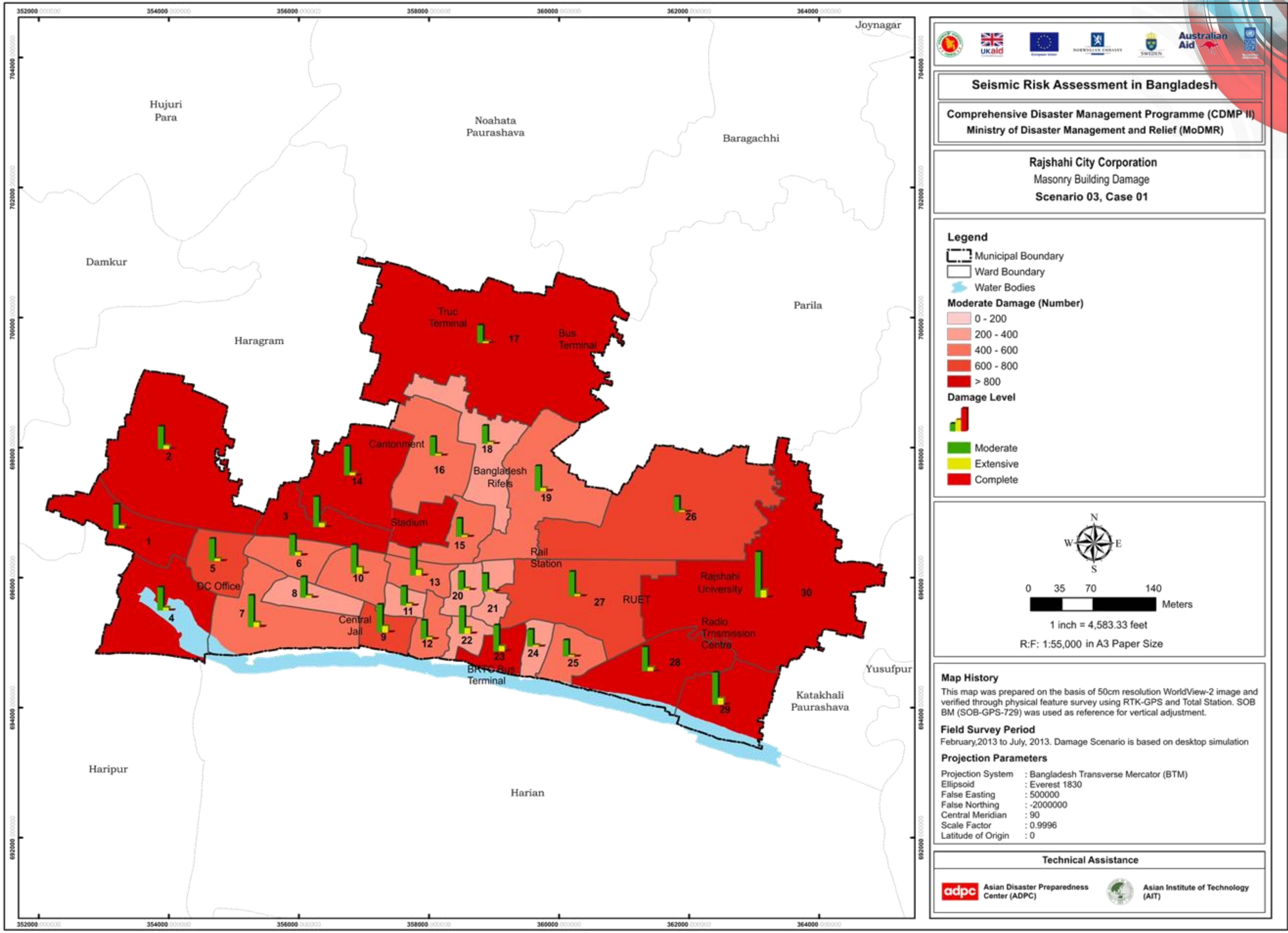
Damkur
Parila
Haragram
Truc Terminal
Bus Terminal
Cantonment
Bangladesh Rifels
Stadium
Rail Station
Rajshahi University
RUET
DC Office
Central Jail
Radio Trnsmission Centre
BRTC Bus Terminal
Yusufpur
Katakhali Paurashava
Haripur
Harian
352000
354000
356000
358000
360000
362000
364000
704000
702000
700000
698000
696000
694000
692000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30



Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Masonry Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Moderate Damage (Number)
0 - 200
200 - 400
400 - 600
600 - 800
> 800
Damage Level
Moderate
Extensive
Complete
N
W
E
S
0
35
70
140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
Map History
This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-729) was used as reference for vertical adjustment.
Field Survey Period
February,2013 to July, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
SWEDEN
Joynagar
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Parila
Haragram
Yusufpur
Katakhali Paurashava
Haripur
Harian
Truc Terminal
Bus Terminal
Cantonment
Bangladesh Rifels
Stadium
Rail Station
Rajshahi University
RUET
DC Office
Central Jail
Radio Trnsmission Centre
BRTC Bus Terminal
352000
354000
356000
358000
360000
362000
364000
704000
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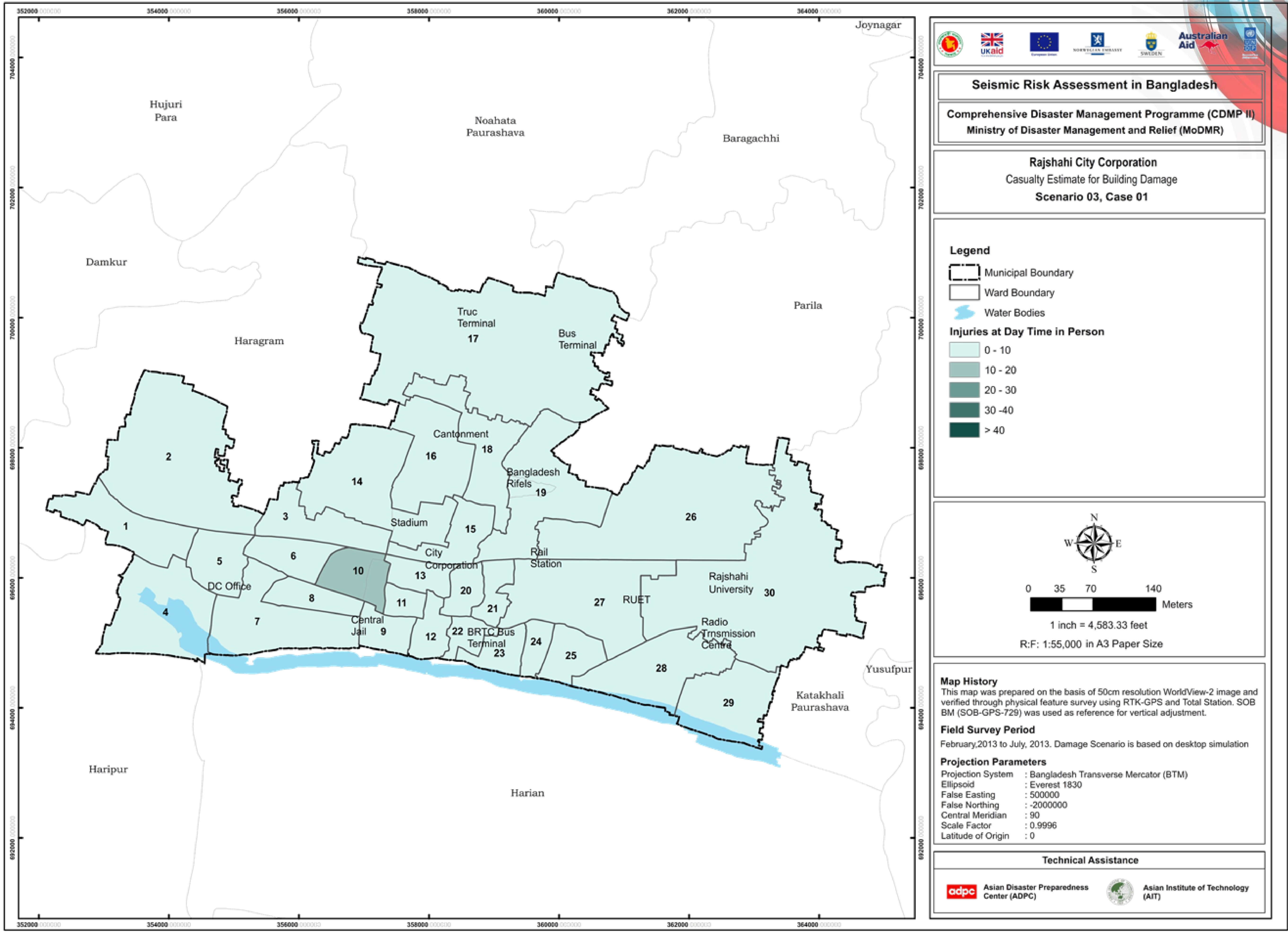
700000
698000
696000
694000
692000



Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Casualty Estimate for Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Injuries at Day Time in Person
0 - 10
10 - 20
20 - 30
30 -40
> 40
N
S
E
W
0 35 70 140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
Map History
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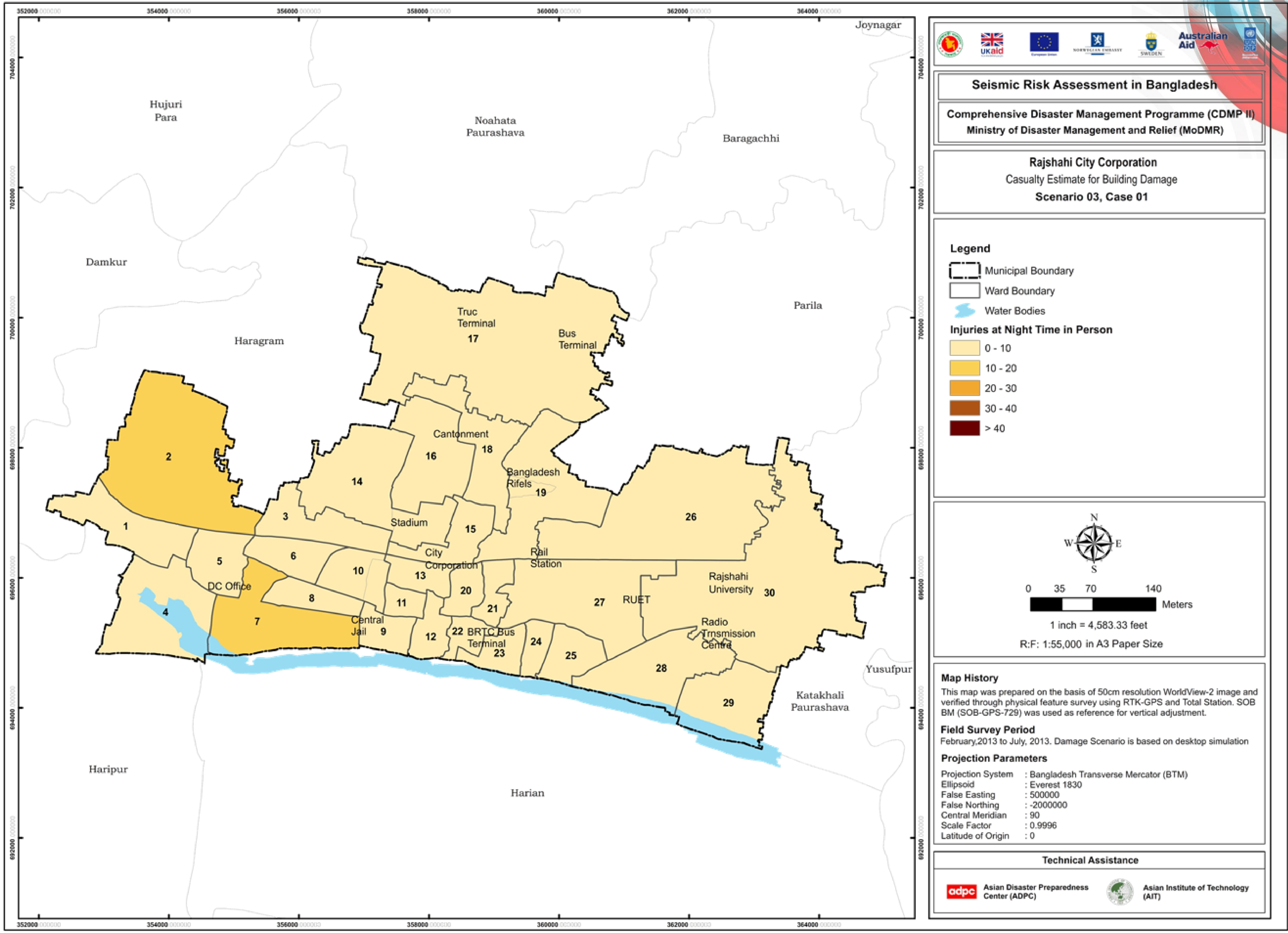
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Joynagar
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Parila
Haragram
Truc Terminal
Bus Terminal
Cantonment
Bangladesh Rifels
Stadium
City Corporation
Rail Station
Rajshahi University
RUET
DC Office
Central Jail
BRTC Bus Terminal
Radio Trnsmission Centre
Yusufpur
Katakhali Paurashava
Haripur
Harian
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
352000 354000 356000 358000 360000 362000 364000
704000 702000 700000 698000 696000 694000 692000


Joynagar
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Parila
Haragram
Truc Terminal
17
Bus Terminal
Cantonment
18
16
14
2
Bangladesh Rifels
19
26
3
Stadium
15
1
5
6
City Corporation
Rail Station
10
13
DC Office
8
20
Rajshahi University
30
4
7
11
21
27
RUET
Central Jail
9
12
22 BRTC Bus Terminal
23
24
25
Radio Trnsmission Centre
28
29
Yusufpur
Katakhali Paurashava
Haripur
Harian
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Casualty Estimate for Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Injuries at Night Time in Person
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
W
E
S
0 35 70 140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
Map History
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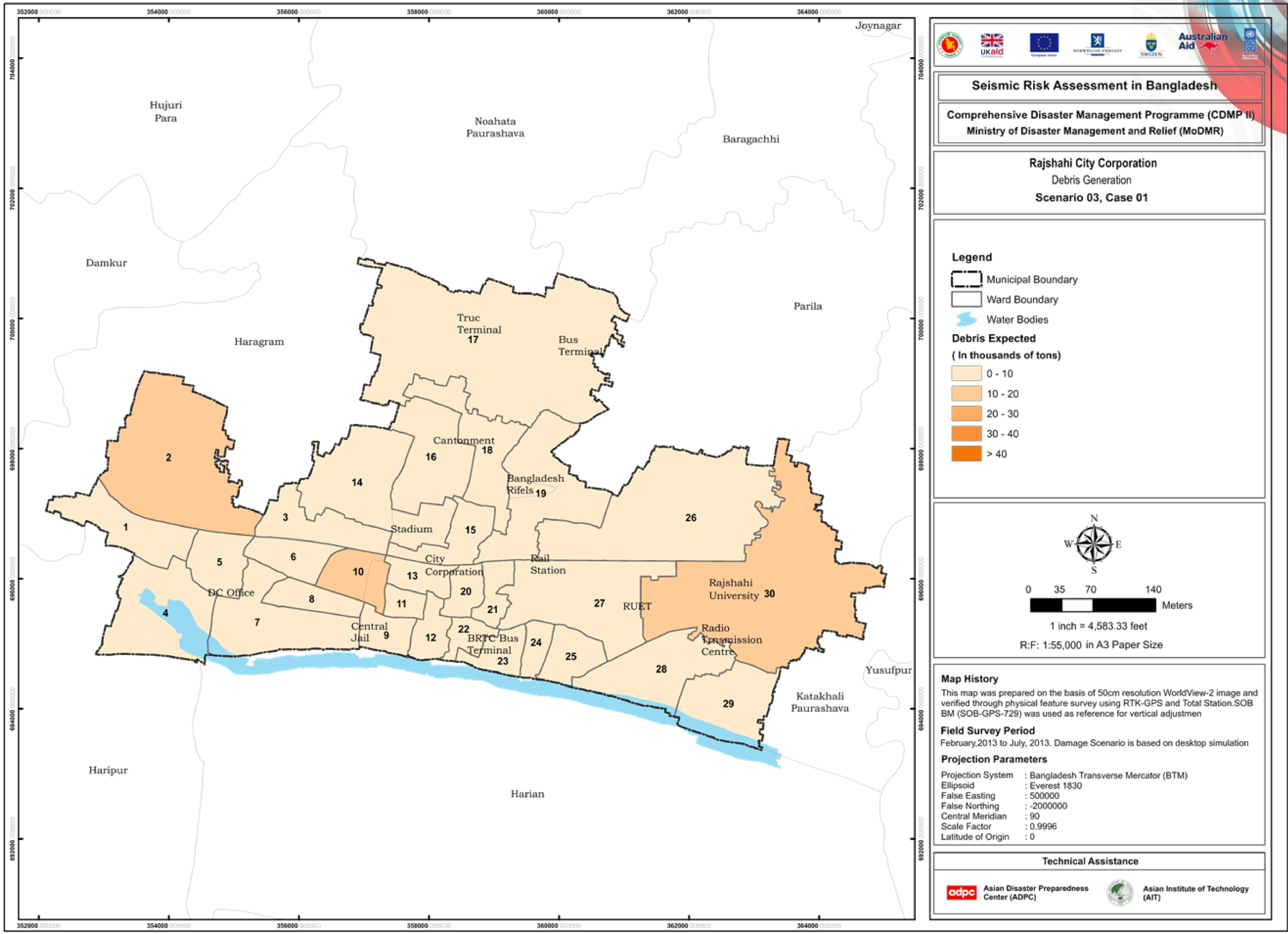
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Debris Generation
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Debris Expected
(In thousands of tons)
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
W
E
S
0 35 70 140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
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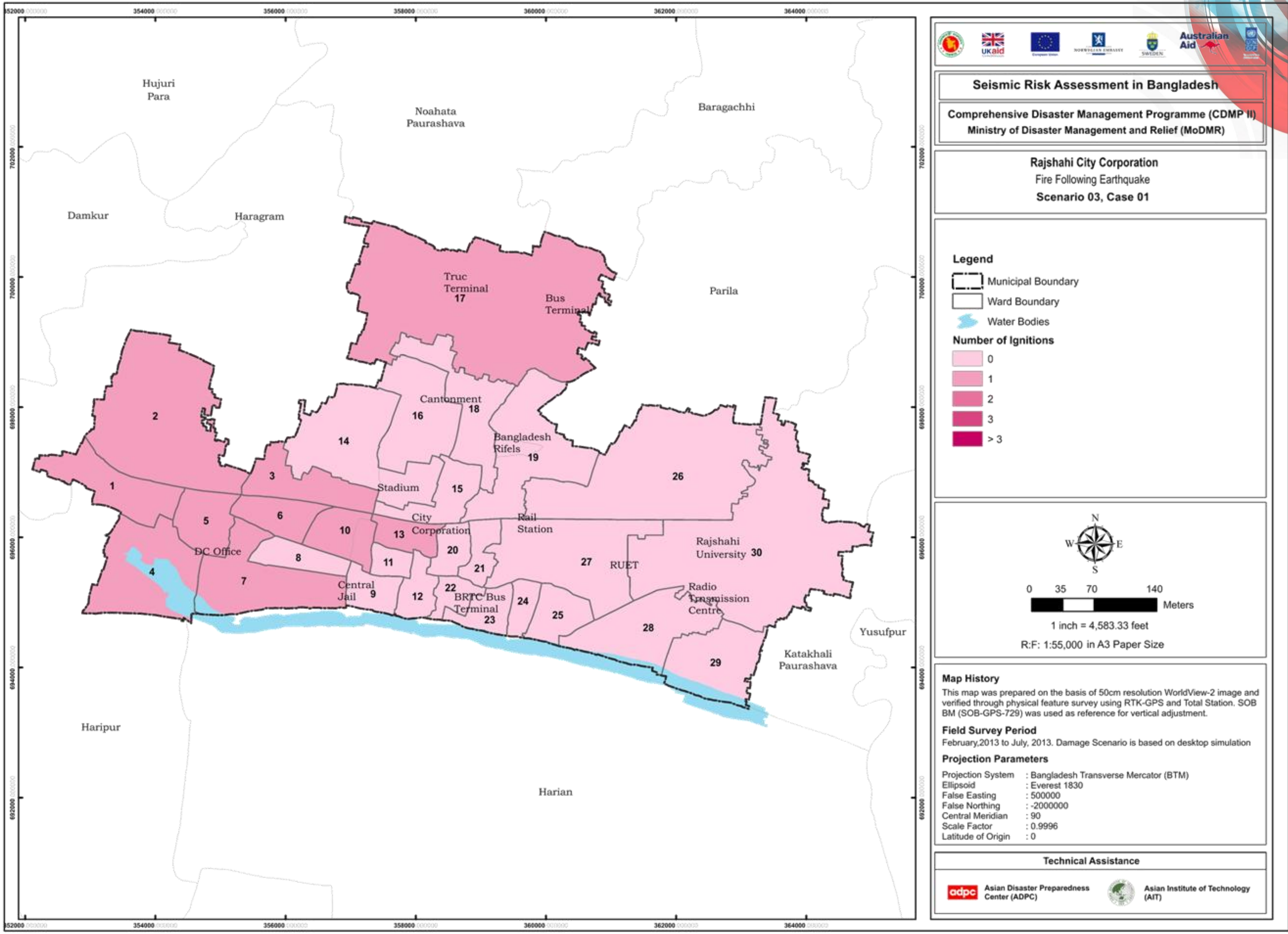
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Joynagar
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Haragram
Parila
Truc Terminal 17
Bus Terminal
Cantonment 18
Bangladesh Rifels 19
Stadium
City Corporation
Rail Station
DC Office
Central Jail
BRTC Bus Terminal
RUET
Rajshahi University 30
Radio Transmission Centre
Yusufpur
Katakhali Paurashava
Haripur
Harian



Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Fire Following Earthquake
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Number of Ignitions
0
1
2
3
> 3
N
S
E
W
0 35 70 140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
Map History
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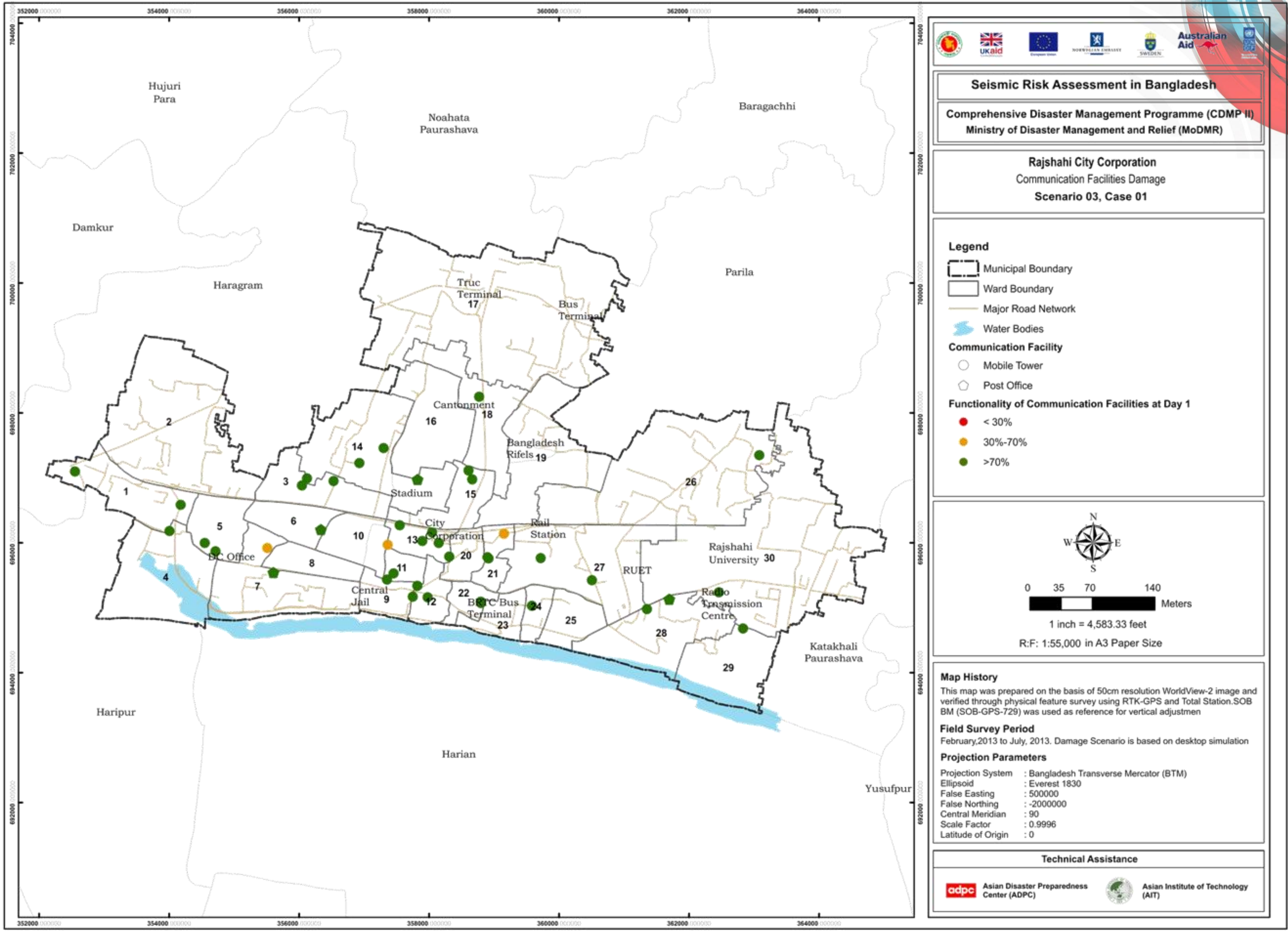
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Haragram
Parila
Truc Terminal
Bus Terminal
Cantonment
Bangladesh Rifels
Stadium
City Corporation
Rail Station
Rajshahi University
RUET
DC Office
Central Jail
BRTC Bus Terminal
Radio Transmission Centre
Yusufpur
Katakhali Paurashava
Haripur
Harian
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Communication Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Communication Facility
Mobile Tower
Post Office
Functionality of Communication Facilities at Day 1
< 30%
30%-70%
>70%
N
W
E
S
0
35
70
140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
Map History
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Ellipsoid : Everest 1830
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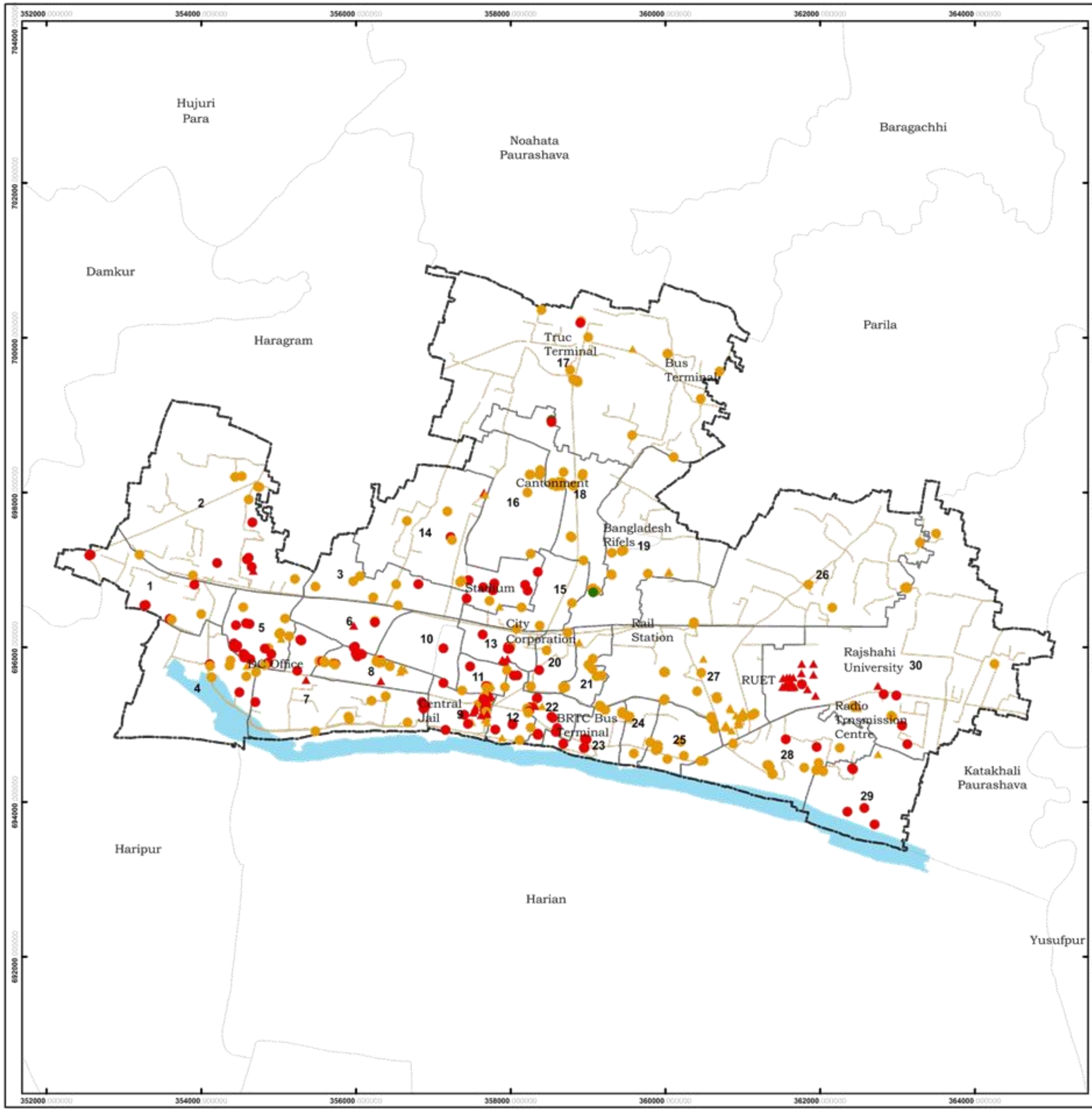
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Haragram
Parila
Truc Terminal
Bus Terminal
Cantonment
Bangladesh Rifels
Stadium
City Corporation
Rail Station
Rajshahi University
RUET
DC Office
Central Jail
BRTC Bus Terminal
Radio Transmission Centre
Katakhali Paurashava
Haripur
Harian
Yusufpur



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rajshahi City Corporation
Educational Institutes Damage
Scenario 03, Case 01

Legend

- Municipal Boundary
- Ward Boundary
- Major Road Network
- Water Bodies

Educational Institutes

- College
- School

Functionality of Educational Institutes at Day 1

- <30%
- 30%-70%
- >70%

0 35 70 140 Meters

1 inch = 4,583.33 feet

R:F: 1:55,000 in A3 Paper Size

Map History

This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station.SOB BM (SOB-GPS-729) was used as reference for vertical adjustmen

Field Survey Period

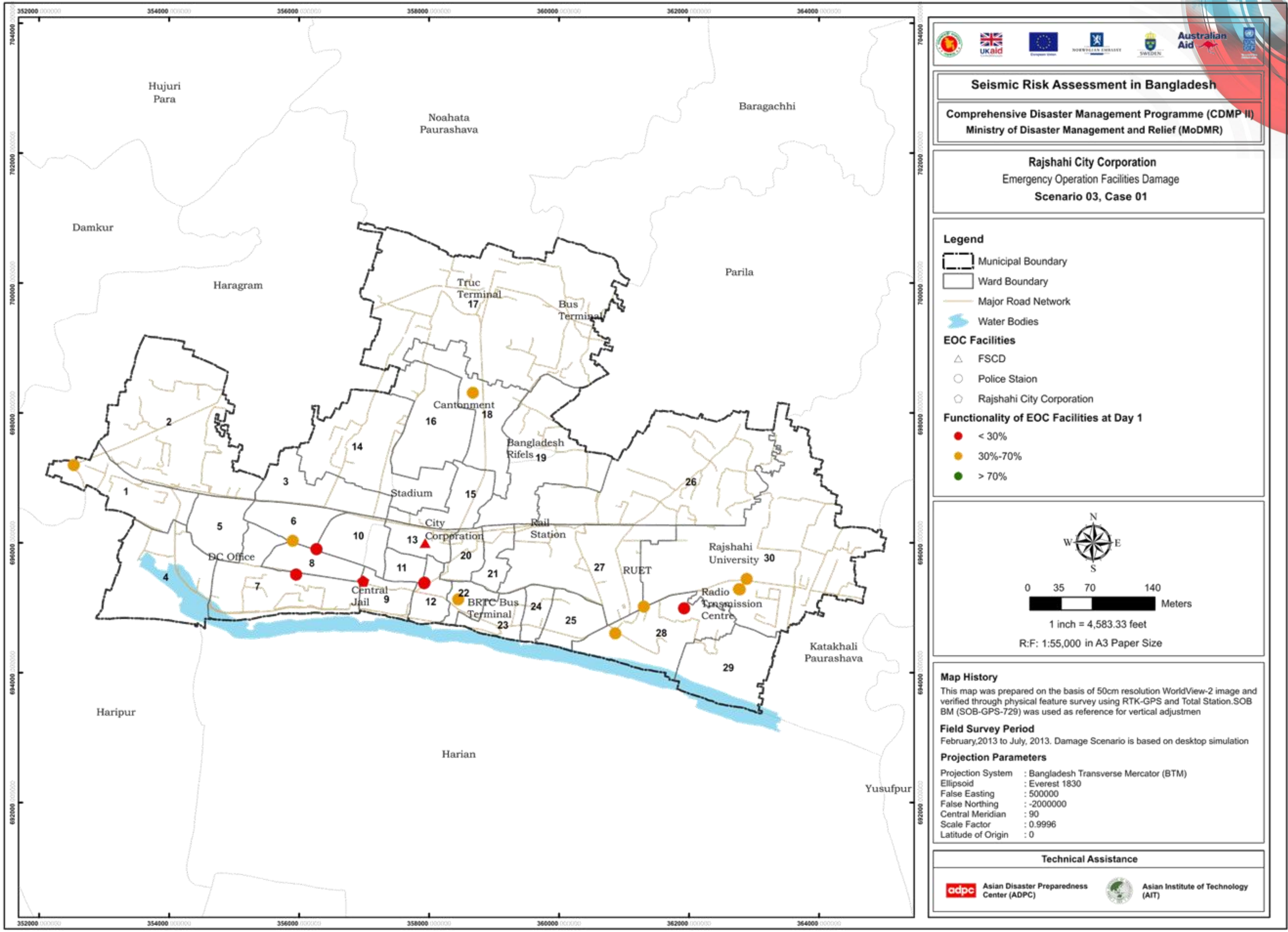
February,2013 to July, 2013. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Emergency Operation Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
EOC Facilities
FSCD
Police Staion
Rajshahi City Corporation
Functionality of EOC Facilities at Day 1
< 30%
30%-70%
> 70%
N
W
E
S
0 35 70 140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
Map History
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False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Haragram
Parila
Truc Terminal
Bus Terminal
Cantonment
Bangladesh Rifels
Stadium
City Corporation
Rail Station
DC Office
Central Jail
BRTC Bus Terminal
RUET
Rajshahi University
Radio Transmission Centre
Katakhali Paurashava
Haripur
Harian
Yusufpur
352000
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358000
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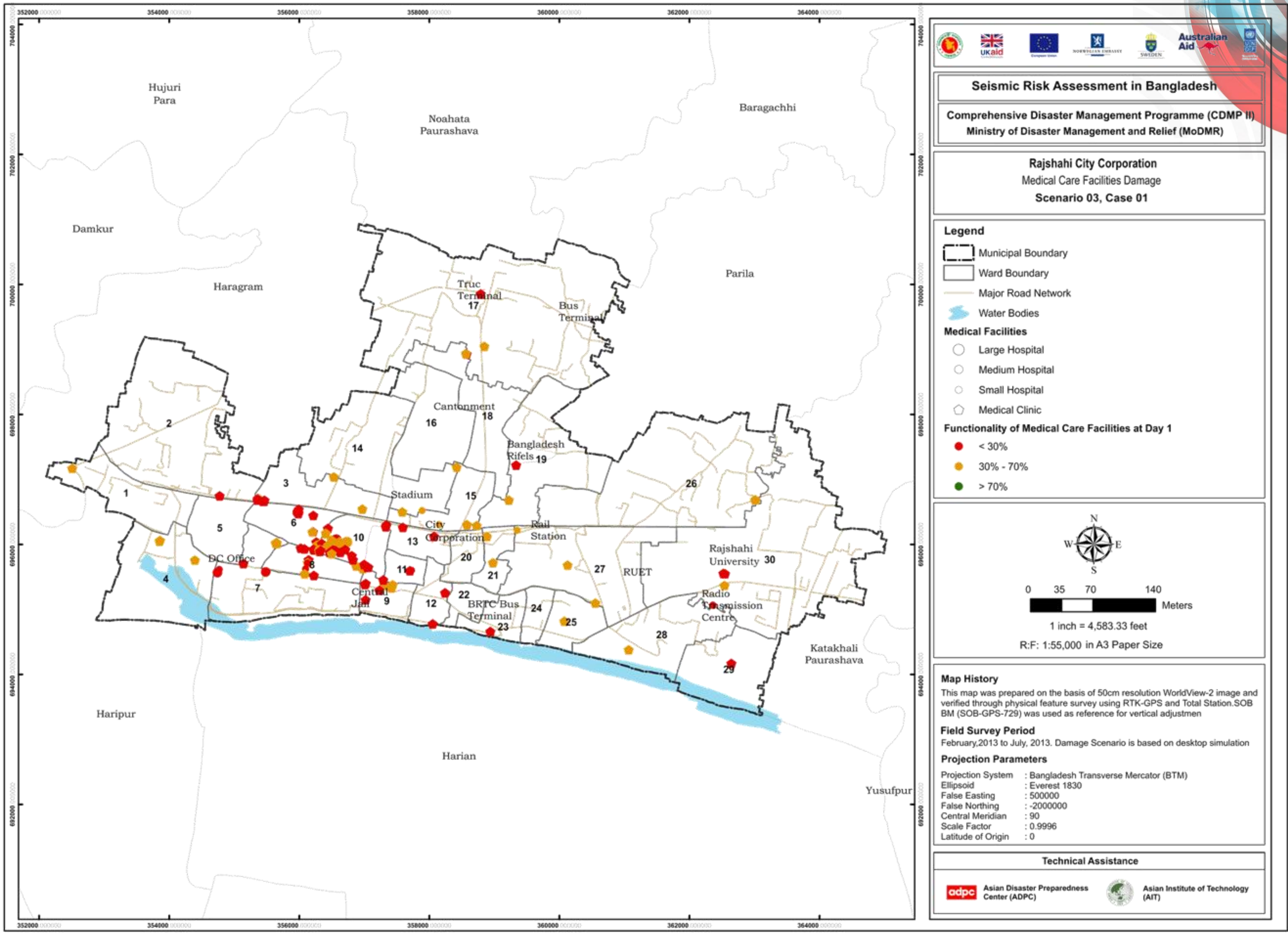
362000
364000
704000
702000
700000
698000
696000
694000
692000


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Medical Care Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Medical Facilities
Large Hospital
Medium Hospital
Small Hospital
Medical Clinic
Functionality of Medical Care Facilities at Day 1
< 30%
30% - 70%
> 70%
N
W
E
S
0 35 70 140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
Map History
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False Easting : 500000
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Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Haragram
Parila
Truc Terminal
Bus Terminal
Cantonment
Bangladesh Rifels
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Rajshahi University
Radio Transmission Centre
Katakhali Paurashava
Haripur
Harian
Yusufpur
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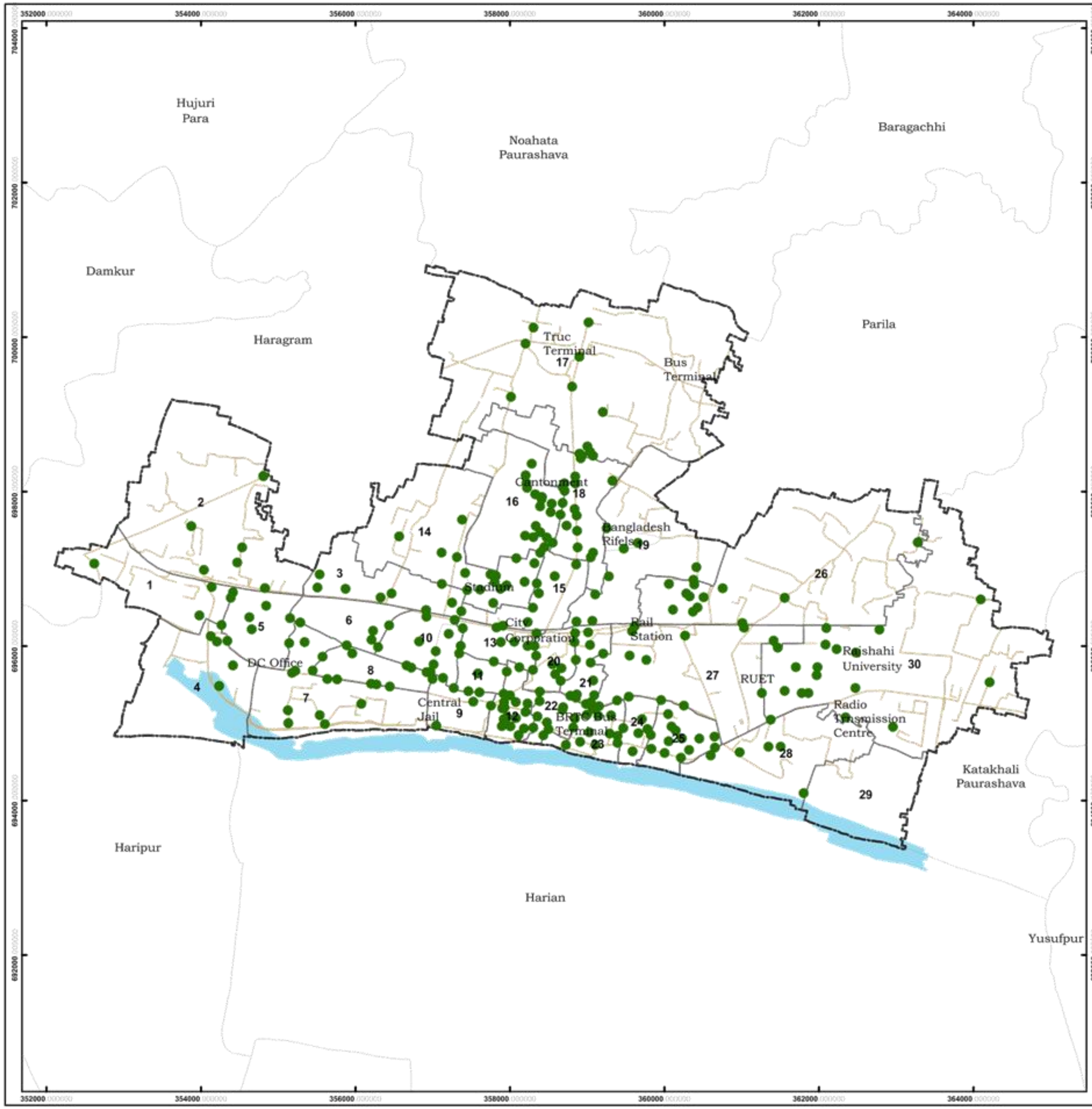


Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rajshahi City Corporation
Power System Damage
Scenario 03, Case 01

Legend

- Municipal Boundary
- Ward Boundary
- Major Road Network
- Water Bodies

Electrical Facilities

- Electric Transformer

Functionality of Electric Facilities at Day 1

- < 30%
- 30% - 70%
- > 70%

N
W E
S

0 35 70 140 Meters

1 inch = 4,583.33 feet

R:F: 1:55,000 in A3 Paper Size

Map History

This map was prepared on the basis of 50cm resolution WorldView-2 image and verified through physical feature survey using RTK-GPS and Total Station.SOB BM (SOB-GPS-729) was used as reference for vertical adjustmen

Field Survey Period

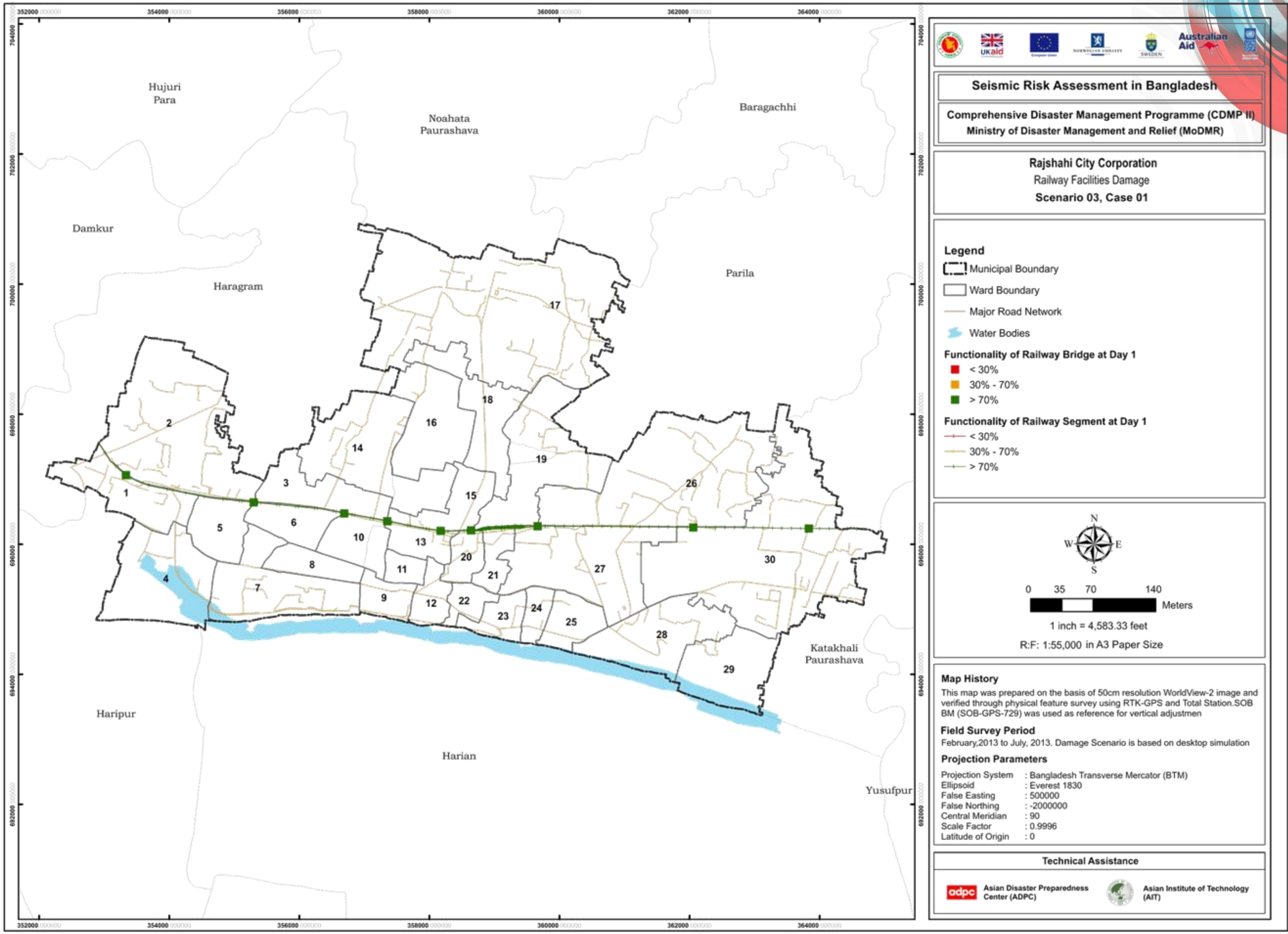
February,2013 to July, 2013. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)



Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Railway Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Functionality of Railway Bridge at Day 1
< 30%
30% - 70%
> 70%
Functionality of Railway Segment at Day 1
< 30%
30% - 70%
> 70%
0 35 70 140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
Map History
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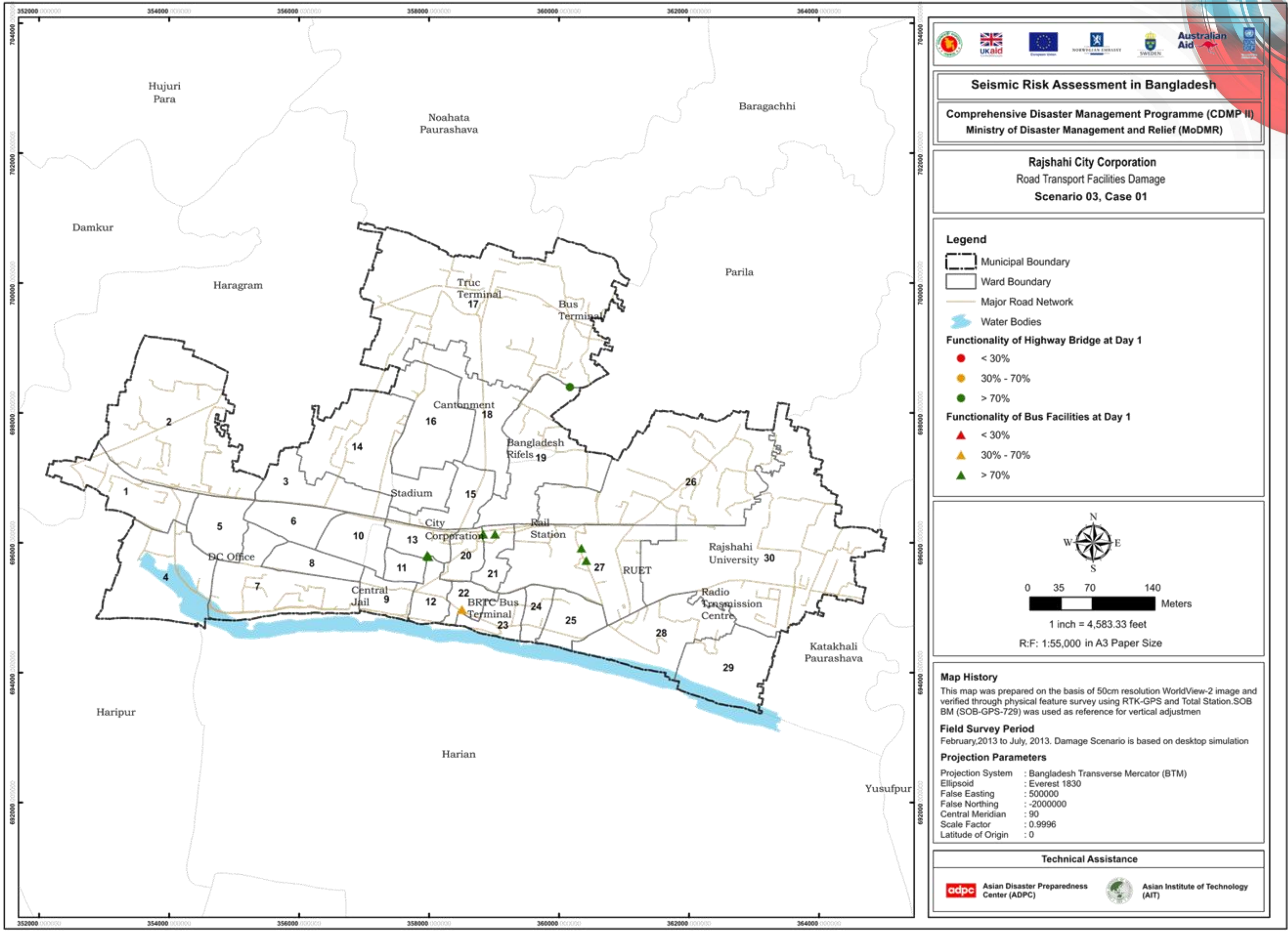
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Haragram
Parila
Katakhali Paurashava
Haripur
Harian
Yusufpur


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rajshahi City Corporation
Road Transport Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Functionality of Highway Bridge at Day 1
< 30%
30% - 70%
> 70%
Functionality of Bus Facilities at Day 1
< 30%
30% - 70%
> 70%
N
W
E
S
0 35 70 140
Meters
1 inch = 4,583.33 feet
R:F: 1:55,000 in A3 Paper Size
Map History
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False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Hujuri Para
Noahata Paurashava
Baragachhi
Damkur
Haragram
Parila
Truc Terminal
Bus Terminal
Cantonment
Bangladesh Rifels
Stadium
City Corporation
Rail Station
DC Office
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BRTC Bus Terminal
RUET
Rajshahi University
Radio Transmission Centre
Katakhali Paurashava
Haripur
Harian
Yusufpur
352000
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362000
364000
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702000
700000
698000
696000
694000
692000

Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rajshahi City Corporation
Road Segment Damage
Scenario 03, Case 01

Legend
- Municipal Boundary
- Ward Boundary
- Water Bodies

Functionality of Road Segment at Day 1
- < 30%
- 30% - 70%
- > 70%

0 35 70 140 Meters

1 inch = 4,583.33 feet

R:F: 1:55,000 in A3 Paper Size

Map History
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Field Survey Period
February,2013 to July, 2013. Damage Scenario is based on desktop simulation

Projection Parameters

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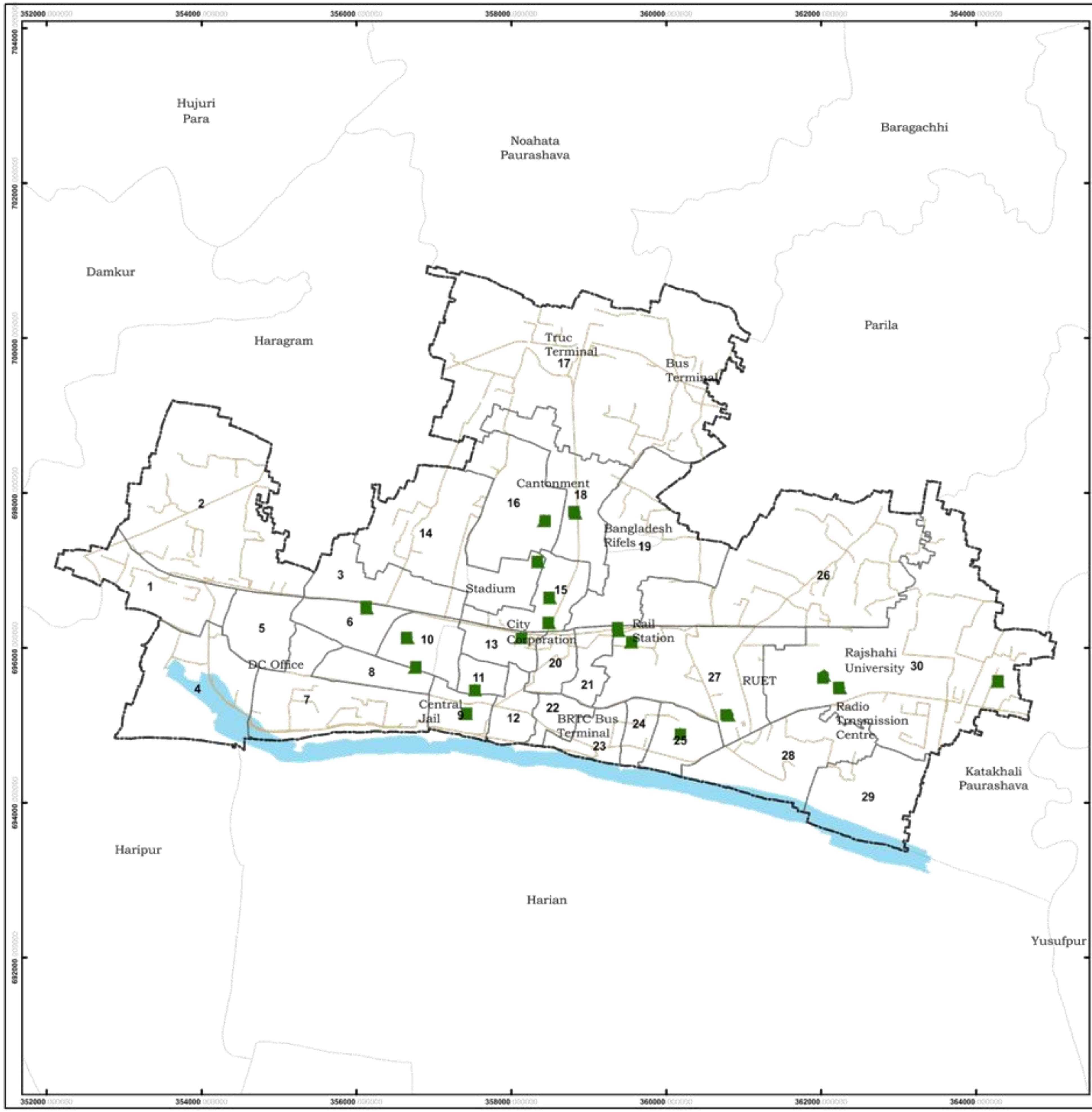
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rajshahi City Corporation
Potable Water System Damage
Scenario 03, Case 01

Legend

- Municipal Boundary
- Ward Boundary
- Major Road Network
- Water Bodies

Potable Water Facilities

- Overhead Tank
- Water Pump

Functionality of Potable Water Facilities at Day 1

- < 30%
- 30% - 70%
- > 70%

Potable Water Supply Network

Number of Repair Per k.m.

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

N W E S

0 35 70 140 Meters

1 inch = 4,583.33 feet

R:F: 1:55,000 in A3 Paper Size

Map History

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Field Survey Period

February,2013 to July, 2013. Damage Scenario is based on desktop simulation

Projection Parameters

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Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Asian Disaster Preparedness Center (ADPC)

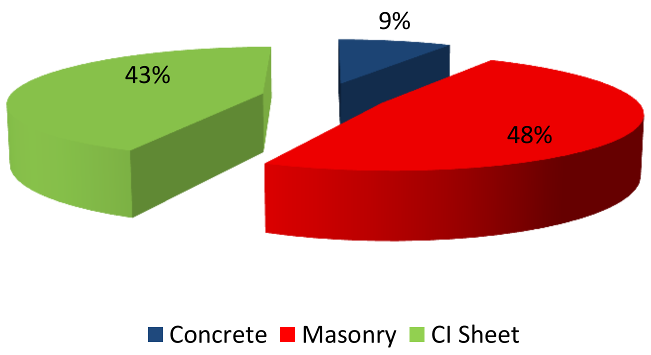
Asian Institute of Technology (AIT)

Rangpur City Corporation

Rangpur, established in 1869, is one of the oldest paurashavas in Bangladesh. Rangpur was declared as a District headquarters on 16 December 1769. The municipal office building was erected in 1892 under the precedence of Raja Janaki Ballav, Sen. Chairman of the Paurashava to whom Rangpur is indebted for many works of public utility and for his assiduous efforts to advance the improvement of the town. In 1890, Shyama Sundari Khal was excavated for improvement of the town.

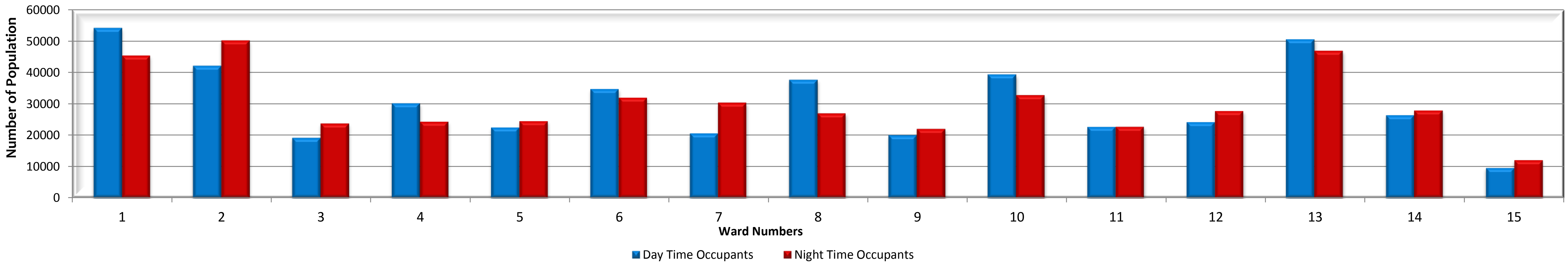
The Paurashava is located in the north western part of Bangladesh. Rangpur was upgraded as an 'A-1' category Paurashava in 1986. In 2012, the Paurashava was upgraded to City Corporation and divided into 33 wards. Its previous population was 294265 (2001 census) covering an area of 50.66 sq km and the number of households is 64,127. Before becoming City Corporation, Rangpur had 15 wards and a population density of 5,808 and average household size is 4.57. Area of the present city corporation with extended areas is 203.19 sq km and population is about 10 Lac. The major tourist attractions in Rangpur are Tajhat Palace or Rangpur Museum, Begum Rokeya Museum, Rangpur Medical College and the Carmichael College, Begym Rokeya University, Keramat Ali Mosque, and Rangpur Cadet Collage.

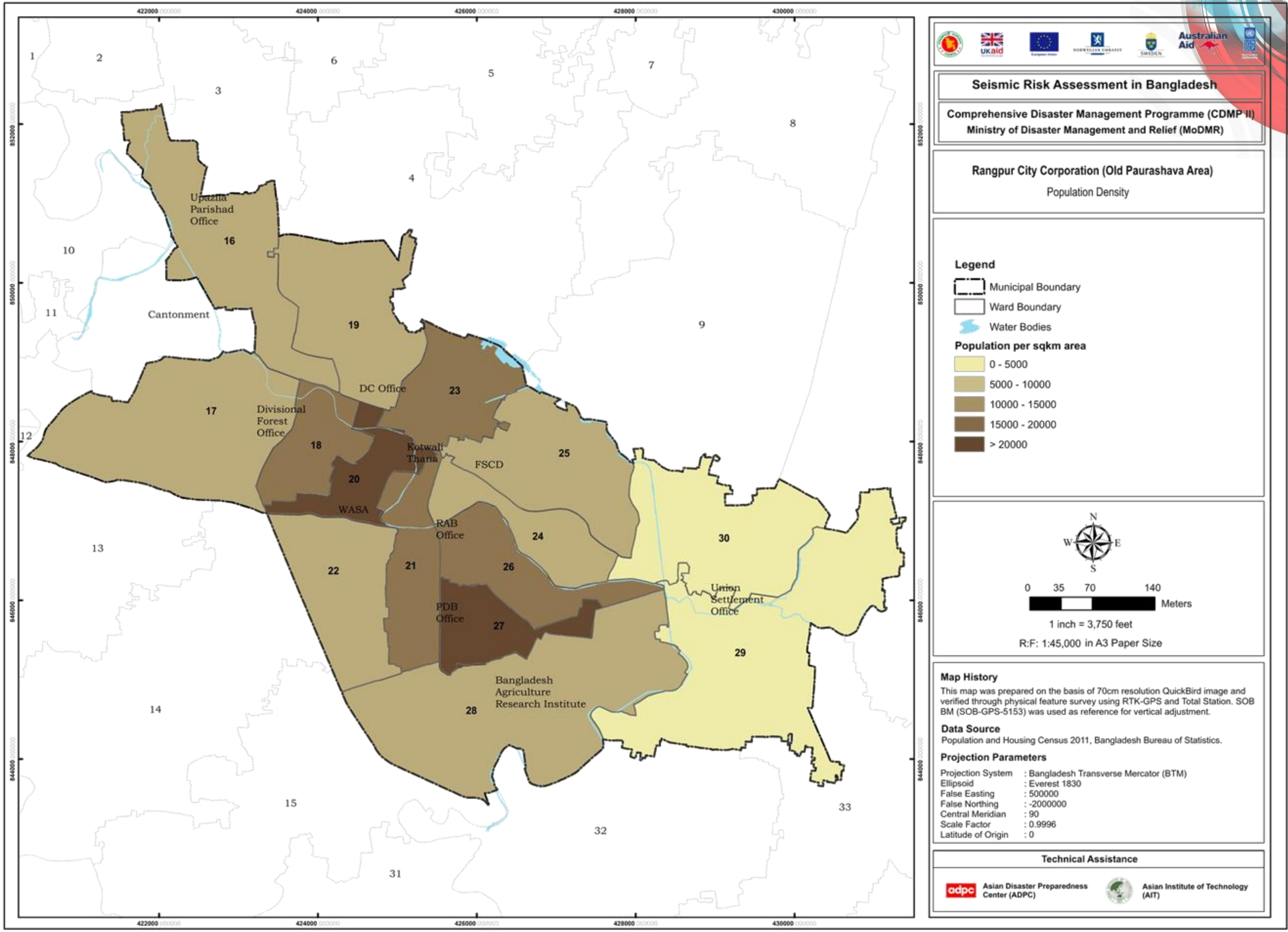
Structural type of Rangpur City Corporation (Old Pourashava Area)



Brief Information of the City	
Name of the City	Rangpur
Name of the Paurashava	Rangpur City Corporation
Year of Establishment	At first Established in 1869. In 2012, the Paurashava upgrade to City Corporation
Total Area	203.19 sq. km or 50209.34 acre
Number of Wards	33
Total Population	1000000
Population Growth Rate (2011)	1.24%
Road Network	591.56 km
Railways	10.23 km
Water Ways	N/A
Natural Water Bodies	879.069 acre
Open Space	74.923
Education Institutions	347
Health Facilities	110
Re-fueling Stations	9
Fire Station	1
Police Station	2

Day & Night Occupants in Rangpur City Corporation (Old Pourashava Area)




Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Population Density
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Population per sqkm area
0 - 5000
5000 - 10000
10000 - 15000
15000 - 20000
> 20000
N
W
E
S
0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.
Data Source
Population and Housing Census 2011, Bangladesh Bureau of Statistics.
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Upazila Parishad Office
Cantonment
DC Office
Divisional Forest Office
Kotwali Thana
FSCD
WASA
RAB Office
PDB Office
Union Settlement Office
Bangladesh Agriculture Research Institute
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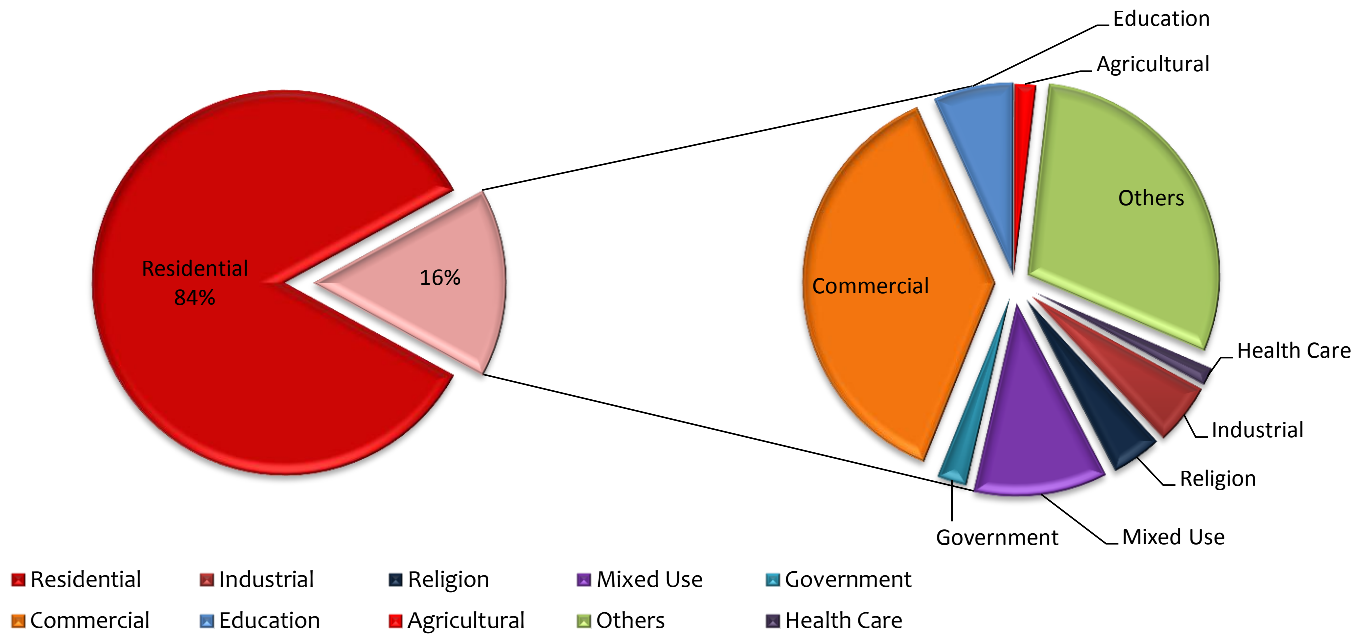
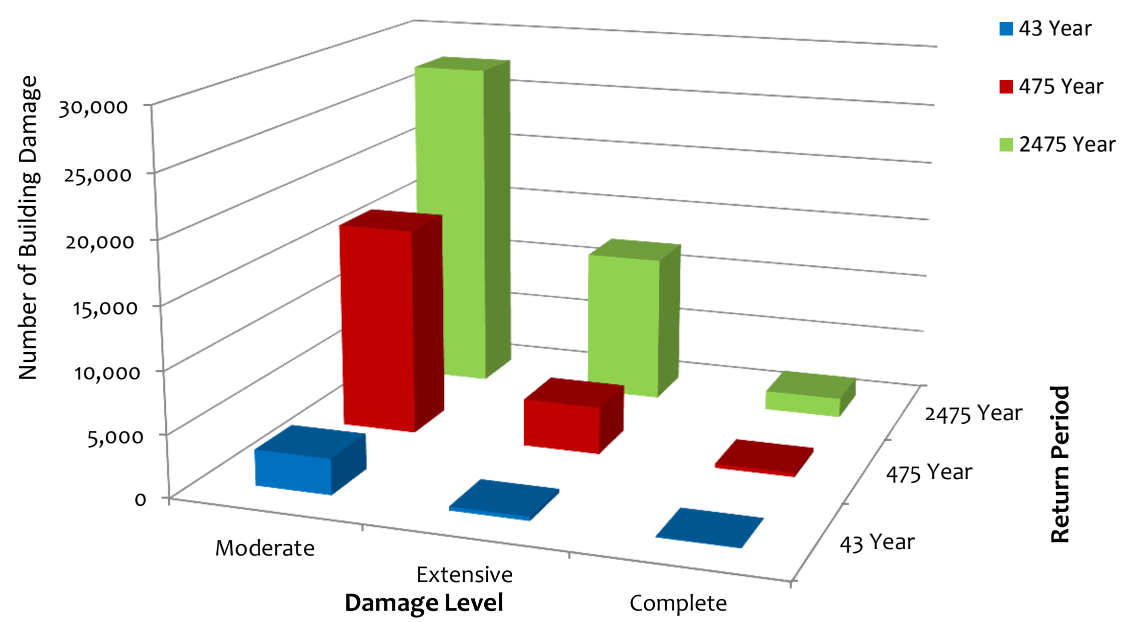
Distribution of Different Occupancy Classes in Rangpur City Corporation (Old Pourashava Area)



Number of Damage Building in Rangpur City Corporation (Old Pourashava Area)



EXPECTED PHYSICAL DAMAGE STATES

Table 21: Expected physical damage states of buildings for different scenario cases

Scenarios	Total Structure	Concrete Structure					Masonry Structure					Informal Structures				
		Total Concrete Structure	Moderate Damage		Complete Damage		Total Masonry Structure	Moderate Damage		Complete Damage		Total Zinc Shed and Bamboo Structure	Moderate Damage		Complete Damage	
			No.	%	No.	%		No.	%	No.	%		No.	%	No.	%
Scenario 1 Case 1	76424	6294	1135	18.03%	6	0.10%	37436	1478	3.95%	17	0.05%	32694	294	0.90%	14	0.04%
Scenario 2 Case 2	76424	6294	851	13.52%	43	0.68%	37436	558	1.49%	1	0.00%	32694	98	0.30%	0	0.00%
Scenario 3 Case 1	76424	6294	2652	42.14%	124	1.97%	37436	11232	30.00%	141	0.38%	32694	3095	9.47%	80	0.24%
Scenario 4 Case 2	76424	6294	1824	28.98%	762	12.11%	37436	10549	28.18%	4019	10.74%	32694	1862	5.70%	38	0.12%
Scenario 5 Case 1	76424	6294	2400	38.13%	673	10.69%	37436	17075	45.61%	775	2.07%	32694	8113	24.81%	152	0.46%
Scenario 6 Case 2	76424	6294	1972	31.33%	1883	29.92%	37436	5180	13.84%	15790	42.18%	32694	3486	10.66%	50	0.15%

Debris Generation

Table 22: Expected debris generation for different scenario cases

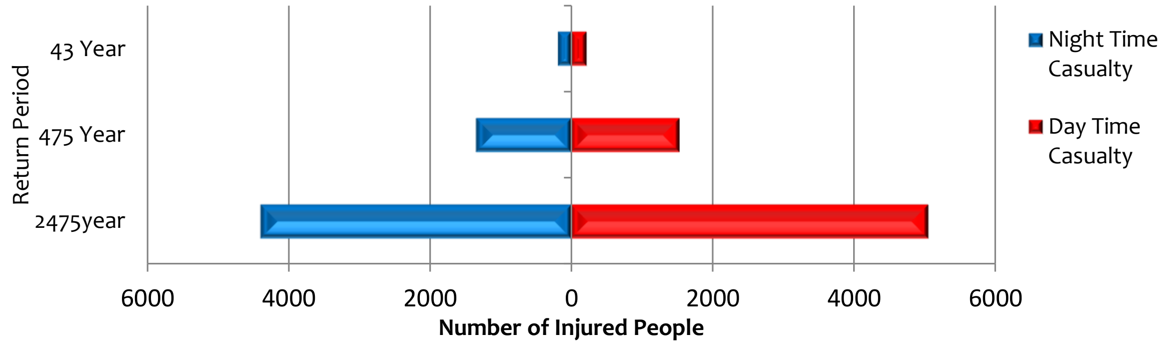
Earthquake Scenario	Amount of Debris (million tons)	% of Concrete and Steel materials	% of Brick and Wood materials
Scenario 1 Case 1	0.080	44%	56%
Scenario 2 Case 2	0.090	57%	43%
Scenario 3 Case 1	0.510	60%	40%
Scenario 4 Case 2	1.140	69%	31%
Scenario 5 Case 1	1.350	70%	30%
Scenario 6 Case 2	2.810	73%	27%

Damage to Utility Systems

Table 23: Expected damage to utility systems for different scenario cases

Potable Water	Scenario 1 Case 1	Scenario 2 Case 2	Scenario 3 Case 1	Scenario 4 Case 2	Scenario 5 Case 1	Scenario 6 Case 2
Total Length Pipelines (km)	191	191	191	191	191	191
No. of Leaks	8	6	40	46	79	112
No. of Breaks	20	3	87	52	130	79

Expected Casualties in Rangpur City Corporation (Old Pourashava Area)

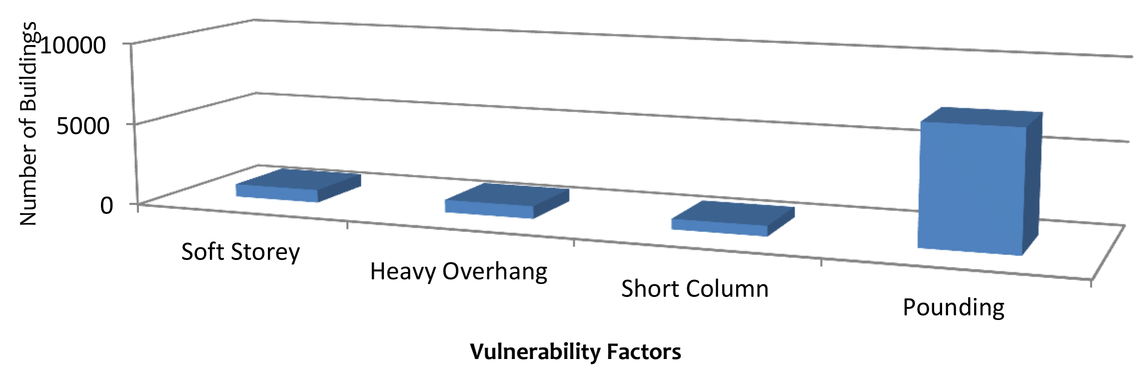


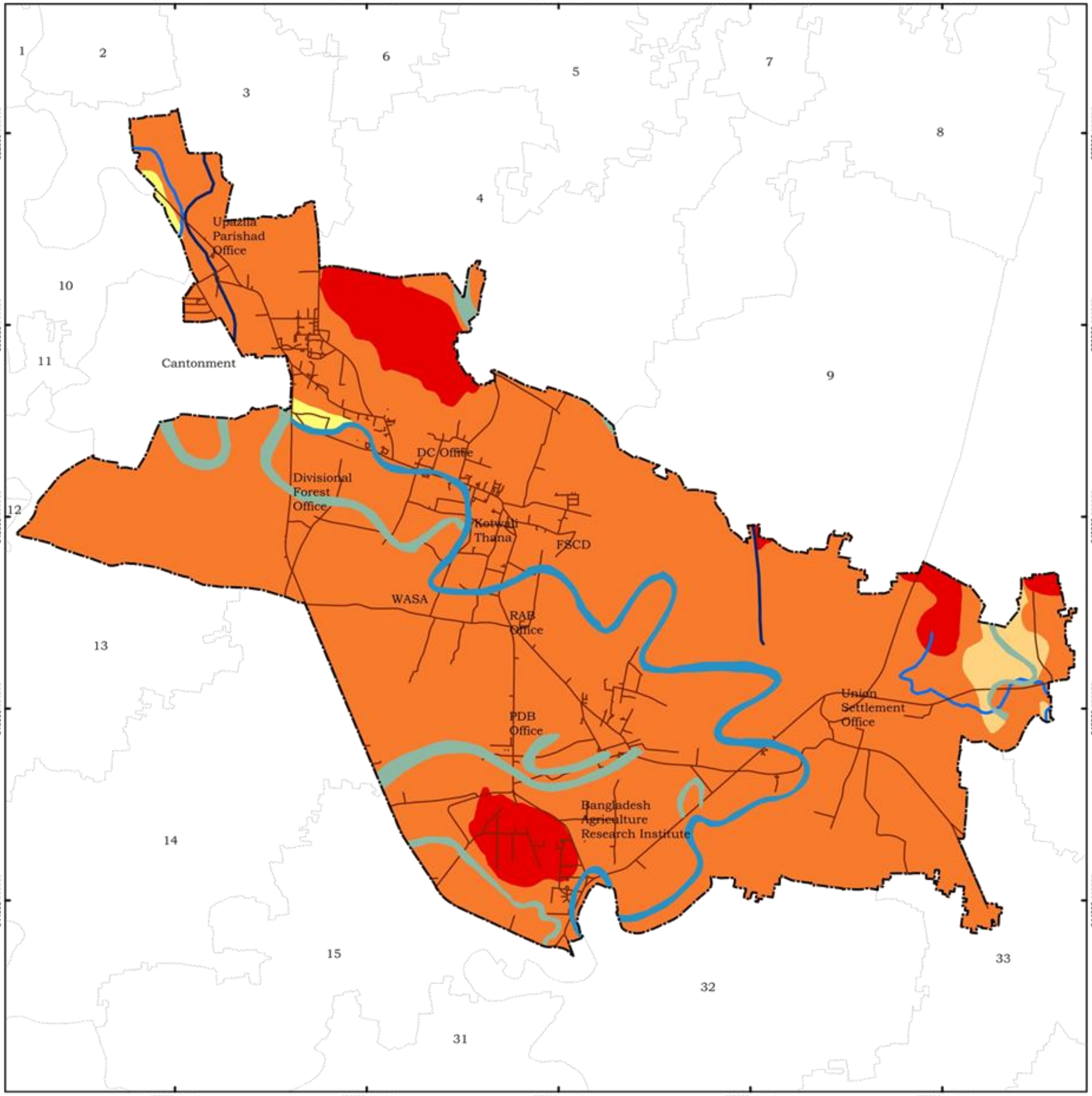
Damage of Utility and Lifelines

Table 24: Expected damage to lifelines for scenario case 3

System	Component	Total	Moderate Damage	Complete Damage	At least 50% Functional	
					Day 1	Day 7
Highway	Segments	5139	0	0	5109	5109
	Bridges	42	0	0	42	42
	Facilities	28	0	0	28	28
Railway	Segments	24	0	0	24	24
	Bridges	3	0	0	3	3
	Facilities	5	0	0	5	5

Vulnerability Factors in Rangpur City Corporation (Old Pourashava Area)





UKaid Australian Aid

Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rangpur City Corporation (Old Paurashava Area)

Geology

Legend

- Municipal Boundary
- Major Road Network

Tista Fan Alluvium

- Active Channel Deposits
- Abandoned Channel Deposits
- Bar Deposits
- Natural Levee Deposits
- Alluvium Fan Deposits
- Back Swamp Deposits

N S W E

0 35 70 140 Meters

1 inch = 3,750 feet

R.F: 1:45,000 in A3 Paper Size

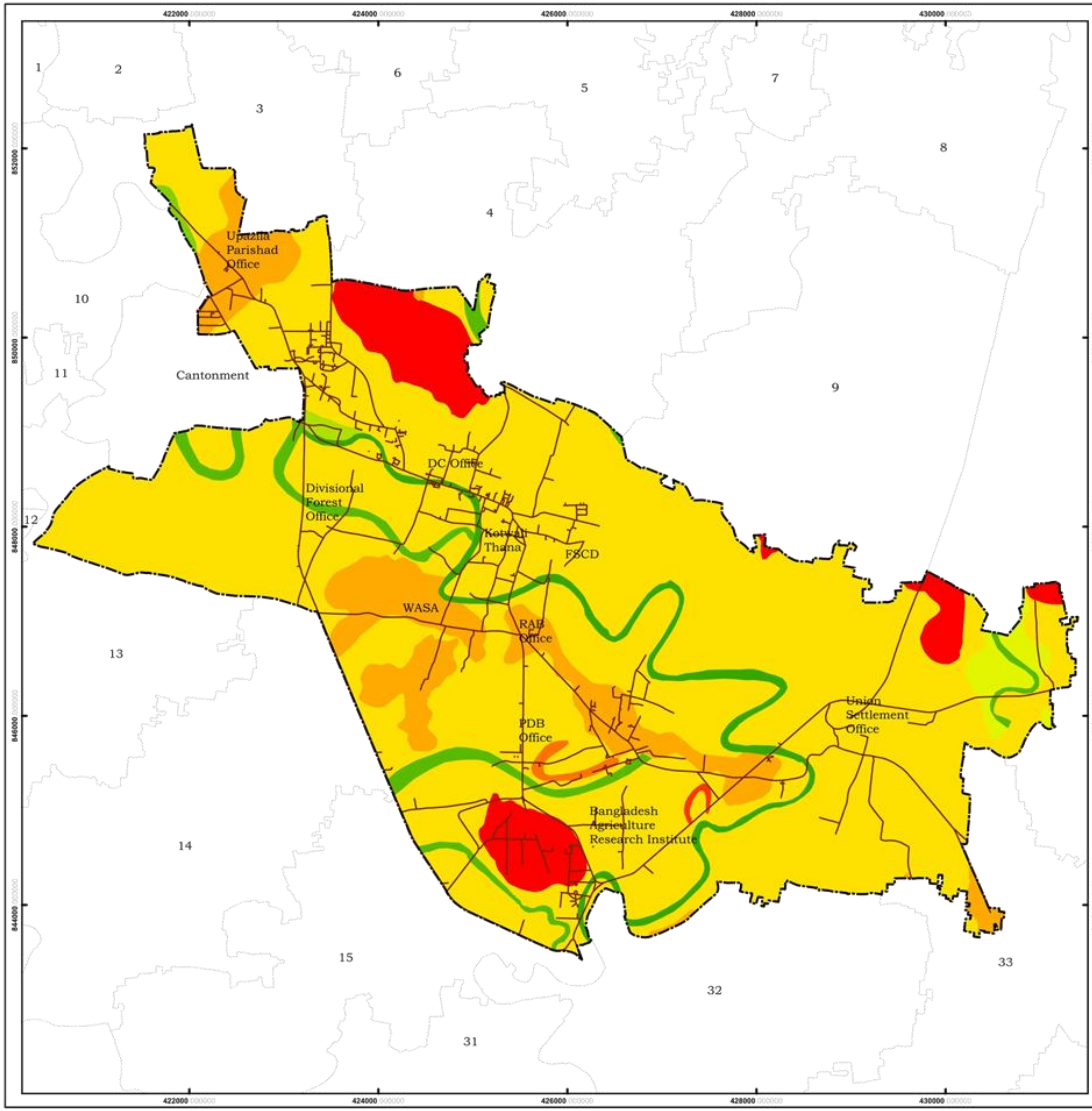
Tista Fan Alluvium	
Active channel deposits	Light brownish grey (10YR 6/2) medium to fine very loose sand
Abandoned Channel deposits	Bluish grey (5B 5/1) to grey (10YR 5/1) clayey silt, sandy silt and fine sand
Bar deposits	Light brownish grey (10YR 6/2) to grey (10YR 5/1) silty sand and sand
Natural leeve deposits	Light grey (10YR 7/1) to light brownish grey (10YR 6/2) silt and medium sand
Alluvial plain deposits	Bluish grey (5B 5/1), light brownish grey (10YR 6/2) and grey (10YR 5/1) sandy silt and clayey silt
Back swamp deposits	Bluish grey (5B 5/1) to grey (10YR 5/1) clayey silt and silty clay

Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0

Technical Assistance

Geological Survey of Bangladesh (GSB)

adpc Asian Disaster Preparedness Center (ADPC)



Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rangpur City Corporation (Old Paurashava Area)

Geomorphology

Legend

- Municipal Boundary
- Major Road Network

Active Tista Fan Units

- Active Channel
- Abandoned Channel
- Younger Point Bar
- Old Point Bar
- Natural Levee
- Alluvial Plain
- Higher Alluvial Plain
- Meander Scar
- Ox-bow Lake
- Back Swamp

N W E S

0 35 70 140 Meters

1 inch = 3,750 feet

R:F: 1:45,000 in A3 Paper Size

Active Tista Fan Units	
Active channel	Elongated meander channels with flowing water consists of fine sand
Abandoned channel	Elongated narrow channels with or without water formed by the shifting of stream courses and filling by sandy silt and fine sand
Young Point bar	Crescent shaped recent accumulation of silty sand along the meandering channel deposits
Old point bar	Crescent shaped older accumulation of silty sand along the channel deposited within the Tista Fan
Natural levee	Irregular linear accumulation of sediments along the both banks of the river at eastern part of Tista Fan consists of silt and medium to fine sand
Alluvial plain	Flat distal part of Tista Fan having south-east slope consist of sandy silt and clayey silt
High alluvial plain	Irregular shaped slightly elevated lobes within the fan surface consists of sandy silt and clayey silt
Meander scar	Crescent shaped sandy silt remnant of mender channels within the Tista Fan formed due to channels shifting and neck cut off
Ox-bow lake	Ox-bow shaped body of water within the Tista Fan formed by neck cut off of meander channels and consisted of clayey silt, sandy silt and fine sand
Back swamp	Irregular shaped swampy, depressed areas within Tista Fan consisted of clayey silt and silty clay

Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
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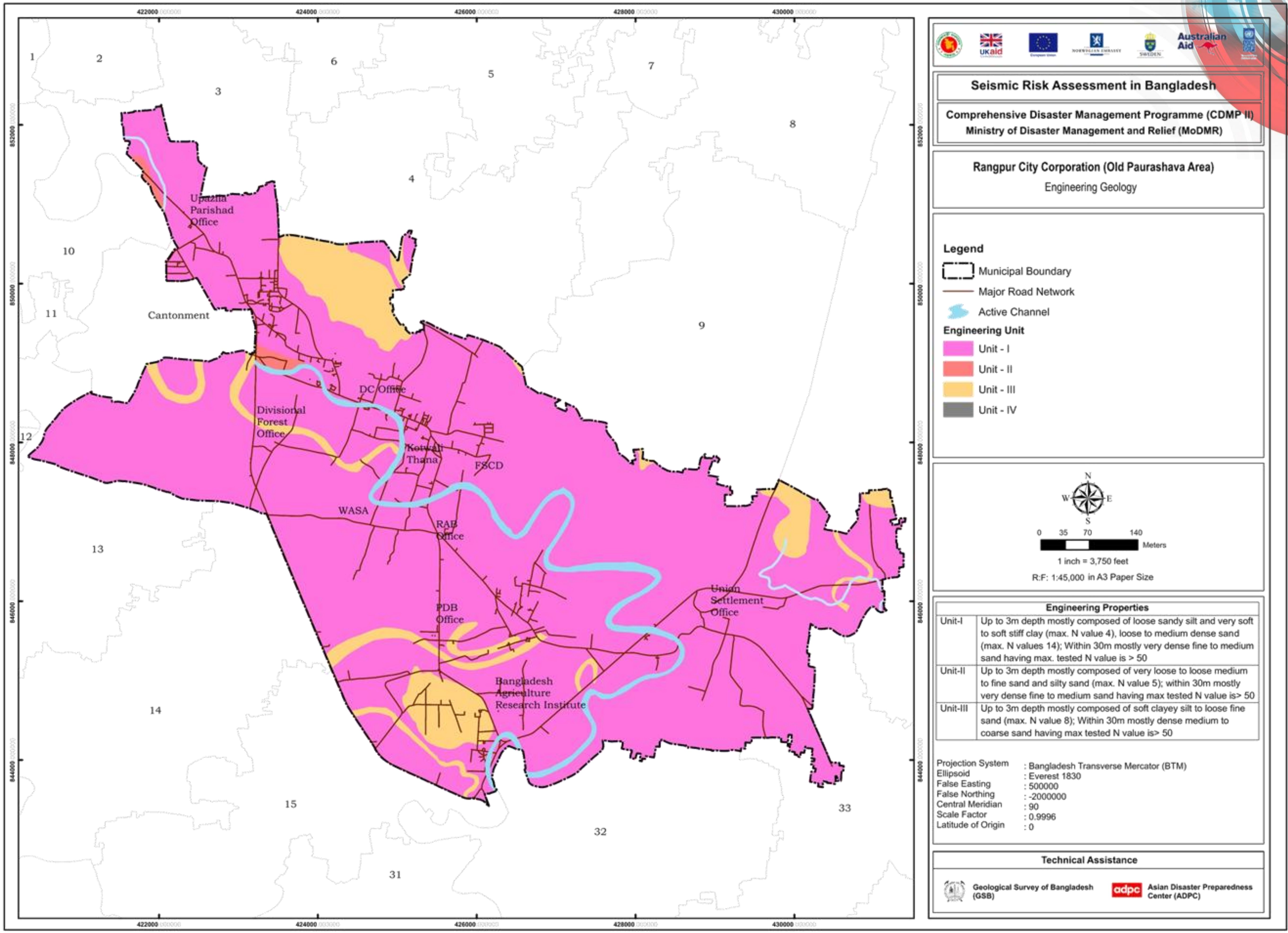
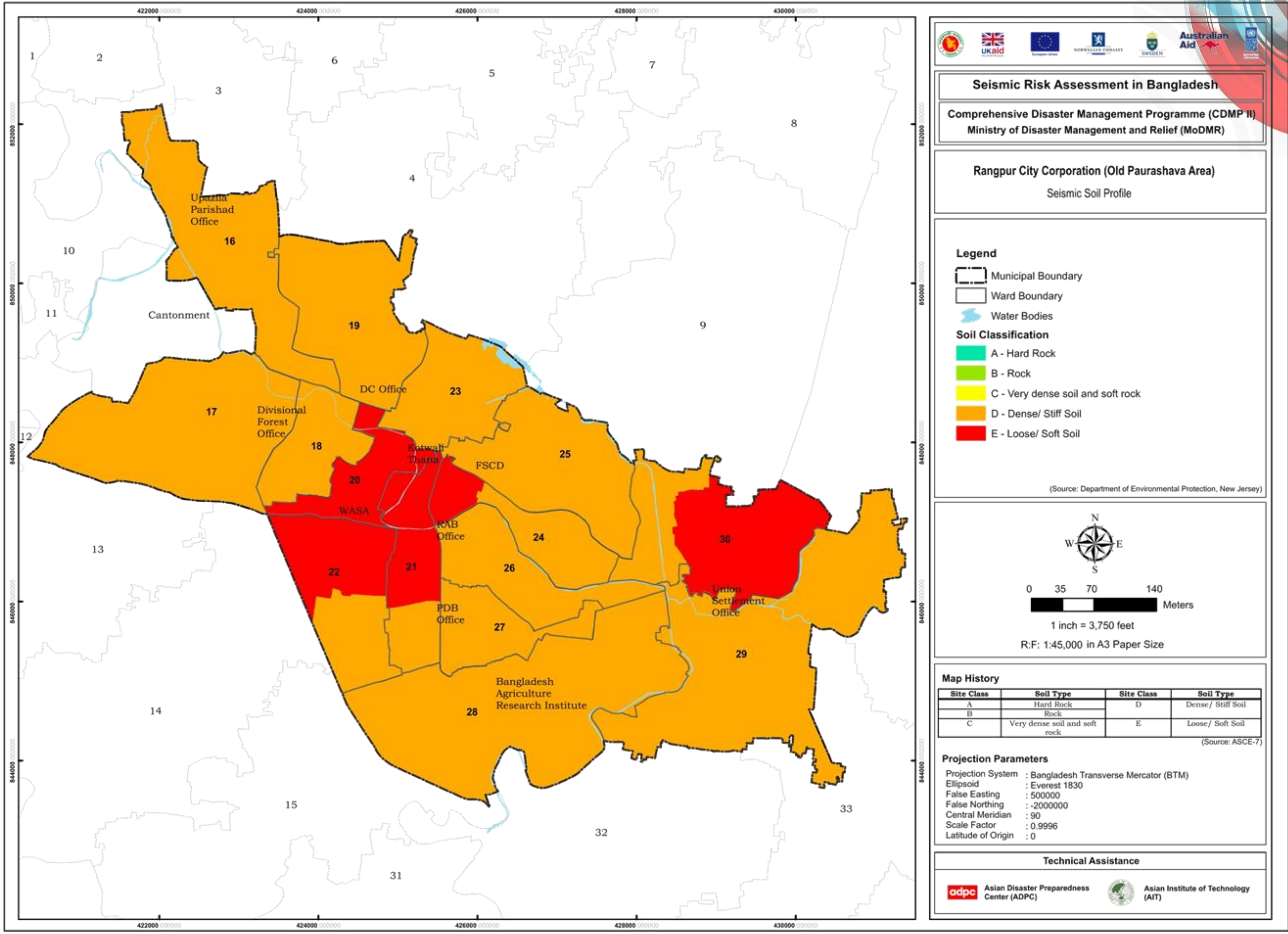
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0

Technical Assistance

Geological Survey of Bangladesh (GSB)

Asian Disaster Preparedness Center (ADPC)


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Engineering Geology
Legend
Municipal Boundary
Major Road Network
Active Channel
Engineering Unit
Unit - I
Unit - II
Unit - III
Unit - IV
1 inch = 3,750 feet
R.F: 1:45,000 in A3 Paper Size
0 35 70 140 Meters
Engineering Properties
Unit-I Up to 3m depth mostly composed of loose sandy silt and very soft to soft stiff clay (max. N value 4), loose to medium dense sand (max. N values 14); Within 30m mostly very dense fine to medium sand having max. tested N value is > 50
Unit-II Up to 3m depth mostly composed of very loose to loose medium to fine sand and silty sand (max. N value 5); within 30m mostly very dense fine to medium sand having max tested N value is> 50
Unit-III Up to 3m depth mostly composed of soft clayey silt to loose fine sand (max. N value 8); Within 30m mostly dense medium to coarse sand having max tested N value is> 50
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Geological Survey of Bangladesh (GSB)
Asian Disaster Preparedness Center (ADPC)
Upazila Parishad Office
Cantonment
DC Office
Divisional Forest Office
Kotwali Thana
FSCD
WASA
RAB Office
PDB Office
Bangladesh Agriculture Research Institute
Union Settlement Office
UKaid
Australian Aid



Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Seismic Soil Profile
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Soil Classification
A - Hard Rock
B - Rock
C - Very dense soil and soft rock
D - Dense/ Stiff Soil
E - Loose/ Soft Soil
(Source: Department of Environmental Protection, New Jersey)
N
W
E
S
0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
Site Class | Soil Type | Site Class | Soil Type
A | Hard Rock | D | Dense/ Stiff Soil
B | Rock
C | Very dense soil and soft rock | E | Loose/ Soft Soil
(Source: ASCE-7)
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Upazila Parishad Office
Cantonment
DC Office
Divisional Forest Office
Kotwali Thana
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Union Settlement Office
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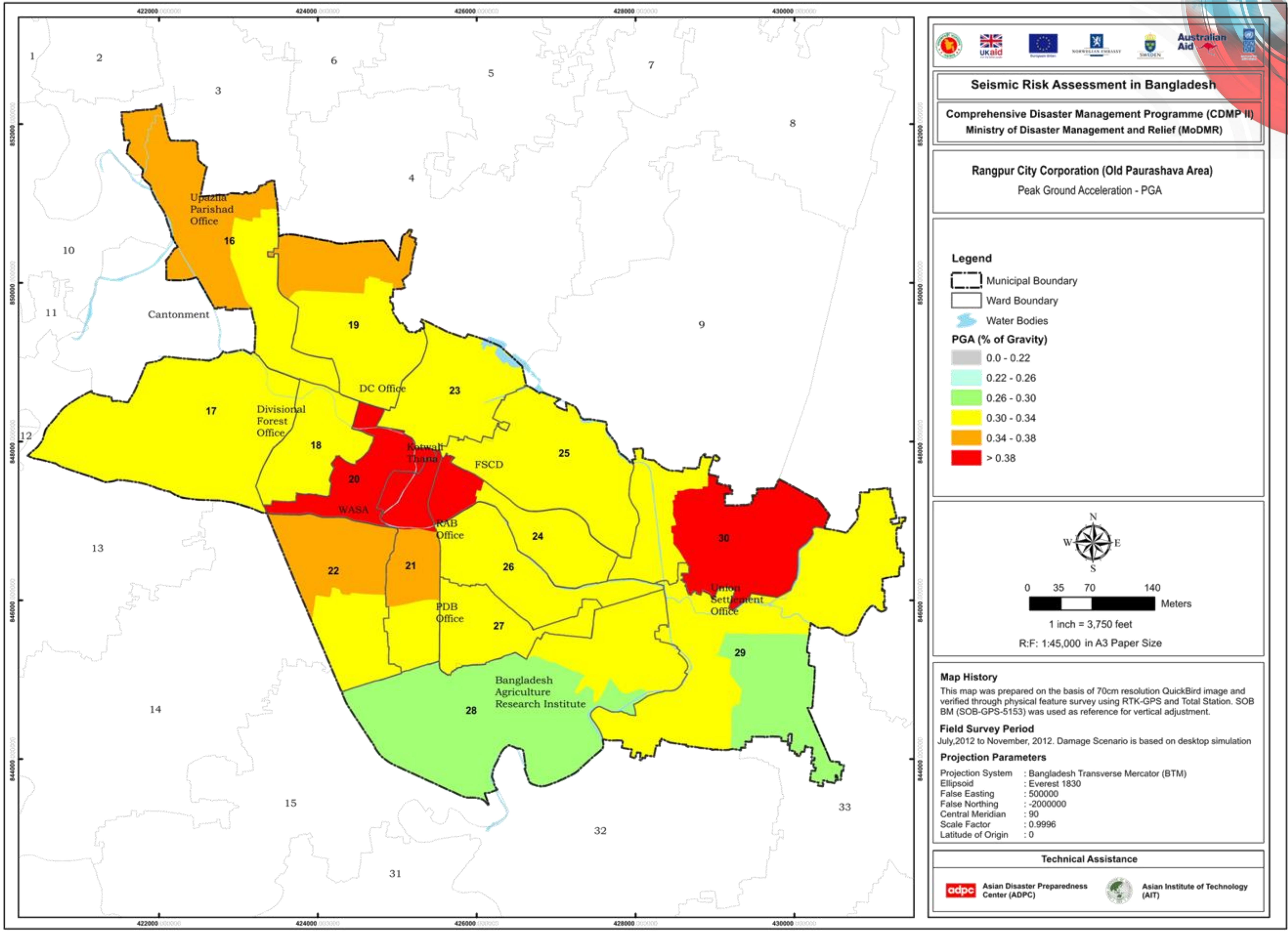
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Peak Ground Acceleration - PGA
Legend
Municipal Boundary
Ward Boundary
Water Bodies
PGA (% of Gravity)
0.0 - 0.22
0.22 - 0.26
0.26 - 0.30
0.30 - 0.34
0.34 - 0.38
> 0.38
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Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.
Field Survey Period
July,2012 to November, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Upazila Parishad Office
Cantonment
DC Office
Divisional Forest Office
Kotwali Thana
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Union Settlement Office
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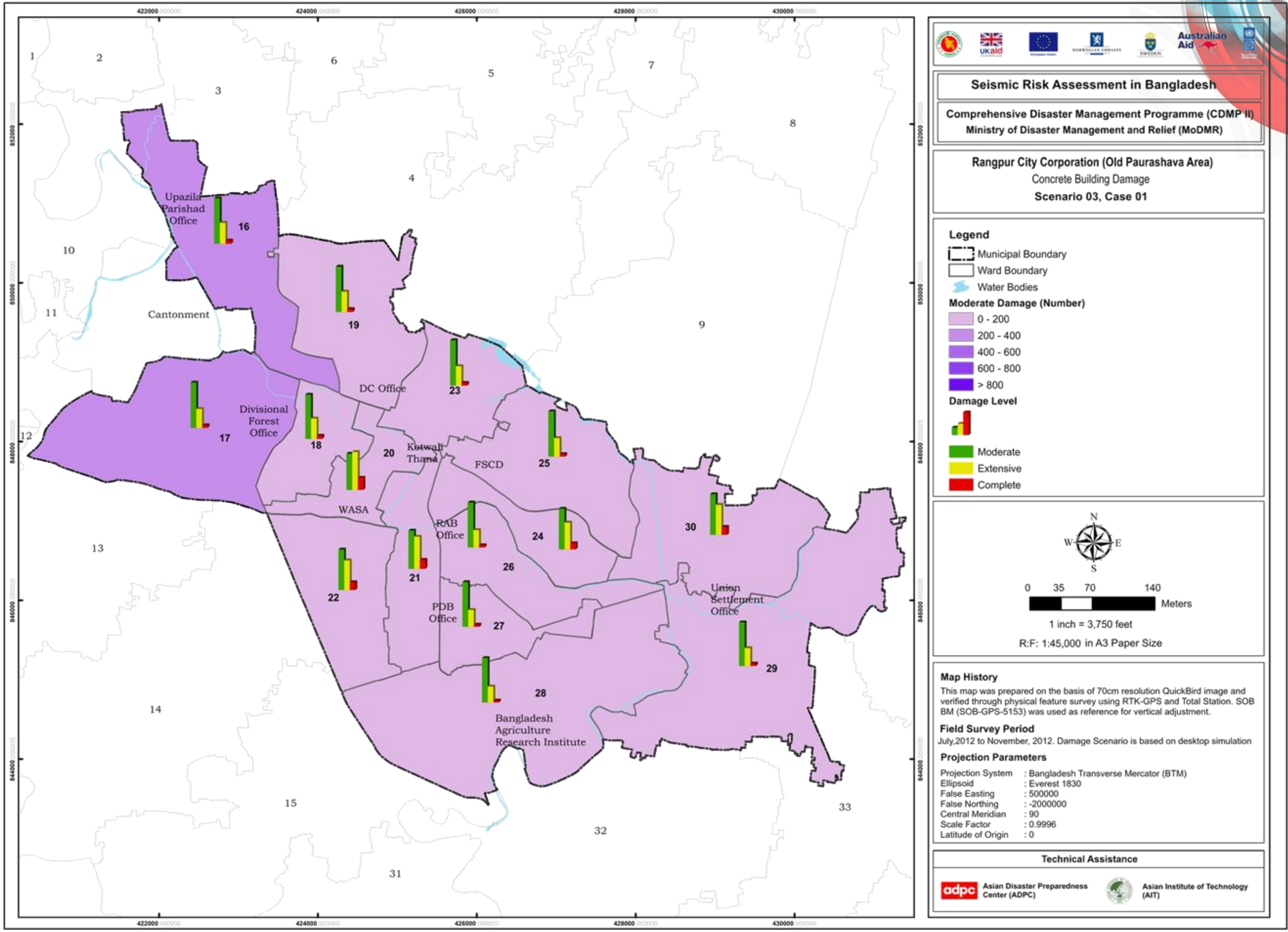

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Concrete Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Moderate Damage (Number)
0 - 200
200 - 400
400 - 600
600 - 800
> 800
Damage Level
Moderate
Extensive
Complete
N
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0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
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Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
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Upazila Parishad Office
Cantonment
Divisional Forest Office
DC Office
Kotwali Thana
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PDB Office
Union Settlement Office
Bangladesh Agriculture Research Institute
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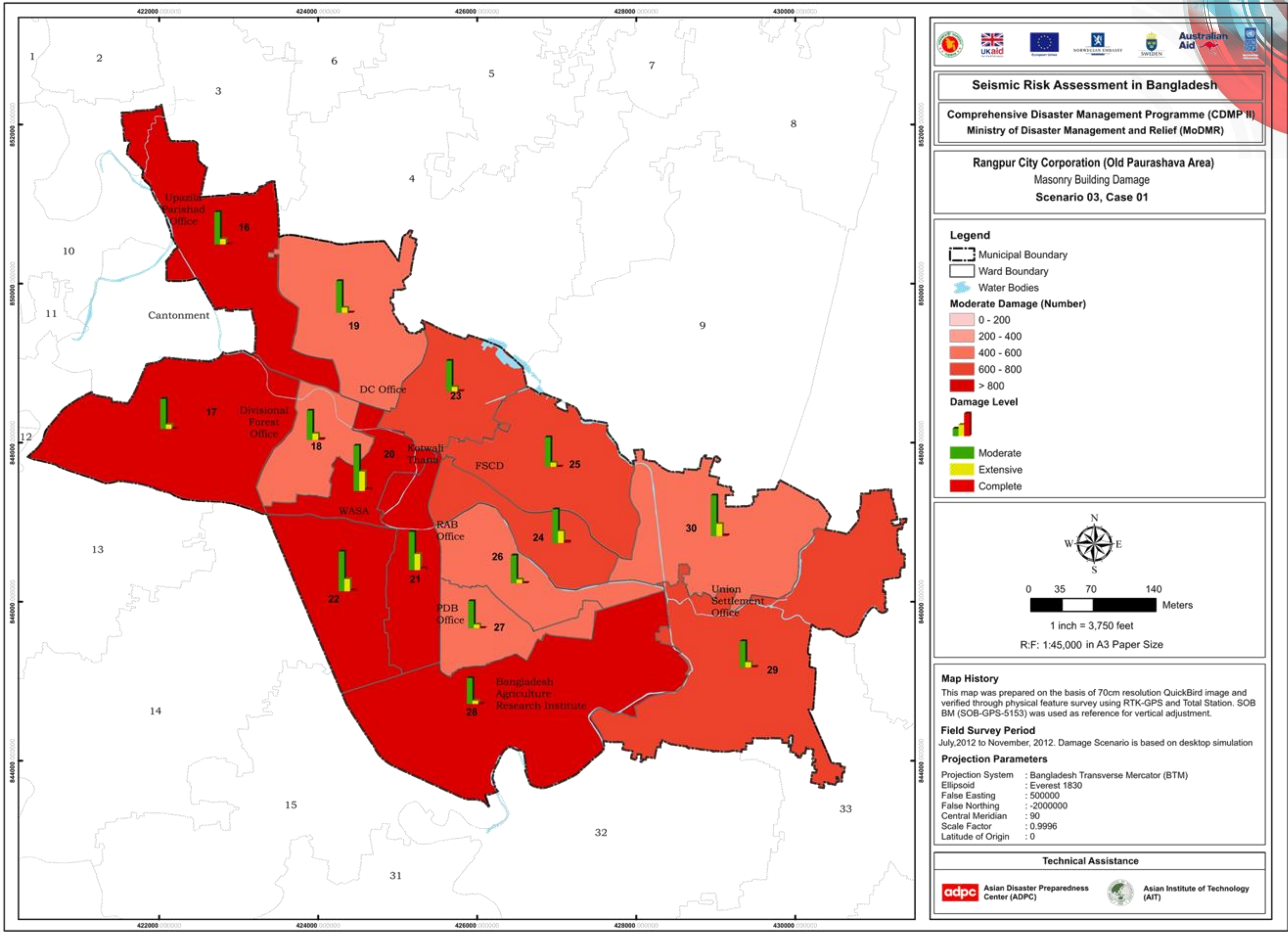
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Masonry Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Moderate Damage (Number)
0 - 200
200 - 400
400 - 600
600 - 800
> 800
Damage Level
Moderate
Extensive
Complete
0 35 70 140 Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
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Field Survey Period
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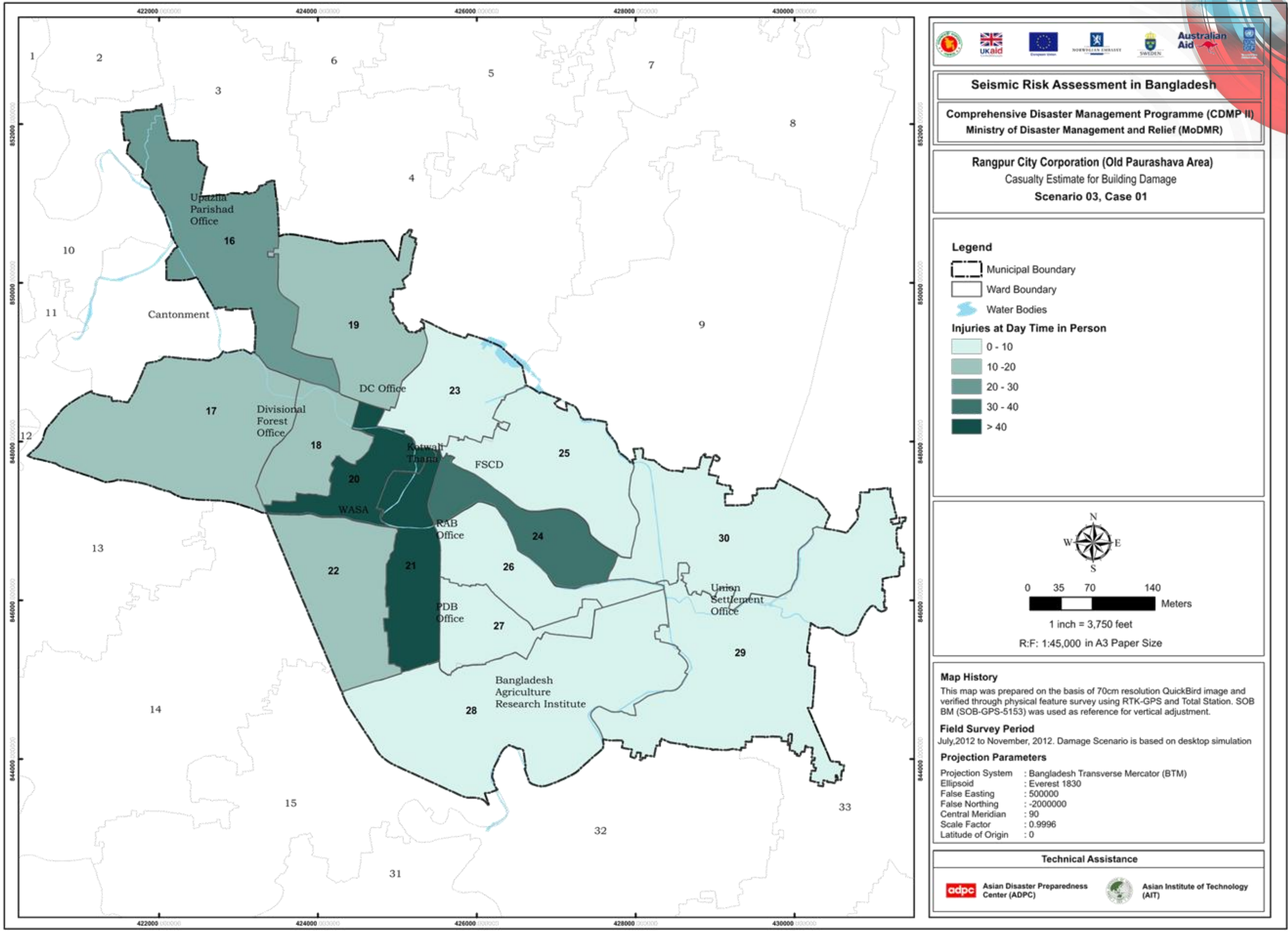
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Casualty Estimate for Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Injuries at Day Time in Person
0 - 10
10 -20
20 - 30
30 - 40
> 40
N
W
E
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0
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70
140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
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Technical Assistance
Asian Disaster Preparedness Center (ADPC)
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Upazila Parishad Office
Cantonment
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Bangladesh Agriculture Research Institute
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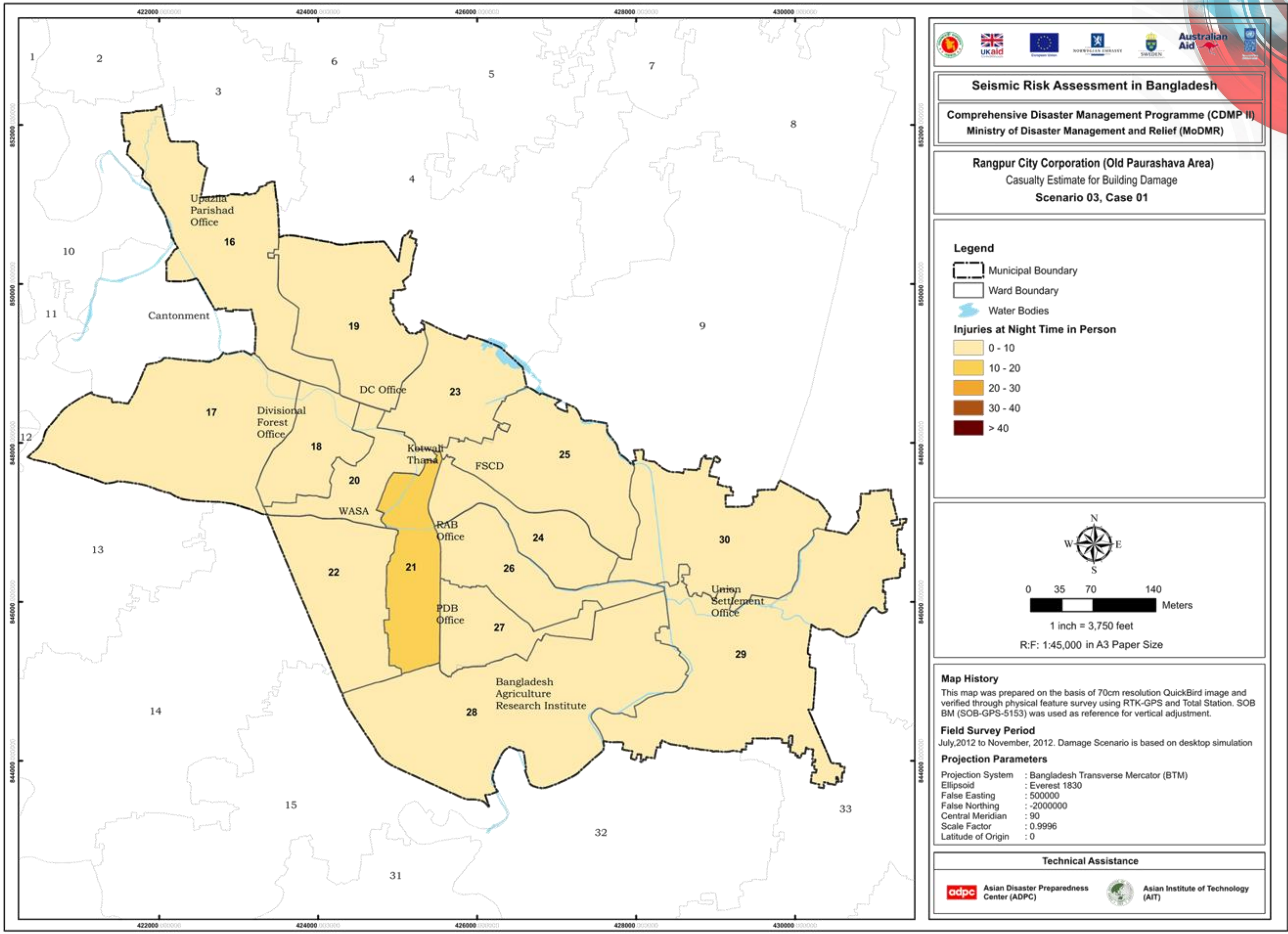
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Casualty Estimate for Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Injuries at Night Time in Person
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
W
E
S
0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.
Field Survey Period
July,2012 to November, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
adpc Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Upazila Parishad Office
Cantonment
DC Office
Divisional Forest Office
Kotwali Thana
FSCD
WASA
RAB Office
PDB Office
Union Settlement Office
Bangladesh Agriculture Research Institute
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422000 424000 426000 428000 430000
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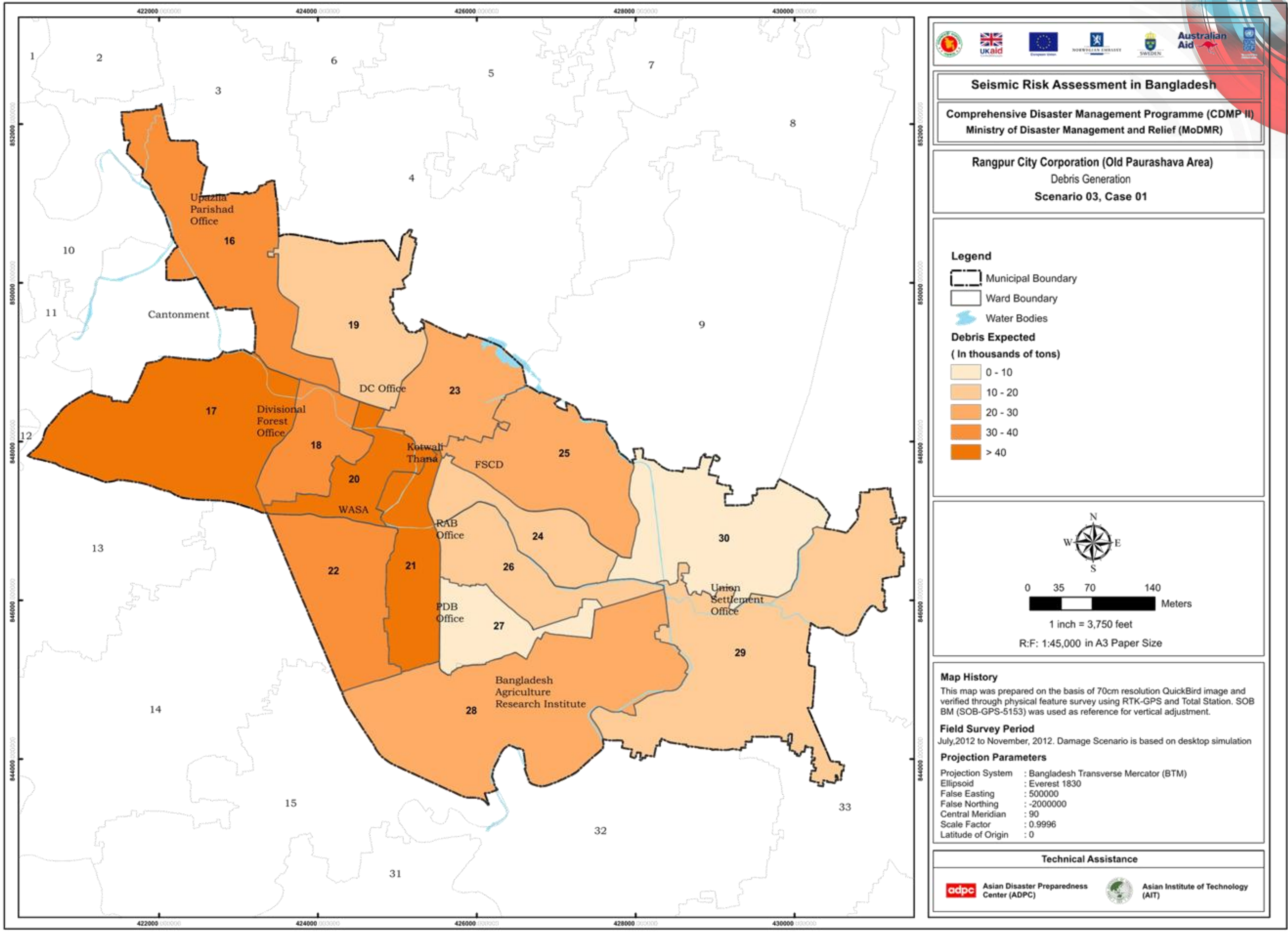
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Debris Generation
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Debris Expected
(In thousands of tons)
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
W
E
S
0 35 70 140
Meters
1 inch = 3,750 feet
R.F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.
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False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Upazila Parishad Office
Cantonment
DC Office
Divisional Forest Office
Kotwali Thana
FSCD
WASA
RAB Office
PDB Office
Union Settlement Office
Bangladesh Agriculture Research Institute
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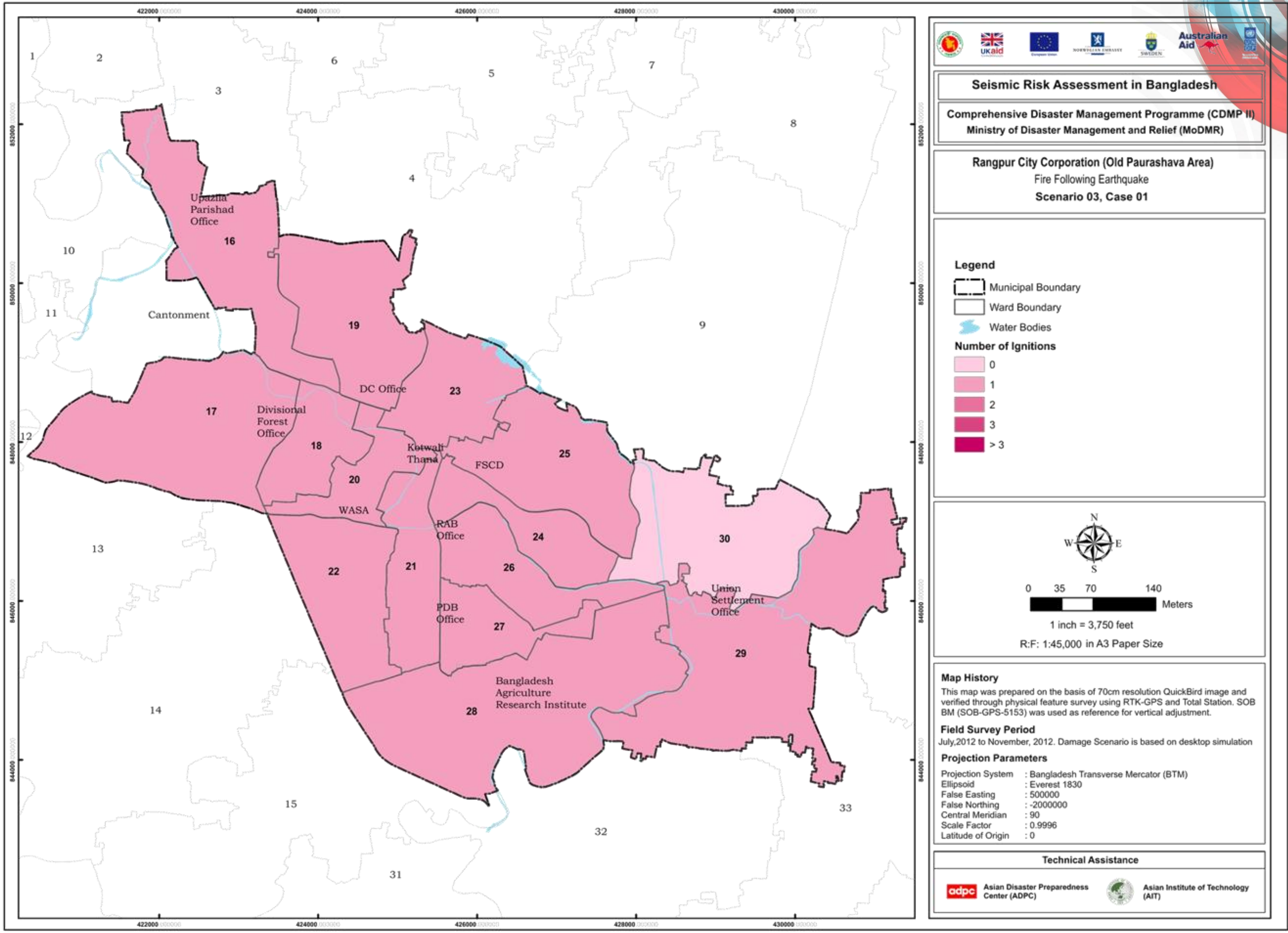

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Fire Following Earthquake
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Number of Ignitions
0
1
2
3
> 3
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0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
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July,2012 to November, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Upazila Parishad Office
Cantonment
DC Office
Divisional Forest Office
Kotwali Thana
FSCD
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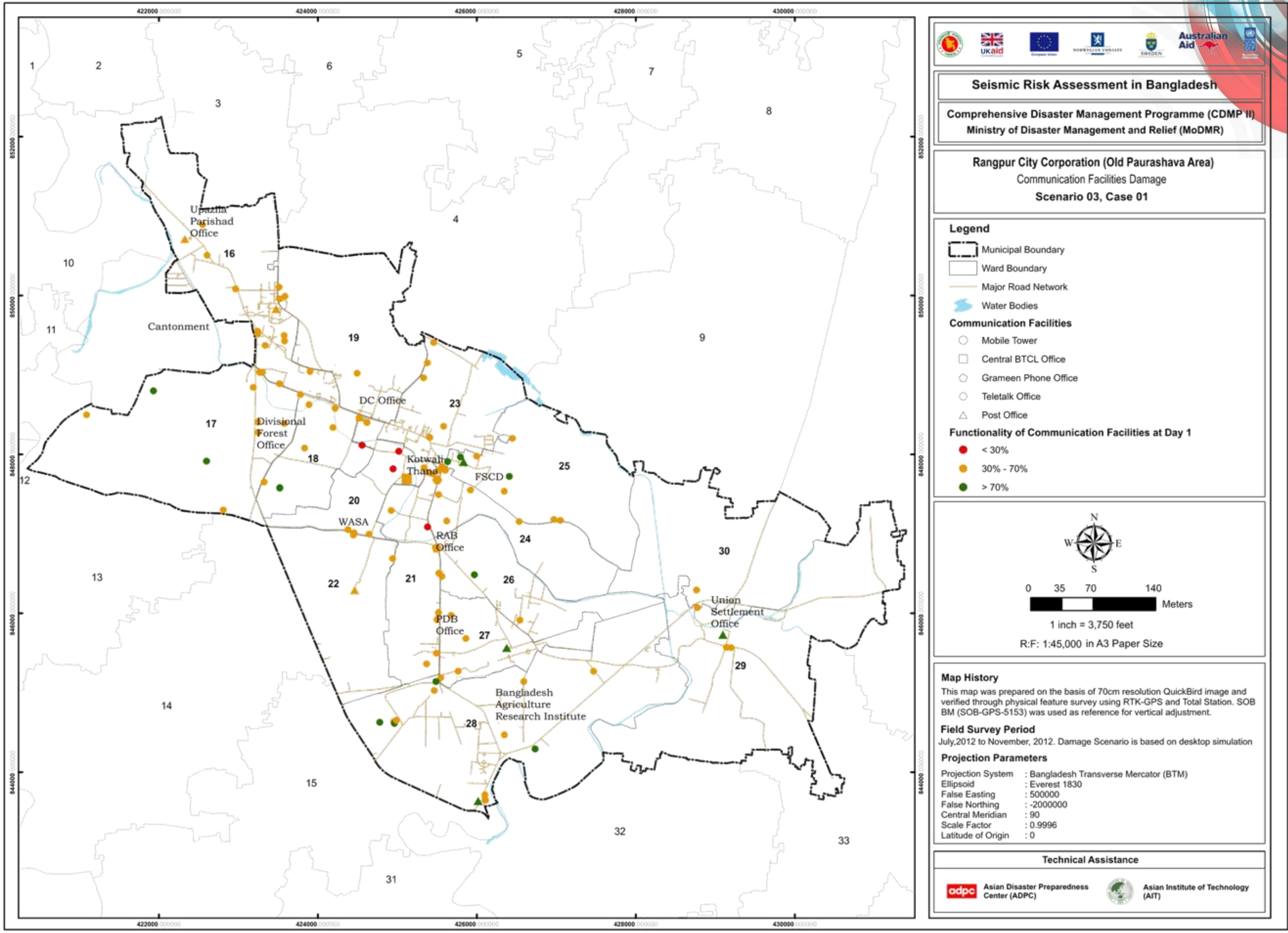
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Communication Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Communication Facilities
Mobile Tower
Central BTCL Office
Grameen Phone Office
Teletalk Office
Post Office
Functionality of Communication Facilities at Day 1
< 30%
30% - 70%
> 70%
N
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0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.
Field Survey Period
July,2012 to November, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Upazila Parishad Office
Cantonment
DC Office
Divisional Forest Office
Kotwali Thana
FSCD
WASA
RAB Office
PDB Office
Union Settlement Office
Bangladesh Agriculture Research Institute
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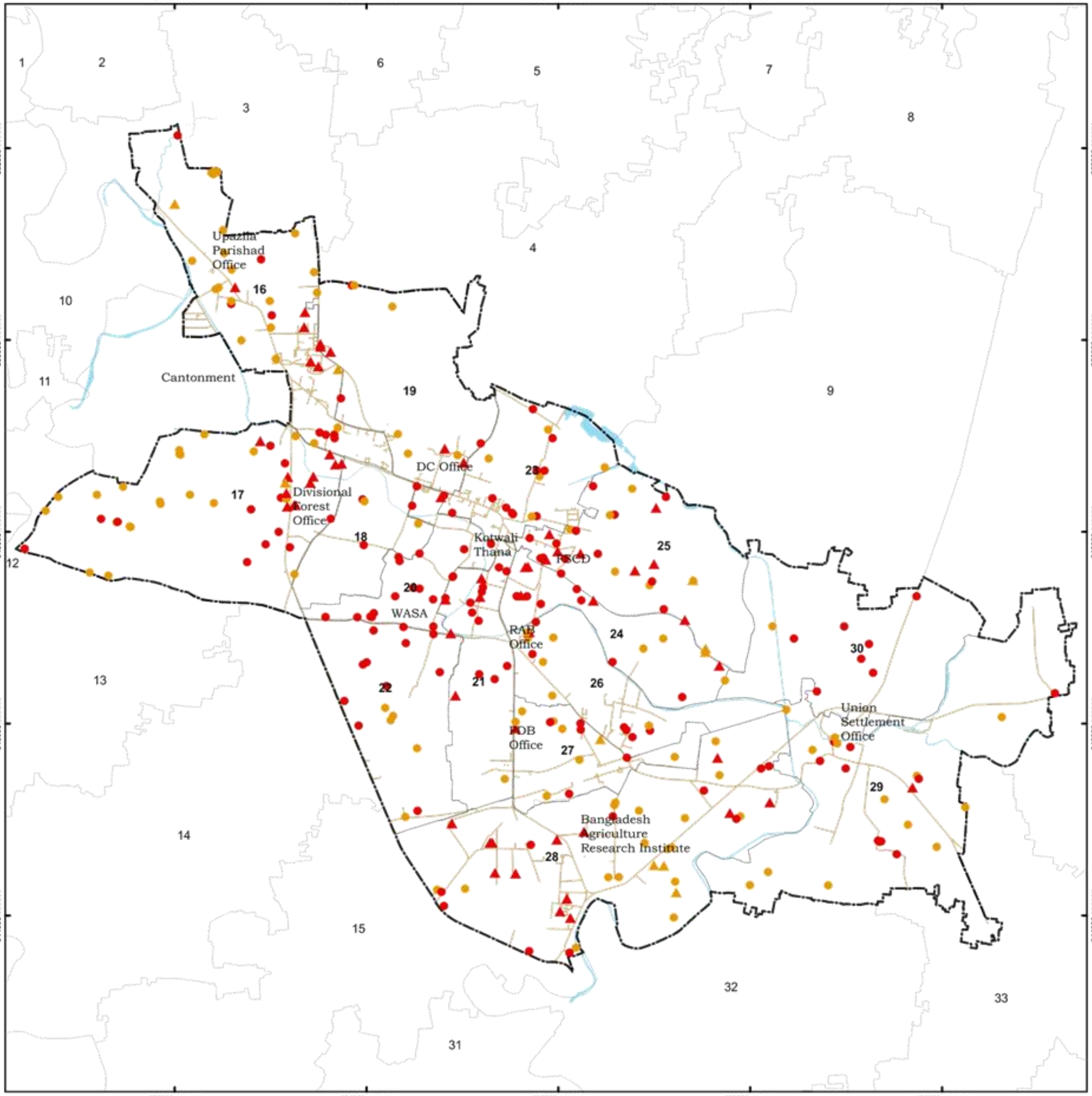


Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rangpur City Corporation (Old Paurashava Area)
Educational Institutes Damage
Scenario 03, Case 01

Legend

Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies

Educational Institutes

College
School

Functionality of Educational Institutes at Day 1

< 30%
30% - 70%
> 70%

N W E S

0 35 70 140 Meters

1 inch = 3,750 feet

R:F: 1:45,000 in A3 Paper Size

Map History

This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.

Field Survey Period

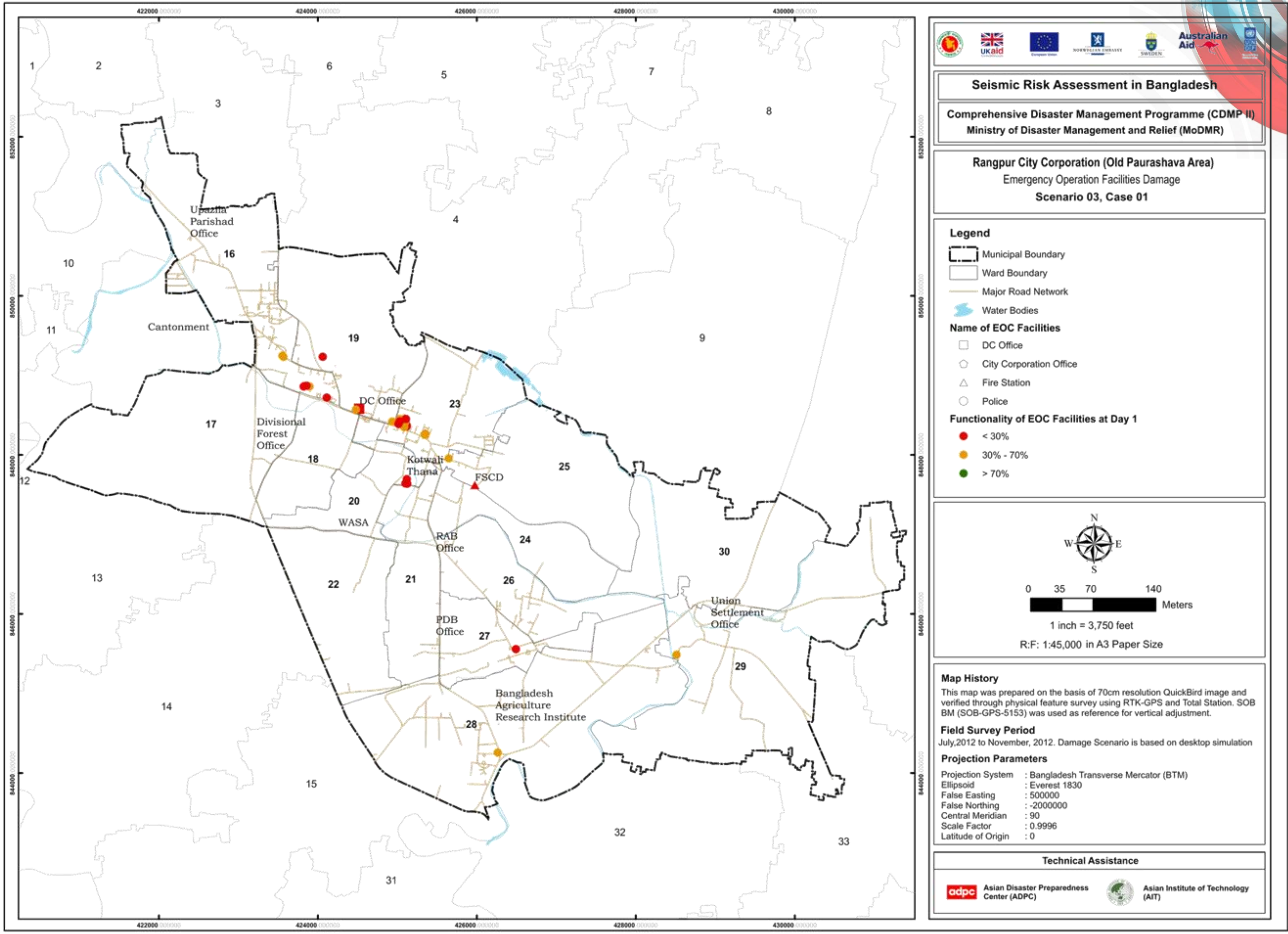
July,2012 to November, 2012. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Emergency Operation Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Name of EOC Facilities
DC Office
City Corporation Office
Fire Station
Police
Functionality of EOC Facilities at Day 1
< 30%
30% - 70%
> 70%
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Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.
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July,2012 to November, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
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Upazila Parishad Office
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DC Office
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Union Settlement Office
Bangladesh Agriculture Research Institute
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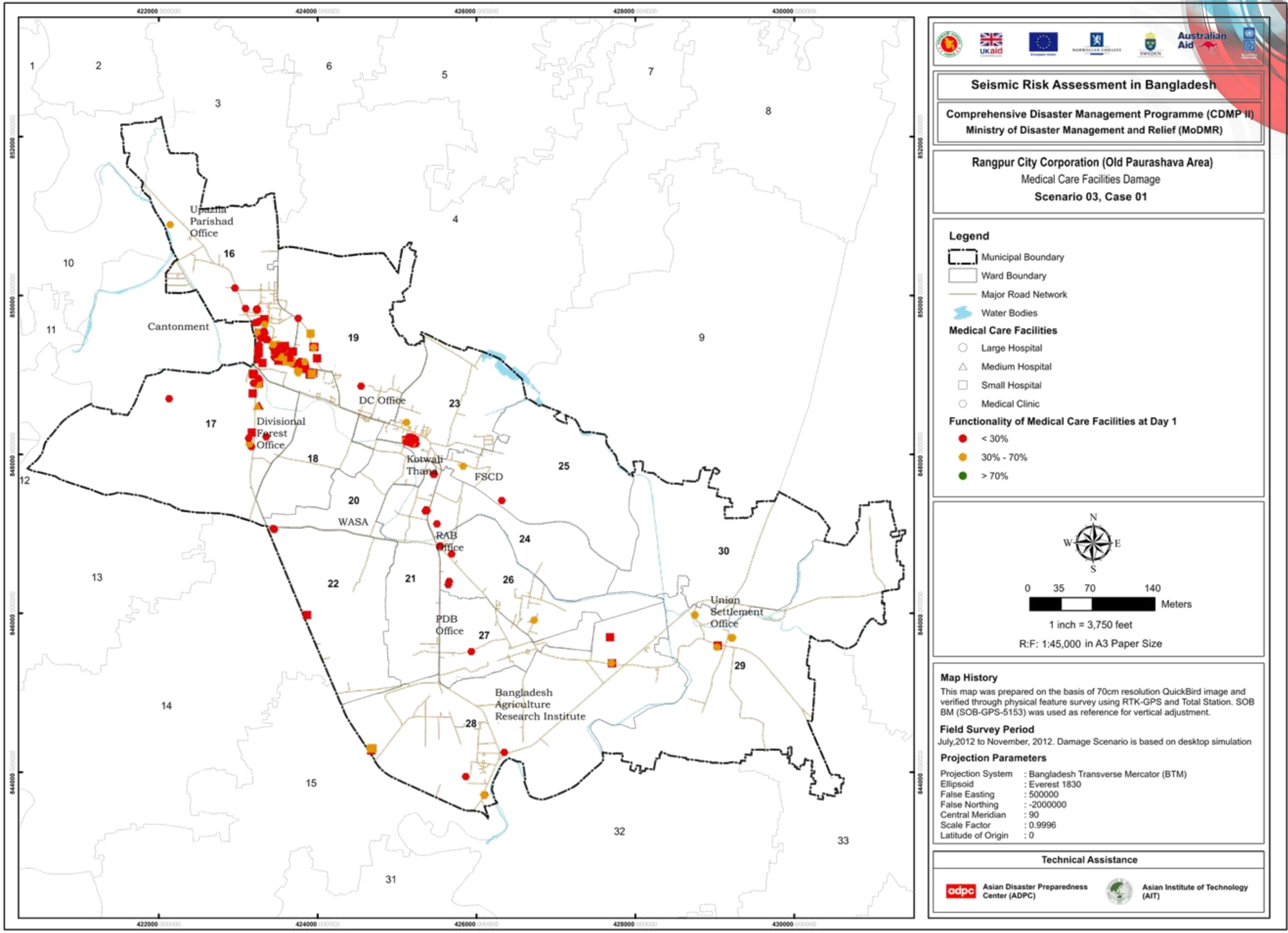
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Medical Care Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Medical Care Facilities
Large Hospital
Medium Hospital
Small Hospital
Medical Clinic
Functionality of Medical Care Facilities at Day 1
< 30%
30% - 70%
> 70%
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Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.
Field Survey Period
July,2012 to November, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Upazila Parishad Office
Cantonment
Divisional Forest Office
DC Office
Kotwali Thana
FSCD
WASA
RAB Office
PDB Office
Union Settlement Office
Bangladesh Agriculture Research Institute
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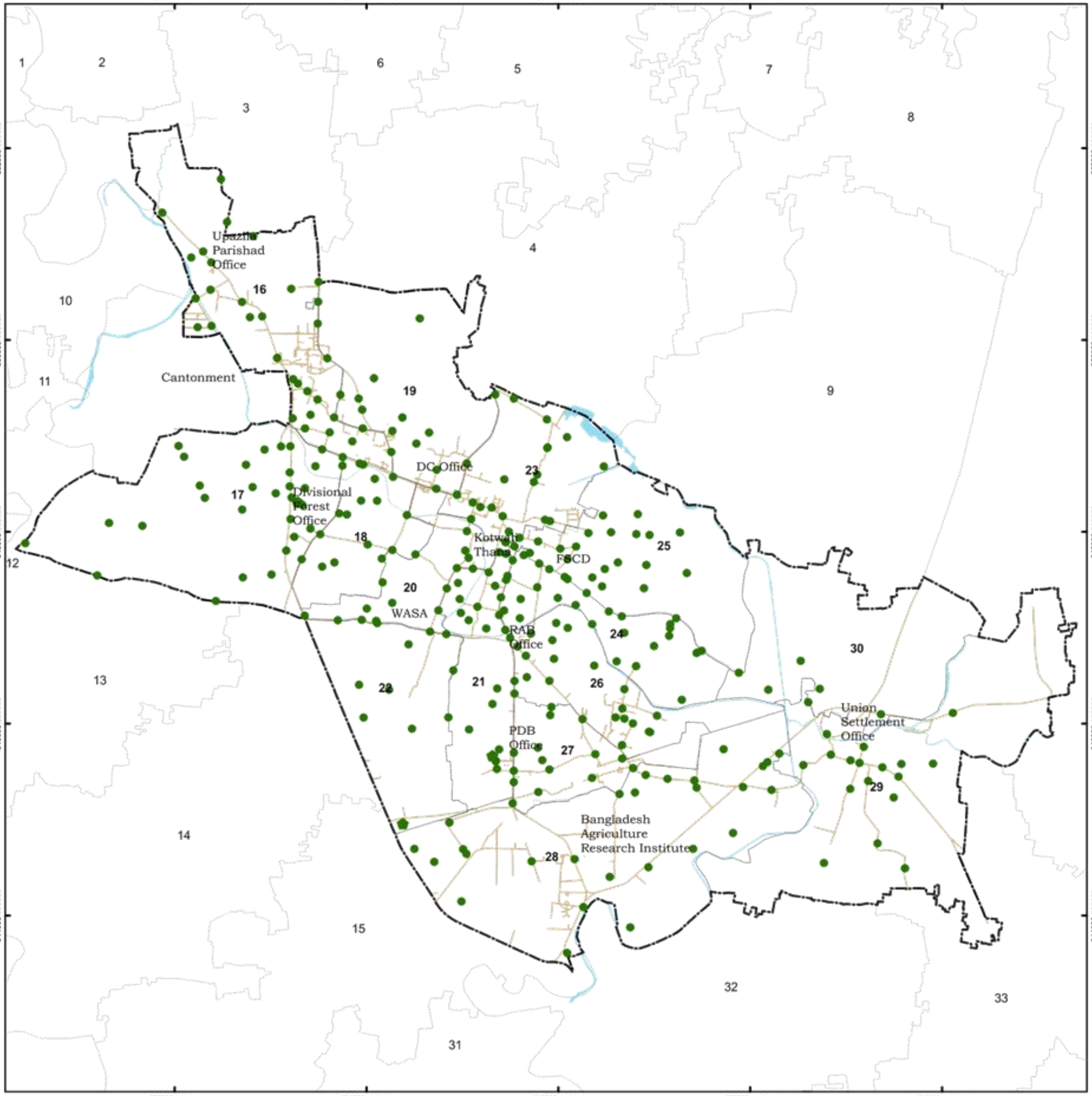


Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rangpur City Corporation (Old Paurashava Area)
Power System Damage
Scenario 03, Case 01

Legend

- Municipal Boundary
- Ward Boundary
- Major Road Network
- Water Bodies

Electric Facilities

- Electric Transformer
- Sub-Station

Functionality of Electric Facilities at Day 1

- < 30%
- 30% - 70%
- > 70%

N S W E

0 35 70 140 Meters

1 inch = 3,750 feet

R:F: 1:45,000 in A3 Paper Size

Map History

This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.

Field Survey Period

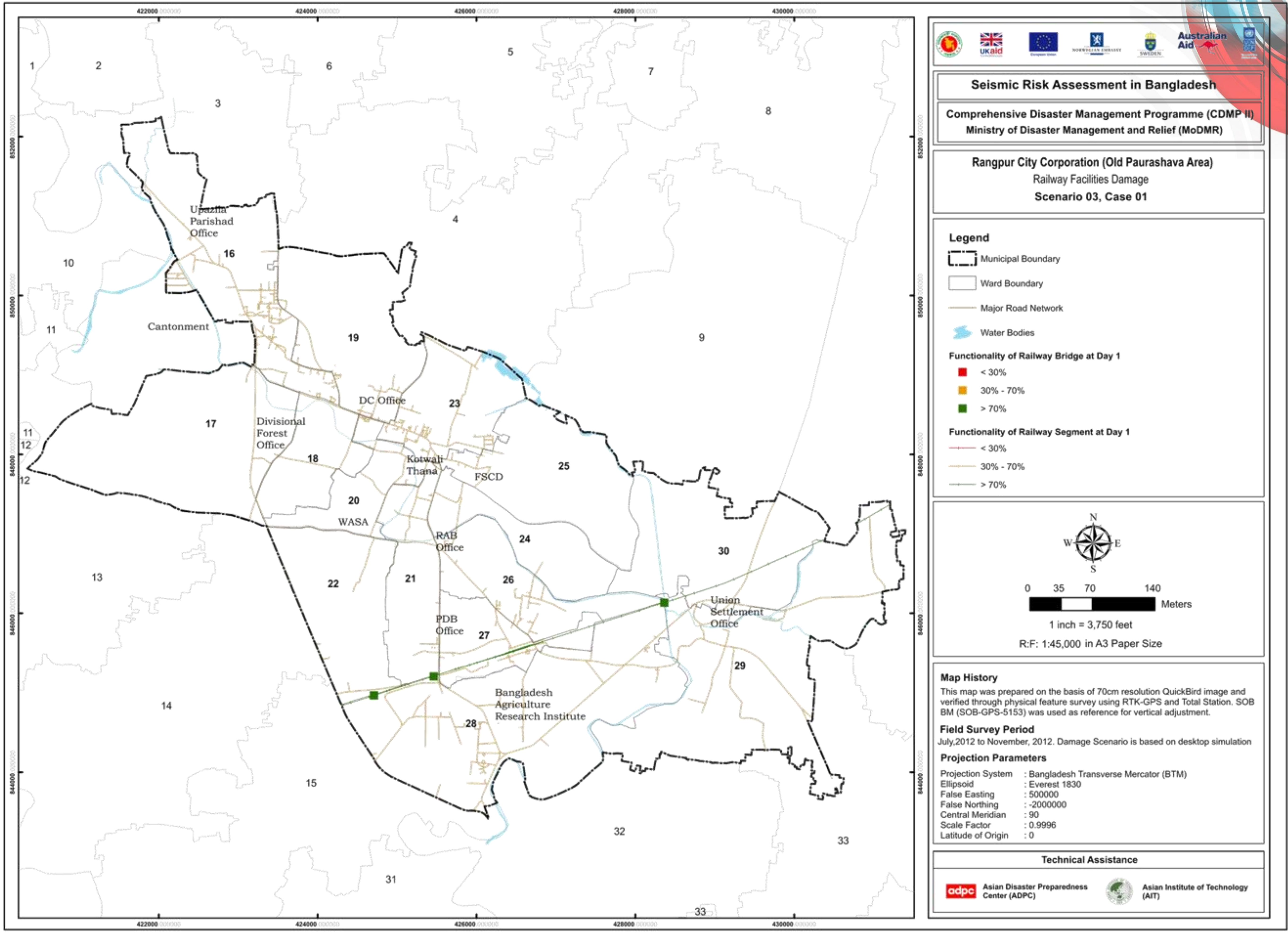
July,2012 to November, 2012. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Railway Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Functionality of Railway Bridge at Day 1
< 30%
30% - 70%
> 70%
Functionality of Railway Segment at Day 1
< 30%
30% - 70%
> 70%
N
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0 35 70 140
Meters
1 inch = 3,750 feet
R:F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.
Field Survey Period
July,2012 to November, 2012. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Upazila Parishad Office
Cantonment
DC Office
Divisional Forest Office
Kotwali Thana
FSCD
WASA
RAB Office
PDB Office
Union Settlement Office
Bangladesh Agriculture Research Institute
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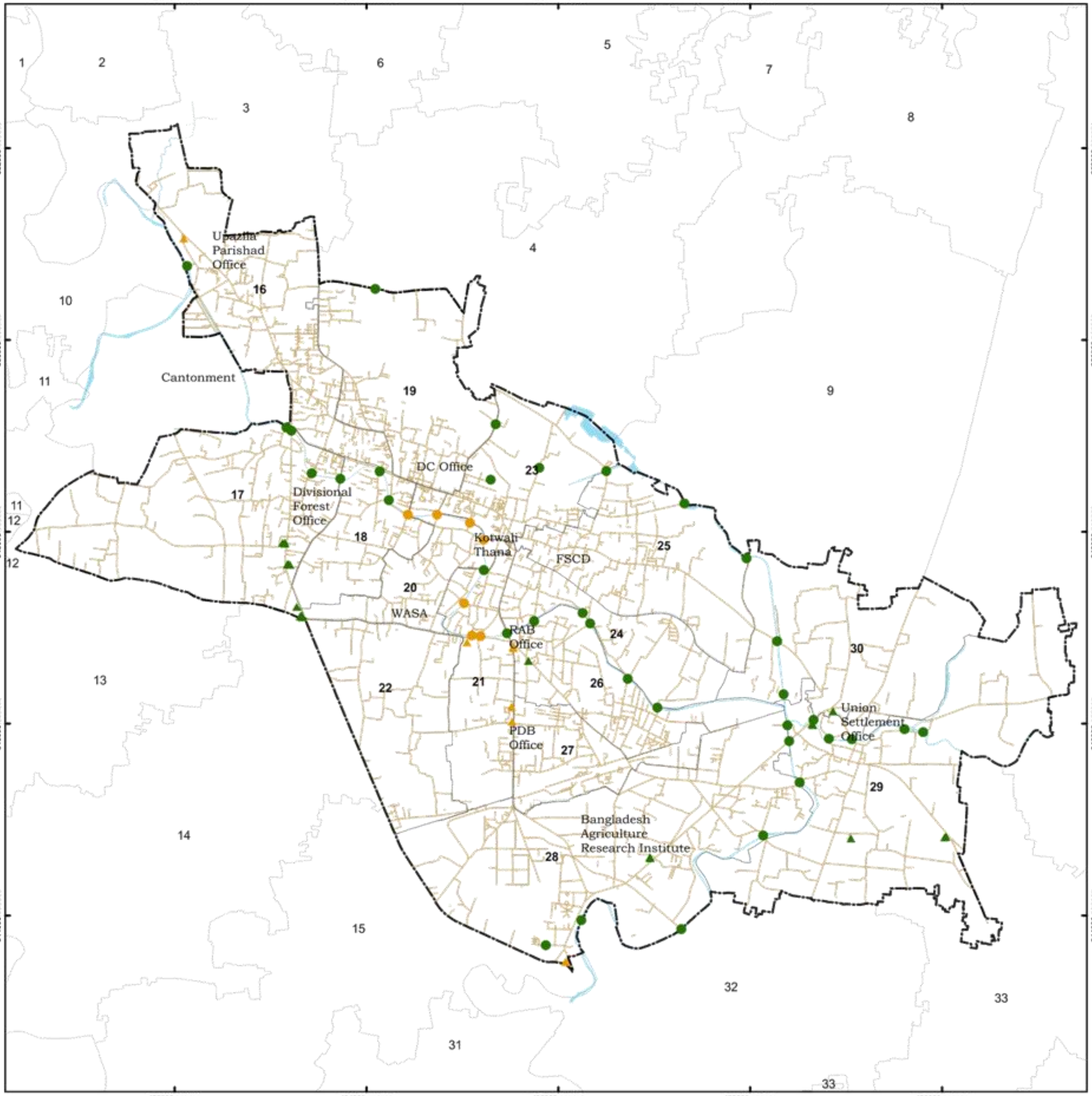


Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rangpur City Corporation (Old Paurashava Area)
Road Transport Facilities Damage
Scenario 03, Case 01

Legend
- Municipal Boundary
- Ward Boundary
- Major Road Network
- Water Bodies

Functionality of Highway Bridge at Day 1
- < 30%
- 30% - 70%
- > 70%

Functionality of Bus Facilities at Day 1
- < 30%
- 30% - 70%
- < 70%

N W E S

0 35 70 140 Meters

1 inch = 3,750 feet

R:F: 1:45,000 in A3 Paper Size

Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.

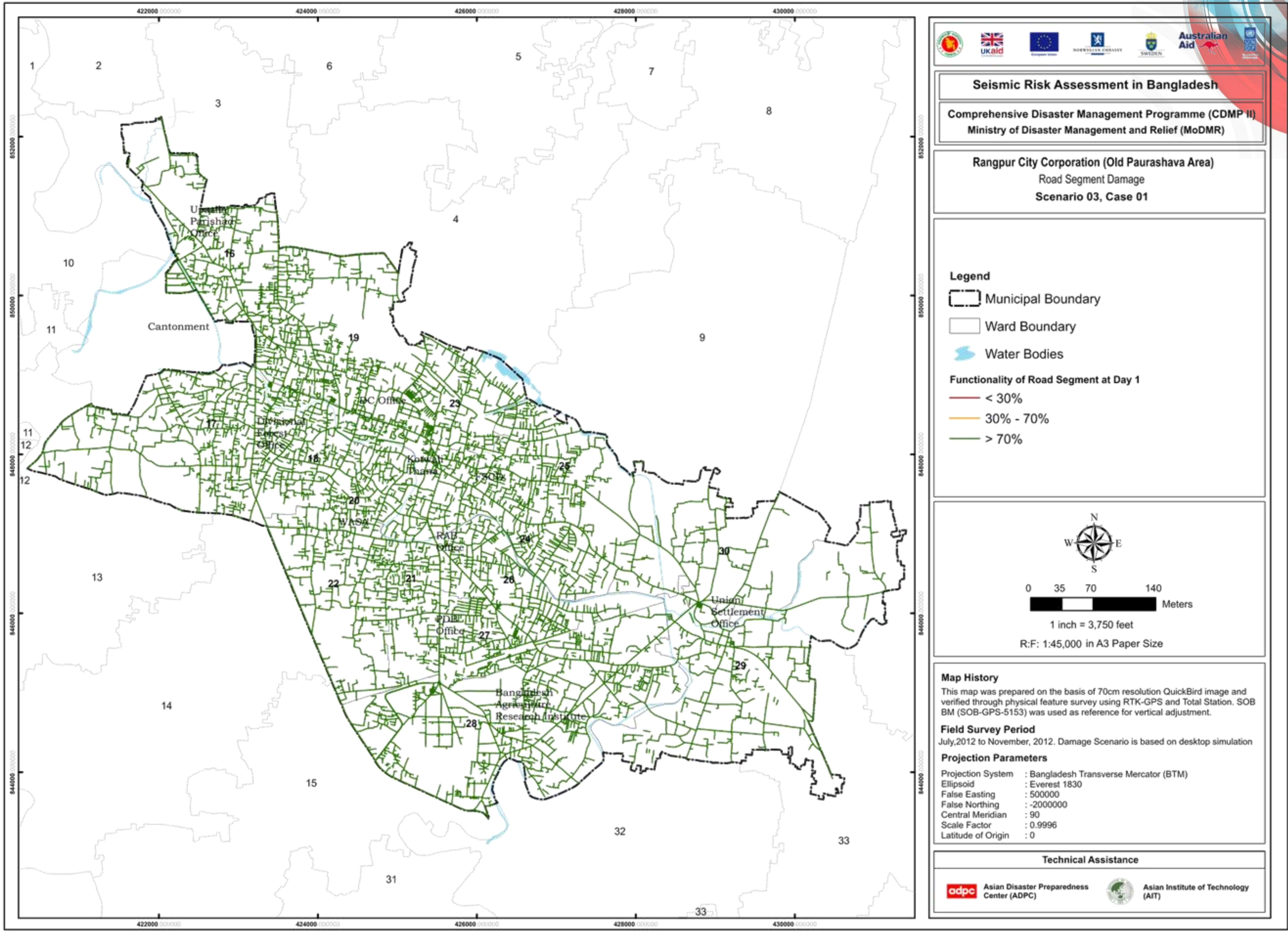
Field Survey Period
July,2012 to November, 2012. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)



Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Rangpur City Corporation (Old Paurashava Area)
Road Segment Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Functionality of Road Segment at Day 1
< 30%
30% - 70%
> 70%
N
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0 35 70 140
Meters
1 inch = 3,750 feet
R.F: 1:45,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-5153) was used as reference for vertical adjustment.
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Ellipsoid : Everest 1830
False Easting : 500000
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Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Cantonment
Upazila Parishad Office
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Kotwali Thana
WASA
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Union Settlement Office
Bangladesh Agriculture Research Institute
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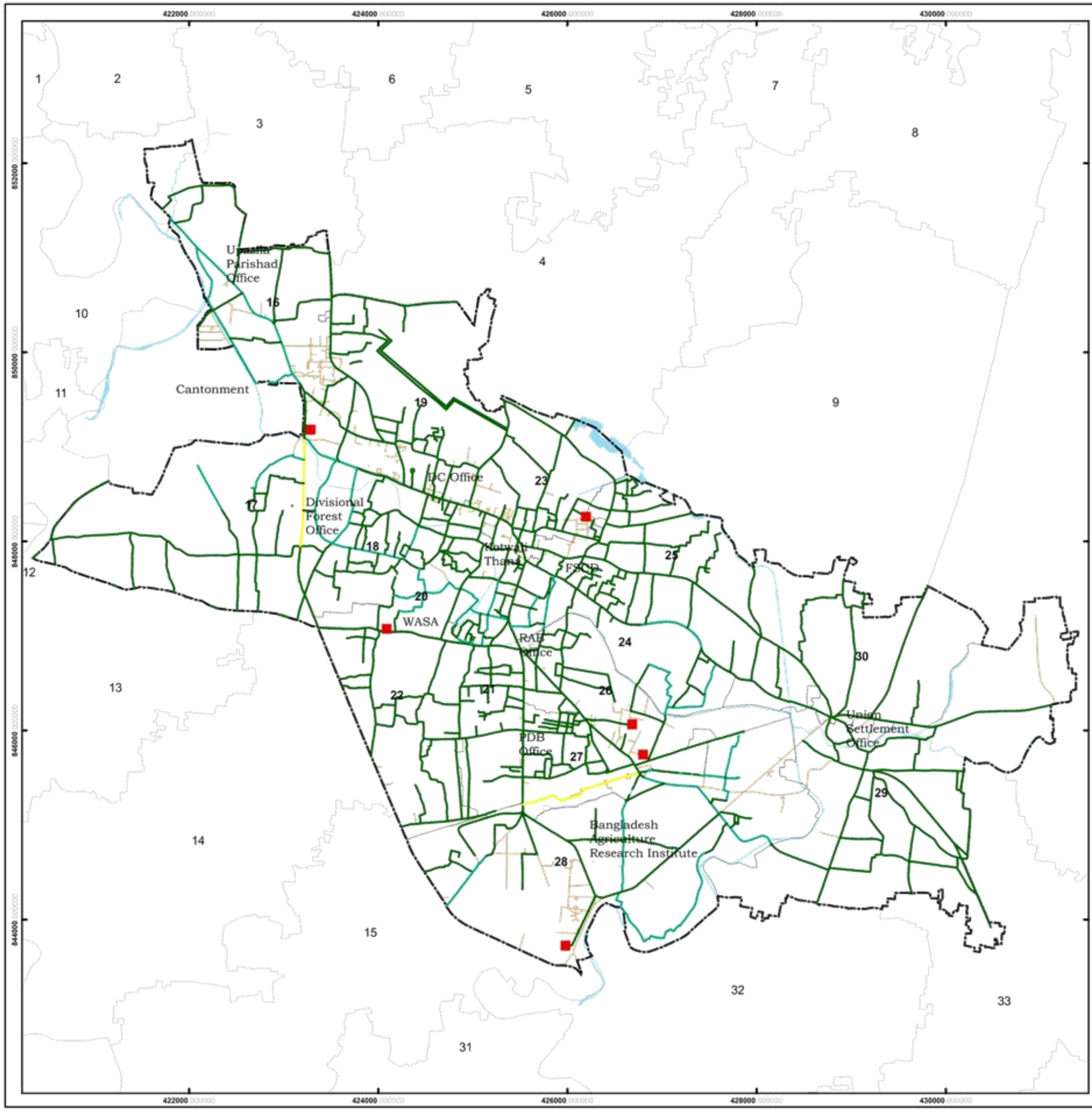

Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Rangpur City Corporation (Old Paurashava Area)
Potable Water System Damage
Scenario 03, Case 01

Legend

- Municipal Boundary
- Ward Boundary
- Major Road Network
- Water Bodies

Potable Water Facilities

- Overhead Tank
- Water Pump

Functionality of Potable Water Facilities at Day 1

- < 30%
- 30% - 70%
- > 70%

Potable Water Supply Network

Number of Repair Per k.m.

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- > 4

N
W E
S

0 35 70 140
Meters

1 inch = 3,750 feet

R.F: 1:45,000 in A3 Paper Size

Map History

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Field Survey Period

July,2012 to November, 2012. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance

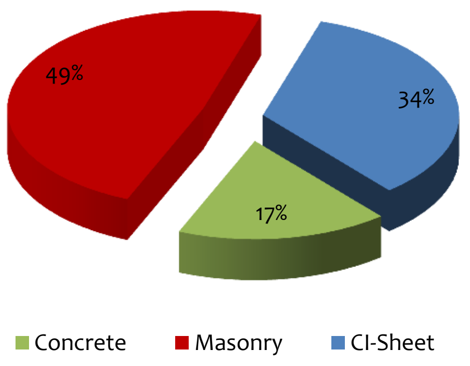
Asian Disaster Preparedness Center (ADPC)

Asian Institute of Technology (AIT)

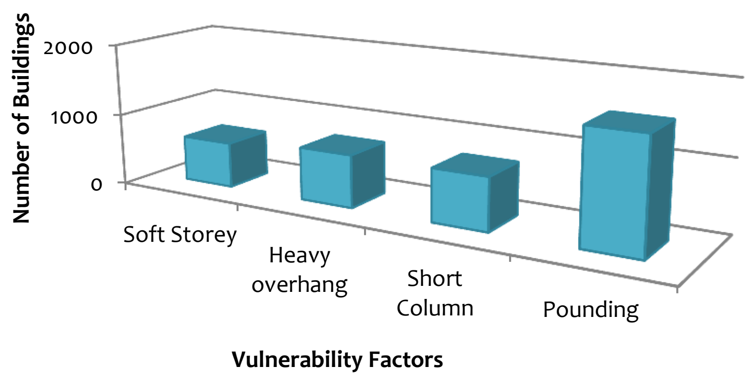
Tangail Paurashava

Tangail Paurashava was established in 1876.The main town of the District is the Tangail Paurashava which consists of 18 wards and 63 mahallas. The area of the town is 35.22 sq. km. It has a population of 167412 (male 51.44%%, female 48.56%). The population density is 4753 per sq km. Main occupations include agriculture 31.89%, agricultural laborer 13.74%, wage laborer 3.58%, weaving 3.9%, industry 3.13%, commerce 14.56%, transport 6.16%, service 10.7%, and others 12.34%.

Structural type in Tangail Paurashava

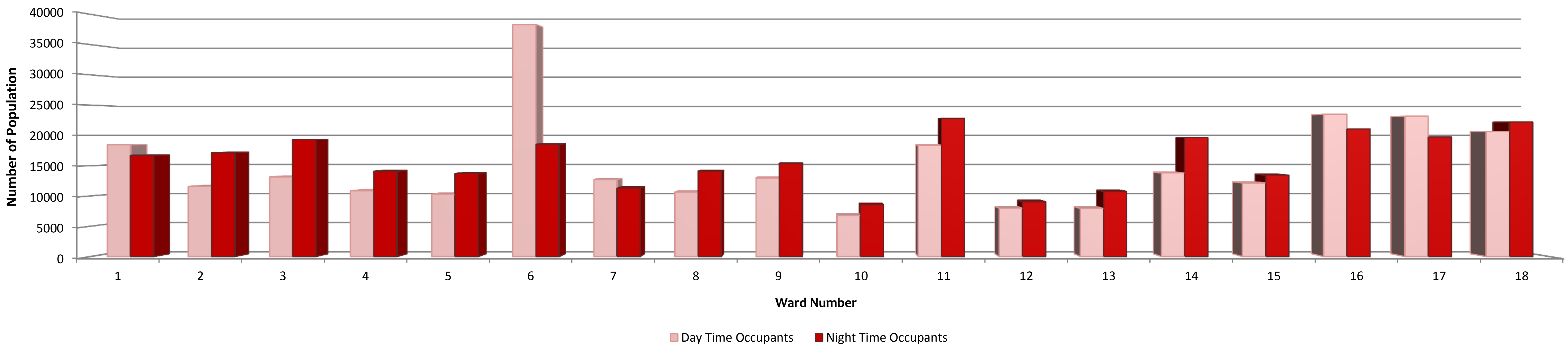


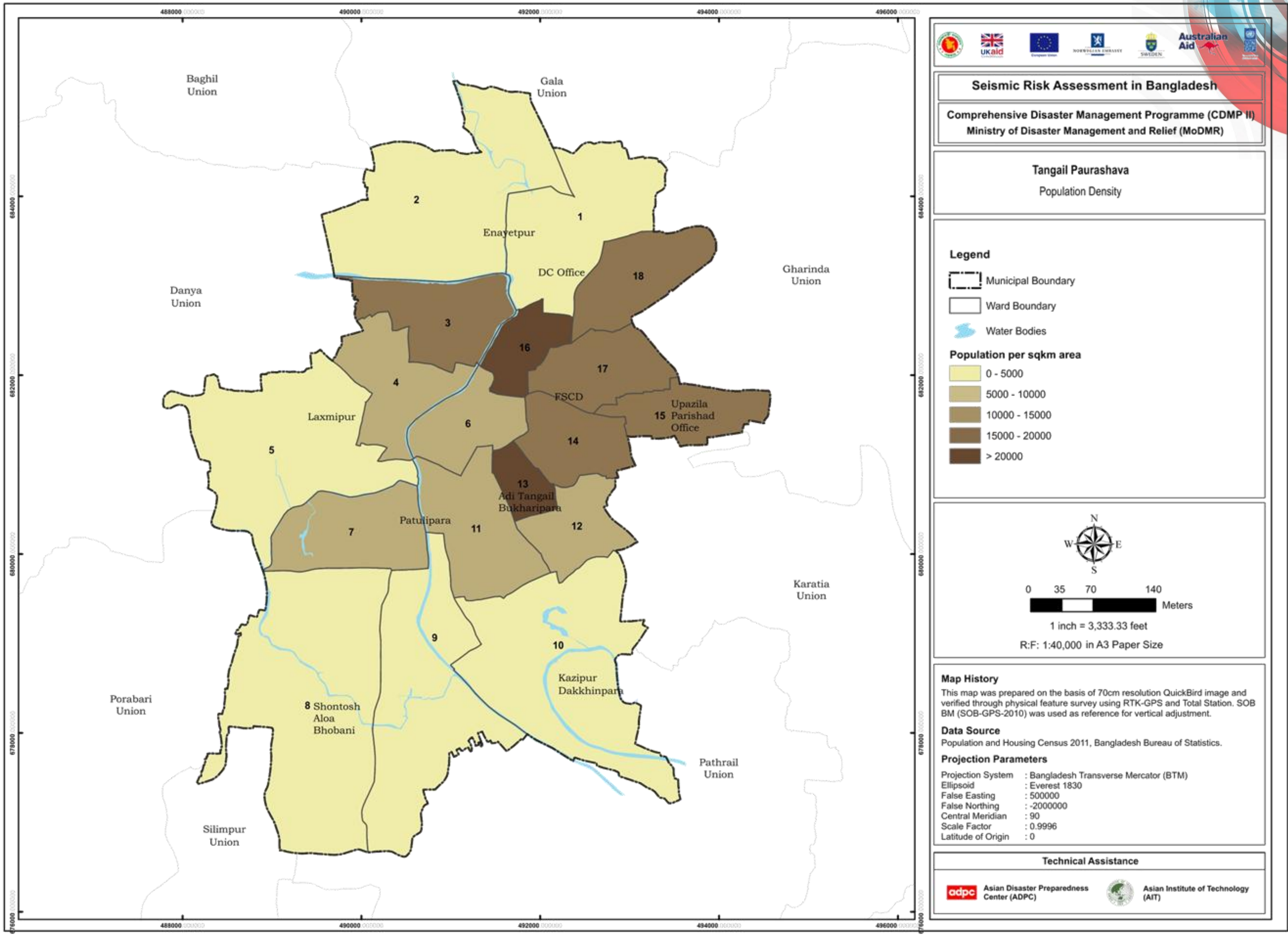
Vulnerability factors in Tangail Paurashava



Brief Information of the City	
Name of the City	Tangail
Name of the Paurashava	Tangail Paurashava
Year of Establishment	1876
Total Area	35.22 sq. km.
Number of Wards	18
Total Population	167412(Male-84741, Female-82671)
Population Growth Rate (2011)	0.90%
Road Network	256.50 km
Railways	N/A
Water Ways	N/A
Natural Water Bodies	2.7 km or 681.5 Acre
Open Space	137064 sq. m or 33.87 Acre
Education Institutions	174
Health Facilities	40
Re-fueling Stations	8
Fire Station	1
Police Station	1

Day & Night Occupants in Tangail Paurashava




Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Population Density
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Population per sqkm area
0 - 5000
5000 - 10000
10000 - 15000
15000 - 20000
> 20000
N
W
E
S
0 35 70 140
Meters
1 inch = 3,333.33 feet
R:F: 1:40,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-2010) was used as reference for vertical adjustment.
Data Source
Population and Housing Census 2011, Bangladesh Bureau of Statistics.
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Baghil Union
Gala Union
Danya Union
Gharinda Union
Karatia Union
Porabari Union
Pathrail Union
Silimpur Union
Enayetpur
DC Office
FSCD
Upazila Parishad Office
Laxmipur
Patulipara
Adi Tangail Bukharipara
Shontosh Aloa Bhobani
Kazipur Dakkhinpara
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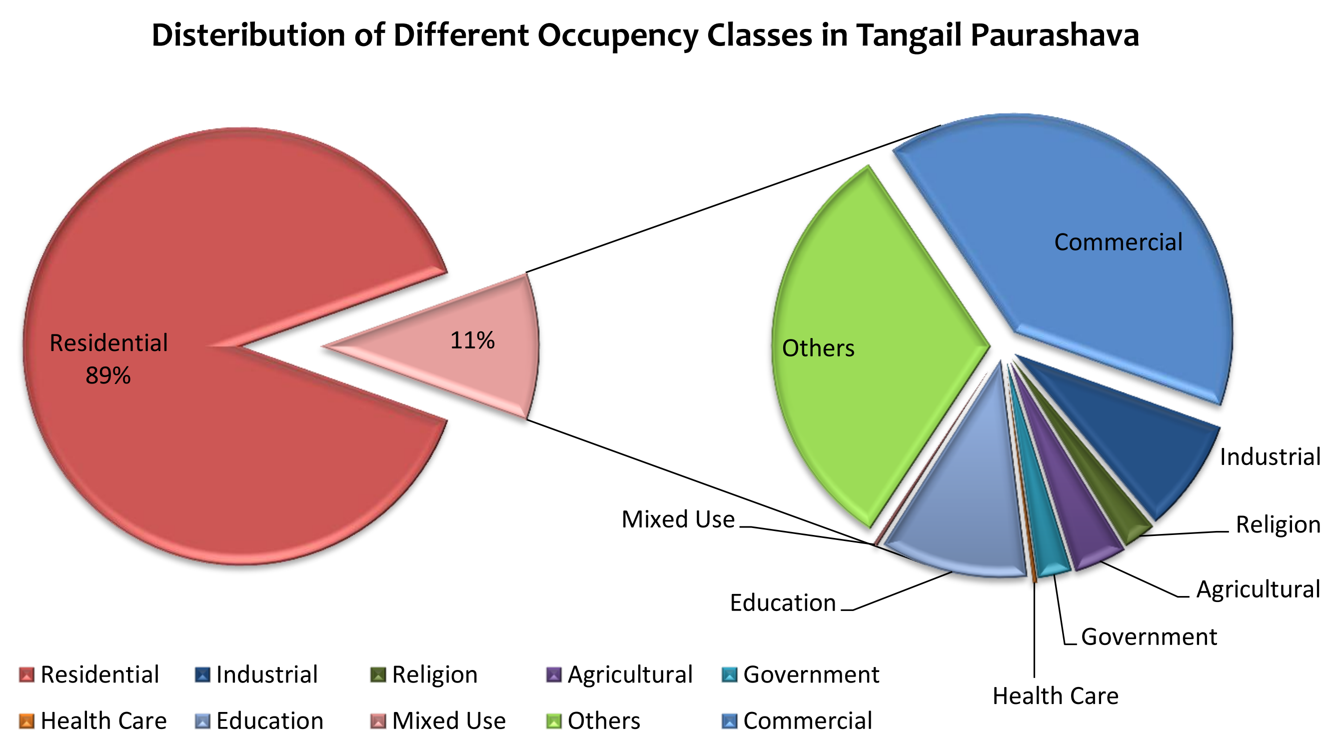
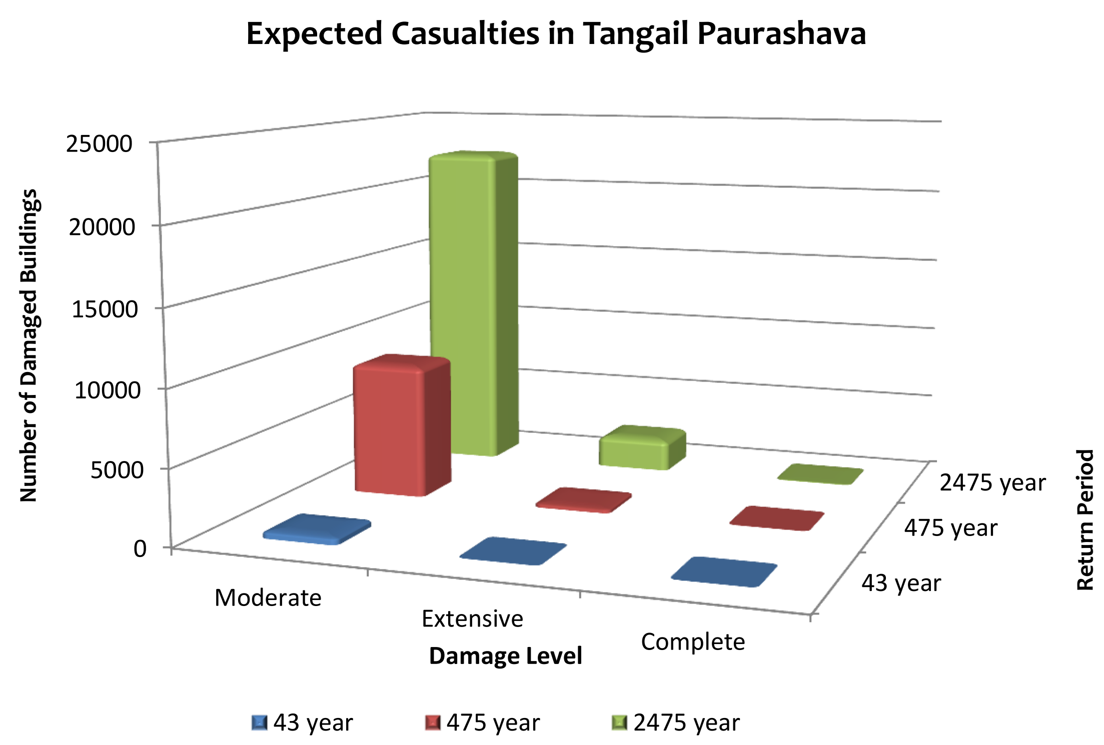




Expected physical damage states

Table 25: Expected physical damage states of buildings for different scenario cases

Scenarios	Total Structure	Concrete Structure						Masonry Structure						Informal Structures				
		Total Concrete Structure	Moderate Damage		Complete Damage		Total Masonry Structure	Moderate Damage		Complete Damage		Total Zinc Shed and Bamboo Structure	Moderate Damage		Complete Damage	
			No.	%	No.	%		No.	%	No.	%		No.	%	No.	%
Scenario 1 Case 1	62357	4864	44	0.90%	0	0.00%	13076	150	1.15%	0	0.00%	44417	333	0.75%	0	0.00%
Scenario 2 Case 2	62357	4864	155	3.19%	0	0.00%	13076	23	0.18%	0	0.00%	44417	36	0.08%	0	0.00%
Scenario 3 Case 1	62357	4864	804	16.53%	0	0.00%	13076	2475	18.93%	4	0.03%	44417	5758	12.96%	0	0.00%
Scenario 4 Case 2	62357	4864	1328	27.30%	46	0.95%	13076	829	6.34%	25	0.19%	44417	1343	3.02%	0	0.00%
Scenario 5 Case 1	62357	4864	1968	40.46%	9	0.19%	13076	5585	42.71%	57	0.44%	44417	14914	33.58%	3	0.01%
Scenario 6 Case 2	62357	4864	999	20.54%	514	10.57%	13076	5235	40.04%	776	5.93%	44417	5360	12.07%	0	0.00%

Debris Generation

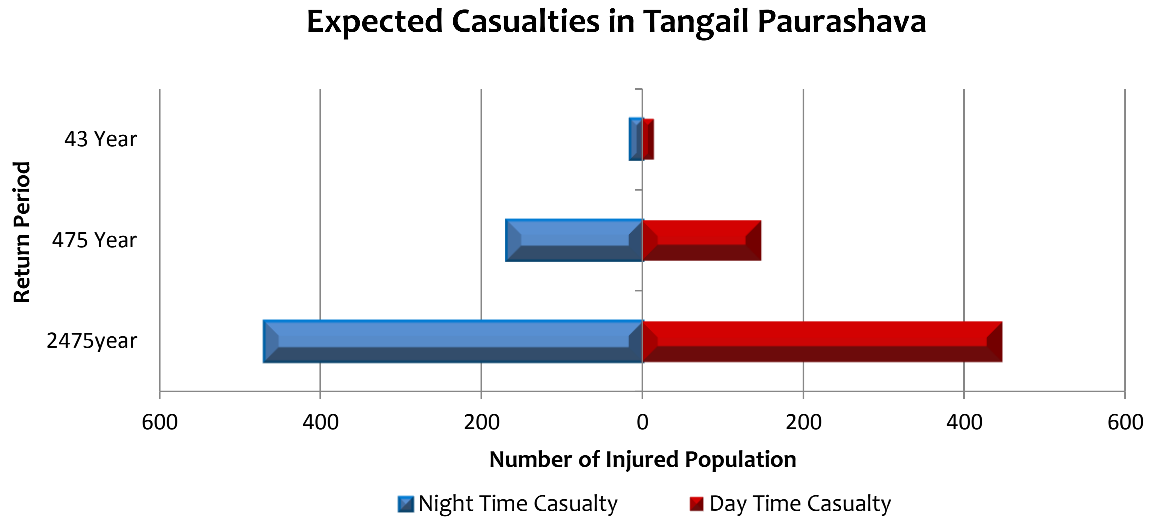
Table 26: Expected debris generation for different scenario cases

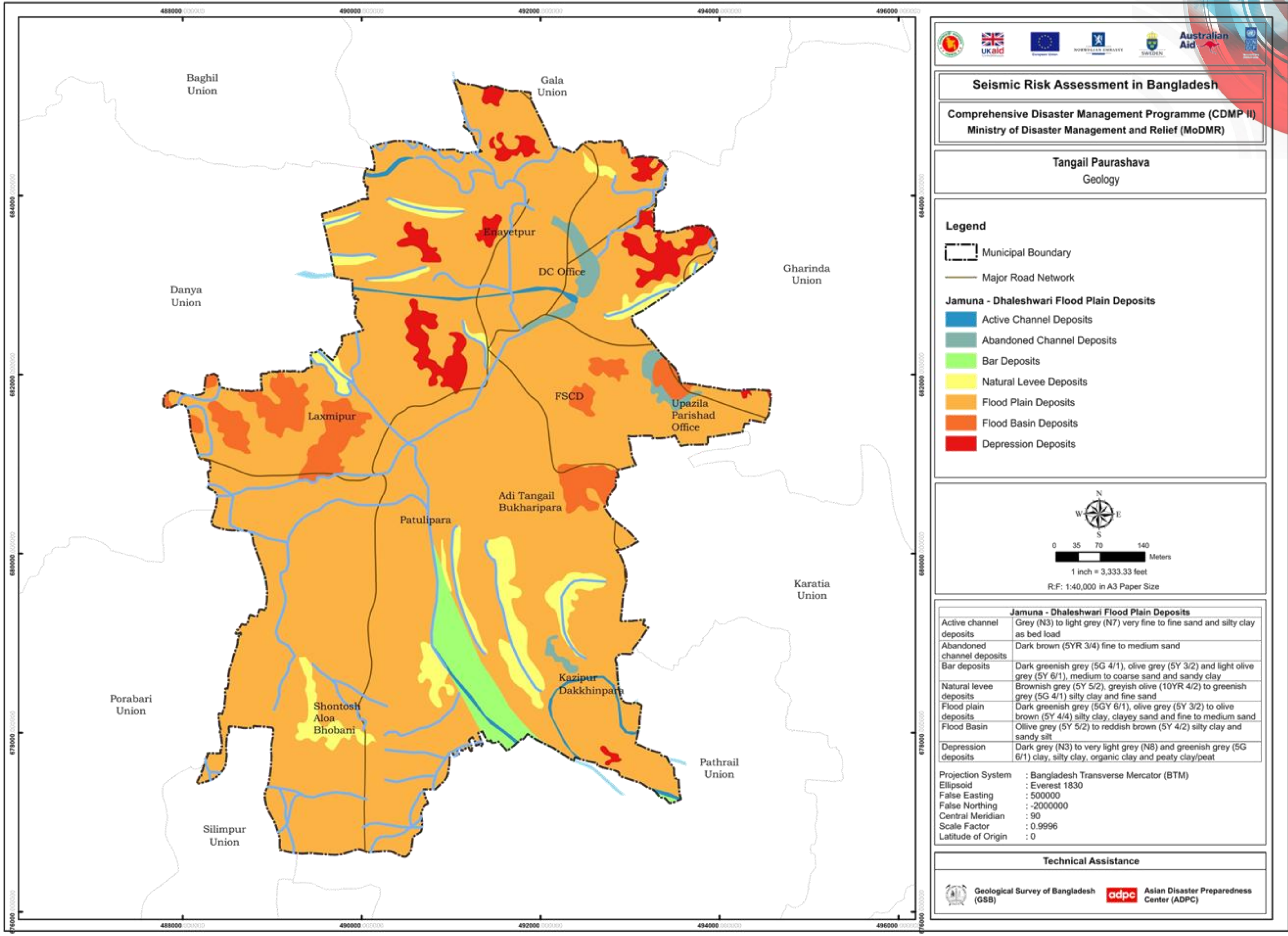
Earthquake Scenario	Amount of Debris (million tons)	% of Concrete and Steel materials	% of Brick and Wood materials
Scenario 1 Case 1	0.0	0.0	0.0
Scenario 2 Case 2	0.0	0.0	0.0
Scenario 3 Case 1	0.040	33%	67%
Scenario 4 Case 2	0.070	58%	42%
Scenario 5 Case 1	0.13	51%	49%
Scenario 6 Case 2	0.35	72%	28%

Damage of Utility and Lifelines

Table 27: Expect Expected damage to lifelines for scenario3 case 1

System	Component	Total	Moderate Damage	Complete Damage	At least 50% Functional	
					Day 1	Day 7
Highway	Segments	2510	0	0	2510	2510
	Bridges	48	0	0	48	48
	Facilities	11	0	0	11	11




Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Geology
Legend
Municipal Boundary
Major Road Network
Jamuna - Dhaleshwari Flood Plain Deposits
Active Channel Deposits
Abandoned Channel Deposits
Bar Deposits
Natural Levee Deposits
Flood Plain Deposits
Flood Basin Deposits
Depression Deposits
N
S
E
W
0
35
70
140
Meters
1 inch = 3,333.33 feet
R:F: 1:40,000 in A3 Paper Size
Jamuna - Dhaleshwari Flood Plain Deposits
Active channel deposits: Grey (N3) to light grey (N7) very fine to fine sand and silty clay as bed load
Abandoned channel deposits: Dark brown (5YR 3/4) fine to medium sand
Bar deposits: Dark greenish grey (5G 4/1), olive grey (5Y 3/2) and light olive grey (5Y 6/1), medium to coarse sand and sandy clay
Natural levee deposits: Brownish grey (5Y 5/2), greyish olive (10YR 4/2) to greenish grey (5G 4/1) silty clay and fine sand
Flood plain deposits: Dark greenish grey (5GY 6/1), olive grey (5Y 3/2) to olive brown (5Y 4/4) silty clay, clayey sand and fine to medium sand
Flood Basin: Ollive grey (5Y 5/2) to reddish brown (5Y 4/2) silty clay and sandy silt
Depression deposits: Dark grey (N3) to very light grey (N8) and greenish grey (5G 6/1) clay, silty clay, organic clay and peaty clay/peat
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Geological Survey of Bangladesh (GSB)
adpc
Asian Disaster Preparedness Center (ADPC)
UKaid
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Danya Union
Gharinda Union
Karatia Union
Porabari Union
Pathrail Union
Silimpur Union
Enayetpur
DC Office
FSCD
Upazila Parishad Office
Laxmipur
Adi Tangail Bukharipara
Patulipara
Kazipur Dakkhinpara
Shontosh Aloa Bhobani
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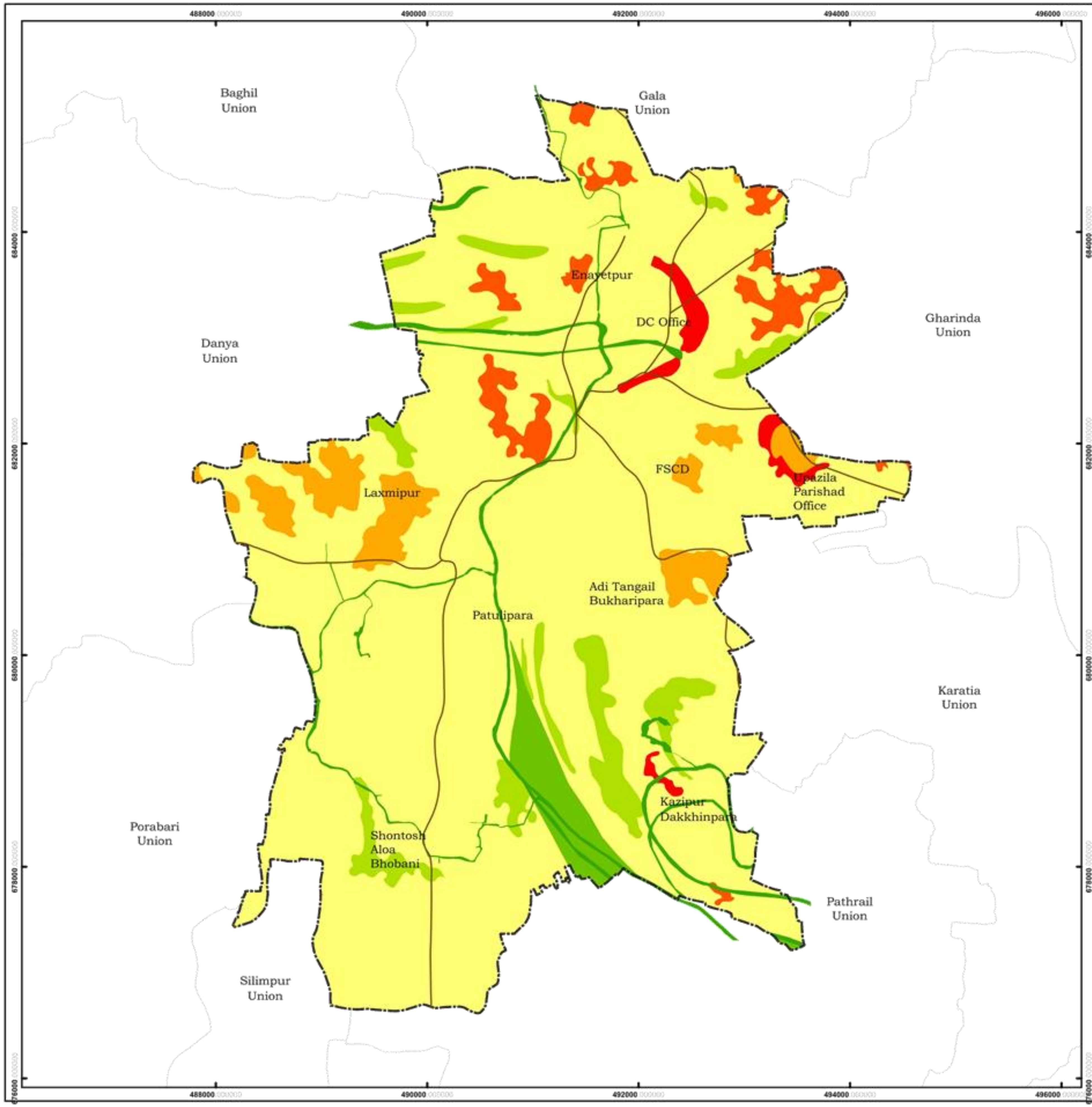

Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
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Geomorphology

Legend

- Municipal Boundary
- Major Road Network

Jamuna - Dhaleshwari Flood Plain

- Active Channel
- Lateral Bar
- Natural Levee
- Flood Plain
- Flood Basin
- Depression
- Ox-bow Lake

N W E S

0 35 70 140 Meters

1 inch = 3,333.33 feet

R:F: 1:40,000 in A3 Paper Size

Jamuna - Dhaleshwari Flood Plain	
Active channel	Channel with flowing water having sand as bed loads
Lateral bar	Lateral accumulation of sand along the river consists of medium to course sand
Natural levee	Irregular shaped deposit of sediments built up along and sloping towards the flood plain; consist of sand and silty clay
Flood plain	Broad flood areas normally inundated by seasonal flood consist of silty clay and clayey sand
Flood basin	Irregular shaped low-lying parts within the flood plain having seasonal water body; consists of silty clay and sandy silt
Depressi on	Irregular shaped depressed areas within floodplain having permanent water; consists of clay, silty clay and peaty clay/peat
Ox-bow lake	Ox-bow shaped body of water formed by neck cut off of meandering channels; consists of fine to medium sand

Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0

Technical Assistance

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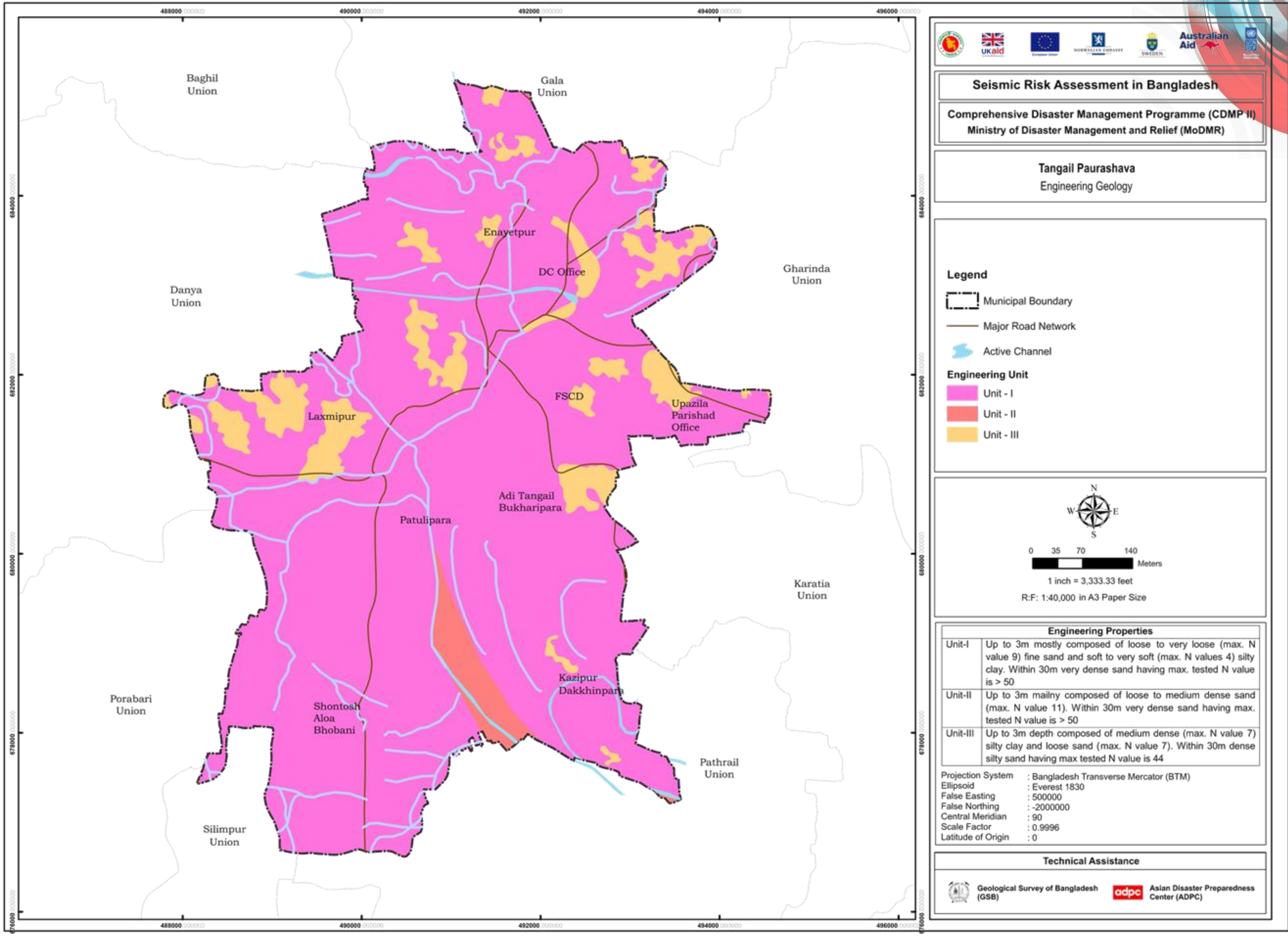

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Engineering Geology
Legend
Municipal Boundary
Major Road Network
Active Channel
Engineering Unit
Unit - I
Unit - II
Unit - III
N
W
E
S
0
35
70
140
Meters
1 inch = 3,333.33 feet
R:F: 1:40,000 in A3 Paper Size
Engineering Properties
Unit-I
Up to 3m mostly composed of loose to very loose (max. N value 9) fine sand and soft to very soft (max. N values 4) silty clay. Within 30m very dense sand having max. tested N value is > 50
Unit-II
Up to 3m mailny composed of loose to medium dense sand (max. N value 11). Within 30m very dense sand having max. tested N value is > 50
Unit-III
Up to 3m depth composed of medium dense (max. N value 7) silty clay and loose sand (max. N value 7). Within 30m dense silty sand having max tested N value is 44
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Geological Survey of Bangladesh (GSB)
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Asian Disaster Preparedness Center (ADPC)
UKaid
Australian Aid
SWEDEN
Baghil Union
Gala Union
Danya Union
Gharinda Union
Karatia Union
Porabari Union
Pathrail Union
Silimpur Union
Enayetpur
DC Office
Laxmipur
FSCD
Upazila Parishad Office
Adi Tangail Bukharipara
Patulipara
Kazipur Dakkhinpara
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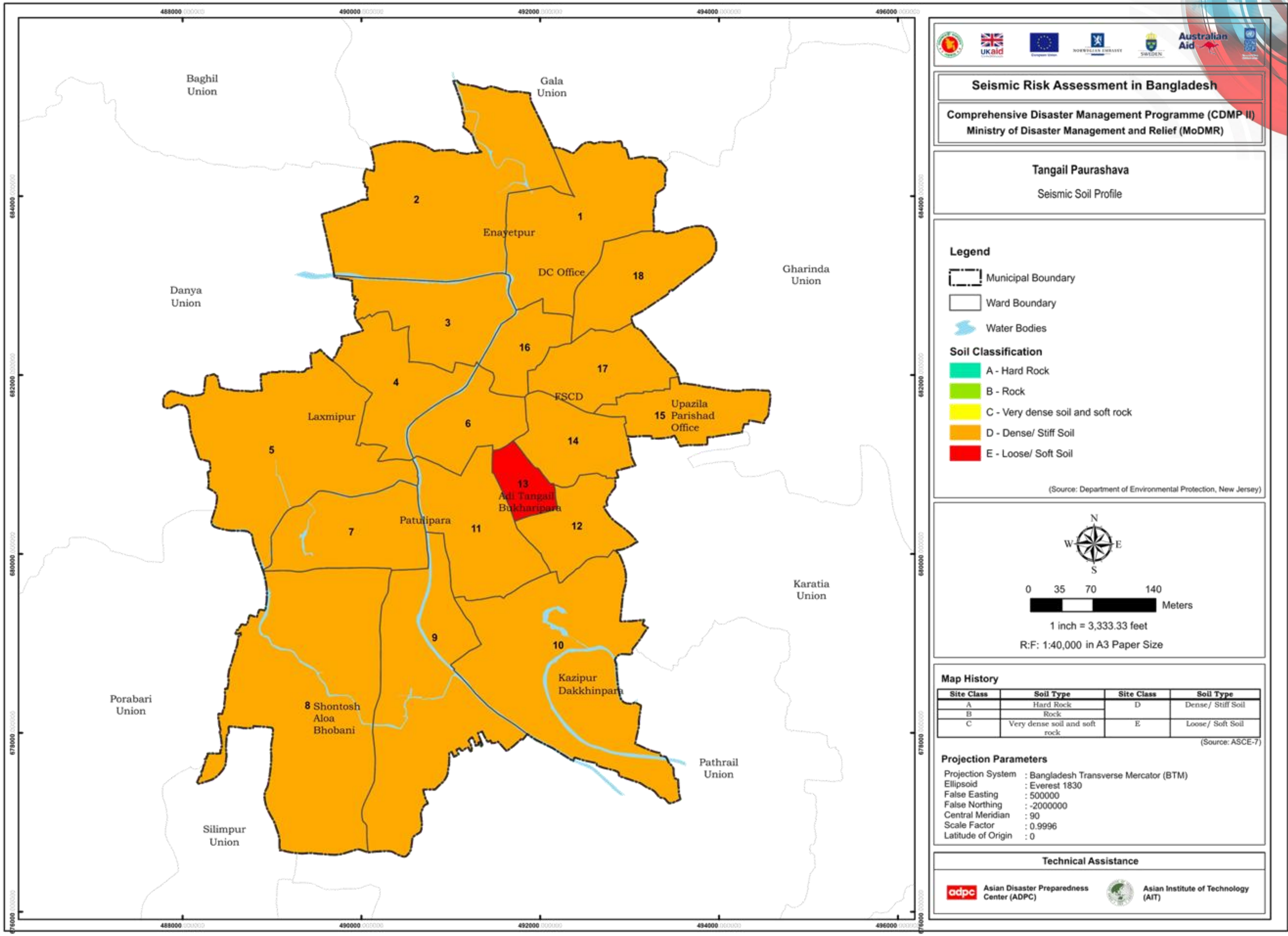
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Seismic Soil Profile
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Soil Classification
A - Hard Rock
B - Rock
C - Very dense soil and soft rock
D - Dense/ Stiff Soil
E - Loose/ Soft Soil
(Source: Department of Environmental Protection, New Jersey)
N
W
E
S
0 35 70 140
Meters
1 inch = 3,333.33 feet
R.F: 1:40,000 in A3 Paper Size
Map History
Site Class | Soil Type | Site Class | Soil Type
A | Hard Rock | D | Dense/ Stiff Soil
B | Rock
C | Very dense soil and soft rock | E | Loose/ Soft Soil
(Source: ASCE-7)
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
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Asian Institute of Technology (AIT)
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Baghil Union
Gala Union
Danya Union
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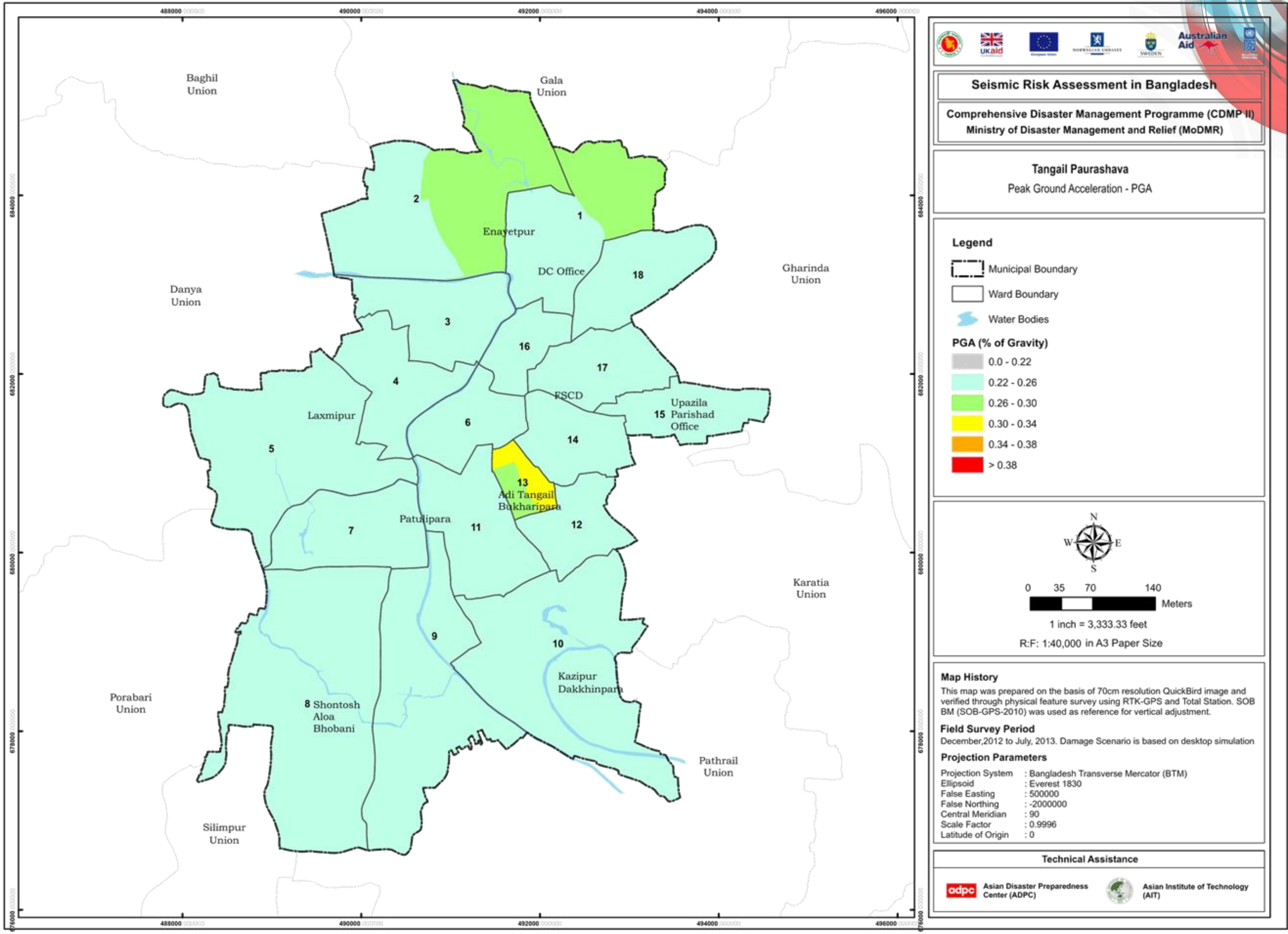
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Peak Ground Acceleration - PGA
Legend
Municipal Boundary
Ward Boundary
Water Bodies
PGA (% of Gravity)
0.0 - 0.22
0.22 - 0.26
0.26 - 0.30
0.30 - 0.34
0.34 - 0.38
> 0.38
N
W
E
S
0 35 70 140
Meters
1 inch = 3,333.33 feet
R.F: 1:40,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-2010) was used as reference for vertical adjustment.
Field Survey Period
December,2012 to July, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
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Asian Institute of Technology (AIT)
UKaid
Australian Aid
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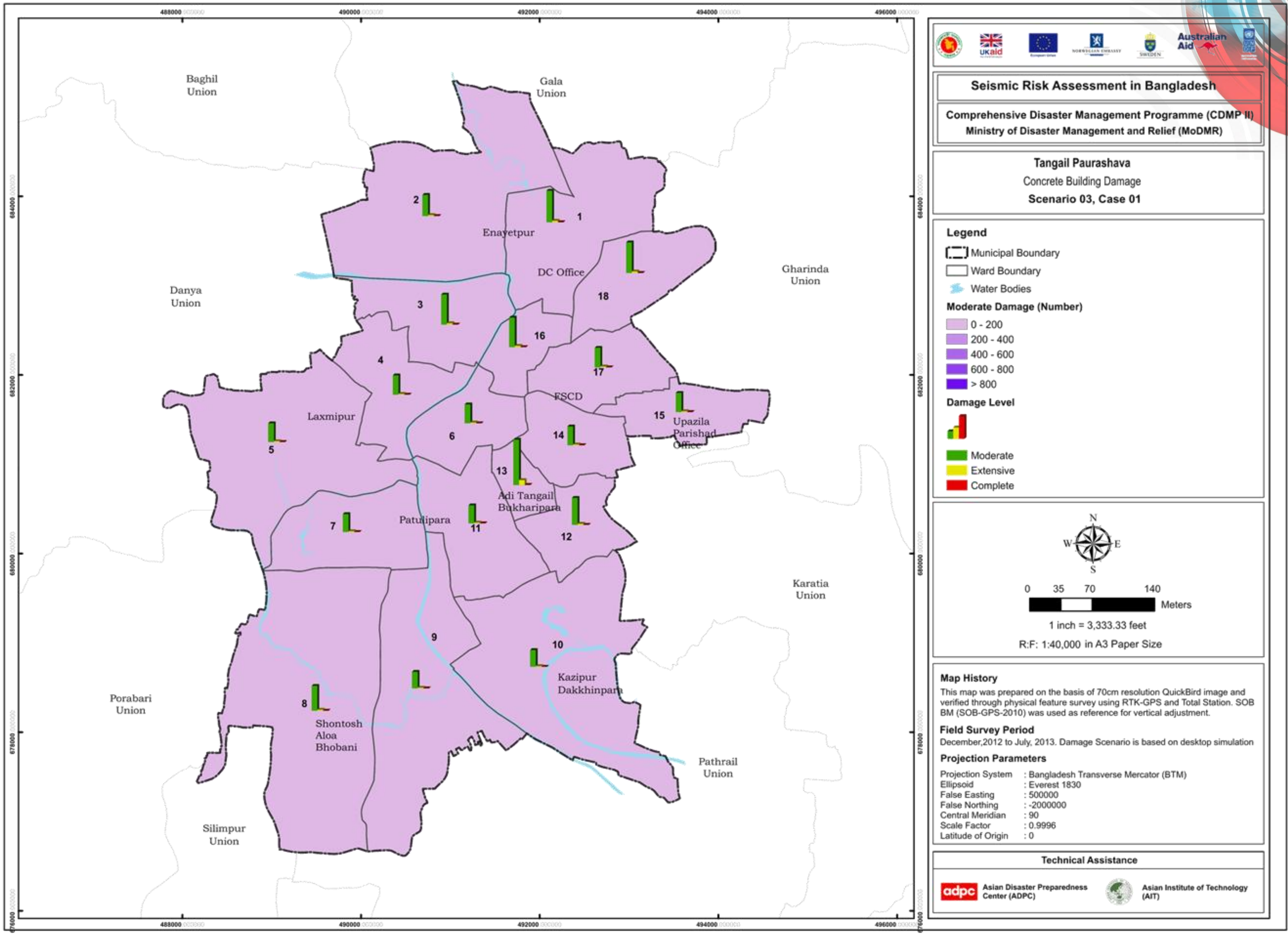
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Concrete Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Moderate Damage (Number)
0 - 200
200 - 400
400 - 600
600 - 800
> 800
Damage Level
Moderate
Extensive
Complete
N
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E
W
0 35 70 140
Meters
1 inch = 3,333.33 feet
R:F: 1:40,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-2010) was used as reference for vertical adjustment.
Field Survey Period
December,2012 to July, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
Projection System : Bangladesh Transverse Mercator (BTM)
Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
Baghil Union
Gala Union
Danya Union
Gharinda Union
Karatia Union
Porabari Union
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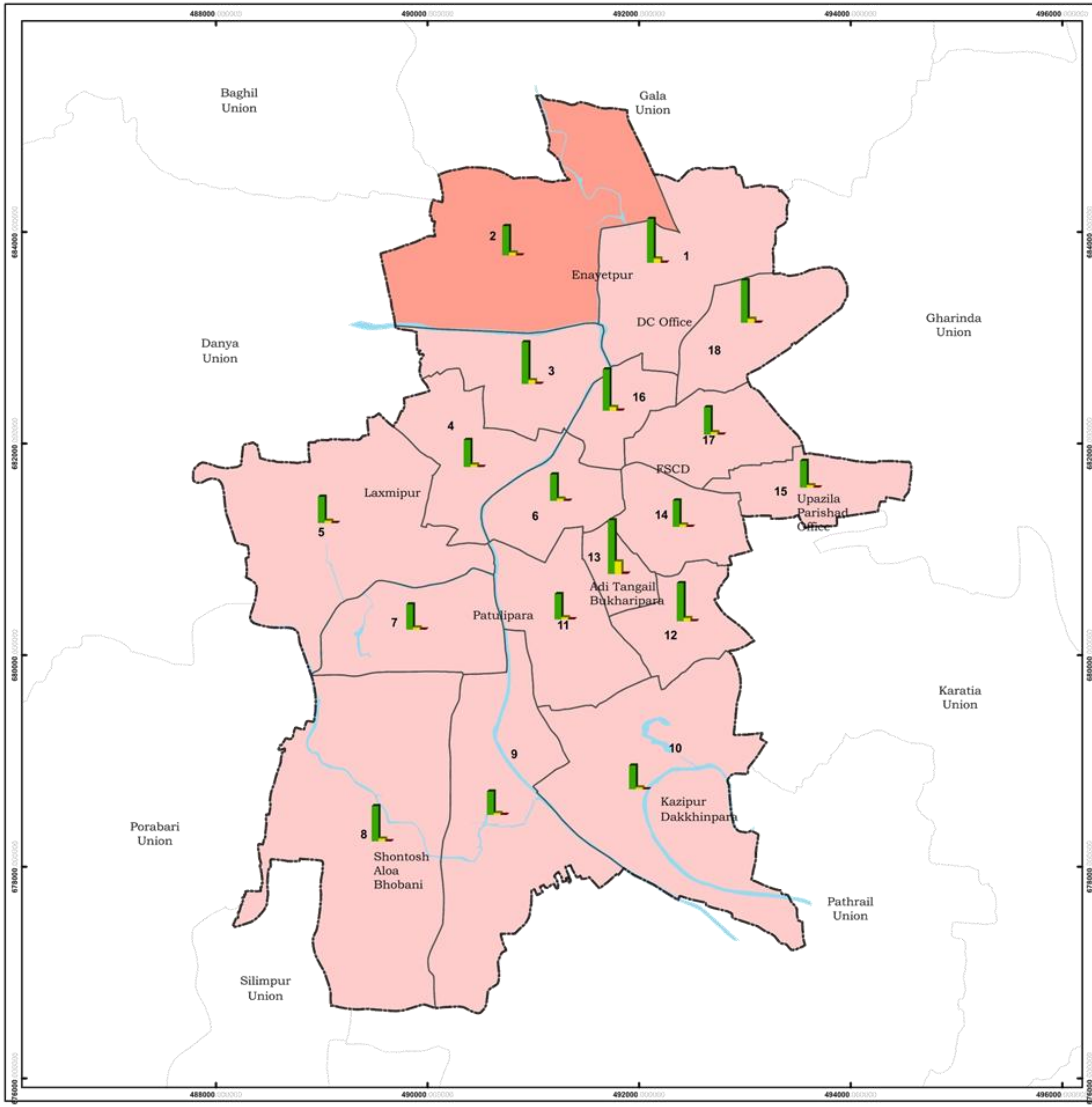

Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Tangail Paurashava
Masonry Building Damage
Scenario 03, Case 01

Legend
Municipal Boundary
Ward Boundary
Water Bodies

Moderate Damage (Number)
0 - 200
200 - 400
400 - 600
600 - 800
> 800

Damage Level
Moderate
Extensive
Complete

N W E S

0 35 70 140 Meters
1 inch = 3,333.33 feet
R:F: 1:40,000 in A3 Paper Size

Map History
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Field Survey Period
December,2012 to July, 2013. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
False Northing	: -2000000
Central Meridian	: 90
Scale Factor	: 0.9996
Latitude of Origin	: 0

Technical Assistance
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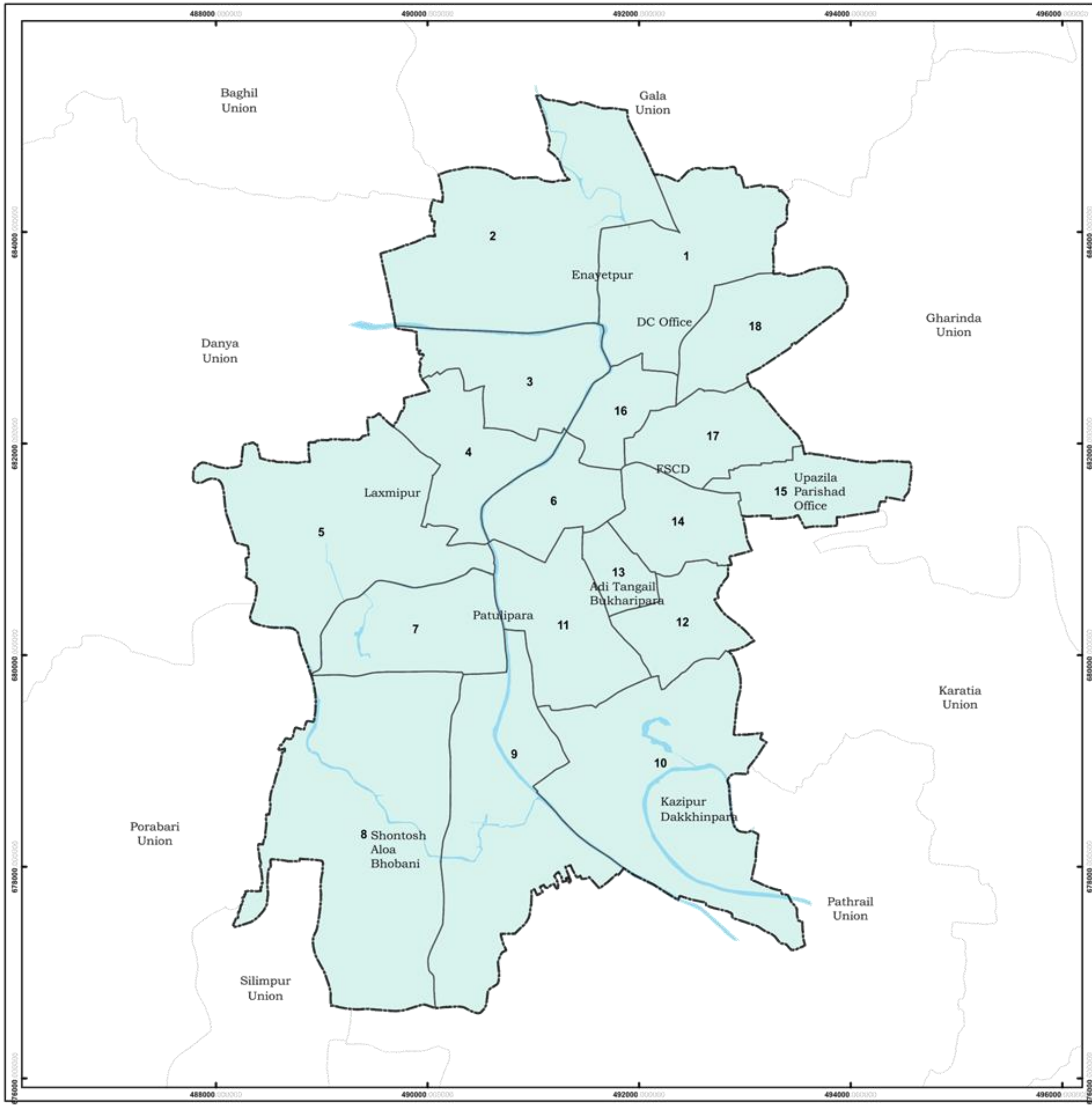

Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Tangail Paurashava
Casualty Estimate for Building Damage
Scenario 03, Case 01

Legend

Municipal Boundary
Ward Boundary
Water Bodies

Injuries at Day Time in Person

- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- > 40

N
W E
S

0 35 70 140 Meters

1 inch = 3,333.33 feet

R:F: 1:40,000 in A3 Paper Size

Map History

This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-2010) was used as reference for vertical adjustment.

Field Survey Period

December,2012 to July, 2013. Damage Scenario is based on desktop simulation

Projection Parameters

Projection System	: Bangladesh Transverse Mercator (BTM)
Ellipsoid	: Everest 1830
False Easting	: 500000
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Central Meridian	: 90
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Latitude of Origin	: 0

Technical Assistance

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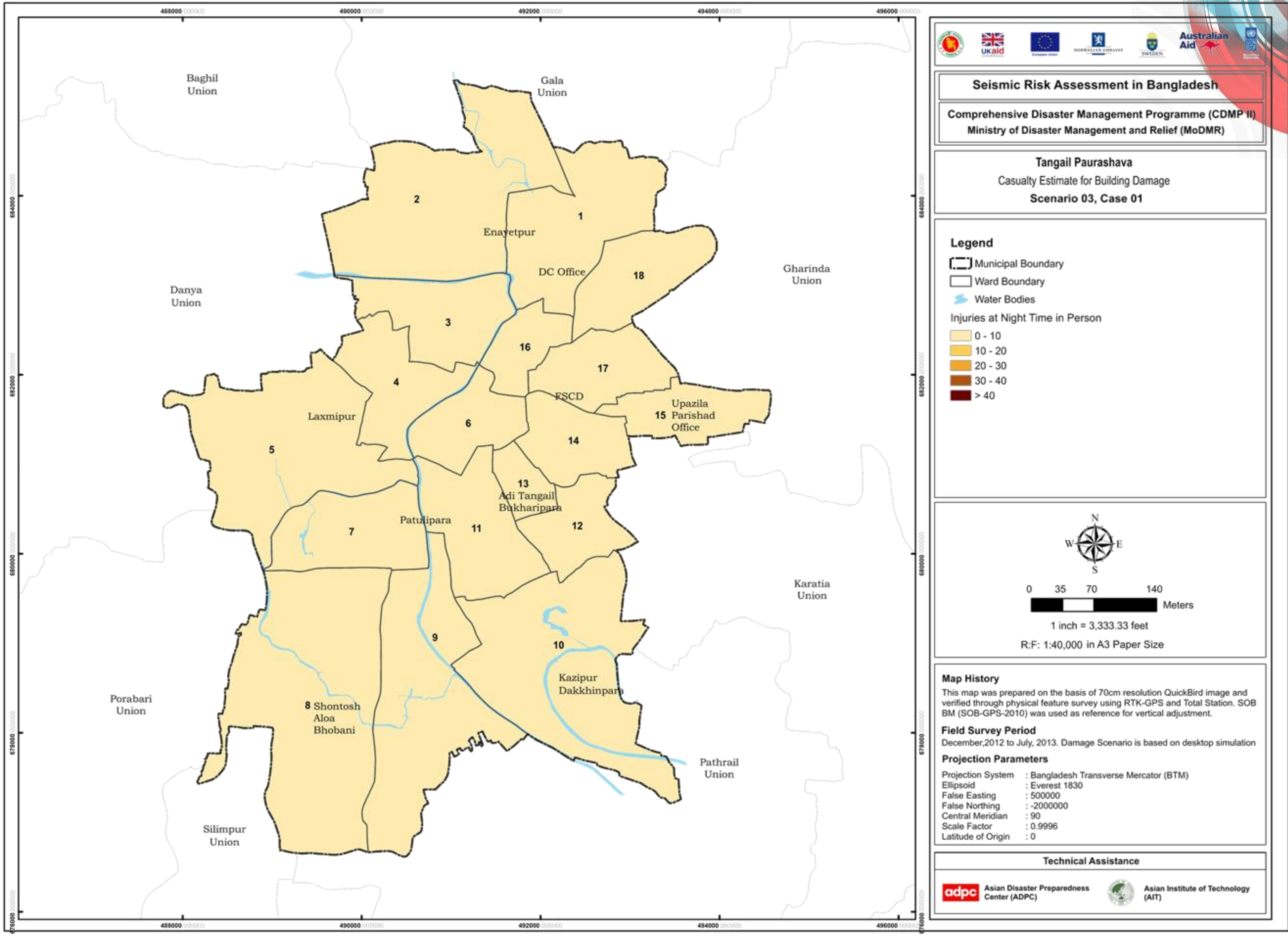
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Casualty Estimate for Building Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Injuries at Night Time in Person
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
W
E
S
0
35
70
140
Meters
1 inch = 3,333.33 feet
R:F: 1:40,000 in A3 Paper Size
Map History
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Field Survey Period
December,2012 to July, 2013. Damage Scenario is based on desktop simulation
Projection Parameters
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Ellipsoid : Everest 1830
False Easting : 500000
False Northing : -2000000
Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
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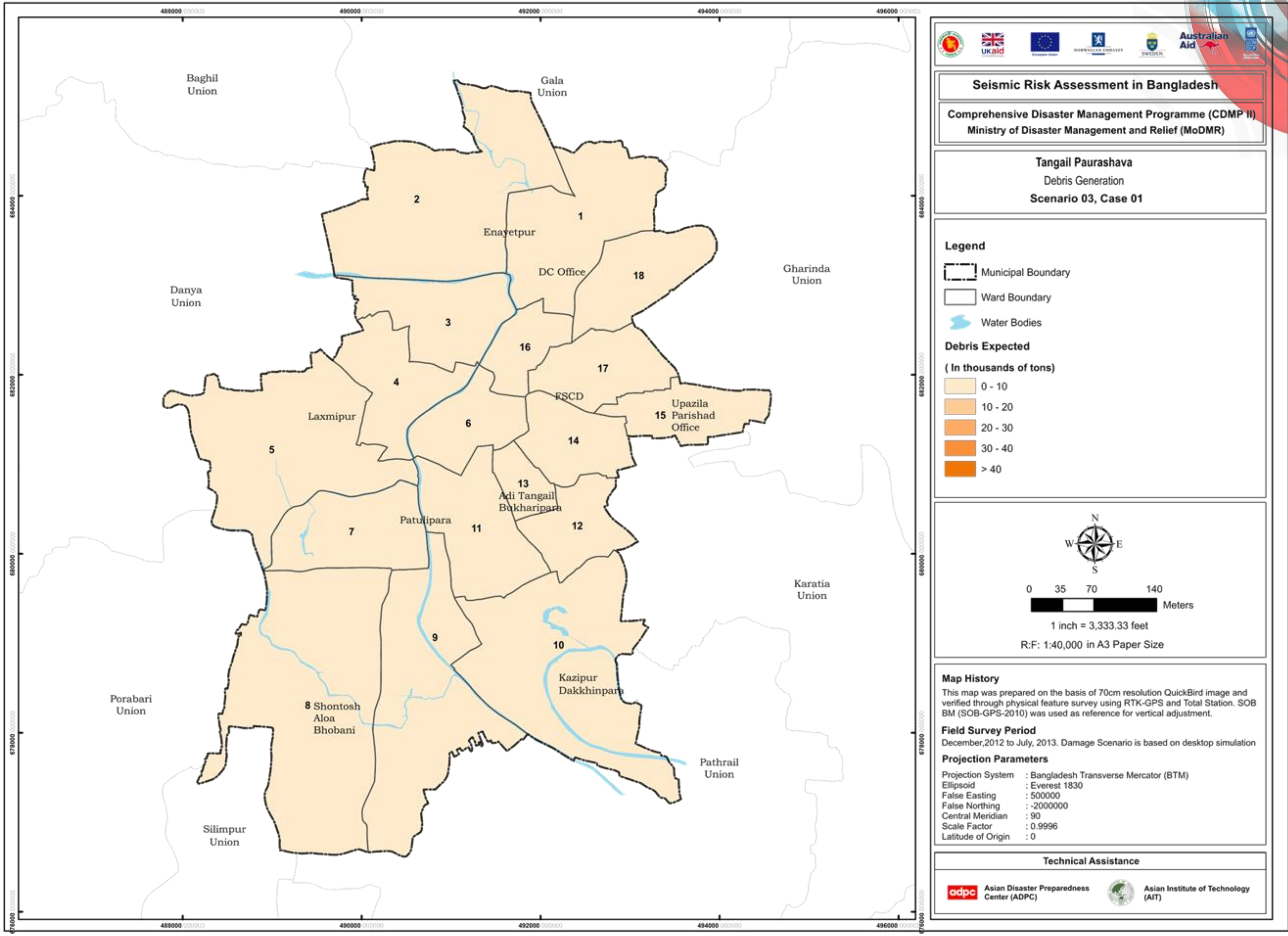

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Debris Generation
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Debris Expected
(In thousands of tons)
0 - 10
10 - 20
20 - 30
30 - 40
> 40
N
W
E
S
0
35
70
140
Meters
1 inch = 3,333.33 feet
R:F: 1:40,000 in A3 Paper Size
Map History
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Field Survey Period
December,2012 to July, 2013. Damage Scenario is based on desktop simulation
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False Easting : 500000
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Central Meridian : 90
Scale Factor : 0.9996
Latitude of Origin : 0
Technical Assistance
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Baghil Union
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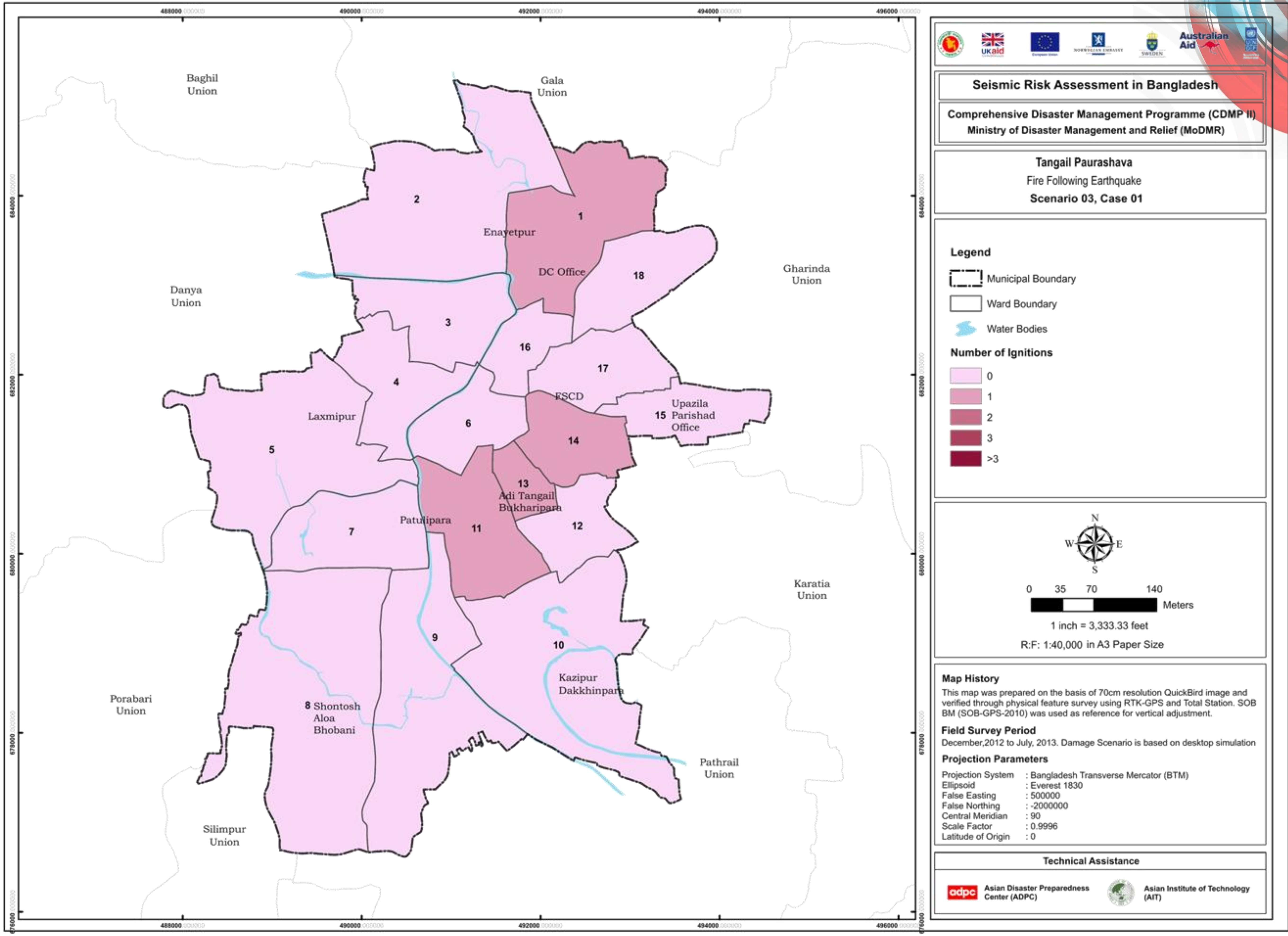

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Fire Following Earthquake
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Number of Ignitions
0
1
2
3
>3
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0 35 70 140
Meters
1 inch = 3,333.33 feet
R:F: 1:40,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-2010) was used as reference for vertical adjustment.
Field Survey Period
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Ellipsoid : Everest 1830
False Easting : 500000
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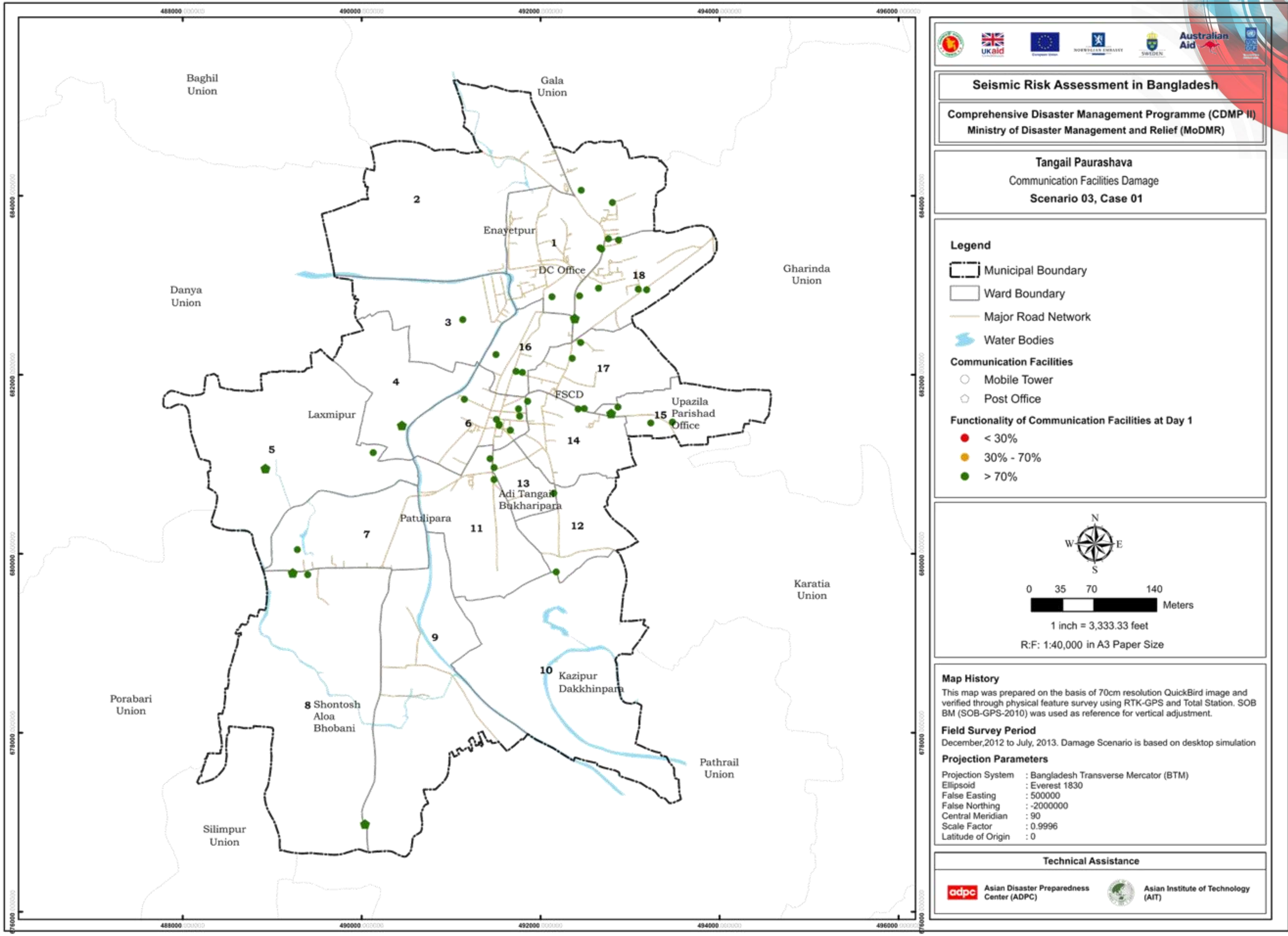

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Communication Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Communication Facilities
Mobile Tower
Post Office
Functionality of Communication Facilities at Day 1
< 30%
30% - 70%
> 70%
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Meters
1 inch = 3,333.33 feet
R:F: 1:40,000 in A3 Paper Size
Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-2010) was used as reference for vertical adjustment.
Field Survey Period
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Projection Parameters
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False Northing : -2000000
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Technical Assistance
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Baghil Union
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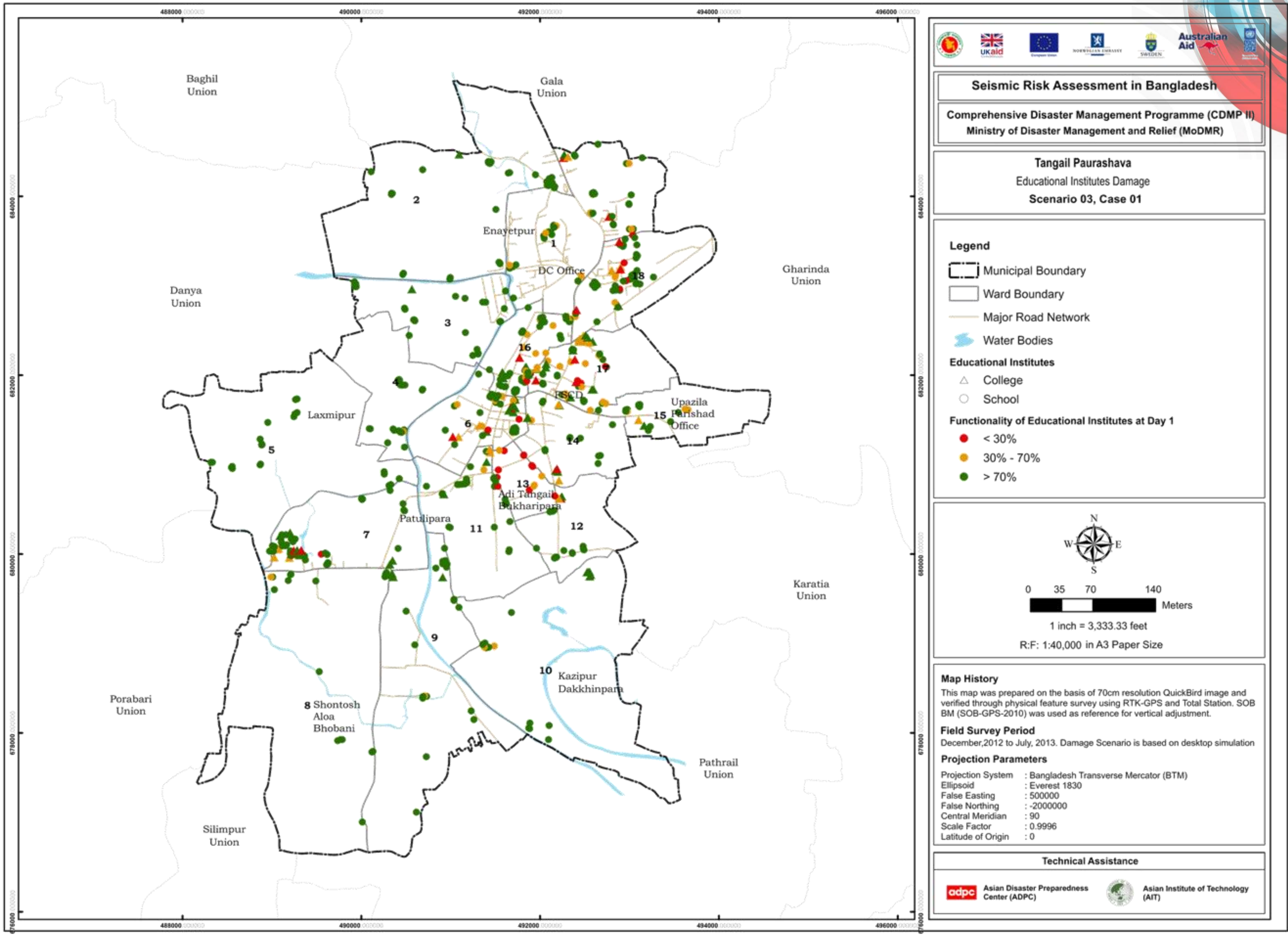
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Educational Institutes Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Educational Institutes
College
School
Functionality of Educational Institutes at Day 1
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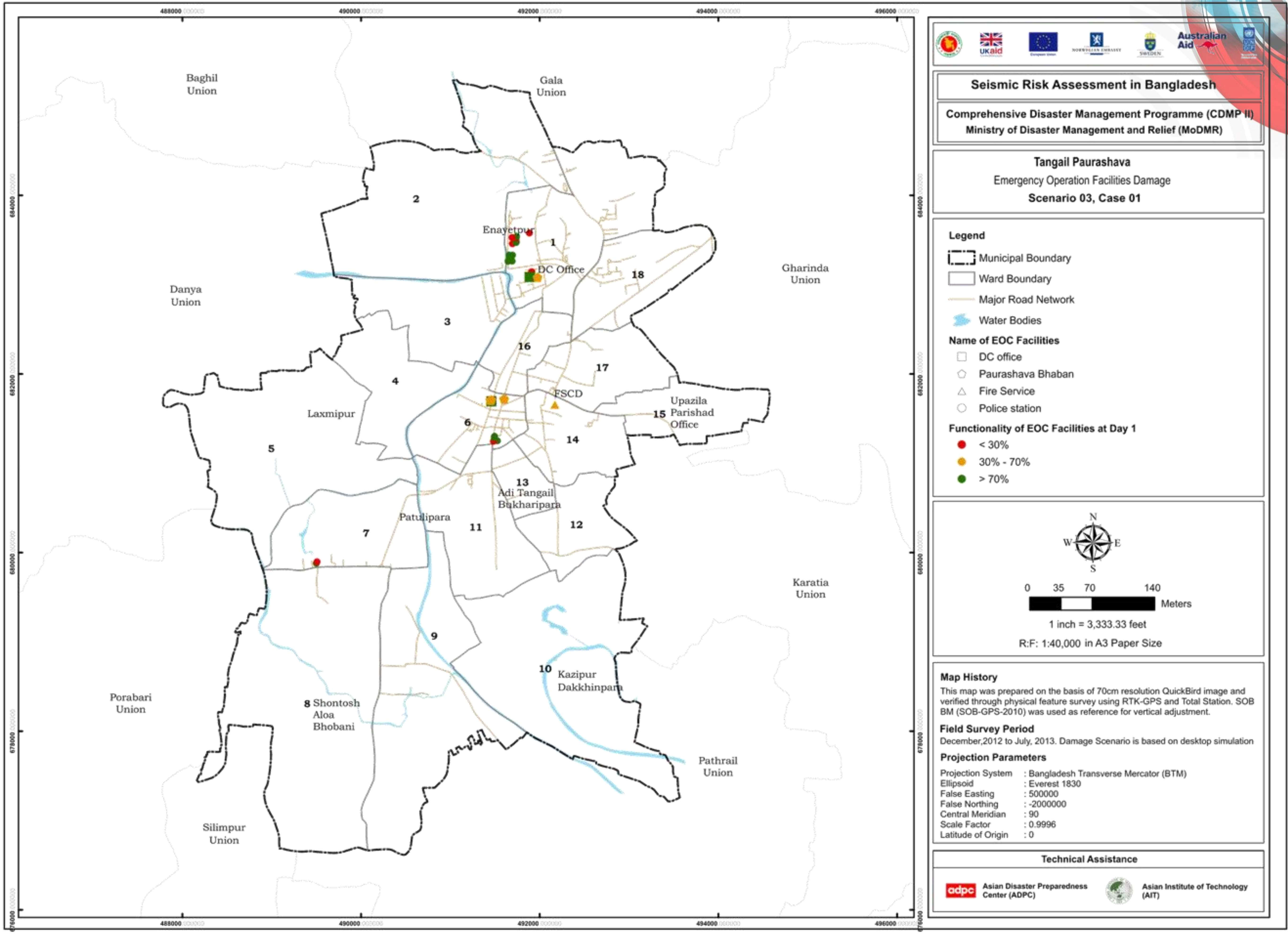

Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Emergency Operation Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Name of EOC Facilities
DC office
Paurashava Bhaban
Fire Service
Police station
Functionality of EOC Facilities at Day 1
< 30%
30% - 70%
> 70%
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Meters
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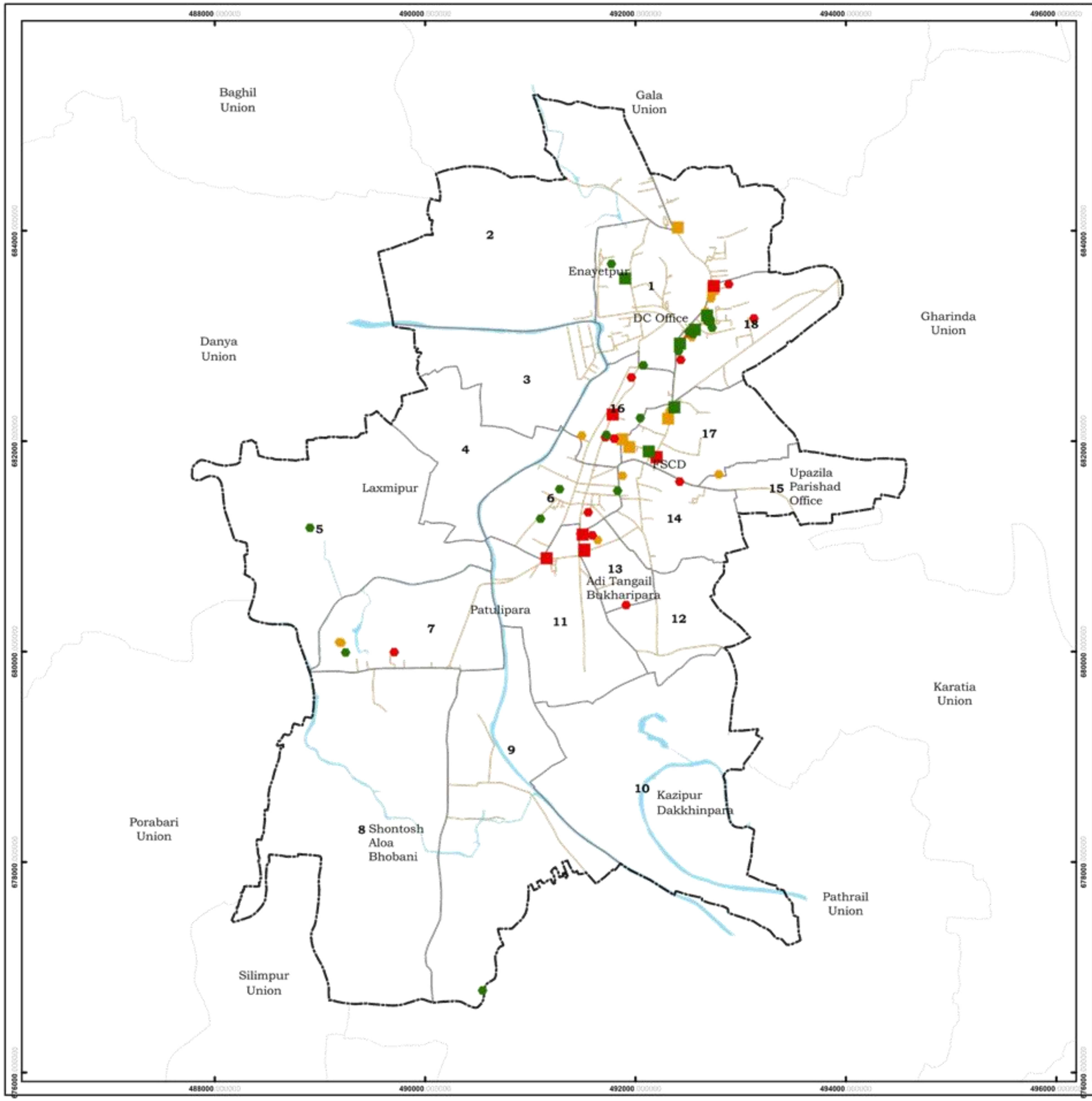

Seismic Risk Assessment in Bangladesh

Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)

Tangail Paurashava
Medical Care Facilities Damage
Scenario 03, Case 01

Legend

- Municipal Boundary
- Ward Boundary
- Major Road Network
- Water Bodies

Medical Care Facilities

- Large Hospital
- Medium Hospital
- Small Hospital
- Medical Clinic

Functionality of Medical Care Facilities at Day 1

- < 30%
- 30% - 70%
- > 70%

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1 inch = 3,333.33 feet

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Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-2010) was used as reference for vertical adjustment.

Field Survey Period
December,2012 to July, 2013. Damage Scenario is based on desktop simulation

Projection Parameters

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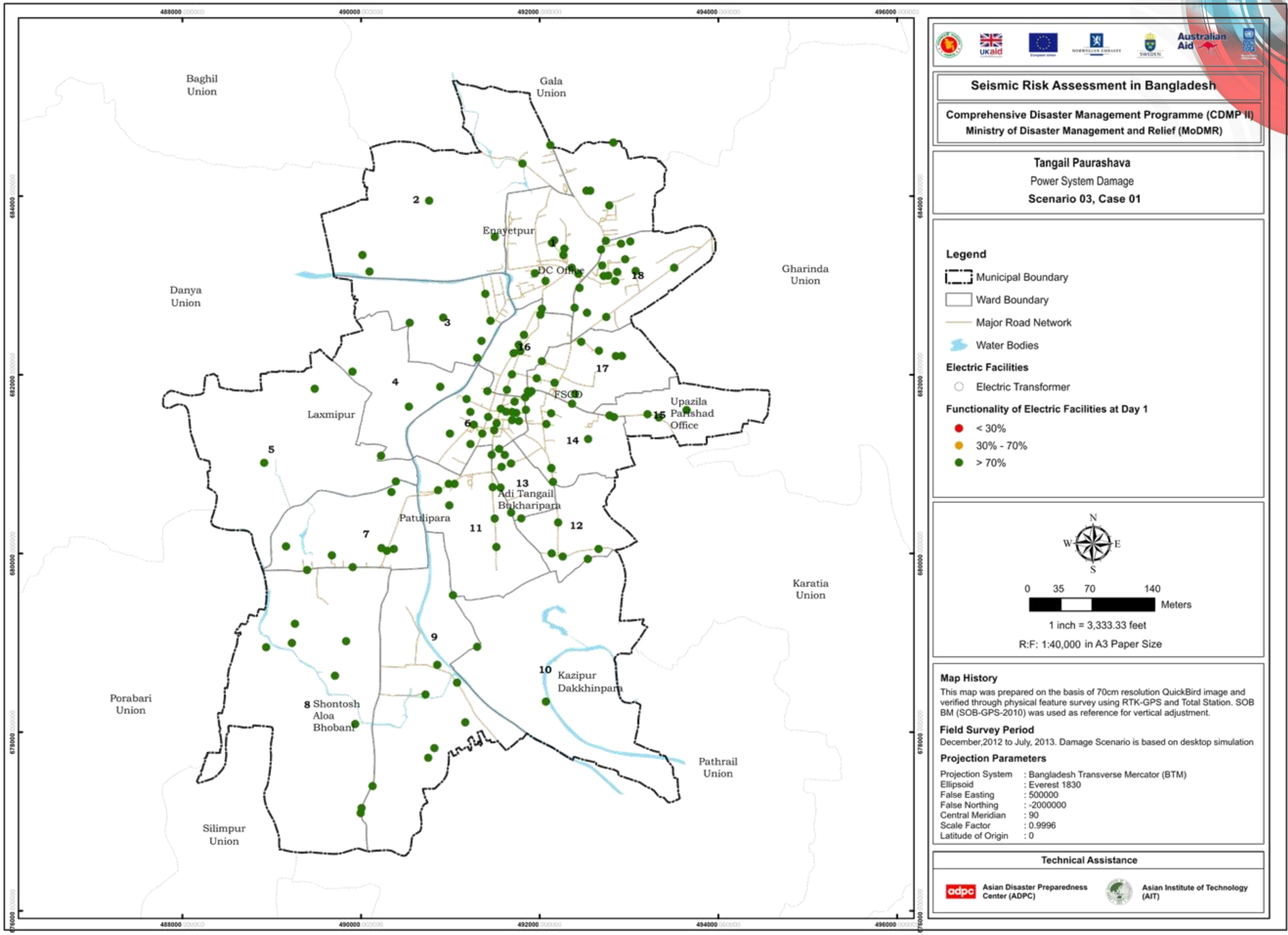
Technical Assistance

Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)


Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Power System Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Electric Facilities
Electric Transformer
Functionality of Electric Facilities at Day 1
< 30%
30% - 70%
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Meters
1 inch = 3,333.33 feet
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Map History
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Technical Assistance
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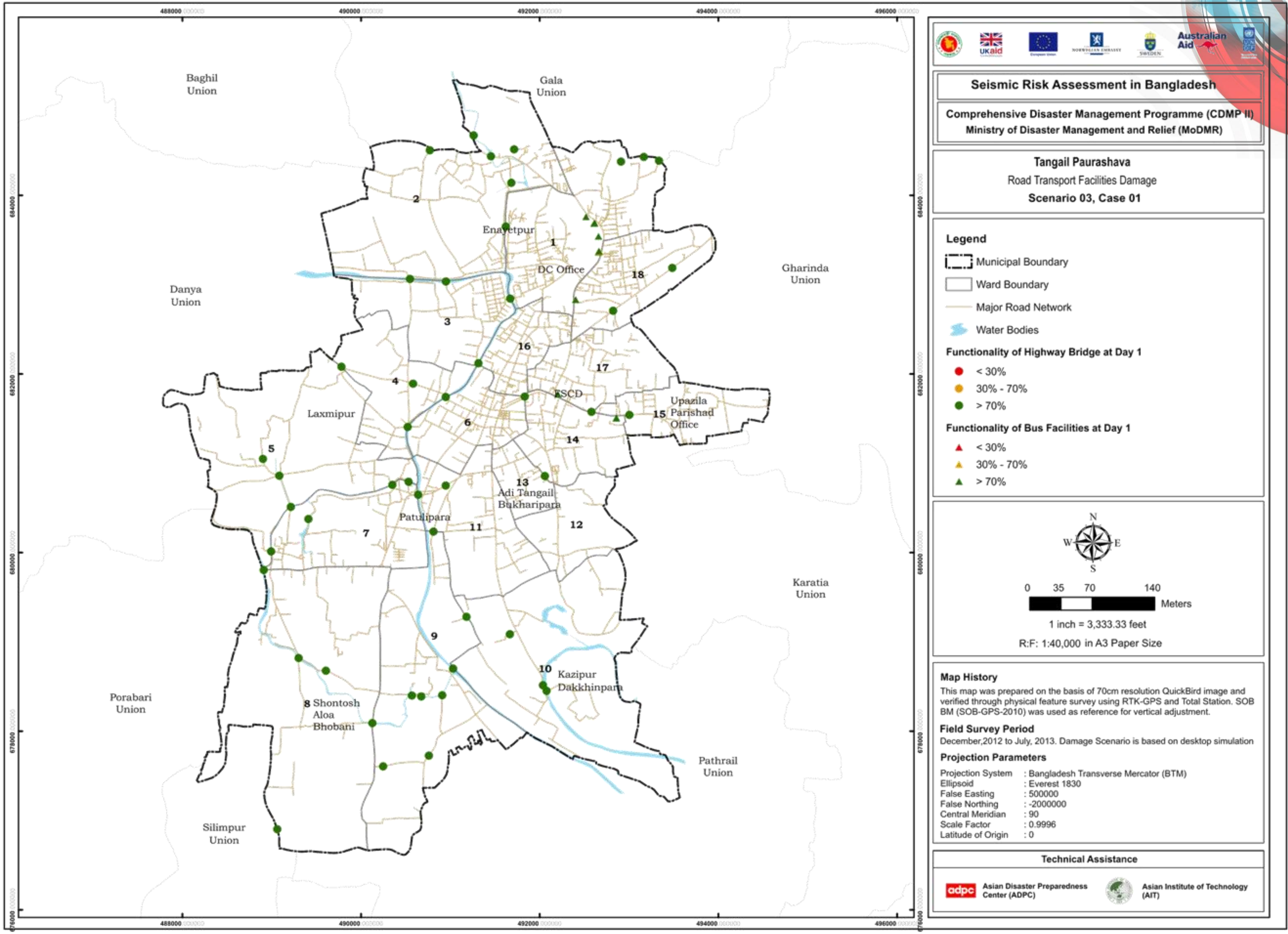
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Road Transport Facilities Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Functionality of Highway Bridge at Day 1
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Functionality of Bus Facilities at Day 1
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Asian Disaster Preparedness Center (ADPC)
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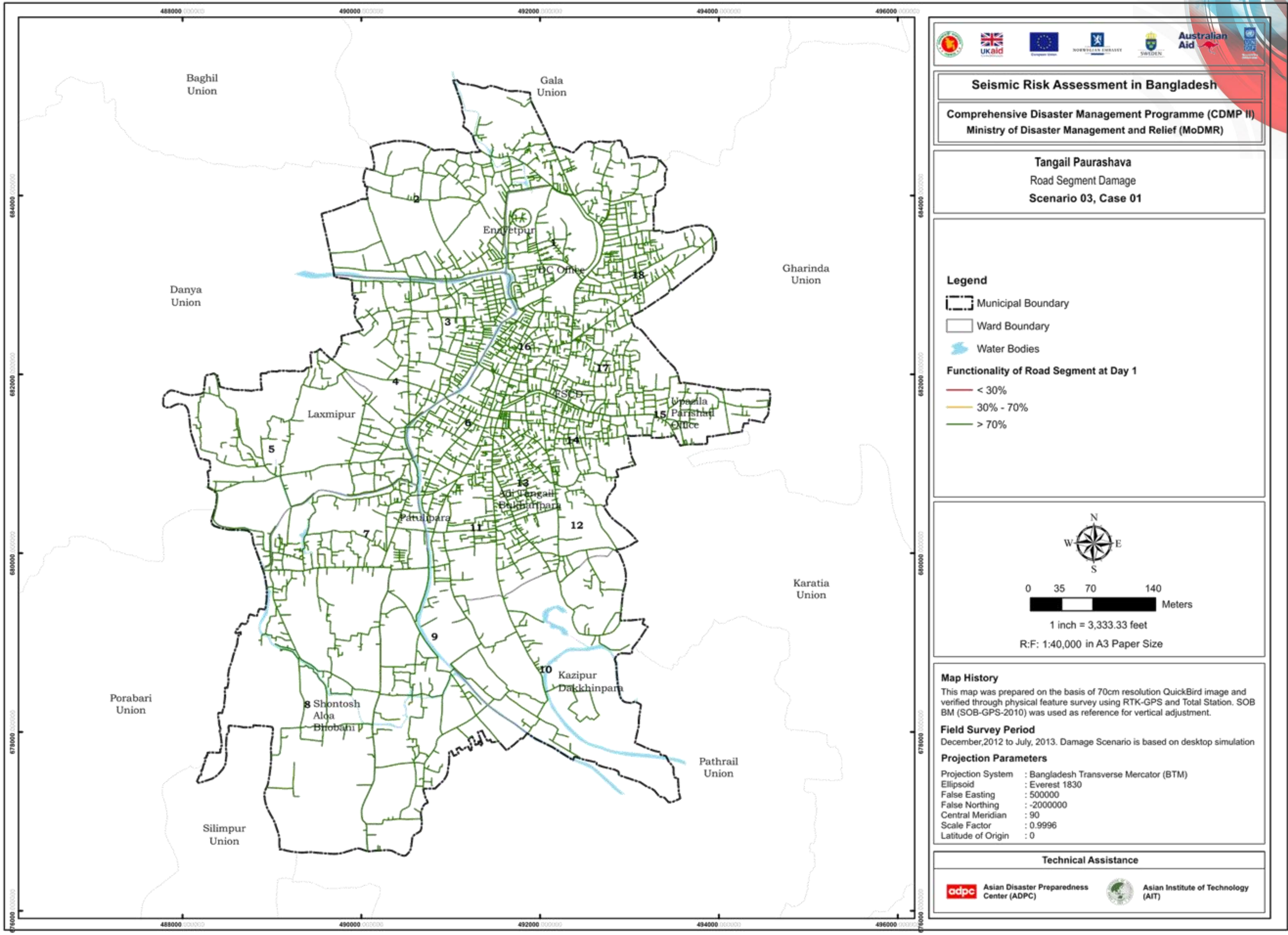
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Road Segment Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Water Bodies
Functionality of Road Segment at Day 1
< 30%
30% - 70%
> 70%
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Meters
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Map History
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Projection System : Bangladesh Transverse Mercator (BTM)
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Technical Assistance
Asian Disaster Preparedness Center (ADPC)
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Baghil Union
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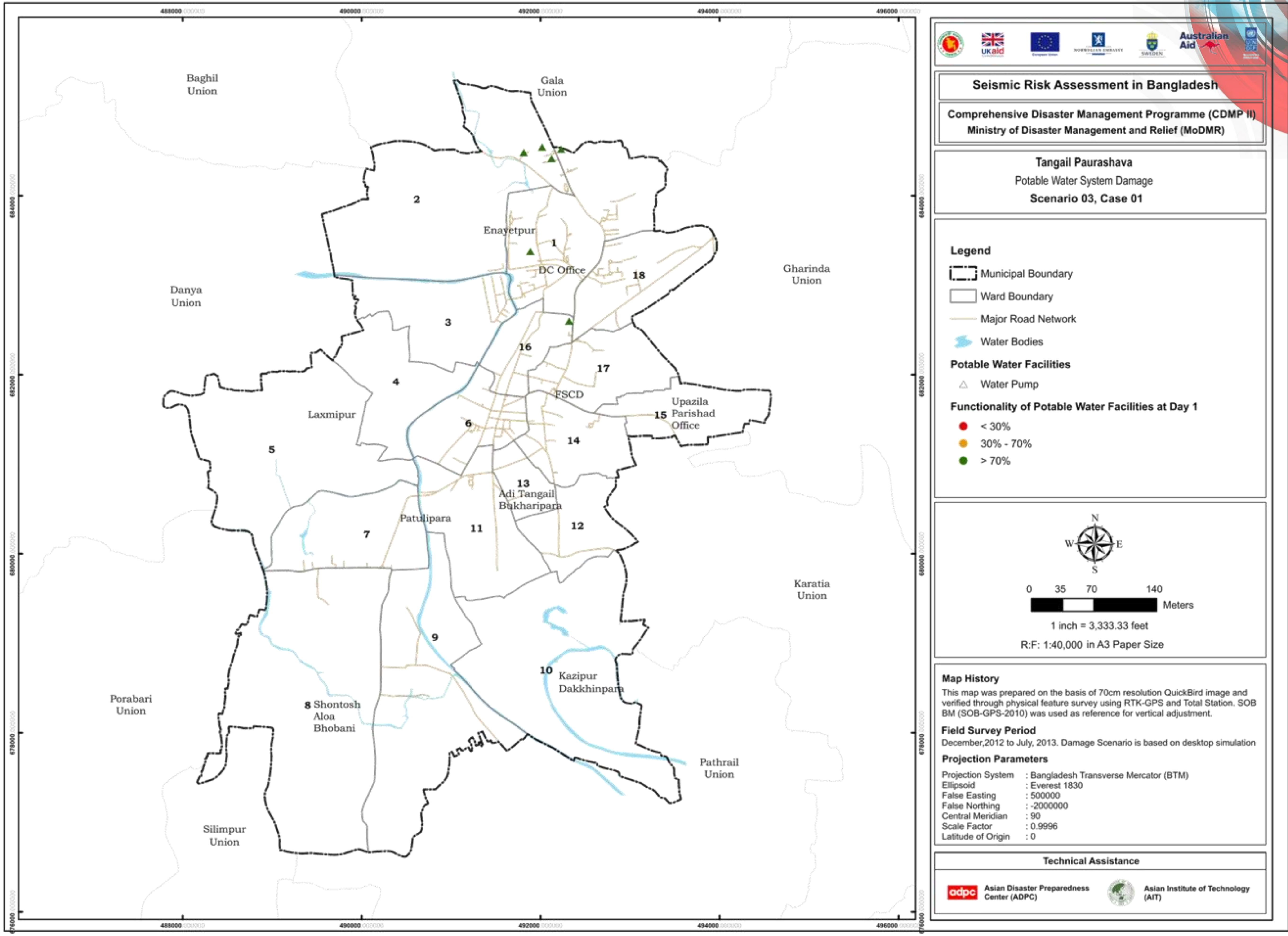
Seismic Risk Assessment in Bangladesh
Comprehensive Disaster Management Programme (CDMP II)
Ministry of Disaster Management and Relief (MoDMR)
Tangail Paurashava
Potable Water System Damage
Scenario 03, Case 01
Legend
Municipal Boundary
Ward Boundary
Major Road Network
Water Bodies
Potable Water Facilities
Water Pump
Functionality of Potable Water Facilities at Day 1
< 30%
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Meters
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Map History
This map was prepared on the basis of 70cm resolution QuickBird image and verified through physical feature survey using RTK-GPS and Total Station. SOB BM (SOB-GPS-2010) was used as reference for vertical adjustment.
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Projection Parameters
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False Easting : 500000
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Central Meridian : 90
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Technical Assistance
Asian Disaster Preparedness Center (ADPC)
Asian Institute of Technology (AIT)
UKaid
Australian Aid
Baghil Union
Gala Union
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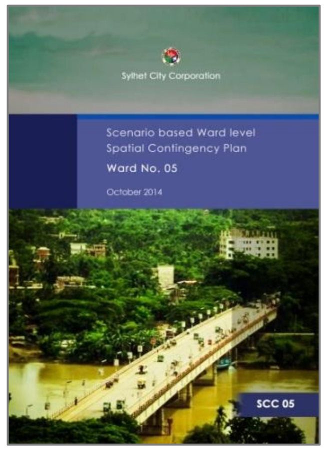
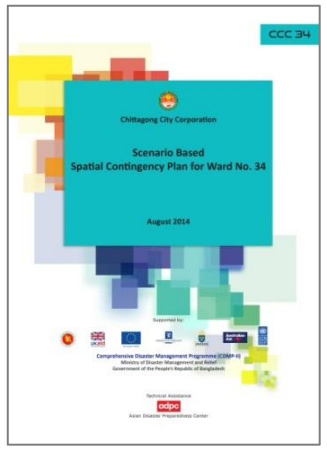
CHAPTER - 04
SEISMIC PREPAREDNESS INITIATIVES

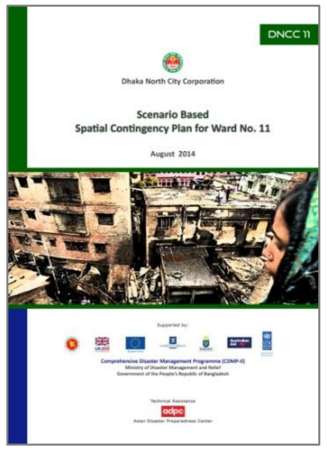
4.1 Spatial Contingency Plans

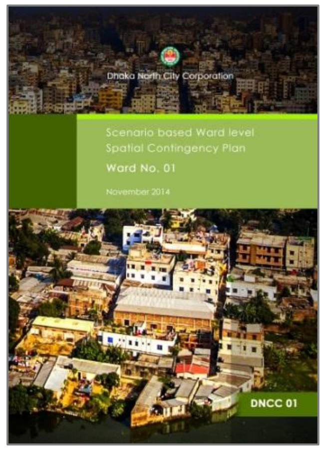
Earthquake hazard risks need to be addressed in four phases, viz., mitigation, preparedness, emergency response and recovery phases. However, an Earthquake Contingency Plan only addresses the emergency response management. Need for a comprehensive geo-hazard risk reduction "Contingency Planning" strategy that is linked to an easy implementation framework has been felt for quite some time now. It is therefore, extremely important to anticipate as best as possible, the future probable earthquake threats in the country as well as areas of high vulnerability, especially, the urban centers and plan for the quick and early recovery for impending earthquake emergency.

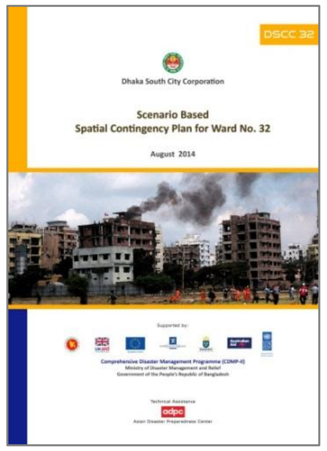
As part of Preparedness initiative, Contingency Plan focusing earthquake has been prepared for different level for the study cities. In CDMP I Scenario Based Contingency Plans were prepared for National Level, City Level for the city corporations in Dhaka, Chittagong and Sylhet and Agency Level Contingency Plans for the Department of Disaster Management (DDM), Armed Forces Division (AFD), Directorate General of Health Services (DGHS), Directorate of Relief and Rehabilitation (DRR), Fire Service and Civil Defense (FSCD), Titas Gas Transmission and Distribution Company Limited (TGTDCL), Bangladesh Telecommunication Company Limited (BTCL), Dhaka Power Distribution Company Limited (DPDC) and Dhaka Water Supply and Sewerage Authority (DWASA). During CDMP II scenario based Contingency Plans have been prepared at city level for the Cities of Bogra, Dinajpur, Mymensingh, Rajshahi, Rangpur and Tangail and at Ward Level for Dhaka North City Corporation (13 Wards), Dhaka South City Corporation (12 Wards), Chittagong City Corporation (15 Wards) and Sylhet City Corporation (10 Wards). The plans have identified the evacuation routes, emergency shelter locations, identified the gaps in the resource and needs by the responding agencies.











4.2 Trainings for Preparedness at Different Level

Training, Advocacy and Awareness with regard to Earthquake

A good number of Trainings were provided for different target group During CDMP I and CDMP II across nine project cities. Objectives of the training, advocacy and awareness with regard to earthquake activities are mainly to impart training, execute evacuation drills, and undertake advocacy and awareness campaign in different cross-sections of the people from the government official to at risk communities. Besides, decision makers and planners are educated on Contingency Plans and Seismic Hazard Maps. School children, teacher and religious leaders are made aware about the danger of earthquake hazard and masons are trained in constructing earthquake resistant buildings.

Following activities were conducted during CDMP I and CDMP II for increasing earthquake preparedness of the country so far:

Training for decision makers and planners on Contingency Plan and Seismic Hazard Maps, safety and evacuation training to the school children and teachers, training for religious leaders (imams) for awareness about earthquake dangers, training for masons and bar-binders about earthquake safe construction practices, training for the managers/concerned officers of critical infrastructures on fire safety and evacuation, preparation of documentary to develop awareness of earthquake hazard and vulnerability, and finally, production and dissemination of poster on earthquake vulnerability reduction measures.

4.3 Earthquake Simulation Drill

Earthquake simulation drill was organized at community level in Dhaka North City Corporation, Chittagong City Corporation and Sylhet City Corporation areas. The main objective of the simulation drills was to validate the Ward-level Spatial Contingency Plan for assessing its effectiveness through participation of community and local-level responsible agencies and stakeholders so that they are more aware on the use and application of it in a coordinated manner. At the same time, it also helped to raise community awareness about emergency preparedness activities during an earthquake.

The simulation drill in each selected ward was organized by respective city corporation and led by concerned ward councilor office/ zonal office with technical support from the study team. A simulation preparation committee was formed in each city comprising representative from different locally responsible first responder agencies, utility service agencies, and other ward-level stakeholders as per the structure of Ward Disaster Management Committee proposed in the Contingency Plan. Each committee conducted several meetings to review the Contingency Plan, identify the simulation activities, select the community to be involved, identify the suitable site, and define the roles and responsibilities for simulation. Extensive ward-level publicity was made through variety of audio visual media such as leaflets, posters, banners, festoons, micing, power point presentation, and one-to-one communication to raise the community awareness as well as to ensure community participation in the simulation drills.











CHAPTER - 05
CONCLUSION

Conclusion

This atlas is limited to present the main findings of the Seismic Risk Assessment study. A good number of different studies under the current initiative of CDMP II have been carried out and reports are available at e-library of CDMP (http:www.dmic.org.bd/e-library). The maps presented in this document can be used as a reference, for more detail it is recommended to consult the main reports.

The study team had its all-out efforts for collecting information for conducting the study. There were initiatives for primary data gathering in the cases where there was data and information unavailability. However, in some cases it was not at all possible to get information from some of the government institutions due to their policy restrictions. In such cases study team decided to continue the study based on expert judgment in the respective areas.

Year-long detailed investigation using state of the art technology with relentless efforts by both national and international panel of experts this study produced significant results. Research of this nature and scale is first time initiative in Bangladesh, therefore the findings from this study is very important for the decision makers for designing and implementing future Earthquake Preparedness Initiatives in the country.

Moreover, the maps developed under this study will be useful for development control to reduce earthquake risk in the respective cities and countries as a whole. The significant findings from the study are as followings:

- In general, at short return period, i.e. 43 years, the observed seismicity in and around Bangladesh controls the hazard for most considered structural periods.
- Ground motion across Bangladesh represented by PGA is in the range of 0.1–0.6g, corresponding to the 475-year return period and in the range of 0.1–1.0 g, corresponding to the 2,475-year return period.
- The effect of high-slip-rate of Duaki fault could be observed as the largest seismic hazard in Bangladesh.

Among structural type of non-engineered building, BFL is the most common type in all the study cities. From the survey results, age of buildings has been found to be related to structural types. For example, it was found that most buildings with concrete slab-column frames are constructed less than 10 years. On the other hand, most masonry buildings with concrete floors ages more than 10 years. Also, light reinforced concrete buildings are found to be older than reinforced concrete buildings.

Academic institutions at nationals and local level should take initiative to carry out research aimed towards the further improvement and development of the earthquake hazard and risk maps for different cities/ towns, and should also be given a task in transferring the knowledge, through the establishment professional courses, on hazard and risk assessment.

The Government of Bangladesh and respective paurashavas should initiate for opportunities to incorporate Disaster Risk Reduction into the urban development planning methodologies in all of the relevant sectors and relevant levels. The implementation of these guidelines in risk assessment and incorporation of hazard and risk information into spatial planning should therefore be mandatory.

Respective paurashavas and city corporations should continue using and update the database periodically. This will be helpful for the city authorities for initiating preparedness efforts for the city dwellers.

The GIS database and maps have been used to generate the seismic hazard, vulnerability and risk maps in this Atlas should be kept on a web-server and should be shared and updated by the respective agencies. Apart from this, local agencies should set-up a data bank on Spatial Data Infrastructure, and define specific data formats and standards for collecting, storing, updating the database for further analysis.

CHAPTER - 06
ANNEX

Glossary of Terms

Acceleration

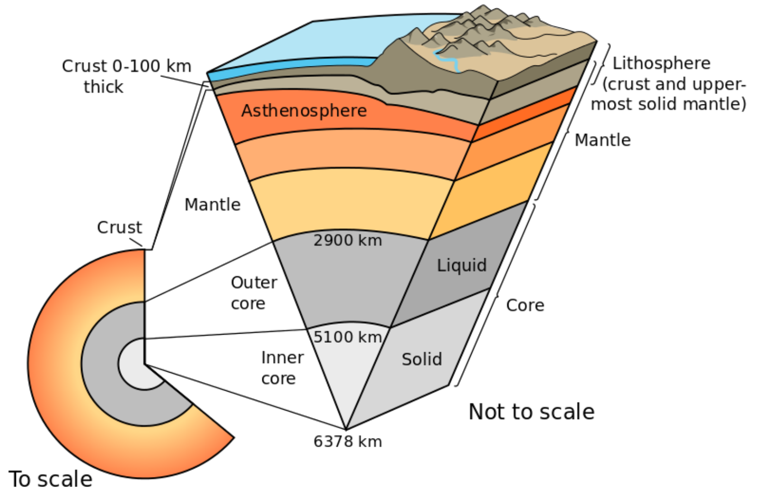
In physics acceleration is used as the change of velocity with respect to time. Here we use the rate of change of velocity of a reference point. Commonly expressed as a fraction or percentage of the acceleration due to gravity (g) where g = 980 cm/s2.

Active Fault

Fault is the offset of geological structure where one type of rock can be seen butting up against rock of quite another type. A fault that is considered likely to undergo renewed movement within a period of concern to humans is known as active fault. Faults are commonly considered to be active if they have moved one or more times in the last 10,000 years, but they may also be considered active when assessing the hazard for some applications even if movement has occurred in the last 500,000 years.

Asthenosphere

The highly viscous mechanically weak region is the upper mantle of the Earth. It lies below the lithosphere (crust and upper most solid mantle), at depths between 80 and 200 km (50-124 miles) below the surface, but perhaps extending as deep as 400 km. Asthenosphere is generally solid although some of its regions could be melted; e.g. below mid-ocean ridge.



The layers of earth mantle

Aftershock

Secondary tremors that may follow the largest shock of an earthquake sequence. Such tremors can extend over a period of weeks, months, or years.

Most moderate to shallow earthquakes are followed by numerous earthquakes in the same vicinity. A big earthquake sometimes followed by the incredible number of aftershocks. Most aftershocks are located over the full area of the fault rupture or along the fault plane or other faults within the volume affected by the strain associated with the main shock. The pattern of aftershock helps confirm the size of area that slipped during the main shock.

Blind fault

Blind fault is a fault that does not rupture all the way up to the surface. So there is no evidence of it on the ground. It is buried under the upper most layers of the rock in the crust. It usually terminates upward in the axial region of an anticline. If is dip is less than 45 degrees, it is a blind thrust.

Casualties

Casualties estimates of the number of people that will be injured and killed by the earthquake. The casualties are broken down into four severity levels that described the extent of injuries. The levels are described as follows:

- Severity level 1: Injuries will require medical attention but hospitalization is not needed.
- Severity level 2: Injuries will require hospitalization but are not considered life-threatening.
- Severity level 3: Injuries will require hospitalization and can become life threatening if not promptly treated.
- Severity level 4: Victims are killed by the earthquake.

The casualty estimates are provided by two times of day: 2:00 AM and 2:00 PM. These times represent the periods of the day that different sectors of the community are at their peak occupancy loads. The 2:00 AM estimate considers that the residual occupancy loads are the maximum and 2:00 PM estimate considers that the educational, commercial and industrial sector loads are maximum.

Crust

Crust is the outermost major layer of the Earth, ranging from about 10 to 65 km in thickness worldwide. The continental crust is about 40 km thick in the Pacific Northwest. The thickness of the oceanic crust in this region varies between about 10 and 15 km. The crust is characterized by P-wave velocities less than about 8 km/s. The uppermost 15-35 km of crust is brittle enough to produce earthquakes. The seismic crust is separated from the lower crust by the brittle-ductile boundary.

Debris Generation

Debris generation estimates the amount of debris that will be generated by the earthquake. The debris is categorized in two sections: a) Brick/Wood and b) Reinforced Concrete/Steel. This distinction is made because of the different types of material handling equipment required to handle the debris.

Deep Earthquake

An earthquake whose focus is located more than 300 kilometers from the earth's surface. Earthquake-report.com differs from the official notification calling earthquakes with a depth of more than 100 km as "Deep". This is mainly because of the non-damaging impact of these earthquakes. 3 percent of total of total energy comes from deeper earthquake.

Earthquake

Earthquake is any sudden shaking of the ground caused by the passage of seismic waves through the Earth's rocks. Seismic waves are produced when some form of energy stored in the Earth's crust is suddenly released, usually when masses of rock straining against one another suddenly fracture and slip.

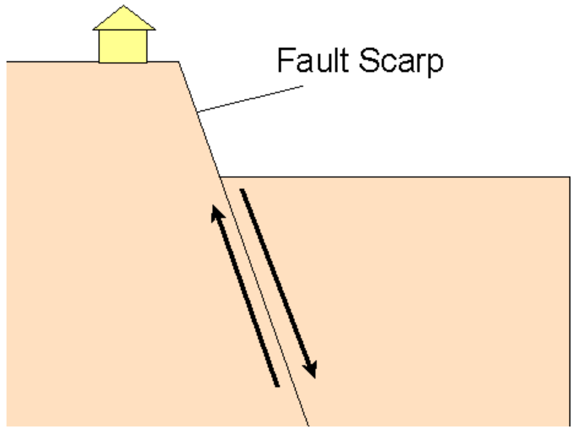
Earthquake Risk

Earthquake risk is the probability that humans will incur loss or damage to their built environment if they are exposed to a seismic hazard. In other words, earthquake risk or seismic risk is an interaction between seismic hazard and vulnerability (humans or their built environment). In general, seismic risk can be expressed qualitatively as

Seismic risk= seismic hazard x vulnerability

Fault Scarp

A fault scarp is a small step on the ground surface where one side of a fault has moved vertically with respect to another. It is the topographic expression of faulting attributed to the displacement of the land surface by movement along faults.

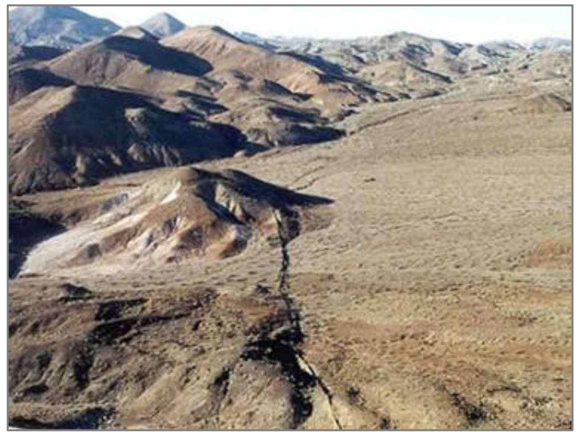


Fault Scarp `

Fault scarp, Zhangye thrust, Qilian Shan, NE Tibet

Fault Trace

Intersection of a fault with the ground surface; also, the line commonly plotted on geologic maps to represent a fault. It is more like intersection of fault with geological surface and leaving a mark.



Fault surface trace of the Hector Mine fault after the October 16, 1999 M7.1 rupture. (Photo by Katherine Kendrick, U.S. Geological Survey)

Fire Following Earthquake

Damage to infrastructure after an earthquake is a major loss trigger. One of the consequences of such damage is fire following a seismic event. Fires often associated with broken electrical and gas lines, gas is set free as gas lines are broken and a spark will start bringing "inferno". To complicate things water lines are broken and so there is no water to extinguish the fire. So an earthquake can not only trigger a fire by releasing combustible material but also impair passive or active firefighting systems.

Ground Failure

An effect of seismic activity, such as an earthquake, where the ground becomes very soft, due to the shaking, and acts like a liquid, causing landslides, liquefaction and lateral spreads.

Ground Motion (Shaking)

Ground motion is a term referring to the qualitative or quantitative aspects of movement of the Earth's surface from earthquakes or explosions. Ground motion is produced by waves that are generated by sudden slip on a fault or sudden pressure at the explosive source and travel through the Earth and along its surface.

Intensity

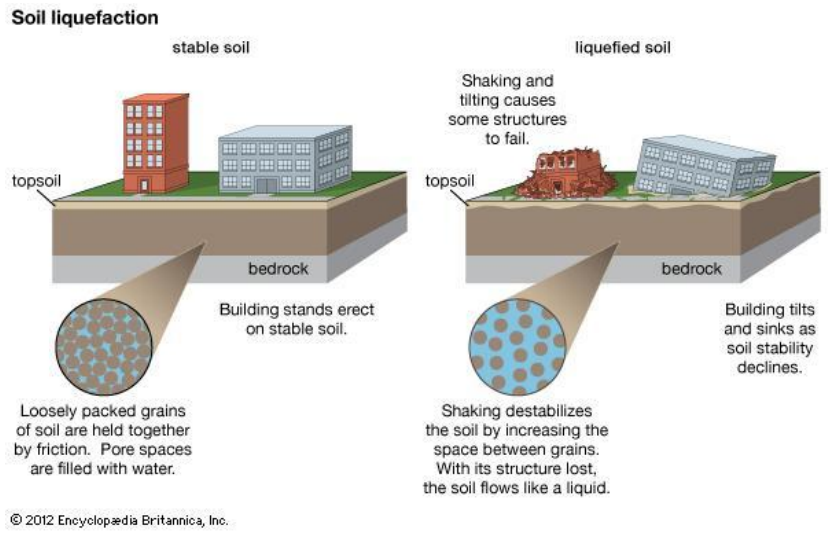
The intensity is a number (written as a Roman numeral) describing the severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures. Several scales exist, but the ones most commonly used are the Modified Mercalli scale and the Rossi-Forel scale. The intensities of earthquake are measured, depending on location where it is needed to measure, unlike the magnitude, which is one number for each earthquake.

Intermediate Earthquake

An earthquake whose focus is located between 70 to 300 kilometers from the earth's surface. Earthquake-report.com differs from the official notification calling earthquakes with a depth of more than 40 to 00 km as "Intermediate". This is mainly because of the limited damaging impact of these earthquakes. Of the total energy released in earthquakes, 12 percent comes from intermediate earthquakes.

Liquefaction

The transformation of a granular material from a solid state into a liquefied state as a consequence of increased pore water pressures and reduced effective stress. In engineering seismology, it refers to the loss of soil strength as a result of an increase in pore pressure due to ground motion. This effect can be caused by earthquake shaking.



Liquefaction occurs in saturated soils, that is, soils in which the space between individual particles is completely filled with water. This water exerts a pressure on the soil particles that influences how tightly the particles themselves are pressed together. Prior to an earthquake, the water pressure is relatively low. However, earthquake shaking can cause the water pressure to increase to the point where the soil particles can readily move with respect to each other.

When liquefaction occurs, the strength of the soil decreases and, the ability of a soil deposit to support foundations for buildings and bridges is reduced as seen in the image below.

Foundation Weakening Due to Soil Liquefaction in Adapazari, Turkey

Locked Fault

Locked fault is a fault that is not slipping because frictional resistance on the fault is greater than the shear stress across the fault. Such faults may store strain for extended periods that is eventually released in an earthquake when frictional resistance is overcome. A locked fault condition contrasts with fault-creep conditions and an unlocked fault.

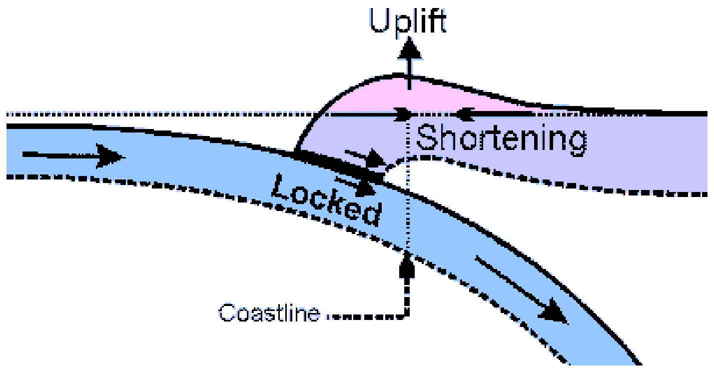


Image courtesy of Geological Survey of Canada

Magnitude

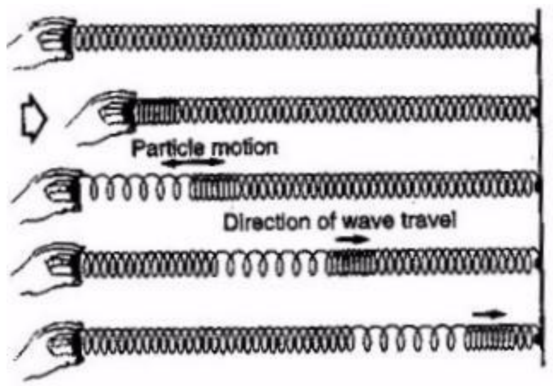
Magnitude is a number that characterizes the relative size of an earthquake. Magnitude is based on measurement of the maximum motion recorded by a seismograph (sometimes for earthquake waves of a particular frequency), corrected for attenuation to a standardized distance. Several scales have been defined, but the most commonly used are (1) local magnitude (ML), commonly referred to as Richter magnitude, (2) surface-wave magnitude (Ms), (3) body-wave magnitude (Mb), and (4) moment magnitude (Mw). ML, Ms and Mb have limited range and applicability and do not satisfactorily measure the size of the largest earthquakes. The moment magnitude (Mw) scale, based on the concept of seismic moment, is uniformly applicable to all sizes of earthquakes but is more difficult to compute than the other types. In principal, all magnitude scales could be cross calibrated to yield the same value for any given earthquake, but this expectation has proven to be only approximately true, thus the need to specify the magnitude type as well as its value. An increase of one unit of magnitude (for example, from 4.6 to 5.6) represents a 10-fold increase in wave amplitude on a seismogram or approximately a 30-fold increase in the energy released. In other words, a magnitude 6.7 earthquake releases over 900 times (30 times 30) the energy of a 4.7 earthquake – or it takes about 900 magnitude 4.7 earthquakes to equal the energy released in a single 6.7 earthquake! There is no beginning nor end to this scale.

However, rock mechanics seem to preclude earthquakes smaller than about -1 or larger than about 9.5. A magnitude -1.0 event releases about 900 times less energy than a magnitude 1.0 quake. Except in special circumstances, earthquakes below magnitude 2.5 are not generally felt by humans.

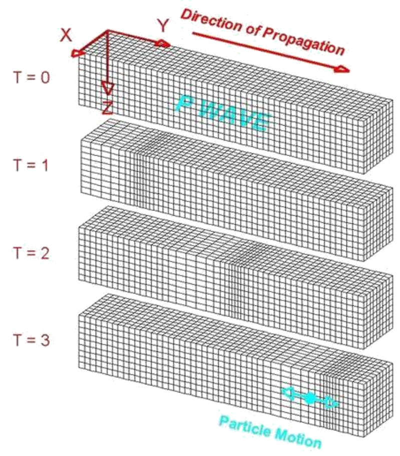
P Wave

P-waves are a type of body wave that is the first wave to arrive to the seismograph, called seismic waves in seismology. It can travel through a continuum. The continuum is made up of gases (as sound waves), liquids, or solids, including the Earth. P-waves can be produced by earthquakes and recorded by seismographs. The name P-wave is often said to stand either for primary wave, as it has the highest velocity and is therefore the first to be felt; or pressure wave, as it is formed from alternating compressions and rarefactions.

This compressive wave, shake the ground back and forth in the same direction and the opposite direction as the direction the wave is moving.



(a)



(b)

Example of propagation of P-wave

PGA

A small particle attached to the earth during an earthquake will be moved back and forth rather irregularly. This movement can be described by its changing position as its changing acceleration as a function of time. The peak ground acceleration is the maximum acceleration that a building or any structure situated at the ground at the time of an earthquake.

PGD

Peak ground displacement is the maximum horizontal distance a structure will move during the time of an earthquake.

PGV

An object attached to the earth during an earthquake will be shaken irregularly. This movement can be described by its changing position as its changing velocity as a function of time. The peak ground velocity is the maximum velocity that a building or a structure situated at the ground during the time of earthquake.

Phase

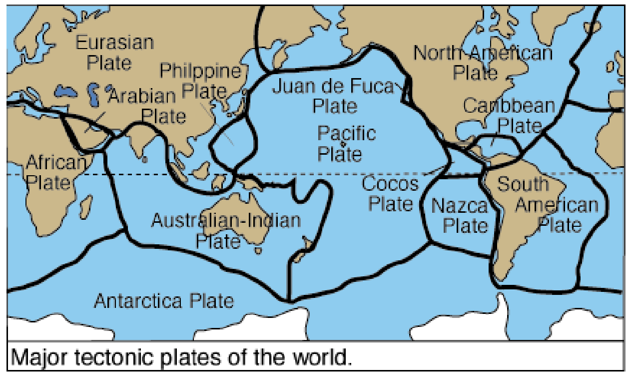
A stage in periodic motion, such as wave motion or the motion of an oscillator measured with respect to a point and expressed in angular measure. The change of seismic velocities within Earth, as well as the possibility of conversions between compressional (P) waves and shear (S) waves, results in many possible wave paths. Each path produces a separate seismic phase on seismograms.

Plate

The Earths rocky outer crust solidified billions years ago. This crust is not a solid shell; it is broken up into huge thick plates. These relatively large rigid segments of the Earth's lithosphere move in relation to other plates over the asthenosphere.

Plate Tectonics

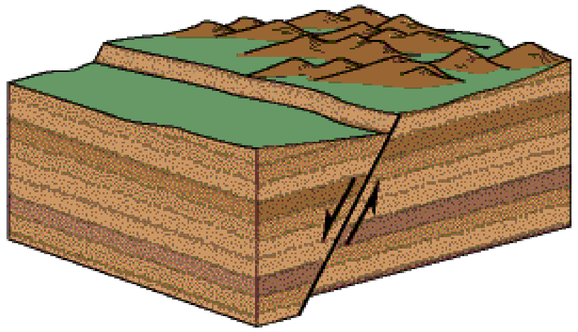
A theory supported by a wide range of evidence that considers the Earth's crust and upper mantle to be composed of several large, thin, relatively rigid plates. Centre of earth's temperature is high as 2500° c and at the upper suface is 25°c. There is also a huge amount of pressure in the inner mantle. This huge temperature and pressure caused the semiliquid material of inner mantle to move regularly. This causes the plates to move with respect to one another and faults are created. Several styles of faults bound the plates, including thrust faults along which plate material is subducted or consumed in the mantle, oceanic spreading ridges along which new crustal material is produced, and transform faults that accommodate horizontal slip (strike slip) between adjoining plates.



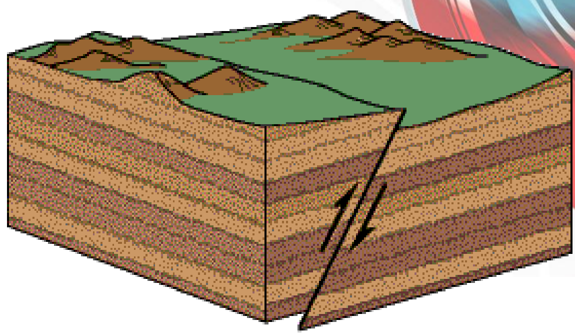
Major tectonic plates of the world

Normal and Reverse Fault

Normal and Reverse fault are classified according to their relative movement to each other .In figure one there are two faults -the right one which are more like a foot is named as footwall and the other left one which is more like hanging or resting above to the footwall is the hanging wall. When due to gravity hanging wall moves downward with respect to footwall it is called normal fault (9-a). When the hanging wall moves upward with respect to footwall is called reverse fault (9-b).



(a) Normal fault



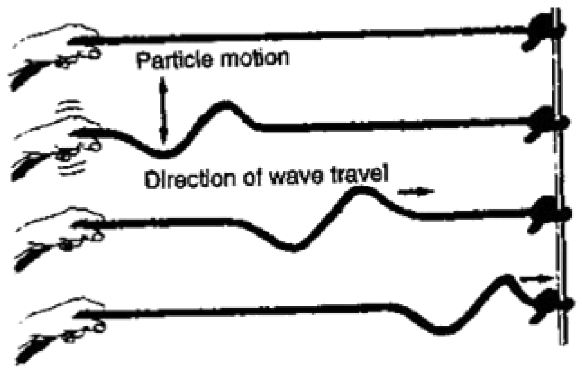
(b) Reverse fault

Risk Assessment

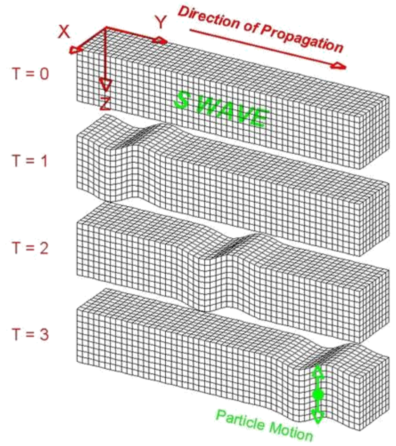
A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend. Comment: Risk assessments (and associated risk mapping) include: a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability including the physical social, health, economic and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities in respect to likely risk scenarios. This series of activities is sometimes known as a risk analysis process.

Secondary Wave

It is the second type of body wave other than P-wave that arrives in seismograph. It is called secondary wave because it arrives later than the P-wave because it moves slower in the rock. It is also called shear or transverse wave, as it moves perpendicular to the direction of wave propagation. Unlike P-wave, Secondary wave can travel only through the solid material and are not able to pass through liquids.



(a)



(b)

Propagation of Secondary wave or S-wave

Seismic hazard

Seismic hazard refers to the study of expected earthquake ground motions at the earth's surface, and its likely effects on existing natural conditions and man-made structures for public safety considerations; the results of such studies are published as seismic hazard maps, which identify the relative motion of different areas on a local, regional or national basis. With hazards thus determined, their risks are assessed and included in such areas as building codes for standard buildings, designing larger buildings and infrastructure projects, land use planning and determining insurance rates.

Seismic Waves

Seismic waves are the result of an earthquake, explosion or volcano where sudden release of energy burst out in form of waves. During the energy release different type of seismic waves are created. There are body waves (P-wave and S-wave) which travel through the interior of the earth and there are surface waves which travel through the surface of the earth.

Seismicity

The geographic and historical distribution of earthquakes. A term introduced by Gutenberg and Richter to describe quantitatively the space, time, and magnitude distribution of earthquake occurrences. Seismicity within a specific source zone or region is usually quantified in terms of a Gutenberg-Richter relationship.

Shallow Earthquake

An earthquake whose focus is located within 70 kilometers of the earth's surface. Earthquake - report.com differs from the official notification calling earthquakes with a depth up to 40 km as "Shallow". This is mainly because of the possible damaging impact of these earthquakes.

It is the shallow earthquake that are the most devastating, and they contribute about the three-quarters of the total energy released in the earthquake throughout the world.

Spectral Acceleration

Spectral acceleration (SA) is a unit measured in g (the acceleration due to Earth's gravity, equivalent to g-force) that describes the maximum acceleration in an earthquake on an object (example structure) specifically a damped, harmonic oscillator moving in one physical dimension. This can be measured at (or specified for) different oscillation frequencies and with different degrees of damping, although 5% damping is commonly applied.

Surface Faulting

Displacement that reaches the Earth's surface during slip along a fault. Commonly accompanies moderate and large earthquakes having focal depths less than 20 km. Surface faulting also may accompany aseismic tectonic creep or natural or man-induced subsidence.

Seismic Risk Assessment: Available Research Documents in Bangladesh

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Technical Assistance

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