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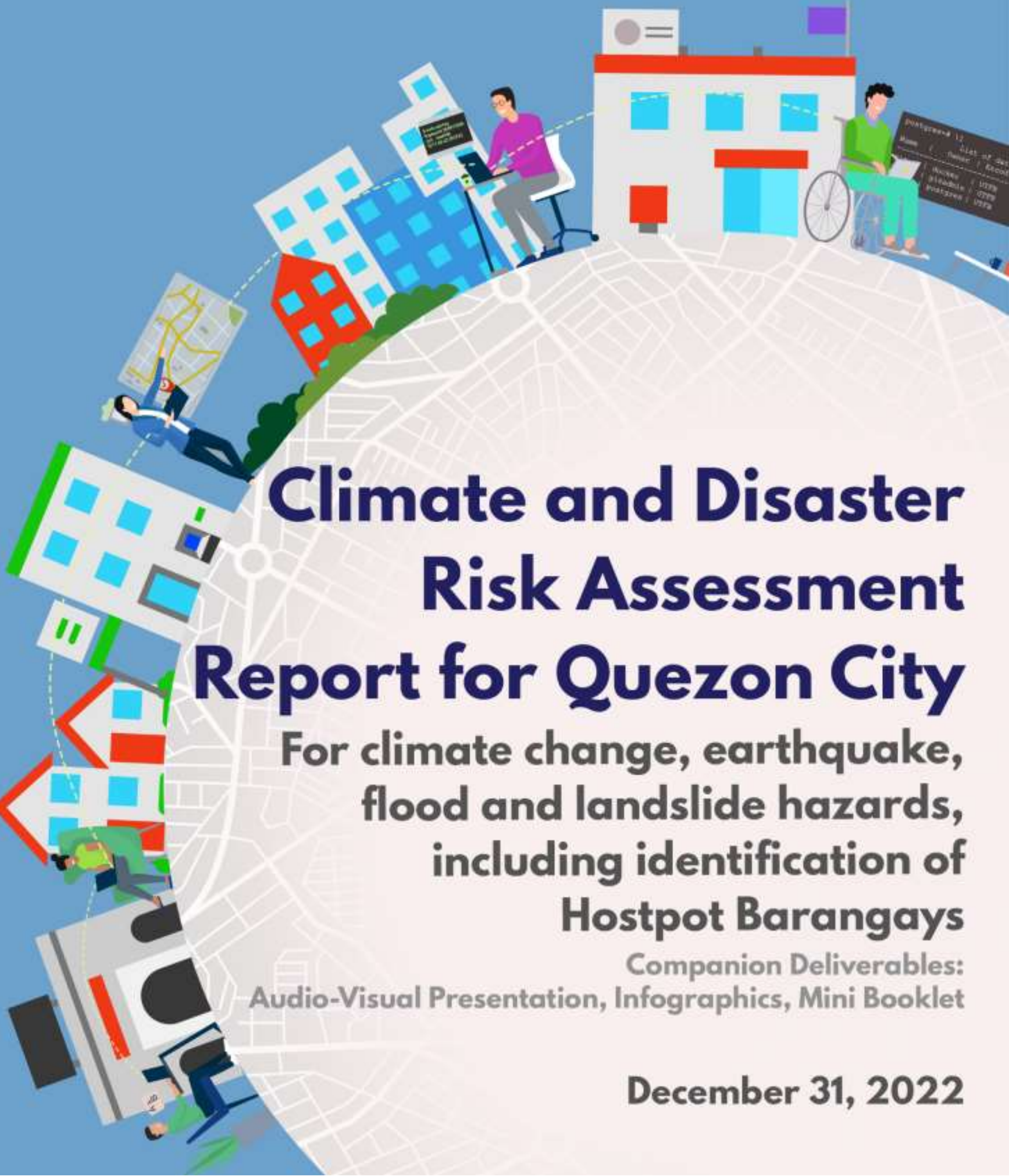
Conduct of an Updated Climate and Disaster Risk Assessment (CDRA) for Quezon City, Philippines

Deliverable 11



Climate and Disaster Risk Assessment Report for Quezon City

For climate change, earthquake, flood and landslide hazards, including identification of Hostpot Barangays

Companion Deliverables:
Audio-Visual Presentation, Infographics, Mini Booklet

December 31, 2022

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Executive Summary

This report constitutes **Deliverable 11 of the Conduct of an Updated Climate and Disaster Risk Assessment (CDRA) Project**. It summarizes the climate and disaster risk assessment key parameters, outputs, their interpretation and their significance. The CDRA is concerned with four hazards: climate change, flood, landslide and earthquake hazards. This report is a companion report to **Deliverable 8: Hazard, Vulnerability and Risk Maps for all 142 Barangays** dated September 30, 2022. The latter provides detailed explanations on the methodologies, underlying data, assumptions behind the hazard and risk assessment associated with the four hazards as well as a full presentation of the outputs and the findings. The reader is referred to the Deliverable 8 report for more details. In addition, the reader is also referred to the **Risk Profile and Atlas (**Deliverable 14), which provides large scale maps and non-technical explanations of the main outputs of the CDRA and puts these outputs in the context of policy-making, awareness raising, and planning.

This report focuses more on **outputs** and their relevance in the context of the CDRA requirements. In addition, it presents the **hotspot barangays** identified from the Barangay Vulnerability Index (BVI). Furthermore, it is supported by three accompanying Information, Education and Communication (IEC) elements, namely: An **audio-visual presentation (AVP)**, **infographics** for each hazard, and **mini booklet**, which contains key highlights of the study and the top risk hotspots in the city. The mini booklet is produced in both English and Filipino languages. These companion deliverables are submitted separately. Soft versions of the IEC material can be accessed through the following link.

https://drive.google.com/drive/folders/1vvR2f4cSSH-1TN6Hs0MlPrOGkjuAn_7_?usp=share_link

The report has seven parts:
Part 1 is the summary of the exposure data used in the assessment, particularly in population, land use and critical point facilities.
Part 2 is a representation of climate change hazards for Quezon City, particularly in terms of impacts on temperature and rainfall.
Part 3 presents the flood hazard and risk assessment. It includes outputs for climate change projections for Metro Manila, RCP 8.5 rain flood event for 100-year flood map for the city based on the QC Drainage Project preliminary studies, and flood vulnerability analysis from the CDRA workshops held on October 21, October 28 and November 4 with the barangay representatives.
Part 4 tackles the earthquake hazard and risk. It provides a higher-resolution earthquake intensity map, building damage estimates per barangay, expected casualties (i.e., injuries and loss of life), and estimates of displaced population based on the M7.2 earthquake scenario on the West Valley Fault.
Part 5 is about the landslide hazard and risk. This provides updated landslide susceptibility maps by complementing the current available data from the Mines and Geosciences Bureau (MGB). This also includes the overlay analysis of critical assets to the updated landslide susceptibility maps.
Part 6 presents the Hotspot barangays of Quezon City, which are the barangays that represent the highest potential vulnerability for one or multiple hazards.
Part 7 reflects on the progress made by Quezon City in the last decade to manage and reduce its disaster risk and provides a road map for the future.

The report is illustrated with relevant maps and charts to facilitate comprehension and interpretation.

This study does not duplicate data and outputs found in other similar studies. Rather, it updates them to current 2022 exposure and improves significantly on the resolution of the analysis. It establishes an in-depth and high resolution (street level) assessment of the impacts of hazards on population, buildings, critical point facilities, and infrastructure. It also includes the assessment of the impact of secondary effects such as the spread of waterborne diseases for floods or liquefaction and fire following for earthquakes. The outputs include count of buildings and their associated area affected by various hazard for each barangay as well as other metrics that are essential for preparedness and planning purposes. Results are presented by district and by barangay to facilitate the reading and interpretation of the maps and their association with the related charts. One of the main intent is to inform the update of the city's various city development plans, its physical framework and its land use plan in the early future (2020-2039). Another target objective is to support data-driven and science-based barangay level and community level planning and preparedness efforts.

The report is a complement to the Hazard, Vulnerability, Risk and Hotspots Assessment (HVRA) for the earthquake, flood and landslide hazards affecting the 142 barangays of Quezon City (QC) by integrating inputs from the Climate and Disaster Risk Assessment Workshops for the barangays from six districts. It also, includes a full chapter on the hotspot barangays as well as a concluding chapter providing a vision of a resilient future for Quezon City.

The flood susceptibility assessment is anchored on the Quezon City Drainage Master Plan (QC-DMP) preliminary report in 2021 on RCP 8.5 (2020-2039) 100-year rain return scenario, the Mines and Geosciences Bureau (MGB) Flood Susceptibility Updating Report in 2021 and the Greater Metro Manila Area Risk Assessment Project (GMMA-RAP) which is a benchmark study in 2013. The latter was undertaken through a collaborative project between the Government of the Philippines and Geoscience Australia. The flood depth maps taken from the QC-DMP and MGB studies are the most recent scientific representation of inundation useful for hazard and risk analysis for the Quezon City agencies and recommended for disaster risk management (DRM) planning by public and private agencies including local government units such as Quezon City Government (QCG).

The earthquake hazard and risk assessment is based on the M7.2 earthquake scenario on the West Valley Fault. The study attempts to duplicate the science behind the GMMA-RAP earthquake risk assessment, whenever available, but improves on the resolution by refining the spatial grid of analysis from 1.1km x 1.1km adopted in the GMMA-RAP to 175m x 175m, corresponding to close to 40 times increase in the resolution.

The CDRA study adopted the scientific approach and results from the different studies but improved on several components as follows:

1) It uses updated (2022) exposure data from Quezon to represent today's conditions.
2) It uses geo-political boundaries for Quezon City and for its 142 barangays that are officially used by QCG.
3) It significantly improves the analysis resolution to guide barangay level and community level preparedness and planning.
4) It includes a section on rainfall, temperature tropical cyclones, sea level, and climate extremes projections and implications of climate change in Metro-Manila and QC.
5) It includes simulation results from the QC-DMP flood studies (preliminary) and MGB flood susceptibility mapping to develop the flood impact analyses.
6) It establishes the hotspot barangays
7) It customizes all outputs to Quezon City's DRRM and presents a series of applications pertinent to improving the management of disaster risk, supporting disaster preparedness and response, establishing priorities for risk reduction investments and mainstreaming hazard and risk reduction objectives in land use and development plans.

All outputs are presented in maps and charts and their relevance to Disaster Risk Reduction and Management planning is elaborated.

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- The Philippine Institute of Volcanology and Seismology (PHIVOLCS) for providing the digitized earthquake hazard data for Greater Metro Manila and technical clarifications on the hazard parameters;
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Disclaimer

This document was developed for the project "*Conduct of an Updated Climate and Disaster Risk Assessment (CDRA) for Quezon City (CONSUL-21-001)*". It was developed by EMI for the Quezon City Government.

Data, information, maps, tables, findings, and analyses presented in the document are based on information collected from Quezon City Departments and offices, reports and data from various hazard and risk assessment studies, as well as information available online or from media sources and academe. Hypotheses and assumptions were developed by EMI experts with extensive experience in their respective fields of expertise to treat the datasets and come up with a comprehensive geo-spatial exposure for Quezon City and a sound assessment of the hazard, vulnerability and risk for Quezon City.

In order to improve on the assessments, trainings, workshops, focus group exercises, key informants' interviews and field visits were conducted over several occasions during the undertaking of the project. The validation procedures include flooding situations to augment flood models, spatial locations and attributes of essential facilities, and importance of disaster risk variables in terms of emergency response, coping capacities, and hazard exposures.

The analysis for earthquake related hazards is scenario-based. The magnitude 7.2 earthquake scenario on the West Valley Fault (Model 8 in MMEIRS) is recognized by PHIVOLCS as well as experts in the earthquake field as representing the worst-case scenario for Metro Manila. The same scenario is also considered in the GMMA-Risk Analysis Project (GMMA-RAP) study. The occurrence of such an earthquake is possible but very rare. While earthquakes with lesser magnitudes will provide lower levels of constraints and loss, planning for the worst-case scenario is recommended by international standards (e.g., ISO3000) and by recent earthquake occurrences globally because it help organizations and institutions prepare for the unforeseen.

The sources of flood data used in the study include various models based on flooding due to Typhoon Ondoy (2009), Typhoon Ulysses, the Mines and GeoSciences Bureau Flood Susceptibility Study for Quezon City, the GMMA-RAP study, Quezon City Drainage Master Plan Preliminary Reports. EMI made no attempt to qualify or validate the assumptions, methodologies or outputs of these studies. They are used "as-is". Flood hazard maps are indicative inundation maps for large flood events and useful for preparedness and for planning purposes.

Vulnerability and Damage impact assessments and projections provided in this report are meant to inform QCG on the risks provided by climate change, earthquakes, landslides, and floods so they can improve on their planning and policy making processes. The information provided in this report is not meant, and should not be interpreted, to replicate the realities of the impacts of an actual event. Consequences from actual events can vary significantly from the projections provided in this report.

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Acronyms

AEP	Annual Exceedance Probability
BDRRMP	Barangay Disaster Risk Reduction and Management Plans
BSWM	Bureau of Soils and Water Management
CENRO	City Environmental and Natural Resources Department
CEO	City Engineering Office
CHD	City Health Department
CPDD	City Planning and Development Department
CSCAND	Collective Strengthening of Community Awareness for Natural Disasters
CSWD	City Social Welfare and Development
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DEPED	Department of Education
DFE	Design Flood Event
DO	Dissolved Oxygen
DOH	Department of Health
DOST	Department of Science and Technology
DPWH	Department of Public Works and Highways
DRR	Disaster Risk Reduction
DRRM	Disaster Risk Reduction and Management
DRRMO	Disaster Risk Reduction and Management Office
EMI	Earthquakes and Megacities Initiative
GA	Geoscience Australia
GIS	Geographic Information System
GK	Gawad KALASAG
GMICE	Ground Motion Intensity Equation
GMMA	Greater Metro Manila Area
GMMA-RAP	Enhancing Risk Analysis Capacities for Flood, Tropical Cyclone Severe Wind and Earthquake for the Greater Metro Manila Area' Project also referred to as Greater Metro Manila Area Risk Analysis Project
GMPEs	Ground Motion Prediction Equations
GMPMs	Ground Motion Prediction Models
GSED	Geo Spatial Exposure Database
GSO	General Services Office
HVRA	Hazards, Vulnerability, Risk Assessment
IFSAR	Interferometric Synthetic Aperture Radar
ILQ	Institutional Living Quarter
IPCC AR[6]	Intergovernmental Panel on Climate Change Sixth Assessment Report
IPCC SROCC	Intergovernmental Panel on Clliate Change Special Report on the Ocean and Cryosphere in a Changing Climate
JICA	Japan International Cooperation Agency
KALASAG	Kalamidad at Sakuna Labanan, Sariling Galing ang Kaligtasan
KKK	Kataastaasan, Kagalanggalangan na Katipunan
LGU	Local Government Unit
LiDAR	Light Detection and Ranging
MERALCO	Manila Electric Railroad and Light Company
MGB	Mines and Geosciences Bureau
MMEIRS	Metropolitan Manila Earthquake Impact Reduction Study
MMI	Modified Mercalli Intensity Scale
MSL	Mean Sea Level

NAMRIA	National Mapping and Resource Information Authority
NDSM	Normalized Digital Surface Model
NEHRP	National Earthquake Hazard Reduction Program
NHCS	Napindan Hydraulic Control Structure
NOAH	Nationwide Operational Assessment of Hazards
OBO	Office of the Building Official
OSM	OpenStreetMap
PAGASA	Philippine Atmospheric, Geophysical, and Astronomical Services Administration
PAR	Philippine Area of Responsibility
PCG BFP	PCG Bureau of Fire Protection
PEIS	PHIVOLCS Earthquake Intensity Scale
PEMSEA	Partnerships in the Environmental Management of the Seas of East Asia
PGA	peak ground acceleration
PHIVOLCS	Philippine Institute of Volcanology and Seismology
PIO	Public Information Office
PRRCMO	Pasig River Coordinating and Management Office
PSA	Philippine Statistics Authority
QCDRRMO	Quezon City Disaster Risk Reduction and Management Office
QCG	Quezon City Government
QC-DMP	Quezon City Drainage Master Plan
RA	Republic Act
RCP 4.5	Representative Concentrated Pathways 4.5
RCP 8.5	Representative Concentrated Pathways 8.5
RCP 8.5 (2020-2039)	RCP 8.5 early future
RIDF	Rainfall Intensity Duration and Frequency
RPA	Risk Profile and Atlas
SLR	Sea level rise
TS	Tropical Storm
TSS	Total Suspended Solids
TWG	Technical Working Group
UNDRR	United Nations Office for Disaster Risk Reduction
UP	University of the Philippines
UPAO	Urban Poor Affairs Office
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VHU	Vacant Homes Unit
VS30	time-averaged shear velocity to 30 m depth
WB	World Bank
WVF	West Valley Fault

Link to Annex Tables

https://bit.ly/CDRATables2022

Drive Link: https://drive.google.com/drive/folders/10A0Khji3yoZzpqI9NxvpblWp3vJG1MPS?usp=share_link

**You may also access using the bit.ly link and the QR Code shown*

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Link to Information, Education and Communication (IEC) deliverables associated with the CDRA report.

https://bit.ly/CDRAIEC2022

Drive Link: https://drive.google.com/drive/folders/1vvR2f4cSSH-1TN6Hs0MlPrOGkjuAn_7_?usp=share_link

**You may also access using the bit.ly link and the QR Code shown*

- Audio-visual Presentation (AVP)
- Infographics for each hazard
- Mini booklet (available in both English and Filipino languages)

Definition of Terms

Adaptive Capacity
The ability of people, organizations and systems using available skills and resources, to adapt, adjust and transform to the negative impact of hazardous events.

Capacity
The combination of all the strengths, attributes, and resources available within a community, society or organization that can be used to achieve agreed goals.

Climate Change
The change in the state of the climate (i.e., temperature, humidity, atmospheric pressure, wind, precipitation, and other meteorological variables) in a given region that can be identified by changes in the mean and/or variability of its properties and that persists for an extended period, typically three decades or longer.

Climate Change Adaptation
The process of adjustment to actual or expected climate and its effects. In human systems, it seeks to moderate or avoid harm or exploit beneficial opportunities.

Contingency Planning
A management process that analyses disaster risks and establishes arrangements in advance to enable timely, effective and appropriate responses.

Coping Capacity
The ability of people, organizations and systems, using available skills and resources, to manage adverse conditions, risk or disasters. The capacity to cope requires continuing awareness, resources and good management, both in normal times as well as during disasters or adverse conditions. Coping capacities contribute to the reduction of disaster risks.

Critical Infrastructure
The physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society

Critical Point Facility
Critical facilities are facilities needed for emergency response such as hospitals, fire stations, emergency centers, police stations, certain public buildings that house functions needed by the public, data centers, and power plants.

Disaster Risk
The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

Disaster Management
The organization, planning and application of measures preparing for, responding to and recovering from disasters.

Disaster Risk Management
Disaster risk management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.

Disaster Risk Reduction
Disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development.

Exposure
The totality of tangible assets (i.e., people, property, infrastructure, cultural heritage, natural and biological systems, production capacity, services, institutions, or other material elements) present in hazard zones that are, thereby, subject to potential losses.

Hazard
A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.

High-loss facility
High-loss facilities are facilities whose failure carries a large potential for loss of life. Typically, they include gas stations and other industrial facilities that contain hazardous materials, schools, markets, malls, hotels and high occupancy buildings, hospitals, and assembly halls such as churches, sports arenas, and others.

Mitigation
The lessening or minimizing of the adverse impacts of a hazardous event.

Preparedness
The knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters.

Prevention
Activities and measures to avoid existing and new disaster risks.

Recovery
The restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society, aligning with the principles of sustainable development and “build back better”, to avoid or reduce future disaster risk.

Response
Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

Resilience
The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.

Rehabilitation
The restoration of basic services and facilities for the functioning of a community or a society affected by a disaster.

Risk
The probability (or likelihood) of any exposed asset to sustain a certain amount of loss should a hazard event happen.

Risk Identification & Assessment
A structured analytical process designed 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.

Social Impacts
Consequences of a hazardous event on the physical, economic, and psychological well-being of individuals and on the functioning of a community. They also refer to the features of a social system that help to avoid losses and maintain or recover satisfying living conditions after a shock.

Vulnerability
The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.

Vulnerable Population
Vulnerable populations are individuals who are at greater risk of poor physical and social health status. They are considered vulnerable because of disparities in physical, economic, and social health status when compared with the dominant population. Vulnerable populations may be less able to anticipate, cope with, resist, or recover from the impacts of a hazard. The degree to which populations are vulnerable to disasters is not primarily dependent on proximity to the source of disaster. For instance, it may take only a moderate hazard event to disrupt the well-being of many socially vulnerable populations.

Part 1:

Key Exposure Data

1. Key Exposure Data

This chapter reproduces selected exposure data, including population distribution, lifelines and building distribution, critical point facilities, and land use in Quezon City (QC). These are the main exposure data that were considered in the hazard, vulnerability and risk assessment. The actual layers identifying the characteristics of this data is included in the Geo-Spatial Exposure Database, which is Deliverable 12 of the project.

1.1. Population Distribution in Quezon City

The population distribution in each of district of Quezon City are shown in Figure 1 to Figure 3. They are based on the projected values for year 2022 provided by the QC City Planning and Development Department (CPDD).

1.2. Critical Point Facilities

Information on critical facilities provides an overview of private and public sector capabilities providing support, resources, programs, implementation, and services to save lives, properties and environment, and restore essential facilities during an emergency. These datasets may include but not limited to police stations, fire stations, evacuation center, hospitals, health centers. These data were collected from different departments of Quezon City Government (mostly CPDD) and other national and private agencies.

1.3. Lifeline and Utilities

Major lifeline and utilities that are affected by different hazards are road networks and water supply facilities. These are datasets collected for the use risk assessment. Impacts to these infrastructures are important to assess for appropriate response and continuous delivery of service during and after an emergency.

1.4. Building Footprint

Based on the high resolution ortho-imagery and LiDAR-derived elevation model provided by the National Mapping and Resource Information Authority (NAMRIA), building footprint was manually digitized. Update occupancy distribution and story categories are key attributes in the risk assessment. These were derived from data collected from the different department of the Quezon City Government, national and private agencies, and open sources.

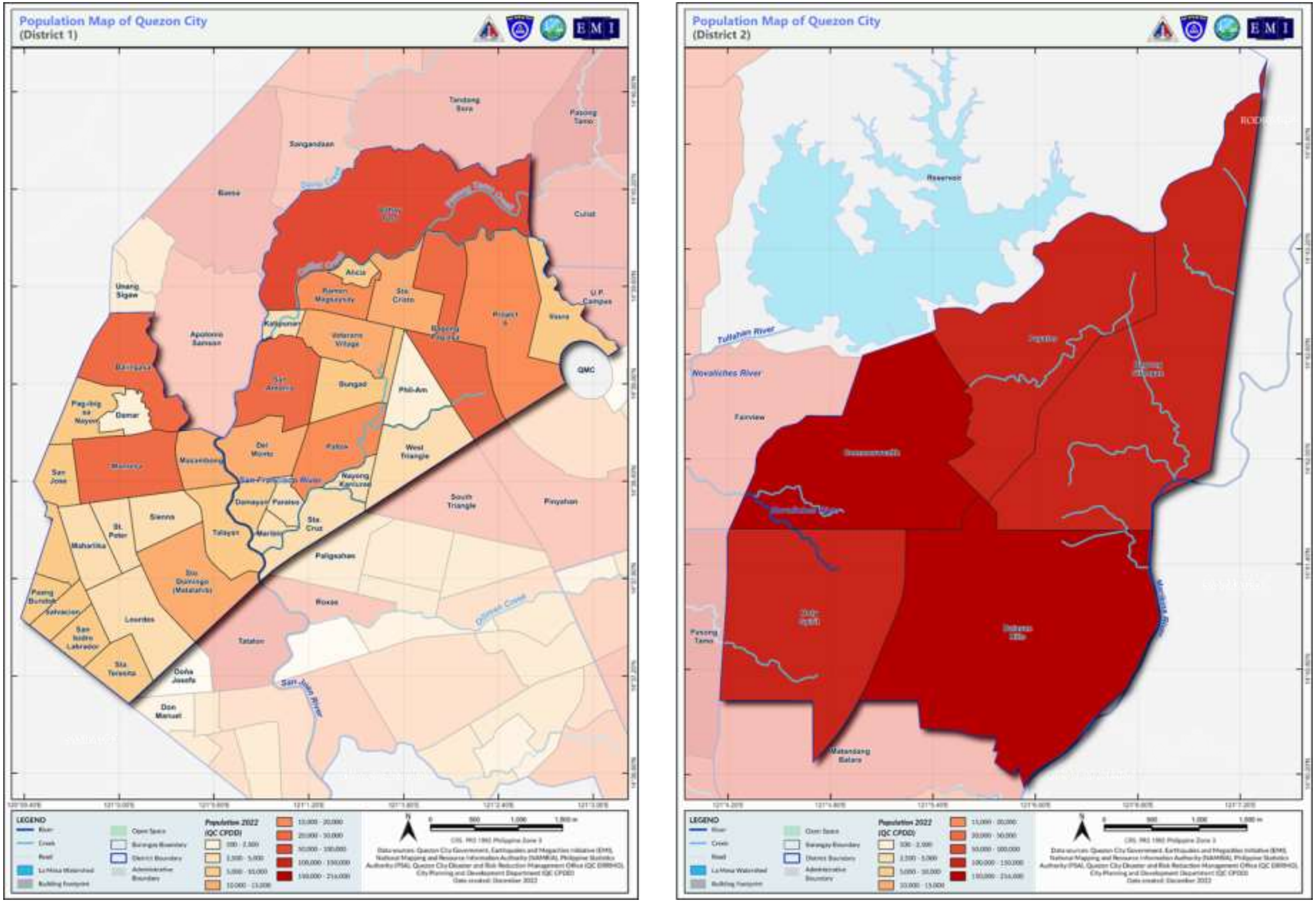


Figure 1. Population data for District 1 and District 2 (Source: QC –CPDO 2022)

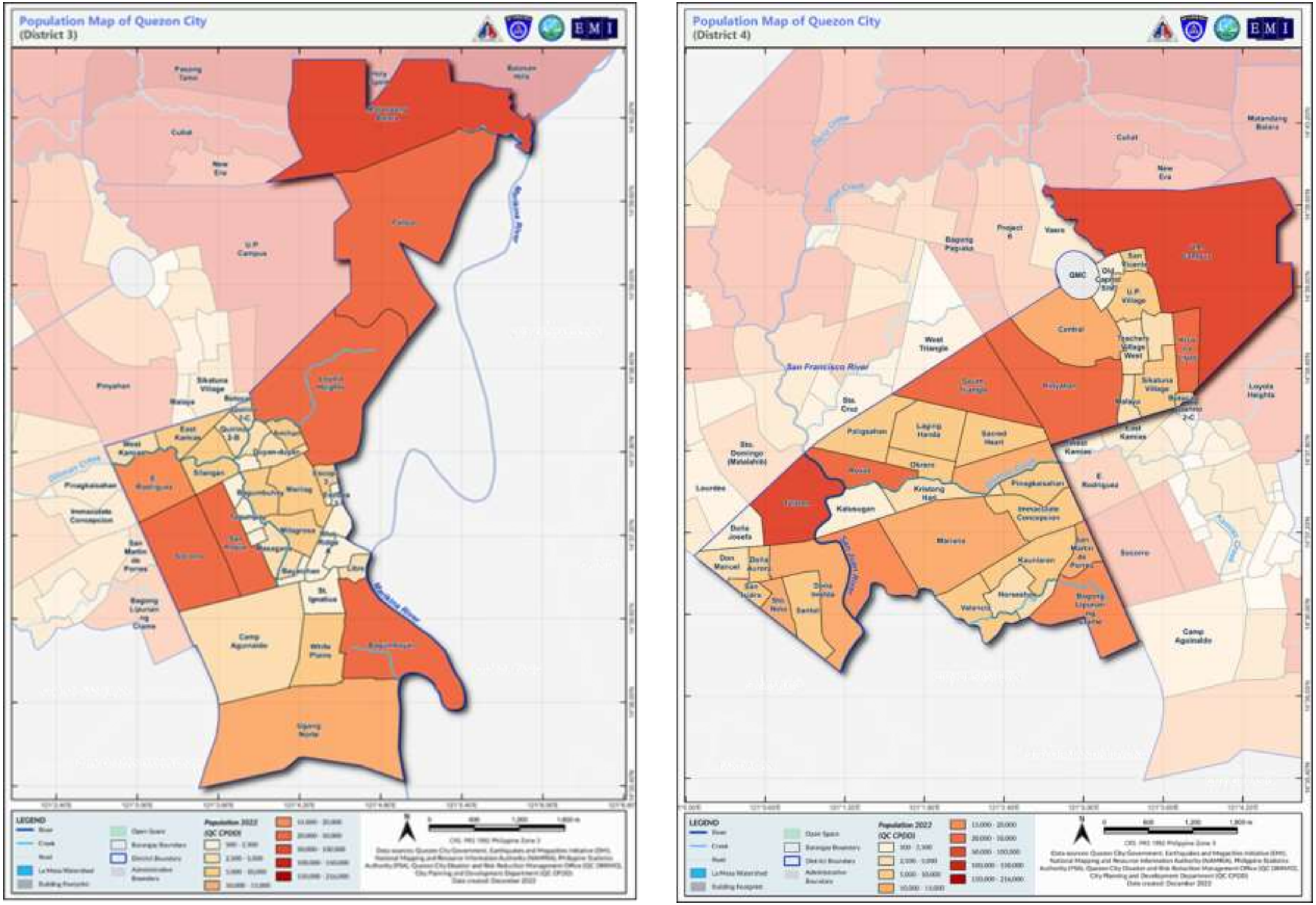
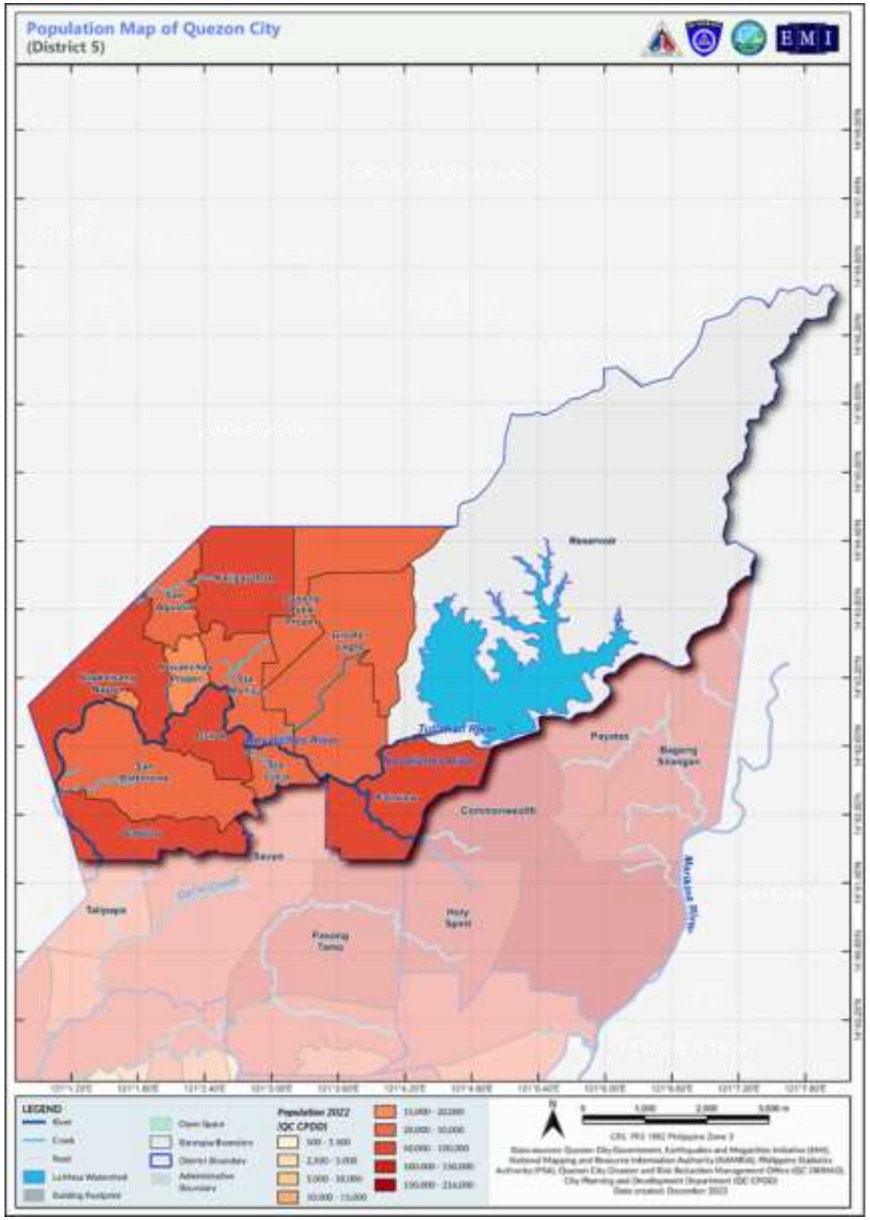


Figure 2. Population data for District 3 and District 4 (Source: QC –CPDO 2022)



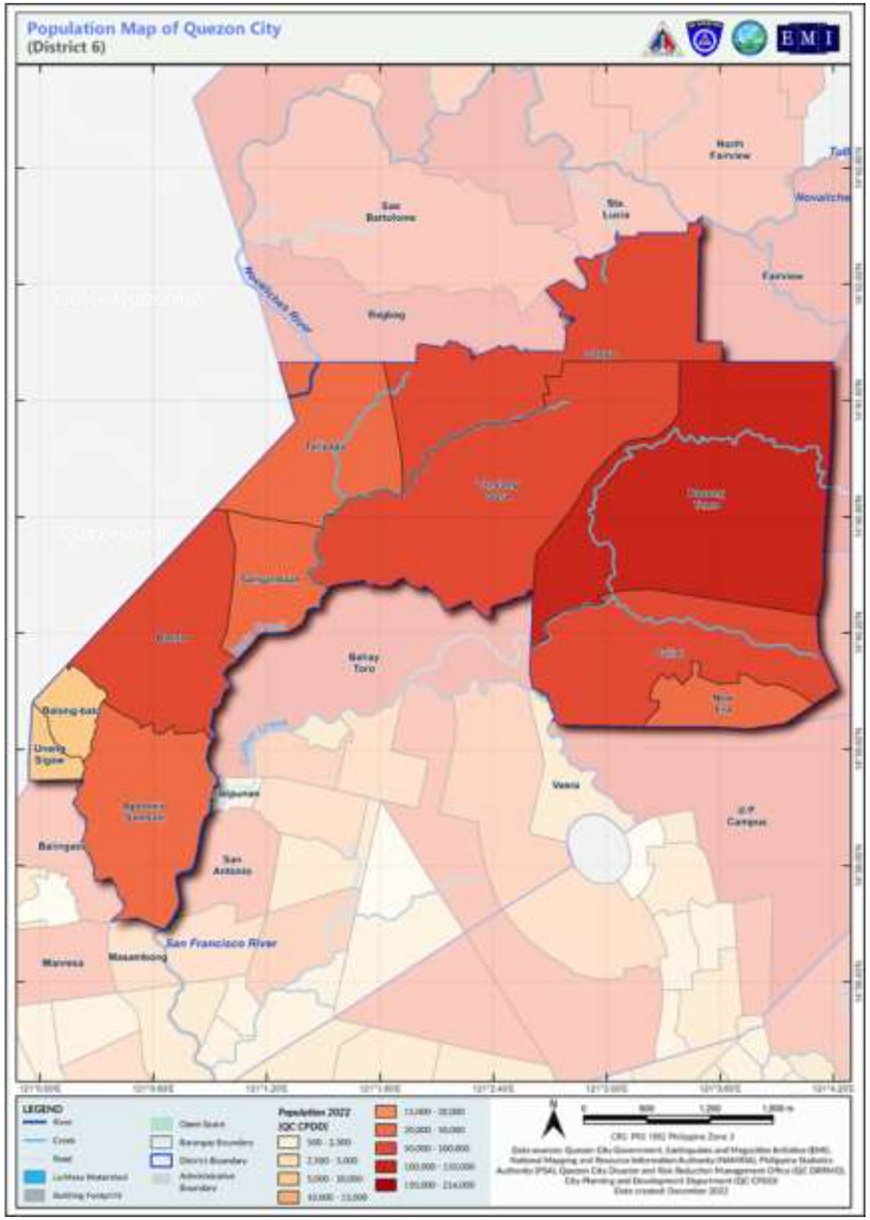


Figure 3. Population data for District 5 and District 6   (Source: QC–CPDO 2022)

1.5. Land Uses in Quezon City

The total land area of Quezon City is estimated at 16, 113 hectares. Residential uses include 3,898 hectares of formal properties, 400 hectares of low-cost housing and 901 hectares of informal settlements. As of 2018, the formal residential properties have a total of 3,898 hectares, socialized housing 800 hectares, and informal settlements occupying 800 hectares. New residential subdivision developments took place Barangays Sauyo, Tandang Sora, Talipapa, Culiat, Open spaces and vacant lots, are interspersed in these residential areas.

Pasong Tamo, Matandang Balara while high-rise or condominium type of developments are noted especially at the southern half and some at the Lagro and Fairview areas in the north. In-filling of vacant areas throughout the city can be seen from construction of new houses in once vacant lots of existing communities and in the vacant portions of already occupied lots.

Institutional areas in 2018 have about 1,226 hectares comprising of school campuses, hospitals, government offices, religious institutions, and other similar land uses. Between 2009 and 2018 District 6 had the biggest share in this growth followed by District 2 with 10.6 hectares added, District 1 with 6 hectares and 2 hectares in District 3.

Figure 4 shows the land use area distributions for Residential-Informal Settlements and for Institutional for Quezon City based on data provided by the QC City Planning and Development Office (CPDO).

The commercial uses cover 1,212 hectares of the city area. These areas follow a ribbon-like pattern along roads and create commercial nodes over the city. Cubao, Balintawak and Novaliches are the old commercial hubs in the city that have considerably expanded in land area covered.

The development and growth of North EDSA, Munoz and Sta. Mesa considerably expanded. Commercial nodes also followed towards Ugong Norte and at Lagro-North Fairview vicinity such as at Ever Commonwealth, Bagumbayan. In the last two decades, a rejuvenation of the Timog-Morato area, the Banawe area, sometimes called the "Chinatown of Quezon City" and the addition of new commercial nodes such as the U.P. Techno Hub and Town Center, the Robinson's Magnolia and Ayala Mall at Balintawak are among the evidences of commercial growth in the City.
These nodes are crossed by several main roads and are supported by various modes of transport such as railways (e.g., LRTs, MRTs) and other public transport such as jeepneys, buses and taxis. The ride sharing schemes (e.g., Grab, UV express) in the Metro has allowed more access to these commercial nodes.

Utility areas amount to 360 hectares of the City area and include water pipelines, power transmission lines, easements for stormwater drainage utilities, sewerage treatment plants and water filtration, treatment, Q and recovery facilities, the closed dump site (Payatas), telecommunication facilities, garages and terminals for cargo and commuter transport units, gasoline stations and slaughterhouses.

The largest area of natural open space is the La Mesa Watershed Reservation; also known as the Novaliches Reservoir. It is 2500-hectare watershed hectares protected area that feeds to the La Mesa Dam and Reservoir, the primary source of potable drinking water for Metro-Manila population.

Figure 5 shows a distribution of commercial and industrial use areas in Quezon City. One can find the clusters of industrial sites to be located on the western side of Quezon City and adjacent to waterways.

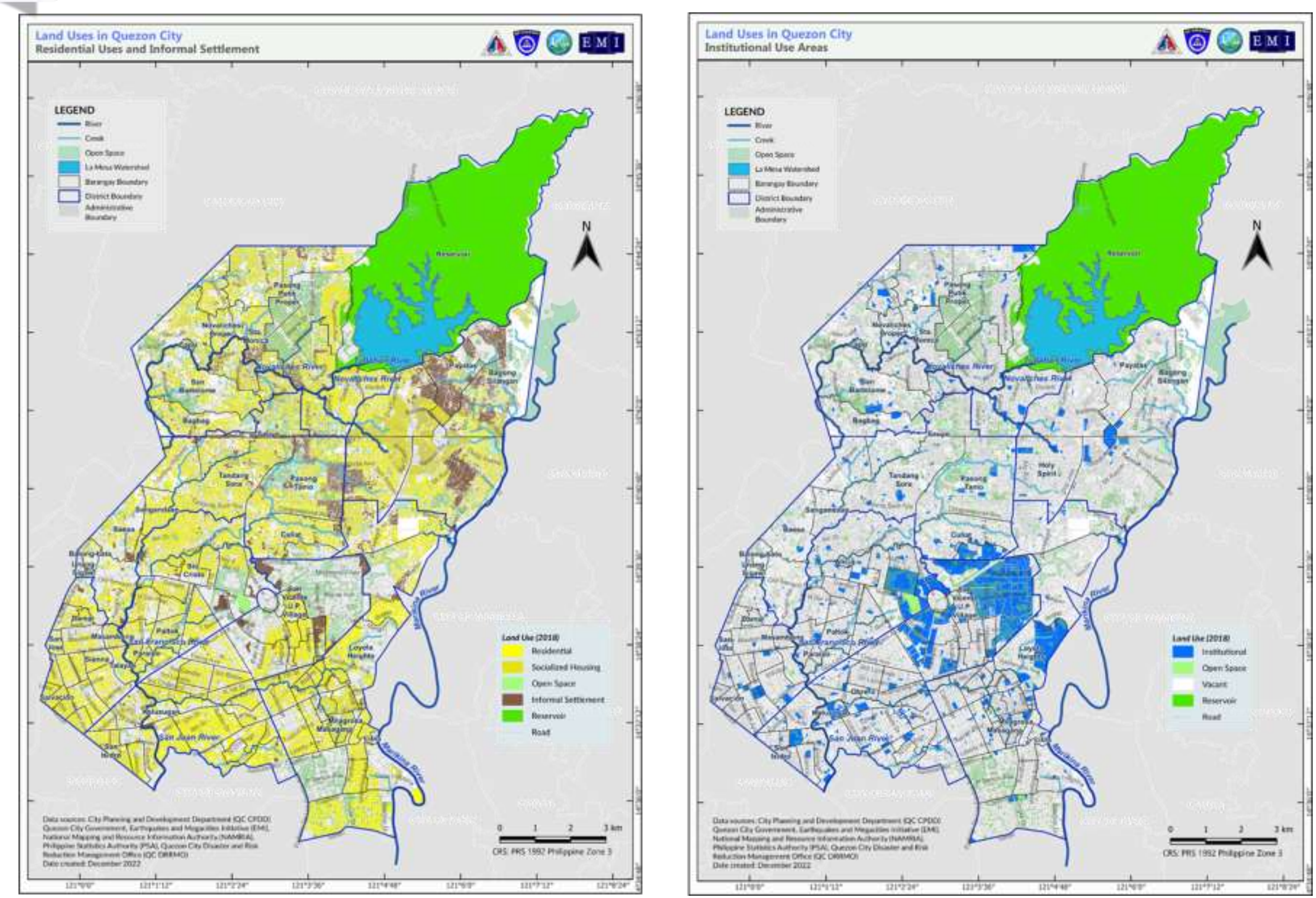


Figure 4. Residential Use Areas and Institutional Use Areas in Quezon City (Source: QC-City Planning and Development Department (CPDD), 2019)

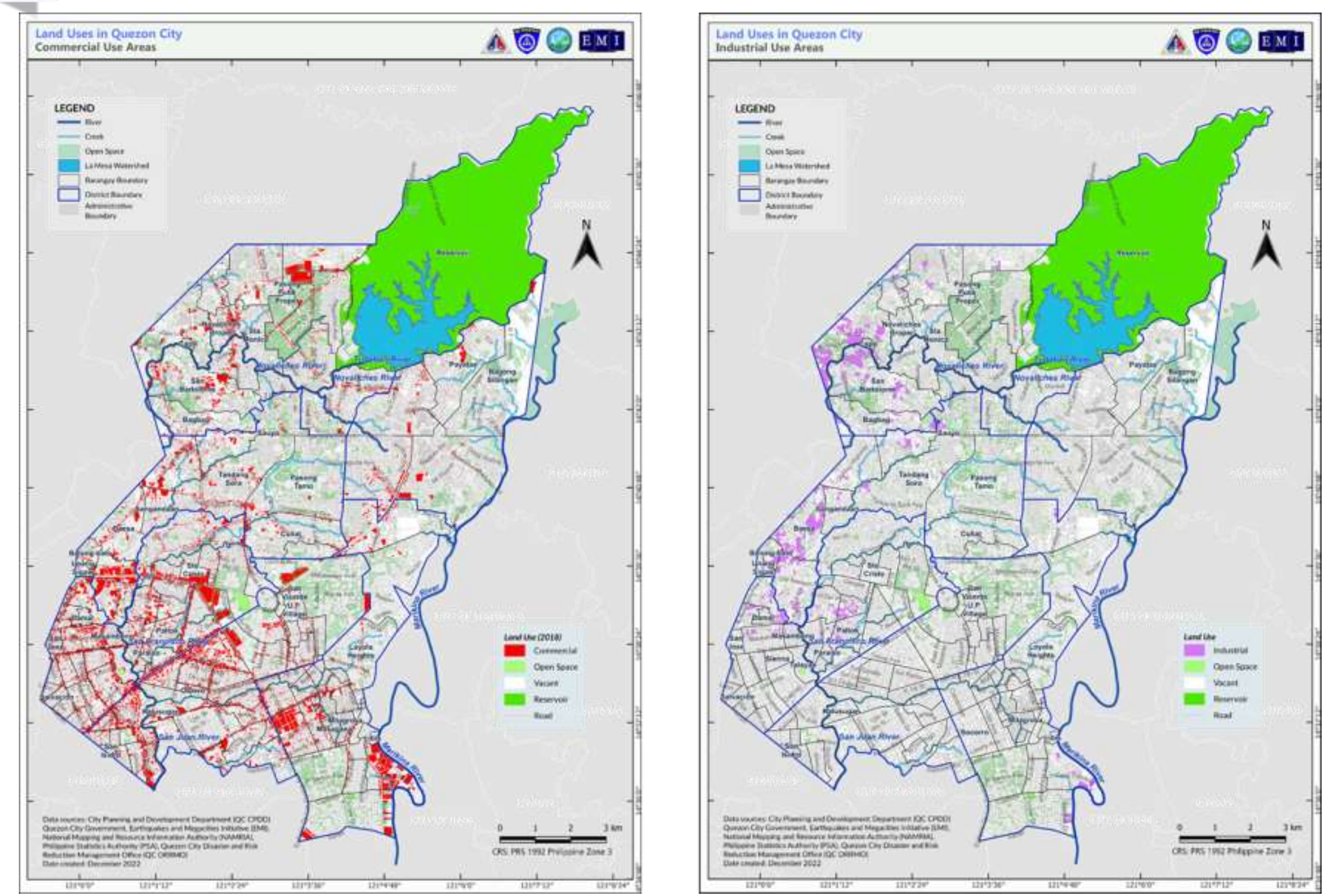


Figure 5. Commercial Use Areas and Industrial Use Areas in Quezon City (Source: QC-City Planning and Development Department (CPDD), 2019)

Part 2:

Climate Change Hazards

2. Climate Change Hazards

This section summarizes climate projections in Metro Manila, the implications of climate change in Quezon City and the tools for climate risk assessments, in terms of changes in mean values of temperature and rainfall as well as in terms of trends of extreme temperature and rainfall. More in-depth discussion, additional pertinent data, projections and potential impacts of climate change are provided in Deliverable 8: Hazard, Vulnerability and Risk Assessment of 142 Barangays, dated September 30, 2022.

Climate-resilient disaster risk reduction planning requires a careful consideration of the so-called climate projections or climate scenarios. The CERAM tool is introduced to gather initial perceptions and input from relevant stakeholders on climate change impact for various sectors. Training was provided to officials from the 142 barangays of Quezon City to introduce them to the CERAM tool and to get them engaged in understanding the terminologies and concept behind climate change hazard assessment as well as to raise awareness on climate change.

2.1. What is Climate Change?

The United Nations defines climate change as referring to long-term shifts in temperature and weather patterns. These shifts may be natural such as through the variations in the solar cycle. But since the 1800s, human activities have been the main driver of climate change, primarily due to burning fossil fuels like coal, oil and gas, and land-use change. Burning fossil fuels generates greenhouse gas emissions that act like a blanket wrapped around the Earth, trapping the sun's heat, and raising temperatures. Examples of greenhouse gas emissions that are causing climate change include carbon dioxide and methane. These come from using gasoline for driving a car or coal for heating a building, for example. Clearing land and forests can also release carbon dioxide. Landfills for garbage are a major source of methane emissions.

2.2. Baseline Data and Climate change projections for temperature and rainfall

This section discusses the parameters of hydro-meteorological hazards such as baseline and decadal climatological data on Quezon City and Metro Manila.

2.2.1. Baseline Data

Quezon City Climate Type

Quezon City, situated in the heart of Metro Manila, is endowed with a climate best characterized as Climate Type I (based on the rainfall-dependent Modified Coronas climate classification) shown in Figure 6. The City has distinct wet (June to September) and dry (December to April) periods (PAGASA,2018).

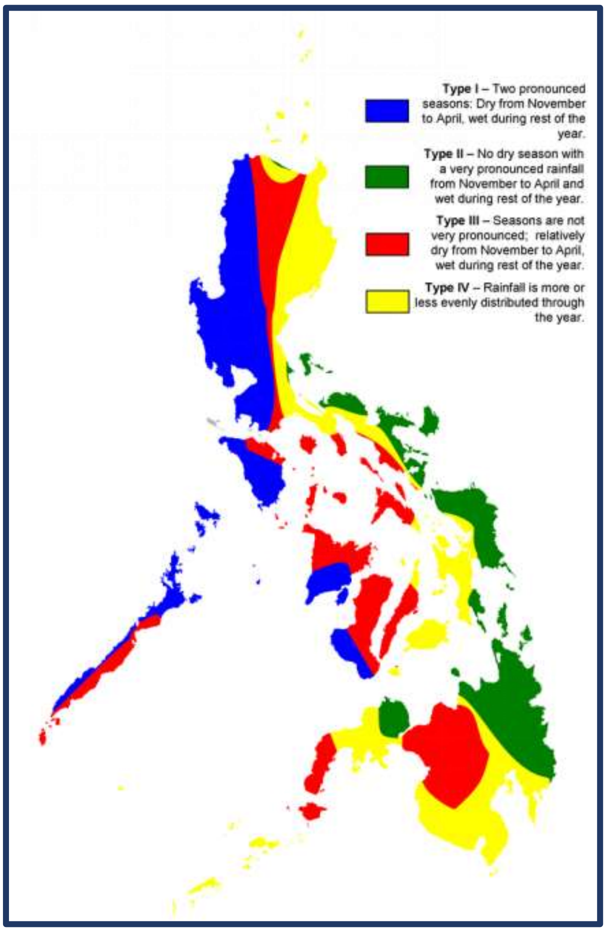


Figure 6. Climate Types under Corona's Classification (Source: Science Garden)

Temperature

In a similar manner as that of the changing climate that is being observed regionally and nationally, Quezon City has also been experiencing some changes in terms of weather/climate variables called climate impact drivers; notably, temperatures and rainfall. Referring to Table 1 below, the following observations can be made:

- The mean annual rainfall has been steadily increasing but in a highly variable way. A gradual increase is seen in the first two assessment periods (1961-1990 and 1971-2000), then a more significant increase (as much as 13%) between the two assessment periods, then a decrease in the 1981-2020 assessment.
- Minimum temperatures are increasing faster than maximum temperatures; and mean temperatures have also steadily increased.

Table 1. Decadal changes in climatological normals of temperatures and rainfall observed in Science Garden, Quezon City.

Weather variable	Climatological normals (1961-1990)	Climatological normals (1971-2000)	Climatological normals (1981-2010)	Climatological normals (1991-2020)
Maximum Temperature (°C)	31.8	32.1	32.2	32.1
Minimum Temperature (°C)	22.3	22.8	23.1	23.6
Mean Temperature (°C)	27.1	27.4	27.7	27.8
Rainfall (mm)	2,403.8	2,531.0	2,574.4	2,785.6
Number of rainy days	134	135	153	143

Note: Climatological normals are 30-year averages of these weather parameters and being indicated here are essentially moving 30-year averages. (Adopted from PAGASA's Climatological Normals)

Figure 7 and Figure 8 show the observed trends in the climate of Quezon City, in terms of temperature and rainfall anomalies or departures from 30-year (1990-2020) averages or normals.

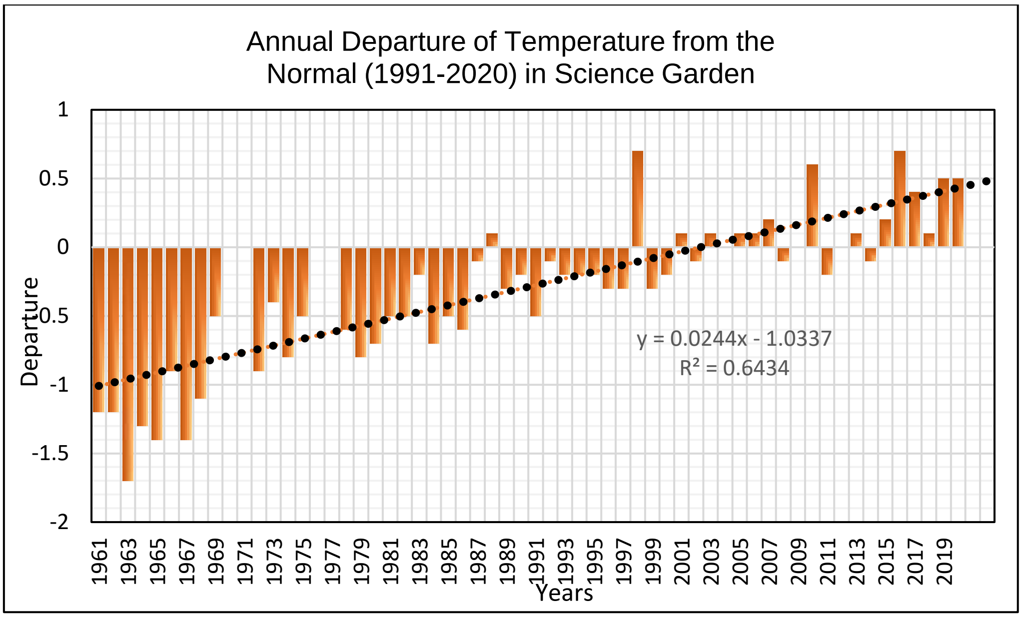


Figure 7. Annual departure of mean temperature from the normal (1991-2020) at Science Garden, Quezon City (Source: PAGASA)

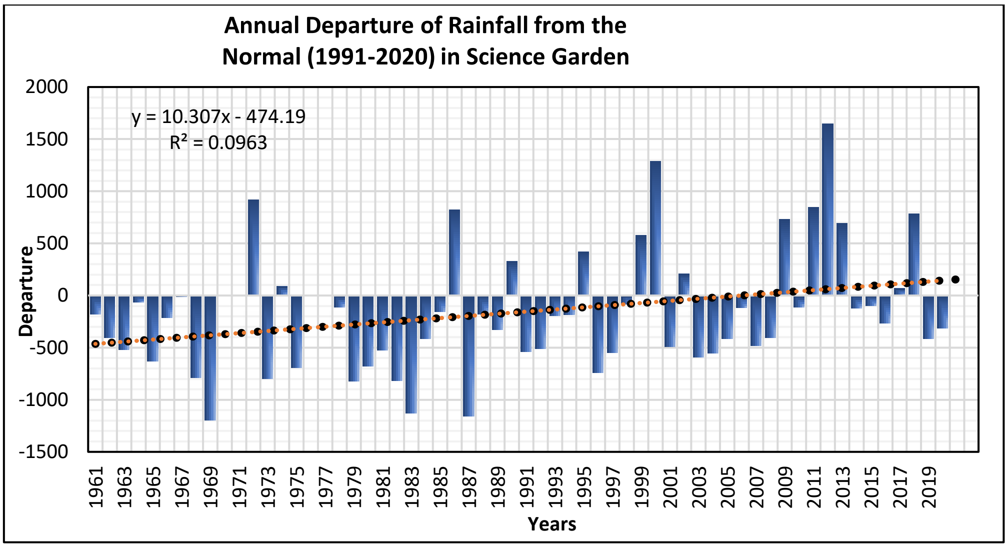


Figure 8. Annual departure of rainfall from the normal (1991-2020) at Science Garden, Diliman, Quezon City. (Source: PAGASA)

These graphs indicate increasing trends in both annual mean temperatures and annual rainfall totals in Quezon City. Trend line analysis indicates that the yearly mean temperature has increased by **one degree Celsius** over 50 years.

Rainfall Distribution and Rainfall Extremes for Metro-Manila

Annual rainfall distribution is shown in Figure 9. The year 2012 with an annual rainfall total of 4,431.7 mm (brought about by both strong monsoon and tropical cyclone-associated rains) was the wettest year on record. The strongest floods usually are brought by one-day to two-day rainfall periods.

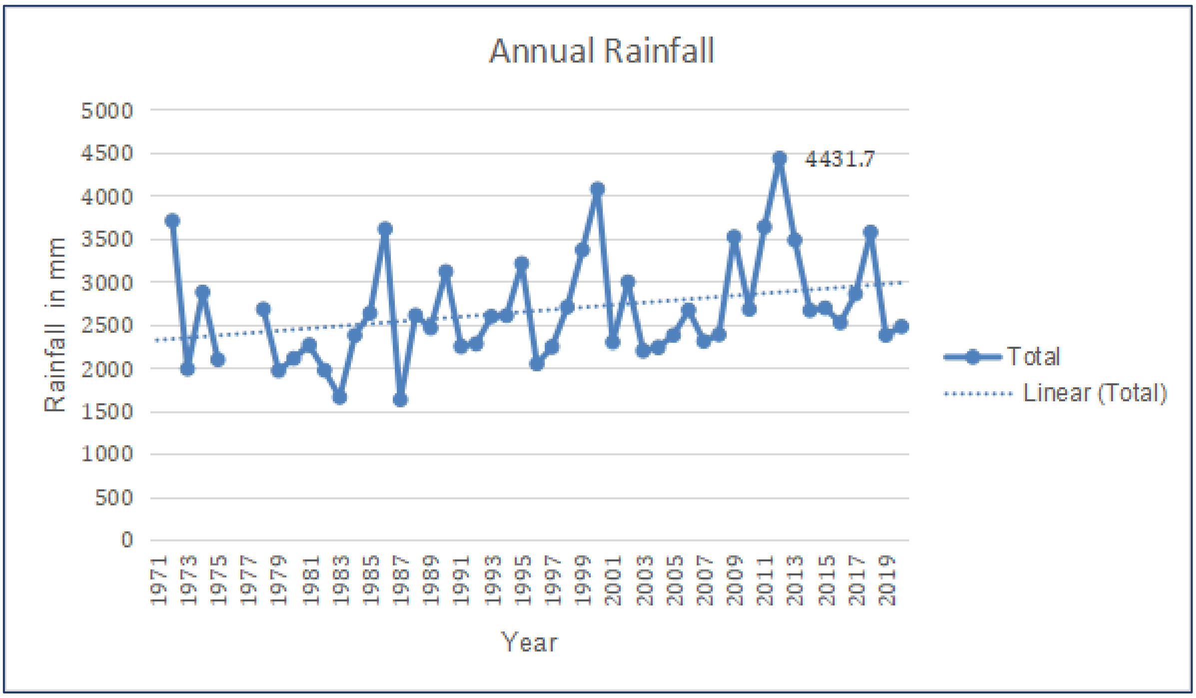


Figure 9. The Annual Rainfall Totals by Year from 1971 to 2020 Observed at the Science Garden Station in Quezon City (Source: PAGASA)

The highest rainfall totals for a one-day rainfall recorded at Science Garden was on September 26, 2009, pouring 455mm of rainfall brought by severe tropical storm Ondoy (International: Ketsana). People from Metro Manila remember that Ondoy produced one of the worst floods in Metro Manila. However, the southwest monsoon torrential rains from August 1 to 8, 2012 brought in the highest two-day rainfall totals in Metro Manila with 684mm.

2.2.2. Climate Projections

Climate projections are simply defined as **plausible climate futures that could happen in any area of interest**. These are quantitative projections of future climate change presented in ranges. The ranges allow for differences in how future climate may evolve in an area of interest due to three factors, namely: The greenhouse gas emissions, the climate response and the natural variability in the climate.

The Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) developed and prepared climate projections for the country and published these in a Report entitled **"Observed Climate Trends and Projected Climate Change in the Philippines**" in 2018. This was followed by another set of climate trends and projected climate extremes developed and prepared jointly by the PAGASA, the Manila Observatory and the Ateneo de Manila University in a Report entitled **"Philippine Climate Extremes Report 2020: Observed and Projected Climate Extremes in the Philippines to Support Informed Decisions on Climate Change Adaptation and Risk Management"** in recognition of the glaring fact that extreme weather/climate events have been increasingly causing many adverse impacts on communities and natural and managed systems in the country.

These two sets of climate projections consist of changes in the mean values of temperature and rainfall; in the tropical cyclone occurrence; and in sea level rise in the country (in PAGASA,2018) and in the extreme temperature and rainfall indices (in Philippine Climate Extremes Report 2020).

Table 2 below delineates the features and differences between these two sets of projections for Metro Manila.

Table 2. Characteristics and features of the two Climate Trends and Projections Report; the PAGASA, 2018 and the Philippine Climate Extremes Report, 2020.

Characteristics	Climate projections in the PAGASA, 2018 Report	Climate projections in the Philippine Extremes Report, 2020
Greenhouse gas emission scenarios used	RCP 4.5 and RCP 8.5	RCP 4.5 and RCP8.5
Time frames	Mid-21st century (2036-2065) Late-21st century (2070-2099)	Early future (2020-2039) Mid-future (2045-2065) Late-future (2080-2099)
Baseline used	1971-2000 climatological normals*	1986-2005 climatological normals
Weather/ climate variables or parameters	Observed values based on 1971-2000 climatological normals and range of projected changes of temperatures (maximum, minimum and mean) and rainfall	Observed values based on 1986-2005 climatological normals and range of projected values of each of the climate extremes indices

**Normals means the 30-year average value of the variable or parameter. Source: PAGASA, 2018, 2020*

2.2.3. Seasonal mean temperature and rainfall projections

A set of ranges in seasonal changes in temperature and rainfall under two emission scenarios (the moderate-emission or RCP 4.5 and the worst-emission scenario or RCP8.5) during the mid-century (2036-2065) for Metro Manila are provided in the PAGASA, 2018 Report and given below in Table 3 and Table 4. respectively.

Table 3. Projected seasonal changes in temperature in °C and rainfall in percentages under the medium- emission scenario (RCP 4.5) during the mid-21st century (2036-2065).

Climate variable	Dec-Jan-Feb	Mar-Apr-May	Jun-Jul-Aug	Sept-Oct-Nov
Mean Temperature	1.0 to 1.6 °C	0.9 to 1.7°C	1.0 to 1.8°C	1.0 to 1.8°C
Rainfall	0.1%-decrease to 55%-increase	0.7% to 25.7%-increase	21.3%-decrease to 0.4%-decrease	10%-decrease to 7.7 %-increase

Source: PAGASA, 2020

Table 4. Projected seasonal changes in mean temperature in °C and rainfall in percentages under the high -emission scenario (RCP 8.5) during the mid-21st century (2036-2065)

Climate variable	Dec-Jan-Feb	Mar-Apr-May	Jun-Jul-Aug	Sept-Oct-Nov
Mean Temperature	1.2 to 1.9 °C	1.3 to 2.2 °C	1.3 to 2.3 °C	1.3 to 2.2 °C
Rainfall	2.7% to 55%-increase	7.2%-decrease to 14.8 %-increase	17%-decrease to 7.7 %-increase	8%-decrease to 19.9 %-increase

Source: PAGASA, 2020

The climate futures indicate the differentiated projected changes in rainfall during the four seasons of the country for a specific time period (2036-2065). The actual change will depend on the actual global temperature increase and will be influenced by whether the world follows a medium-emission or a high-emission scenario. For example, for the coldest season of the year (December to February) temperature increases will range from 1.0 °C to 1.9 °C. Whereas, the projected changes in rainfall are from a 0.1 %-decrease to as much as a 55% increase. On the other hand, during the warmest season of the year (March to May), the mean temperature during the same period of 2036-2065, will increase from 0.9 °C to 2.2 °C. For rainfall, during this season, the range of increase will be from 0.7%-increase to 14.8%-increase.

2.2.4. Projections on extreme temperatures and rainfall

For Metro Manila, a set of ranges in changes in extreme temperature and rainfall indices under two emission scenarios (the moderate-emission RCP 4.5 and the worst-emission or RCP8.5) are given.
gives a summary of the terminologies used for temperature and rainfall indices to describe the projections.

Table 6 and 7 below provide the projections for median extreme temperature and median extreme rainfall indices as given in the Philippine Climate Extremes Report 2020. The median values are the most suitable for planning purpose and are recommended by EMI.

Table 5. Summary of temperature and rainfall indices

Name	Units	Definition	Description
Temperature Extremes Indices			
Magnitude			
TNn	°C	Minimum daily minimum temperature	Coldest nighttime temperature
TNm	°C	Mean daily minimum temperature	Average nighttime temperature
TNx	°C	Maximum daily minimum temperature	Warmest nighttime temperature
TXn	°C	Minimum daily maximum temperature	Coldest daytime temperature
TXm	°C	Mean daily maximum temperature	Average daytime temperature
TXx	°C	Maximum daily maximum temperature	Warmest daytime temperature
DTR	°C	Average range of daily maximum and minimum temperature	Daily temperature range
Frequency			
TN10p	%	Percentage of days when daily temperature <10th percentile	Fraction of cold nights
TN90p	%	Percentage of days when daily minimum temperature>90th percentile	Fraction of warm nights
TX10p	%	Percentage of days when maximum temperature <10th percentile	Fraction of cool days
TX90p	%	Percentage of days when maximum temperature>90th percentile	Fraction of hot days
Duration			
WSDI	days	Warm Spell Duration Indicator: number of days contributing to events when 6 or more consecutive days have daily maximum temperature >90th percentile	Number of days contributing to a warm period
Rainfall Extremes Indices Magnitude			
PRCPTOT	mm	Total precipitation on wet days	Total wet-day rainfall
SDN	mm/day	Simple daily intensity index: total rainfall divided by the number of wet days	Average daily rainfall intensity
Rx1day	mm	Maximum amount of rainfall that falls in 1 day	Maximum 1-day rainfall total
Rx5day	mm	Maximum amount of rainfall that falls in 5 consecutive days	Maximum 5-day rainfall total
P95	mm	95th percentile of wet days	Rainfall on very wet days
P99	mm	99th percentile of wet days	Rainfall on extremely wet days
R95p	mm	Total daily rainfall >95th percentile	Total rainfall from very wet days
R99p	mm	Total daily rainfall >99th percentile	Total rainfall from extremely wet days
Frequency			
P95d	days	Number of days when daily rainfall>95th percentile	Number of very wet days
P99d	days	Number of days when daily rainfall>99th percentile	Number of extremely wet days
Duration			
CWD	days	Consecutive wet days: maximum number of consecutive days when daily rainfall> 1 mm	Longest wet spell
CDD	days	Consecutive dry days: maximum number of daily rainfall < 1 mm	Longest dry spell

Source: PAGASA, 2020

Table 6. Temperature Extreme Indices for Metro Manila

TEMPERATURE Climate Extreme Indices		Baseline	Scenario	Range	EARLY-CENTURY Projected Change		MID-CENTURY Projected Change		LATE CENTURY Projected Change	
CODE	Description (*unit*)	Col 3	Col 4	Col 4	Projected	Projected Change	Projected Value	Projected Change	Projected Value	Projected Change
TNn	Coldest nighttime temperature (°C)	18	RCP4.5	Median	19	1	19.3	1.3	19.6	1.6
			RCP8.5	Median	19	1	19.8	1.8	21.5	3.5
TNm	Average nighttime temperature (°C)	23.1	RCP4.5	Median	23.8	0.7	24.3	1.2	24.6	1.5
			RCP8.5	Median	23.9	0.8	24.8	1.7	26.3	3.2
TNx	Warmest nighttime temperature (°C)	26.6	RCP4.5	Median	27.3	0.7	27.8	1.2	28.2	1.6
			RCP8.5	Median	27.4	0.8	28.3	1.7	29.7	3.2
TXn	Coldest daytime temperature (°C)	25.7	RCP4.5	Median	26.4	0.7	26.8	1.2	27.1	1.4
			RCP8.5	Median	26.4	0.8	27.3	1.7	28.6	3
TXm	Average daytime temperature (°C)	31.8	RCP4.5	Median	32.4	0.6	33	1.2	33.3	1.5
			RCP8.5	Median	32.6	0.8	33.4	1.6	35	3.2
TXx	Warmest daytime temperature (°C)	36.4	RCP4.5	Median	37.1	0.6	37.7	1.3	38.2	1.7
			RCP8.5	Median	37.3	0.9	38.2	1.8	40.1	3.6
DTR	Daily Temperature Range (°C)	8.7	RCP4.5	Median	8.6	-0.1	8.7	0	8.8	0.1
			RCP8.5	Median	8.7	0	8.7	0	8.7	0
TN10p	Fraction of cold nights (%)	11.4	RCP4.5	Median	3.3	-8.1	1.7	-9.7	1.3	-10.1
			RCP8.5	Median	2.6	-8.8	1	-10.4	0.4	-11.1
TN90p	Fraction of warm nights (%)	11.5	RCP4.5	Median	35.9	24.6	59.3	48	70.7	59.4
			RCP8.5	Median	43.2	31.9	78.3	67	96.5	85.2
TX10p	Fraction of cool days (%)	11.4	RCP4.5	Median	5	-6.5	2.4	-9.2	1.7	-9.9
			RCP8.5	Median	4.1	-7.5	1.6	-10	0.9	-10.6
TX90p	Fraction of hot days (%)	11.6	RCP4.5	Median	26.3	14.7	49.7	38.2	61.9	50.3
			RCP8.5	Median	35.4	23.8	63.2	51.6	90.6	79
WSDI	Number of days contributing to a warm period (days)	7.2	RCP4.5	Median	73.6	66.5	226.2	219	364.3	357.1
			RCP8.5	Median	129.1	121.9	448.8	441.6	930.3	923.1

Source: PAGASA, 2020

Table 7. Rainfall Extreme Indices for Metro Manila

RAINFALL Climate Extreme Indices		Baseline	Scenario	Range	EARLY-CENTURY Projected Change		MID-CENTURY Projected Change		LATE-CENTURY Projected Change	
CODE	Description (*unit*)	Col 3	Col 4	Col 4	Projected Value	Projected Change	Projected Value	Projected Change	Projected Value	Projected Change
PRCPTOT	Total wet-day rainfal (mm)	2259.8	RCP4.5	Median	2204.6	-55.1	2214.8	-44.9	2147	-112.7
			RCP8.5	Median	2255.6	-4.1	2198.9	-60.9	2029.1	-230.6
SDII	Average daily rainfall intensity (mm/day)	15.4	RCP4.5	Median	15.3	-0.2	15.1	-0.3	14.6	-0.8
			RCP8.5	Median	15.3	-0.2	14.9	-0.6	14.2	-1.2
Rx1day	Maximum 1-day rainfall total (mm)	121.4	RCP4.5	Median	126.9	5.5	132.3	10.9	124.7	3.3
			RCP8.5	Median	135.7	14.3	131.3	9.9	128.2	6.8
Rx5day	Maximum 5-day rainfall total (mm)	268.8	RCP4.5	Median	289.3	20.5	290.5	21.7	261.9	-6.9
			RCP8.5	Median	277.6	8.8	289	20.2	279	10.2
P95	Rainfall on very wet days (mm)	52.4	RCP4.5	Median	50.6	-1.8	51.3	-1.1	48.5	-3.8
			RCP8.5	Median	51.1	-1.3	50.4	-1.9	48.4	-3.9
P99	Rainfall on extremely wet days (mm)	101	RCP4.5	Median	100	-1	106.1	5.2	98.8	-2.2
			RCP8.5	Median	98.9	-2.1	103.5	2.5	103.3	2.4
R95p	Total rainfall from very wet days (mm)	585.8	RCP4.5	Median	564.2	-21.6	632	46.2	552.4	-33.4
			RCP8.5	Median	590.6	4.8	579.6	-6.1	543.2	-42.6
R99p	Total rainfall from extremely wet days (mm)	189.7	RCP4.5	Median	175.9	-13.9	216.2	26.4	198.6	8.9
			RCP8.5	Median	200.3	10.5	215.4	25.6	198.3	8.6
P95d	Number of very wet days (days)	7.2	RCP4.5	Median	6.7	-0.4	7.1	0	6.4	-0.8
			RCP8.5	Median	6.9	-0.2	6.8	-0.4	6.3	-0.9
P99d	Number of extremely wet days (days)	1.5	RCP4.5	Median	1.5	0	1.7	0.2	1.5	0
			RCP8.5	Median	1.5	0	1.6	0.1	1.5	0
CWD	Longest wet spell (days)	17	RCP4.5	Median	14.4	-2.7	17	0	15.7	-1.3
			RCP8.5	Median	15.5	-1.5	17.2	0.2	15.3	-1.7
CDD	Longest dry spell (days)	39.8	RCP4.5	Median	37.4	-2.4	37	-2.9	41.8	2
			RCP8.5	Median	37.1	-2.7	36.7	-3.1	37.2	-2.6

Source: PAGASA, 2020

It is to be noted that this study this study focuses on two indices, i.e., extreme temperatures and extreme rainfall for the early 21st century (2020-2039) and not the whole set of extreme indices. These have the most impact on floods and landslides hazards.

2.3. Tropical cyclones, and sea-level rise (SLR) baseline data and climate change projections

This section provides the baseline data and climate change projections for tropical cyclone and sea-level rise (SLR)

2.3.1 Tropical Cyclone Baseline Data

Tropical Cyclone (TC) classifications by PAGASA are shown in Table 8. It also gives the range of wind speeds used prior to 2015, between 2015 and 2022, and recently in March 2022. In 2015, PAGASA added the category of a super typhoon and recently, the ranges of wind speeds were redefined between a typhoon and a super typhoon category.

Table 8. Tropical Cyclone (TC) Classifications by PAGASA.

Classification	Before May 2015	May 2015 to Feb 2022	March 2022 to Present
TD-Tropical Depression	63 kph or less	61 kph or less	61 kph or less
TS-Tropical Storm	64-118 kph	62-88 kph	62-88 kph
STS-Severe Tropical Storm		89-117 kph	89-117 kph
TY-Typhoon	More than 118kph	118-120 kph	118-184 kph
STY-Super Typhoon		More than 120 kph	More than 184 kph

A total of 71 tropical cyclones have crossed within 50 km from Metro Manila from 1948 to 2021. Among these 13 (18%) were tropical depressions, 19 (27%) were tropical storms, 4 (6%) were severe tropical storms, 26 (36%) were typhoons, and 9 (12%) were super typhoons. Thus, close to 50% of the tropical cyclones were either typhoons or super typhoons. About 18 of the 71 have crossed Metro-Manila. Typhoons that crossed within a 50-kilometer radius of Metro Manila from 1960 to 2021.

The strongest of these windstorms were super typhoons Olive, Lusing, Welming in the 60's, Yuling and Unding in the 70s, Rosing and Loleng in the 90's. Typhoon Ulysses and Severe Tropical Storm Ondoy are shown for reference.

2.3.2 Frequency of recurrence of tropical cyclones

How often does a tropical cyclone of a certain category recur (Filipino-maulit) in Metro Manila? Table 9 provides and estimates for storms that cross within 50 kilometers of Metro-Manila. On average, super typhoons recur almost every 90 months (7.5 years), while typhoons recur every 35 months (2.9 years).

Table 9. Estimated Average Return of Tropical Cyclones Within 50 km Crossing Metro Manila

Category	Number of Occurrence	First Occurrence	Last Occurrence	No. of months in between	Number of Recurrence	Average return (mos,)
TD	13	20/11/1948	11/08/2002	644	12	53.7
TS	19	12/10/1957	11/06/2020	751	18	41.7
STS	4	28/04/1971	24/09/2009	460	3	153.3

TY	26	23/07/1948	06/09/2021	877	25	35.1
STY	9	23/06/1960	29/10/2020	724	8	90.5

2.3.3. Projections on tropical cyclone occurrence for Metro Manila

There are no detailed projections for tropical cyclone occurrence in Metro Manila. The PAGASA 2018 Report provides projections for the whole country. It is highlighted that tropical cyclones in the western North Pacific basin (in which the Philippine Area of Responsibility or the so-called PAR is situated) will see an **increase in the intensity** of those classified as typhoons and super typhoons. Tropical cyclone **frequency is not projected to increase**, although there have been changes in their trajectories. It is, moreover, to be noted that in the recently released Intergovernmental Panel on Climate Change Sixth Assessment Reports (IPCC SROCC, IPCC AR6), the projections on these short-lived weather systems are also affirmed.

2.3.4. Projection on the sea-level rise for Metro Manila

Projections on the sea-level rise as indicated in the PAGASA, 2018 Report is for the country and the increase is found to be slightly larger than the global rate. Under both emission scenarios (RCP 4.5 and RCP 8.5, the projected sea-level rise will be approximately the same until the mid-century (2036-2065), diverging only towards the end of the 21st century when that of **the RCP 8.5 will be at 0.2m**. It is being highlighted that the projected increase in sea level may worsen storm surge hazards and must be considered in disaster risk reduction planning.

Other important related findings are those of the Partnerships in Environmental Management for the Seas in East Asia (PEMSEA) 2012 study on integrating climate change risk scenarios into coastal and sea use planning in Manila Bay. The study stressed that the areas around Manila Bay are vulnerable to inundation under sea-level rise and that extreme relative sea level consists of the effects of global warming, rate of subsidence, and storm surge during the passage of intense tropical cyclones. The most important findings for Quezon City are:

1) Under a 1-m sea-level rise in the Manila Bay area, 16,365. 899 ha of land area in Quezon City will be affected, 0.03 % of which (or an estimated 5.463 ha) will be inundated; and
2) Under a 2-m sea-level rise, 14.735 ha (or approximately 0.09%) of the affected areas will be under water.

The different sets of projections (e.g., increases in mean temperatures, changes in rainfall, changes in extreme temperature and rainfall indices, frequency and intensity of tropical cyclones and sea-level rise) will have serious implications for the characterization of future climate hazards and risks; in particular, those of floods, including cascading impacts on the population, urban use, lifelines, and critical facilities.

2.4. The Climate Extremes Risk Analysis Matrix (CERAM)

2.4.1 What is the CERAM Tool?

The Climate Extremes Risk Analysis Matrix (CERAM) Tool was developed to provide decision makers/policy makers a wider range of plausible futures for adaptation planning. The CERAM Tool can be used to update the risk assessments in the Quezon City's Enhanced LCCAP (2020-2050) which had used the first set of projections (on the changes in seasonal mean temperature and rainfall), as it can identify areas and sectors which are at high risk to climate extremes. It will, however, require more in-depth rapid disaster risk assessment and climate change adaptation planning. Additionally, it is a tool to collect and process inputs from various stakeholders, typically completed either individually by key informants or in small-group workshop settings.

We need to change Quezon City's Enhanced LCCAP (2020-2050) to Quezon City's Enhanced LCCAP (2021-2050).

2.4.2. Training and implementation of the CERAM Tool with Quezon City stakeholders

A series of trainings/workshops were held in October 21, 28 and November 4, 2022, with barangay representatives to undertake the CERAM exercise. Table 10 shows selected annual extreme indices used in the exercise. The first objective was to train the participants in the CERAM tool and to raise their awareness on climate change. The second objective was to use the set of future changes to get the participant's perceptions and inputs on the impacts of and adaptation to climate change in Quezon City relative to populations, communities, and ecosystems, and more particularly to identify areas and sectors at high risk from climate extremes. The general approach is to undertake a more in-depth disaster risk assessment that would lead to climate change adaptation planning for these particular areas. Due to time limitations, only two indices each were used in the workshop; namely, **maximum daytime temperature** and **fraction of hot days for extreme temperature** indices to examine the impacts of increasing heat index, and **maximum 1-day and maximum 5-day rainfall totals** to analyze impacts on flood hazards. An important consideration for participants was the flooding already occurring regularly in the barangays. It was important to examine how these flooding events will evolve in the future considering the projections.

The CERAM exercise is quite elaborate and this was the first exposure to this type of exercise for the majority in the audience. Thus, this was more an opportunity to undertake training and to get the participants familiar with its process and content. The objective is for Quezon City to further develop the capacity to use this Tool and to continue these types of exercises as a training tool first, and also to start the collection of related pertinent data that would ultimately be used in the risk analysis/assessment and planning process on the impacts of climate change.

Table 10 Summary of extreme temperature and rainfall indices used in the workshop

Name	Units	Definition	Description
Temperature Extremes Indices			
Magnitude			
TXx	°C	Maximum daily maximum temperature	Warmest daytime temperature
DTR	°C	Average range of daily maximum and minimum temperature	Daily temperature range
Frequency			
TN10p	%	Percentage of days when daily temperature <10th percentile	Fraction of cold nights
TN90p	%	Percentage of days when daily minimum temperature>90th percentile	Fraction of warm nights
TX90p	%	Percentage of days when maximum temperature>90th percentile	Fraction of hot days
Duration			
WSDI	days	Warm Spell Duration Indicator: number of days contributing to events when 6or more consecutive days have daily maximum temperature >90th percentile	Number of days contributing to a warm period
Rainfall Extremes Indices Magnitude			
PRCPTOT	mm	Total precipitation on wet days	Total wet-day rainfall
Rx1day	mm	Maximum amount of rainfall that falls in 1 day	Maximum 1-day rainfall total
Rx5day	mm	Maximum amount of rainfall that falls in 5 consecutive days	Maximum 5-day rainfall total

2.4.3. Workshop Summary of Results

Table 11 summarizes the inputs provided by stakeholders of potential impacts of projected changes in temperature and rainfall extremes in selected sectors. The considered sectors are: water resources, including associated flooding risks, health, environment and biodiversity, infrastructure, including critical facilities and lifelines, services (including energy) supply and delivery.

Table 12 gives a summary of the adaptation options given by participants relative to the same selected sectors. It is interesting to note the range of options provided by the stakeholders indicating a fairly high level of interest and knowledge in climate change issues.

Table 11 Examples potential impacts of projected changes in temperature extreme indices on selected sectors collected from the stakeholder consultations on Oct 21 and 28 and Nov 4, 2022, workshops

Sectors	Potential impacts
Water resources, including associated flooding risks	Impacts (both positive and negative) on water supply to result from increases/decreases in rainfall extremes, such as: • Drier conditions resulting from increase in extreme temperature indices and those from projected decrease in extreme rainfall indices can lead to lower streamflow and lower water supply that could impact adversely on communities in terms of less water (water rationing) and possibly, less water quality; • More frequent and longer dry conditions could lead to water service disruption; • Increased rainfall extremes could increase flood risks to low-lying areas and those already identified to be at moderate and high risks for floods; • Increase in the extreme 1-day and 5-day rainfall totals may lead to less stable ground stability (Bgy. Payatas) and possibly lead to land movement or landsides in slopes near creeks; • Increase in extreme rainfall indices could lead to challenges in water management and flood control infrastructures; • Increase in extreme rainfall indices could lead disruption in water service delivery and quality of water.
Health	• Higher temperatures shorten the life stages in the life cycle of mosquitoes that lead to their increased number and thus, more biting rates and increased transmission, spread and prevalence of dengue; • Changes in extreme rainfall frequency and intensity could increase occurrences of dengue and gastro-enteritis and other diseases such as leptospirosis and others; • Projected increase in extreme temperature indices such as warmest daytime temperature and fraction of hot days could lead to more incidences of respiratory illnesses including asthma and skin diseases (rashes) among the young and hypertension and heart attack among the elderly; • Mortality, especially in young children and the elderly and those with comorbidities are heat-related with a daytime and nighttime threshold value of 38.3°C and 24. 3°C, respectively; • Increases in incidences of discomfort, irritable, difficulty in sleeping and, bouts of depression, both when indices of extreme temperature and rainfall increase; • Projected food shortages; • Could lead to increased air pollution;

	• Could possibly lead to more street dwellers.
Environment and biodiversity	• Improper waste disposal during rainfall extremes could lead to degraded environment including clogged drainage, pollution, and unsanitary conditions; • Dryness in some land areas under extreme temperature; • Could lead to more fires; • Wilting of plants under heat stress.
Infrastructure, including critical facilities and lifelines	• Infrastructures are prone to damages, especially from excessive rainfall, as they age; • Extreme temperatures could lead to structural damage in bridges and other infrastructures, such as in light railway tracks, etc.; • Extreme rainfall amounts, including those from intense typhoons result to flooding, landslides, erosion that could cause infrastructures to weaken; • Extreme rainfall leading to floods could lead to closure of roads and bridges, including the electrical operation of traffic and streetlights; • Extreme rainfall could lead to partial/total damages to properties (houses) and even slow down communication.
	• Increase in drier conditions (increase in extreme temperature indices) could lead to heat events and demand for more energy supply; • Increase in extreme temperature indices could lead to problems in service delivery and even disruption/brown-outs; • Increase in rainfall extreme indices could lead to more service delivery disruption and even, stoppage; • Hospitals could be overwhelmed with medical emergencies and with increased number of patients after events of increases in extreme temperature and rainfall indices; • Schools could be rendered unable to cope with damages in their resources, not discounting school suspensions; • Disruption of services, including means of communications.
Mobility	• Increase in extreme rainfall indices could lead to more frequent flooding events and higher flood water levels resulting to less mobility among the population and most affected are school children, housewives needing to purchase food and medicinal supplies and wage earners commuting for work; • Difficulty in doing rescue operations when events warrant these services;

	• Difficulty in moving people to evacuation centers, hospitals.
Work productivity and livelihoods	Increase in both extreme temperature and extreme rainfall indices could lead to decreased work productivity, thereby could lead to less income and cascading effects could be diminished capacity to provide for family's basic needs; • Loss of jobs; • Could lead to price increases and hoarding; • Increased expenditures on utilities; • Economic losses.

Table 12. Summarized list of desired adaptation options collected from the stakeholder consultations on Oct 21 and 28 and Nov 4, 2022, workshops

Sectors	Adaptation Options		
Water resources	• Structural and physical: engineering and built environment, technological, ecosystem-based • Regular maintenance. • EWS to include telemetering in waterways and EWS protocols for monitoring and preparedness.	• Social: educational, informational, behavioral. • Rational and efficient use of resources • Coordination with PAGASA. • Awareness campaign on climate-related risks.	• Institutional: laws/regulations/resolutions, • Government programs. • Full implementation and monitoring of compliance to land use plan; • Initiate resolutions to address climate change from the barangay to the city level
Public health	• Efficient/effective surveillance and provision and/or enhancement of adequate, capable and well-equipped health services in barangays. • Early warning system (EWS), including access to correct interpretation of forecasts. • Regular clean-up drives, including fumigation if warranted.	• More health workers for health info dissemination. • Easy access to health services when needed. • Preparedness for emergencies. • Practice proper hygienic practices • Rescue operations.	•
Environment and biodiversity	• Tree planting in all vacant spaces, • maintenance of existing parks/urban gardening, vertical gardens; • Engage in urban farms, including hydrophonics • Green architecture • Shift to renewable energy (solar panels in rooftops, etc.); • Clean up drives, declogging, etc.	• 3 R's; • Rational use of resources; • Engage in programs like para sa Tao-love mother Earth, IEC and • Awareness campaign on environment protection; • Stop use of plastics and other hazardous materials;	• Compliance to environment codes (e.g., proper disposal of wastes).
Infrastructures, critical facilities and lifelines	• Updating of risks assessments, cognizant of lifetimes of existing infrastructures. • Strategic planning, specifically for critical lifelines under different scenarios to avoid	• Regular/enhanced awareness and dissemination campaigns and engaging residents in better	• Updating of green building codes; • Regular monitoring and implementation of compliance to green building codes;

	late and/or non-delivery, especially during times of emergency; • Review, maintenance of flood drainage systems. • Additional better evacuation centers, retaining walls, drainage systems, color-coded EWS devices; etc. • Provision of more rubber boats, ayuda food packs, • Relocation of some IFS, especially those located near waterways	monitoring and surveillance during extreme events; • Activate BDRMMC;	
Service delivery	• Efficient use of supply (e.g., electrical power); • Strategic plan for sufficient supply where and when critically needed;	• Awareness campaign on green energy; • Use of solar panels	• Green building codes to minimize use of power (e.g., bigger windows for increased ventilation, vertical gardens, etc.)

2.4.4 Impact Chain Diagram and Analysis

Hereunder are two simplified impact chain diagrams to facilitate the analysis of direct and indirect impacts of projected climate change scenarios, including increase in temperature, changes in rainfall amounts, changes in frequency and/or severity of tropical cyclones; in particular, typhoons and super typhoons) which could translate to higher maximum winds and gustiness and possibly, greater associated rainfall, and accelerated sea level rise). Figure 10 presents an impact chain for Quezon City.

CLIMATE STIMULI	HAZARD	BIOPHYSICAL IMPACT	SOCIOECONOMIC IMPACT
Increase in temperature	Extreme maximum temperatures	Increases in heat stress, increasing heat index, stress on infrastructures, such as MRT tracks in extreme cases	Health impacts such as increases in pulmonary diseases, cardiovascular diseases such as heat strokes, etc. Impacts are increased need for medical services
Changes in rainfall amounts/patterns	Floods /droughts	Injuries/mortalities Damage to property, infrastructure, critical facilities, lifelines, roads & bridges, etc.	Diminished mobility that could lead to less work productivity Increased loss and damage Stress on QC budgetary requirements
Increased intensity/frequency of tropical cyclone occurrences	Increasing maximum winds and more intense associated rainfall	Same as above	Same as above
Sea level rise	Salt water intrusion in groundwater	Diminished quality of water supply	Health impacts such as water-based diseases (e.g. gastroenteritis)
	Higher floodwater depths near waterways in QC	Same as those of flooding events	Same as those of flooding events

Figure 10. Simplified impact chain diagram for Quezon City

Another way of analyzing impacts (direct and indirect) is looking individually at each of the projected changes/ increases for each of the climate impact drivers and consider potential impacts of these changes, based on historical and/or present impacts. See Figure 11 below.

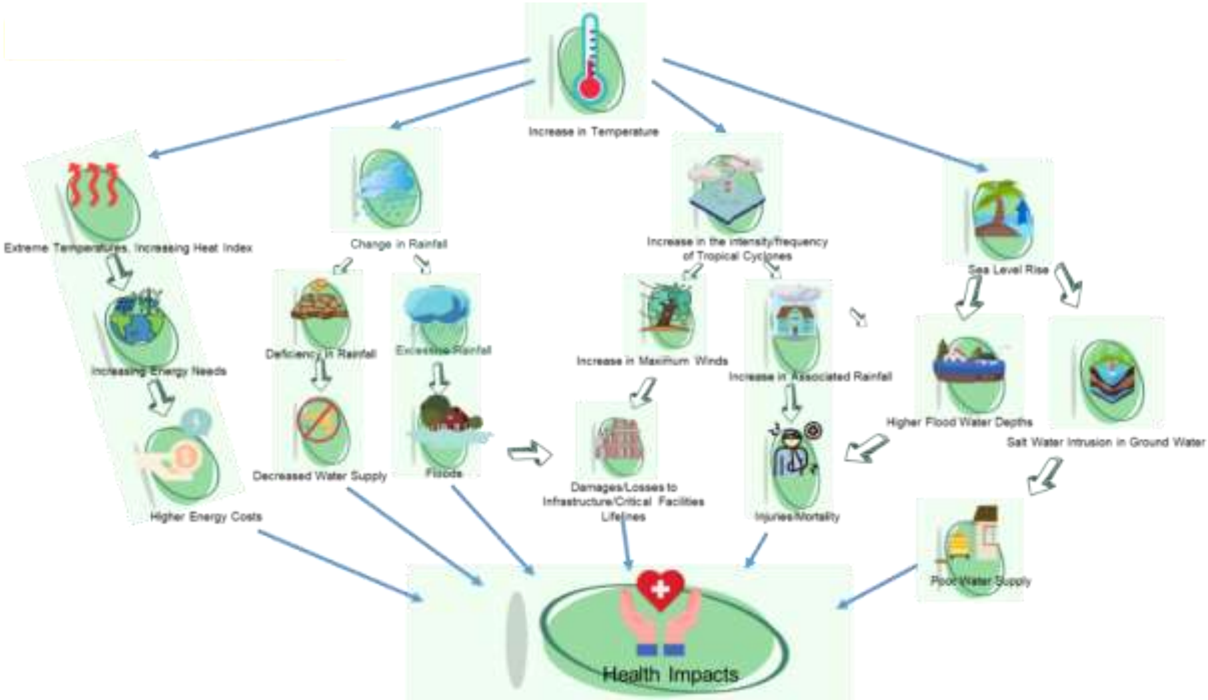


Figure 11. Chain diagram for increase in temperature that could be applied to assess climate impact on Quezon City

Part 3:
Flood Hazard and Risk Assessment

3. Flood Hazard and Risk Assessment

3.1. Rationale, Justification and Objectives

The methods, underlying data, assumptions, findings, outputs and interpretation of outputs for the climate change and flood hazard and risk assessment have been presented and extensively discussed in the **Hazard, Vulnerability and Risk Maps for all 142 Barangays – Deliverable 8** Report dated September 30, 2022. The reader is referred to that particular deliverable for more details. This chapter summarizes key outputs and their relevance in the context of the CDRA requirements.

The hazard and risk assessment of the CDRA focuses on analyzing the impact of an **RCP8.5 100-year rain return flood scenario** on the population and buildings in District 1 to District 6 of Quezon City. The flood hazard parameter in this study is flood depth. Flood duration and/or flood speed are not considered. The flood depth values were obtained from **Quezon City Drainage Master Plan (QC-DMP) study** and the **Mines and Geosciences Bureau (MGB) flood susceptibility map**, which provided information on the highest flood depths expected along a set of grid (or pixel) points covering the full geography of Quezon City. For brevity, the RCP8.5 (2020-2039) 100-year rain return flood scenario will be named the "RCP 8.5 100-year flood" in this report. The selection of the '100-year flood' term used in this report was made because the patterns of inundation and damages that can be expected are closer to TS Ondoy and the City Quezon City stakeholders can relate to this event.

This study does not reproduce information found elsewhere such as estimates of casualties and economic loss find in GMMA-RAP study of 2013. The flood hazard and risk analysis intends to, as much as possible, find meaningful interpretations of the MGB flood susceptibility map and the QC-DMP's RCP 8.5 100-year flood scenario map for the time frame 2022-2032. It focuses more on assessing the impact of the projected flood hazards in these study, particularly the RCP 8.5 100-year flood scenario. It establishes an in-depth and high resolution (street level) assessment of the impacts of floods on population, buildings, critical point facilities, and infrastructure. It also includes the assessment of the impact of secondary effects such as the spread of waterborne diseases. The count of buildings and their associated area affected by flood is provided for each barangay as well as other metrics that are essential for planning purposes. Results are presented by district and by barangay to facilitate the reading and interpretation of the maps and their association with the related charts. One of the main intent is to inform the update of the city's various city development plans, its physical framework and its land use plan in the early future (2020-2039). Another target objective is to inform data-driven and science-based barangay level and community level planning and preparedness efforts.

3.2. Approach to Flood Risk Study

Flood risk analysis involves the combination of 1) flood hazard information, which describes the likelihood and intensity of a flood event; 2) exposure information, which describes the distribution of people and elements 'at-risk' from a flood event; and 3) vulnerability information, which describes how the exposed elements would be affected when subject to a given intensity of flooding. The impact is assessed by overlay of the exposure data over the flood hazard using GIS technology. **Flood depth of half a meter (0.5 m)** was selected as the threshold that would pose significant hazards to people and support systems and facilities.

The impact of the flood scenario is analyzed base on the updated the 2022 Geospatial Exposure Database (GSED) of Quezon City (Deliverable 12 of this report) incorporating the implications of the RCP 8.5

climate-change related rainfall projection. More details on the approach, methodology and underlying data for modeling can be found in the Hazard, Vulnerability and Risk for 142 barangays report (Deliverable 8). Some of the key considerations are reproduced here.

3.3. What does the flood scenario mean as a flood hazard?

Typically, the category starts at 0.2 meter (8 inches) where any increase of floodwater may start to affect stability of a moving vehicle. A 0.5m flood depth can result in drowning esp. for small children and threaten the stability of adults. It can also cause injuries (e.g., cuts, falling into open manholes, and body contamination from microbial hazards). Moving water at this depth is enough to 'carry' or dislodge small to medium sized vehicles from the road. Roads are likely impassable to light and medium sized vehicles, resulting in disruption to movement.

When these flood heights exceed the thresholds of building openings (e.g., doors, windows, cracks), a disruption of household activities, possible injuries (e.g., electrocution, contamination of water taps), and damage to house furniture and appliances and other building contents typically happens. Some residents will be forced to evacuate to higher grounds.

At 1.5 meters of standing water, one may expect the building utilities and services to be no longer functional (water and sanitation, electrical) or possibly cut-off from supply.

When flood waters rise to 3 meters deep, space for human occupancy is lost within the ground floor level. People in buildings with upper floors can move to these spaces but more damage can be expected to the building contents and to the structure. The opportunity to body harm or getting a disease by infections through skin contact (e.g., leptospirosis) or ingestion of contaminated water (e.g., gastro-enteritis, diarrhea) is appreciable.

3.4. The Main Tributaries of Quezon City

Quezon City is drained by four (4) main waterways namely: San Juan River, Tullahan River, Marikina River, and Meycauayan River as indicated in Figure 12.

- San Juan River stretches about 100 km has the largest coverage. It includes the east side of of Quirino Highway at Barangays San Bartolome, Bagbag and Talipapa eastwards to Holy Spirit then at south from Mayon Street in La Loma down to Camp Aguinaldo on the east side.

- Tullahan River stretches 12 kms and drains the Barangays of Commonwealth, Fairview, Lagro then westward to Novaliches, Nagkaisang Nayon then southwards to part of Talipapa on the west side of Quirino Highway. Tullahan River also is the outflow channel of La Mesa Reservoir. About 28 km of creeks act as tributaries to this waterway (CLUP 2011-2025, CPDD).

- About 9 km of Marikina River serves as the city's natural boundary into which 25 kilometers of creeks and canals directly flow. It covers the area on the north side of Commonwealth Avenue in Barangay Commonwealth, eastward to Payatas, Bagong Silangan then southwards following the down slope of the ridge at Batasan Hills, Old Balara and Pansol towards Ugong Norte.

- The northernmost part of the City (Green Fields Subd in Barangay San Agustin and Kaligayahan and Maligaya Park Subd in Pasong Putik) is part of the Meycauayan River basin. A small catchment area can be found at the southwest periphery of the city which flows down towards Pasig River (CLUP 2011-2025, CPDD).

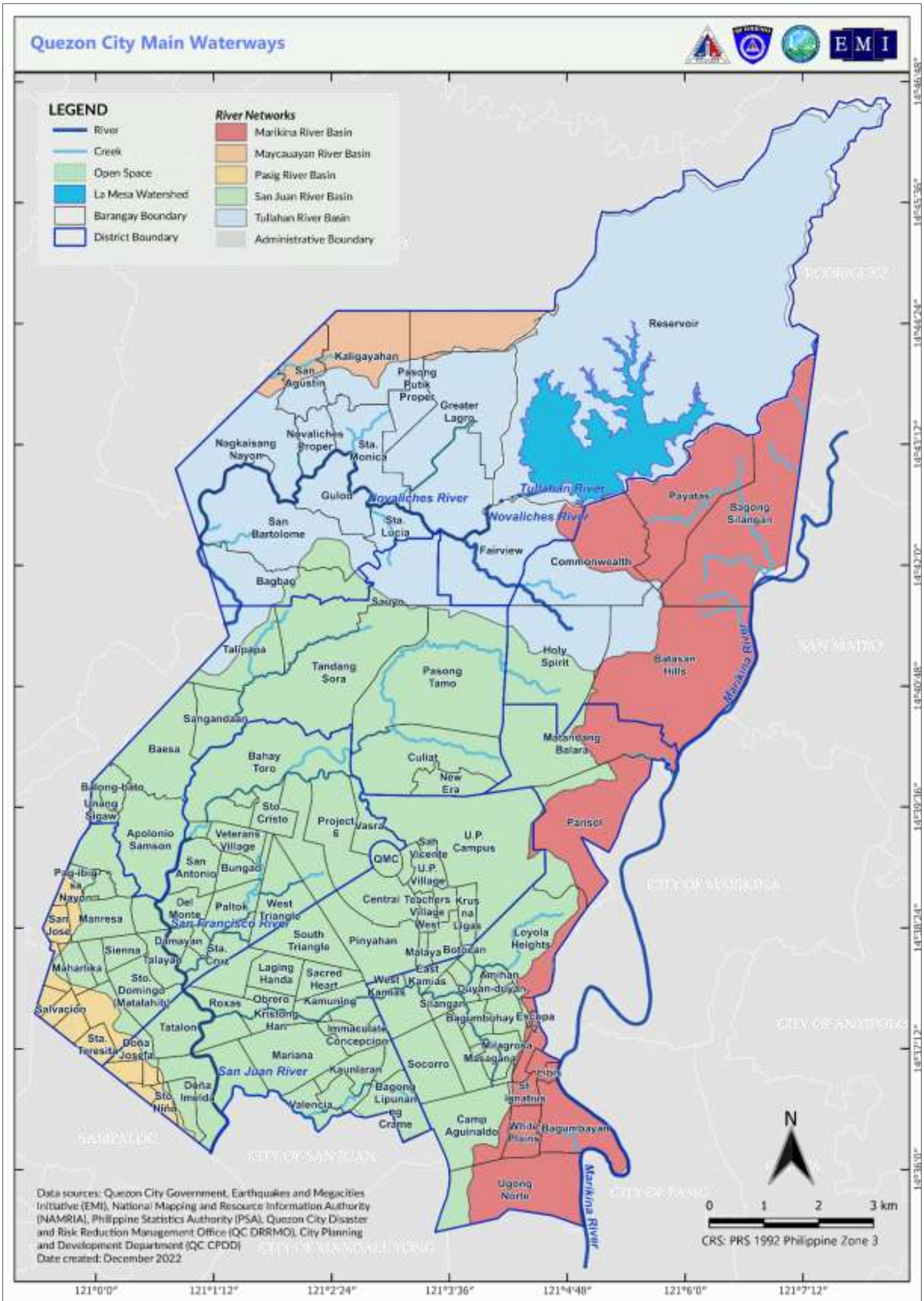


Figure 12. Rivers and Creeks in Quezon City (Source: QC-City Planning and Development Department (CPDD), 2022)

3.5. MGB Flood Susceptibility Mapping in Quezon City

3.5.1 Background and baseline data

Mines and Geo-Sciences Bureau (MGB) produced a 1:10,000 scale for flood susceptibility and rain-induced landslide map for Quezon City in 2021. Table 13 presents the four susceptibility levels for flood considered in the MGB map. The relevant flood considerations by district are presented below:

Table 13. Flood Susceptibility Levels

Susceptibility Levels	Descriptions
Very High Flood Susceptibility (VHF Depth)	Areas likely to experience flood heights in excess of 2.0 meters and/or flood duration of more than 3 days; also prone to flashfloods
High Flood Susceptibility (HF)	Areas likely to experience flood heights of 1.0 to 2.0 meters and/or flood duration of more than 3 days. These areas are immediately flooded during heavy rains of several hours.
Moderate Flood Susceptibility (MF)	Areas likely to experience flood heights of 0.5 to 1.0 meter and/or flood duration of 1 to 3 days.
Low Flood Susceptibility (LF)	Areas likely to experience flood heights of <0.5 meter and/or flood duration of less than 1 day. These areas include low hills and gentle slopes. They also have sparse to moderate drainage density.

Source: Mines and Geosciences Bureau, 2021

3.5.2 Flood susceptibility results by district

Flood Susceptibility of Barangays in District 1

- Barangays Mariblo, Katipunan, Talayan, St.Peter, Damayan, Sienna, Sto.Domingo (Matalahib), Paraiso and Maharlika and Masambong make up the top 10 of the 37 barangays whose land area are identified with moderate to very high susceptibility to flooding in District 1. Most of these barangays are traversed by creeks that drain to the San Juan River. Maharlika and St. Peter are farther from creeksides but join the flooded parts of Sienna and Sto. Domingo (Matalahib).

- Sta. Cruz, Masambong, Bahay Toro, Del Monte and Damar round the barangays where half (50%) of the land areas experiences flood depths of 0.5m and higher flood.

Table 14 provides a breakdown of the percentages of the barangays with highest percentage of flooded area. Figure 13 presents a distribution of flood susceptibility assignment in District 1. The map should be used conjointly with Table 14.

Table 14. Flood Susceptibility in District 1 based on percentage of land area assigned to flood water depth

District 1	Barangay Land Area Submerged in Percent			
Barangay	depth 0.5m-1m	depth 1m-2m	depth >2m	flooded area >0.5m
Mariblo	23.37	17.84	58.51	99.72
Katipunan	25.34	33.80	36.47	95.61
Talayan	13.65	15.84	43.10	72.59
St. Peter	11.82	49.36	10.34	71.52
Damayan	34.10	13.44	22.61	70.15
Sienna	13.73	33.07	22.85	69.65
Sto. Domingo (Matalahib)	20.22	19.42	27.21	66.84
Paraiso	30.69	12.21	21.62	64.52
Maharlika	39.50	23.30	0.70	63.49
Masambong	11.50	13.50	35.18	60.18
Del Monte	11.77	23.87	20.14	55.78
Sta. Cruz	19.57	10.43	23.72	53.72
Damar	53.50	0.00	0.00	53.50
Nayong Kanluran	14.44	13.92	17.28	45.64
Balingasa	20.78	6.07	15.70	42.55
Paltok	29.30	5.81	5.30	40.40
San Antonio	10.72	11.42	15.54	37.67
Vasra	14.86	13.32	3.98	32.16
Ramon Magsaysay	14.81	12.75	2.81	30.37
Sta. Teresita	29.66	0.00	0.00	29.66
Bahay Toro	13.11	8.86	6.66	28.63
Bagong Pag-asa	8.80	12.30	7.03	28.13
Manresa	10.56	10.08	7.47	28.11
Alicia	11.12	9.86	6.20	27.18
San Isidro Labrador	24.92	0.00	0.00	24.92
Lourdes	13.01	4.95	0.00	17.95
West Triangle	10.58	5.66	1.31	17.55
Salvacion	16.93	0.00	0.00	16.93
Pag-ibig sa Nayon	15.57	0.00	0.00	15.57
Sto. Cristo	4.75	2.80	3.55	11.10
Phil-Am	8.58	1.71	0.36	10.65
Paang Bundok	7.91	0.00	0.00	7.91
San Jose	7.05	0.00	0.00	7.05
N. S. Amoranto (Gintong Silahis)	4.29	0.00	0.00	4.29
Project 6	1.89	1.71	0.00	3.60
Veterans Village	3.35	0.18	0.00	3.53
Bungad	1.13	0.00	0.00	1.13

Source of data: CPDD, 2022, MGB, 2021

Flood Susceptibility of Barangays in District 2

- Barangays of District 2 have less than 22% of their barangay land areas in the range of moderate to very high flood susceptibility.

- Batasan Hills and Bagong Silangan lead the five barangays on susceptibility. They lie near the Marikina River while Barangays Commonwealth and Holy Spirit area traversed by the Novaliches River

Table 15 provides a breakdown of the percentages.. Figure 154 presents a distribution of flood susceptibility assignment in District 2. The map should be used conjointly with Table 15.

Table 15. Flood Susceptibility in District 2 based on percentage of land area assigned to flood water depth categories.

District 2	Barangay Land Area Submerged in Percent			
Barangay	depth 0.5m-1m	depth 1m-2m	depth >2m	flooded area >0.5m
Batasan Hills	9.27	5.03	7.33	21.63
Bagong Silangan	4.80	4.17	9.50	18.47
Commonwealth	6.73	4.85	5.17	16.75
Holy Spirit	6.93	4.02	0.12	11.07
Payatas	2.58	2.12	0.04	4.74

Source of data: CPDD, 2022, MGB, 2021

Flood Susceptibility of Barangays in District 3

- Three barangays of District 3 land area were found to have about fifty percent of more of the barangay areas to be in the range of moderate to very high flood susceptibility. These include Barangays Libis, West Kamias and Bagumbayan.
- Barangays Libis, Blue Ridge, Bagumbayan and Ugong Norte lie to the east side of the Marikina River. Barangay West Kamias, Quirino2-A, Quirino 2-B and Quirino 2-C are traversed by the Diliman Creek.

Table 16 provides a breakdown of the percentages.   Figure 15 presents a distribution of flood susceptibility assignment in District 2.

Table 16. Flood Susceptibility in District 3 based on percentage of land area assigned to flood water depth categories.

District 3	Barangay Land Area Submerged in Percent			
Libis	28.62	36.97	32.24	97.83
West Kamias	0.00	68.16	8.05	76.21
Bagumbayan	21.93	24.94	16.08	62.95
Quirino 2-A	0.00	15.36	20.92	36.29
East Kamias	0.00	24.41	10.32	34.74
Quirino 2-B	0.00	16.15	16.44	32.59
Quirino 2-C	0.00	30.81	0.00	30.81
Bagumbuhay	0.00	26.42	0.00	26.42
Blue Ridge B	8.07	10.77	6.13	24.97
Claro (Quirino 3-B)	0.00	20.20	4.13	24.34
Quirino 3-A	0.00	14.70	4.81	19.51
Silangan	0.00	10.47	6.68	17.15
Mangga	0.00	16.64	0.00	16.64
Tagumpay	0.00	12.69	0.00	12.69
E. Rodriguez	0.00	6.49	3.02	9.51
Ugong Norte	5.58	1.90	1.33	8.81
Matandang Balara	3.05	1.41	2.37	6.83
Loyola Heights	0.93	5.52	0.00	6.45
Socorro	2.42	0.00	0.00	2.42
Amihan	0.00	1.61	0.00	1.61
Milagrosa	0.00	1.48	0.00	1.48
Pansol	0.65	0.00	0.00	0.66

Source of data: CPDD, 2022, MGB, 2021

Flood Susceptibility of Barangays in District 4

- District 4 is traversed by San Juan River stretching across Roxas, Tatalon, Kalusugan, Damayang Lagi and Dona Imelda. Santol located on the downstream stretch is inside the highly susceptible areas. Barangays Horseshoe and Valencia and Bagong Lipunan ng Crame are traversed by the Valencia Creek. Pinyahan (East Triangle), San Vicente and Old Capitol Site are found to be traversed by upstream creeks.
- Interior flooding of UP Village may be more related to storm water drainage system performance rather than overbank spills of smaller natural waterways.

Barangays Doña Imelda, Tatalon, Santol, San Vicente and Damayang Lagi top the highly flood susceptible areas, having more than 50% of their land areas in high to very high flood susceptibility.

Table 17 provides a breakdown of these percentages. Figure 16 presents a distribution of flood susceptibility assignment in District 4.

Table 17. Flood Susceptibility in District 4 based on percentage of land area assigned to flood water depth categories.

District 4	Percent of Barangay Land Area Submerged			
Barangay	depth 0.5m-1m	depth 1m-2m	depth >2m	flooded area >0.5m
Doña Imelda	4.91	17.08	68.10	90.08
Tatalon	5.34	12.00	72.11	89.45
Santol	20.59	47.42	16.86	84.87
San Vicente	17.82	43.08	19.30	80.20
Damayang Lagi	28.05	14.01	36.71	78.77
Old Capitol Site	20.12	23.10	0.00	43.22
Roxas	6.94	7.26	27.36	41.55
U. P. Village	30.76	3.28	0.00	34.03
Kalusugan	13.94	0.00	16.65	30.59
Doña Josefa	13.60	8.76	1.65	24.01
Sto. Niño	17.49	6.48	0.00	23.98
Valencia	20.01	0.00	2.86	22.87
Pinyahan	11.74	8.26	2.08	22.07
Bagong Lipunan ng Crame	10.40	9.09	0.00	19.49
Teachers Village West	17.93	0.00	0.00	17.93
Mariana	13.40	0.00	0.18	13.58
Teachers Village East	13.27	0.00	0.00	13.27
Don Manuel	11.42	0.00	0.00	11.42
U. P. Campus	3.52	3.65	0.98	8.15
Horseshoe	8.04	0.00	0.00	8.04
San Isidro	7.03	0.00	0.00	7.03
Paligsahan	3.64	2.29	0.64	6.56
Malaya	0.00	6.41	0.00	6.41
Doña Aurora	5.34	0.25	0.00	5.59
South Triangle	4.71	0.00	0.27	4.98
Central	4.41	0.00	0.00	4.41
Botocan	0.00	4.12	0.00	4.12
Kristong Hari	0.40	0.00	1.85	2.25
Kaunlaran	1.45	0.00	0.00	1.45
Laging Handa	0.14	0.00	0.00	0.14

Source of data: CPDD, 2022, MGB, 2021

Flood Susceptibility of Barangays in District 5

- Fourteen barangays of District 5 land area were found to be identified with moderate to very high flood susceptibility. Barangays Capri, Sta. Lucia, Sta. Monica, and Novaliches Proper have more than 50% of the areas susceptible to more than 0.5m depth of flood. These barangays are traversed by the Novaliches River continuing to Tullahan River outside of Quezon City.

Table 18 provides a breakdown of the percentages. Figure 17 presents a distribution of flood susceptibility assignment in District 5.

Table 18. Flood Susceptibility in District 5 based on percentage of land area assigned to flood water depth categories.

District 5	Barangay Land Area Submerged in Percent			
Barangay	depth 0.5m-1m	depth 1m-2m	depth >2m	flooded area >0.5m
Capri	13.92	14.34	57.45	85.71
Sta. Lucia	14.57	13.19	30.20	57.97
Novaliches Proper	10.41	13.32	30.50	54.24
Gulod	10.73	10.52	23.74	44.99
Sta. Monica	8.72	8.49	23.46	40.67
San Agustin	8.58	11.31	7.96	27.86
Nagkaisang Nayon	9.10	7.11	10.40	26.62
San Bartolome	8.63	4.71	10.16	23.49
Bagbag	8.14	8.96	5.49	22.58
Fairview	7.13	5.61	2.38	15.12
North Fairview	4.33	3.05	5.73	13.11
Pasong Putik Proper	6.09	1.09	0.75	7.93
Kaligayahan	5.14	1.86	0.85	7.85
Greater Lagro	0.30	0.00	0.00	0.30

Source of data: CPDD, 2022, MGB, 2021

Flood Susceptibility of Barangays in District 6

- Eleven Barangays of District 6 were found to be in the range of moderate to very high flood susceptibility. Barangay Sangandaan has more than 50% of its area under high flood depths.

Table 19 provides a breakdown of the percentages. Figure 18 presents a distribution of flood susceptibility assignment in District 6.

Table 19. Flood Susceptibility in District 6 based on percentage of land area assigned to flood water depth categories.

District 6	Barangay Land Area Submerged in Percent			
Barangay	depth 0.5m-1m	depth 1m-2m	depth >2m	flooded area >0.5m
Sangandaan	30.23	23.25	5.39	58.87
Talipapa	20.76	17.38	5.27	43.41
Apolonio Samson	23.48	5.54	13.77	42.79
Unang Sigaw	33.50	0.00	2.10	35.60
Culiat	12.51	13.41	7.00	32.92
Baesa	15.90	8.52	1.09	25.52
Pasong Tamo	12.47	6.25	0.26	18.98
Sauyo	7.96	6.56	3.87	18.39
Balong-bato	12.74	0.00	0.00	12.74
Tandang Sora	5.65	3.28	1.39	10.33
New Era	0.22	0.00	0.00	0.22

Source of data: CPDD, 2022, MGB, 2021

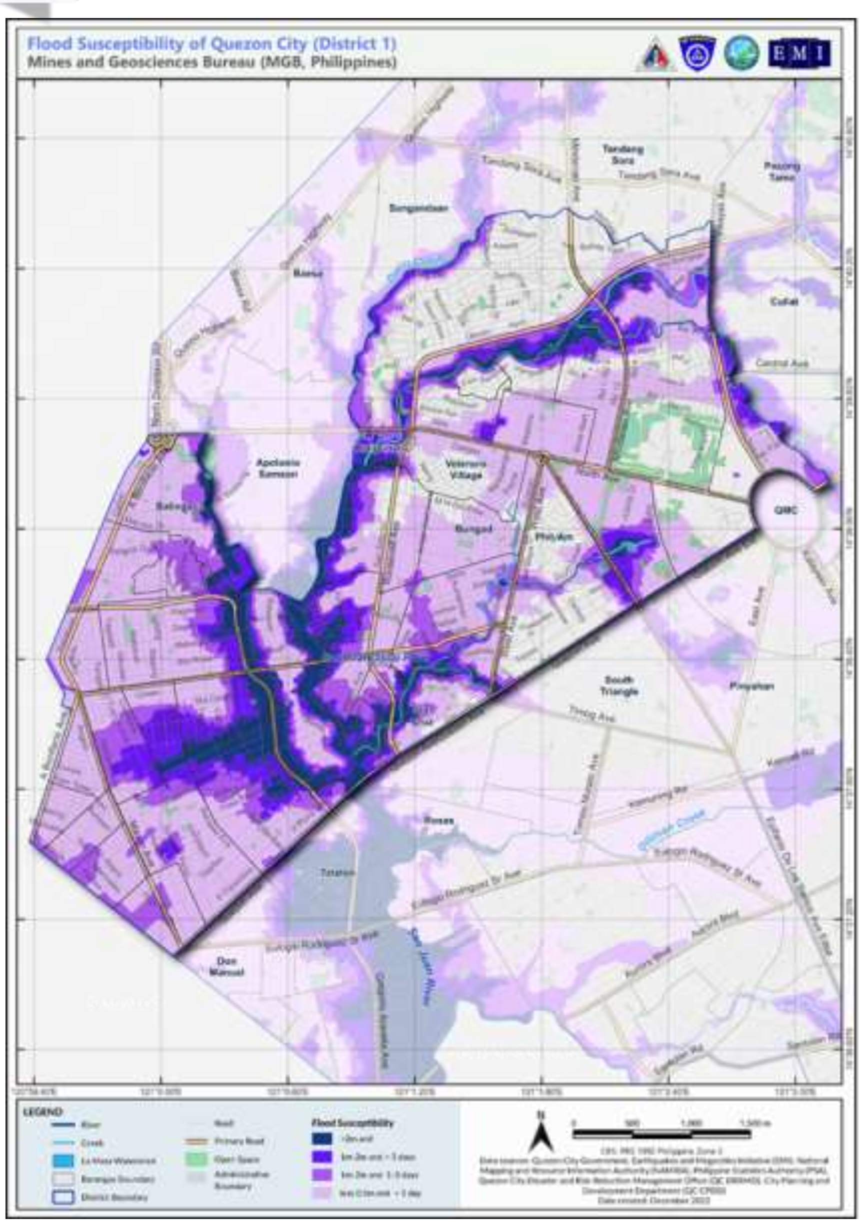


Figure 13. Flood Susceptibility of District 1 of Quezon City
(Source: MGB Flood Susceptibility Report, 2021)

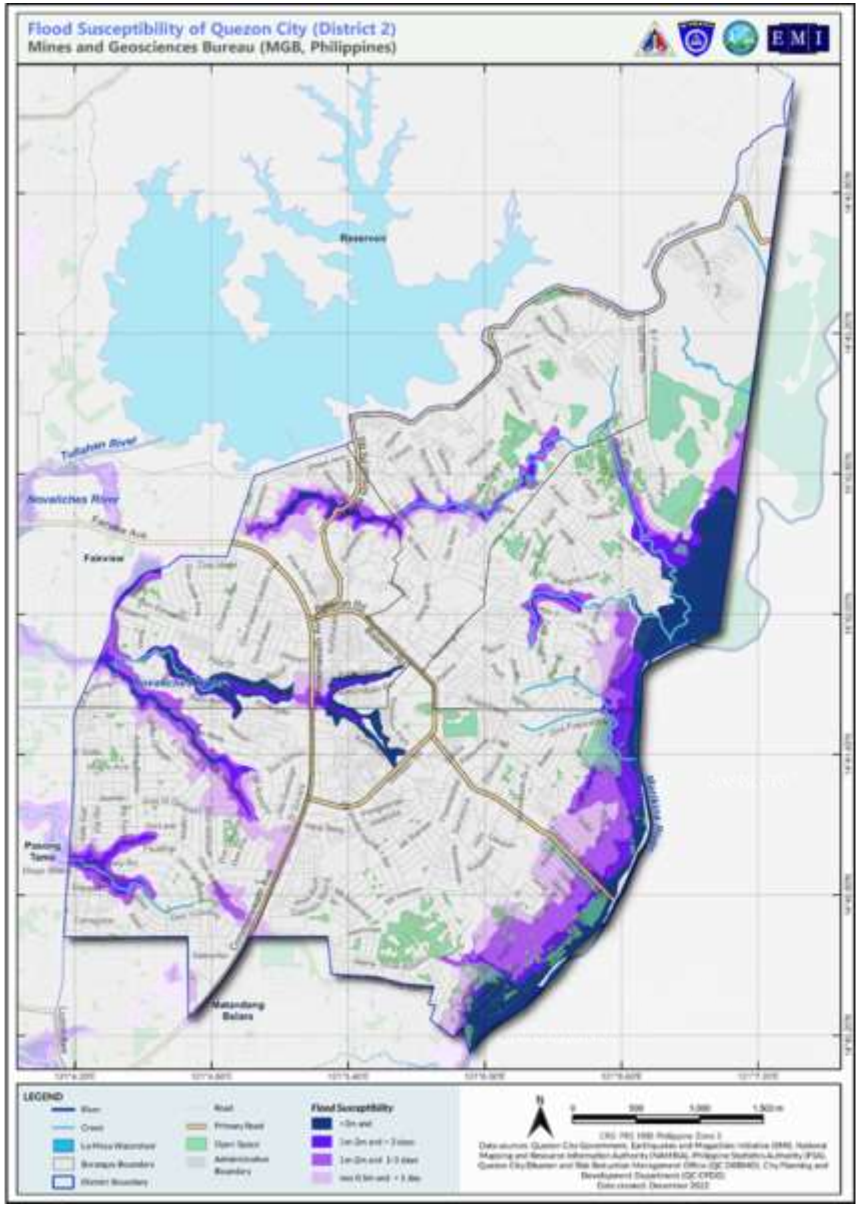


Figure 14. Flood Susceptibility of District 2 of Quezon City
(Source: MGB Flood Susceptibility Report, 2021)

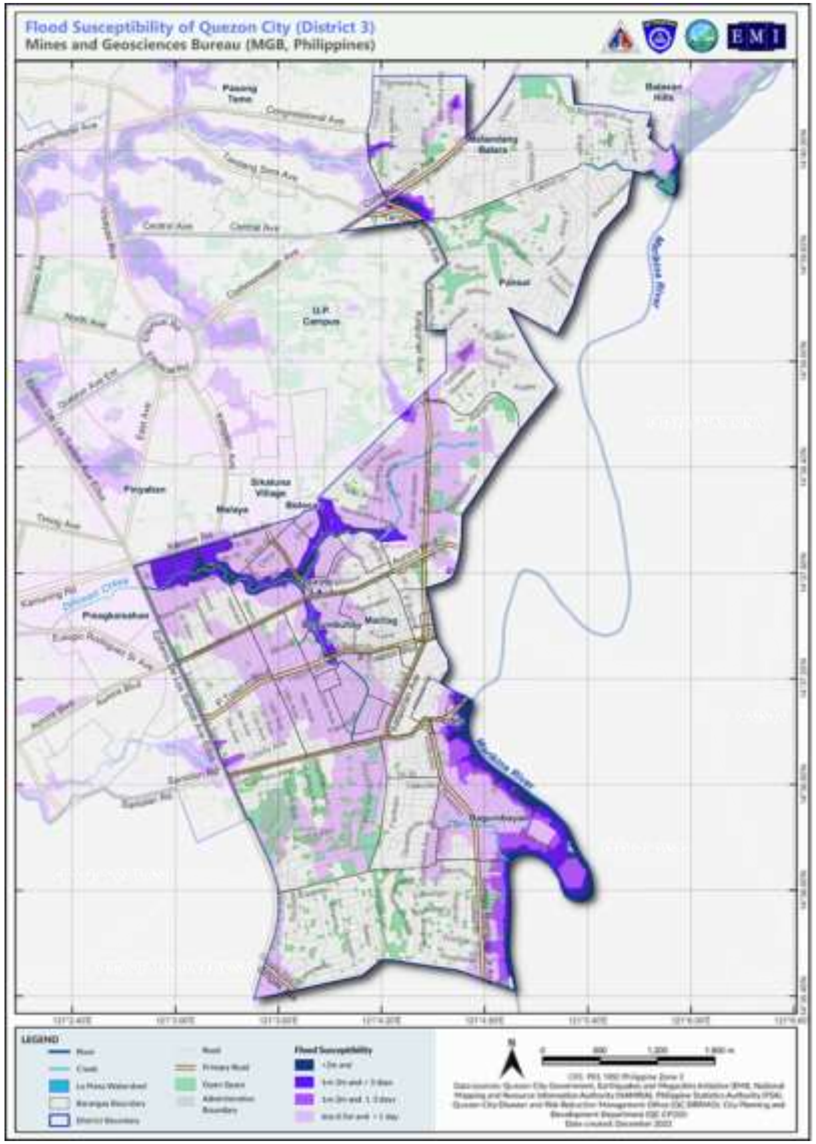


Figure 15. Flood Susceptibility of District 3 of Quezon City
(Source: MGB Flood Susceptibility Report, 2021)

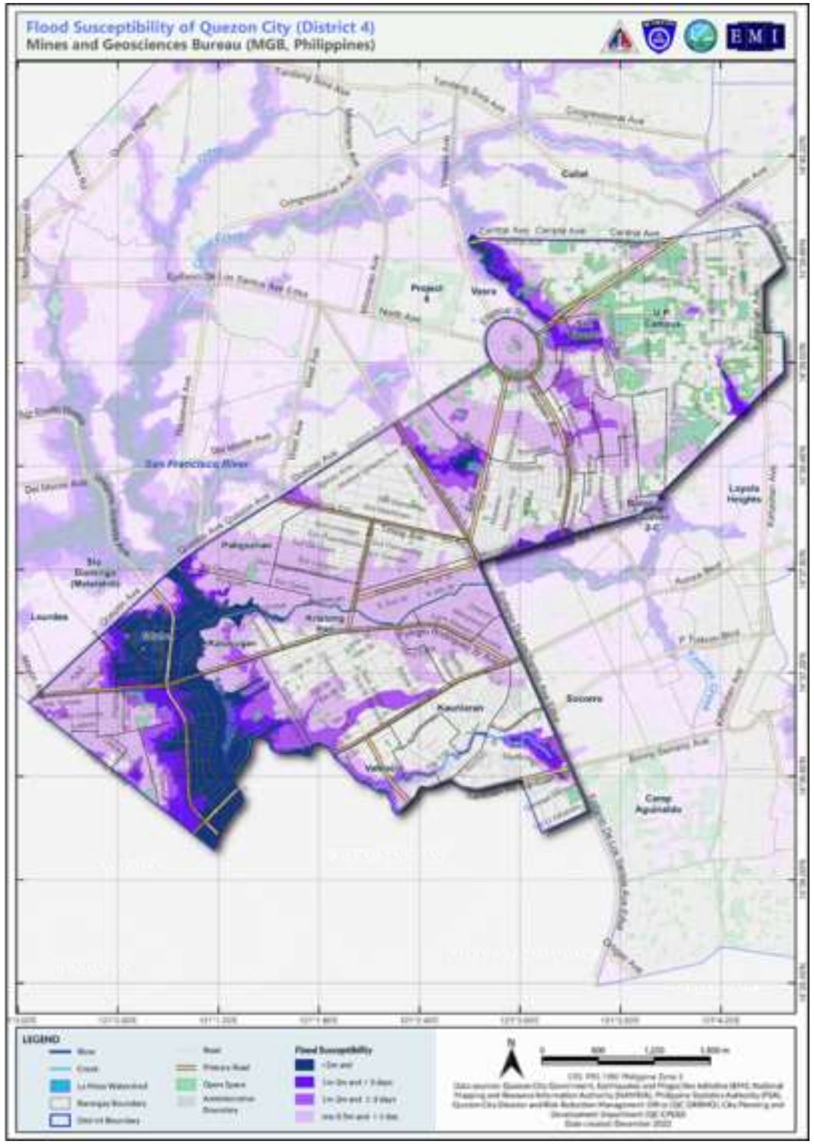


Figure 16. Flood Susceptibility of District 4 of Quezon City
(Source: MGB Flood Susceptibility Report, 2021)

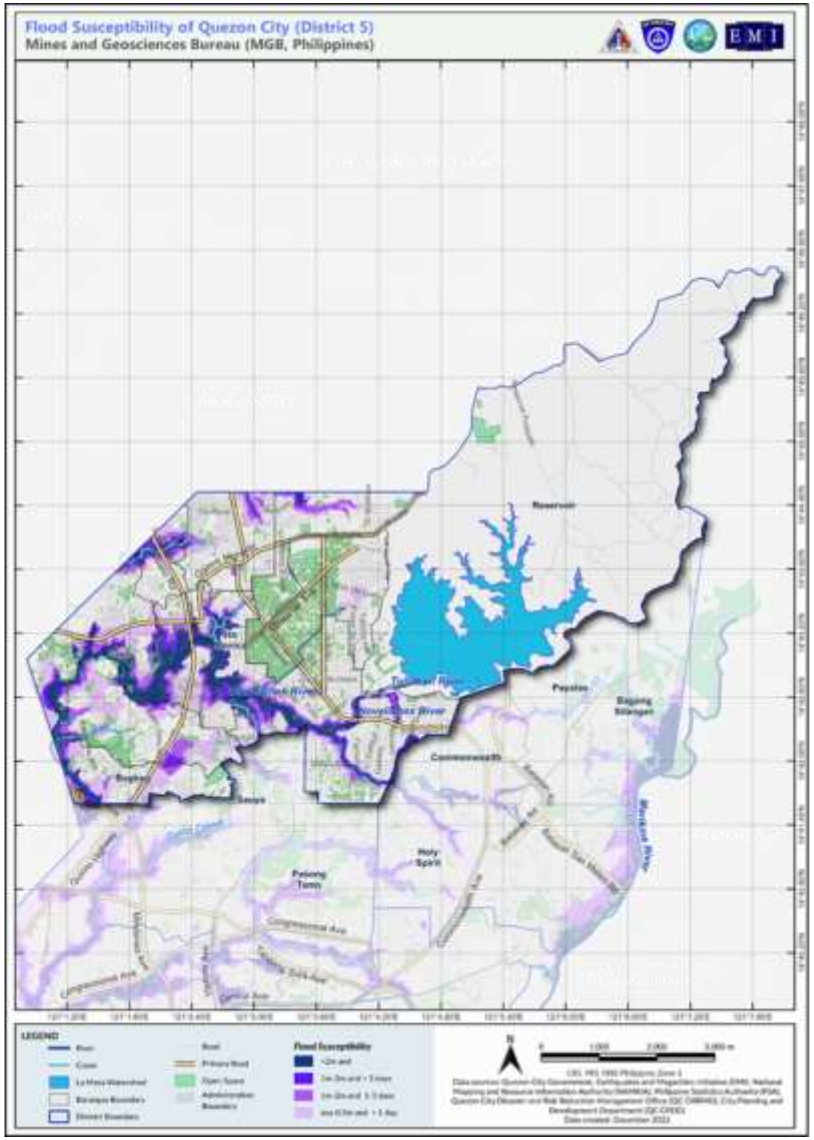


Figure 17. Flood Susceptibility of District 5 of Quezon City
(Source: MGB Flood Susceptibility Report, 2021)

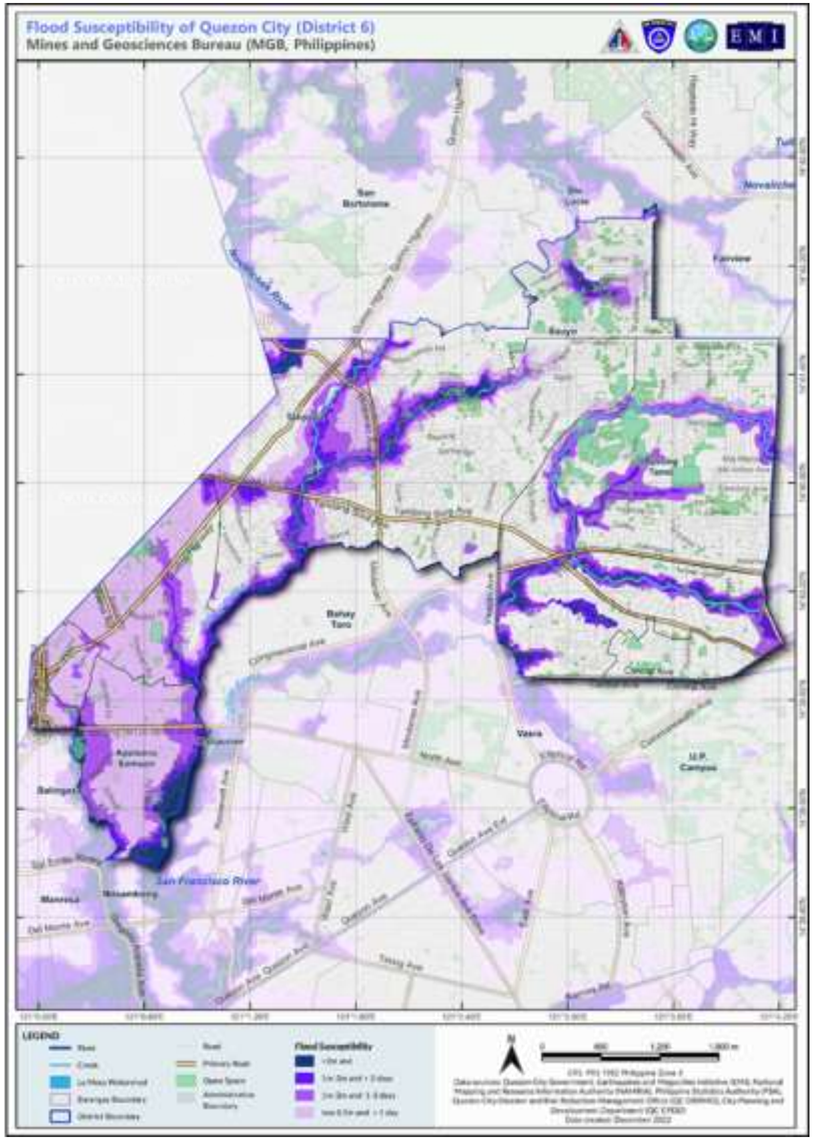


Figure 18. Flood Susceptibility of District 6 of Quezon City
(Source: MGB Flood Susceptibility Report, 2021)

3.6. QC-Drainage Master Plan (QC-DMP) Flood Hazard Simulation

3.6.1 Background

Flood inundation simulation results for Quezon City for flow depth maps for the 5-year, 25-year, 50-year, and 100-year rain return scenarios were made available for the QC-DMP study. These scenarios were simulated for the early-future, mid-future, and late-future periods, and with moderate (RCP 4.5) and high (RCP 8.5) emission scenarios. The climate-change adjusted rainfall values used for flood model simulation in Quezon City were calculated based on the data provided in the Philippine Climate Extremes Report 2020 published by PAGASA and the Manila Observatory and the Ateneo de Manila University (DOST-PAGASA, Manila Observatory and the Ateneo de Manila University, 2021). The flood simulation results provided information on the flood behavior over 36 hours, with rain falling over the initial 24 hours. A maximum 1-day rainfall total was taken to produce extreme flood flow values and attain flood peak depths.

3.6.2 The Climate Change Adjusted 100-Year Rain Return Flood baseline scenario

The adjusted 100-year rainfall return flood may be the worst flood scenario. Table 20 provides an estimate of the maximum rainfall totals for the National Capital Region (Source; QC- Drainage Master Plan). For the climate-adjusted rainfall, the percent change between the baseline rainfall value for a 100-year event (e.g., 436.6 mm) and the different projected percentage increases under scenarios for the early future, mid future and late future (i.e., under RCP 4.5 and RCP 8.5) can be multiplied to obtain the Climate adjusted rainfalls.

Table 20. Maximum 1-Day Totals for NCR under various Emission Scenarios (Source: QC-Drainage Master Plan, 2021)

		Moderate Emission (RCP 4.5)			High Emission (RCP 8.5)		
	Baseline	Early (2020-2039)	Mid (2046 – 2065)	Late (2080 – 2099)	Early (2020-2039)	Mid (2046 – 2065)	Late (2080 – 2099)
% Increase		5.50%	10.90%	3.30%	14.30%	9.90%	6.80%
5-yr	229.9	242.6	255	237.5	262.8	252.7	245.6
25-yr	343.2	362	380.6	354.5	392.2	377.1	366.5
50-yr	390.1	411.5	432.6	402.9	445.8	428.7	416.6
100-yr	436.6	460.6	484.2	451	499	479.8	466.3

The 100-year rain return flood scenario map shown in Figure 19 it is simulated using a one-day rainfall of an early future scenario (2020-2039) under RCP 8.5 that the baseline one-day total rainfall is 436.6 mm, and when multiplied by 14.3% gives 499 mm. This rainfall is then distributed over a 24-hour period having a peak value at some hour in a day. In comparison STS-Ondoy generated 455mm of rainfall in a day (Source: Science Garden, PAGASA). The flood depth in Figure 19 are segregated into four colors with each representing a flood depth category - 0.2m to 0.5m, 0.5m to 1.5m, 1.5m to 3m, and 3m and above. The map indicates the highest flood depths that may be expected at each location.

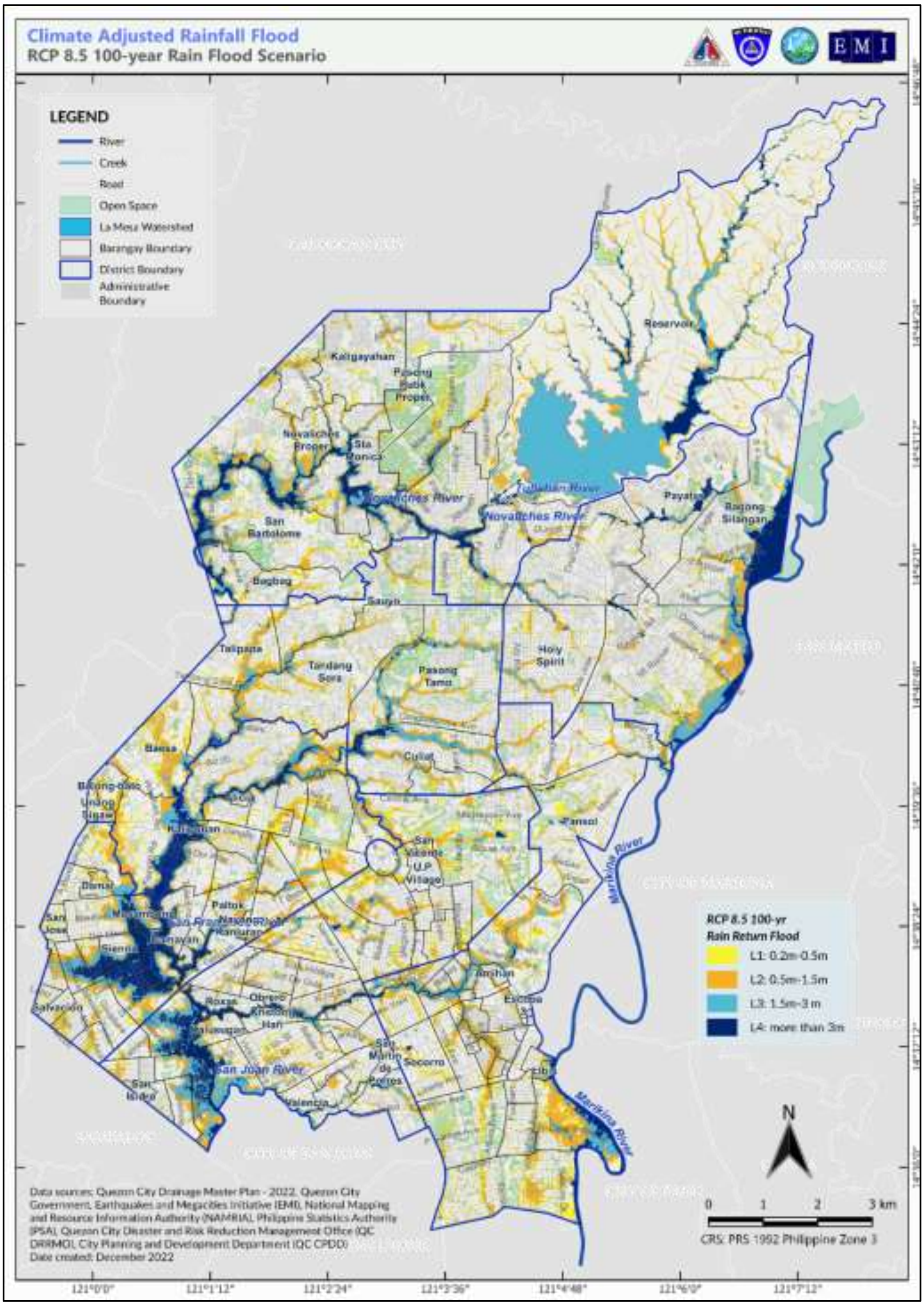


Figure 19. RCP 8.5(2020-2039) 100-Year Rain Flood Scenario in Quezon City (Source: QC-DMP, Preliminary Report, 2022)

3.6.3 Flood susceptibility results by district

RCP 8.5 rain flood scenario in District 1

- Thirty-seven barangays in District 1 can be severely flooded with depths more than half a meter under the climate adjusted rainfall for a 100-year flood scenario.
- Eight barangays with more than 50 percent of barangay bounded area affected include Katipunan (97 %), Talayan (91%), Masambong (88%), Sto. Domingo -Matalahib (81%), St.Peter (65%), Maribo (64%), Sienna(62%) and Maharlika (61%).

Table 21 provides a breakdown of the percentages of land area. Figure 20 presents a distribution of barangays according to flood depth categories.

Table 21. RCP 8.5 100 Year Flood Scenario Percentage of Land Area flooded at different flood levels in District 1.

District 1	Barangay Land Area Flooded in Percent		
Barangay	depth 0.5m-1.5m	Depth > 1.5m	Flooded area >0.5m
Katipunan	8	89	97
Talayan	7	84	91
Masambong	20	68	88
Sto. Domingo (Matalahib)	14	66	81
FloodSt. Peter	16	48	65
Mariblo	9	55	64
Sienna	10	52	62
Maharlika	18	44	61
Alicia	10	30	39
Damayan	5	31	37
San Antonio	6	29	36
Bahay Toro	15	20	36
Nayong Kanluran	18	18	35
Del Monte	7	26	33
Paltok	21	11	32
Balingasa	20	11	30
Sta. Cruz	9	21	30
Paraiso	6	22	28
N. S. Amoranto (Gintong Silahis)	23	5	28
West Triangle	19	6	25
Manresa	8	17	25
Vasra	15	8	23
Sto. Cristo	12	10	22
Bagong Pag-asa	14	6	20
Ramon Magsaysay	9	9	18
Phil-Am	12	3	16
Project 6	14	2	16
Damar	14	0	14
Bungad	11	4	14
San Isidro Labrador	14	0	14
Sta. Teresita	12	0	12
Veterans Village	7	4	12
Lourdes	7	2	10
Salvacion	8	0	8
San Jose	5	0	5
Paang Bundok	3	0	3
Pag-ibig sa Nayon	2	0	2

RCP 8.5 rain flood scenario in District 2

- Five barangays that are affected by deep floods and ranges between 8-25 percent of their areas. Bagong Silangan leads with about 25 percent of the land area susceptible to flooding with more than 0.5m.

Table 22 provides a breakdown of the percentages. Figure 21 presents a distribution of barangays according to flood depth levels for District 2.

Table 22. RCP 8.5 100 Year Flood Scenario Percentage of Land Area flooded at different flood levels in District 2.

District 2	Barangay Land Area Flooded in Percent		
Barangay	depth 0.5m-1.5m	Depth > 1.5m	Flooded area >0.5m
Bagong Silangan	7.23	18.25	25.48
Batasan Hills	9.78	13.01	22.79
Payatas	3.98	7.02	11
Holy Spirit	6.84	1.57	8.41
Commonwealth	4.23	4.08	8.31

RCP 8.5 rain flood scenario in District 3

- Thirty-five barangays in District 3 can be severely flooded with depths more than half a meter under the climate adjusted rainfall for a 100-year flood scenario.
- Four barangays with more than 50 percent of barangay bounded area include Bagumbayan (66 %), Claro-Quirino 3B (62%), Libis (62%), and West-Kamias (61%).

Table 23 and **Error! Reference source not found.**22 present a distribution of barangays according to flood depth levels for District 3.

Table 23. RCP 8.5 100 Year Flood Scenario Percentage of Land Area flooded at different flood levels in District 3.

District 3	Barangay Land Area Submerged in Percent		
Barangay	depth 0.5m-1.5m	Depth > 1.5m	Flooded area >0.5m
Bagumbayan	33.29	33.13	66.42
Claro (Quirino 3-B)	19.14	42.81	61.95
Libis	24.06	37.67	61.73
West Kamias	24.03	36.66	60.69
Silangan	17.6	27.69	45.29
Masagana	39.39	2.32	41.71
Tagumpay	29.86	10.06	39.92
Quirino 2-A	11.4	28.35	39.75
East Kamias	25.21	14.32	39.53
Quirino 2-C	22.26	16.52	38.78
Mangga	27.12	11.59	38.71
Villa Maria Clara	34.48	0.06	34.54
Quirino 3-A	15.94	17	32.94
Bagumbuhay	18.65	14.15	32.8
Quirino 2-B	11.13	20.51	31.64
Amihan	19.45	7.56	27.01

District 3	Barangay Land Area Submerged in Percent		
Barangay	depth 0.5m-1.5m	Depth > 1.5m	Flooded area >0.5m
Loyola Heights	15.32	5.96	21.28
E. Rodriguez	11.79	8.27	20.06
Milagrosa	16.1	3.23	19.33
Ugong Norte	12.14	2.86	15
Blue Ridge B	5.68	8.83	14.51
Matandang Balara	8.93	3.26	12.19
Bayanihan	9.75	0.47	10.22
White Plains	4.07	5.15	9.22
San Roque	7.76	0.23	7.99
Pansol	5.9	2.05	7.95
Duyan-duyan	7.25	0.04	7.29
Marilag	7.17	0.04	7.21
Socorro	5.51	1.2	6.71
Camp Aguinaldo	6.24	0.15	6.39
St. Ignatius	3.56	0.46	4.02
Dioquino Zobel	3.98	0	3.98
Blue Ridge A	2.64	0.27	2.91
Escopa 2	1.42	0	1.42
Escopa 3	0.11	0	0.11

RCP 8.5 rain flood scenario in District 4

- Thirty-eight barangays in District 4 can be severely flooded with depths more than half a meter under the climate adjusted rainfall for a 100-year flood scenario.
- Three barangays with more than 50 percent of barangay bounded area include Tatalon (79%), Doña Imelda (77%), and Damayang Lagi (55%).

Table 24 and Figure 23 present a distribution of barangays according to flood depth levels for District 4.

Table 24. RCP 8.5 100 Year Flood Scenario Percentage of Land Area flooded at different flood levels in District 4.

District 4	Barangay Land Area Submerged in Percent		
Barangay	depth 0.5m-1.5m	Depth > 1.5m	Flooded area >0.5m
Tatalon	10.42	68.73	79.15
Doña Imelda	17.14	59.76	76.9
Damayang Lagi	11.55	43.54	55.09
San Vicente	40.61	4.48	45.09
Santol	13.59	23.74	37.33
Kalusugan	16.06	19.79	35.85
Roxas	6.5	28.8	35.3
Old Capitol Site	25.75	7.37	33.12
Kristong Hari	8.31	24.55	32.86
Kamuning	11.18	20.8	31.98
Botocan	28.54	1.06	29.6

District 4	Barangay Land Area Submerged in Percent		
Barangay	depth 0.5m-1.5m	Depth > 1.5m	Flooded area >0.5m
Valencia	8.24	16.2	24.44
Central	20.55	3.55	24.1
Horseshoe	14.59	6.6	21.19
Obrero	5.22	14.17	19.39
Don Manuel	18.66	0	18.66
South Triangle	13.74	3.76	17.5
Immaculate Concepcion	9.4	7.16	16.56
Pinagkaisahan	6.25	8.86	15.11
Bagong Lipunan ng Crame	8.58	5.77	14.35
Pinyahan	9.2	3.58	12.78
U. P. Campus	9.25	2.78	12.03
Mariana	8.08	1.81	9.89
Paligsahan	6.42	1.45	7.87
Laging Handa	7.31	0.11	7.42
San Martin de Porres	5.09	2.31	7.4
Teachers Village West	6.31	0.13	6.44
Kaunlaran	3.63	2.58	6.21
Doña Josefa	6.01	0.14	6.15
San Isidro	5.33	0	5.33
Sikatuna Village	5.28	0	5.28
Sacred Heart	3.61	0.13	3.74
U. P. Village	3.17	0	3.17
Doña Aurora	2.89	0	2.89
Krus na Ligas	2.56	0	2.56
Teachers Village East	2.52	0	2.52
Sto. Niño	1.56	0	1.56
Malaya	0.61	0	0.61

RCP 8.5 rain flood scenario in District 5

- Fourteen barangays in District 5 can be severely flooded with depths more than half a meter under the climate adjusted rainfall for a 100-year flood scenario.
- Barangay Capri in District 5 has 97 percent of its area flooded. Other barangays are flooded varying from 6- 38 percent of their areas.

Table 25 and **Error! Reference source not found.**24 presents a distribution of barangays according to flood depth levels.

Table 25. RCP 8.5 100 Year Flood Scenario Percentage of Land Area Flooded at Different Flood Levels in District 5.

District 5	Barangay Land Area Submerged in Percent		
Barangay	depth 0.5m-1.5m	Depth > 1.5m	Flooded area >0.5m
Capri	24.17	72.52	96.69

District 5	Barangay Land Area Submerged in Percent		
Barangay	depth 0.5m-1.5m	Depth > 1.5m	Flooded area >0.5m
Gulod	9.97	27.65	37.62
Novaliches Proper	22.25	13	35.25
Sta. Lucia	8.25	26.42	34.67
Sta. Monica	9.31	23.18	32.49
Nagkaisang Nayon	9.44	14.24	23.68
San Bartolome	7.92	13.56	21.48
Bagbag	7.27	10.29	17.56
North Fairview	7.37	9.69	17.06
Fairview	6.6	8.56	15.16
San Agustin	8.6	0.8	9.4
Greater Lagro	6.05	1.78	7.83
Pasong Putik Proper	6.12	1.05	7.17
Kaligayahan	5.52	0.51	6.03

RCP 8.5 rain flood scenario in District 6

- District 6 has eleven areas that are affected by deep floods but range between 10-41 percent of the barangay areas.

Table 26 and Figure 25 present a distribution of barangays according to flood depth levels.

Table 26. RCP 8.5 100 Year Flood Scenario Percentage of Land Area Flooded at Different Flood Levels in District 6.

District 6	Barangay Land Area Submerged in Percent		
Barangay	depth 0.5m-1.5m	Depth > 1.5m	Flooded area >0.5m
Apolonio Samson	14.49	26.14	40.63
Unang Sigaw	29.95	1.64	31.59
Culiat	13.32	16.67	29.99
Baesa	20.63	5.8	26.43
Sangandaan	9.95	13.41	23.36
Balong-bato	20.49	2.61	23.1
Talipapa	14.18	5.1	19.28
Pasong Tamo	10.68	8.49	19.17
Tandang Sora	10.51	4.06	14.57
Sauyo	8.22	3.81	12.03
New Era	9.94	0.13	10.07

(Source: QC-DMP, Preliminary Report, 2022)

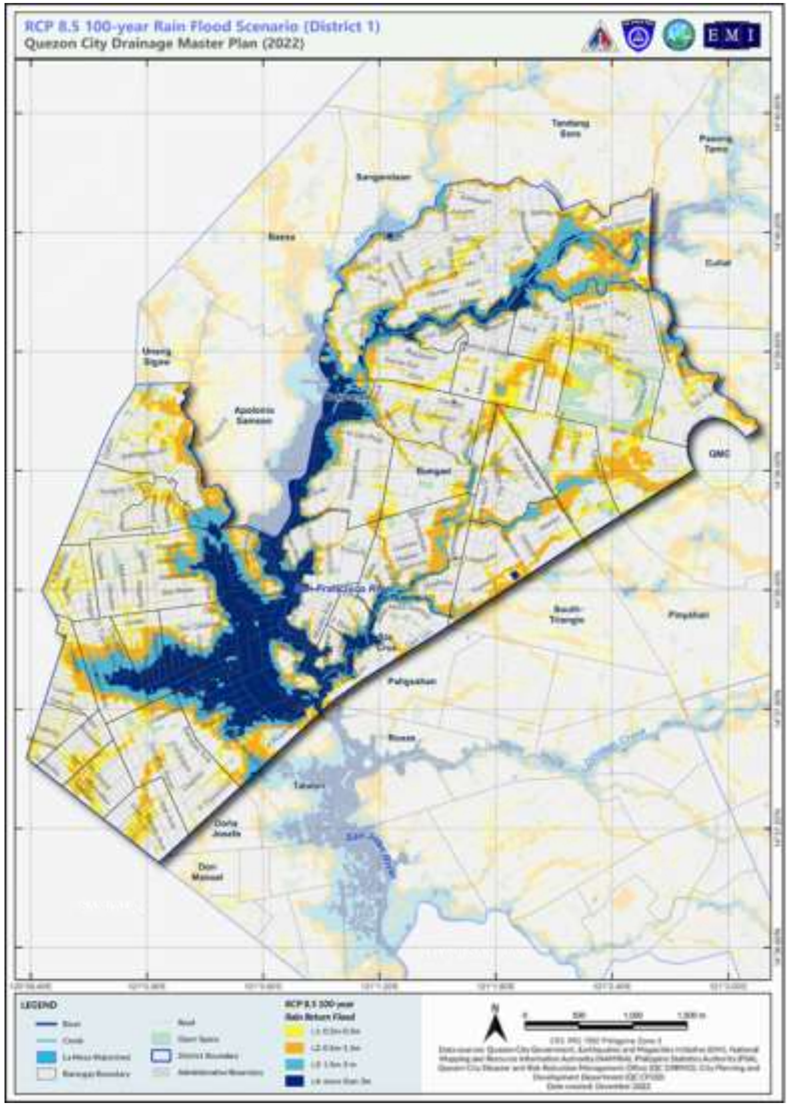


Figure 20. RCP 8.5(2020-2039) 100-Year Rain Flood Scenario in District 1 (Source: QC-DMP, Preliminary Report, 2022)

Figure 21. RCP 8.5(2020-2039) 100-Year Rain Flood Scenario in District 2 (Source: QC-DMP, Preliminary Report, 2022)

Figure 22. RCP 8.5(2020-2039) 100-Year Rain Flood Scenario in District 3 (Source: QC-DMP, Preliminary Report, 2022)

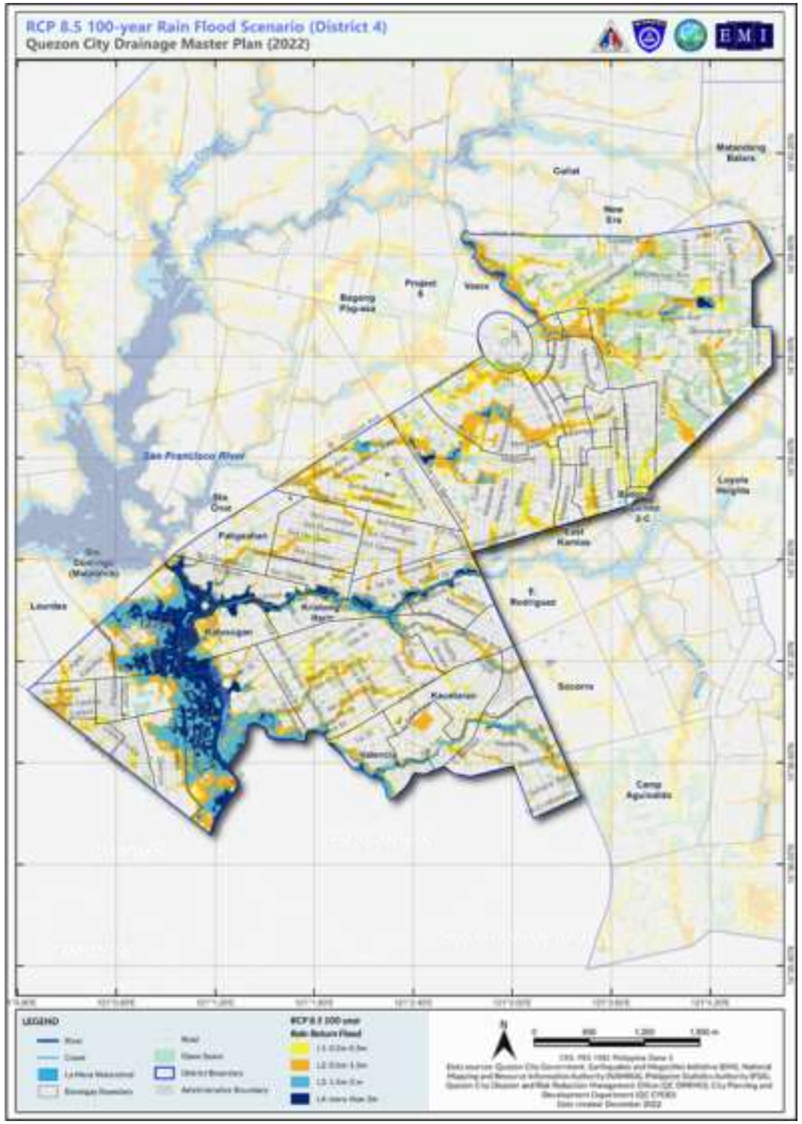


Figure 23. RCP 8.5(2020-2039) 100-Year Rain Flood Scenario for District 4 (Source: QC-DMP, Preliminary Report, 2022)

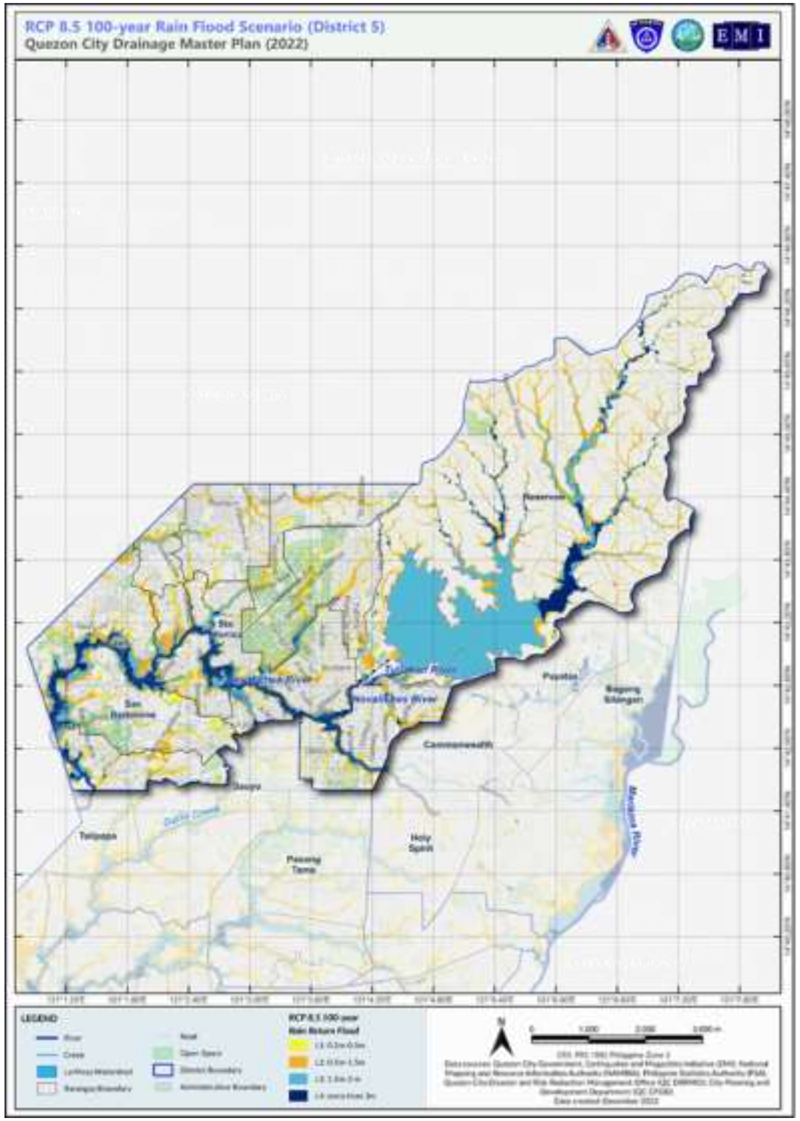


Figure 24. RCP 8.5(2020-2039) 100-Year Rain Flood Scenario for District 5
(Source: QC-DMP, Preliminary Report, 2022)

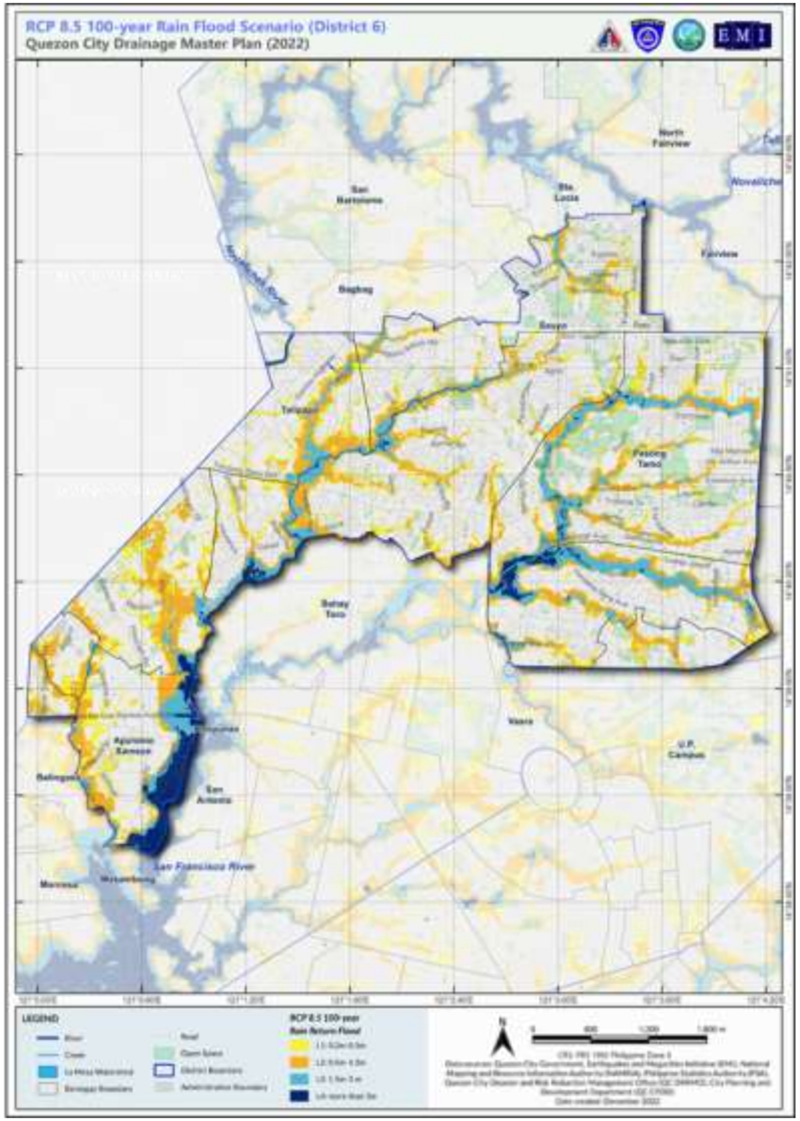


Figure 25. RCP 8.5(2020-2039) 100-Year Rain Flood Scenario for District 6
(Source: QC-DMP, Preliminary Report, 2022)

3.7. Flood Risk Assessment (RCP 8.5 100-Year Flood)

To demonstrate the parameters of risk to Quezon City, this section used the 100-year flood map to overlay exposure and establish the risk to the following exposed assets:

- Population and settlements
- Buildings of various occupancies
- Public facilities used for health and emergency
- Facilities used for safety and security
- Urban Land Use
- Utilities and infrastructures

The 100-year flood model simulation runs using the RCP 8.5-rain projections from the QC-DMP study provide the most relevant outputs for planning and for preparedness.

3.7.1. Flood Displaced Population

This section discusses the flood displaced population under an RCP8.5 100-year rain flood scenario. The distribution of the flood-affected population in Quezon City is discussed. The building footprints in (light colored shapes shown in Figures 26-31 in a barangay boundary) indicate one-and two story structures that should expect more than half a meter (0.5 m) of flood which will be potentially damaging to the building structure or its contents. Most one-story buildings are largely for residential use and are less than four (4) meters high from floor to ceiling.

The flood-displaced population was obtained by taking the proportion of the residential, one- and two-story building footprint area that are in locations where flood depths exceed half a meter. This is multiplied by an estimate of the population per unit area of the building footprint to obtain the potential number of flood displaced population. The flood depth ranges used were 0.5m and below, 0.5 m- 1.5 m, and 1.5 m and above were derived from the RCP8.5 rain flood scenario.

Informal settlers that reside in Quezon City are high-risk areas. These settlements, due to their informality, are often not built to code or with flood resistant materials which increases their vulnerability to flood events.

In 2021, there are 200, 591 informal settler families (ISFs) listed in 2021 by the Quezon City Government. A great number of these are in flood prone areas. District 1 lists 21,518 ISFs and about 95 % (20,491) are situated where flood depths can be higher than 0.5 meter. All of 61,439 ISFs can experience high flood depths. District 3 has 21,780 ISFs, and 21,039 or about 97% can experience depths higher than 0.5m. District 4 has 42,722 ISFs and 98% (41,955) can experience depths higher than 0.5m. District 5 has 11,060 ISFs listed, and all are in locations prone to floods. District 6 has 42,072 ISFs and all these families are in flood prone areas. Long term solutions tied with affordable housing, relocation and resettlement can reduce the ISFs in dangerous locations. Pre- evacuation sites, resources and response are needed when a 100-year rain flood scenario like this develops

The sections below provide the findings per district.

Flood Displaced Population in District 1

A summary of the flood-displaced population in District 1 at three flood levels (moderate flood with depth of 0.5 to 1.5 m and high flood with depth of >1.5 m) is shown Table 27. Barangays Bahay Toro, San Antonio, Masambong are estimated to bring the larger numbers of flood displaced population affected under 0.5 m and above depths. Figure 26 presents a distribution of displaced population for District 1.

Table 27. Flood displaced population in District 1 in an RCP100-year 8.5 Rain Flood Scenario

Barangay (District 1)	Number of people Displaced
Bahay Toro	16,849
San Antonio	6,568
Masambong	6,201
Sto. Domingo (Matalahib)	5,042
Paltok	3,821
Del Monte	2,740
Bagong Pag-asa	2,602
Talayan	2,529
Damayan	1,942
Vasra	1,888
Alicia	1,822
Mariblo	1,638
Manresa	1,491
Project 6	1,405
Maharlika	1,404
Veterans Village	1,395
St. Peter	1,390
Balingasa	1,356
Katipunan	1,217
San Isidro Labrador	1,129
Sto. Cristo	1,108
Sta. Cruz	957
Sienna	919
N. S. Amoranto (Gintong Silahis)	807
Ramon Magsaysay	752
Bungad	577
West Triangle	559
Paraiso	554
Sta. Teresita	497
Salvacion	480
Phil-Am	428
Lourdes	407
Nayong Kanluran	406
Pag-ibig sa Nayon	283
Damar	204
San Jose	130
Paang Bundok	12
Total	**73,511**

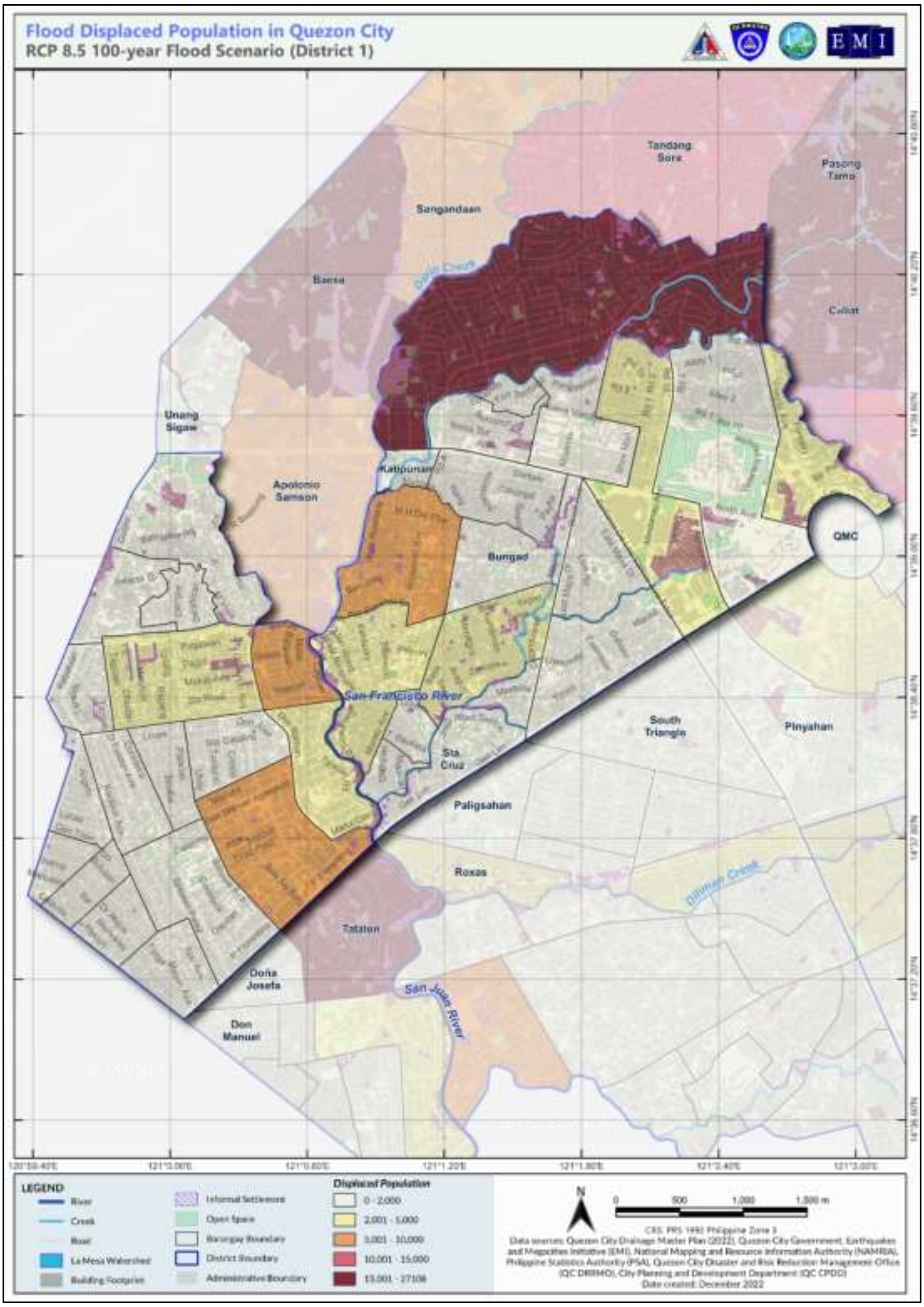


Figure 26. Displaced Population from Single Family, One- and Two-Story Structures and Informal Settler Family Structures in a 100-Year Rain Flood Scenario for District 1 (Source: QC-DMP, Preliminary Report, 2021)

Flood Displaced Population in District 2

A summary of the flood-displaced population in District 2 is shown in Table 28. The flood depth ranges used 0.5 m- 1.5 m, and 1.5 m and above were derived from the RCP8.5 rain flood scenario. Barangay Batasan Hills is estimated to bring the larger numbers of flood displaced population affected under 0.5 m and above depths. Figure 27 presents a distribution of displaced population for District 2.

Table 28. Flood displaced population in District 2 in an RCP100-year 8.5 Rain Flood Scenario

Barangay (District 2)	Number of people Displaced
Batasan Hills	19,064
Commonwealth	11,387
Bagong Silangan	10,286
Holy Spirit	7,221
Payatas	3,004
Total	**50,962**

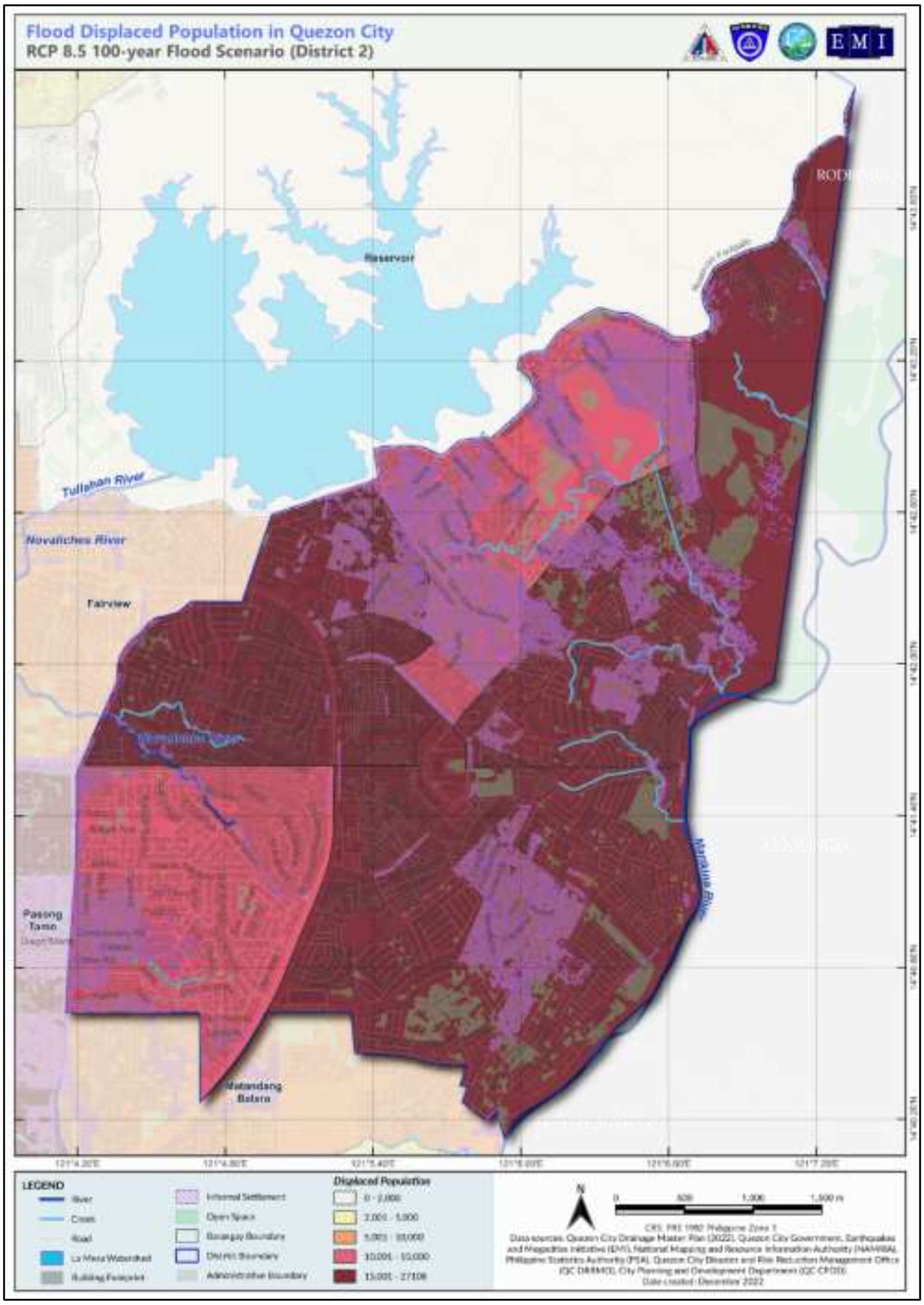


Figure 27. Displaced Population from Single Family, One- and Two-Story Structures and Informal Settler Family Structures in a 100-Year Rain Flood Scenario for District 2 (Source: QC-DMP, Preliminary Report, 2021)

Flood Displaced Population in District 3

A summary of the flood-displaced population in District 3. Barangays Bagumbayan and Matandang Balara are estimated to bring the larger numbers of flood displaced population affected under 0.5 m and above depths as shown in Table 29. Figure 28 presents a distribution of displaced population for District 3.

Table 29. Flood displaced population in District 3 in an RCP100-year 8.5 Rain Flood Scenario

Barangay	Number of people Displaced
Bagumbayan	4,746
Matandang Balara	4,387
Loyola Heights	3,295
E. Rodriguez	2,481
West Kamias	2,072
Pansol	2,070
East Kamias	1,625
Bagumbuhay	1,620
Claro (Quirino 3-B)	1,596
Masagana	1,589
Quirino 2-A	1,481
Silangan	1,476
Ugong Norte	1,248
San Roque	1,087
Amihan	955
Villa Maria Clara	830
Marilag	813
Milagrosa	784
Quirino 2-C	678
Quirino 2-B	672
White Plains	656
Socorro	440
Quirino 3-A	354
Libis	254
Tagumpay	227
Duyan-duyan	227
Mangga	205
Blue Ridge B	166
St. Ignatius	136
Bayanihan	127
Dioquino Zobel	124
Blue Ridge A	110
Escopa 3	17
Escopa 4	0
Escopa 1	0
Camp Aguinaldo	0
Escopa 2	0
Total	**38547**

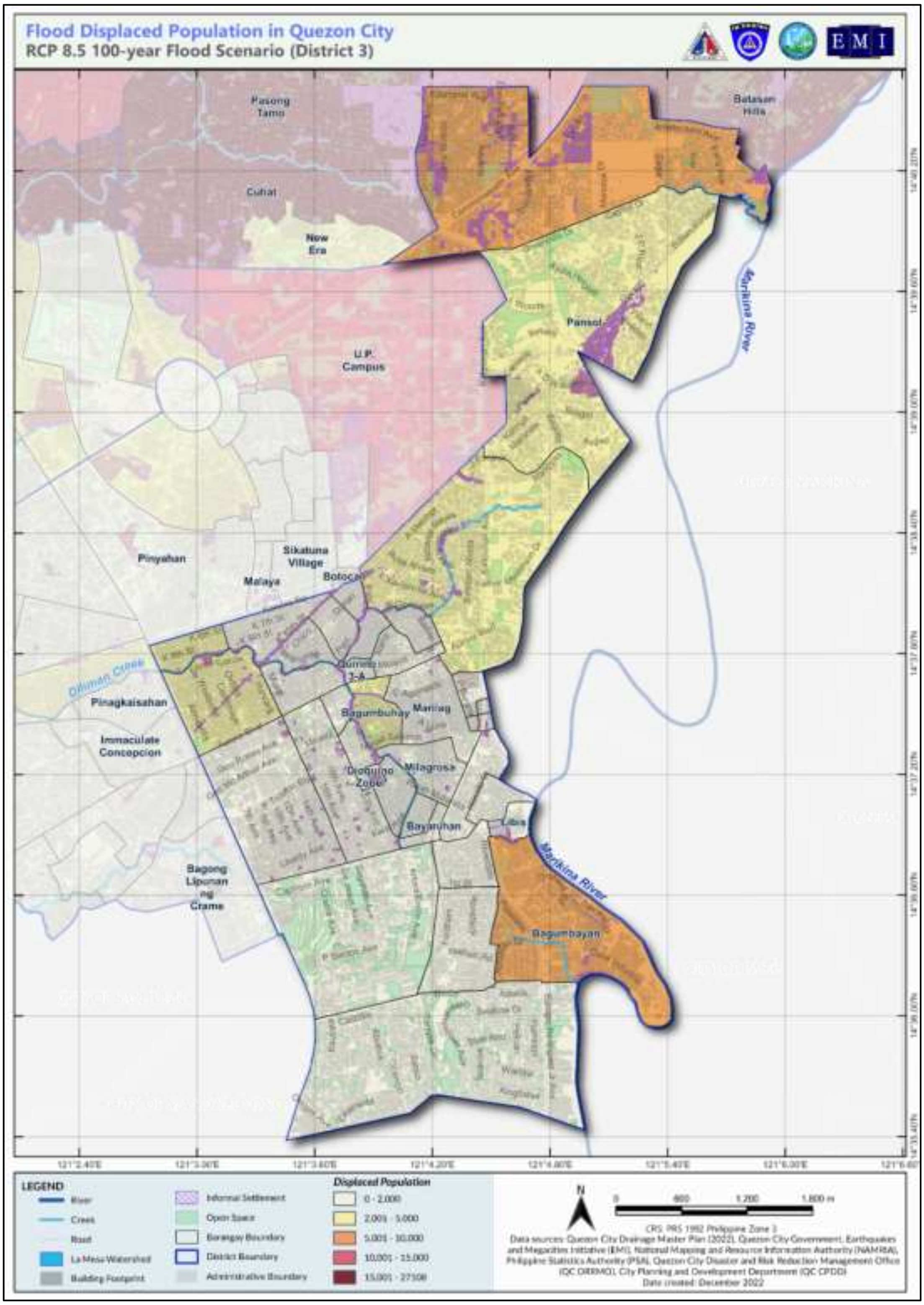


Figure 28. Displaced Population from Single Family, One- and Two-Story Structures and Informal Settler Family Structures in a 100-Year Rain Flood Scenario for District 3 (Source: QC-DMP, Preliminary Report, 2022)

Flood Displaced Population in District 4

Table 30 gives a summary of the flood-displaced population in District 4. The flood depth ranges used were 0.5 m- 1.5 m, and 1.5 m and above were derived from the RCP8.5 rain flood scenario. Barangay Talalon is estimated to bring the larger numbers of flood displaced population affected under 0.5 m and above depths. Figure 29 presents a distribution of displaced population for District 4.

Table 30. Flood displaced population in District 4 in an RCP100-year 8.5 Rain Flood Scenario

Barangay	Number of people Displaced
Tatalon	20,921
Damayang Lagi	5,018
Roxas	3,350
Kamuning	3,194
Doña Imelda	2,608
Central	1,834
Bagong Lipunan ng Crame	1,533
Obrero	1,277
Santol	1,184
South Triangle	878
Mariana	840
Pinagkaisahan	757
Immaculate Concepcion	708
San Isidro	707
U. P. Campus	696
Botocan	688
Kristong Hari	524
Pinyahan	485
Don Manuel	477
Valencia	404
Laging Handa	384
Horseshoe	380
San Vicente	376
Teachers Village West	311
Sto. Niño	279
San Martin de Porres	254
Paligsahan	228
Sacred Heart	203
U. P. Village	189
Sikatuna Village	164
Kaunlaran	142
Teachers Village East	124
Doña Aurora	121
Kalusugan	43
Malaya	32
Old Capitol Site	24
Doña Josefa	20
Krus na Ligas	0
Total	**51,354**

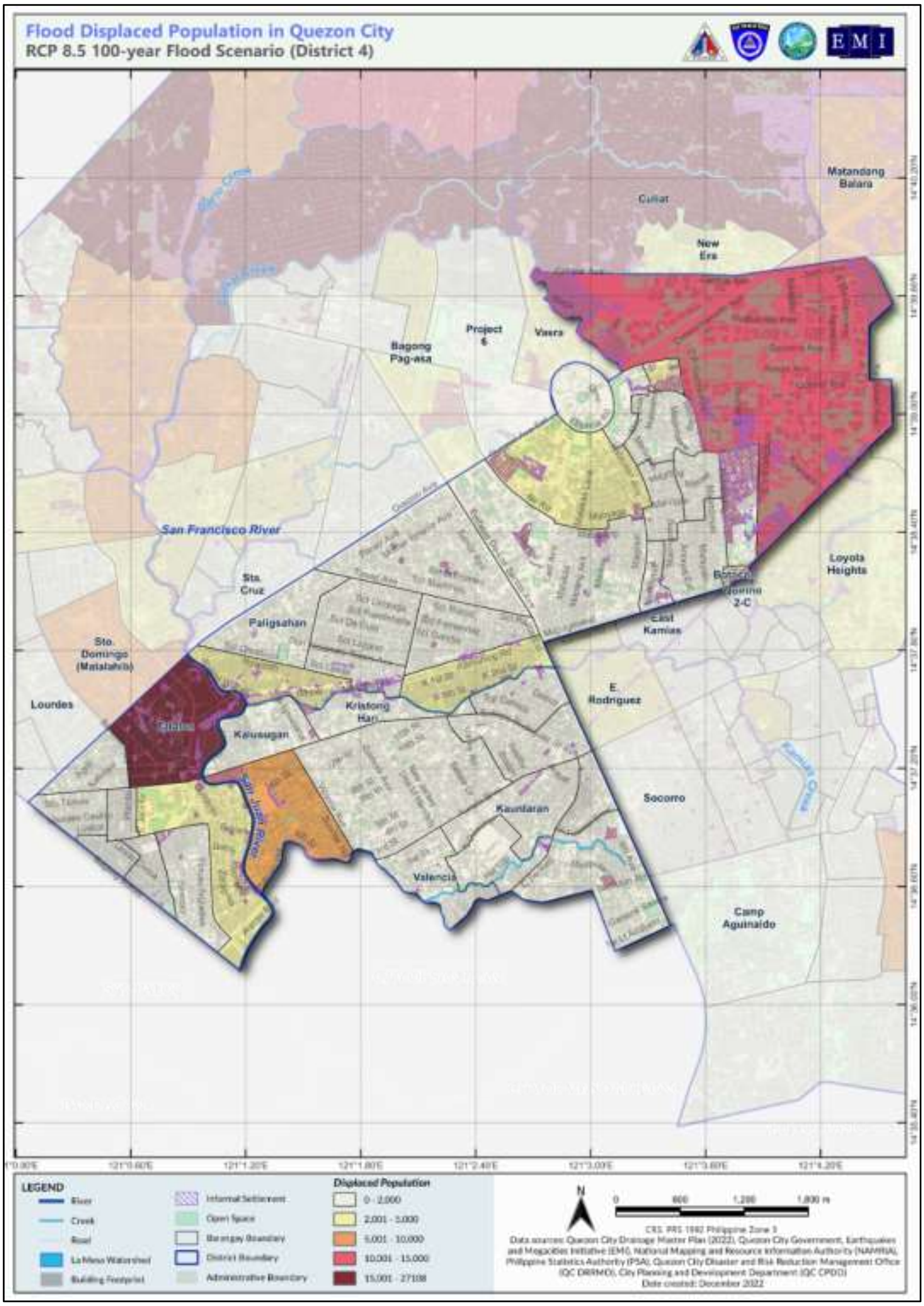


Figure 29. Displaced Population from Single Family, One- and Two-Story Structures and Informal Settler Family Structures in a 100-Year Rain Flood Scenario for District 4 (Source: QC-DMP, Preliminary Report, 2022)

Flood Displaced Population in District 5

A summary of the flood-displaced population in District 5 is shown in Table 31. The flood depth ranges used were 0.5 m- 1.5 m, and 1.5 m and above were derived from the RCP8.5 rain flood scenario. Barangays Capri, Bagbag and Sta. Monica are estimated to bring the larger numbers of flood displaced population affected under 0.5 m and above depths. Figure 30 presents a distribution of displaced population for District 5.

Table 31. Flood displaced population in District 5 in an RCP100-year 8.5 Rain Flood Scenario

Barangay	Number of people Displaced
Capri	13,405
Bagbag	13,364
Sta. Monica	10,561
San Bartolome	8,169
Nagkaisang Nayon	7,817
Gulod	7,369
Sta. Lucia	4,551
Novaliches Proper	4,302
North Fairview	3,598
Fairview	3,575
Kaligayahan	3,126
Greater Lagro	1,905
San Agustin	1,869
Pasong Putik Proper	1,147
Total	**84,760**

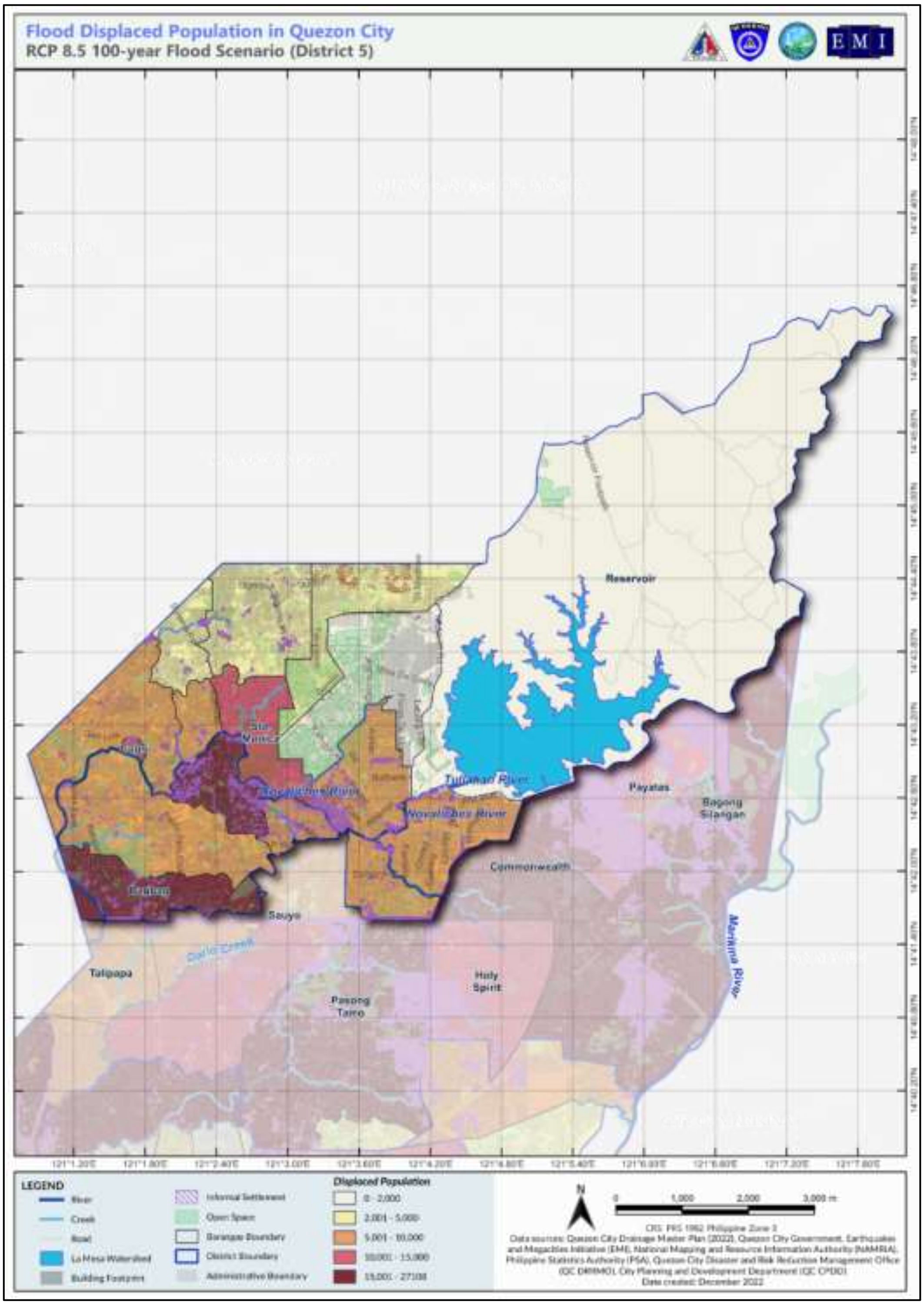


Figure 30. Displaced Population from Single Family, One- and Two-Story Structures and Informal Settler Family Structures in a 100-Year Rain Flood Scenario for District 5 (Source: QC-DMP, Preliminary Report, 2022)

Flood Displaced Population in District 6

A summary of the flood-displaced population in District 6 is shown in Table 32. The flood depth ranges used were 0.5 m- 1.5 m, and 1.5 m and above were derived from the RCP8.5 rain flood scenario. Barangays Culiat, Baesa, and Pasong Tamo are estimated to bring the larger numbers of flood displaced population affected under 0.5 m and above depths. Figure 31 presents a distribution of displaced population for District 6.

Table 32. Flood displaced population in District 6 in an RCP100-year 8.5 Rain Flood Scenario

Barangay	Number of people Displaced
Culiat	15,688
Baesa	12,604
Pasong Tamo	12,575
Tandang Sora	11,419
Apolonio Samson	7,724
Sauyo	5,902
Sangandaan	5,546
Talipapa	4,765
New Era	2,916
Balong-bato	1,152
Unang Sigaw	310
Total	**80,600**

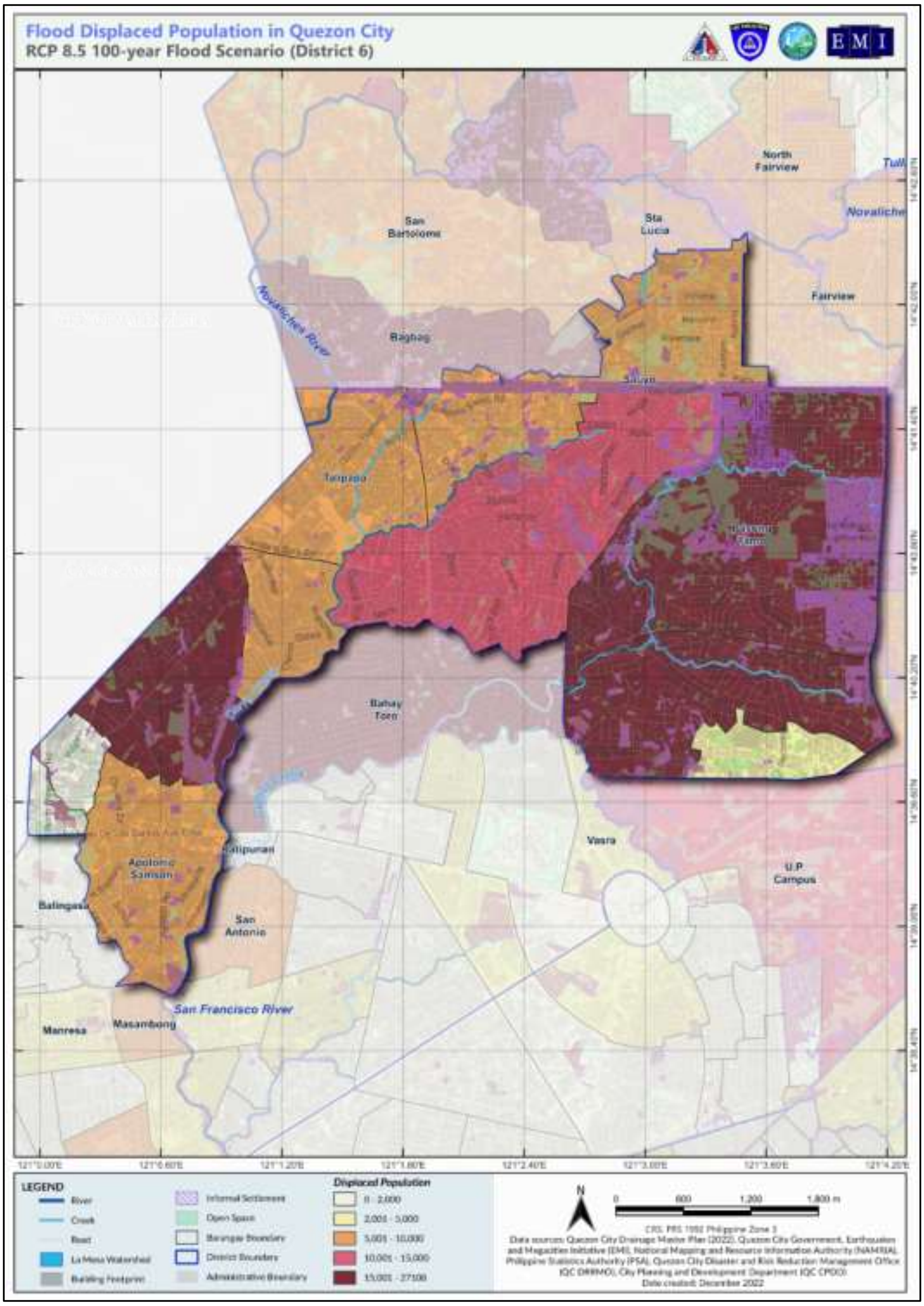


Figure 31. Displaced Population from Single Family, One- and Two-Story Structures and Informal Settler Family Structures in a 100-Year Rain Flood Scenario for District 6 (Source: QC-DMP, Preliminary Report, 2022)

3.7.2. Flood Affected Buildings

A focus on vacant or open spaces that are less prone to flooding from river overflows can be used for the deployment of emergency response services. This is taken as potentially damaging to the building structure or its contents. Most one-story buildings are largely for residential use and are less than four (4) meters high from floor to ceiling.

Table 33 to Table 38 show the distribution of flood affected buildings located in Quezon City in an RCP 8.5 100-year rain flood scenario. They present a count of structures that should expect more than half a meter (0.5 m) of flood which maybe potentially damaging to the building structure or its contents.

The key metrics are provided below by district.

Flood Affected Buildings in District 1

In terms of count of building footprint covering all occupancy types (1-2 stories) in a flood depth of half a meter deep or more, Barangays Toro, San Antonio, Sto. Domingo (Matalahib) forms the top 3 barangays.

In terms of area of building footprint covering single family residential type (1-2 stories) and including those in Informal Settler Families that were estimated to be flooded in half a meter deep or more, Barangays Toro, Talayan, San Antonio form the top 3 barangays.

Table 323 shows a ranking of the one- and two-story building footprint areas expected to be flooded under 0.5m and higher in District 1.

Table 33. Count of building footprint for all occupancy types in a flood category in District 1 for flood depth 0.5m and higher

Barangay	L2: 0. 5m- 1.5m	L3: 1. 5m- 3 m	L4: 3m and above	Total (depth>0.5m)
Bahay Toro	1,443	1,020	3,956	6,419
San Antonio	296	728	1,234	2,258
Sto. Domingo (Matalahib)	243	781	1,203	2,227
Talayan	97	576	727	1,400
Masambong	260	309	814	1,383
Bagong Pag-asa	272	108	918	1,298
Manresa	347	191	641	1,179
Del Monte	115	404	647	1,166
Paltok	181	91	744	1,016
St. Peter	169	192	504	865
Sienna	134	247	459	840
Damayan	53	273	383	709
Maharlika	177	88	380	645
Balingasa	161	34	422	617
Vasra	155	32	401	588
Mariblo	54	209	304	567
Sto. Cristo	86	129	290	505
Sta. Cruz	63	139	270	472
Katipunan	42	186	232	460
Alicia	86	110	257	453
Veterans Village	122	2	309	433
Project 6	61	3	352	416
West Triangle	81	5	220	306
Bungad	66	6	218	290
Ramon Magsaysay	61	39	156	256

Barangay	L2: 0. 5m- 1.5m	L3: 1. 5m- 3 m	L4: 3m and above	Total (depth>0.5m)
Nayong Kanluran	62	36	142	240
Paraiso	36	59	122	217
San Isidro Labrador			210	210
Lourdes	27		159	186
Phil-Am	35		149	184
N. S. Amoranto (Gintong Silahis)	19		164	183
Sta. Teresita			144	144
Salvacion			74	74
Damar			69	69
Pag-ibig sa Nayon			44	44
San Jose			27	27
Paang Bundok			6	6
Total	**5,004**	**5,997**	**17,351**	**28,352**

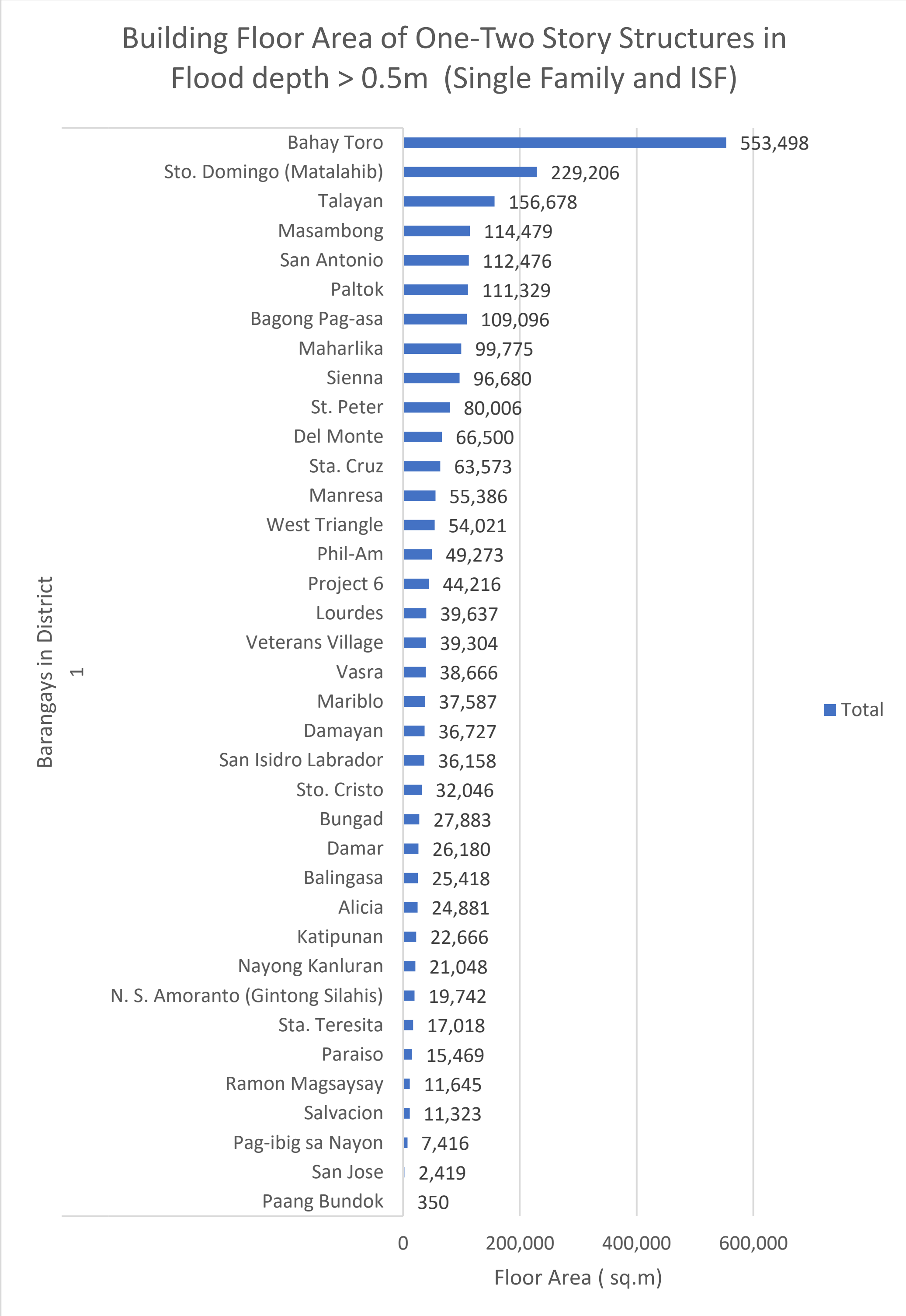


Figure 32. Area of One -Story, Single Family and Informal Settler Family Building Footprint in depths greater than half meter in District 1

Flood Affected Buildings in District 2

A count of building footprint covering all occupancy types (1-2 stories) that were estimated to be flooded in half a meter or more, Barangays Bagong Silangan, Commonwealth and Batasan Hills form the top 3 barangays.

Table 334 shows a ranking of the one- and two-story building footprint including those in Informal Settler Families areas expected to be flooded under 0.5m and higher in District 2.

Table 34. Count of building footprint for all occupancy types in a flood category in District 2 for flood depth 0.5m and higher

Barangay	L2: 0. 5m- 1.5m	L3: 1. 5m- 3 m	L4: 3m and above	Total (depth > 0.5m)
Bagong Silangan	1,197	1,810	4,287	7,294
Commonwealth	920	852	2,878	4,650
Payatas	473	812	2,336	3,621
Batasan Hills	1,018	500	3,339	4,857
Holy Spirit	488	8	1,868	2,364
Grand Total	**4,096**	**3,982**	**14,708**	**22,786**

A sum of building footprint area covering single family residential type (1-2 stories) estimated to be flooded in half a meter or more, Barangays Batasan Hills, Bagong Silangan, and Holy Spirit form the top 3 barangays.

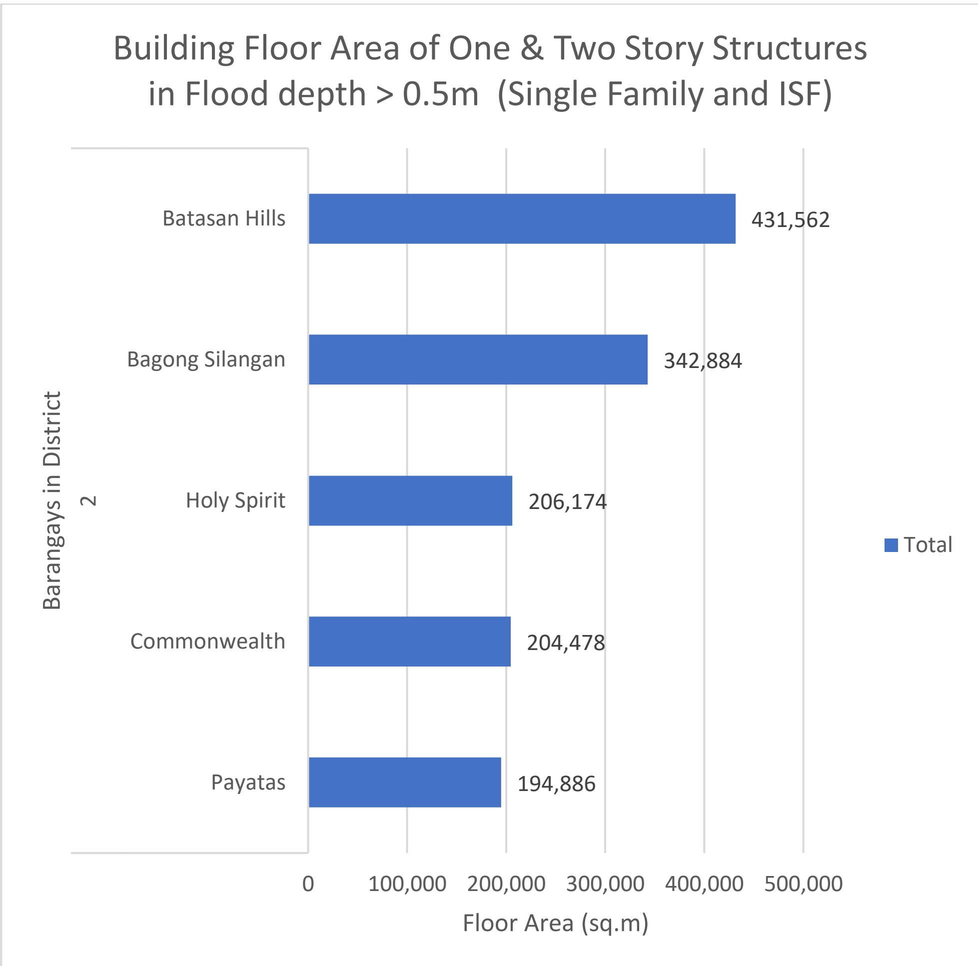


Figure 33. Area of One -Story, Single Family and Informal Settler Family Building Footprint in depths greater than half meter in District 2

Flood Affected Buildings in District 3

A count of total of building footprints covering all occupancy types (1 & 2 stories) that were estimated to be flooded in half a meter or more, Barangays Matandang Balara, Loyola Heights and Bagumbayan form the top 3 barangays.

Table 345 shows a ranking of the one- and two-story building footprint areas and including those in Informal Settler Family areas expected to be flooded under 0.5m and higher in District 3.

Table 35. Count of building footprint for all occupancy types in a flood category in District 3 for flood depth 0.5m and higher

Barangay	L2: 0. 5m- 1.5m	L3: 1. 5m- 3 m	L4: 3m and above	Total (depth>0.5m)
Matandang Balara	443	62	1,726	2,231
Bagumbayan	347	170	1,056	1,573
Loyola Heights	352	29	973	1,354
Claro (Quirino 3-B)	259	32	416	707
Quirino 2-A	171	95	369	635
West Kamias	195	51	362	608
E. Rodriguez	114	27	460	601
Bagumbuhay	192		399	591
East Kamias	110	49	407	566
Quirino 2-B	158	27	277	462
Masagana	36		388	424
Amihan	110	3	278	391
Ugong Norte	12	15	339	366
Silangan	117	23	219	359
Pansol	15	6	325	346
Quirino 2-C	79	9	181	269
Tagumpay	79		155	234
San Roque	9		218	227
Milagrosa	35		189	224
Marilag	1		207	208
White Plains	58		123	181
Libis	27	13	105	145
Villa Maria Clara			144	144
Quirino 3-A	42	11	87	140
Socorro		3	119	122
Mangga	41	3	54	98
Camp Aguinaldo			74	74
Duyan-duyan			53	53
Blue Ridge B	15		38	53
St. Ignatius	6		38	44
Blue Ridge A	2		34	36
Bayanihan	2		24	26
Dioquino Zobel			9	9
Escopa 3			2	2
Total	**3,027**	**628**	**9,848**	**13,503**

In terms of area of building footprint covering single-family residential type (1 & 2 stories) and estimated to be flooded in half a meter or more, Barangays Ugong Norte, Matandang Balara, and Loyola Heights form the top 3 barangays.

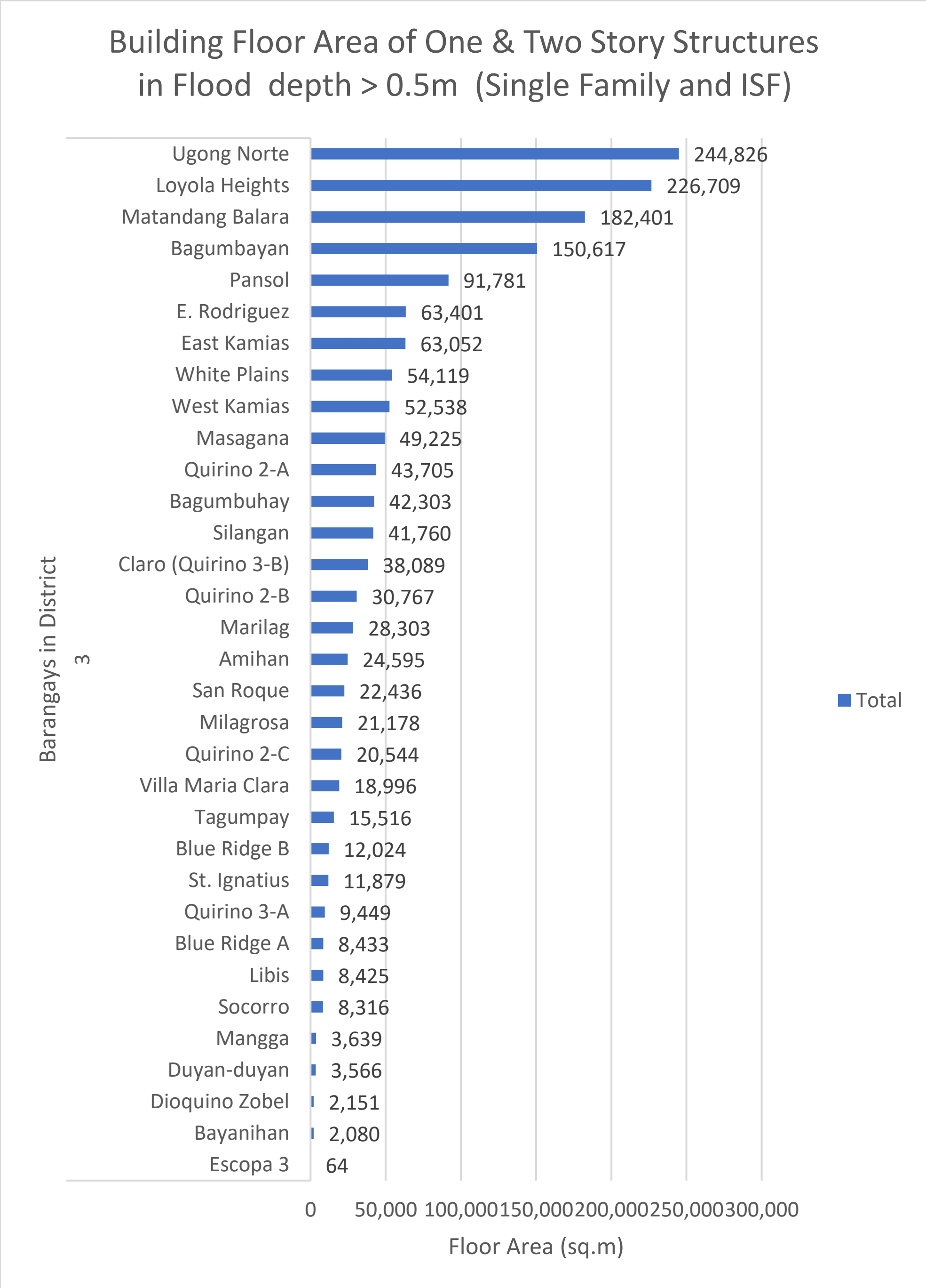


Figure 34. Area of One -Story, Single Family and Informal Settler Family Building Footprint in depths greater than half meter in District 3

Flood Affected Buildings in District 4

Using a count of building footprint covering all occupancy types (1 & 2 stories) estimated to be flooded in half a meter or more, Barangays Tatalon, U.P. Campus and Doña Imelda form the top 3 barangays.

In terms of count of building footprint covering single-family residential type (1 & 2 stories) and including those in Informal Settler Family areas that were estimated to be flooded in half a meter or more, Barangays

Tatalon, Damayang Lagi, and Roxas form the top 3 barangays. Table 356 shows a ranking of the one- and two-story building footprint areas expected to be flooded under 0.5m and higher in District 4.

Table 36. Count of building footprint for all occupancy types in a flood category in District 4 for flood depth 0.5m and higher

Barangay	L2: 0. 5m-1.5m	L3: 1. 5m-3 m	L4: 3m and above	Total (depth>0.5m and above)
Tatalon	957	1,362	2,611	4,930
U. P. Campus	482	20	1,134	1,636
Doña Imelda	225	314	607	1,146
Damayang Lagi	251	178	544	973
Roxas	98	322	521	941
Kamuning	119	200	515	834
Pinyahan	92	53	330	475
Santol	153	12	277	442
Bagong Lipunan ng Crame	76	16	260	352
Kristong Hari	59	80	179	318
Mariana	42	6	256	304
Valencia	85	37	174	296
Obrero	35	89	170	294
Central	16	1	264	281
San Vicente	24		235	259
Pinagkaisahan	28	42	145	215
South Triangle	33	4	174	211
Immaculate Concepcion	64	3	144	211
Kalusugan	34	24	117	175
Old Capitol Site	49	15	90	154
Laging Handa	1		126	127
Horseshoe	25	7	79	111
Don Manuel			106	106
Kaunlaran	19	1	60	80
Botocan	3		76	79
San Martin de Porres	20		52	72
Paligsahan	9		58	67
San Isidro			65	65
Teachers Village West	3		53	56
Sacred Heart	1		52	53
Sikatuna Village			39	39
Sto. Niño			37	37
U. P. Village			32	32
Doña Aurora			29	29
Teachers Village East			26	26

Barangay	L2: 0. 5m-1.5m	L3: 1. 5m-3 m	L4: 3m and above	Total (depth>0.5m and above)
Krus na Ligas			22	22
Doña Josefa			14	14
Malaya			2	2
Total	3,003	2,786	9,677	15,466

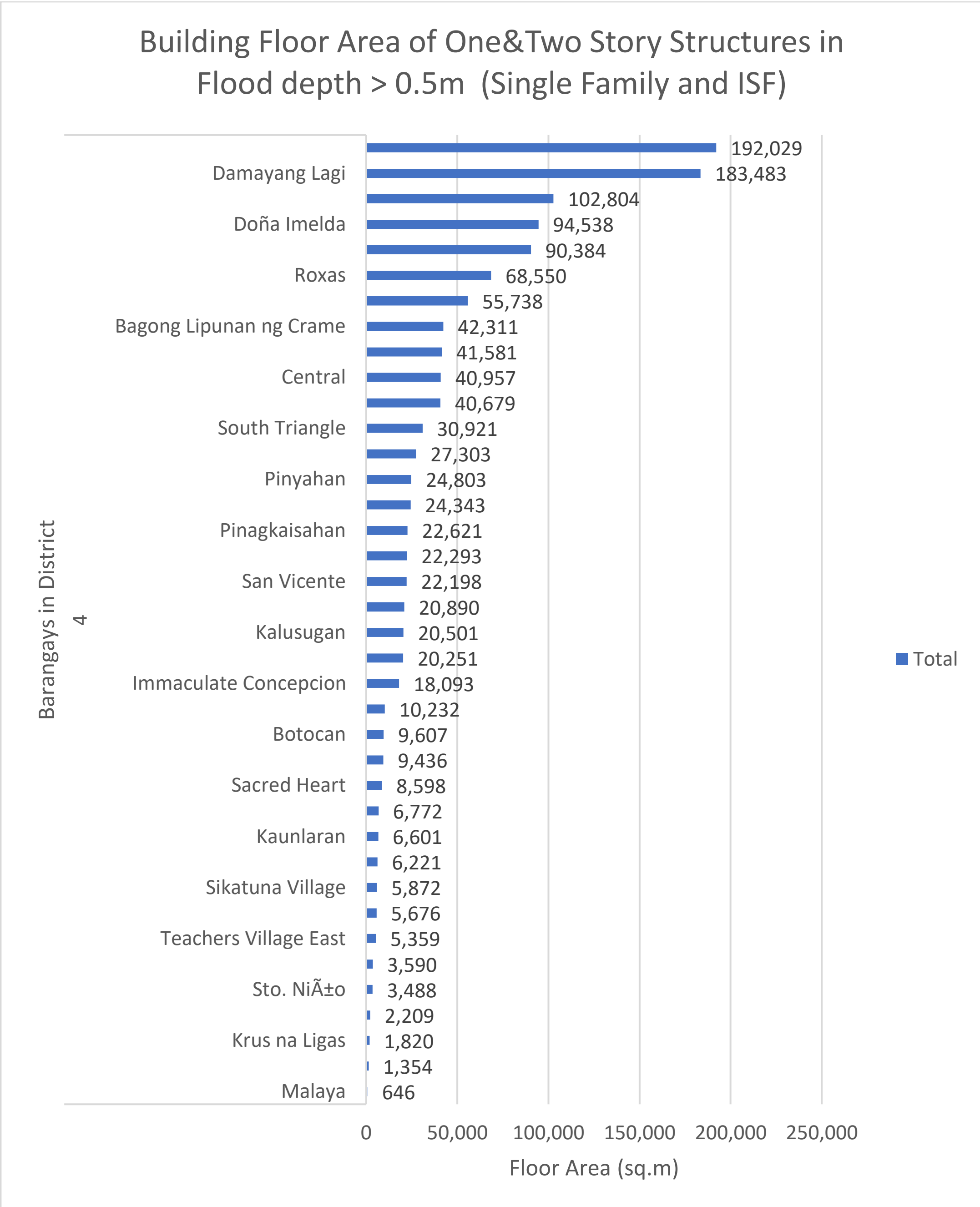


Figure 35. Area of One -Story, Single Family and Informal Settler Family Building Footprint in depths greater than half meter in District 4

Flood Affected Buildings in District 5

Using a count of building footprint covering all occupancy types (1 & 2 stories) that were estimated to be flooded in half a meter or more, Barangays Sta. Monica, Gulod and San Bartolome form the top 3 barangays.

In terms of count of building footprint covering single-family residential type (1-2 stories) and including those in Informal Settler Family areas that were estimated to be flooded in half a meter or more, Barangays Sta. Monica, San Bartolome and Nagkaisang Nayon form the top 3 barangays. Table 367 shows a ranking of the one- and two-story building footprint areas expected to be flooded under 0.5m and higher in District 5.

Table 37. Count of building footprint for all occupancy types in a flood category in District 5 for flood depth 0.5m and higher

Barangay	L2: 0. 5m-1.5m	L3: 1. 5m-3 m	L4: 3m and above	Total (depth>0.5m)
Sta. Monica	891	1,231	2,825	4,947
Gulod	887	1,092	2,519	4,498
San Bartolome	521	632	1,788	2,941
Sta. Lucia	581	662	1,559	2,802
Nagkaisang Nayon	487	301	1,602	2,390
Fairview	386	544	1,455	2,385
Bagbag	429	363	1,380	2,172
North Fairview	298	337	1,121	1,756
Capri	356	348	1,003	1,707
Novaliches Proper	196	92	671	959
Pasong Putik Proper	142	20	728	890
Kaligayahan	82		555	637
Greater Lagro	27	1	383	411
San Agustin	83		312	395
Grand Total	**5,381**	**5,702**	**18,003**	**29,086**

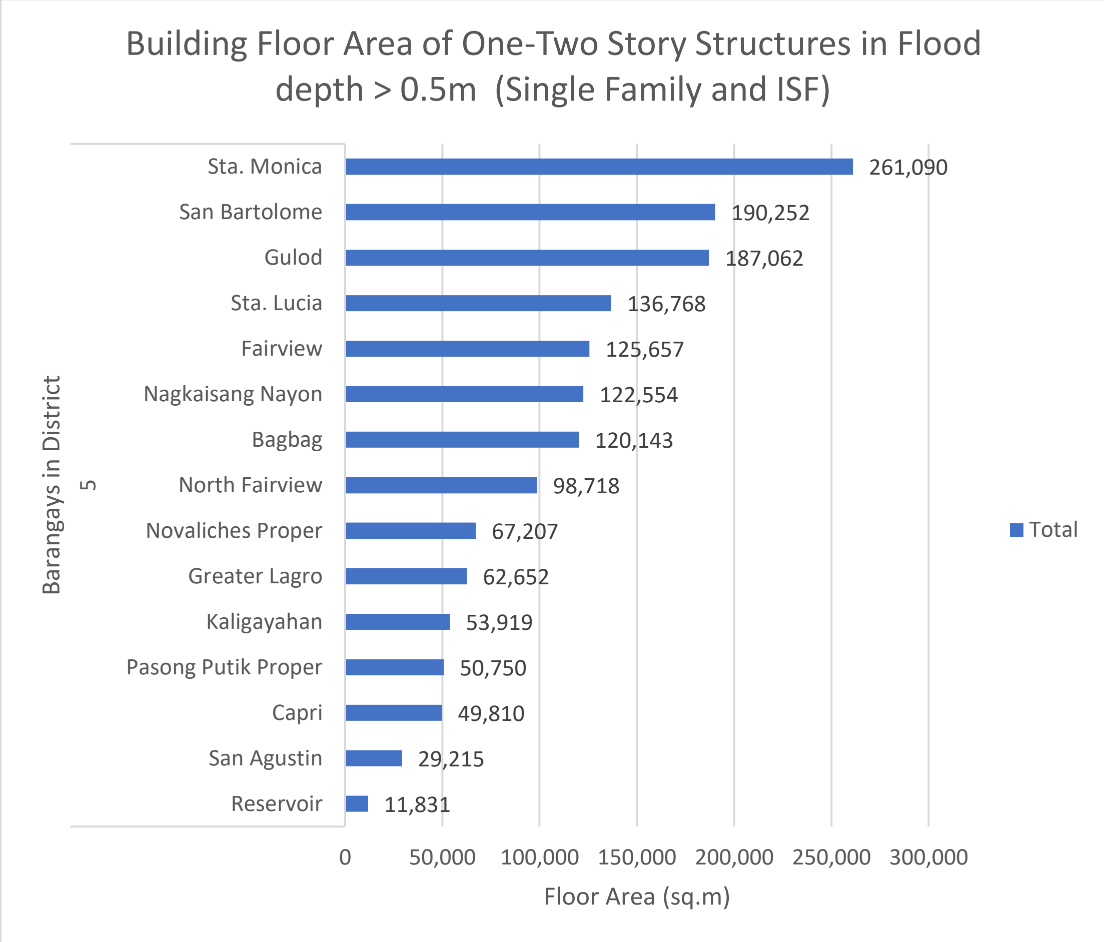


Figure 36. Area of One -Story, Single Family and Informal Settler Family Building Footprint in depths greater than half meter in District 5

Flood Affected Buildings in District 6

Using a count of building footprint covering all occupancy types (1-2 stories) estimated to be flooded in half a meter or more, Barangays Baesa, Pasong Tamo and Culiat form the top 3 barangays.
In terms of count of building footprint covering single-family residential type (1-2 stories) and including those in ISF locations estimated to be flooded in half a meter or more, Barangays Culiat, Pasong Tamo and Tandang Sora form the top 3 barangays.

Table 378 shows a ranking of the one- and two-story building footprint areas expected to be flooded under 0.5m and higher in District 6.

Table 38. Count of building footprint for all occupancy types in a flood category in District 6for flood depth 0.5m and higher

Barangay	L2: 0. 5m- 1.5m	L3: 1. 5m- 3 m	L4: 3m and above	Total (depth>0.5 m)
Pasong Tamo	1,425	449	4,025	5,899
Baesa	941	603	4,192	5,736
Culiat	1,262	358	3,156	4,776
Tandang Sora	533	40	2,533	3,106
Apolonio Samson	258	1,069	1,668	2,995
Sauyo	578	85	1,846	2,509

Barangay	L2: 0. 5m- 1.5m	L3: 1. 5m- 3 m	L4: 3m and above	Total (depth>0.5 m)
Sangandaan	233	204	937	1,374
Talipapa	206	35	1,088	1,329
Balong-bato	79		289	368
Unang Sigaw	28		253	281
New Era	18		224	242
Grand Total	**5,561**	**2,843**	**20,211**	**28,615**

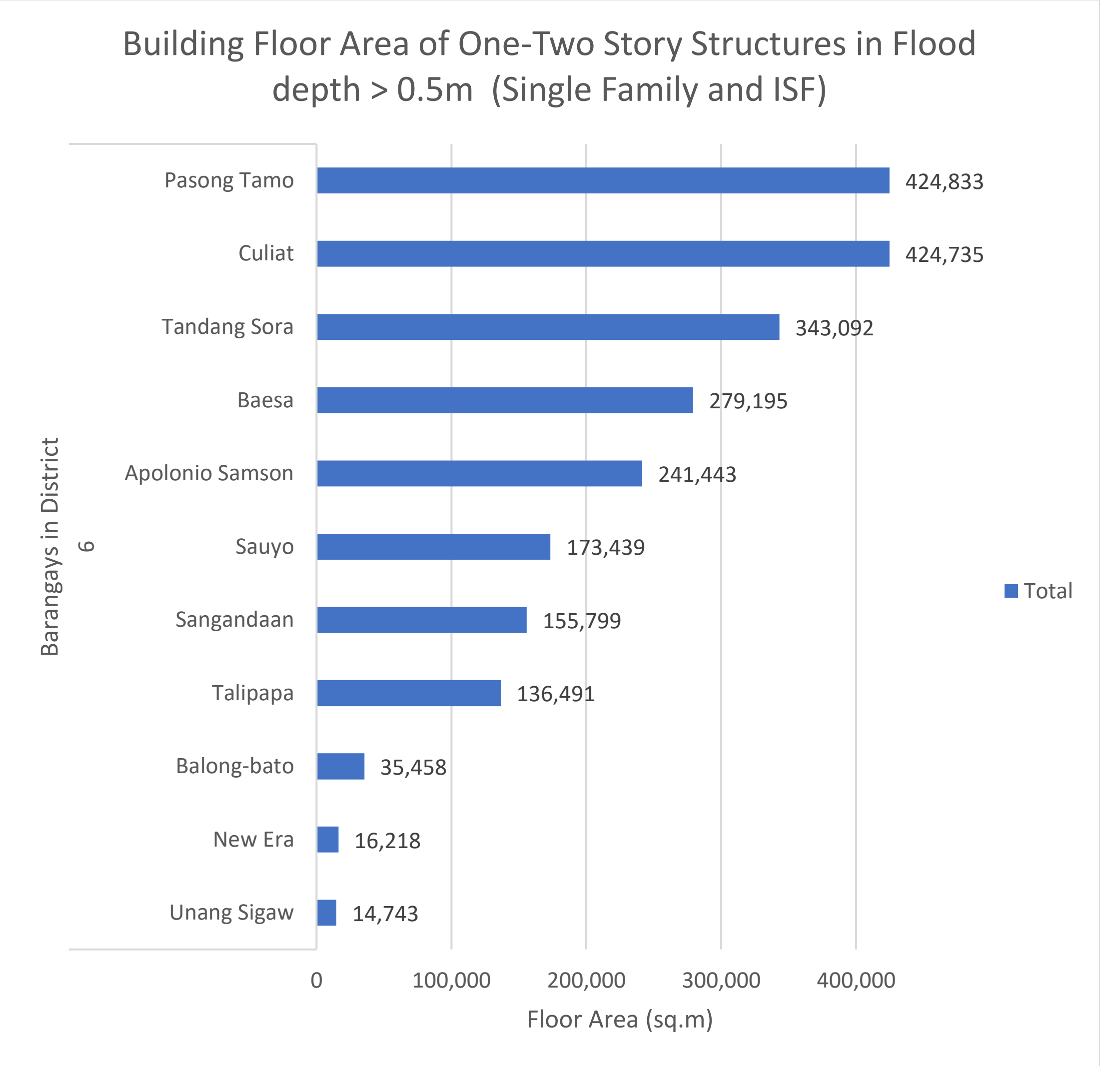


Figure 37. Area of One -Story, Single Family and Informal Settler Family Building Footprint in depths greater than half meter in District 6

3.7.3. Flood Exposure of Health and Emergency Related Facilities

The distribution of police stations, fire stations, and public facilities within the city are considered to be essential functions that must be preserved and functioning during a disaster. In the event of a 100-year flood, these facilities can provide essential services to community members who had to evacuate before the storm. They can serve as temporary shelters during times of emergency. By identifying the facilities most at risk of flooding, actions can be taken to decrease their vulnerability.

Figure 38 to Figure 43 show the distribution hospitals, health centers, identified evacuation centers within Quezon City. The maps also indicate vacant or open spaces that are less prone to flooding from river overflows and can be used for deployment of emergency response services.

Additional key metrics are provided below.

For greater benefits, the outputs from these analyses are provided in the form of Annex A in electronic format and can be accessed through the following link:

LINK TO ANNEX A:
https://drive.google.com/drive/folders/10A0Khji3yoZzpqI9NxvpblWp3vJG1MPS?usp=share_link

Flood Evacuation Centers

There are 272 sites identified as evacuation sites during flood events in QC. Eighty of them are in areas where flood depths can be higher than 0.5m. These include 32 evacuation sites in District 1; 6 in District 2; 13 in District 3; 17 in District 4; 5 in District 5; and 7 in District 6. Refer to Table A1 for a complete list of flood evacuation centers under various flood levels per barangay in link to **Annex A** provided above.

Health Centers

There are health center structures, two-stories high that are in areas where flood exceeds 0.5m (Level 2 and up). Twelve health centers are at risk from high flood depths. There are four each in District 1 and in District 3, two in District 5 and one each in District 4 and 6. Refer to Table A2 for a complete list of hospitals under various flood levels per barangay in link to **Annex A** provided above.

Hospitals

Thirteen hospitals were found in locations where flood depths can be higher than 0.5m in the RCP 8.5 100-year flood scenario. Two in District 1 located in Barangays Sienna and West Triangle, one in Barangay Milagrosa, District 3, Seven in District 4 in barangays Central, Damayang Lagi, Doña Imelda, Doña Josefa, Immaculate Concepcion and Kalusugan. Refer to Table A3 for a complete list of hospitals under various flood levels per barangay in link to **Annex A** provided above.

Multi-purpose halls

There are 101 multipurpose hall locations in Quezon City. About 11 of them are situated where flood waters vary from 0.2m to less than 0.5m. About 16 multi-purpose halls comprising of one- and two-story buildings were situated in areas where flood depths can exceed 0.5m. These buildings and their contents are more susceptible to damage. Disruption of   services and barangay operations are more likely to extend in longer periods. This comprises seven multipurpose hall locations in District 1, three each in Districts 4 and 5 and one each in Districts 2 and 3 and 6. Refer to Table A4 for a complete list of multi-purpose halls under various flood levels per barangay in link to **Annex A** provided above.

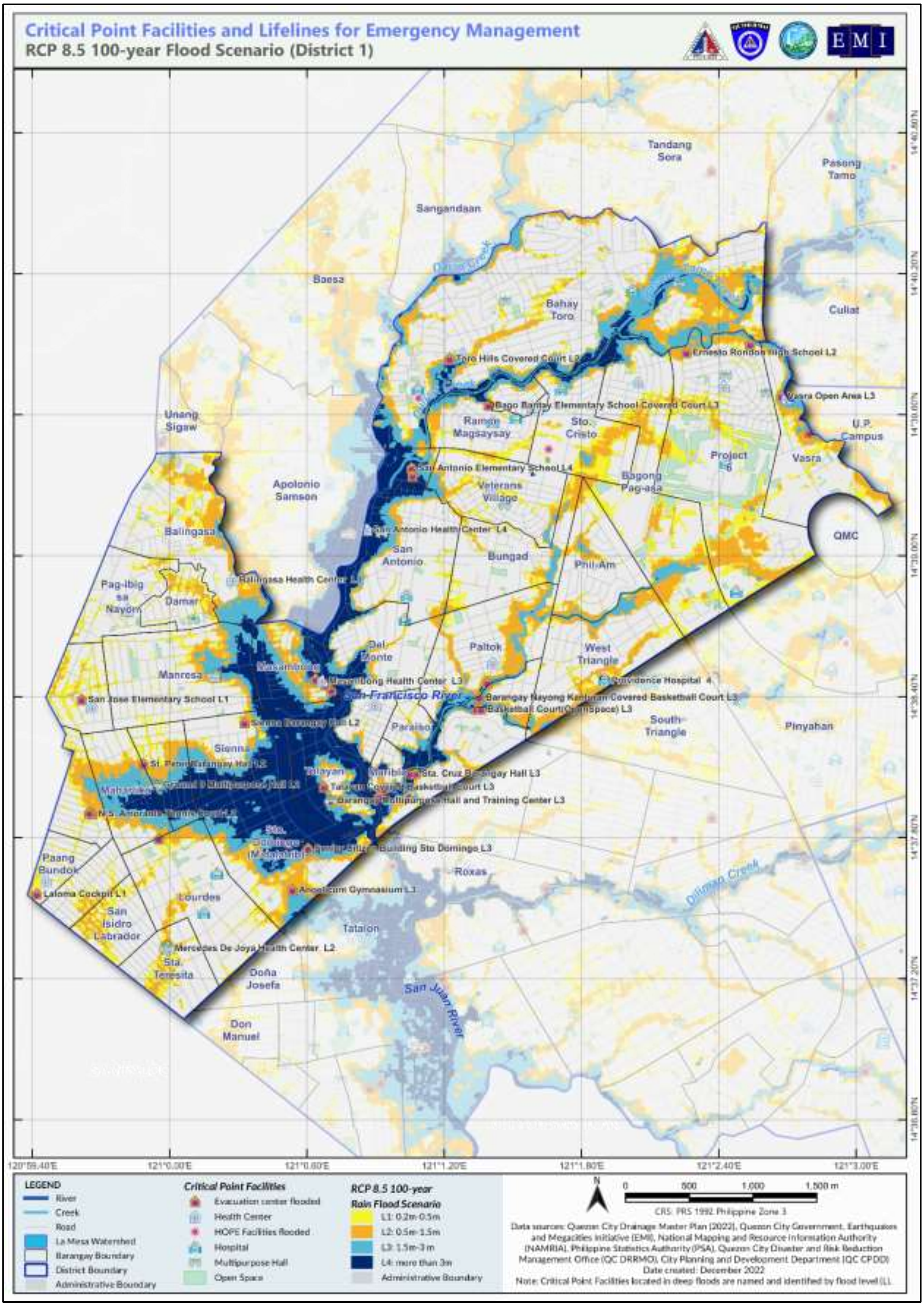


Figure 38. Public Facility (Emergency management related) locations in an RCP 8.5 100- year rain flood scenario in District 1. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Open/Vacant spaces are shown relative to the evacuation center locations

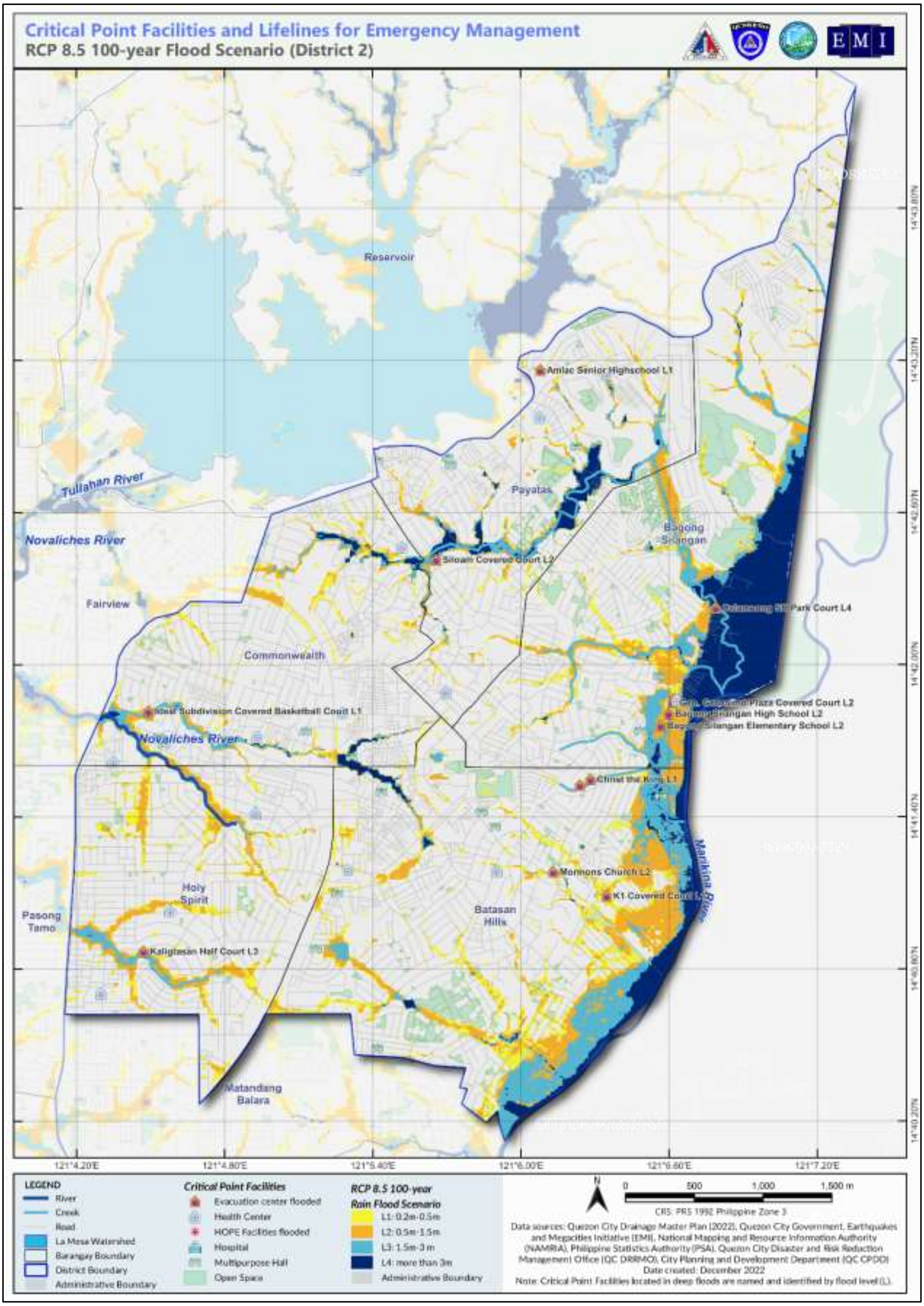


Figure 39. Public Facility (Emergency management related) locations in an RCP 8.5 100- year rain flood scenario in District 2. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Open/Vacant spaces are shown relative to the evacuation center locations

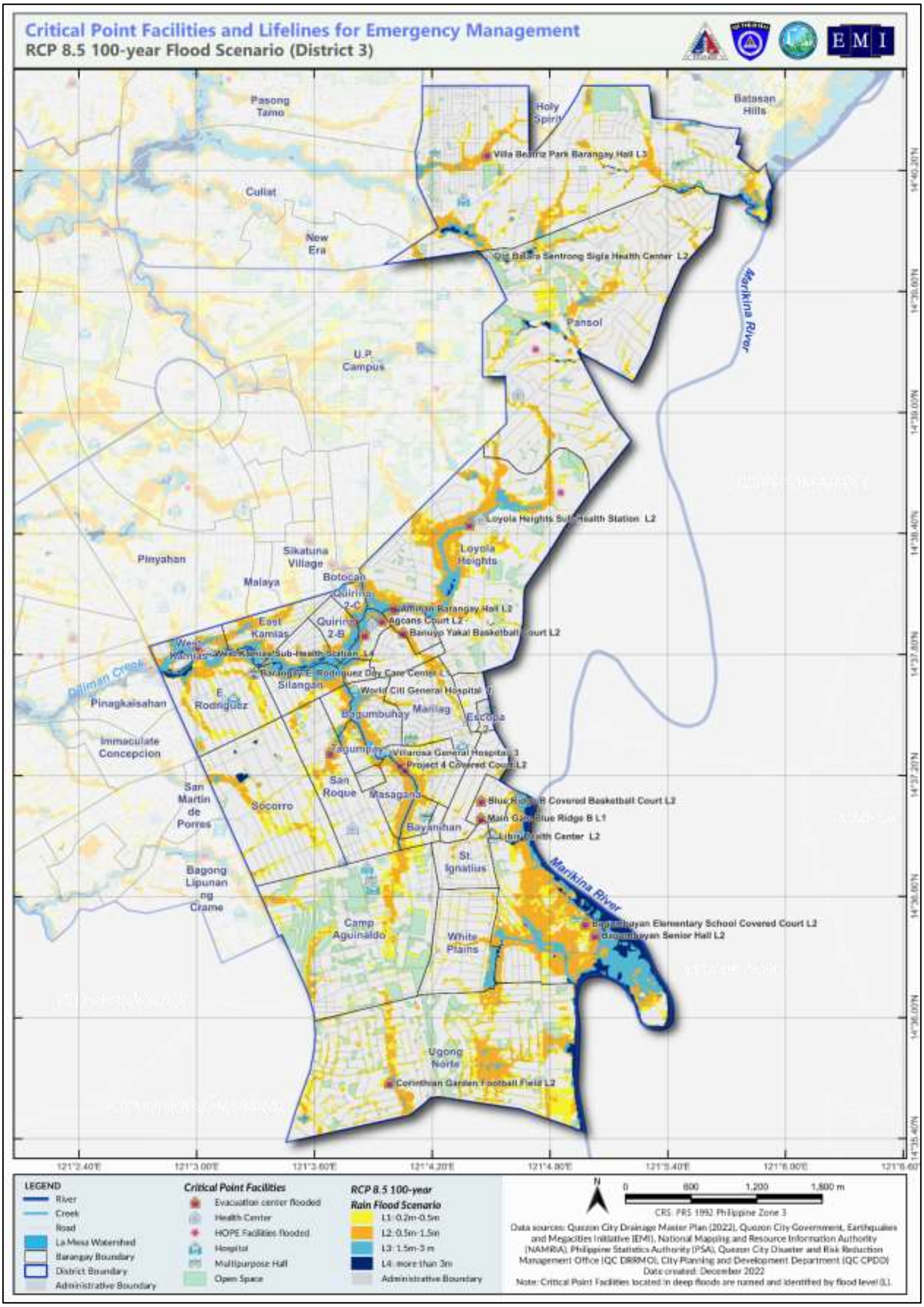


Figure 40. Public Facility (Emergency management related) locations in an RCP 8.5 100- year rain flood scenario in District 3. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Open/Vacant spaces are shown relative to the evacuation center locations

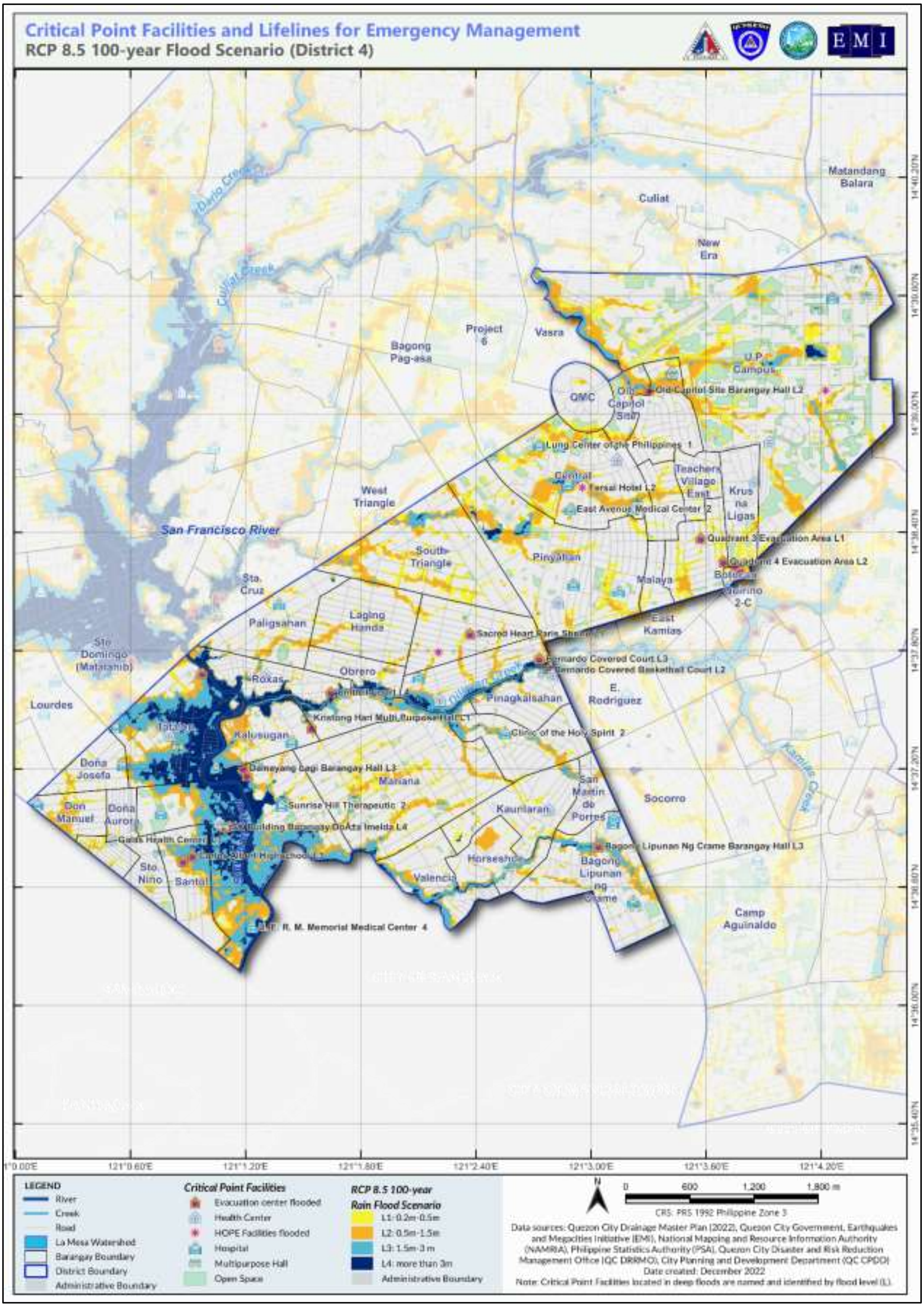


Figure 41. Public Facility (Emergency management related) locations in an RCP 8.5 100- year rain flood scenario in District 4. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Open/Vacant spaces are shown relative to the evacuation center locations

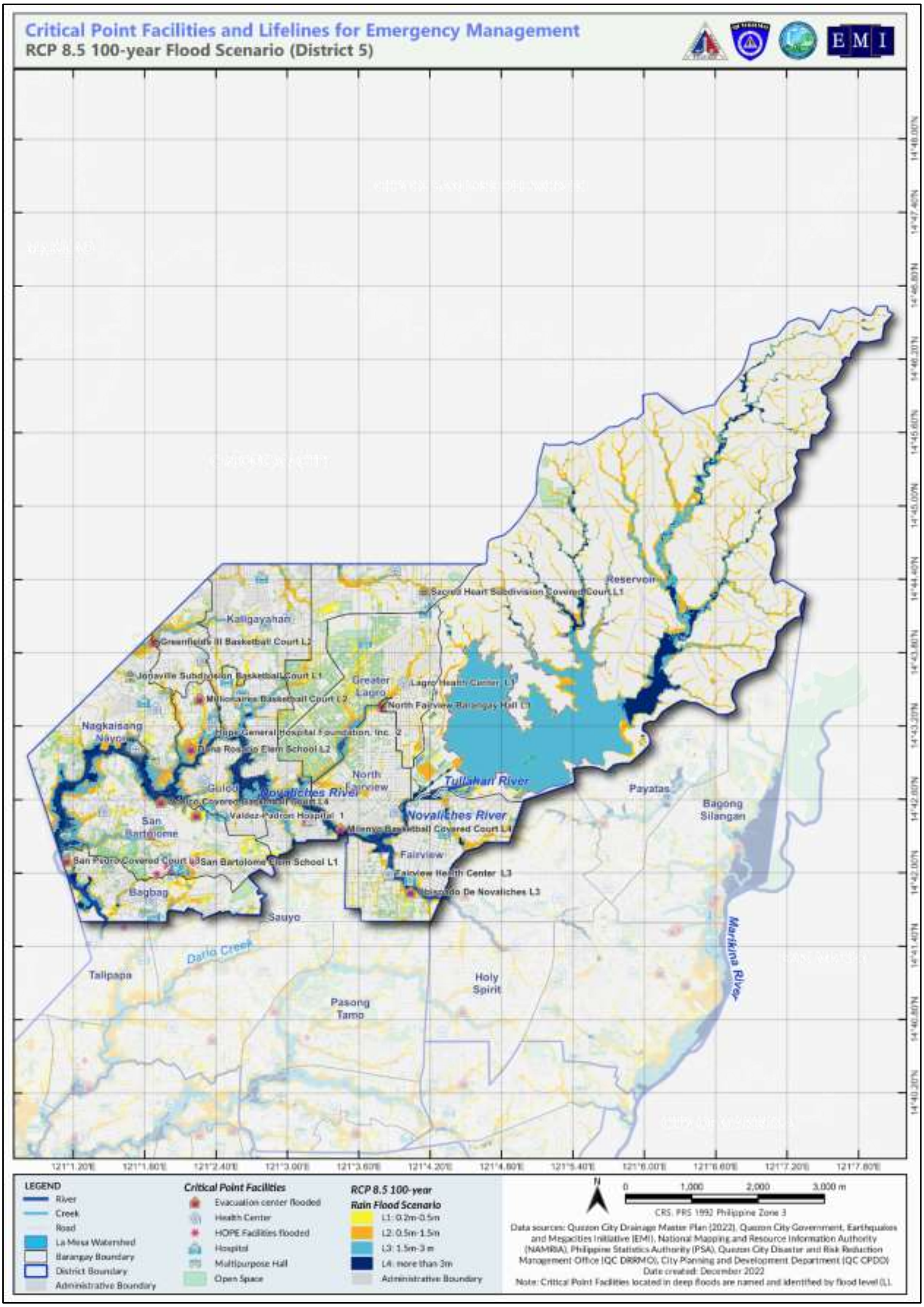


Figure 42. Public Facility (Emergency management related) locations in an RCP 8.5 100- year rain flood scenario in District 5. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Open/Vacant spaces are shown relative to the evacuation center locations

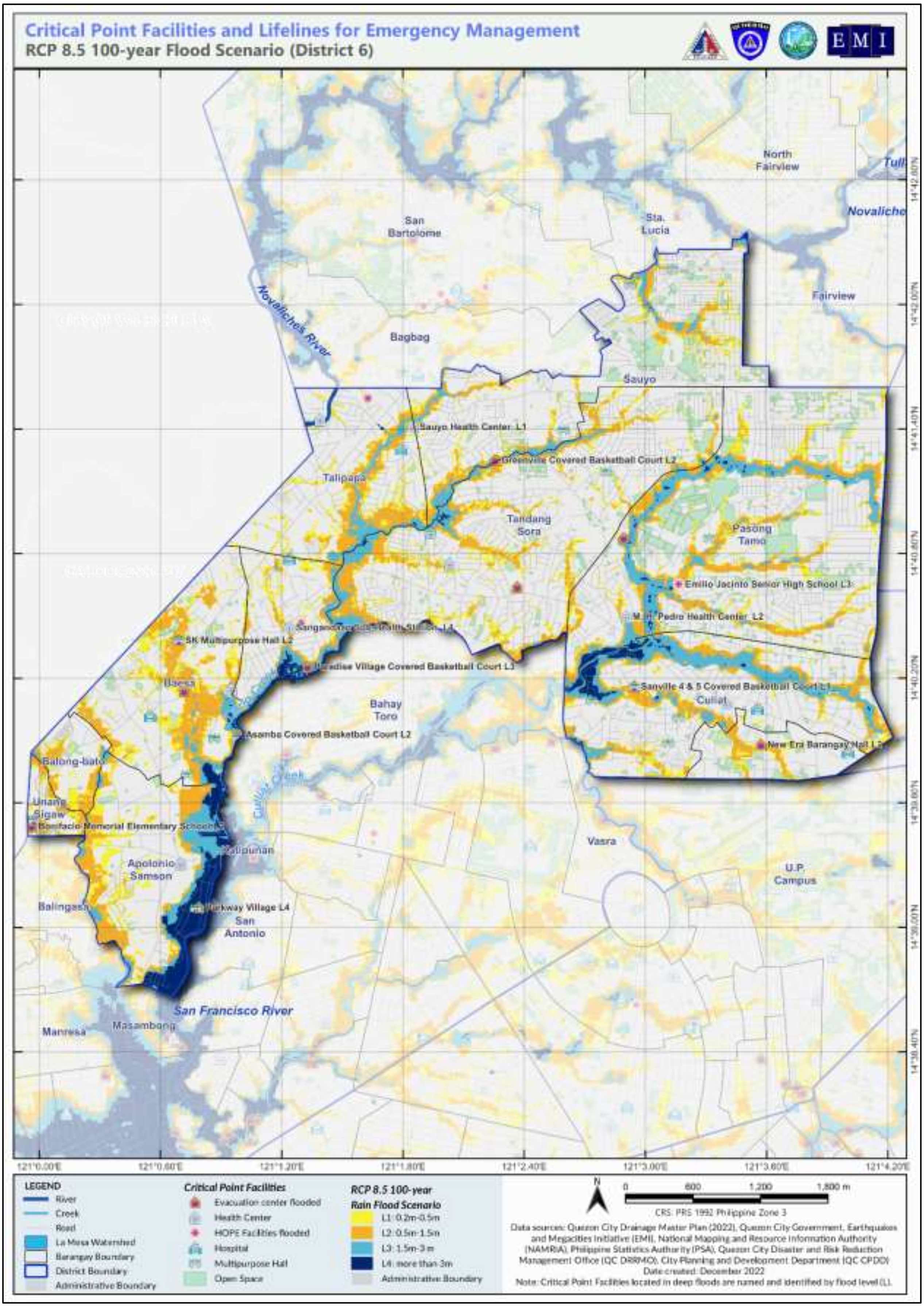


Figure 43. Public Facility (Emergency management related) locations in an RCP 8.5 100- year rain flood scenario in District 6. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Open/Vacant spaces are shown relative to the evacuation center locations

3.7.4. Flood Exposure of Facilities for Safety and Security

Figure 44 to Figure 49 show the distribution police stations, fire stations, barangay halls within Quezon City that, during times of emergency, serve to assist in response, ensure security of affected sites.

The key planning metrics are provided below.

For greater benefits, the outputs from these analyses are provided in the form of Annex A in electronic format and can be accessed through the following link:

LINK TO ANNEX A:
https://drive.google.com/drive/folders/10A0Khji3yoZzpqI9NxvpblWp3vJG1MPS?usp=share_link

Barangay Hall

Several one-story and two-story Barangay halls in Districts 1,3,4 and 5 that are surrounded by half a meter or more deep flood waters (i.e., flood level 2-4). Access to these barangay halls, as well as the possibility of damage to contents inside these buildings can be disruptive to barangay operations after the event. Refer to Table A5 for a complete list of barangay halls under various flood levels per barangay in link to **Annex A** provided above.

Fire station

There are 19 Fire sub-stations all over Quezon City. Three of these in District 1 are in areas that can experience flooding higher than 0.5m. Refer to Table A6 for a complete list of fire stations under various flood levels per barangay in link to **Annex A** provided above.

Police Station

Twenty -eight police locations in Quezon City comprising 11 police stations, 14 community precincts and 3 police assistance centers. About seven them were found to be located in areas where flood depths can be higher than 0.5m. They include three community precincts in District 1, one in District 2, and 1 in District 3. Two are police stations in District 1. Refer to Table A7 for a complete list of police stations under various flood levels per barangay in link to **Annex A** provided above.

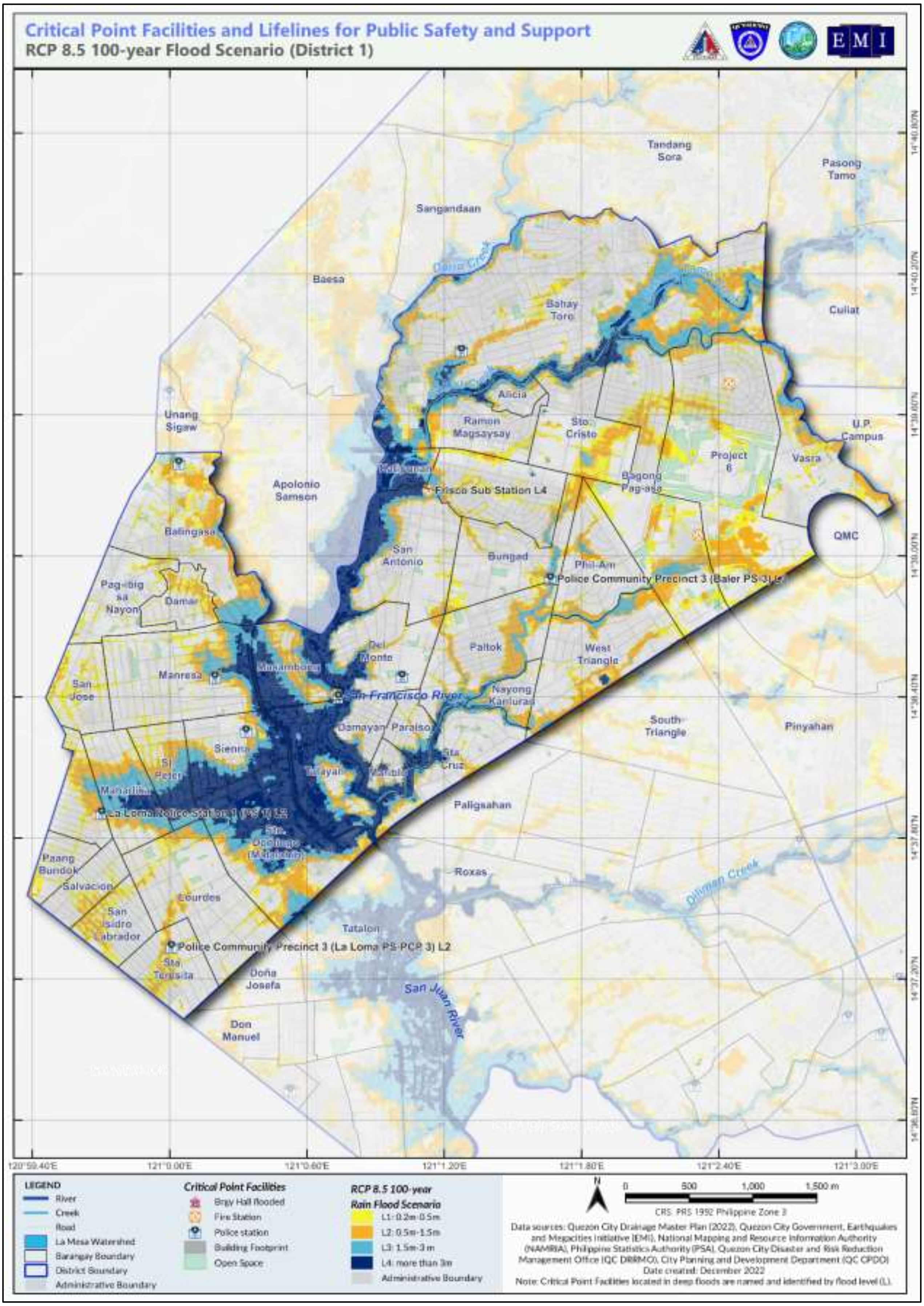


Figure 44. Public Facility (Safety and Security related) locations in an RCP 8.5 100- year rain flood scenario in District 1. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022)

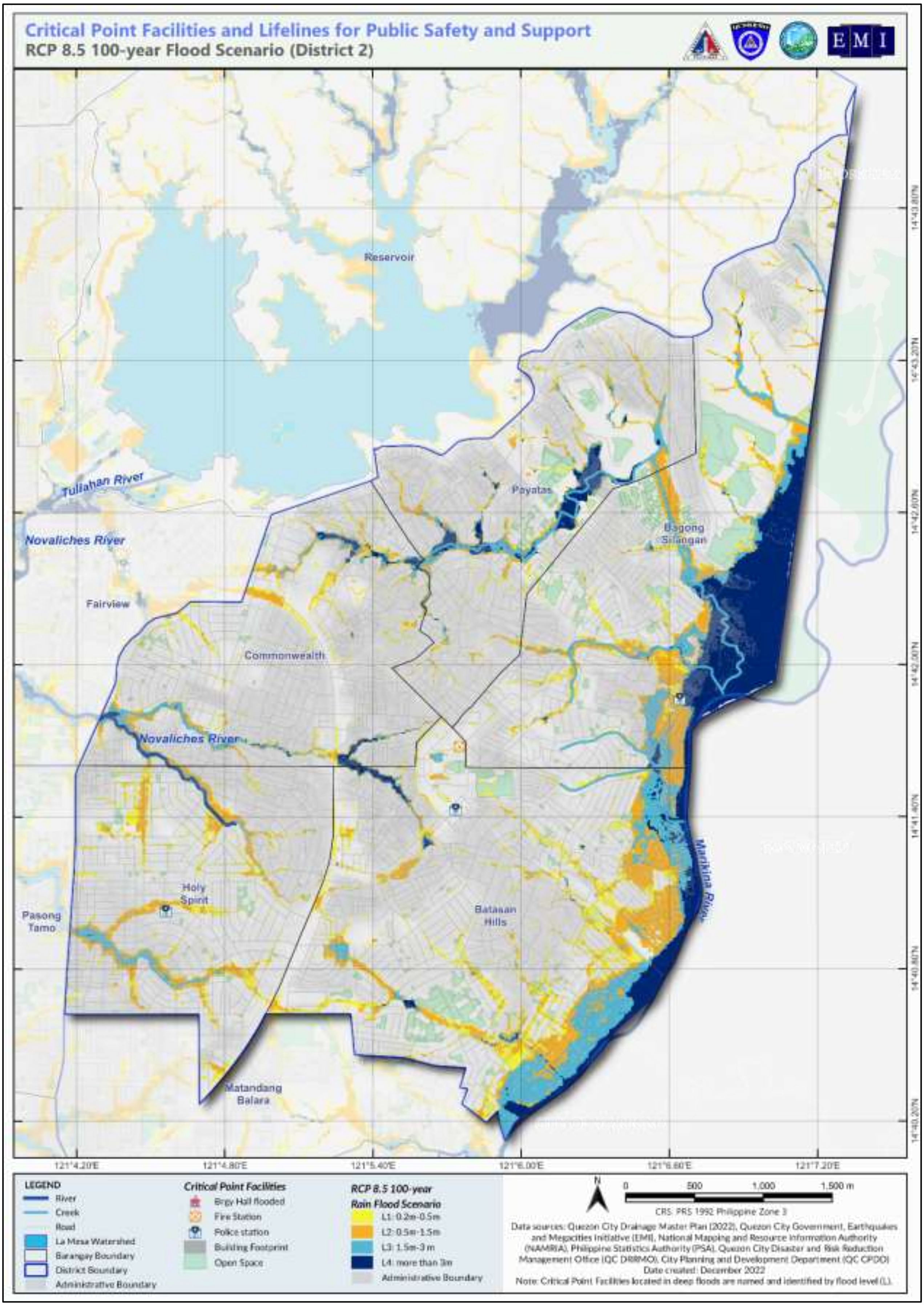


Figure 45. Public Facility (Safety and Security related) locations in an RCP 8.5 100- year rain flood scenario in District 2. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022)

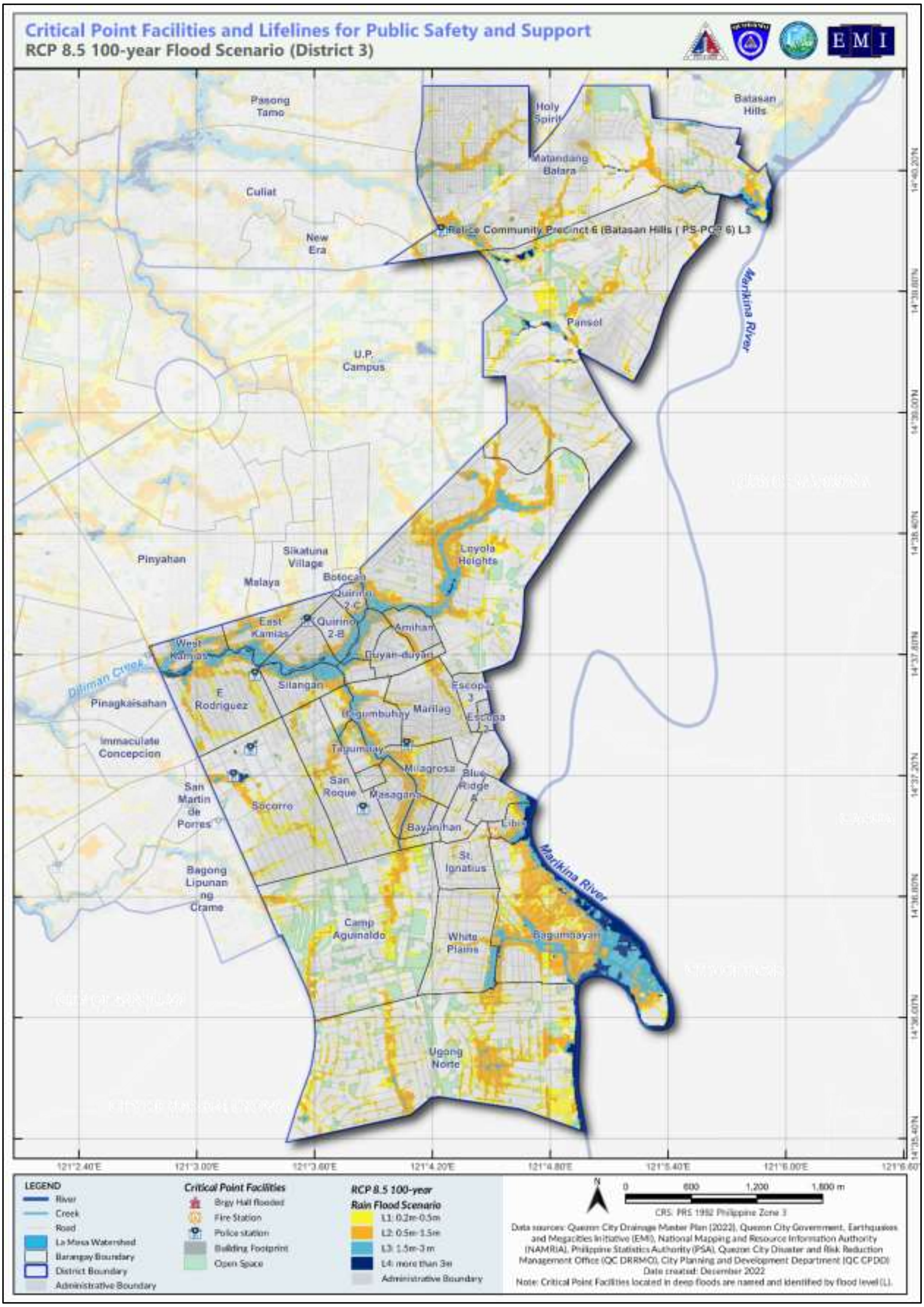


Figure 46. Public Facility (Safety and Security related) locations in an RCP 8.5 100- year rain flood scenario in District 3. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022)

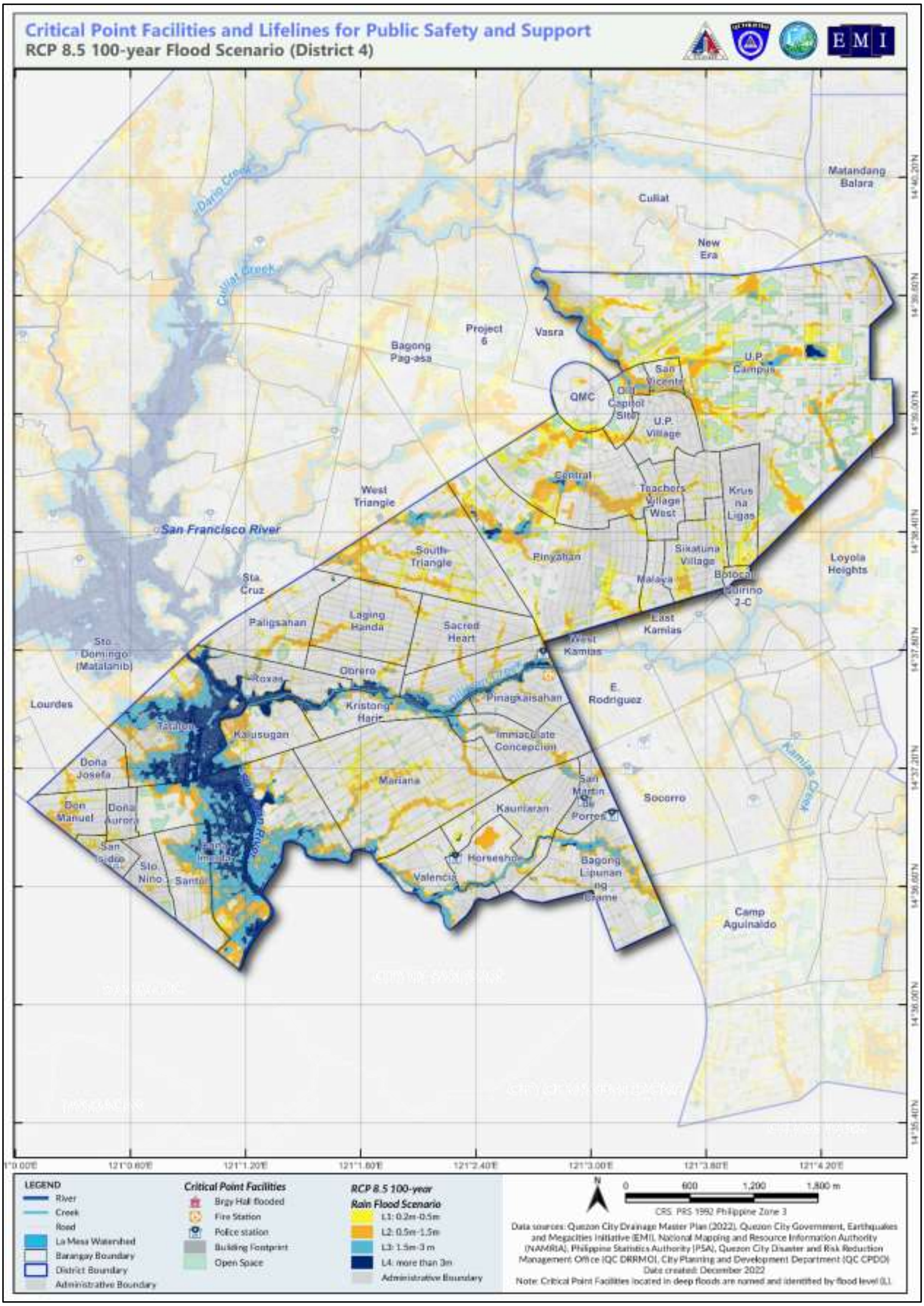


Figure 47. Public Facility (Safety and Security related) locations in an RCP 8.5 100- year rain flood scenario in District 4. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022)

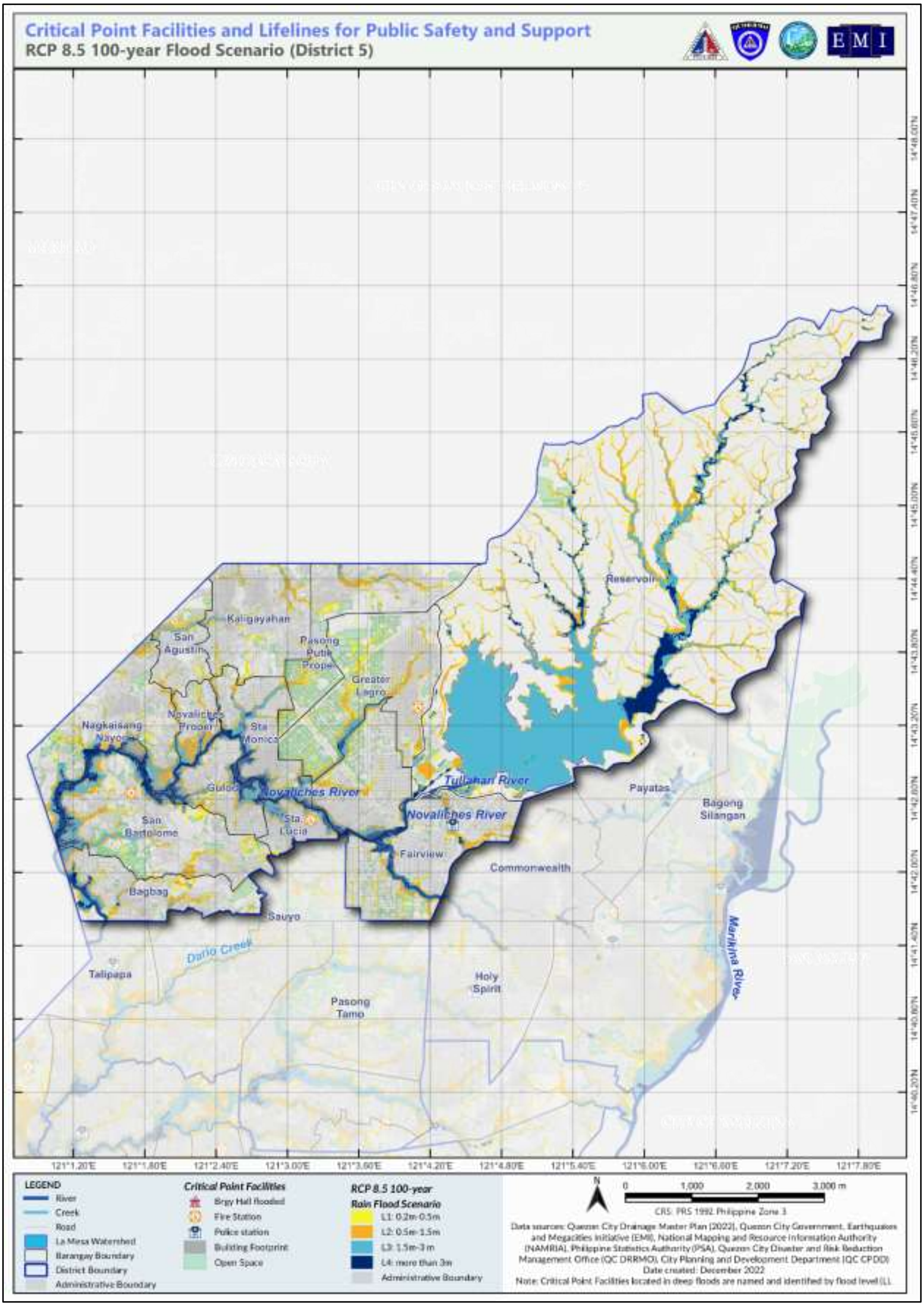


Figure 48. Public Facility (Safety and Security related) locations in an RCP 8.5 100- year rain flood scenario in District 5. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022)

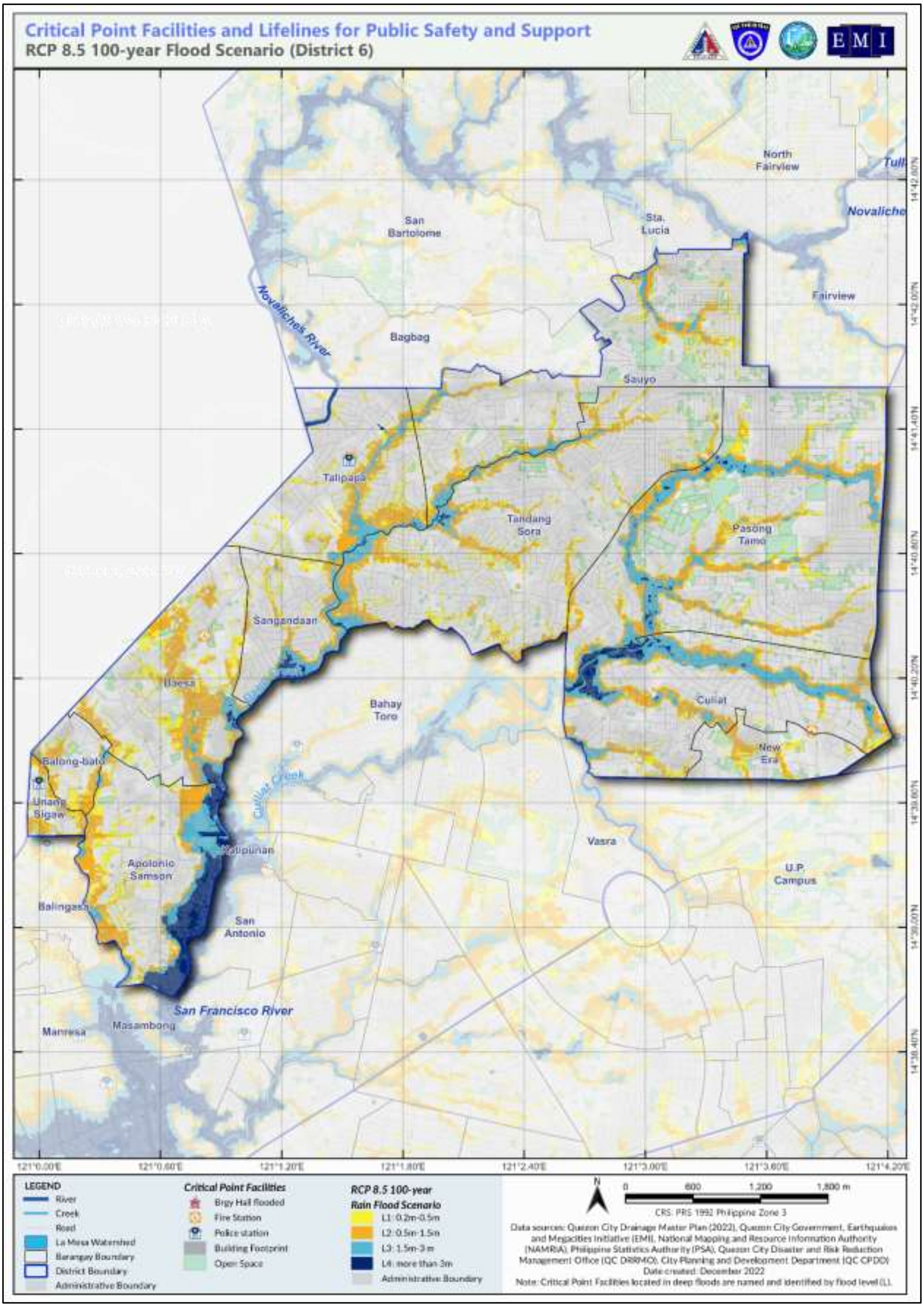


Figure 49. Public Facility (Safety and Security related) locations in an RCP 8.5 100- year rain flood scenario in District 6. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022)

3.7.5. Flood Affected Utilities and Infrastructures

Exposed utilities, infrastructure and other lifelines, such as segments of roads and bridges to higher risks from rain-induced hazards point to increasing sensitivity to climate projections. Higher risks resulting from the projected changes in rainfall under the worst-emission climate scenario will most likely increase the vulnerability and complicate response and recovery after a major disaster.

Figure 50 to Figure 55 highlight the utilities and infrastructure facilities whose operations are likely to be disrupted by the flood. Quantitative metrics are provided in related tables.

Roads

Table 39 gives the total length of flooded roads under of an RCP 8.5 100-year flood scenario for each district. Barangays Toro, Sto Domingo, Masambong, Talayan and San Antonio of District 1 have more than five kilometers of road flooded under 0.5 m and above. Batasan Hills, Bagong Silangan and Holy Spirit of District 2 have road lengths that can be inundated with 0.5m and higher flood depths and can total 5 km. Barangays Ugong Norte, Bagumbayan, Loyola Heights, Matandang Balara tops District 3.

Barangays Tatalon, Doña Imelda, Damayang Lagi, are the barangays in District 4 with more than 5 km of roads that potentially can submerge under 0.5m and above flood depths. In District 5, San Bartolome, Sta, Monica and Nagkaisang Nayon and Gulod have road lengths inundated with 0.5m and higher totalling more than 8 km. District 6, Pasong Tamo, Tandang Sora, Culiat and Apolonio Samson have inundated road segments that exceed 9 km. Possible disruptions to the population movements in these identified areas are expected and can also put people's lives in danger.

Table 39. Barangays with flooded road segments in Districts 1 to 6 (RCP 8.5 100-year rain flood scenario)

District	Flood Level			Total flooded (m)
	L2	L3	L4	
District 1				
Bahay Toro	8,747	6,741	1,814	17,302
Sto. Domingo (Matalahib)	1,742	2023	8247	12,012
Masambong	1,837	2331	2490	6,658
San Antonio	1,069	1,490	3239	5,799
Talayan	758	805	4167	5,730
Sienna	694	986	3143	4,823
Paltok	3,319	854	302	4,475
St. Peter	1,240	1,278	1,830	4,348
Maharlika	1,028	2168	1082	4,278
Manresa	958	1780	1152	3,890
Balingasa	2,521	1049	272	3,842
Bagong Pag-asa	2,737	520	346	3,602
Del Monte	703	644	2007	3,354
West Triangle	2,323	801		3,124
Sta. Cruz	615	835	1341	2,791
Sto. Cristo	976	461	717	2,155
Project 6	1,992	151		2,143

District	Flood Level			Total flooded (m)
	L2	L3	L4	
Vasra	1,259	826	10	2,096
Mariblo	260	372	1,398	2,030
N. S. Amoranto (Gintong Silahis)	1500	421		1,921
Katipunan	254	290	1,185	1,729
Lourdes	1356	330	26	1712
Damayan	242	255	1,138	1,635
Sta. Teresita	1576			1576
Veterans Village	1046	506		1,552
Phil-Am	1055	314		1,370
San Isidro Labrador	1299			1299
Bungad	1189	87		1277
Alicia	303	475	190	968
Damar	907			907
Paraiso	284	213	344	840
Nayong Kanluran	623	157		781
Salvacion	724			724
Ramon Magsaysay	224	243	192	659
San Jose	623			623
Pag-ibig sa Nayon	293			293
Paang Bundok	202			202
District 2				
Batasan Hills	12,667	9,337	957	22,961
Bagong Silangan	7,322	4,277	4,332	15,931
Holy Spirit	5,220	983	40	6,242
Payatas	1,985	1081	1036	4,102
Commonwealth	2,627	614	138	3,380
District 3				
Bagumbayan	6,400	2796	571	9,766
Ugong Norte	8,454	488		8,942
Loyola Heights	5,198	1,960	22	7,180
Matandang Balara	4,266	761	93	5,120
Pansol	3,277	323	48	3,648
West Kamias	848	1274	236	2,357
East Kamias	1,552	714	58	2,324
Bagumbuhay	1,201	1070		2,271
Masagana	2,163	30		2,192
E. Rodriguez	1,570	445	27	2,041
Socorro	1,667	94		1,761
Milagrosa	1,369	376		1,744

District	Flood Level			Total flooded (m)
	L2	L3	L4	
Claro (Quirino 3-B)	355	1203	139	1,696
Silangan	770	912		1682
Quirino 2-A	436	713	181	1,330
Quirino 2-B	411	863	47	1,322
Camp Aguinaldo	1196			1,196
Marilag	1098			1098
White Plains	583	446		1,029
San Roque	972	36		1008
Villa Maria Clara	976			976
Amihan	733	221		955
Libis	492	341		833
Quirino 2-C	388	291		679
Quirino 3-A	217	216		433
Tagumpay	300	123		423
Duyan-duyan	318			318
St. Ignatius	259	49		308
Blue Ridge B	111	151	39	300
Mangga	55	96		151
Blue Ridge A	114		11	125
Bayanihan	94			94
Dioquino Zobel	26			26
Escopa 3	2			2
District 4				
Tatalon	1,561	4416	7749	13,726
Doña Imelda	1,051	3334	4046	8,431
Damayang Lagi	1,211	3581	861	5,653
Central	3,441	546	108	4,096
Mariana	3,392	489	112	3,992
Kamuning	1,471	889	1604	3,965
Kalusugan	2,390	736	643	3,769
Santol	1,055	1873	636	3,564
U. P. Campus	3,154	377		3,531
Pinyahan	2,483	419	15	2,916
South Triangle	2,267	538	20	2,825
Roxas	496	378	1871	2,746
Bagong Lipunan ng Crame	1,029	533		1,561
Don Manuel	1,459			1,459
Valencia	413	897	67	1377
Laging Handa	1267	83		1350

District	Flood Level			Total flooded (m)
	L2	L3	L4	
Obrero	321	302	620	1243
Old Capitol Site	761	174		935
Paligsahan	663	152	49	863
Kristong Hari	258	434	153	844
Immaculate Concepcion	459	378		836
San Vicente	710	86		795
Horseshoe	419	320	32	771
Sikatuna Village	645			645
Doña Josefa	559	70		629
Kaunlaran	328	270		598
Pinagkaisahan	375	118	55	548
San Martin de Porres	337	192		529
Sacred Heart	488			488
San Isidro	397			397
Teachers Village West	356	11		366
U. P. Village	346			346
Botocan	180			180
Teachers Village East	141			141
Doña Aurora	97			97
Malaya	85			85
Sto. Niño	70			70
Krus na Ligas	21			21
District 5				
San Bartolome	5,475	3,922	3866	13,263
Sta. Monica	3,550	3,766	3,936	11,252
Nagkaisang Nayon	4,445	3,099	1,314	8,857
Gulod	2,879	3,738	2,080	8,698
North Fairview	3,840	2,243	1,595	7,677
Greater Lagro	6,294	1144	99	7,537
Fairview	3,293	1,416	2,027	6,737
Bagbag	2,765	2,282	641	5,689
Sta. Lucia	1,517	2,511	1,026	5,053
Capri	1,619	1,627	1706	4,952
Novaliches Proper	3,000	1224	103	4,327
Kaligayahan	3,301	188		3,489
Pasong Putik Proper	2,680	91		2,770
San Agustin	1629	39		1,668
District 6				
Pasong Tamo	9,167	4,533	616	14,317
Culiat	6,204	5,344	1416	12,964

District	Flood Level			Total flooded (m)
	L2	L3	L4	
Tandang Sora	8,778	1,855	207	10,839
Apolonio Samson	3,150	1744	4228	9,123
Sauyo	4,915	1,408	245	6,568
Baesa	4,961	409	41	5,411
Talipapa	4,456	613	123	5,191
Sangandaan	1,575	1,614	705	3,893
New Era	1,189	0		1,189
Unang Sigaw	1,069	20		1,088
Balong-bato	854			854
Grand Total	**255,871**	**129,066**	**89,702**	**474,639**

Bridges

Bridges, both concrete and steel are also identified to be subjected to different flood depths. Forty bridges were found to be in locations where water depths can be higher than 0.5m. The information only reveals location and not actual immersion of structures as these bridges lie above canals and located above ground. In water depths greater than 3m at bridge locations, there are five in District 1, one each in Districts 2 and 3, seven in District 4, two in District 5 and three in District 6, which may need past flood information (e.g., STS Ondoy) to reveal if deck of bridge can get immersed in flood water. Bridges, both concrete and steel (under different conditions as poor, fair and good) are also identified to be subjected to different flood depths. Refer to Table A8 for a complete list of bridges in various flood levels per barangay in link to **Annex A** provided above.

Sewage Treatment Plant

There are 29 sewage treatment plant (STP) locations in Quezon City. Six of them are situated where flood waters can be less than half a meter deep. Twenty-three of these STPs are situated in areas where flood depths can exceed 0.5m. These may result to disruption of operations and result to sanitation. Eleven are in District 1, six in District 6, three in District 3, two in District 4, and one in District 5.

Refer to Table A9 for a complete list of sewage treatment plants in various flood levels per barangay in link to **Annex A** provided above.

Water Pumping Station

The twenty-two water pumping stations (PS) in Quezon City are generally safe from deep flood water. A few of them were located where flood depths can be higher than 0.5 m. These are found in Barangay Maharlika (D.Tuazon PS) and Barangay Pansol (Balara Water PS) and the UP Water (PS). Refer to Table A10 for a complete list of water pumping stations in various flood levels per barangay in link to **Annex A** provided above.

Materials Recovery Facility

Fifty-five locations of materials recovery facilities (MRFs) can be found in Quezon City. About 31 of these locations are relatively safe from floods. About 22 of these were found to be in areas where flood depth can be more than half a meter. There were seven each identified in Districts 1 and 3, three each in Districts 4 and 6 and two in District 5. Refer to Table A11 for a complete list of material recovery facilities under various flood levels per barangay in link to **Annex A** provided above.

Schools

There are 115 school locations in Quezon City that can be flooded by more than 0.5m deep. District 1 has 28, District 2 has 6, District 3 has 12, District 4 has 22, District 5 has 30, and District 6 has 17 school locations. Refer to Table A12 for a complete list of schools under various flood levels per barangay in link to **Annex A** provided above.

Markets

There are 53 market locations in Quezon City. Most of these are one-story structures. Thirteen of these market locations can be flooded by more than 0.5m deep. They are found in Districts 1, 3, 4, 5 and 6. District 4 has five locations, District 6 has three, Districts 3 and 5 have two each and District 1 has one. Refer to Table A13 for a complete list of markets under various flood levels per barangay in link to **Annex A** provided above.

Daycare centers

There are 296-day care centers in QC. Eighty-nine of them are in areas where flood depths can be higher than 0.5m. They include 22-day care centers in District 1, 6 in District 2, 19 in District 3, 13 in District 4, 22 in District 5, and 7 in District 6. Refer to Table A14 for a complete list of daycare centers under various flood levels per barangay in link to **Annex A** provided above.

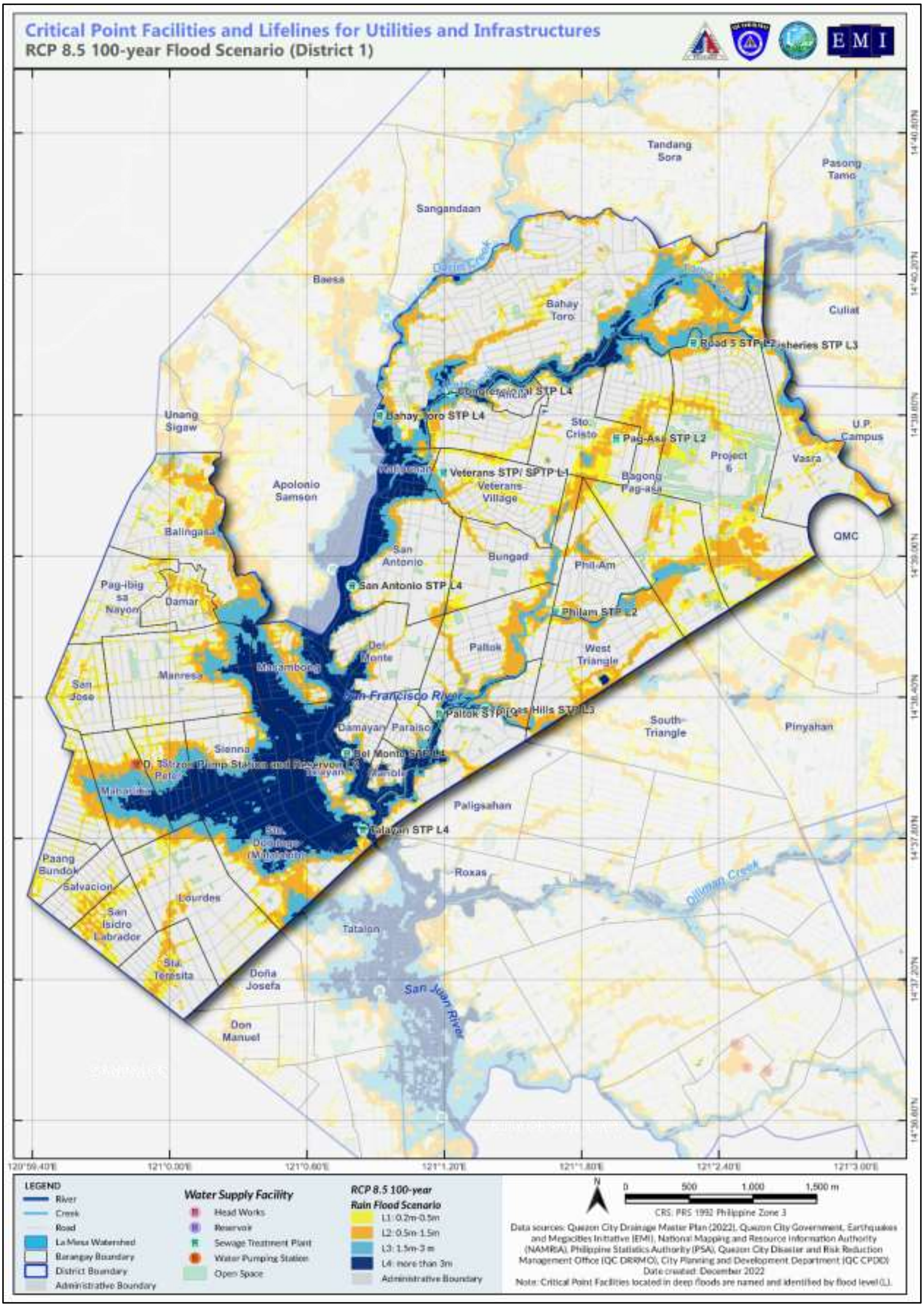


Figure 50. Utilities and Infrastructure locations in an RCP 8.5 100- year rain flood scenario in District 1. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022

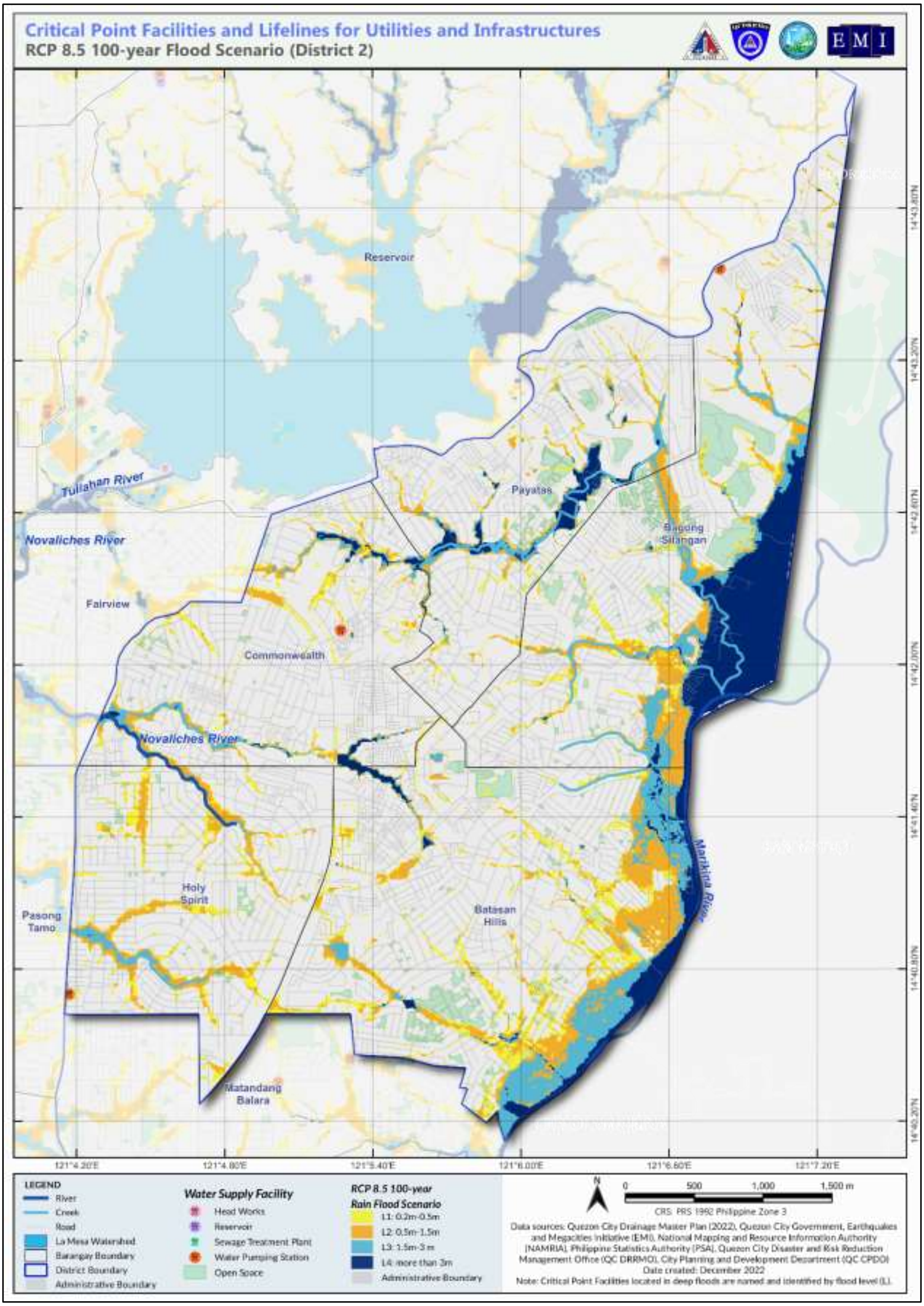


Figure 51. Utilities and Infrastructure locations in an RCP 8.5 100- year rain flood scenario in District 2. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022

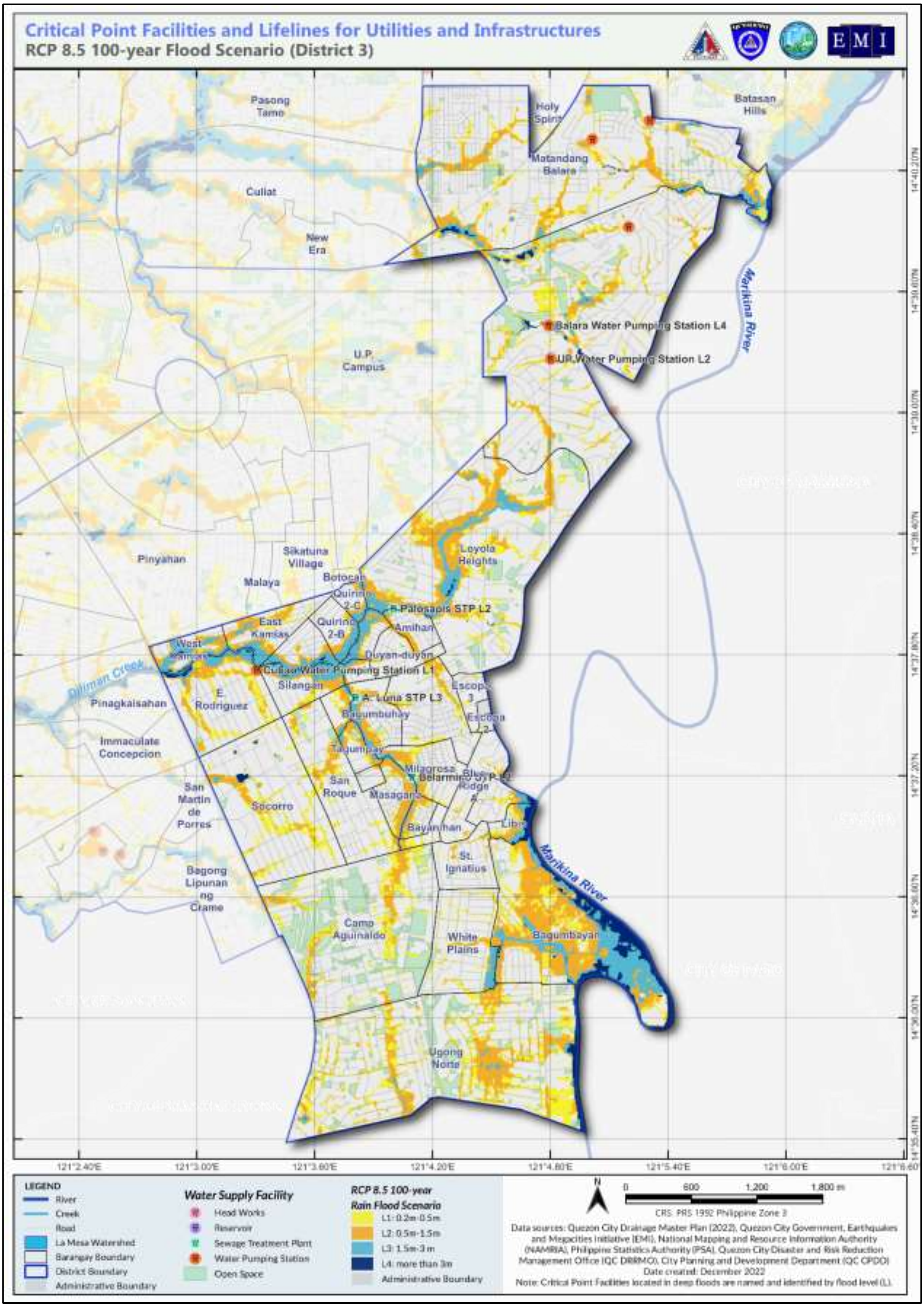


Figure 52. Utilities and Infrastructure locations in an RCP 8.5 100- year rain flood scenario in District 3. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022

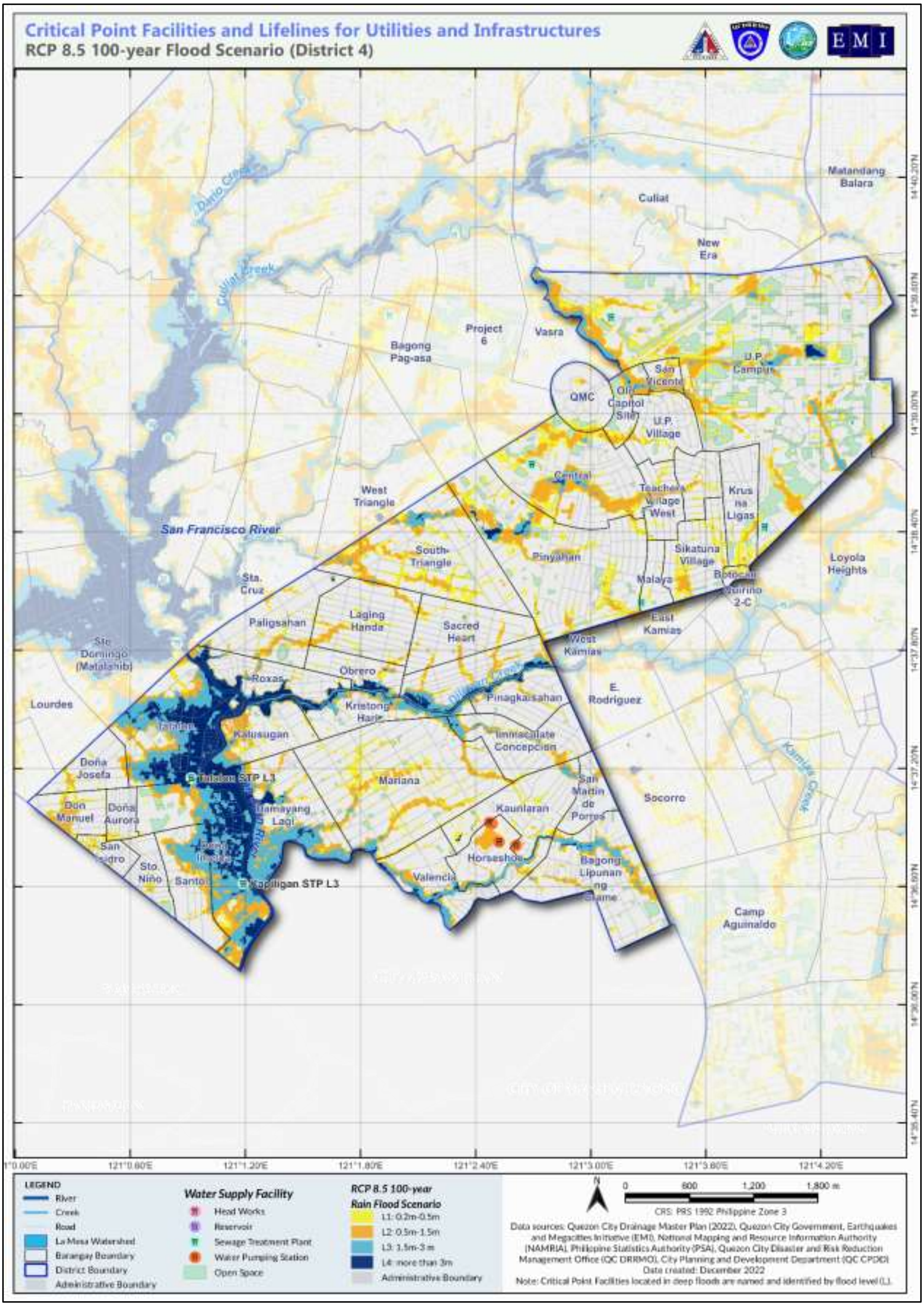


Figure 53. Utilities and Infrastructure locations in an RCP 8.5 100- year rain flood scenario in District 4. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022

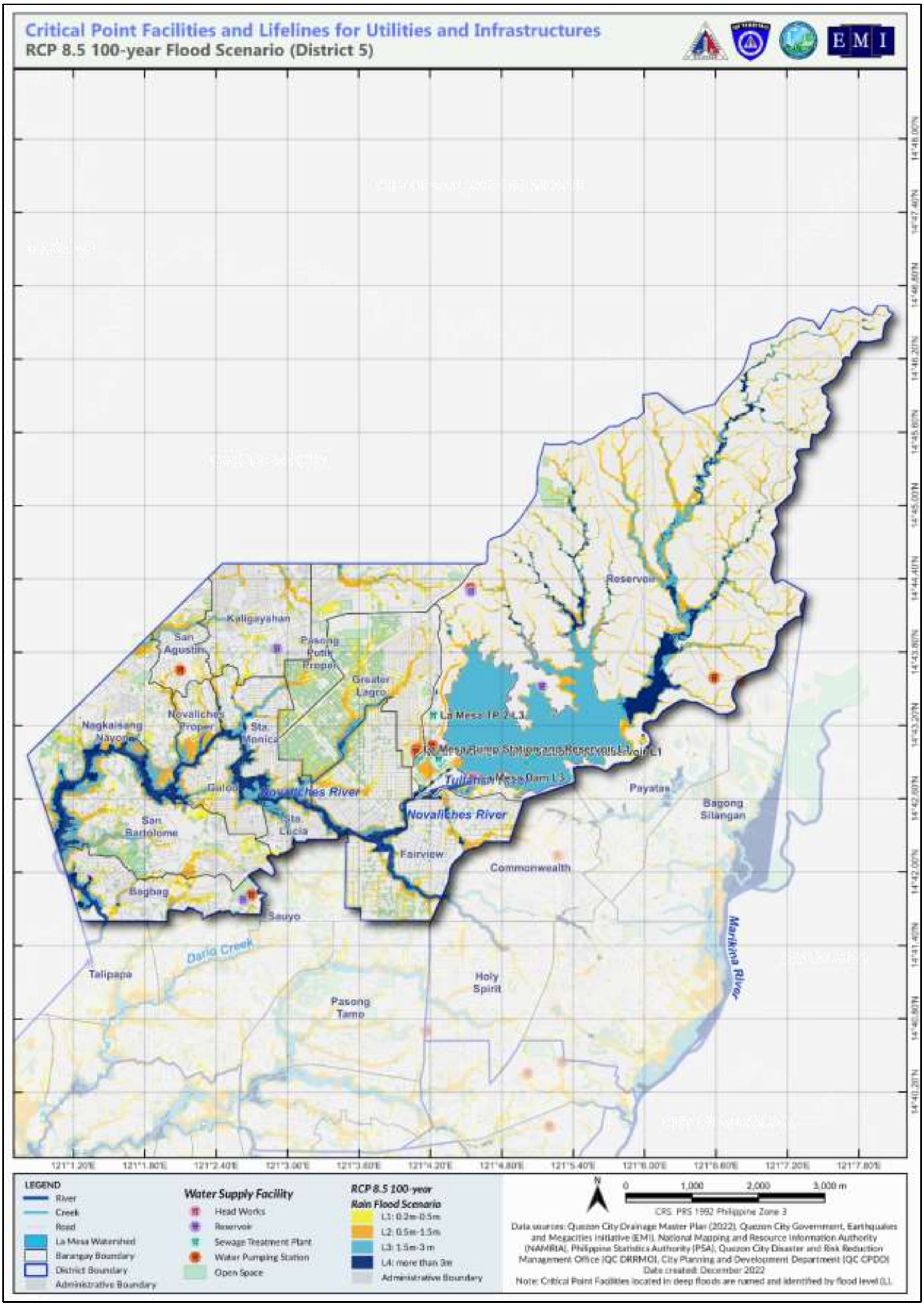


Figure 54. Utilities and Infrastructure locations in an RCP 8.5 100- year rain flood scenario in District 5. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022

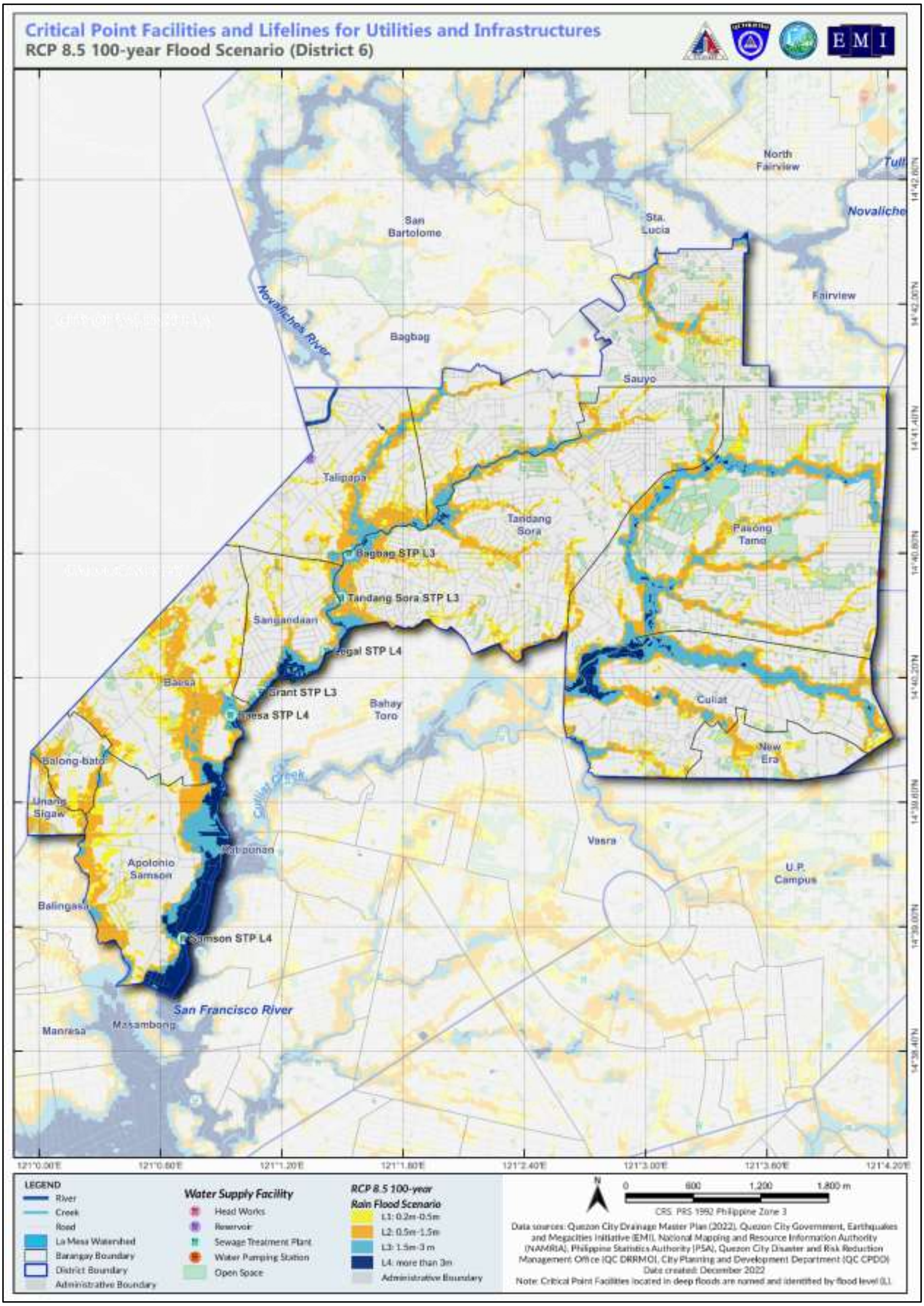


Figure 55. Utilities and Infrastructure locations in an RCP 8.5 100- year rain flood scenario in District 6. Facilities in deep flood locations are shown with their names and flood level indicator (ex. L2). Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022

3.7.6. Flood Affected Land Uses

The key flood metrics for land uses are provided below:

Residential Land Uses

Residential land uses that are closer to main rivers and creeks have higher susceptibility to flooding. Districts 1 and 4 traversed by the San Francisco-San Juan River and the G. Araneta Ave. canal and storm water tributaries (Culiat Creek, Pasong Tamo Creek, Dario Creek, Diliman Creek) are the locations which give the higher share of flood area coverage, number of facilities and length of road network under deeper floods. The floods in residential areas at the eastern side of Districts 2 and 3 are connected to the Marikina River overflows.

In District 6, residential areas closer to creeks such as Pasong Tamo, Tandang Sora, Culiat are locations where floods can expand. The Novaliches River which meanders and crosses Fairview, Sta Lucia, Gulod and Sta. Monica, Nagkaisang Nayon and San Bartolome forms the food prone areas of District 5.

The bigger concentration of institutional use areas is found in District 4 and adjoining areas of District 1 in Vasra, New Era and Bagong Pag-asa. These sites are traversed by upstream stretches of Culiat Creek. Strongly affected by the flood are institutional areas nearer to Diliman Creek connecting to the San Juan River. See Figure 56 for a flood overlay with institutional land use areas.

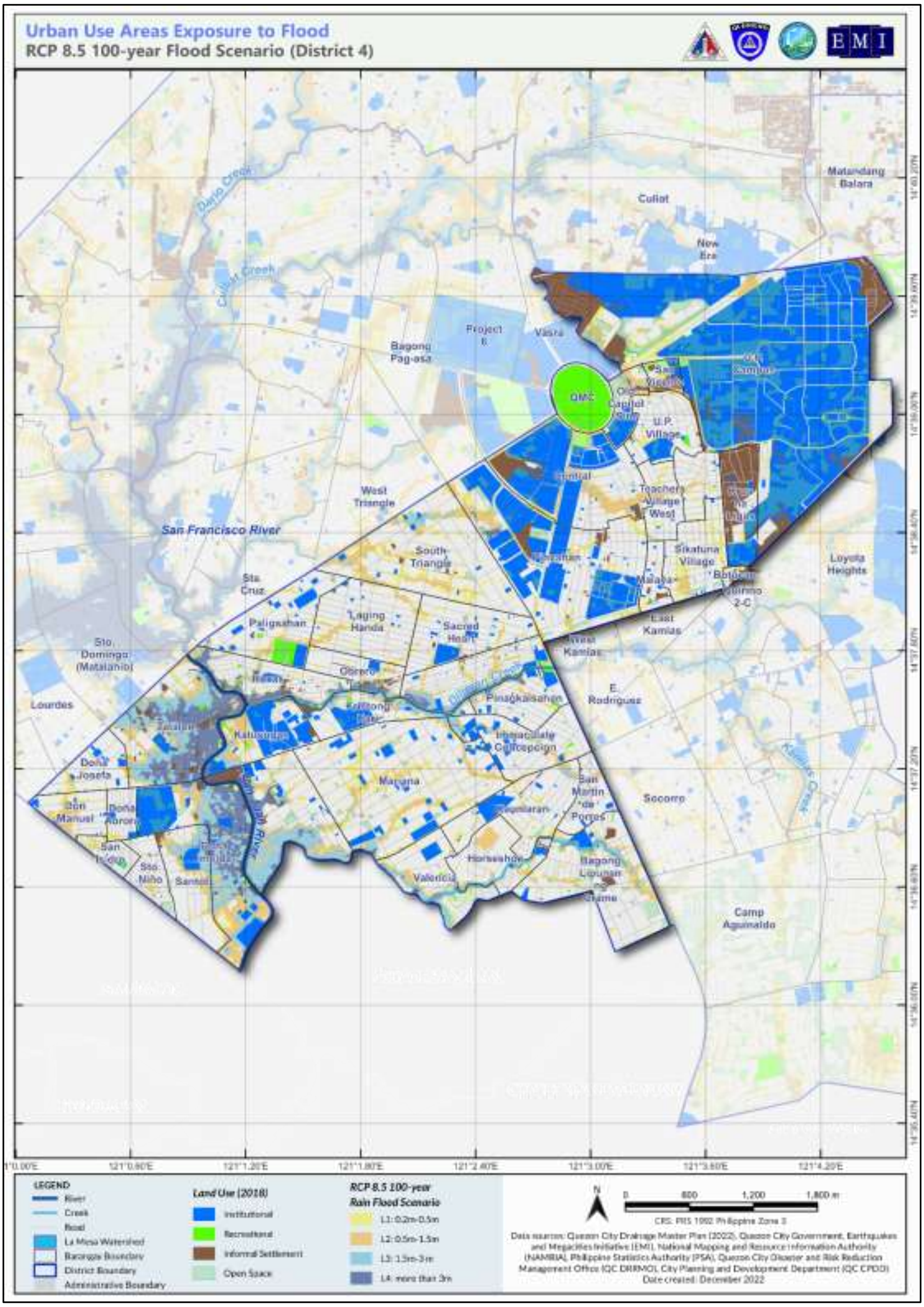


Figure 56. Institutional areas in District 4 in an RCP 8.5 100- year rain flood scenario. Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022)

Commercial Land Uses

Commercial land uses follow a ribbon-like pattern along roads and create commercial nodes over the city. When these roads are adjacent to rivers and creeks, they have the potential to be flooded first. Storm water collector pipes and culverts also connect to these streams allowing for a possible backflow. See Figure 57 and Figure 58 for flood overlays with commercial land use areas in District 4 and District 1.

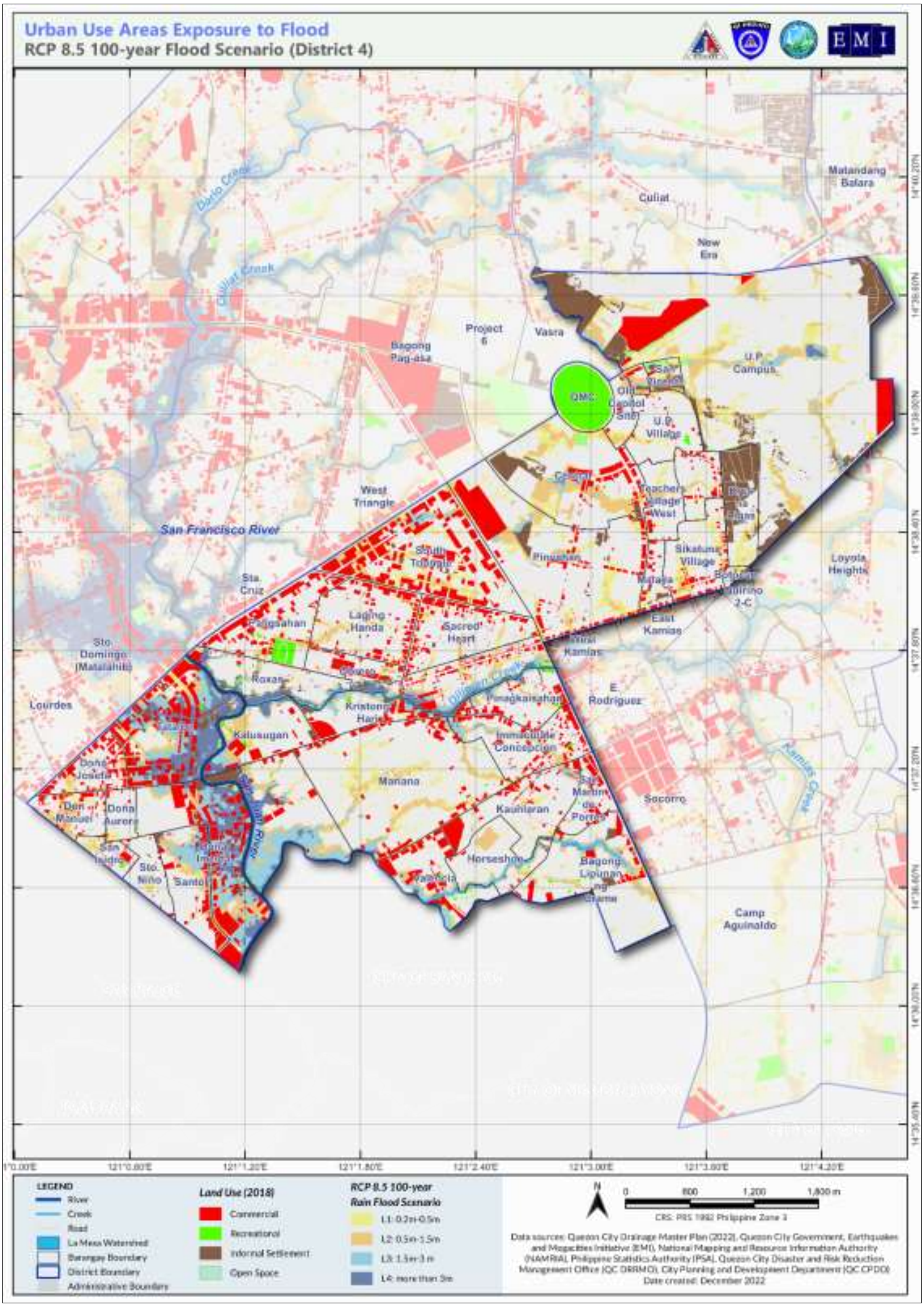


Figure 57. Commercial use areas in District 4 in an RCP 8.5 100- year rain flood scenario. (Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022)

Most affected commercial use areas are those lining the creeks and rivers and along roads adjacent to these waterways, esp. San Francisco River, Diliman Creek, and the G Araneta Ave. open channel and culvert system.

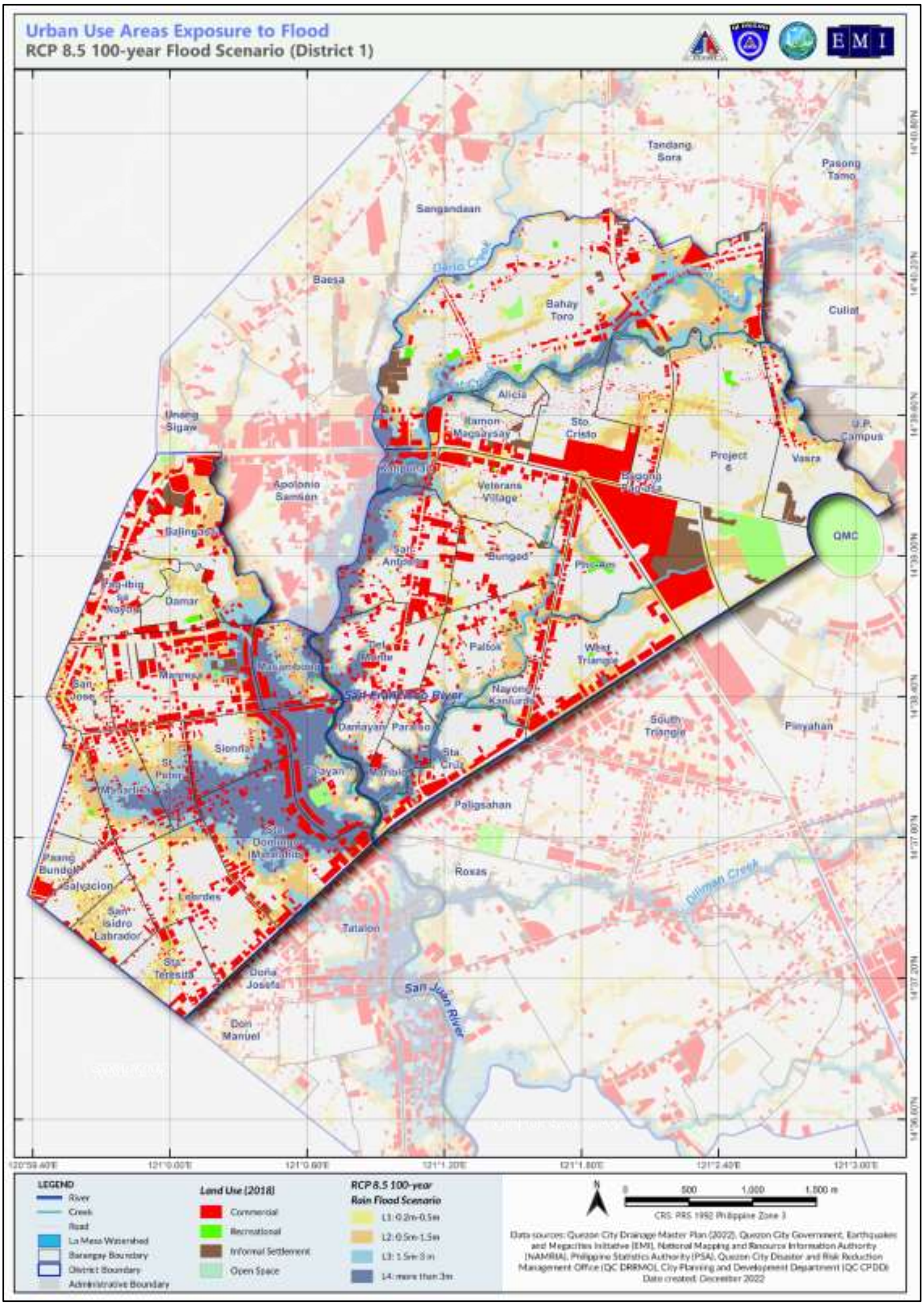


Figure 58. Commercial use areas in District 1 in an RCP 8.5 100- year rain flood scenario. (Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022)

Most affected commercial use areas are those lining the creeks and rivers and along roads adjacent to these waterways such as the San Francisco River, Culiat Creek and the G Araneta Ave. open channel and culvert system.

Industrial land uses

Industrial areas are mostly located at the western side of the City in Districts 1,5 and 6. In District 5, these areas that locate near the Novaliches river are prone to river overflows. In District 6, many of these industrial locations are far from Dario Creek but remain flood prone, likely from ponding of water or from poor drainage.

Figure 59 and Figure 60 show flood overlays with the urban industrial land uses in Quezon City.

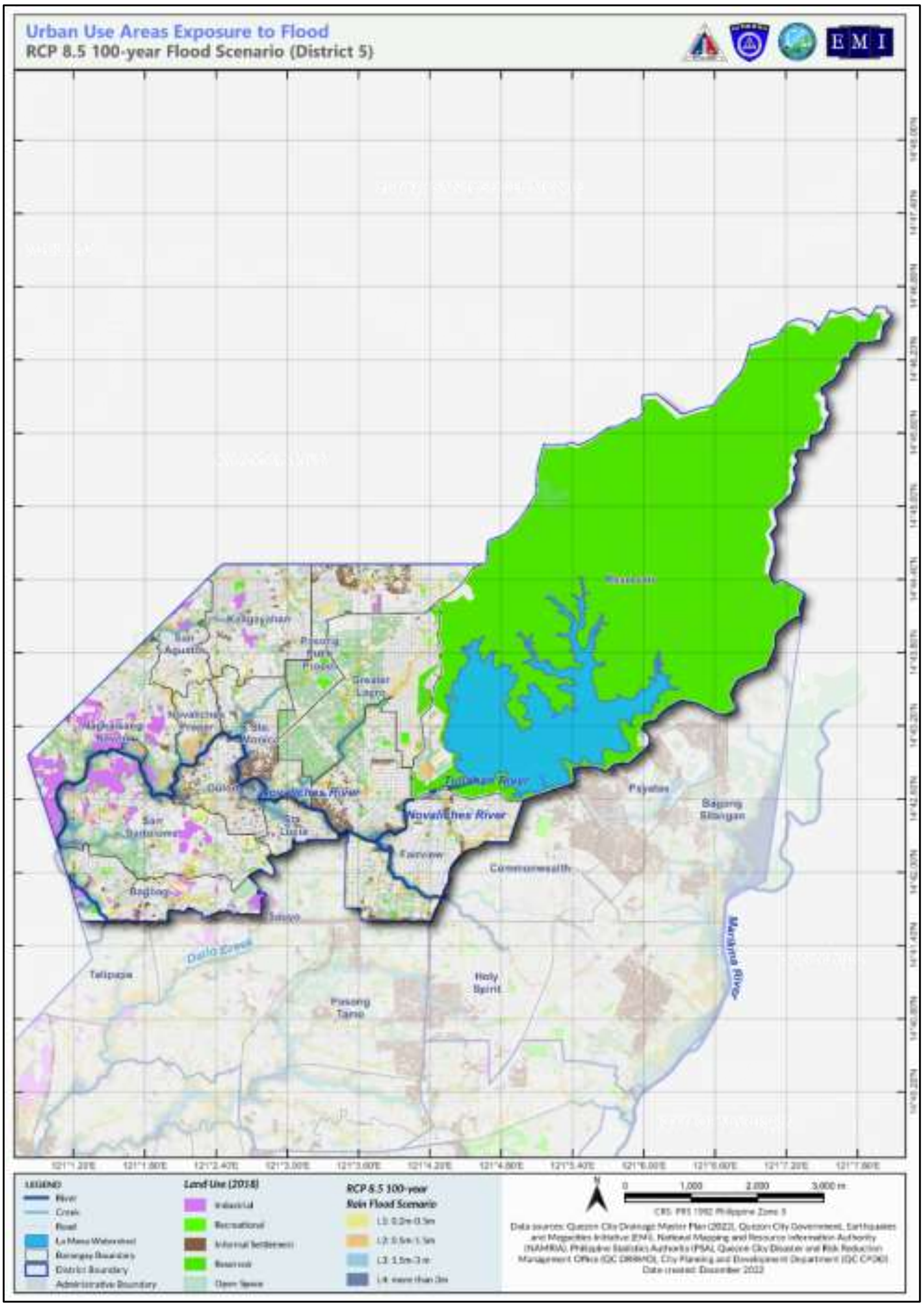


Figure 59. Industrial use areas in District 5 in an RCP 8.5 100- year rain flood scenario. (Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022)

Affected areas are adjacent to the Novaliches River.

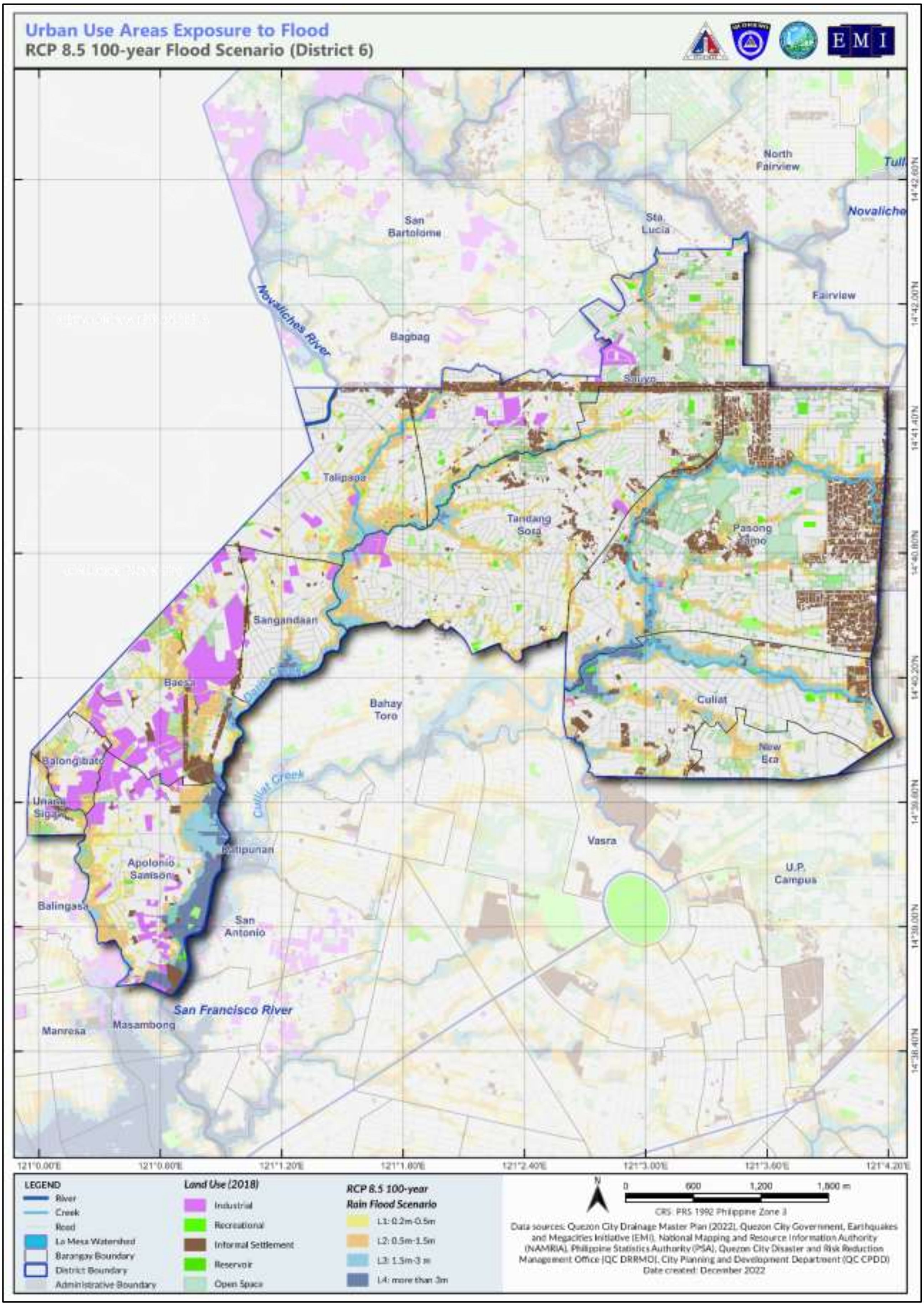


Figure 60. Industrial use areas in District 6 in an RCP 8.5 100- year rain flood scenario. Source: QC-Drainage Master Plan, Preliminary Report 2022, City Planning and Development Department, 2022)

3.8. Post-flood Health Issues – Gastro-Intestinal Infection

Infection can be a result of ingestion of contaminated flood waters as shown in **Error! Reference source not found.**. The full methodology for establishing the probabilities of gastrointestinal infection is explained in the Hazard Vulnerability and Risk Assessment (HVRA) for 142 Barangays report (Deliverable 8) and will not be reproduced here. The key findings are presented below in aggregate and for each district.

The estimated number of exposed populations at three flood levels (low flood with depth of 0.5 m, moderate flood with depth of 0.5 to 1.5 m and high flood with depth of >1.5 m) are shown in Table 40.

District 1

In District 1, an estimate of 1,543 people can be infected by gastro-enteritis. Barangays Toro, Sto. Domingo (Matalahib), Masambong and San Antonio lead 37 barangays.

District 2

In District 2, an estimate of 1,259 people can be infected by gastro-enteritis. Barangays Batasan Hills, Bagong Silangan lead the five barangays of the district.

District 3

In District 3, an estimate of 720 people can be infected by gastro-enteritis. Barangays Bagumbayan and Matandang Balara lead 37 barangays.

District 4

In District 4, an estimate of 1,514 people can be infected by gastro-enteritis. Barangays Tatalon and Damayang-Lagi lead the 38 barangays.

District 5

In District 5, an estimate of 1,577 people can be affected by gastro-enteritis. Barangays Gulod, Capri, Bagbag, Sta. Monica and Nagkaisang Nayon lead the 14 barangays of the district.

District 6

In DIstrict 6, an estimate of 1,321 people can be infected by gastro- enteritis. Barangays Culiat, Pasog Tamo, Apolonio Samson leads the 11 barangays of the district.

Figure 61 to Figure 66 show maps of infection rates among Districts.

Table 40. Ranking of barangays (a)-(f) showing the infection rate (per 1000 population) to Gastro-Enteritis in different Barangays and Districts.

District	Barangay	Rate per 1000
1	Katipunan	13.1
1	Talayan	12.3
1	Masambong	11.0
1	Sto. Doming	10.3
1	Mariblo	8.3
1	St. Peter	8.0
1	Sienna	8.0
1	Maharlika	7.5
1	Alicia	4.9
1	Damayan	4.8
1	San Antonio	4.6
1	Del Monte	4.1
1	Bahay Toro	4.0
1	Nayong Kanl	3.8
1	Sta. Cruz	3.7
1	Paraiso	3.6
1	Paltok	3.1
1	Manresa	3.0
1	Balingasa	3.0
1	N. S. Amorar	2.5
1	Sto. Cristo	2.4
1	Vasra	2.3
1	West Triangl	2.3
1	Ramon Mags	2.0
1	Bagong Pag-	2.0
1	Phil-Am	1.4
1	Bungad	1.4
1	Project 6	1.3
1	Veterans Vill	1.2
1	San Isidro La	1.2
1	Damar	1.2
1	Sta. Teresita	0.9
1	Lourdes	0.9
1	Salvacion	0.7
1	San Jose	0.6
1	Paang Bund	0.4
1	Pag-ibig sa N	0.2

(a) District 1

District	Barangay	Rate per 1000
3	Claro (Quiri	7.4
3	Libis	7.1
3	West Kamia	6.9
3	Silangan	5.2
3	East Kamias	3.9
3	Quirino 2-B	3.7
3	Mangga	3.7
3	Tagumpay	3.6
3	Bagumbuha	3.4
3	Masagana	3.2
3	Villa Maria	2.6
3	Amihan	2.5
3	E. Rodriguez	2.1
3	Loyola Heigl	2.0
3	Milagrosa	1.7
3	Blue Ridge B	1.7
3	Ugong Norte	1.4
3	Matandang	1.2
3	White Plain	1.1
3	Bayanihan	0.9
3	Pansol	0.8
3	San Roque	0.7
3	Socorro	0.6
3	Marilag	0.6
3	Duyan-duya	0.6
3	Camp Aguin	0.5
3	St. Ignatius	0.4
3	Dioquino Zo	0.3
3	Blue Ridge A	0.3
3	Escopa 2	0.2
3	Escopa 3	0.0
3	Escopa 1	0.0
3	Bagumbayai	0.0
3	Escopa 4	0.0
3	Quirino 2-A	0.0
3	Quirino 2-C	0.0
3	Quirino 3-A	0.0

(b) District 3

District	Barangay	Rate per 1000
2	Batasan Hill	2.6
2	Payatas	1.3
2	Holy Spirit	0.8
2	Bagong Silai	0.0
2	Commonwea	0.0

District	Barangay	Rate per 1000
5	Capri	11.9
5	Gulod	4.6
5	Sta. Lucia	4.3
5	Sta. Monica	4.0
5	Novaliches I	3.5
5	Nagkaisang	2.7
5	San Bartoloı	2.5
5	Bagbag	2.0
5	North Fairvi	1.9
5	Fairview	1.7
5	Greater Lagr	0.8
5	Pasong Puti	0.7
5	Kaligayahar	0.5
5	Reservoir	0.0
5	San Agustin	0.0

(d) District 5

District	Barangay	Rate per 1000
6	Apolonio Sa	4.8
6	Sangandaar	2.7
6	Unang Sigav	2.5
6	Baesa	2.4
6	Pasong Tam	2.0
6	Balong-bato	1.9
6	Talipapa	1.8
6	Tandang Soı	1.4
6	Sauyo	1.2
6	New Era	0.8
6	Culiat	0.0

(e) District 6

District	Barangay	Rate per 1000
4	Tatalon	10.4
4	Doña Imelda	9.6
4	Damayang L	7.0
4	Roxas	4.5
4	Santol	4.3
4	Kristong Haı	4.1
4	Kalusugan	4.0
4	Kamuning	3.8
4	San Vicente	3.7
4	Old Capitol	3.0
4	Valencia	2.9
4	Botocan	2.4
4	Obrero	2.4
4	Central	2.1
4	Horseshoe	2.0
4	Pinagkaisah	1.7
4	Immaculate	1.7
4	South Triang	1.6
4	Bagong Lipu	1.5
4	Don Manuel	1.4
4	Pinyahan	1.2
4	U. P. Campu	1.1
4	Mariana	0.9
4	Paligsahan	0.7
4	San Martin	0.7
4	Kaunlaran	0.7
4	Laging Hand	0.6
4	Teachers Vil	0.6
4	San Isidro	0.5
4	Doña Josefa	0.5
4	Sikatuna Vil	0.5
4	Sacred Hear	0.3
4	U. P. Village	0.3
4	Krus na Liga	0.3
4	Doña Aurora	0.3
4	Teachers Vil	0.3
4	Sto. Niño	0.2
4	Malaya	0.1
4	OMC	0.0

(f) District 4

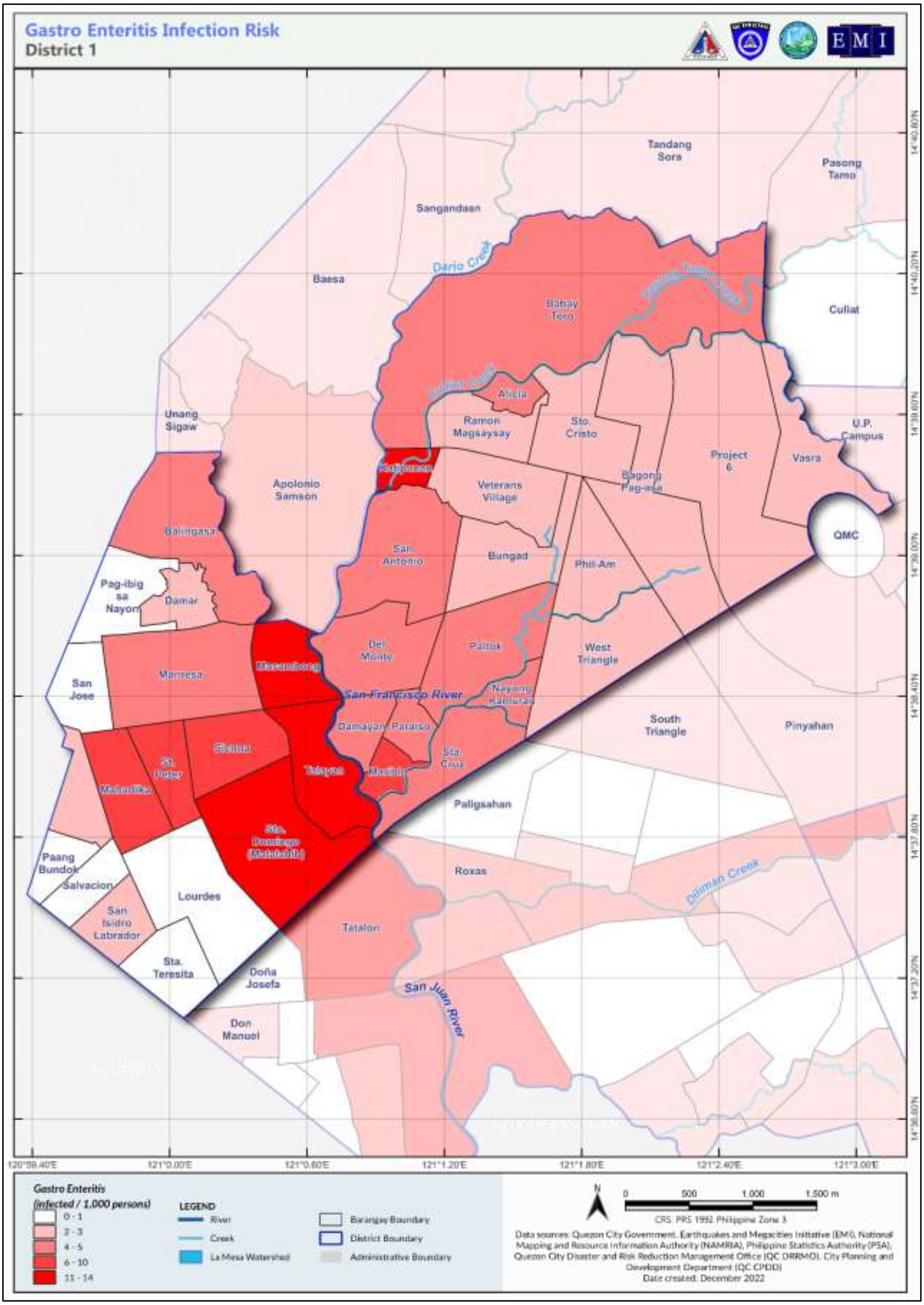


Figure 61. Infection risk to Gastro-Enteritis (infected/1000 persons) in District 1 in an RCP 8.5 100 -year Rain Flood Scenario

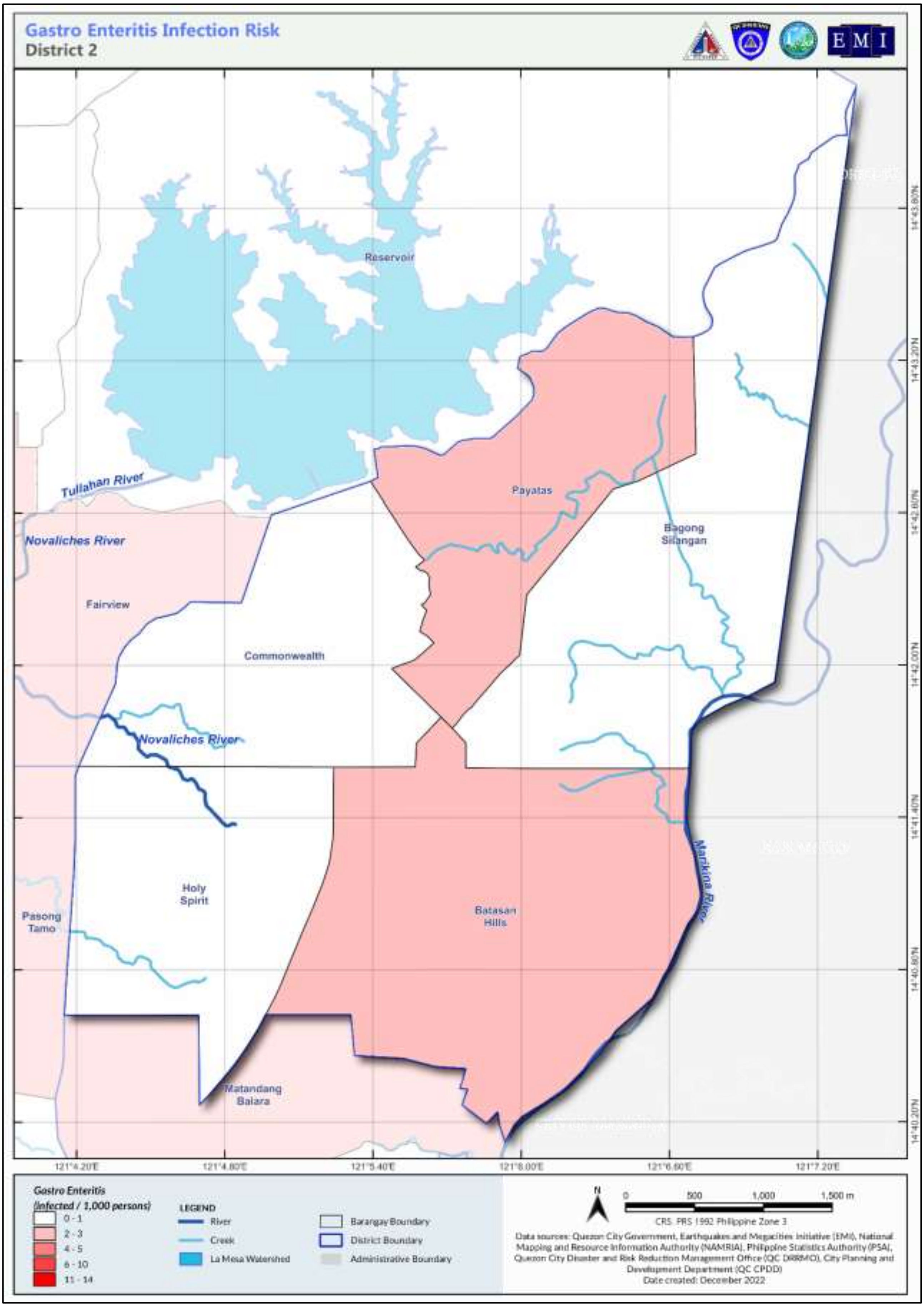


Figure 62. Infection risk to Gastro-Enteritis (infected/1000 persons) in District 2 in an RCP 8.5 100 -year Rain Flood Scenario

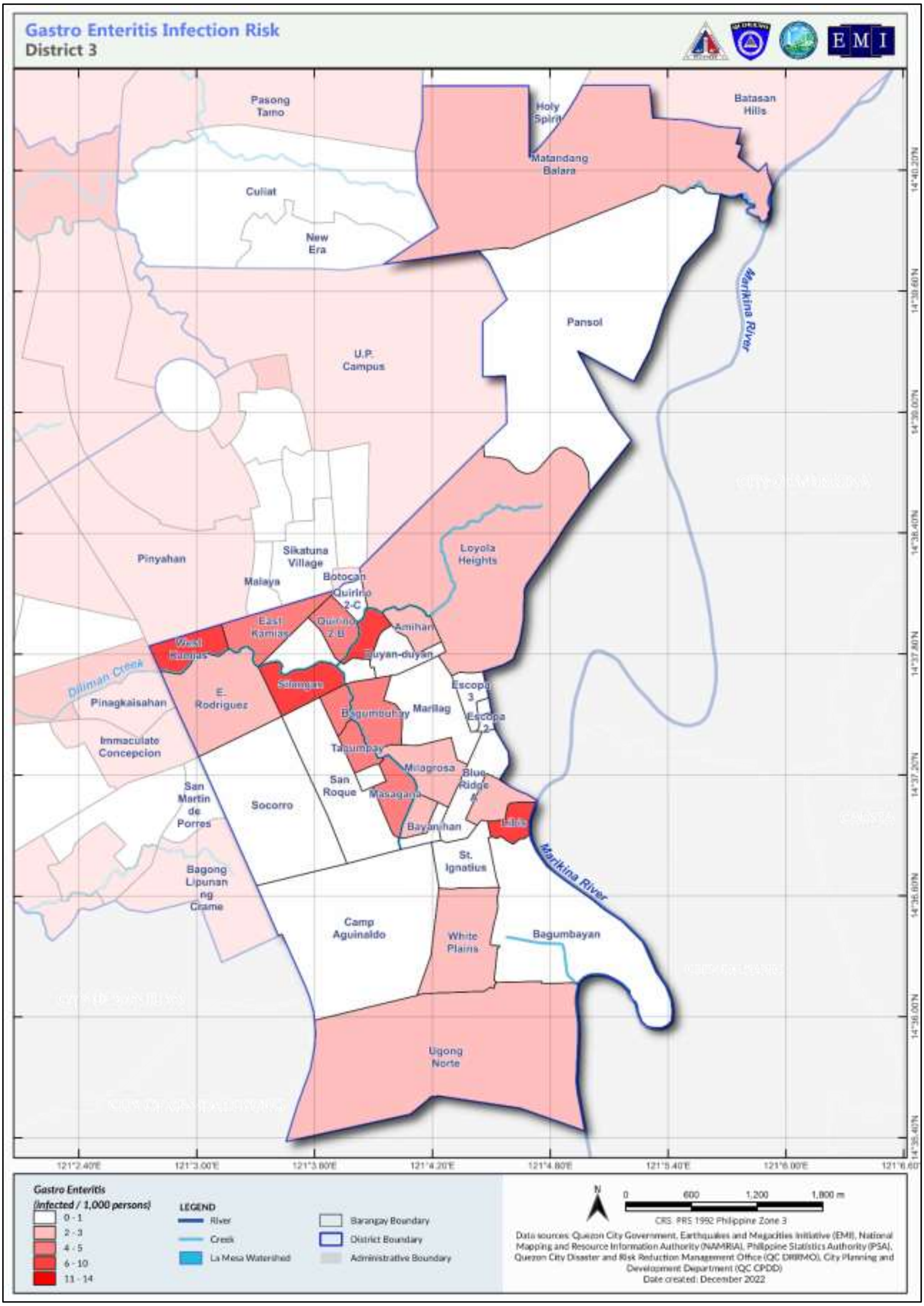


Figure 63. Infection risk to Gastro-Enteritis (infected/1000 persons) in District 3 in an RCP 8.5 100 -year Rain Flood Scenario

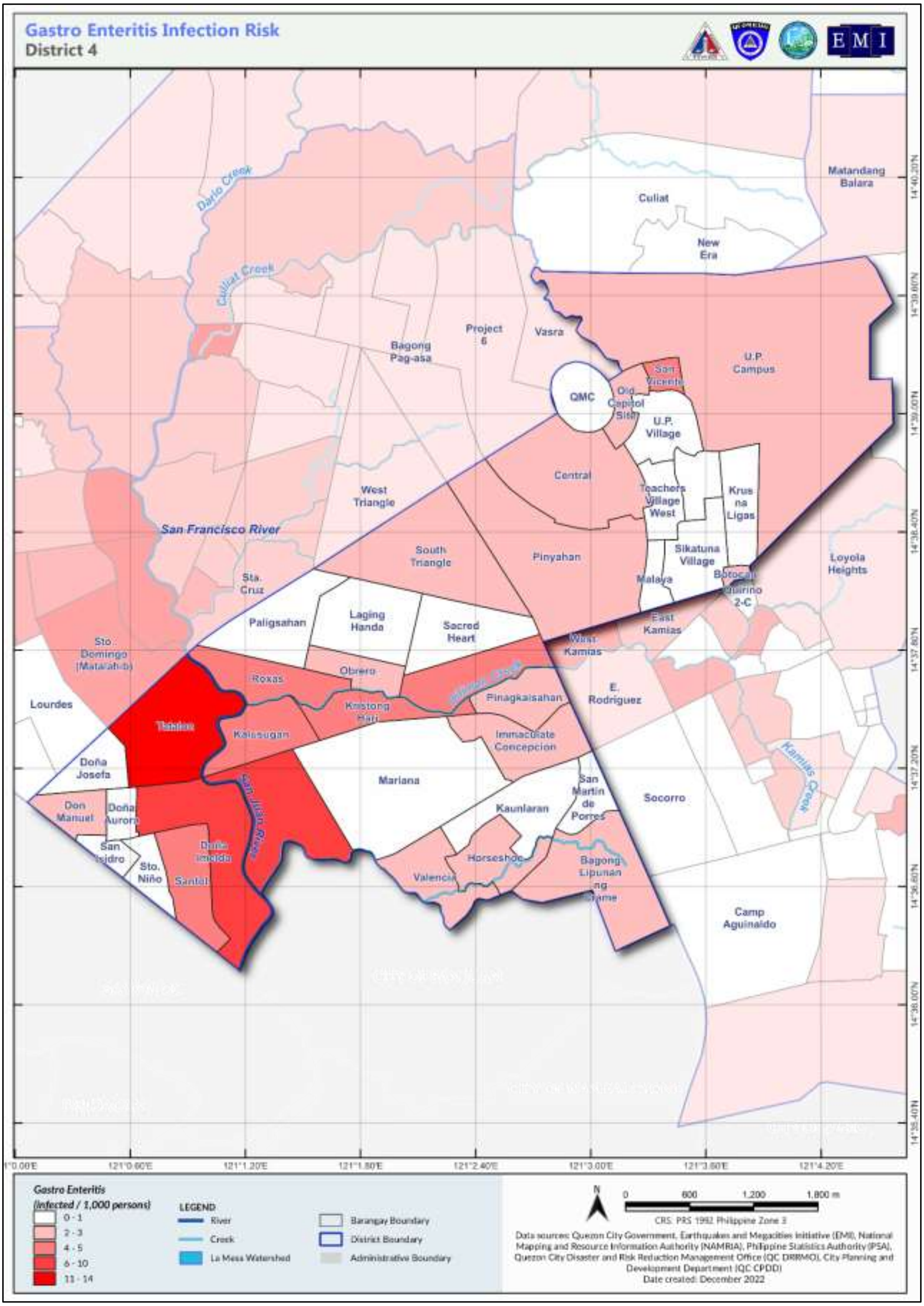


Figure 64. Infection risk to Gastro-Enteritis (infected/1000 persons) in District 4 in an RCP 8.5 100 -year Rain Flood Scenario

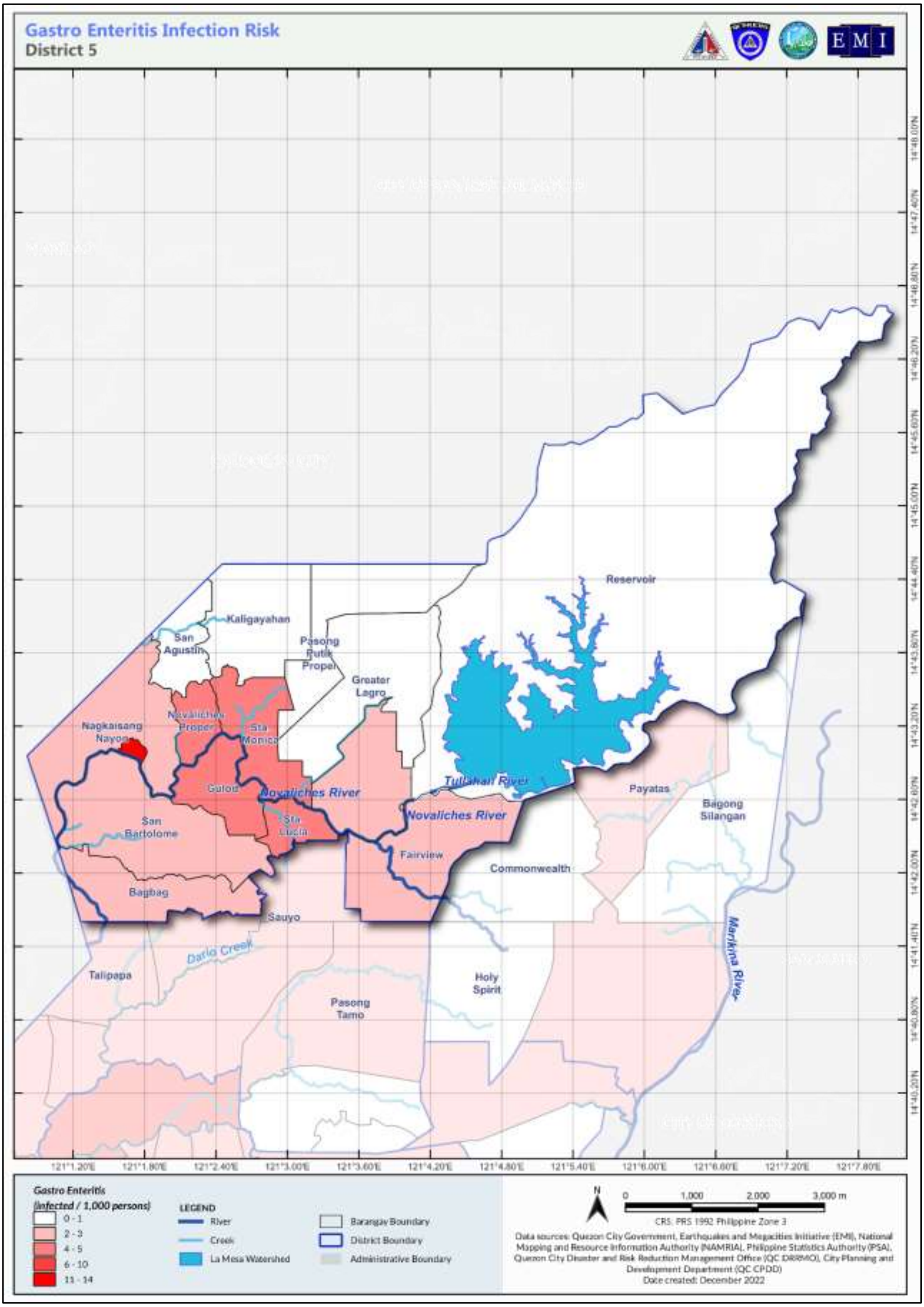


Figure 65. Infection risk to Gastro-Enteritis (infected/1000 persons) in District 5 in an RCP 8.5 100 -year Rain Flood Scenario

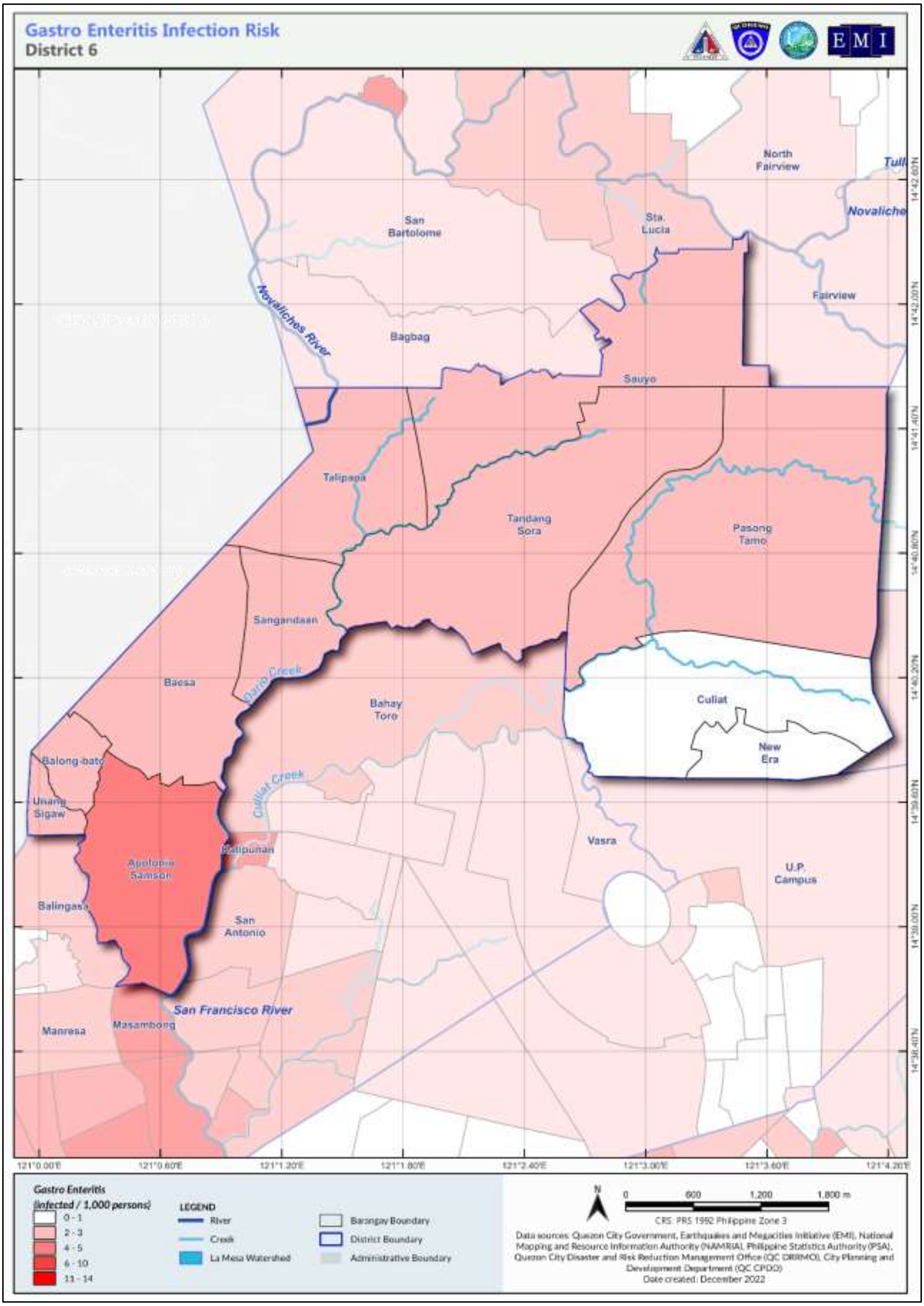


Figure 66. Infection risk to Gastro-Enteritis (infected/1000 persons) in District 6 in an RCP 8.5 100 -year Rain Flood Scenario

Part 4:

Earthquake Hazard and Risk Assessment

4. Earthquake Hazard and Risk Assessment

4.1. Content and Purpose

The Earthquake element of the CDRA focuses on analyzing the impact of a **magnitude 7.2 earthquake generated by the West Valley Fault (WVF)** on the buildings and population of Quezon City. This chapter provides the key outputs from the M7.2 earthquake scenario. It presents various exhibits in terms of charts and maps that illustrate the outputs and can inform internal DRRM and core internal planning functions of Quezon City Government (QCG). A full description of the methodology can be found in Deliverable 8: Hazard, Vulnerability and Risk Assessment of 142 Barangays.

The WVF is an active fault that transects the eastern part of Metropolitan Manila including Quezon City. The aerial view of the trace of the WVF is approximately shown in Figure 67. The maximum magnitude of M7.2 is approximated from the length of the fault using an empirical formula. This is a scientifically acceptable approach because there is a direct correlation between the length of a fault and the maximum magnitude the fault can generate. But it must be kept in mind that the M7.2 represents the worst-case event. It is more probably that the WVF would trigger an earthquake of a smaller magnitude than M7.2. However, it is always advisable to plan for the worst-case scenario because experience has shown that for planning purposes it is possible to scale down but it is very difficult to scale up.

In addition to ground rupture and ground shaking, earthquake can trigger indirect hazards including landslides, liquefaction, fire following, and tsunamis (for offshore faults only – not the WVF). Earthquakes are often followed by a number of additional tremors known as aftershocks. Most of the time, these aftershocks are weaker relative to the main earthquake and decrease in frequency over time. Occurrence of aftershocks can last for several months and are capable of causing additional impact on assets. They also cause significant trauma to survivors and can complicate the recovery process.

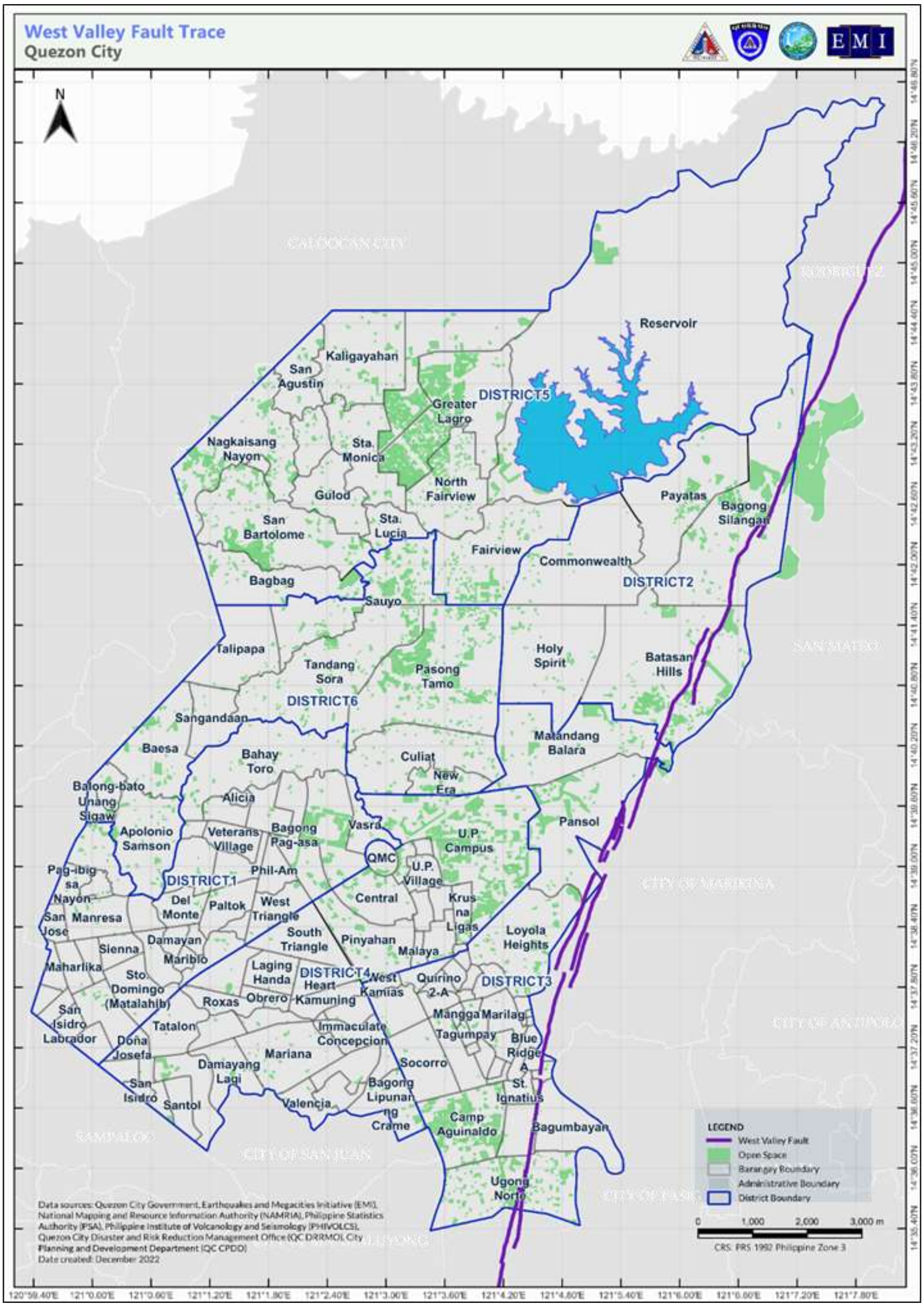


Figure 67. Trace of West Valley Fault in the Vicinity of Quezon City

4.2. General Approach

An earthquake hazard and risk assessment is conducted in two distinct steps:

- First the hazard distribution is calculated in terms of the severity of earthquake shaking at the centroid of a grid point (in this case 175m by 175 m grid) that cover the full geography of the study area (i.e., Quezon City). This assessment is referred to as hazard assessment. The output is generally provided in terms of **Modified Mercali Intensity (MMI)** a widely used earthquake hazard quantity in earthquake engineering and seismology.

- Second, the hazard quantity at each grid point is convolved with the vulnerability of the exposed asset to calculate risk. Risk is a measure of the potential social, physical, economic and environmental damages and losses. The latter assessment is referred to as risk assessment.

In this study, the calculated risk values are building damage, injuries, fatalities and displaced populations. These quantities are calculated using sophisticated algorithms that convolve hazard quantities with the so-called fragility functions associated with each element at risk. The main hazard parameter is the ground shaking severity in terms of Modified Mercalli Intensity Scale. The scale is shown in Table 41

Table 41. The modified Mercalli intensity (MMI) scale (Wood & Neumann, 1931)

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. M people do not recognize it as an earthquake. Standing motor cars may rock slight Vibrations are similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Di windows, doors disturbed, walls make cracking sound. Sensation like heavy truck st building. Standing motors rocked noticeably
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken, and unst objects were overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved, a few fallen plasters. Dar slight.
VII	Very Strong	Damage negligible in buildings of good design and construction; slight to moderate i well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys were broken.
VIII	Severe	Damage is slight in specially designed structures; considerable damage in ordinar substantial buildings with partial collapse. Damage great in poorly built structures. F chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturne
IX	Violent	Damage considerable in specially designed structures; well-designed frame structu well-designed frame structures thrown out of plumb. Damage is great in substant buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures were destroyed; most masonry and frame struc destroyed with foundations. Rails bent

PHIVOLCS has also developed its intensity scale specific to the Philippines referred to as the PHIVOLCS **Earthquake Intensity Scale (PEIS)**, which is very similar to the MMI scale but is a 10-level scale instead of the 12-level scale for the MMI. The two-scale are related so one can calculate an equivalent PEIS value from an MMI value and vice-versa.

The HVRA earthquake study adopts the same scientific approach as the landmark study "Enhancing Risk Analysis Capacities for Flood, Tropical Cyclone Severe Wind and Earthquake for the Greater Metro Manila Area' Project (GMMA-RAP), which was completed for the National Capital Region in 2013 and where all relevant outputs are made available on the Philippine Institute of Volcanology and Seismology (PHIVOLCS) geohazard portal (https://gisweb.phivolcs.dost.gov.ph/gisweb/earthquake-volcano-related-hazard-gis-information).

Ground shaking intensity for the GMMA was generated for M7.2 (estimated maximum size by MMEIRS) earthquake generated by the WFV. PHIVOLCS has generously shared with the project team the grid data for the M7.2 earthquake scenario as shown in Figure 68.

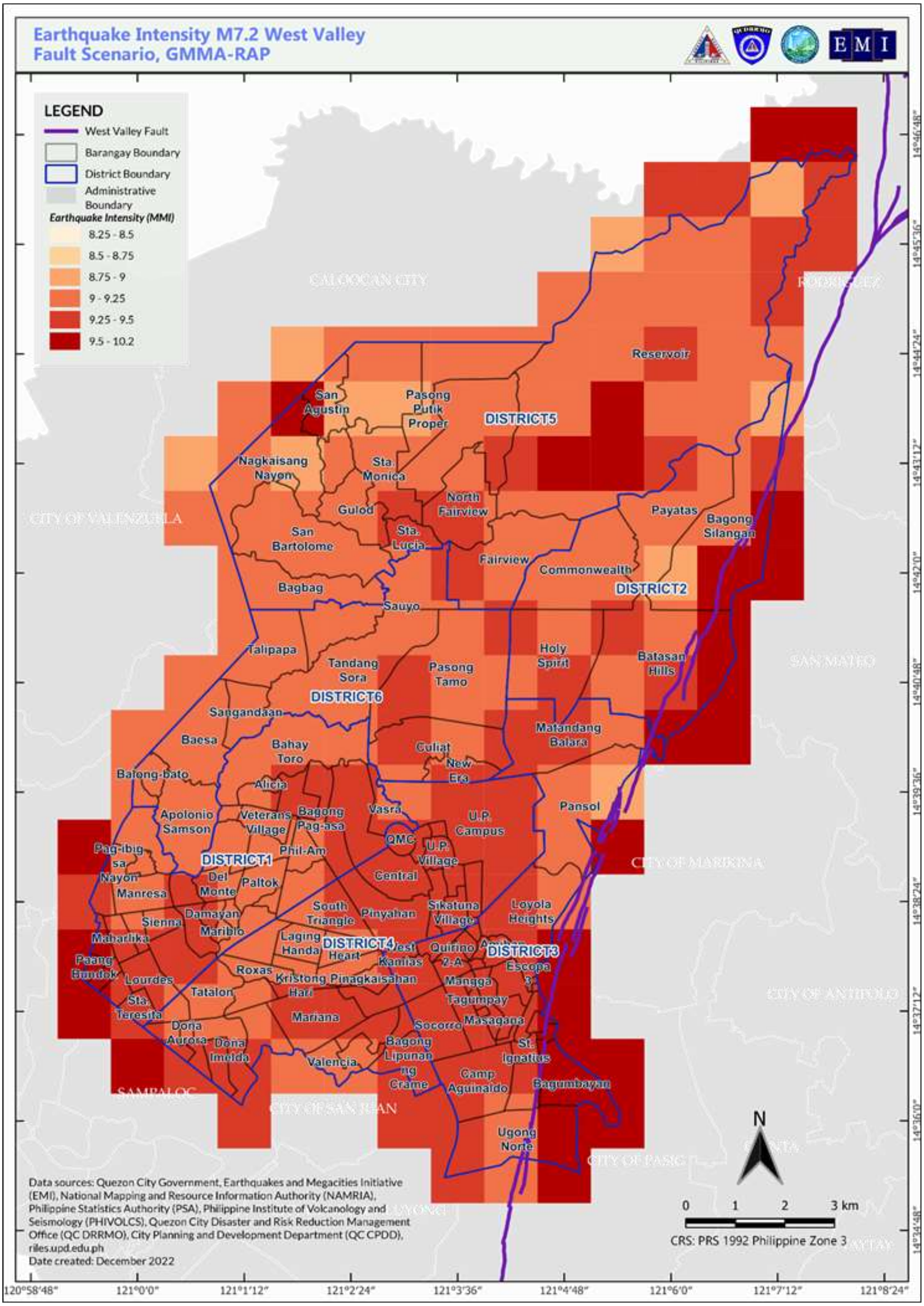


Figure 68. Earthquake intensity (in MMI) for M7.2 scenario of the Greater Metro Manila from the GMMA-RAP study

4.3. Quantifying Earthquake Hazard to Quezon City

4.3.1. Earthquake Shaking Severity

The approach taken by EMI to undertake the earthquake hazard assessment improves on the GMMA-RAP study in two ways.

- It makes use of a 2022 building-footprint level exposure data (i.e., population demographics, buildings, infrastructure and critical facilities) developed on the city and barangays' geo-political boundaries officially recognized by the Quezon City Government.

- It improves the resolution of the analysis from 1.1km by 1.1km for the GMMA-RAP study to 175m by 175m, i.e., the earthquake intensity is calculated at the centroid of a grid of 175mx 175 m instead of 1.1km x 1.1 km. This represents a resolution close to 40 times better than that of the GMMA-RAP study. The resolution of the intensity values calculated at each grid is further improved by re-sampling technique at the building-footprint level. This approach generates close to 400,000 intensity points in the total geography of Quezon City.

The severity of earthquake shaking at any location in Quezon City from the potential impact of the magnitude 7.2 WVF earthquake scenario, is dependent on two parameters: 1) the distance from the fault rupture to the site under consideration; and 2) the characteristics of the soil condition at a particular site.

Considering these two parameters, the earthquake intensity at each grid is calculated from a series of equations, generally referred to as ground motion predication models (GMPMs). A combination of GMPMs were used to best match the outputs of the GMMA-RAP M7.2 scenario for Quezon City. First, the so-called peak ground acceleration (pga) is calculated, then the pga quantities are transformed into MMI values using an empirical relationship that is available in the literature.

A sophisticated algorithm developed by EMI is used to undertake the calculations on grid of 175m x 175 m. The calculation of the distance is a simple formula. However, the development of the soil characteristics requires a highly sophisticated analytical methodology by which the soil data provided in both the GMMA-RAP study and the MMEIRS study were re-sampled to produce a specific soil parameters at each of the 175m x 175 m grids for the full geography of Quezon at the highest resolution possible. This enables a finer representation of the hazard within the city and each barangay. The software program developed by EMI is embedded into the MATLAB platform, which is a powerful engineering development platform. It enables accurate calculations of the MMI intensities at each grid as well as the re-sampling of the intensity values at the building footprint level.

4.3.2 Earthquake intensity in Modified Mercalli Intensity (MMI)

Figure 69 shows the generated earthquake intensity map (in terms of MMI) for the M7.2 on the WVF scenario for the full geography of Quezon City. When compared to the map of figure 68 generated by the GMMA-RAP study, the improvement in the resolution is clearly visible. With such resolution, barangay level and community level planning can be done with high reliability. Figure 70 to Figure 75 shows earthquake intensity distribution for the different districts of Quezon City. The maps are intended to facilitate understanding and to better informed users.

The city generally will experience earthquake intensity of 8 – 10 (MMI) in the case of a M 7.2 West Valley Fault earthquake scenario. In general, the severity of the ground motion is within the same range as the GMMA-RAP. The differences are in terms of the higher resolution.

At the level of MMI Intensity 8 to 10, there will be considerable damage even to specially designed structures. For some areas, there will be slight damage in specially designed structures and considerable damage in ordinary substantial buildings with partial collapse. Damage will be great in poorly built structures. Factory stacks, columns, monuments, and walls will fall and heavy furniture overturned. In a large part of Quezon City, well-designed concrete frame structures can be thrown out of plumb. Damage will be great in substandard buildings that are not competently designed to withstand earthquake forces and the weakest structures will experience partial or full collapse. Many smaller buildings will be shifted off foundations. Damage to structures and buildings is strongly correlated with the ground motion intensity. Also, some well-built wooden structures were destroyed; most masonry and frame structures were destroyed with foundations and rails bent. Thus, the pattern of damage severity will strongly replicate the pattern of the severity of ground shaking shown.

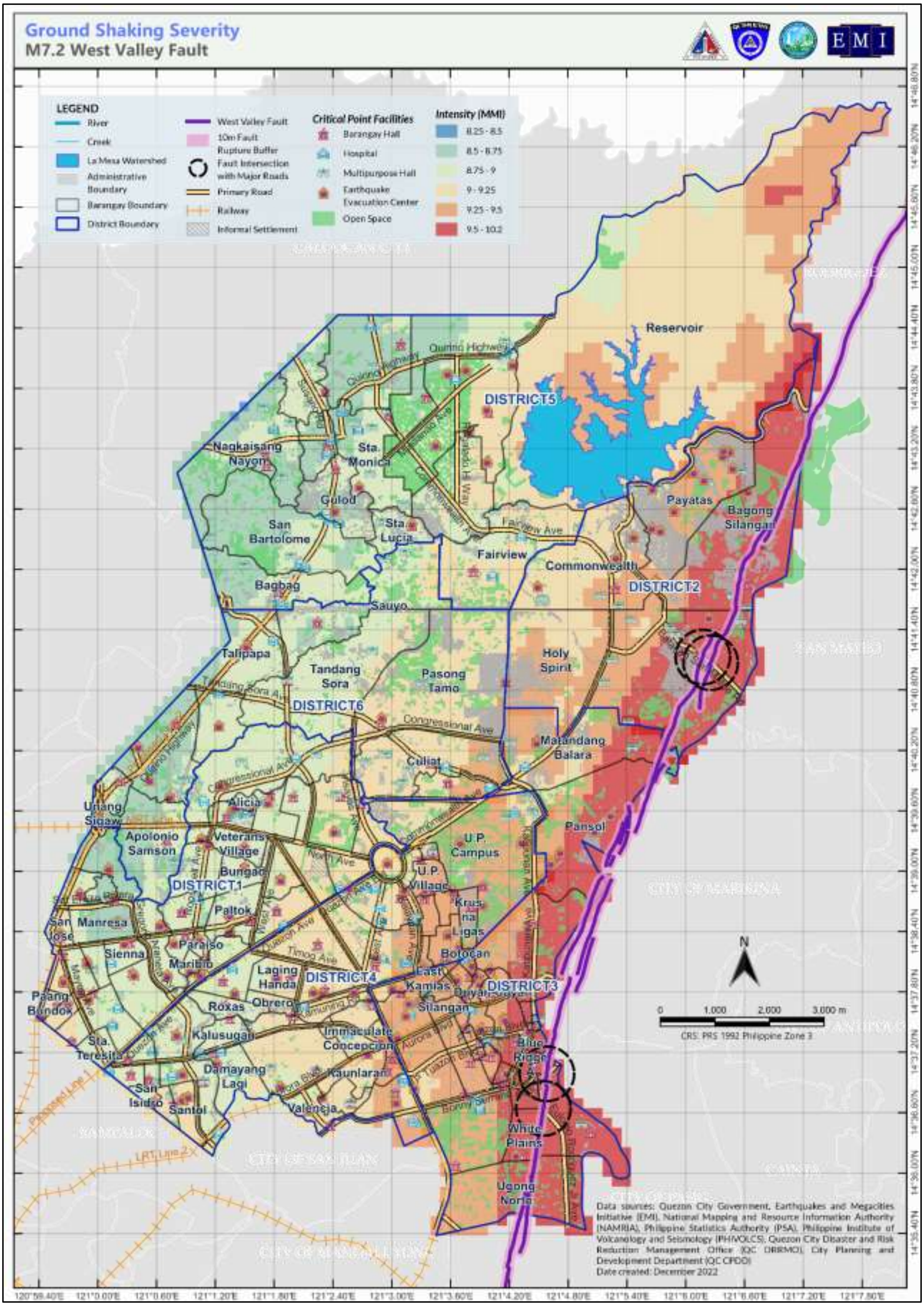


Figure 69. Ground Shaking Severity in Quezon City for an M7.2 West Valley Fault Earthquake Scenario in Modified Mercalli Intensity Scale. (Developed by EMI guided by GMMA-RAP)

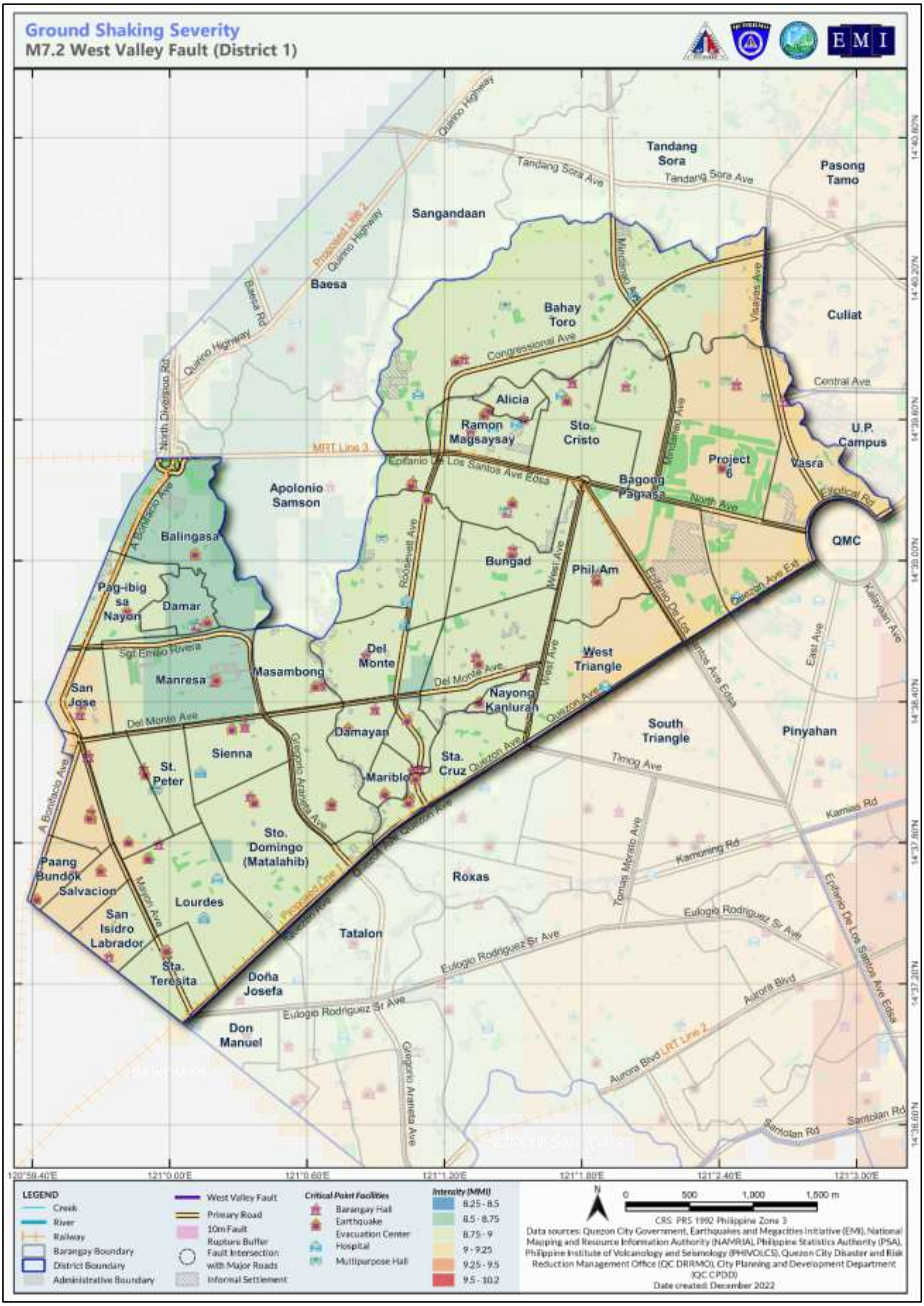


Figure 70. Ground shaking severity for a M7.2 West Valley Fault earthquake scenario for District 1

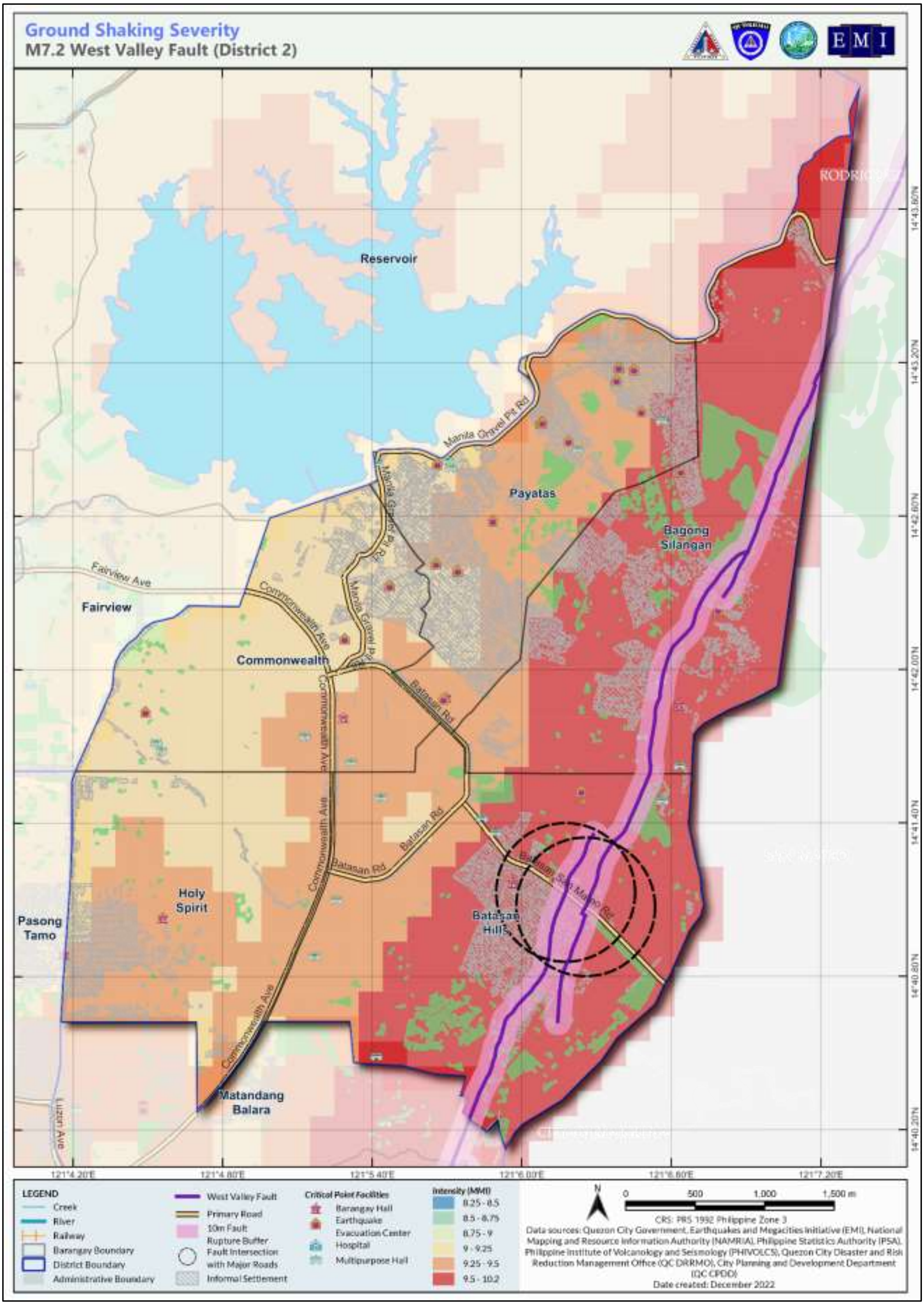


Figure 71. Ground shaking severity for a M7.2 West Valley Fault earthquake scenario for District 2

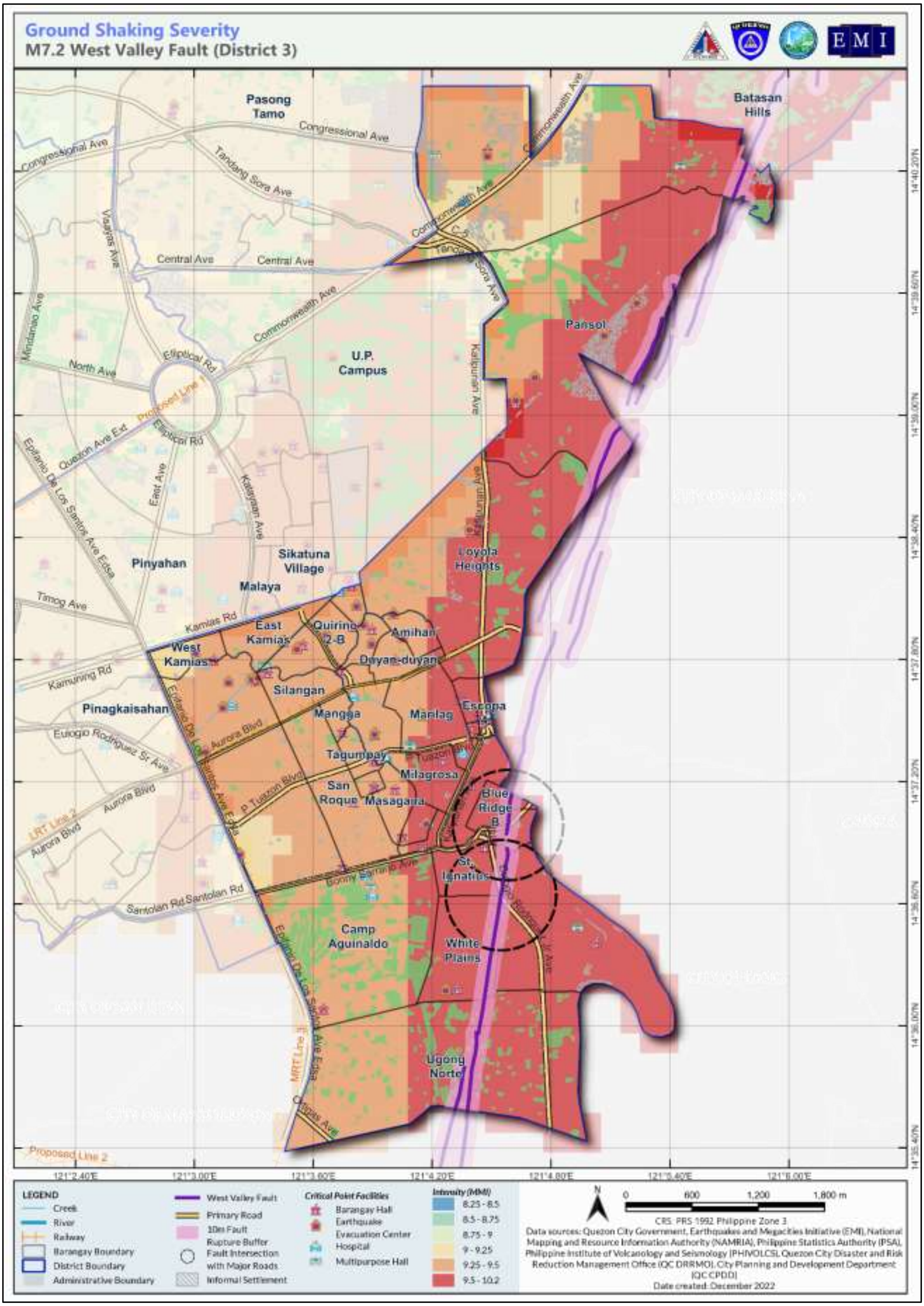


Figure 72. Ground shaking severity for a M7.2 West Valley Fault earthquake scenario for District 3

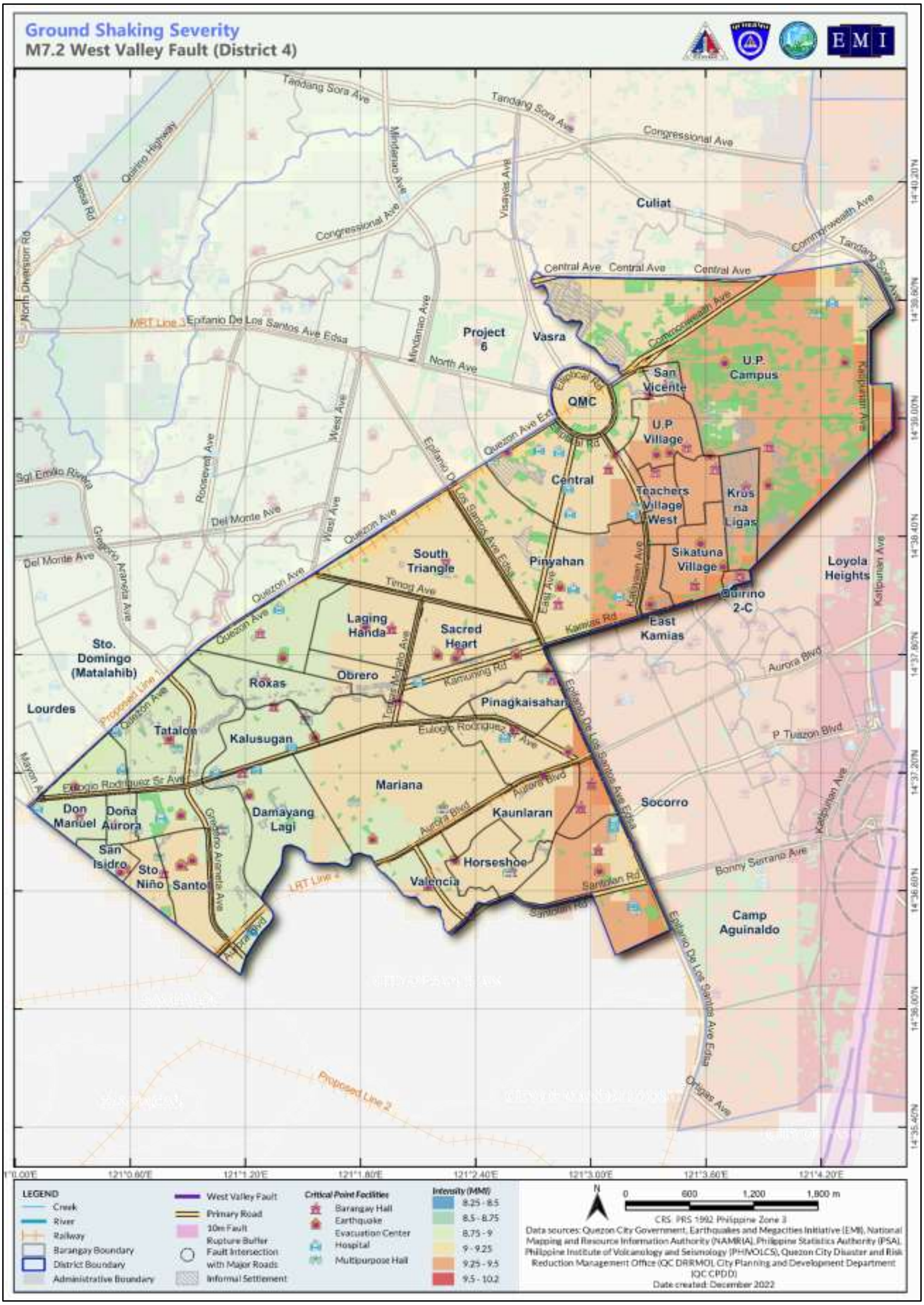


Figure 73. Ground shaking severity for a M7.2 West Valley Fault earthquake scenario for District 4

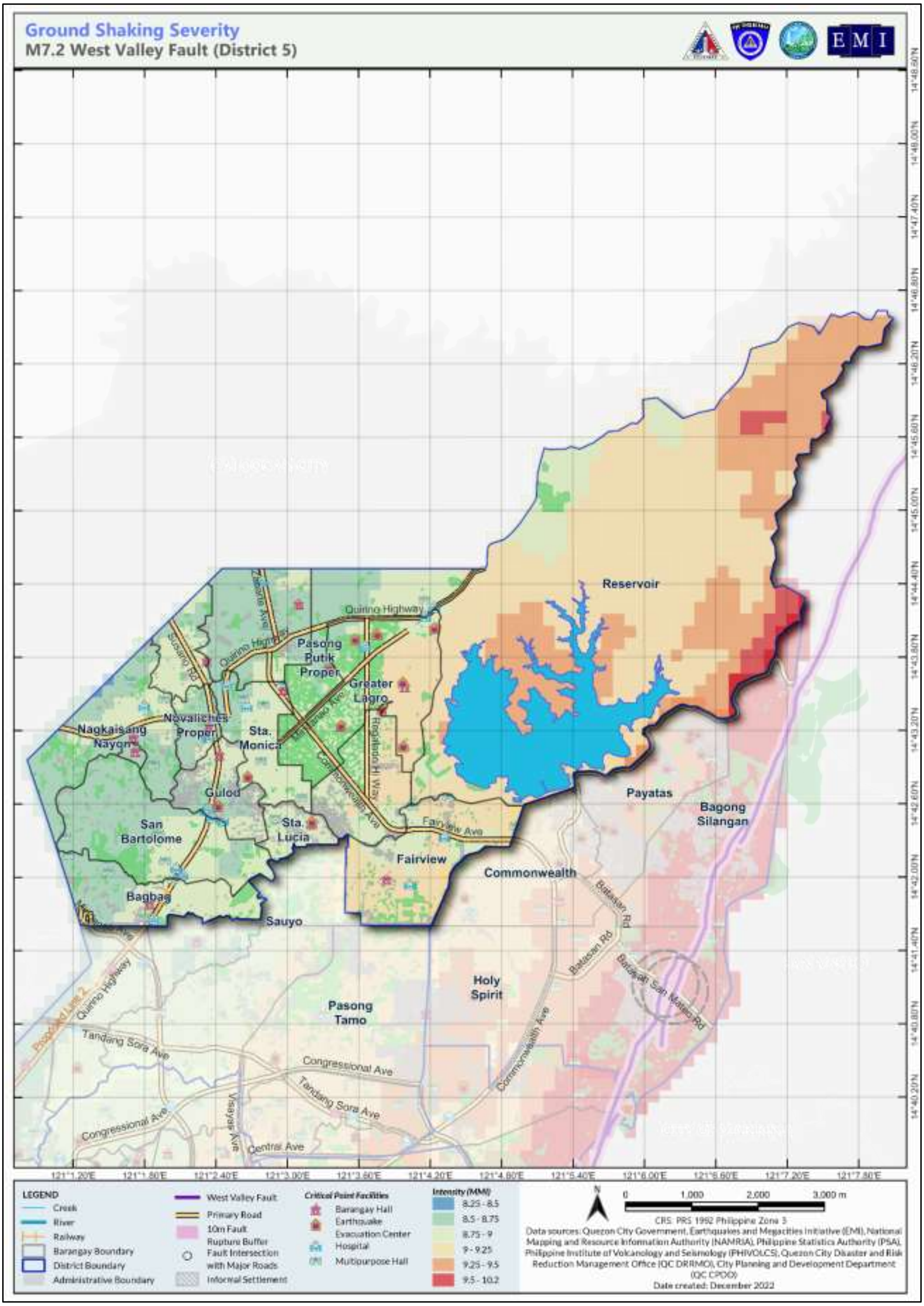


Figure 74. Ground shaking severity for a M7.2 West Valley Fault earthquake scenario for District 5

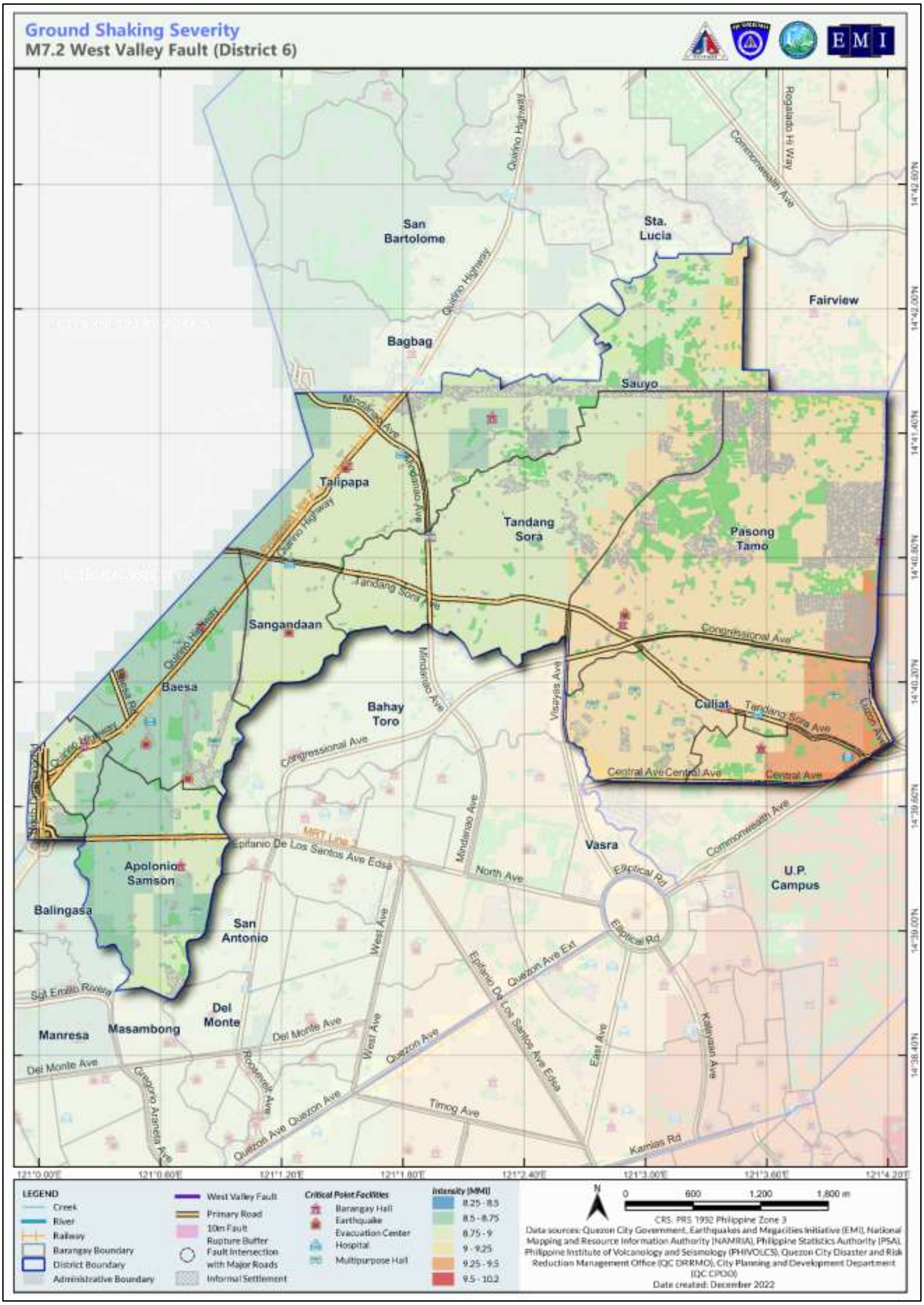


Figure 75. Ground shaking severity (MMI) for a M7.2 West Valley Fault earthquake scenario for District 6

4.3.3. Ground rupture along West Valley Fault

Ground rupture occurs when the movement caused along the fault by an earthquake breaks the Earth's surface. These ruptures can occur vertically or horizontally and on either side of the fault. Any structure built across the fault (or in the ground rupture zone) is at risk of severe structural damage and in some cases can be torn in two.

Along the West Valley Fault, there is a likelihood that ground rupture will occur in the vicinity of around five to ten meters on each side of the fault. For an M7.2, the rupture length could be as high as 1 meter. Any man-made structure within the fault zone area will be exposed to ground rupture which can cause the following effects on various built structures:

- Ground rupture can cause severe damage to buildings and in some instances their complete collapse.
- Ground rupture can displace roads and bridges and necessitate extensive repairs that will put these infrastructures out of commission until repairs are made.
- For buried pipes and structures, a rupture could translate into cracking or complete rupture of pipes, cables, and other underground structures.

Districts 2 and 3 intersects the rupture zone of the West Valley Fault. Barangays situated in the vicinity of fault are: Bagong Silangan, Batasan Hills, Matandang Balara, Pansol, Loyola Heights, Blue Ridge B, Libis, St. Ignatius, Bagumbayan, White Plains, and Ugong Norte. Major roads such as the Batasan San Mateo Road and E. Rodriguez Jr. Avenue intersects the fault rupture zone as shown in Figure 76 and Figure 77.

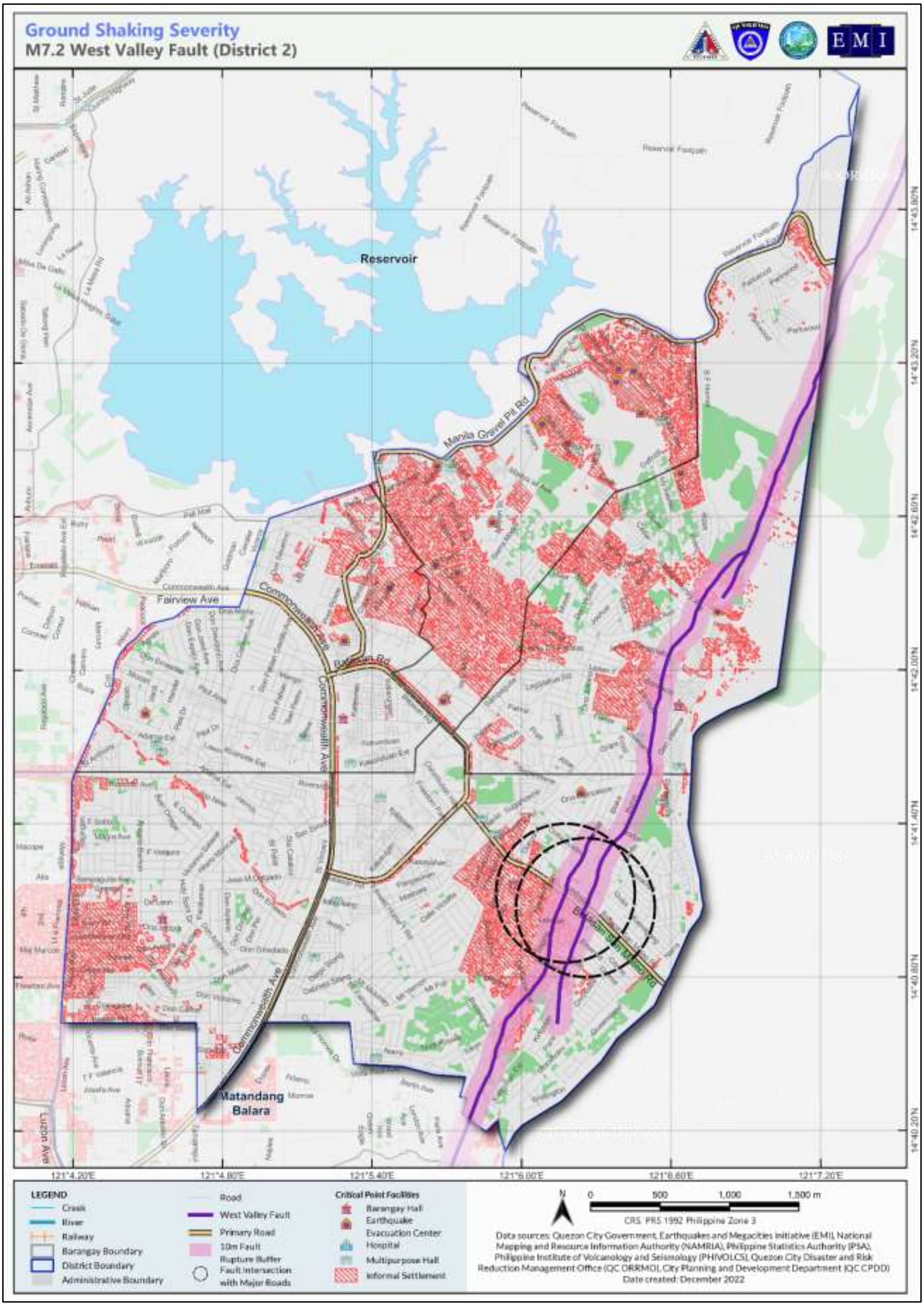


Figure 76. Intersection of District 2 along West Valley Fault with indication of major road segment along the fault trace

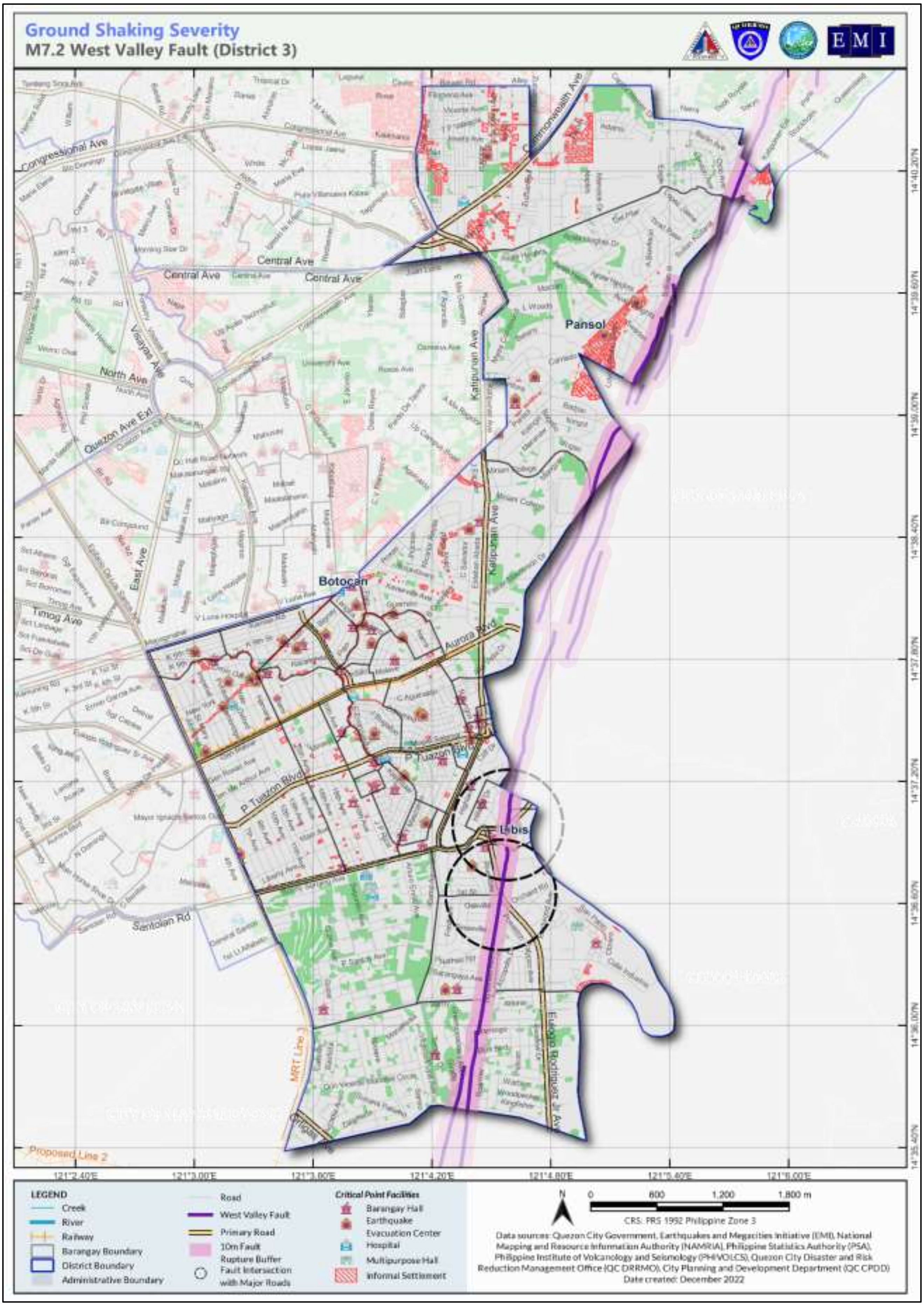


Figure 77. Intersection of District 3 along West Valley Fault with indication of major road segment along the fault trace

4.4. Earthquake Risk Assessment

4.4.1. Introduction

This section will use the estimate the potential damages and losses (i.e., risk) from the M7.2 earthquake scenario on Quezon City based on the hazard data developed in Chapter 2. The calculation of risk requires two elements: 1) The quantification of the earthquake intensity at each grid as calculated in the previous chapter; and 2) the knowledge of vulnerability of (or fragility) of buildings, critical facilities, infrastructure, and populations present in each grid. In this context, this chapter introduces both the concept of vulnerability and the concept of risk. The assessment of impact (or risk) is the most relevant to disaster risk management (DRM) planning and can inform preparedness and awareness activities.

4.4.2. The concept of risk

To better understand this concept of risk, it is important to explain its definition and the factors that comprise the analytical formulation that one uses to assess risk. By definition, risk is the likelihood for populations, the built environment or the natural environment to sustain damage (or loss) should a hazardous event take place. According to the above, risk is a probabilistic quantity, that indicates that there is some chance that a damage/loss will happen. The likelihood of loss is completely conditional on a hazardous event taking place. Without the occurrence of a hazardous event, there is simply zero risk. Also, embedded in the definition of risk is the notion of vulnerability of the exposed assets. In fact, the chances for the risk to be high are directly correlated to the vulnerability of the exposed assets, i.e., populations, built environment or natural environment. Therefore, risk can be considered to be the convolution of physical hazards and the vulnerability of exposed assets.

Risk=Function {Hazard, Vulnerability (Exposed Assets)}

While vulnerability is an inherent property of any asset (i.e., population, built environment or natural environment), risk is a calculated quantity. A risk value represents a quantity of damage (e.g., damage to buildings or bridges) or loss (e.g., loss of life or economic loss).
Typically, ground shaking will cause the most damage during and after an earthquake in terms of the number of structures that will be impacted in various parts of Quezon City.

4.4.3. Building damage approach

It is not economically possible to assess the capacity of each building and how it will withstand ground shaking. To streamline analyses, buildings are grouped into typical construction classes that have shown to exhibit similar patterns of damage in the past. Empirical data and available earthquake engineering knowledge are used to develop **fragility** and **vulnerability** functions, which are then applied to estimate the potential damages to each construction class. Building fragility functions are engineering quantities that provide the probability of exceedance of specific damage states for a particular building class as a function of the earthquake intensity. On the other hand, vulnerability curves provide the cumulative distribution function of the damage ratio of a particular building class as a function of the earthquake intensity. The **damage ratio** is defined as the cost of repairing the earthquake-caused damage to the building over the replacement cost value of the building.

In order to calculate the impact of the M7.2 WVF earthquake scenario, both fragility functions and vulnerability functions for all the building classes must be developed and applied to each building class at each 175m x 175 m grid. The results at the grid level are aggregated to calculate the damage by barangay. The latter are aggregated for the 142 barangays to develop the city-level damage and loss values.

The fragility functions used by EMI have been developed by engineers and scientists at the UPD-ICE (Tingatinga, et al., 2019) and are the same as the ones used in the GMMA-RAP study. This is the current state-of-the-art approach to evaluate the performance of different building types to earthquake shaking and to estimate building damage. Similarly, the same damage states the GMMA-RAP are considered, namely: none, slight, moderate, extensive, collapse and complete collapse. Coefficient table is presented in the paper by Tingatinga et. al., 2019. Some of these values are similar to the input parameters presented in the GMMA-RAP report based on the illustrations for the different fragility and vulnerability models. The analysis assumes that the coefficients from the reference paper are the most recent values from the same team that developed the models for GMMA-RAP.

4.4.4. Building damage results

For an M7.2 WVF earthquake scenario, and following the approach taken by the GMMA-RAP study, the building damage for the different barangays in Districts 1 to 6 in Quezon City can be estimated in terms of building floor area (m^2) associated with each damage state. The results are shown in Table 42 to Table 47.

Table 42. District 1 damaged floor area at each damage state (m^2) for M7.2 West Valley Fault earthquake scenario.

Barangay	Complete with Collapse	Complete without Collapse	Extensive	Moderate	Slight	None
Alicia	1,509	11,646	9,827	8,723	3,669	42,752
Bagong Pag-asa	25,733	270,356	134,062	90,296	41,774	526,769
Bahay Toro	73,912	562,079	274,200	215,107	97,052	905,819
Balingasa	12,324	101,238	58,473	49,892	23,367	243,922
Bungad	13,480	109,488	60,783	45,228	19,745	200,837
Damar	6,377	44,282	21,325	17,609	8,380	63,334
Damayan	5,028	39,749	19,741	16,123	7,444	73,976
Del Monte	10,405	88,954	44,675	35,326	16,389	175,182
Katipunan	2,394	20,536	11,132	8,949	4,139	46,168
Lourdes	16,290	131,107	84,865	68,334	29,983	349,594
Maharlika	10,394	80,395	44,673	34,656	15,376	156,744
Manresa	16,746	150,371	85,393	70,574	32,931	387,899
Mariblo	2,822	23,712	12,041	9,874	4,586	49,800
Masambong	8,486	68,510	35,927	28,068	12,666	132,372
N. S. Amoranto (Gintong Silahis)	10,122	85,173	44,600	36,469	17,387	190,410
Nayong Kanluran	39,653	294,346	181,202	155,607	70,891	649,738
Paang Bundok	4,661	35,860	16,535	11,578	4,760	43,789
Pag-ibig sa Nayon	6,259	53,501	30,788	25,705	11,698	132,987
Paltok	18,728	148,923	71,639	55,145	24,770	234,816
Paraiso	3,116	24,889	15,272	12,643	5,573	61,407
Phil-Am	13,668	100,384	43,058	30,859	13,630	112,831
Project 6	23,142	170,948	80,059	55,214	24,025	273,123
Ramon Magsaysay	6,917	68,729	37,782	29,268	13,525	162,156
Salvacion	12,224	90,615	49,794	41,648	18,858	177,087
San Antonio	44,647	345,123	206,530	168,061	76,931	795,568
San Isidro Labrador	11,423	92,863	39,909	28,581	12,688	121,731
San Jose	5,874	52,674	26,012	19,225	8,539	93,714
Sienna	13,158	96,193	37,276	23,049	8,977	75,456

Barangay	Complete with Collapse	Complete without Collapse	Extensive	Moderate	Slight	None
St. Peter	6,117	54,056	22,724	15,631	6,647	66,141
Sta. Cruz	11,056	84,814	40,377	30,672	13,948	135,526
Sta. Teresita	15,271	118,397	49,684	39,063	18,031	162,858
Sto. Cristo	16,944	200,053	109,288	71,522	33,501	464,062
Sto. Domingo	27,172	227,442	117,352	84,435	38,474	404,961
Talayan	10,996	86,286	42,395	33,355	15,461	150,221
Vasra	13,796	111,772	66,804	44,306	18,447	189,425
Veterans Village	17,871	138,547	66,931	49,470	22,430	217,850
West Triangle	17,915	151,228	70,942	49,996	22,222	226,331

Table 43. District 2 damaged floor area at each damage state (m2) for M7.2 West Valley Fault earthquake scenario.

Barangay	Complete with Collapse	Complete without Collapse	Extensive	Moderate	Slight	None
Bagong Silangan	105,578	811,085	248,166	135,702	51,012	435,721
Batasan Hills	193,220	1,419,615	437,579	231,228	84,856	690,097
Commonwealth	93,535	699,300	326,653	227,956	91,059	820,604
Holy Spirit	97,605	734,007	324,999	217,970	86,373	757,676
Payatas	92,038	740,552	287,017	186,821	75,642	670,496

Table 44. District 3 damaged floor area at each damage state (m2) for M7.2 West Valley Fault earthquake scenario.

Barangay	Complete with Collapse	Complete without Collapse	Extensive	Moderate	Slight	None
Amihan	5,363	37,839	11,959	7,225	2,834	34,428
Bagumbayan	92,111	964,165	279,357	119,159	49,203	502,074
Bagumbuhay	9,685	74,173	26,399	15,295	6,122	59,397
Bayanihan	1,904	16,521	8,208	4,606	1,651	16,685
Blue Ridge A	10,338	72,697	17,672	8,982	3,263	30,076
Blue Ridge B	7,160	48,919	12,278	5,762	1,923	14,995
Camp Aguinaldo	30,095	212,690	97,536	56,423	20,775	179,928
Claro (Quirino 3-B)	4,043	29,628	13,875	8,456	3,056	27,035
Dioquino Zobel	1,822	13,944	4,855	2,888	1,130	10,252
Duyan-duyan	6,072	48,158	22,057	12,491	4,567	43,160
E. Rodriguez	25,111	212,471	91,159	57,448	23,554	234,283
East Kamias	9,425	69,455	32,474	21,024	8,020	69,979
Escopa 1	502	3,494	2,210	1,026	284	2,907
Escopa 2	474	3,511	2,167	933	246	2,792
Escopa 3	2,642	21,309	7,129	3,680	1,341	12,101
Escopa 4	790	5,537	1,532	775	274	2,081
Libis	2,870	21,833	6,320	2,907	1,003	8,782
Loyola Heights	78,706	648,006	222,146	117,472	45,360	411,940
Mangga	4,712	38,789	18,989	10,036	3,791	38,734
Marilag	22,438	161,240	54,464	30,352	11,404	111,146
Masagana	6,861	47,429	14,041	8,332	3,225	44,087
Matandang Balara	91,775	700,511	254,823	156,484	62,254	544,892

Barangay	Complete with Collapse	Complete without Collapse	Extensive	Moderate	Slight	None
Milagrosa	11,227	81,759	26,011	14,706	5,552	56,373
Pansol	68,792	514,796	215,976	117,048	40,192	349,503
Quirino 2-A	4,514	33,627	24,888	15,971	5,451	51,604
Quirino 2-B	6,484	45,730	16,679	10,208	3,939	32,110
Quirino 2-C	3,058	21,349	7,423	4,597	1,772	17,886
Quirino 3-A	3,068	25,955	10,322	5,584	2,289	23,879
San Roque	25,432	206,374	80,300	47,329	18,539	171,817
Silangan	51,206	506,114	218,299	124,786	52,712	558,946
Socorro	32,349	348,561	165,645	105,110	47,344	548,951
St. Ignatius	7,714	64,955	28,817	21,942	10,431	106,052
Tagumpay	3,622	30,854	12,480	7,534	2,951	31,495
Ugong Norte	110,849	837,986	264,357	135,063	48,994	452,927
Villa Maria Clara	3,313	23,328	6,867	4,015	1,549	20,250
West Kamias	5,529	42,833	20,971	14,233	5,707	54,679
White Plains	26,052	178,538	52,114	28,828	10,508	76,840

Table 45. District 4 damaged floor area for each damaged state (m^2) for M7.2 West Valley Fault earthquake scenario.

Barangay	Complete with Collapse	Complete without Collapse	Extensive	Moderate	Slight	None
Bagong Lipunan ng Crame	26,455	226,221	104,367	64,613	25,918	244,783
Botocan	1,206	10,882	3,544	2,229	927	8,838
Central	24,429	238,687	127,989	78,820	34,529	386,307
Damayang Lagi	16,286	136,945	60,763	46,421	21,490	216,412
Doña Aurora	3,263	24,193	14,167	11,771	5,148	53,397
Doña Imelda	19,895	211,271	112,449	75,730	35,208	447,950
Doña Josefa	5,613	50,734	31,926	24,638	11,062	138,966
Don Manuel	5,322	44,206	25,047	19,642	8,745	95,531
Horseshoe	8,142	58,651	28,300	19,410	7,704	67,440
Immaculate	13,801	116,197	57,992	37,312	15,269	154,916
Kalusugan	12,211	106,539	62,041	45,060	20,837	234,875
Kamuning	12,426	96,956	41,828	28,953	12,302	113,788
Kaunlaran	16,720	145,691	65,104	42,515	17,582	167,558
Kristong Hari	6,817	61,332	34,216	24,401	10,275	108,213
Krus na Ligas	12,024	88,304	37,948	23,265	8,756	73,557
Laging Handa	18,197	151,394	67,276	46,666	20,640	195,094
Malaya	3,208	28,390	13,584	7,891	3,194	32,976
Mariana	43,654	318,951	151,700	109,791	46,663	425,960
Obrero	4,228	37,374	21,140	16,337	6,976	75,436
Old Capitol Site	2,966	27,011	11,056	7,442	3,215	31,443
Paligsahan	12,448	130,697	69,784	48,004	22,336	270,104
Pinagkaisahan	6,660	54,436	41,808	28,657	10,815	115,853
Pinyahan	33,146	291,762	140,674	89,895	38,169	396,873
Roxas	8,984	65,013	36,116	29,214	12,649	125,015
Sacred Heart	14,032	117,770	59,800	40,654	16,853	169,960

Barangay	Complete with Collapse	Complete without Collapse	Extensive	Moderate	Slight	None
San Isidro	6,920	54,491	24,368	19,014	8,508	83,300
San Martin de Porres	6,014	56,484	27,837	17,647	7,098	71,948
San Vicente	2,227	17,330	8,914	5,560	2,212	36,481
Santol	53,349	405,120	191,507	152,378	69,022	629,421
Sikatuna Village	9,131	75,057	30,642	18,556	7,494	74,109
South Triangle	10,697	76,818	26,331	13,837	4,859	42,472
Sto. Niño	4,651	36,612	16,183	12,755	5,721	55,585
Tatalon	18,560	172,980	87,144	67,720	31,997	374,082
Teachers Village East	7,143	55,449	20,966	13,016	5,227	44,550
Teachers Village West	7,973	56,156	19,954	12,864	5,153	42,109
U. P. Campus	58,428	464,656	228,766	138,571	55,612	549,044
U. P. Village	10,798	78,633	32,847	20,408	8,125	70,788
Valencia	14,497	153,296	67,100	43,023	19,079	194,110

Table 46. District 5 damaged floor area at each damage state (m^2) for M7.2 West Valley Fault earthquake scenario.

Barangay	Complete with Collapse	Complete without Collapse	Extensive	Moderate	Slight	None
Bagbag	23,179	186,454	97,621	84,984	40,489	437,962
Capri	2,151	15,514	7,890	6,856	3,334	29,184
Fairview	56,981	426,100	187,794	133,324	57,715	508,915
Greater Lagro	45,957	357,340	160,428	111,171	48,596	450,335
Gulod	19,158	155,769	72,534	61,425	29,846	306,461
Kaligayahan	31,200	232,876	126,913	110,032	52,665	532,718
Nagkaisang Nayon	6,608	52,838	25,662	18,428	7,798	74,859
North Fairview	16,298	126,395	69,704	42,798	16,762	166,190
Novaliches Proper	30,975	234,819	96,590	71,752	32,039	272,567
Pasong Putik Proper	23,839	200,424	100,959	81,714	38,858	418,220
San Agustin	15,294	126,329	68,441	55,483	25,216	271,671
San Bartolome	3,472	27,897	12,125	9,029	4,059	38,359
Sta. Lucia	30,755	230,826	119,300	100,635	46,585	469,357
Sta. Monica	10,766	88,070	46,248	34,452	15,703	178,344

Table 47. District 6 damaged floor area at each damage state (m^2) for M7.2 West Valley Fault earthquake scenario.

Barangay	Complete with Collapse	Complete without Collapse	Extensive	Moderate	Slight	None
Apolonio Samson	44,140	371,421	214,587	178,772	82,578	897,894
Baesa	41,124	312,197	189,806	164,072	74,743	744,194
Balong-bato	7,540	54,173	34,309	28,968	12,775	122,315
Culiat	73,846	566,664	218,338	149,938	63,785	550,192
New Era	4,130	34,625	15,809	11,547	5,245	51,991
Pasong Tamo	121,196	890,841	345,992	241,189	102,452	832,819
Sangandaan	24,723	179,089	89,037	73,256	34,006	301,940
Sauyo	11,757	91,220	44,989	33,846	15,600	151,083
Talipapa	38,550	298,114	150,387	122,421	57,143	545,745

Barangay	Complete with Collapse	Complete without Collapse	Extensive	Moderate	Slight	None
Tandang Sora	102,592	759,537	340,638	262,246	117,618	1,007,603
Unang Sigaw	2,097	20,828	12,364	11,015	5,211	68,424

4.4.5 Casualty modeling approach

The primary cause of fatalities in earthquakes is due to building collapse. Estimates of people affected are an important source of information for planning and emergency response. At present, building codes are not retroactive and there are no mandatory requirements for building owners to assess their buildings or to eventually retrofit them to bring them to current earthquake engineering standards. This means that older buildings may not be built to current standards and are likely to sustain more damage, if not collapse. Retrofitting buildings is a complex process that requires high level of earthquake engineering expertise and could be extremely costly and inconvenient. Experience has shown that establishing public policy and related regulations for earthquake retrofit could take several years (if not decades), and could be quite challenging to put in place, particularly for large commercial and residential buildings.

Thus, the casualty estimations provided below should be interpreted within the limitations indicated above. They are mainly provided as parameters for planning and preparedness. That is the full benefit of undertaking earthquake scenarios and simulations.

Injury Classification

In earthquake engineering, casualties and injuries are split into three categories:

- Non-life-threatening injuries (essentially people that do not need to immediately go to the hospital and generally can treat themselves),
- Life-threatening injuries (people who need to go to the hospital), and
- Fatalities.

By classifying casualties and injuries into three categories, public institutions can plan for the number of people that will need to receive medical care to survive during a specific magnitude earthquake event.
The GMMA-RAP presented 4 injury severity levels with descriptions and factors at which the fraction of the population at a specific building damage state will be identified at the different injury severity levels. Table 48 enumerates classification from HAZUS methodology used in the GMMA-RAP study. It should be noted that the HVRA+H combined levels 1 and 2 to comprise non-life-threatening injuries, level 3 for life-threatening and level 4 for loss of life. HAZUS is the official loss estimation tool for the US federal government. Its methodology is widely used in loss estimation and is considered to be state-of-the-art.

Table 48. Injury classification based on Hazus methodology (GMMA-RAP, 2013)

Injury Severity Level	Description
1	Injuries require basic medical aid that could be administered by paraprofessionals. These types of injuries would require bandages or observation. Some examples are a sprain, a severe cut requiring stitches, a minor burn (first degree or second degree on a small part of the body), or a bump on the head without loss of consciousness. Injuries of lesser severity that could be self-treated are not estimated.
2	Injuries requiring a greater degree of medical care and use of medical technology such as x-rays or surgery, but not expected to progress to a life-threatening status. Some

	examples are third-degree burns or second-degree burns over large parts of the body, a bump on the head that causes loss of consciousness, fractured bone, dehydration or exposure.
3	Injuries that pose an immediately life-threatening condition if not treated adequately and expeditiously. Some examples are: uncontrolled bleeding, punctured organ, other internal injuries, spinal column injuries, or crush syndrome.
4	Instantaneously killed or mortally injured

4.4.5. Casualty results

The estimated number of people in a certain injury severity level is equal to the product of indoor casualty rate, damage probability and population for each unit. For each severity level, the number of people from all damage states is summed to obtain the number of people in a severity level. Estimated number of casualties for Districts 1 to 6 in Quezon City is presented in Table 49 to Table 54. Figure 78 to Figure 83 show the distribution of severe and life-threatening injuries. Figure 84 to Figure 89 present the distribution of fatalities for Districts 1 to 6. Total estimated casualties for Quezon City are presented in

Table 55.

An important limitation of the casualty calculations is that the estimates do not consider the potential of one or multiple large high occupancy building(s) collapsing and causing major loss of life. As explained previously, the state-of-the-art in loss estimation is based on empirical relations of patterns of damage to typical construction classes across a city. It is not based on a building-specific assessment. A building-by-building assessment may be necessary for older high occupancy buildings under separate initiatives that should be backed up by specific public policy and regulation. The casualty estimations provided below should be interpreted within the limitations indicated above.

Table 49. Estimated casualties/injuries for a M7.2 West Valley Fault earthquake scenario caused by building damage for District 1

Barangay	Slight Injuries	Serious Injuries	Life-threatening Injuries	Fatalities
Alicia	112	37	6	13
Bagong Pag-asa	491	155	24	47
Bahay Toro	2,077	706	126	250
Balingasa	452	150	26	51
Bungad	149	50	9	17
Damar	54	19	3	7
Damayan	230	78	14	27
Del Monte	314	104	18	35
Katipunan	64	21	4	7
Lourdes	100	33	6	11
Maharlika	104	35	6	12
Manresa	512	166	28	55
Mariblo	100	33	6	11
Masambong	339	113	20	39
N. S. Amoranto (Gintong Silahis)	319	106	18	36
Nayong Kanluran	762	258	46	92
Paang Bundok	182	62	11	22
Pag-ibig sa Nayon	119	39	7	13
Paltok	499	168	30	58
Paraiso	84	28	5	10
Phil-Am	78	27	5	10
Project 6	502	172	31	62
Ramon Magsaysay	341	108	18	34
Salvacion	461	157	28	56
San Antonio	1,714	576	102	202
San Isidro Labrador	358	120	21	41
San Jose	161	53	9	17
Sienna	88	31	6	11
St. Peter	89	29	5	10
Sta. Cruz	135	46	8	16
Sta. Teresita	268	91	16	32
Sto. Cristo	251	77	11	22
Sto. Domingo (Matalahib)	389	129	22	44
Talayan	166	56	10	20
Vasra	267	89	16	31
Veterans Village	432	146	26	51
West Triangle	130	43	7	15

Table 50. Estimated casualties/injuries for a M7.2 West Valley Fault earthquake scenario caused by building damage for District 2

Barangay	Slight Injuries	Serious Injuries	Life-threatening Injuries	Fatalities
Bagong Silangan	4,972	1,714	307	607
Batasan Hills	8,863	3,085	563	1,116
Commonwealth	7,259	2,485	447	885
Holy Spirit	4,440	1,521	273	541
Payatas	5,530	1,874	329	649

Table 51. Estimated casualties/injuries for a M7.2 West Valley Fault earthquake scenario caused by building damage for District 3

Barangay	Slight Injuries	Serious Injuries	Life-threatening Injuries	Fatalities
Amihan	215	75	14	28
Bagumbayan	1,044	336	54	107
Bagumbuhay	293	101	18	36
Bayanihan	42	14	2	5
Blue Ridge A	104	37	7	14
Blue Ridge B	103	36	7	14
Camp Aguinaldo	184	64	12	23
Claro (Quirino 3-B)	169	58	11	21
Dioquino Zobel	85	29	5	10
Duyan-duyan	163	55	10	19
E. Rodriguez	672	224	39	76
East Kamias	221	76	14	27
Escopa 1	87	30	6	11
Escopa 2	60	20	4	7
Escopa 3	401	136	24	47
Escopa 4	114	40	7	15
Libis	187	65	12	23
Loyola Heights	912	308	54	107
Mangga	35	12	2	4
Marilag	420	147	27	53
Masagana	189	67	12	25
Matandang Balara	2,919	1,003	180	356
Milagrosa	289	101	18	37
Pansol	1,863	640	115	229
Quirino 2-A	160	54	10	19
Quirino 2-B	120	42	8	15
Quirino 2-C	126	44	8	16
Quirino 3-A	41	14	2	5
San Roque	780	264	46	92
Silangan	1,250	403	66	130
Socorro	648	204	32	63
St. Ignatius	80	27	5	9
Tagumpay	81	27	5	9

Barangay	Slight Injuries	Serious Injuries	Life-threatening Injuries	Fatalities
Ugong Norte	570	197	36	71
Villa Maria Clara	118	42	8	15
West Kamias	148	50	9	18
White Plains	344	122	23	45

Table 52. Estimated casualties/injuries for a M7.2 West Valley Fault earthquake scenario caused by building damage for District 4

Barangay	Slight Injuries	Serious Injuries	Life-threatening Injuries	Fatalities
Bagong Lipunan ng Crame	597	198	34	68
Botocan	324	108	18	35
Central	386	123	20	40
Damayang Lagi	552	184	32	62
Doña Aurora	140	47	9	17
Doña Imelda	303	95	15	29
Doña Josefa	45	14	2	5
Don Manuel	86	28	5	10
Horseshoe	114	39	7	14
Immaculate Concepcion	260	86	15	29
Kalusugan	15	5	1	2
Kamuning	500	170	30	60
Kaunlaran	243	81	14	27
Kristong Hari	112	37	6	12
Krus na Ligas	893	308	56	111
Laging Handa	271	91	16	31
Malaya	137	45	8	15
Mariana	363	125	23	45
Obrero	203	66	11	22
Old Capitol Site	18	6	1	2
Paligsahan	152	48	8	15
Pinagkaisahan	158	52	9	18
Pinyahan	805	265	45	89
Roxas	543	186	34	67
Sacred Heart	238	79	14	27
San Isidro	557	188	33	66
San Martin de Porres	361	117	19	38
San Vicente	236	79	14	28
Santol	1,021	348	62	123
Sikatuna Village	213	72	12	25
South Triangle	143	50	9	18
Sto. Niño	323	109	19	38
Tatalon	1,573	510	84	165
Teachers Village East	134	46	8	16
Teachers Village West	193	67	12	25
U. P. Campus	2,025	681	120	238
U. P. Village	220	76	14	28

Barangay	Slight Injuries	Serious Injuries	Life-threatening Injuries	Fatalities
Valencia	278	88	14	28

Table 53. Estimated casualties/injuries for a M7.2 West Valley Fault earthquake scenario caused by building damage for District 5

Barangay	Slight Injuries	Serious Injuries	Life-threatening Injuries	Fatalities
Bagbag	2,227	745	130	257
Capri	474	163	30	59
Fairview	2,062	707	127	252
Greater Lagro	815	277	49	97
Gulod	1,337	448	78	154
Kaligayahan	1,514	514	92	183
Nagkaisang Nayon	210	71	12	25
North Fairview	842	284	50	100
Novaliches Proper	1,071	367	66	130
Pasong Putik Proper	960	319	55	108
San Agustin	814	270	47	92
San Bartolome	82	28	5	10
Sta. Lucia	1,714	583	104	207
Sta. Monica	462	154	27	53

Table 54. Estimated casualties/injuries for a M7.2 West Valley Fault earthquake scenario caused by building damage for District 6

Barangay	Slight Injuries	Serious Injuries	Life-threatening Injuries	Fatalities
Apolonio Samson	890	293	50	99
Baesa	1,565	527	94	185
Balong-bato	215	73	13	26
Culiat	3,062	1,049	188	371
New Era	277	92	16	32
Pasong Tamo	5,037	1,741	316	626
Sangandaan	676	232	42	84
Sauyo	508	172	31	61
Talipapa	938	317	56	111
Tandang Sora	3,136	1,076	194	385
Unang Sigaw	140	44	7	14

Table 55. Estimated total casualties of Quezon City for a M7.2 West Valley Fault earthquake scenario

Total	Slight Injuries	Serious Injuries	Life-threatening Injuries	Fatalities
Quezon City	104,955	35,618	6,317	12,494

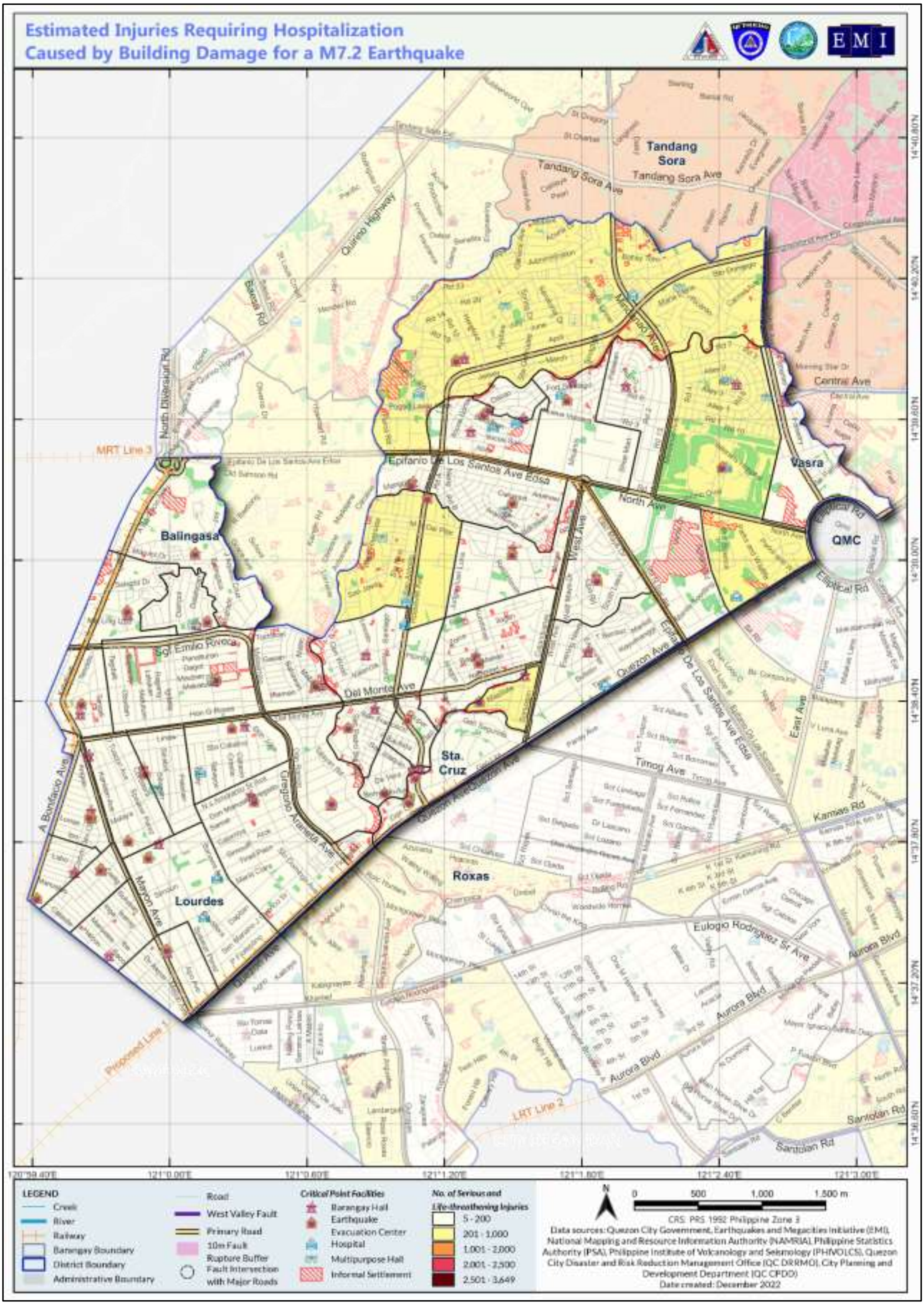


Figure 78. District 1 injuries requiring hospitalization for an M7.2 West Valley Fault earthquake scenario caused by building damage.

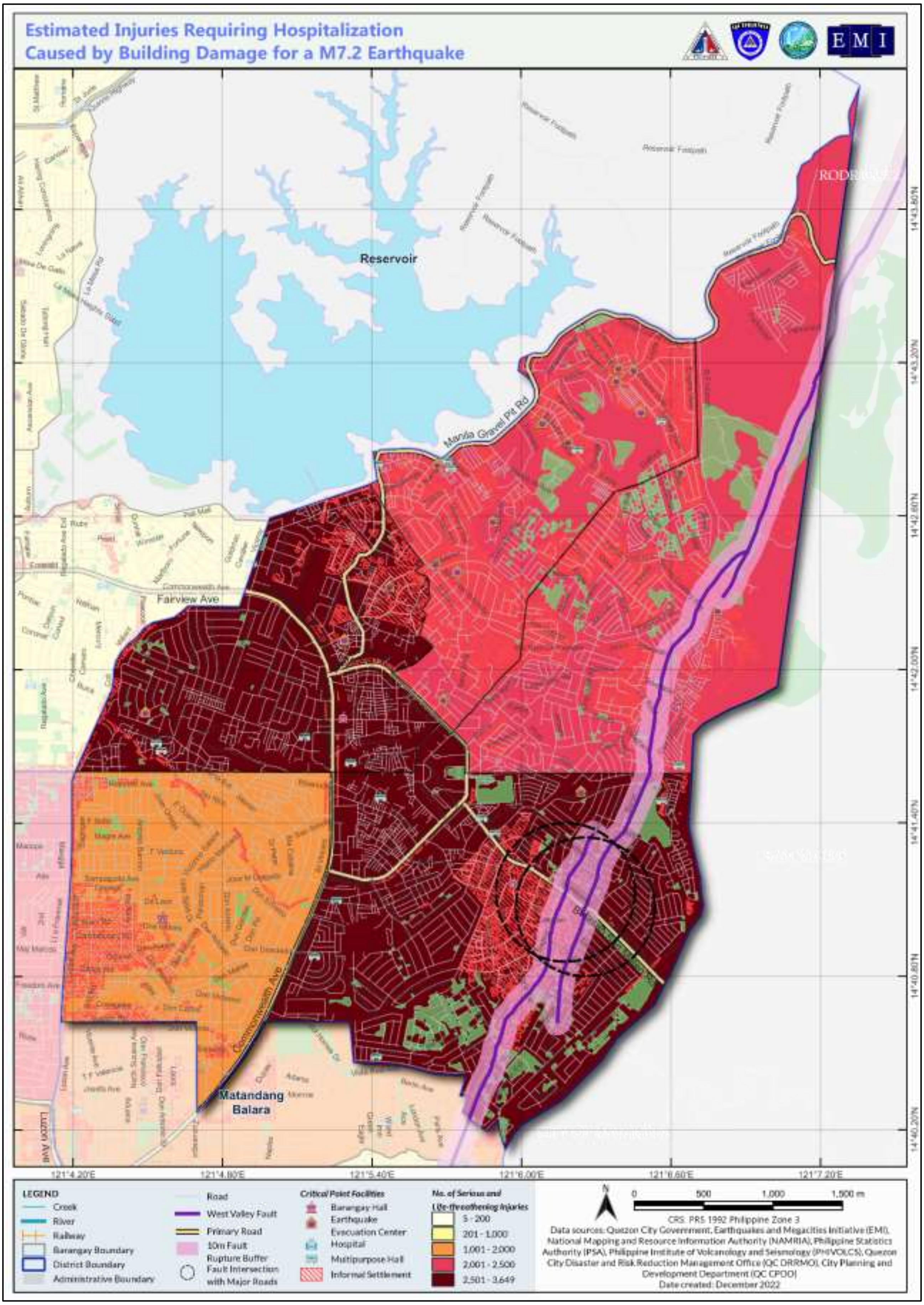


Figure 79. District 2 injuries requiring hospitalization for an M7.2 West Valley Fault earthquake scenario caused by building damage.

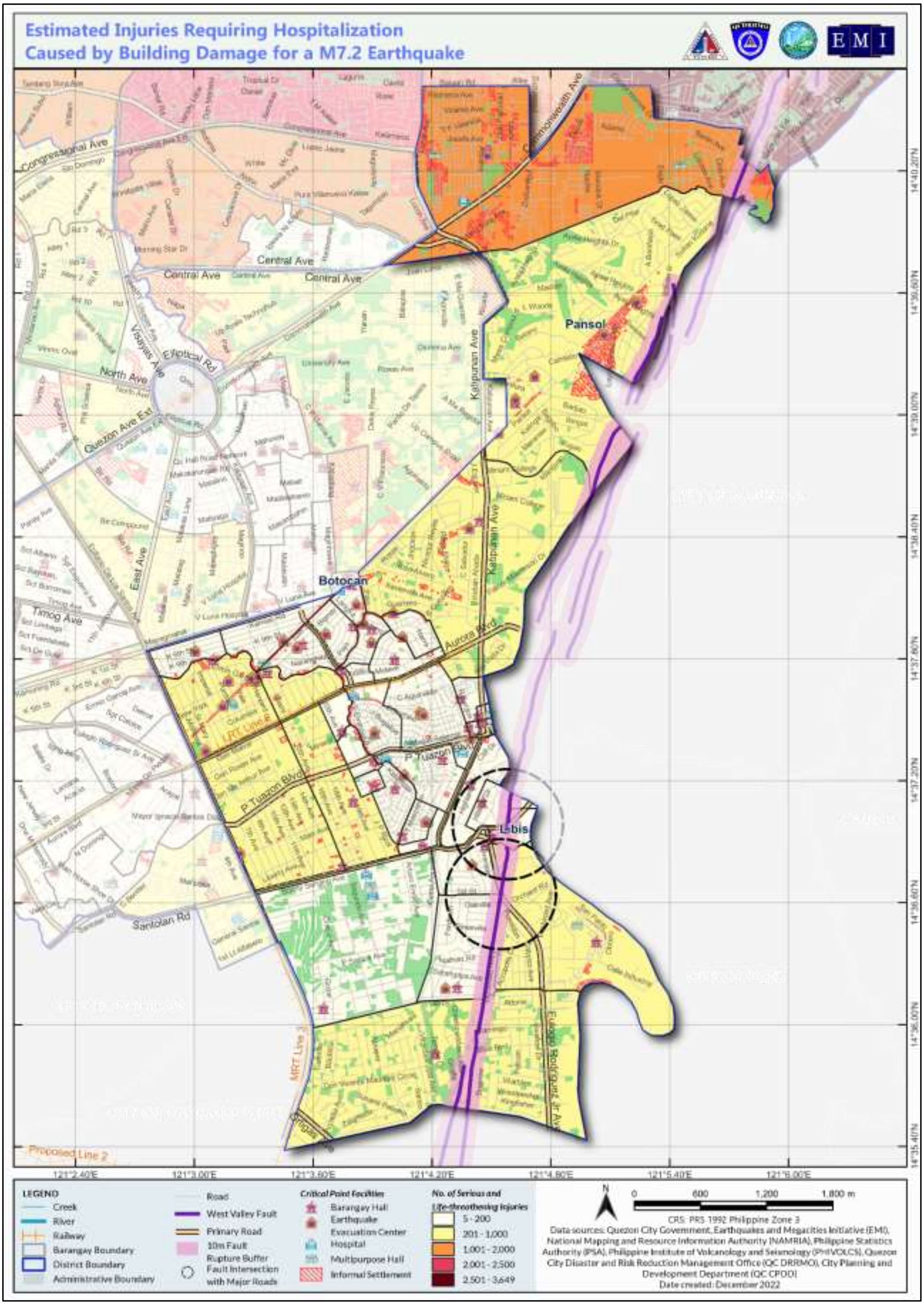


Figure 80. District 3 injuries requiring hospitalization for an M7.2 West Valley Fault earthquake scenario caused by building damage.

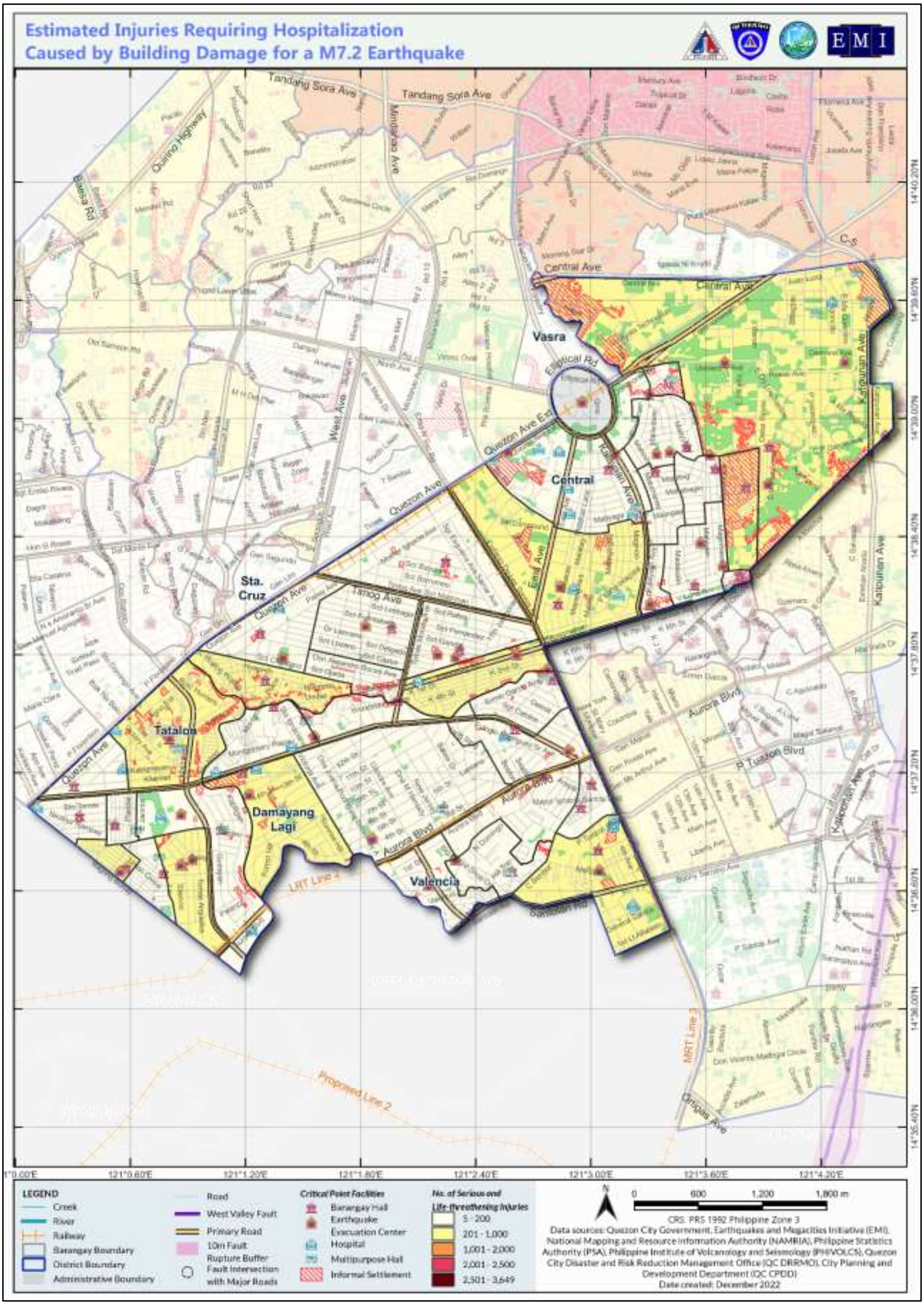


Figure 81. District 4 injuries requiring hospitalization for an M7.2 West Valley Fault earthquake scenario caused by building damage.

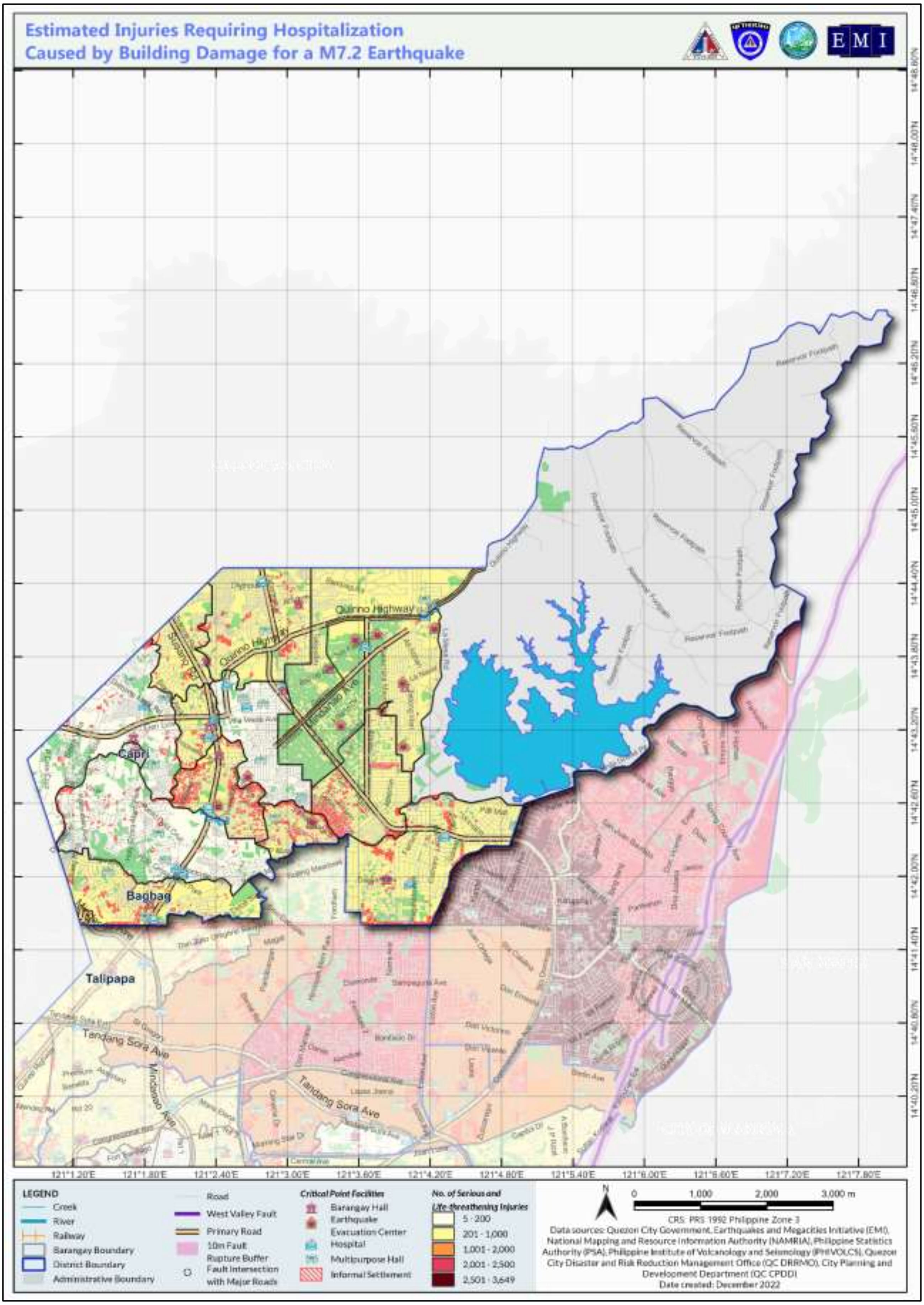


Figure 82. District 5 injuries requiring hospitalization for an M7.2 West Valley Fault earthquake scenario caused by building damage.

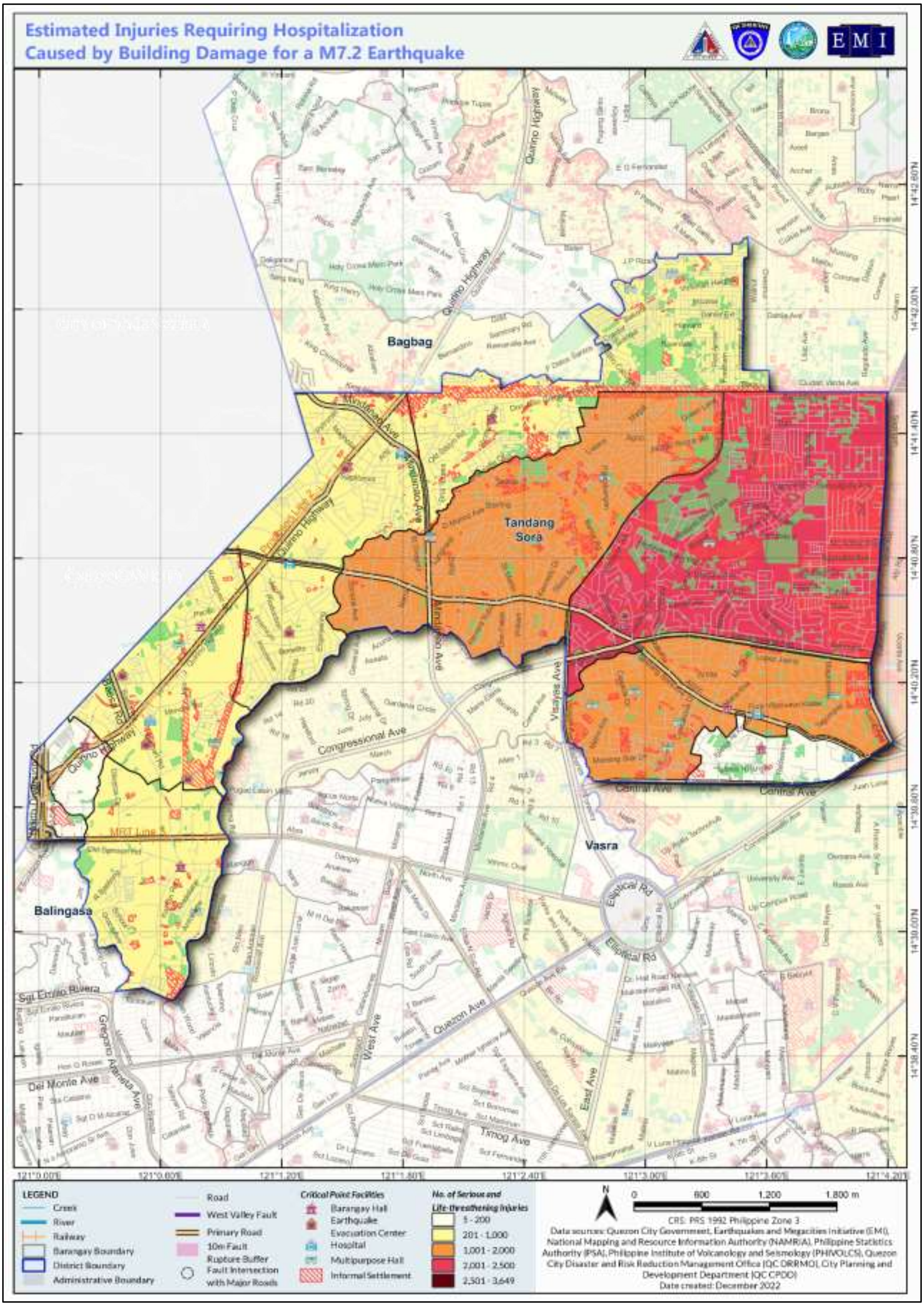


Figure 83. District 6 injuries requiring hospitalization for an M7.2 West Valley Fault earthquake scenario caused by building damage.

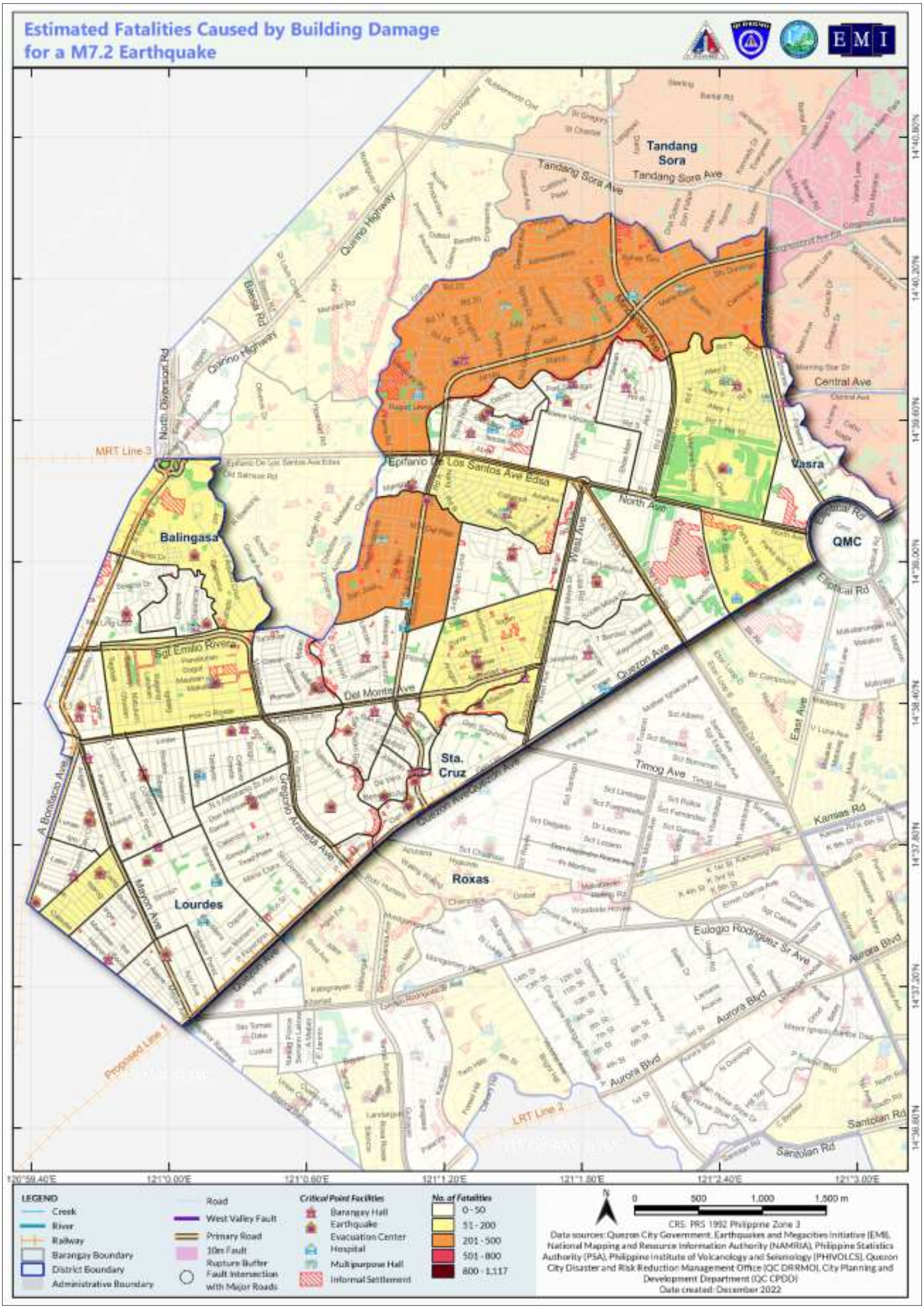


Figure 84. District 1 estimated fatalities for an M7.2 West Valley Fault earthquake scenario caused by building damage.

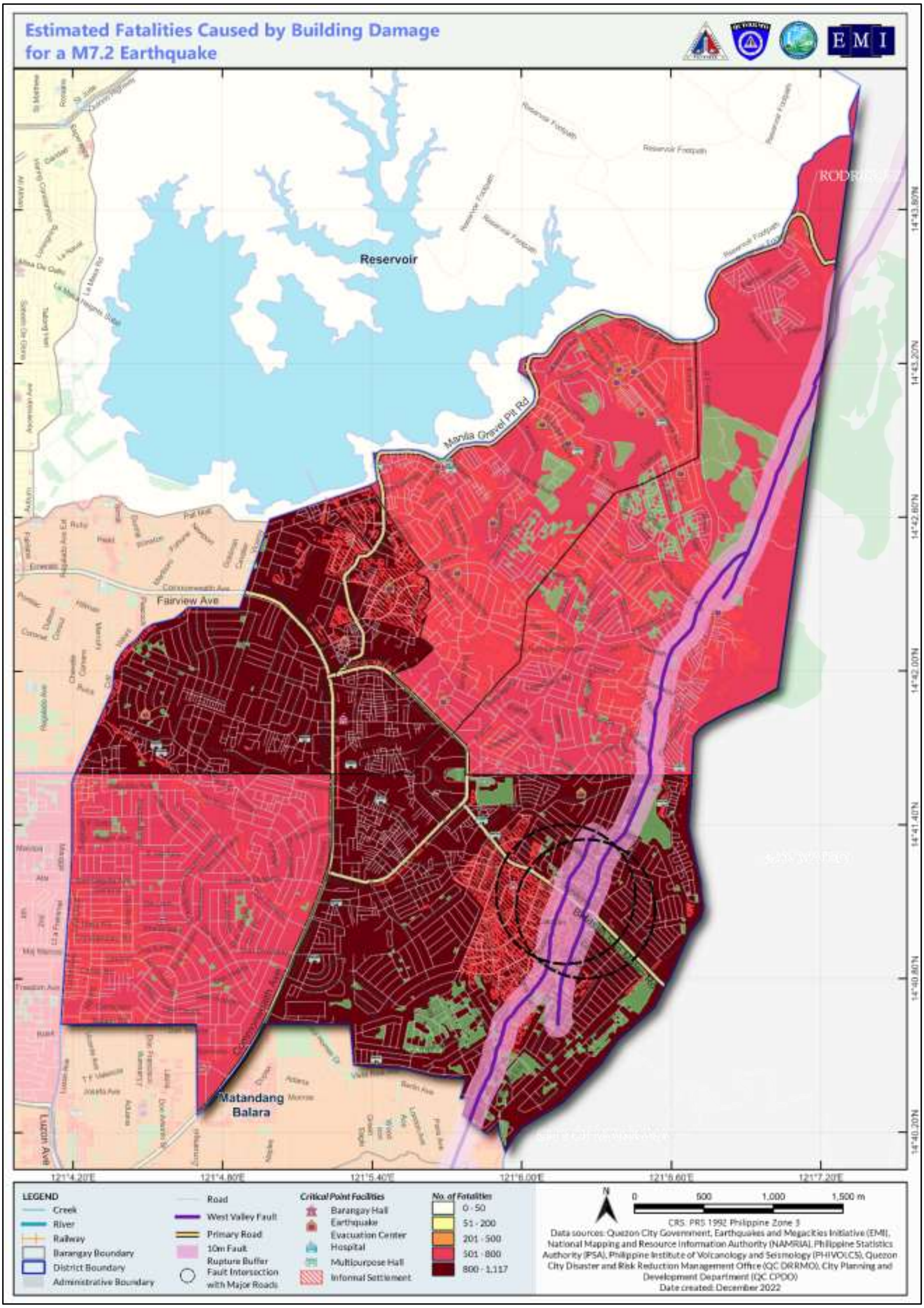


Figure 85. District 2 estimated fatalities for an M7.2 West Valley Fault earthquake scenario caused by building damage.

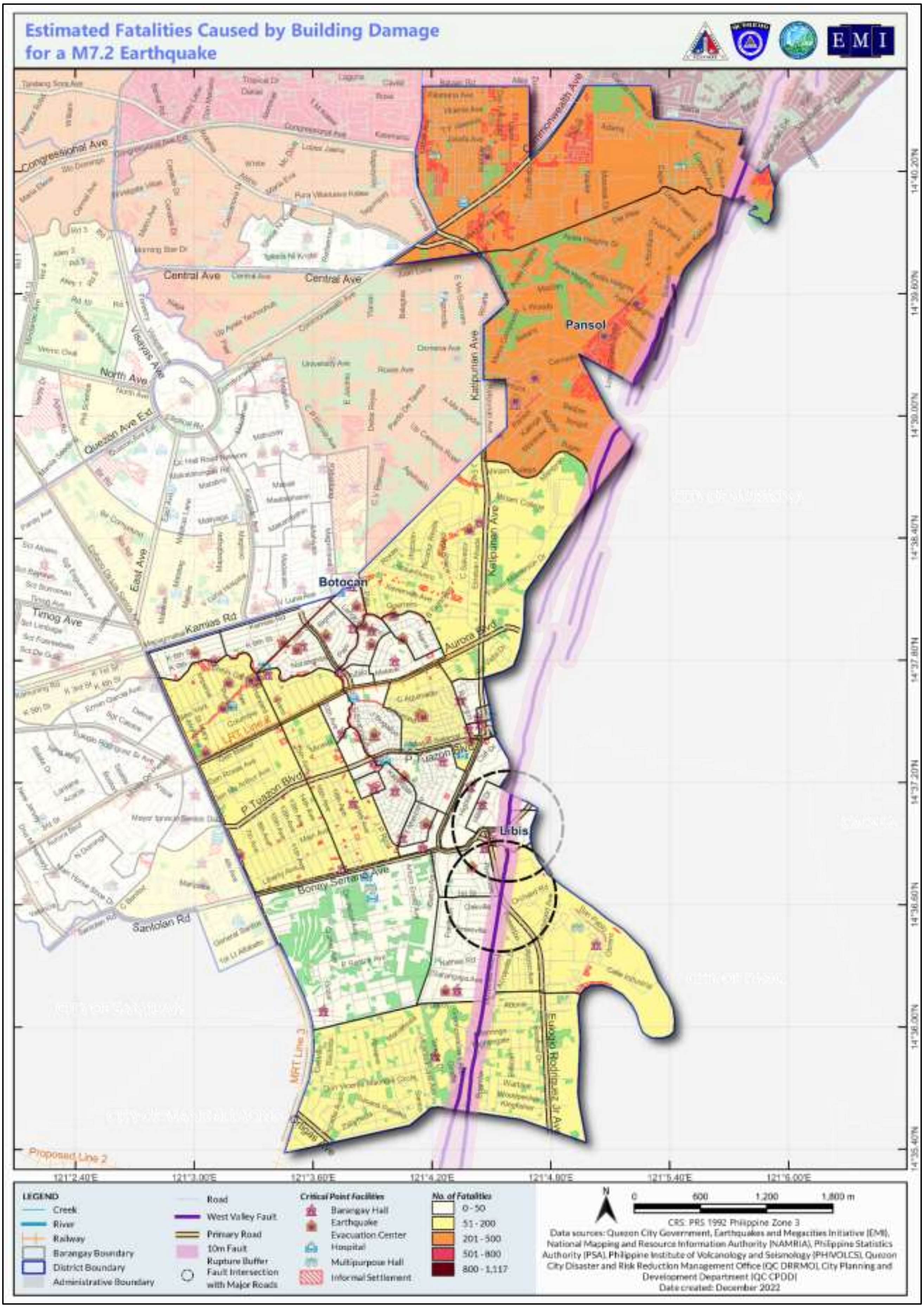


Figure 86. District 3 estimated fatalities for an M7.2 West Valley Fault earthquake scenario caused by building damage.

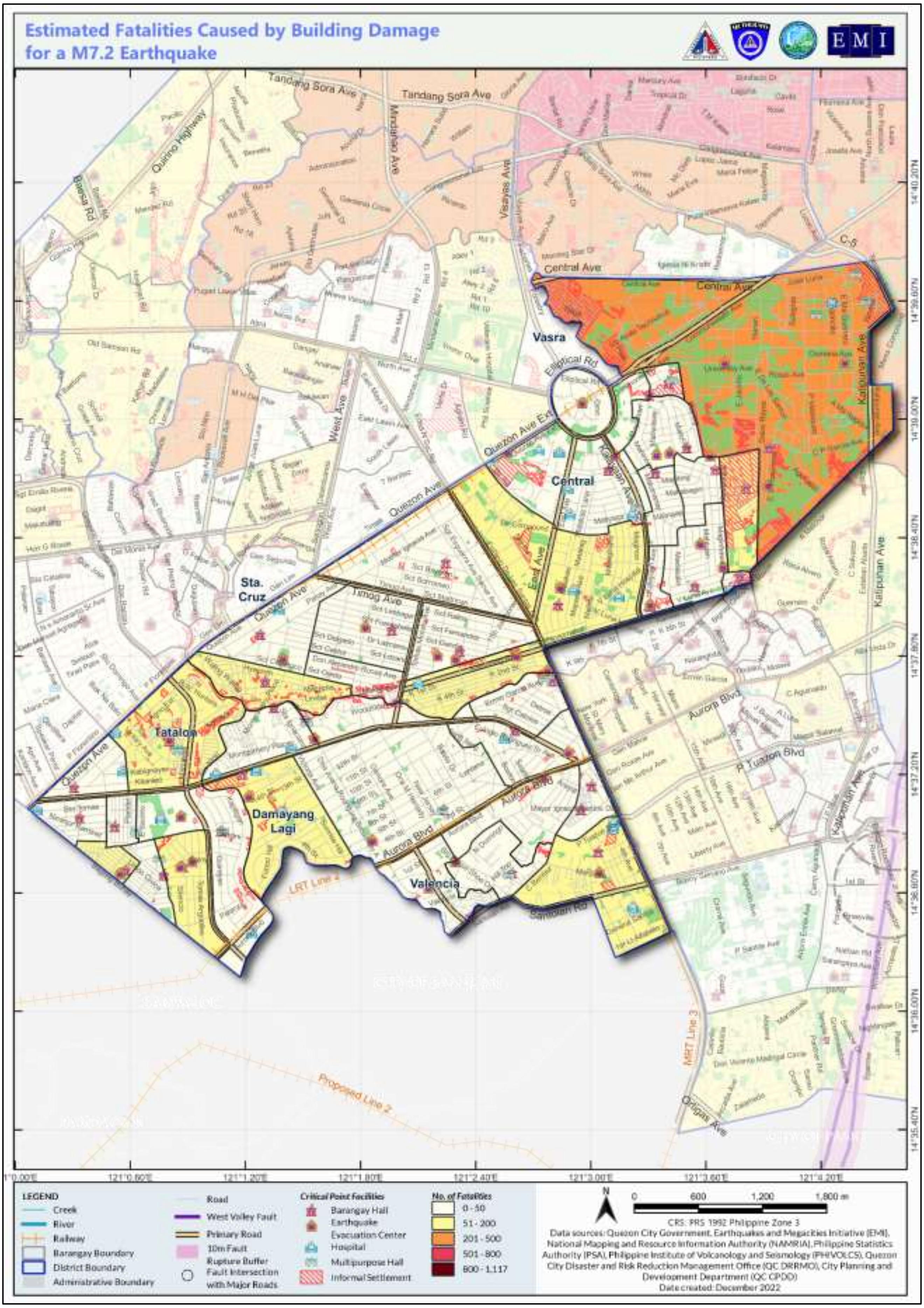


Figure 87. District 4 estimated fatalities for an M7.2 West Valley Fault earthquake scenario caused by building damage.

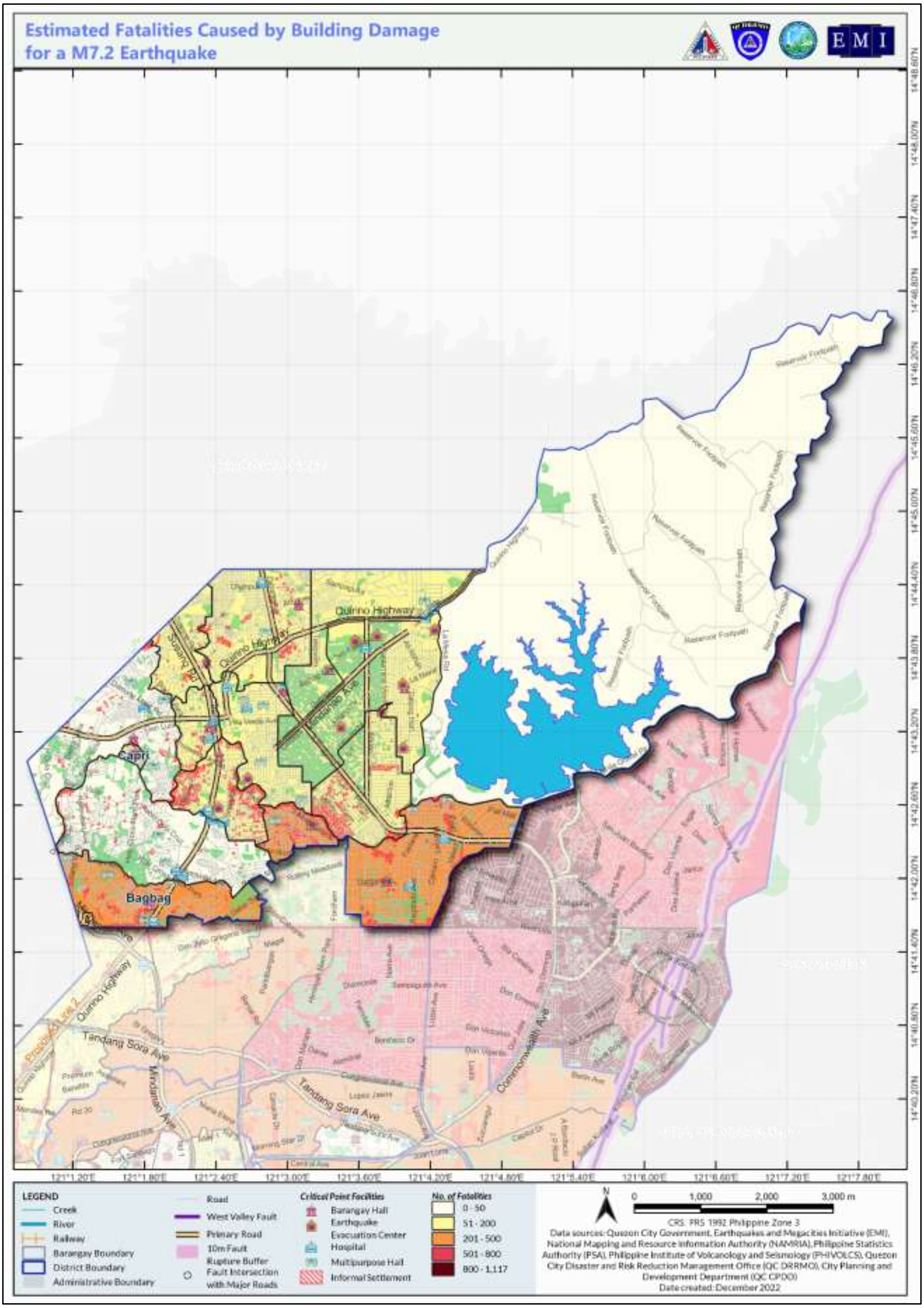


Figure 88. District 5 estimated fatalities for an M7.2 West Valley Fault earthquake scenario caused by building damage.

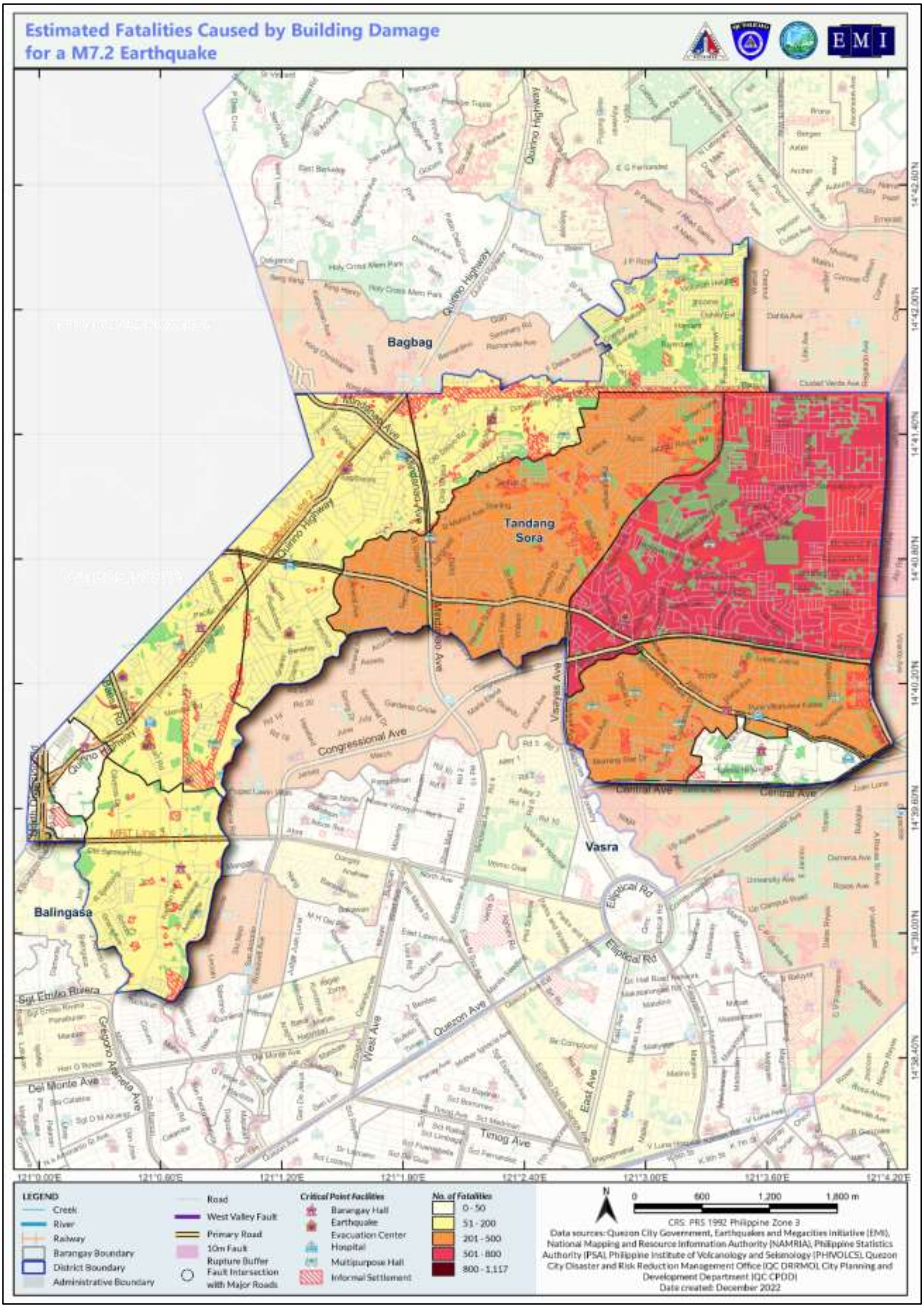


Figure 89. District 6 estimated fatalities for an M7.2 West Valley Fault earthquake scenario caused by building damage.

Displaced Populations

A critical data point that can be derived from building damage are estimates of how many people would be displaced under the M7.2 earthquake scenario. The count of displaced population is obtained from the number of buildings in complete damage state, collapse state and extensive damage state. The assumption is that buildings in these damage states will not inhabitable and their inhabitants will become homeless. Only residential buildings are taken into consideration and the assumption is that the earthquake takes place at night or at the time and day where most people are in their homes. Since there is no data on amount of population by building, a general assumption is made that the population is evenly distributed among the buildings.

Table 56 provides an estimate of the total number of people that would need temporary shelters and eventually require support for a new housing unit after a M7.2 earthquake in Quezon City. It is shown that the earthquake could put almost half of the total population in need of temporary or permanent sheltering.

Table 56. Aggregated estimate of displaced population from M7.2 earthquake scenario

Total Population	Displaced Population	Rate
3,242,298	1,561,765	48%

Figure 90 and Figure 91 provide maps for displaced population by barangay in terms of actual estimated numbers and proportion (or density) of displaced population relative to the total population of the barangay.

Table 57 to Table 62 provide the number and proportion (or ratio) of population displace by barangay for each of the six districts of the city.

It is important to note that earthquakes present a unique challenge in terms of sheltering, including the following:

- Immediately after the earthquake, populations are very scared about going inside their homes because they fear aftershocks and are not confident about the structural integrity of their buildings. They would feel much safer outdoors.
- This situation can last several days or weeks, due to the occurrence of aftershocks. However, after some time, residents can go back to their homes if they develop a sense of security about the integrity of their building.
- In all cases, the number of people needing shelter after an earthquake can be quite large, in this case more than 1.5 million.
- There will be significant pressure on city officials to inspect buildings and to assess the structural integrity of buildings. The city should have a process for rapid safety inspection after an earthquake and for "placarding the buildings according to the safety level. Typically, a three level scale is used: Green (for safe), Orange (for requiring more assessment but residents can enter with caution), and Red (unsafe).
- Earthquakes come with no warning and people who evacuate their homes do not have the time to take with them essential belongings, valuable documents, and resources (e.g., cash or identity documents). This creates a situation where most people do not want to evacuate far from their homes.
- Large earthquakes are followed by several aftershocks that can also be large and damaging. This creates a level of fear for people to go back into their homes. Many residents will stay outdoors even if their homes have very little or no damage due to fears of earthquake aftershocks.

These conditions have pushed emergency managers and planners to shift the notion of sheltering for earthquake to "sheltering-in-place." We recommend evaluating sheltering for earthquakes within the notion of sheltering in place and gradually introducing such a concept based on international best practices and experience.

Table 57 Estimated number and ratio of displaced population for District 1for M7.2 earthquake scenario

Barangays in District 1	Total Population	Displaced Population	Ratio
Bahay Toro	72,440	30,981	43%
San Antonio	25,616	9,332	36%
Manresa	24,958	8,471	34%
Bagong Pag-asa	21,066	8,321	39%
Paltok	17,488	7,554	43%
Project 6	16,785	7,345	44%
Balingasa	20,656	7,264	35%
Veterans Village	14,890	6,482	44%
Sto. Domingo (Matalahib)	14,790	6,114	41%
Ramon Magsaysay	16,290	5,804	36%
Masambong	13,346	5,269	39%
Del Monte	12,729	4,943	39%
Sto. Cristo	12,455	4,539	36%
Vasra	9,986	4,321	43%
Sta. Teresita	7,924	3,602	45%
Damayan	8,802	3,504	40%
San Isidro Labrador	7,263	3,409	47%
Salvacion	7,876	3,080	39%
Paang Bundok	5,526	2,691	49%
San Jose	6,264	2,571	41%
Talayan	6,074	2,505	41%
N. S. Amoranto (Gintong Silahis)	6,714	2,445	36%
Bungad	5,774	2,360	41%
Sta. Cruz	4,674	2,013	43%
West Triangle	4,496	2,004	45%
Alicia	6,643	1,954	29%
Pag-ibig sa Nayon	5,591	1,940	35%
St. Peter	3,941	1,907	48%
Sienna	2,925	1,688	58%
Lourdes	4,818	1,645	34%
Maharlika	4,089	1,618	40%
Mariblo	4,197	1,574	38%
Paraiso	3,874	1,364	35%
Phil-Am	2,230	1,114	50%
Nayong Kanluran	2,864	1,061	37%
Katipunan	2,823	1,031	37%
Damar	1735	774	45%

Table 58 Estimated number and ratio of displaced population for District 2 for M7.2 earthquake scenario

Barangays in District 2	Total Population	Displaced Population	Ratio
Batasan Hills	176,781	118,587	67%
Commonwealth	215,099	106,591	50%
Payatas	147,053	80,212	55%
Bagong Silangan	103,783	67,639	65%
Holy Spirit	123,802	64,540	52%

Table 59 Estimated number and ratio of displaced population for District 3 for M7.2 earthquake scenario

Barangays in District 3	Total Population	Displaced Population	Rate
Matandang Balara	70,759	40,918	58%
Pansol	43,655	26,720	61%
Bagumbayan	23,759	15,818	67%
Socorro	30,312	13,275	44%
Loyola Heights	20,822	12,967	62%
San Roque	20,017	11,363	57%
E. Rodriguez	19,921	10,169	51%
Ugong Norte	11,809	7,743	66%
Marilag	9,302	5,665	61%
Escopa 3	8,767	5,653	64%
White Plains	6,431	4,428	69%
Bagumbuhay	7,098	4,096	58%
Milagrosa	6,377	3,879	61%
East Kamias	6,101	3,229	53%
Silangan	5,564	2,854	51%
Amihan	5,129	2,839	55%
Quirino 2-A	5,754	2,665	46%
Camp Aguinaldo	4,620	2,631	57%
Libis	3,533	2,507	71%
Claro (Quirino 3-B)	4,467	2,467	55%
Duyan-duyan	4,376	2,446	56%
Masagana	4,433	2,443	55%
West Kamias	4,645	2,237	48%
Quirino 2-C	2,971	1,686	57%
Quirino 2-B	2,734	1,636	60%
Villa Maria Clara	2,725	1,539	56%
Escopa 4	2,050	1,466	72%
Escopa 1	2,269	1,351	60%
Blue Ridge A	1,871	1,318	70%
Blue Ridge B	1,713	1,286	75%
Tagumpay	2,288	1,208	53%
Dioquino Zobel	1,992	1,177	59%
Escopa 2	1550	942	61%
St. Ignatius	2099	888	42%
Bayanihan	1237	664	54%
Quirino 3-A	1091	604	55%
Mangga	990	538	54%

Table 60 Estimated number and ratio of displaced population for District 4 for M7.2 earthquake scenario

Barangays in District 4	Total Population	Displaced Population	Ratio
U. P. Campus	61,137	30,745	50%
Tatalon	69,108	25,594	37%
South Triangle	21,143	13,754	65%
Krus na Ligas	22,529	12,775	57%
Pinyahan	27,031	12,706	47%
Bagong Lipunan ng Crame	17,888	9,225	52%
Damayang Lagi	19,510	8,378	43%
Roxas	20,636	8,204	40%
Kamuning	14,855	7,335	49%
Central	14,816	6,505	44%
San Martin de Porres	12,132	5,860	48%
Mariana	11,302	5,300	47%
Doña Imelda	13,736	5,230	38%
Sto. Niño	10,925	4,772	44%
Botocan	8,391	4,748	57%
Valencia	9,565	4,575	48%
Laging Handa	8,646	4,102	47%
Immaculate Concepcion	8,538	4,059	48%
San Isidro	9,136	3,986	44%
Kaunlaran	7,510	3,754	50%
Sacred Heart	8,169	3,735	46%
Sikatuna Village	6,972	3,724	53%
San Vicente	9,085	3,557	39%
Obrero	8,597	3,340	39%
U. P. Village	5,651	3,118	55%
Santol	7,143	3,093	43%
Pinagkaisahan	6,934	2,763	40%
Paligsahan	6,818	2,624	38%
Teachers Village West	4,455	2,598	58%
Malaya	4,286	2,170	51%
Doña Aurora	5,824	2,166	37%
Teachers Village East	3,343	1,909	57%
Kristong Hari	4,440	1,853	42%
Horseshoe	3,318	1,664	50%
Don Manuel	3,657	1,374	38%
Doña Josefa	2283	766	34%
Old Capitol Site	552	273	49%
Kalusugan	680	255	38%

Table 61 Estimated number and ratio of displaced population for District 5 for M7.2 earthquake scenario

Barangays in District 5	Total Population	Displaced Population	Rate
Bagbag	97,933	34,559	35%
Fairview	61,002	29,854	49%
Nagkaisang Nayon	52,377	23,941	46%
Kaligayahan	63,995	23,032	36%
North Fairview	45,317	21,968	48%
San Bartolome	45,794	20,979	46%
Gulod	52,779	20,243	38%
Sta. Monica	49,714	19,307	39%
Pasong Putik Proper	39,913	15,023	38%
Greater Lagro	25,092	12,050	48%
Sta. Lucia	27,311	10,429	38%
San Agustin	23,931	8,938	37%
Novaliches Proper	16,267	7,980	49%
Capri	17,758	6,989	39%

Table 62 Estimated number and ratio of displaced population for District 6 for M7.2 earthquake scenario

Barangays in District 6	Total Population	Displaced Population	Rate
Pasong Tamo	131,396	70,405	54%
Tandang Sora	97,674	45,354	46%
Culiat	82,205	43,507	53%
Sauyo	77,806	33,036	42%
Baesa	69,441	24,713	36%
New Era	33,979	15,031	44%
Apolonio Samson	40,962	14,425	35%
Talipapa	35,363	14,207	40%
Sangandaan	23,824	9,938	42%
Balong-bato	9,081	3,353	37%
Unang Sigaw	8,282	2,437	29%

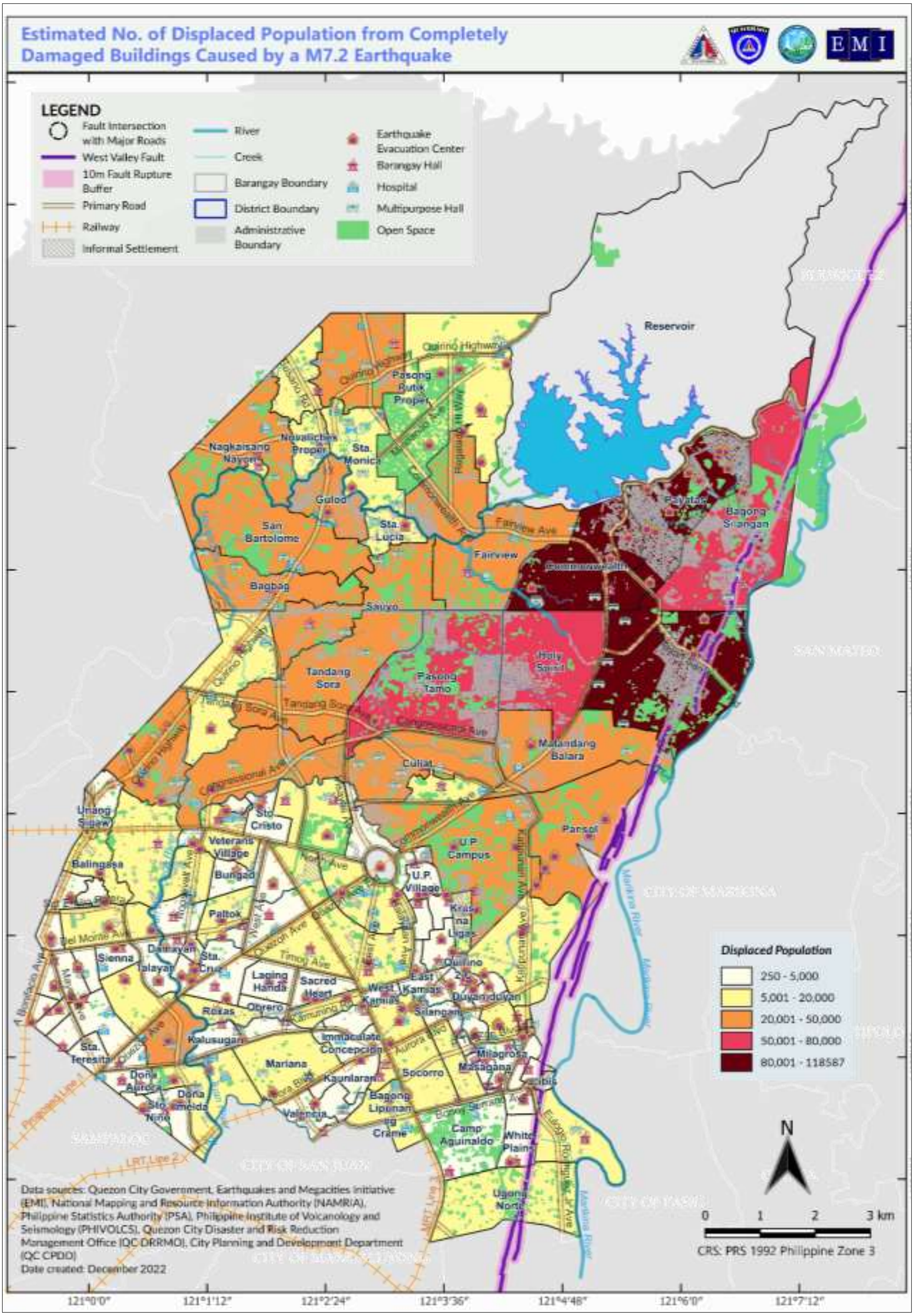


Figure 90 Estimate number of displaced population by barangay for M7,2 earthquake scenario

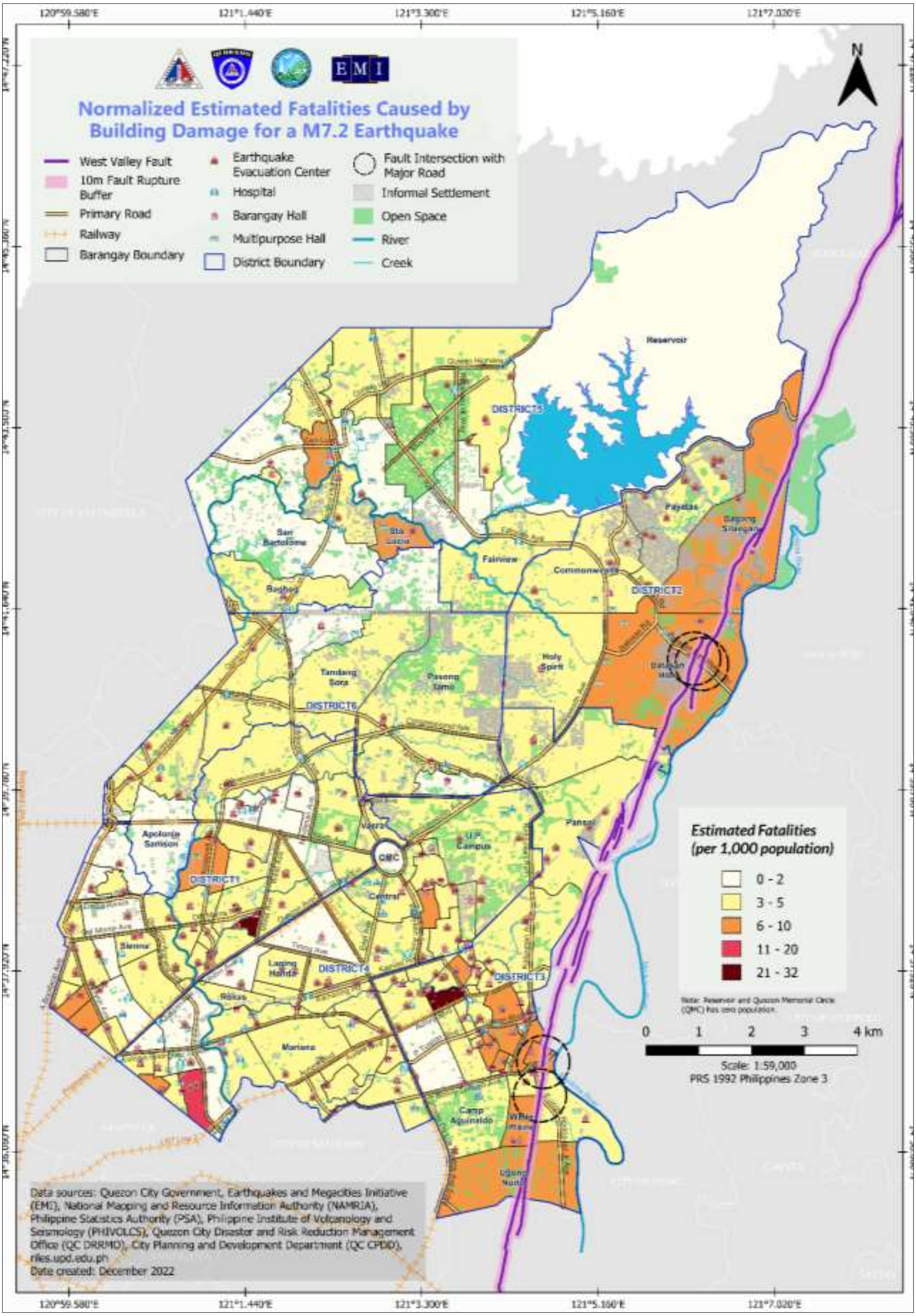


Figure 91 Estimate of proportion of displaced population by barangay from the M7.2 earthquake scenario

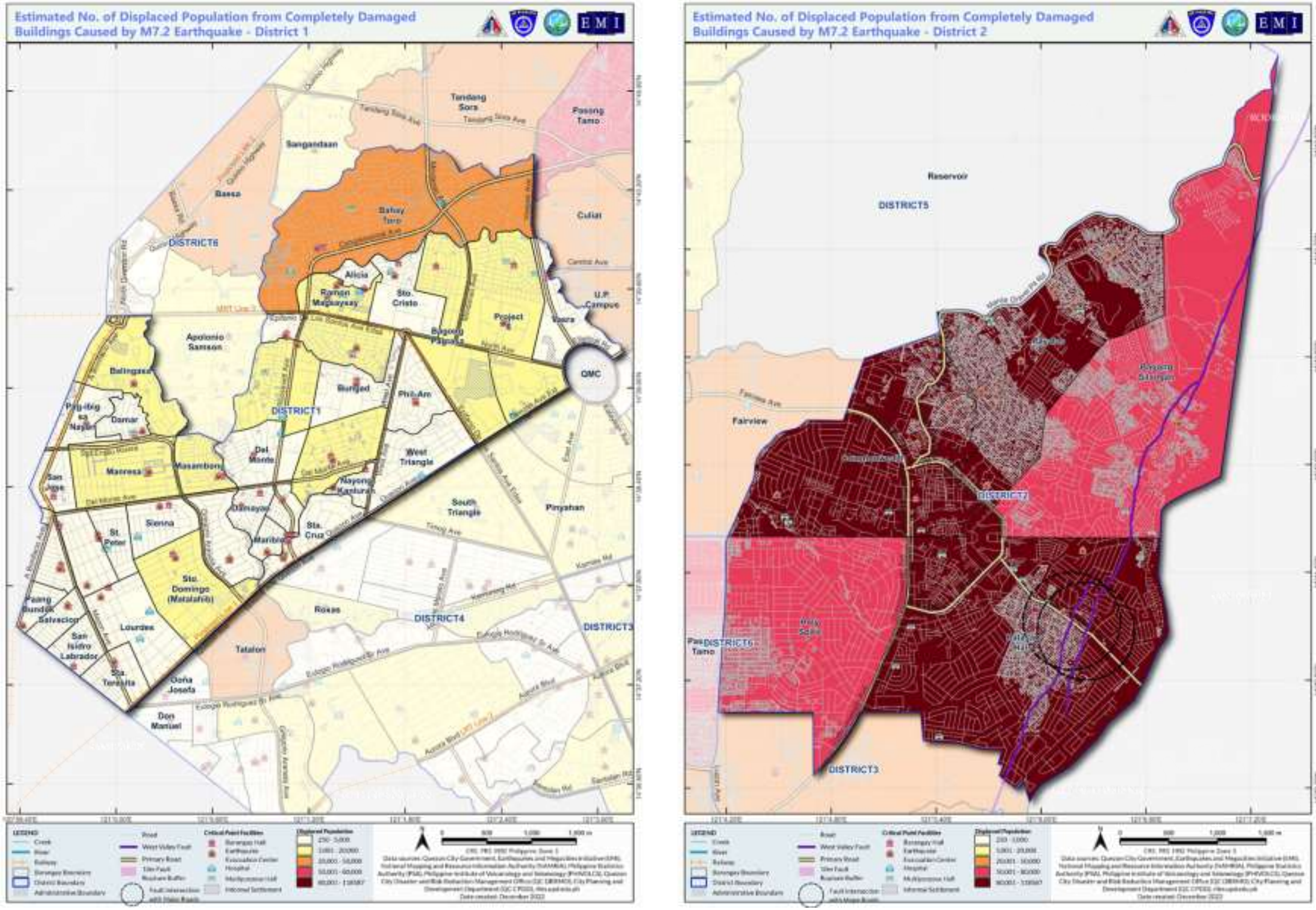


Figure 92 Displaced populations for the M7.2 earthquake scenario for District 1 and District 2

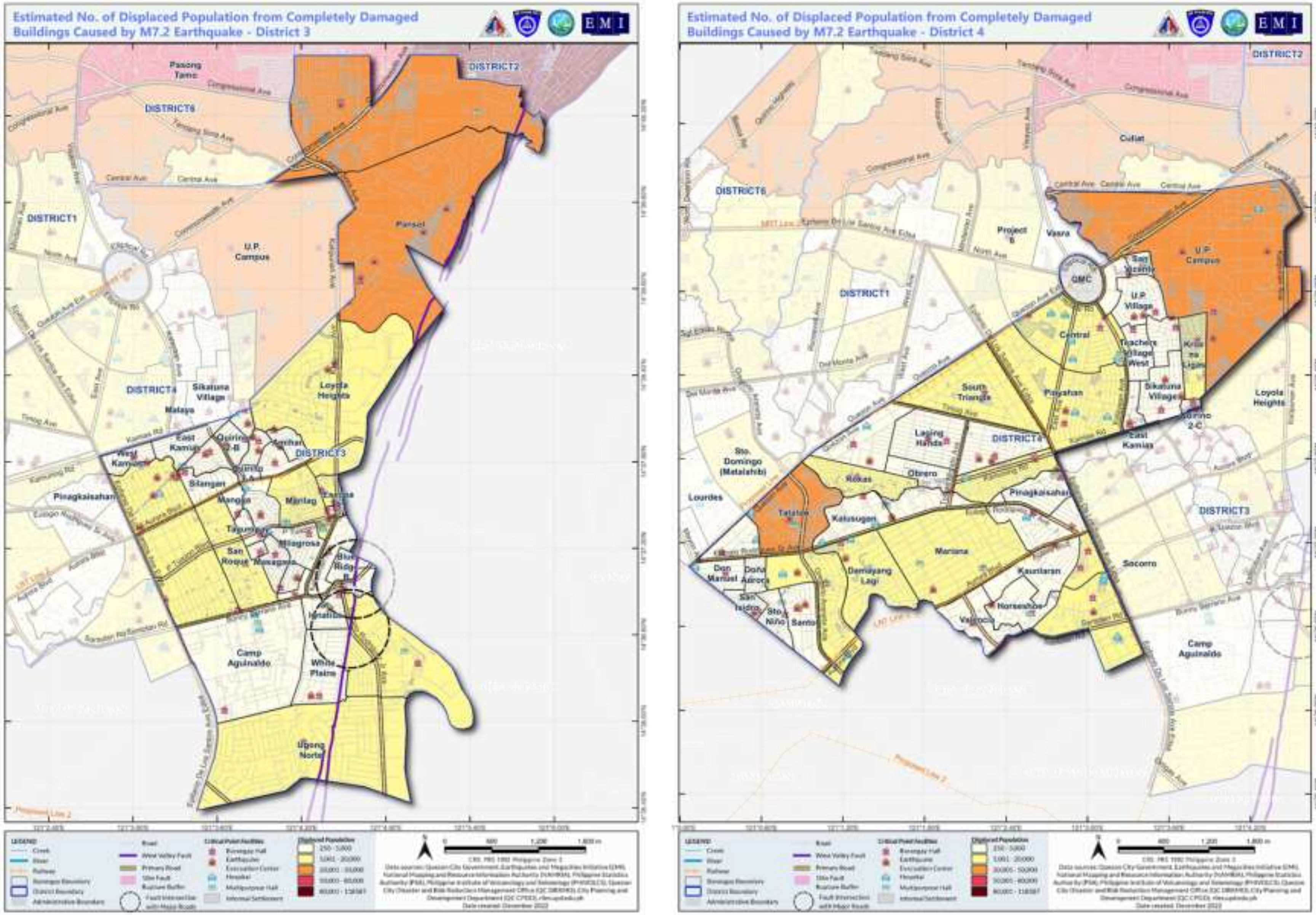


Figure 93 Displaced populations for the M7.2 earthquake scenario for District 3 and District 4

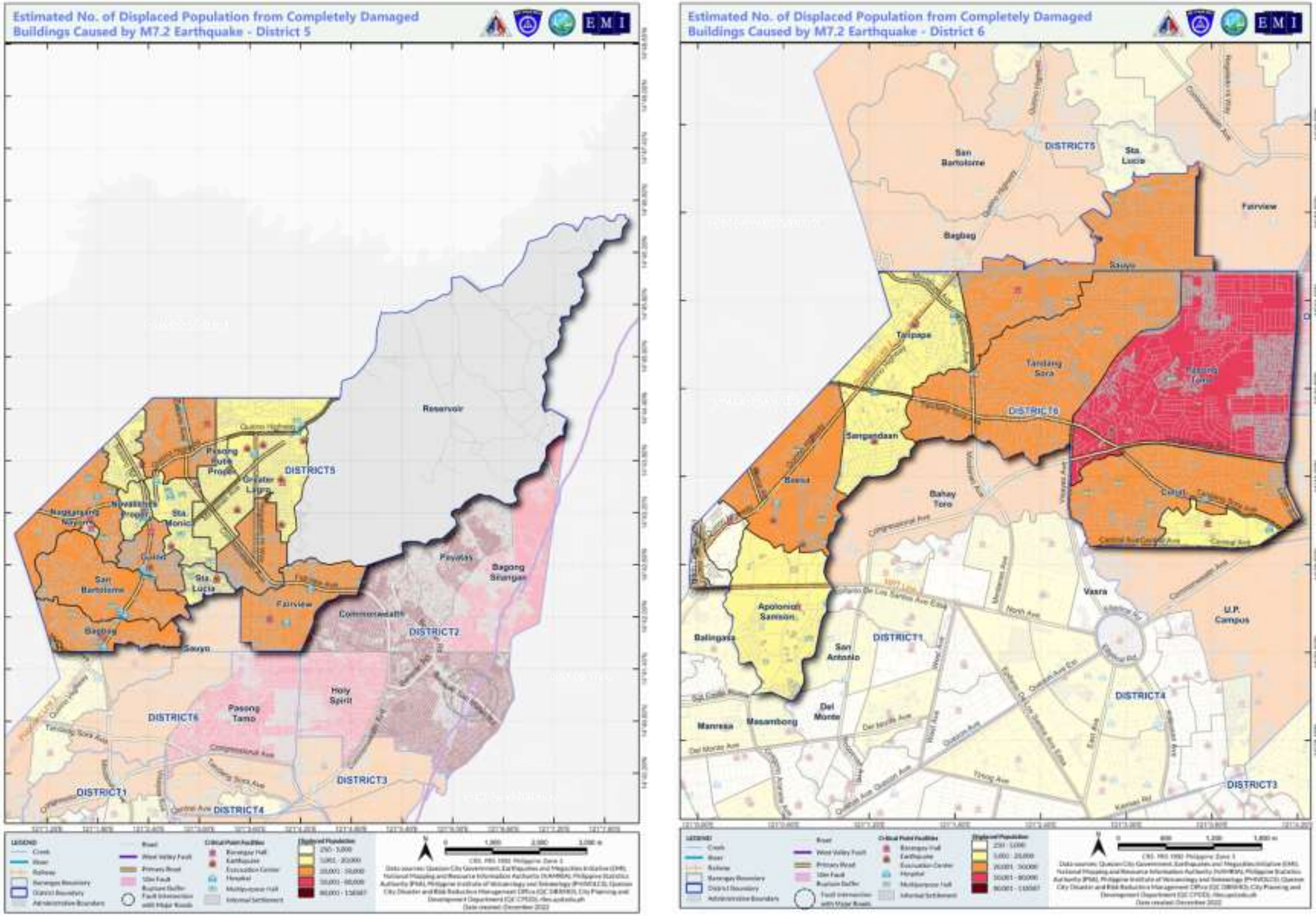


Figure 94 Displaced populations for the M7.2 earthquake scenario for District 5 and District 6

Part 5:

Landslide Hazard and Risk

Part 5. Landslide Hazard and Risk Assessment

5.1 Background and Introduction

Quezon City has a large land area comprising varying geomorphologic features. The city has the highest elevation of 250 m and an average elevation of 67 m above sea level characterized by plain and gentle to steep slopes ranging from eight to fifteen percent (8-15%). A rugged mountainous ridge can be observed on the eastern portion of Quezon City which is influenced by the Valley Fault System, specifically the West Valley Fault. The geologic and structural character of the area renders it prone to slope instabilities. Consequently, several landslide susceptibility studies have been carried out for Quezon City, including the 1: 10,000-scale rain-induced landslide susceptibility maps of Quezon City, Metro Manila by the Bureau of Mines and Geology (MGB) in the Philippines, which are being used as official maps for land-use planning in Metro Manila since they were created in 2014. Updating of the 1:10,000-scale landslide susceptibility map to ensure the accuracy of the landslide susceptibility ratings was carried out successfully through field investigations by a technical team from MGB from August 23 to September 10, 2021 (Mines and Geosciences Bureau, 2021) as shown in Figure 95. The updated susceptibility rating followed the Guidebook for 1:10,000-scale Geohazards Mapping (Mines and Geosciences Bureau, 2010) as shown in Table 63, as well as integrating previous MGB field assessments covering the target areas in Quezon City.

Table 63. Landslide susceptibility parameters used during the assessment.

Landslide Susceptibility Parameters	Low	Moderate	High	Very High
A. Slope Gradient	Low to moderate (<18)	Moderate to steep (18-35)	Steep to very steep (>35)	Steep to very steep (>35)
B. Weathering/ Soil Characteristics	Slight to moderate	Moderate	Intense; Soil usually non-cohesive	Intense; Soil usually non-cohesive
C. Rock Mass Strength	Very good to good	Fair	Poor to very poor	Poor to very poor
D. Ground Stability	Stable with no identified landslide scars, either old, recent or active	Soil creep and other indications for possible landslide occurrence are present	Inactive landslides evident; tension cracks present	Active landslide evident; tension cracks, bulges, terracettes, and seepage present
E. Human Initiated Effects				May be an aggravating factor

The objective of the current project is to re-calibrate the 2021 updated 1:10,000 landslide susceptibility maps using an infinite slope stability method using the SINMAP software. This recalibration will introduce a 5-meter Digital Elevation Model as well as recent information on soil characteristics and other information on the surficial and bedrock geology. The goal is to derive updated landslide susceptibility maps by complimenting the statistical method and field observations inherent to the 1:10,000 MGB maps using a process-driven method that accounts for both fully saturated (wet) and no saturation (dry) conditions in the hydrologic regime to account for best-case and worst-case scenarios due to Climate Change. In a final step, building, infrastructure, and social and economic data available within the project, will be used in a hotspot analysis to classify exposed populations and assets susceptible to landslides in Quezon City. Considerations should also be on the impact of Climate Change in the final report for the landslide risk assessments.

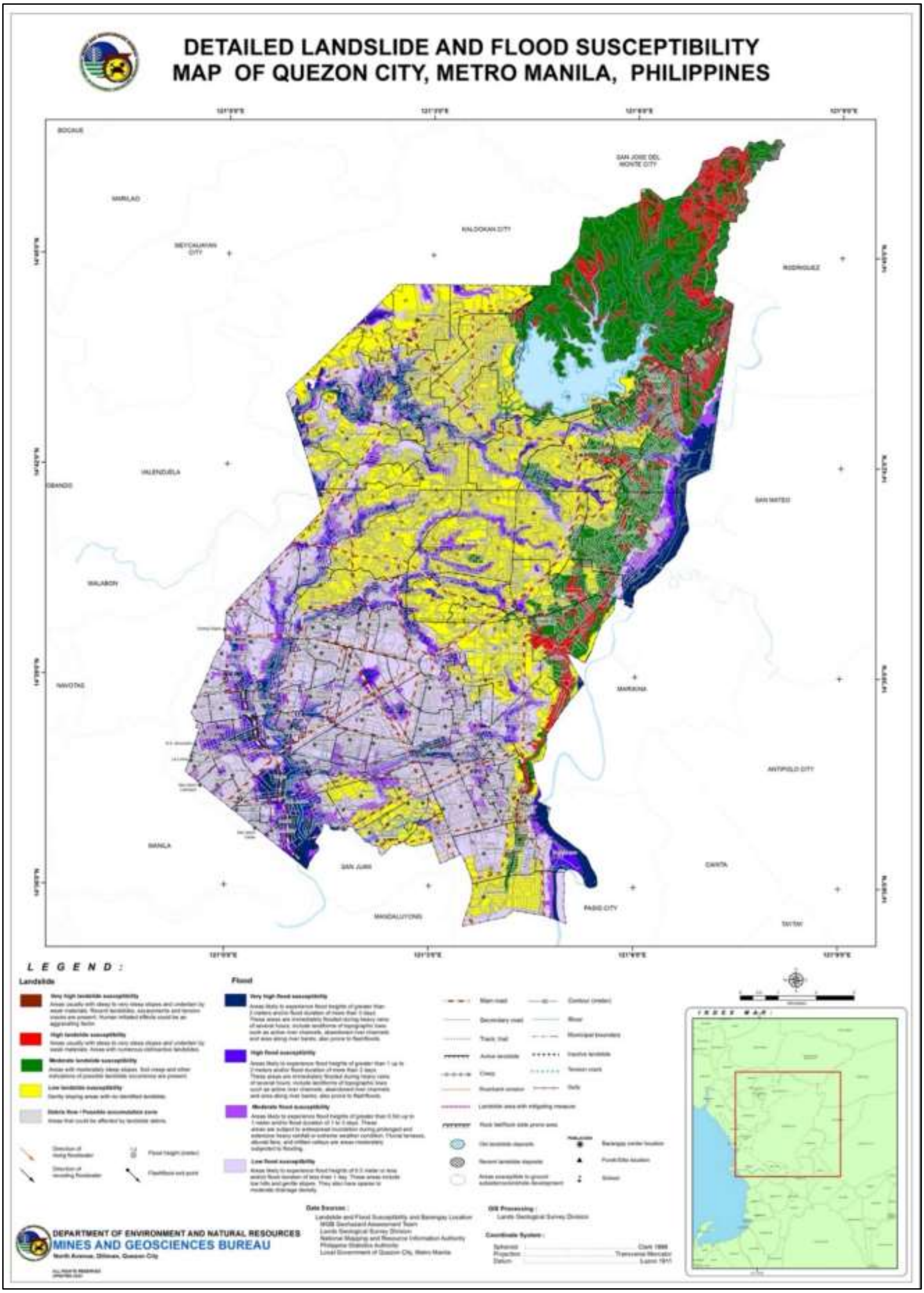


Figure 95. Updated Flood and Landslide Susceptibility Map (MGB, 2021)

5.2. Methodology

Landslide susceptibility is the probability of a landslide occurring in an area by local environmental conditions. It is the degree to which terrain can be affected by slope movements, i.e., an estimate of "where" landslides are likely to occur. Landslide susceptibility modeling can be carried out using statistical (bivariate, multivariate, heuristic) methods which account for correlations between landslide incidence and different layers of geomorphic or lithology data. Another modeling approach is a physics-based or process-driven method that accounts for the horizontal and vertical forces on the slope, which result in a factor of safety against failure, which is 1.0 or greater. The Stability Index Mapping (SINMAP) is one method of landslide susceptibility mapping applied to shallow translational landslide phenomena controlled by shallow groundwater flow convergence. The advantage of SINMAP model implemented in a geographic information system (GIS) environment is that it is possible to analyze quickly over large areas even with limited data. SINMAP modelling combines a slope stability model with a steady-state hydrology model to delineate areas prone to shallow landslides. SINMAP has been successfully applied in the DOST- Project NOAH, one of the hazard-mapping initiatives of the government, to map all landslide hazards in the Philippines using both computer models as well as validating ground data.

SINMAP is the mapping method of landslide susceptibility which uses the slope stability principle. The slope stability of an area is calculated by the following equations:

$$SI = FS = (c + cos\theta \left[1 - \min\left(\frac{R\alpha}{\tau sin\theta}, 1\right) r\right] tan\varphi)/sin\theta$$

$$w = Min\left(\frac{R\alpha}{\tau sin\theta}, 1\right)$$

where SI is stability index or FS is the factor of safety, θ is the slope angle; C is the dimensionless cohesion value integrating both soil and root cohesion, as well as soil density and thickness w is the relative wetness as the relation of water-table height to soil thickness; r is the ratio of the density of water to the density of soil, ϕ is the internal friction angle, and equation (2) is an estimate of the relative wetness, which is the effective water recharge I for a is the internal friction angle. Relative wetness (w) is modeled as induced by topographic conditions and depends on the specific catchment (a) area of a given point.

SINMAP model needs some parameters related to the physical properties of soil and hydrology data such as soil cohesion (C), internal friction angle (ϕ), and a ratio of transmission to effective recharge (T/R) or relative wetness (w). Soil strength parameters such as cohesion and friction angle are material properties that are typically not included on geologic maps or soil maps. Thus, this information, which is a very crucial ingredient to the analysis, often has to be inferred from available databases of soils and geology. A good rule of thumb is, that the better the resolution of these maps, the better the inference that can be made on soil strength parameters. Geologic maps describing the units based on composition and properties of bedrock, the texture of the surficial material (soil cover) and detailed description of material types, bedding thickness and fracture spacing allow the expert to assign strength parameter values to these units. Likewise, soil databases conveying information about the units based on a USCS (Universal Soil Classification System), swelling potential, liquid limit, and particle size among others allow for an intelligent assignment of strength parameters. Unfortunately, soil strength test data is usually proprietary information and difficult to obtain and even when it is available it is highly localized and not easily generalized. Thus, in this context, it is important not to overestimate the predictive capabilities of a GIS model by combining data layers that are not consistent in their level of detail. The goal in assigning strength parameters to geologic units is to aim for a conservative estimate of cohesion value and friction angle, but also to integrate as much information as possible to obtain a level of accuracy consistent with other layers.

5.3. Results

SINMAP modeling of Quezon City is carried out with a 5-meter Interferometric Synthetic Aperture Radar (IFSAR) derived digital terrain model (DTM). Topographic, soil-strength and physical hydrologic parameters, which include cohesion, angle of friction, bulk density and hydraulic conductivity, were assigned to each pixel of a given DTM grid to compute the corresponding factor of safety. In the preliminary landslide susceptibility analysis, soil cohesion (C) values with a lower bound of 0 to an upper bound of 0.8, and internal friction angle (ϕ) of 25 to 35 degrees were used. A soil density of 1900 kg per cubic meter was used as input in the calibration parameters.

The update and resolution of the soil strength data, soil depth and soil saturation which accounts for the effective shear strength parameters are the levers for re-calibrating the 1:10,000 MGB landslide susceptibility maps. Initial values were used for these parameters in the preliminary landslide susceptibility map produced based on datasets shown in Table 64. The value of the soil strength parameters was determined from soil map data based on surficial geologic maps, and Vs30 (260x260m) grids. In the final analysis, the soil strength parameters and saturation conditions will be updated based on the inclusion of more studies and other methods.

The three classes of the 1:10,000 MGB landslide susceptibility map (low, moderate and high) were reclassified into five susceptibility classes of low, moderate, moderate to high, high and very high based on the correlation of the original susceptibility class of the MGB maps and the FS values produced by the SINMAP method (Table 65).

Table 64. Type of data used and the method of acquisition in preliminary analysis.

Type	Comment	Resolution	Source
DEM	5-meter Interferomteric Synthetic Aperture Radar (IFSAR) derived digital terrain model (DTM).	5m	NAMRIA
Vs30	reconstructed using color bands of the 2014 GMMA-RAP report's figure	260m grid	GMMA-RAP, 2014
Updated Landslide Susceptibility Map	Updated from the 2014 maps	1:10,000	Mines and Geosciences Bureau. (2021). Updated 1:10,000-scale Detailed Flood and Landslide Susceptibility Map. Quezon City, Metro Manila, Philippines.
Geologic Map	Digitized from paper map	1:50,000	Philippine Bureau of Mines and Geo-sciences. (1983). Geological Map of Manila and Quezon City Quadrangle. Metropolitan Manila, Philippines.

Table 65. Slope Stability classes and re-classification in susceptibility mapping

Factor of Safety	Classification in 1:10,000 MGB Landslide susceptibility map	Re-Classification
FS>1.5	Low	Low
1.5 > FS > 1.25		Moderate
1.5 > FS > 1.25	Moderate	Moderate
1.25 > FS > 1.0		Moderate to High
FS ≤ 1.0		High
1.5 > FS > 1.25	High	Moderate to High
1.25 > FS > 1.0		High
FS ≤ 1.0		Very High

Figure 96 to Figure 101 show the landslide susceptibility map for Quezon City. Most areas are not susceptible to landslides because they are flat. Landslides only impact particular barangays in Quezon City that are on sloping unstable terrain. Areas in dark red and red are very high susceptibility and high susceptibility, respectively. They are in the northeastern and eastern portion of Quezon City and have high to very high susceptibility. Areas in orange are moderate to high susceptibility areas, green are moderate susceptibility, and areas in yellow are low susceptibility to landslides. These maps can be used to guide the barangays to analyze potential impacts of landslides and evaluating existing conditions of slope instability that could pose a threat to emergency response.

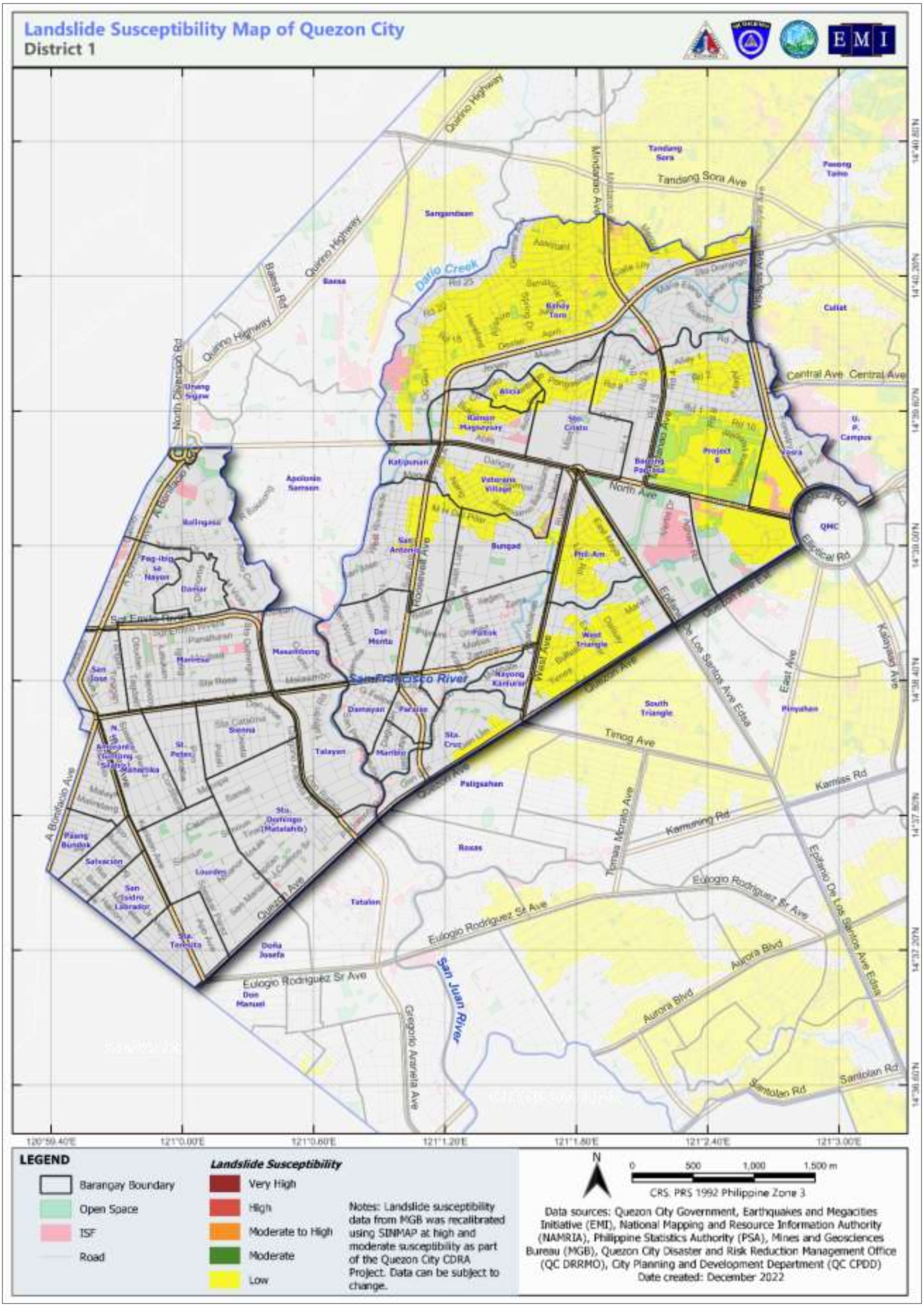


Figure 96. Landslide susceptibility map of District 1 (recalibrated MGB data at moderate and high susceptibility)

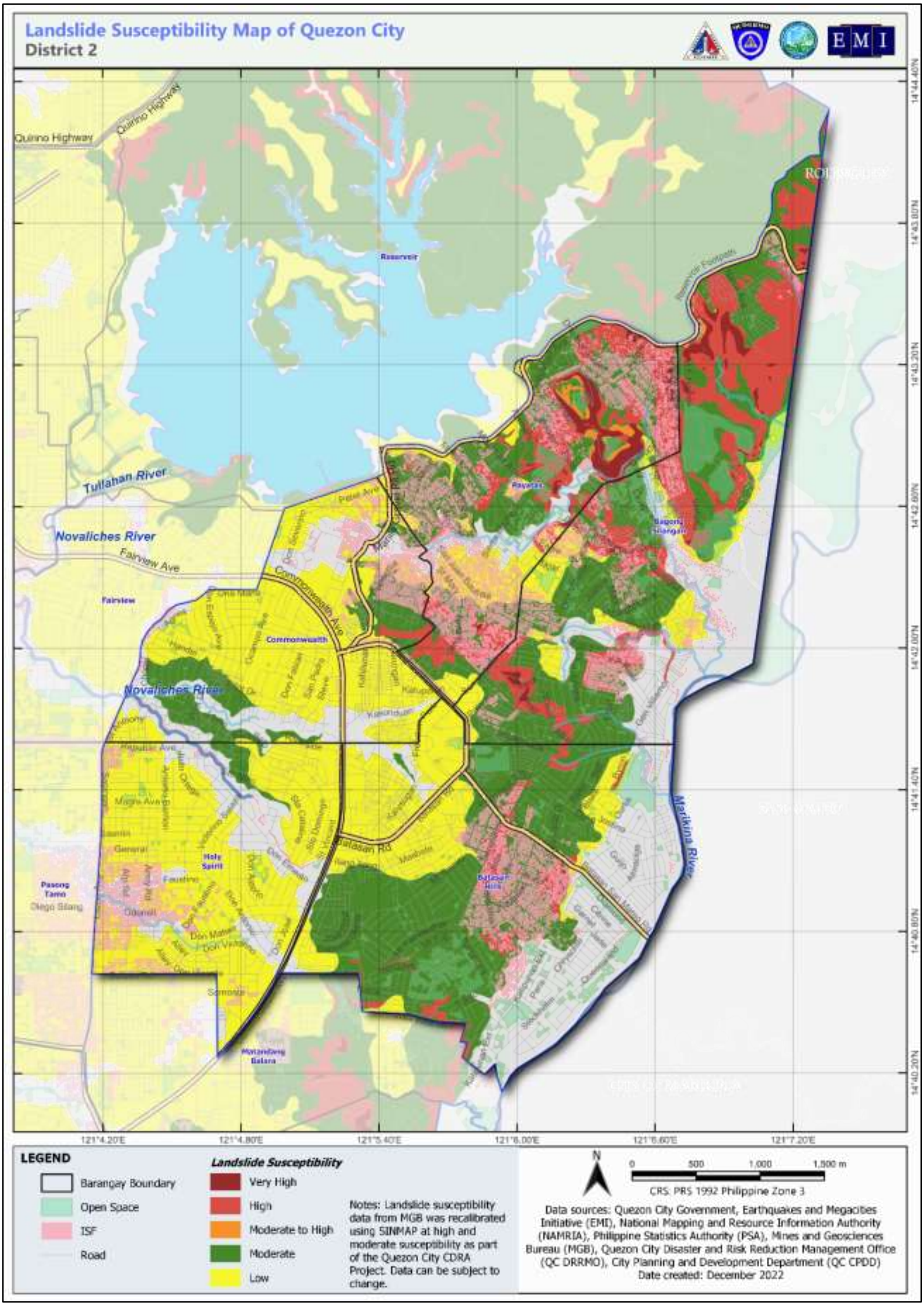


Figure 97. Landslide susceptibility map of District 2 (recalibrated MGB data at moderate and high susceptibility)

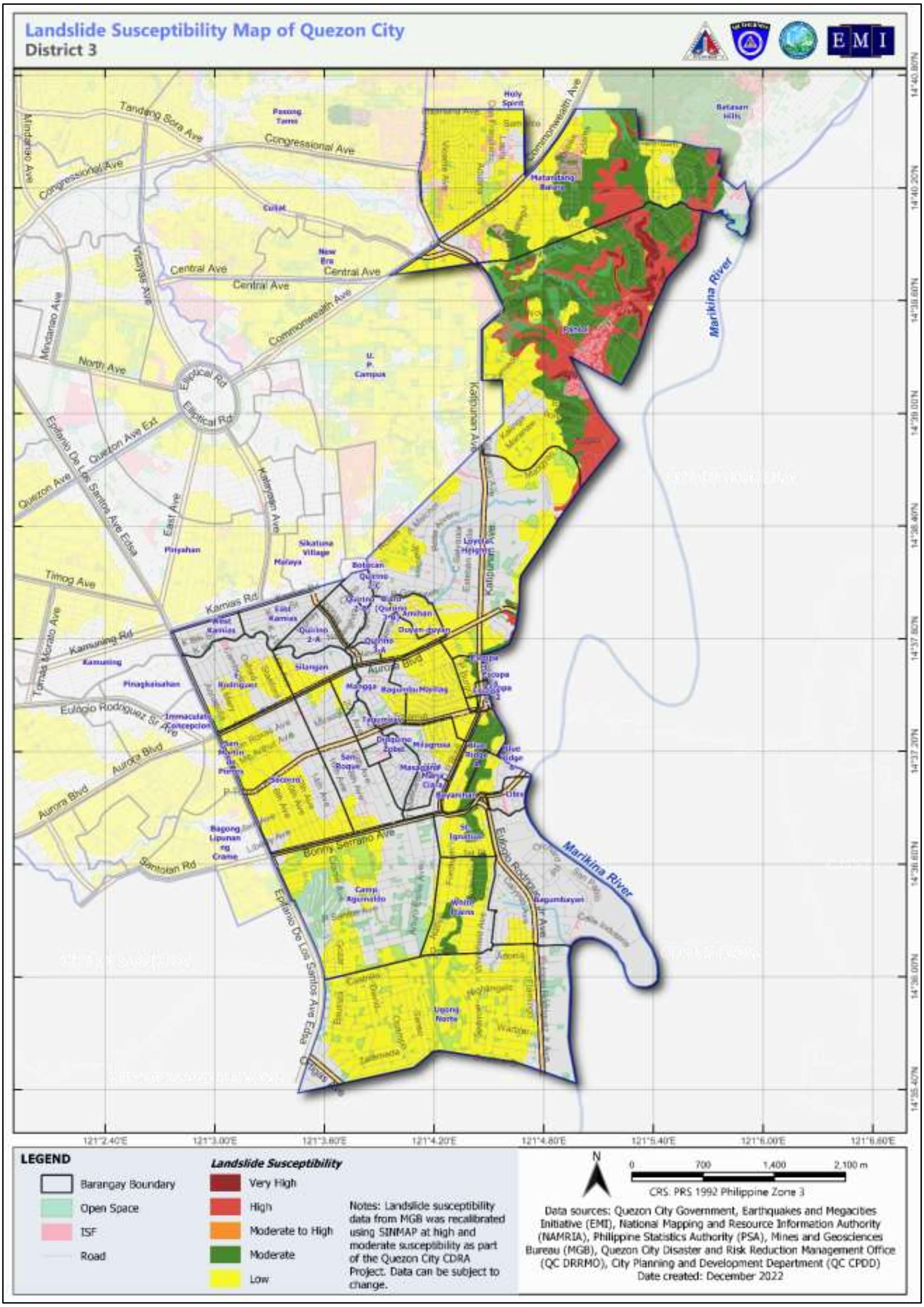


Figure 98. Landslide susceptibility map of District 3 (recalibrated MGB data at moderate and high susceptibility)

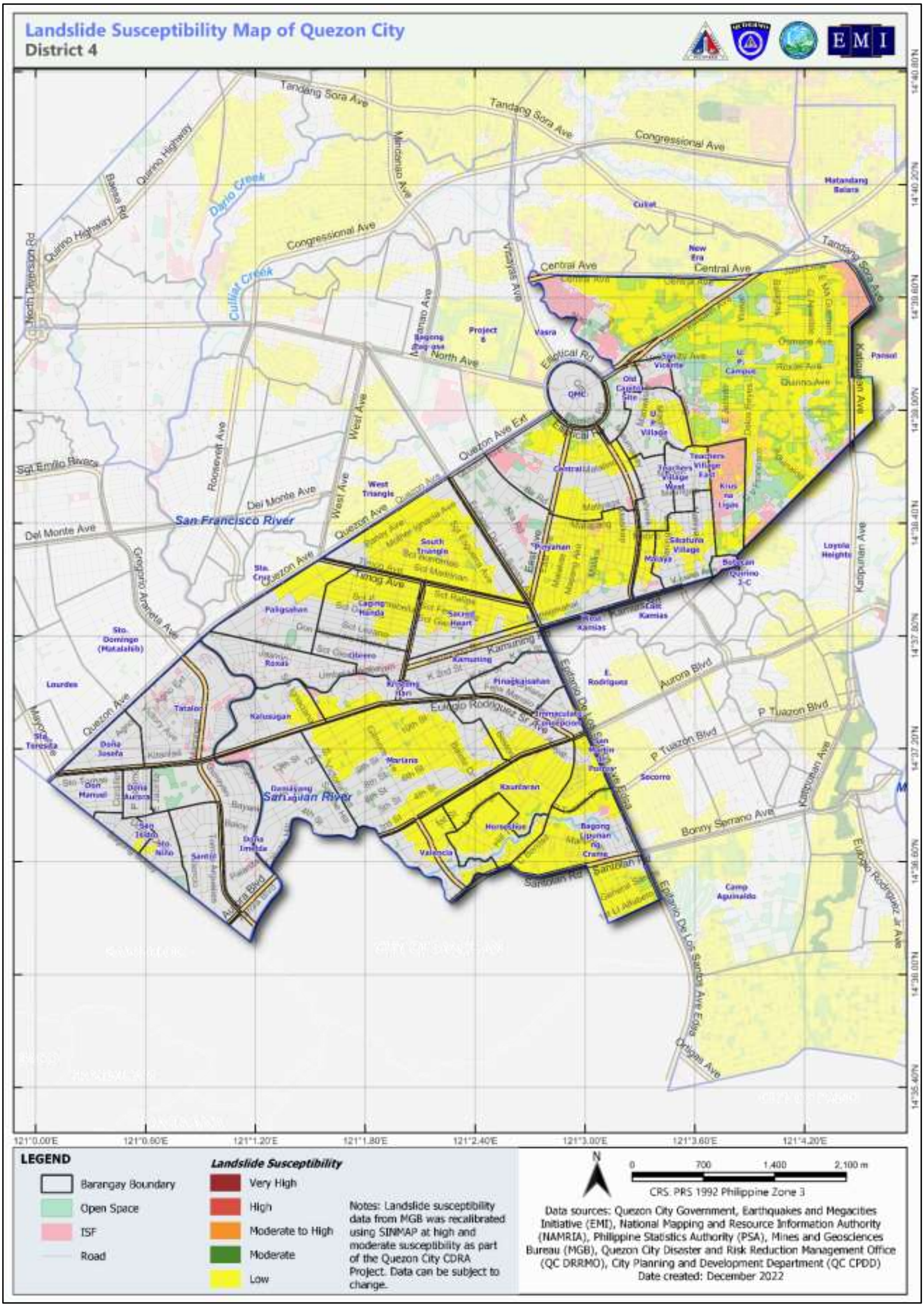


Figure 99. Landslide susceptibility map of District 4 (recalibrated MGB data at moderate and high susceptibility)

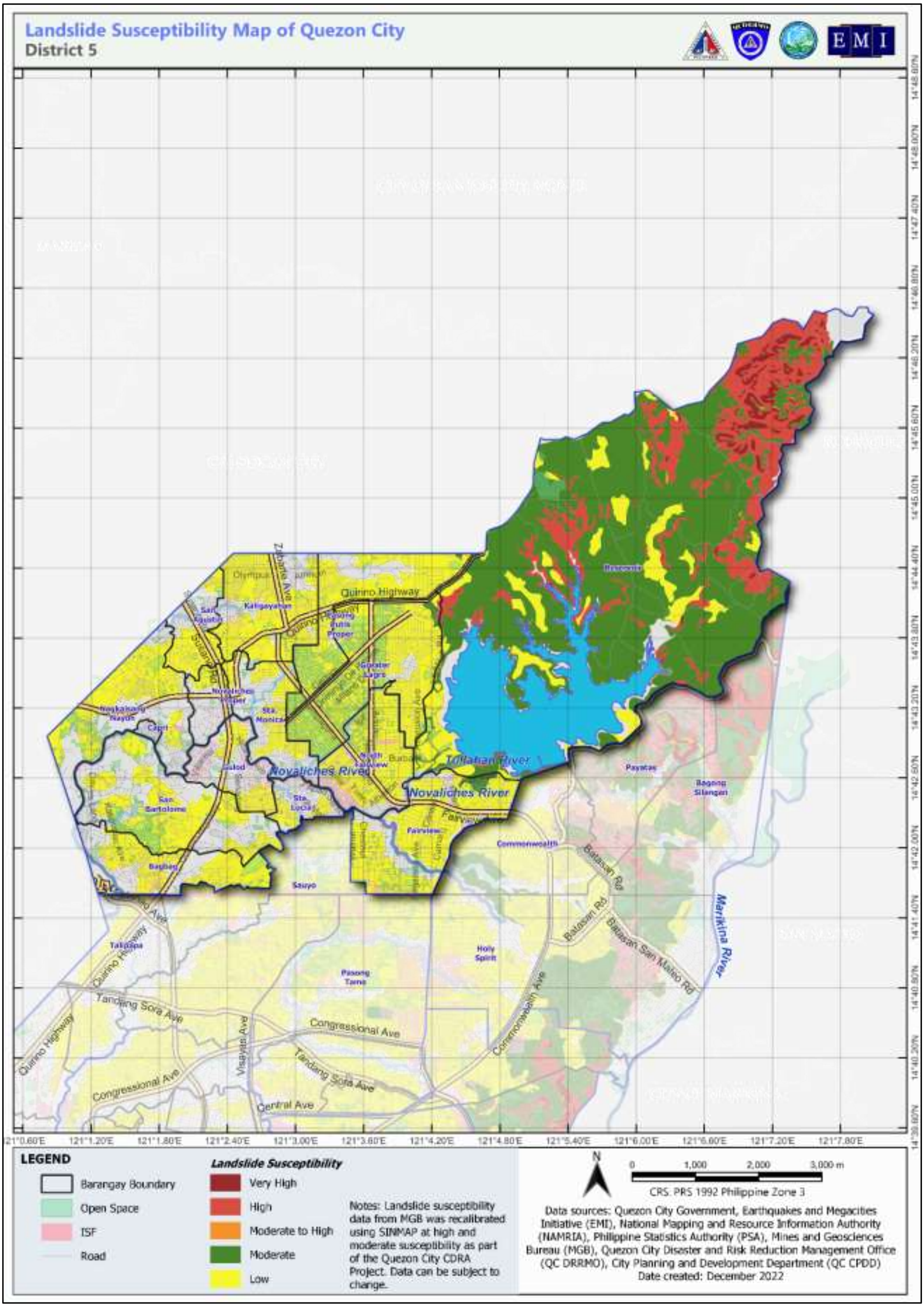


Figure 100. Landslide susceptibility map of District 5 (recalibrated MGB data at moderate and high susceptibility)

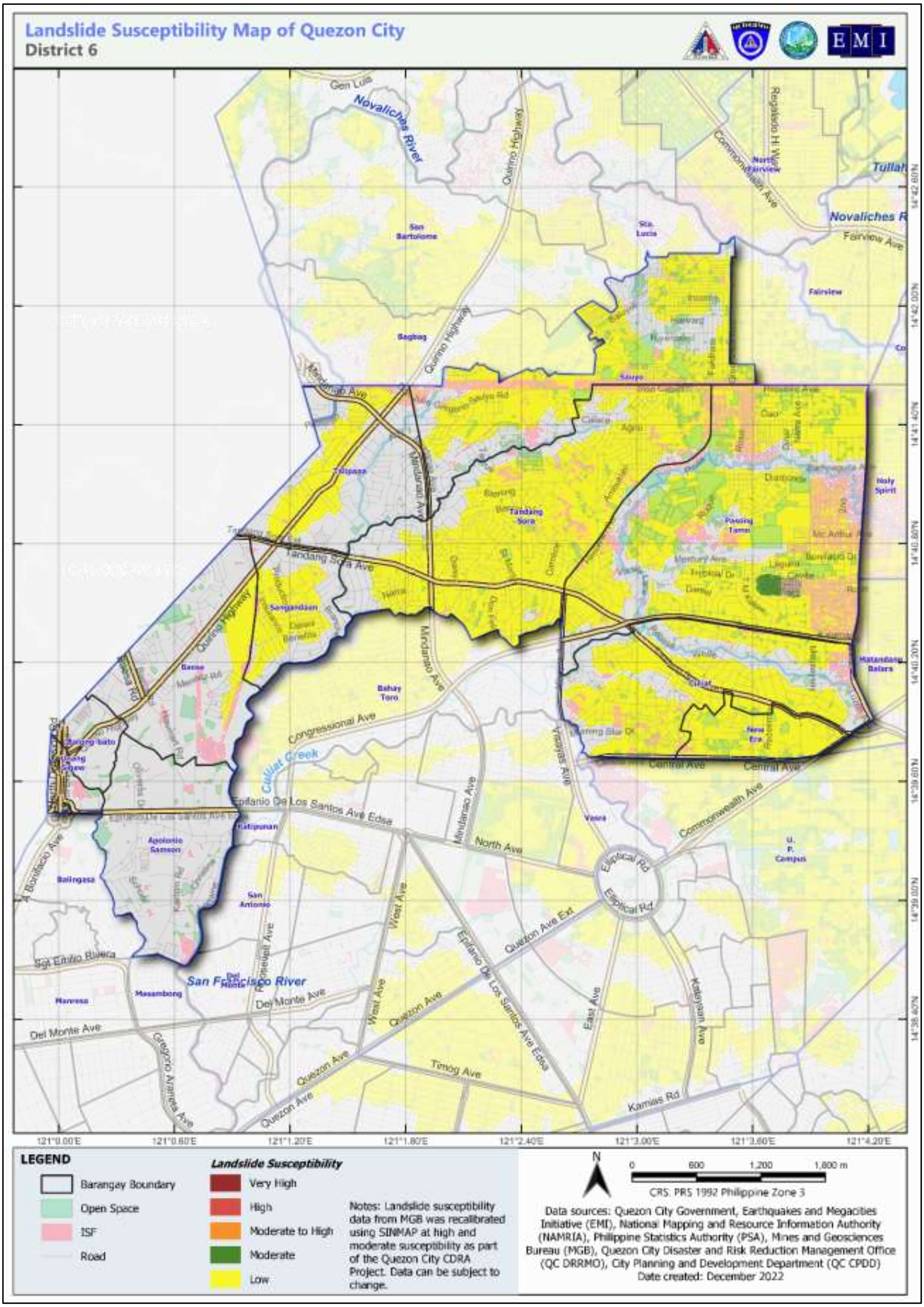


Figure 101. Landslide susceptibility map of District 6 (recalibrated MGB data at moderate and high susceptibility)

5.4. Landslide Risk Assessment

5.4.1. Critical Facilities Affected by Landslide Hazard

The following sections present the critical facilities with overlay on the landslide susceptibility data per district. This indicates that there are a number of critical facilities such as evacuation centers, hospitals, health centers, police stations, fire stations, barangay halls, and other facilities that will be affected by possible landslides in Quezon City. The particular barangays where these facilities are located can also be identified in the related maps.

5.4.2. Facilities for Health and Emergency

Generally, hospitals and health centers are the primary facilities for people needing medical attention in times of emergency. Evacuation centers are pre-identified locations for different areas of Quezon city to provide shelter and initial support to affected people during and after an emergency. Figure 102 to Figure 107 shows critical point facilities such as hospitals, health centers, evacuation centers, and multi-purpose buildings with overlay of the landslide susceptibility map.

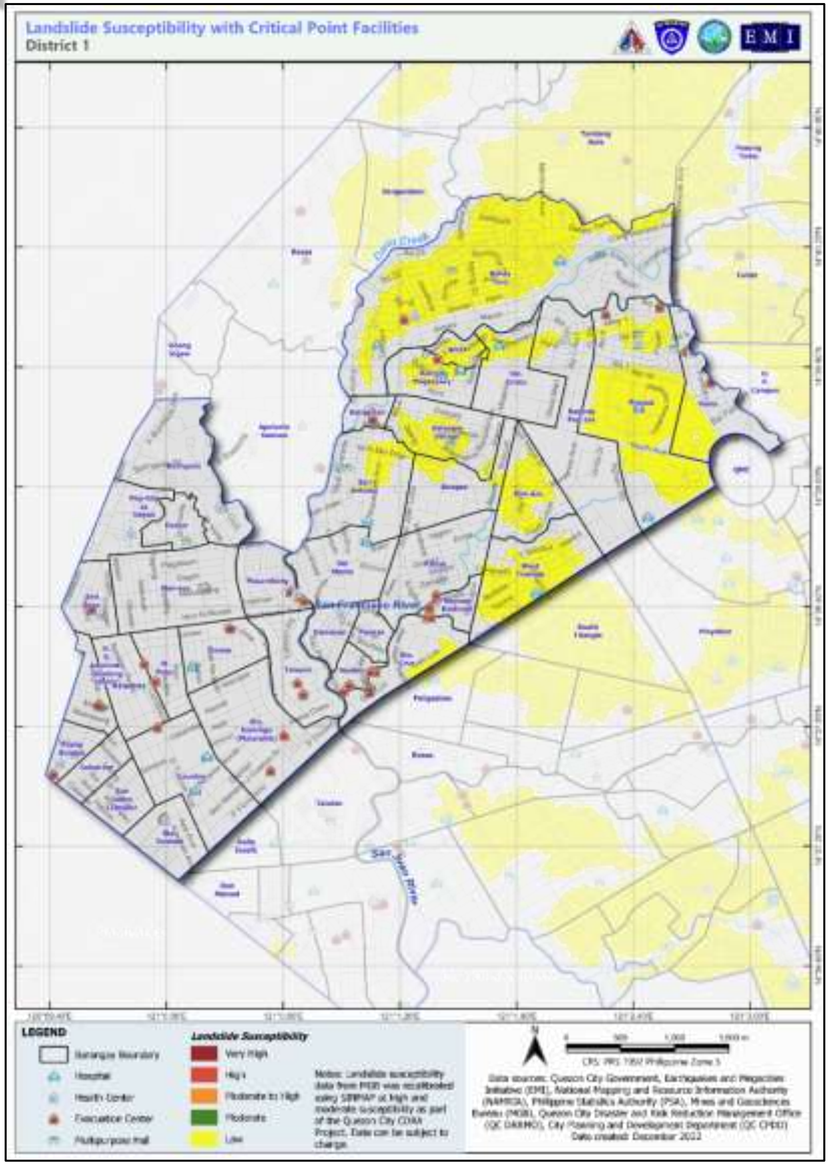


Figure 102. Landslide susceptibility map with hospitals, health center, evacuation centers and multi-purpose halls for District 1

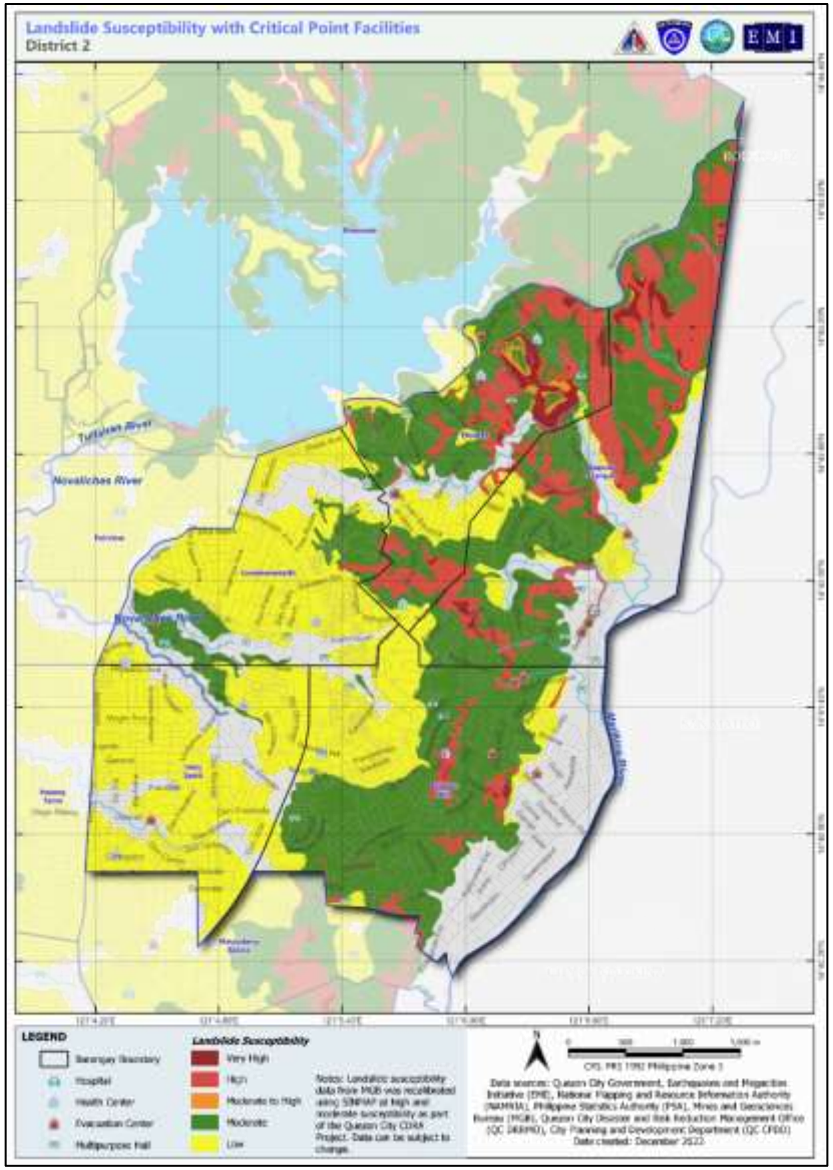


Figure 103. Landslide susceptibility map with hospitals, health center, evacuation evacuation centers and multi-purpose halls for District 2

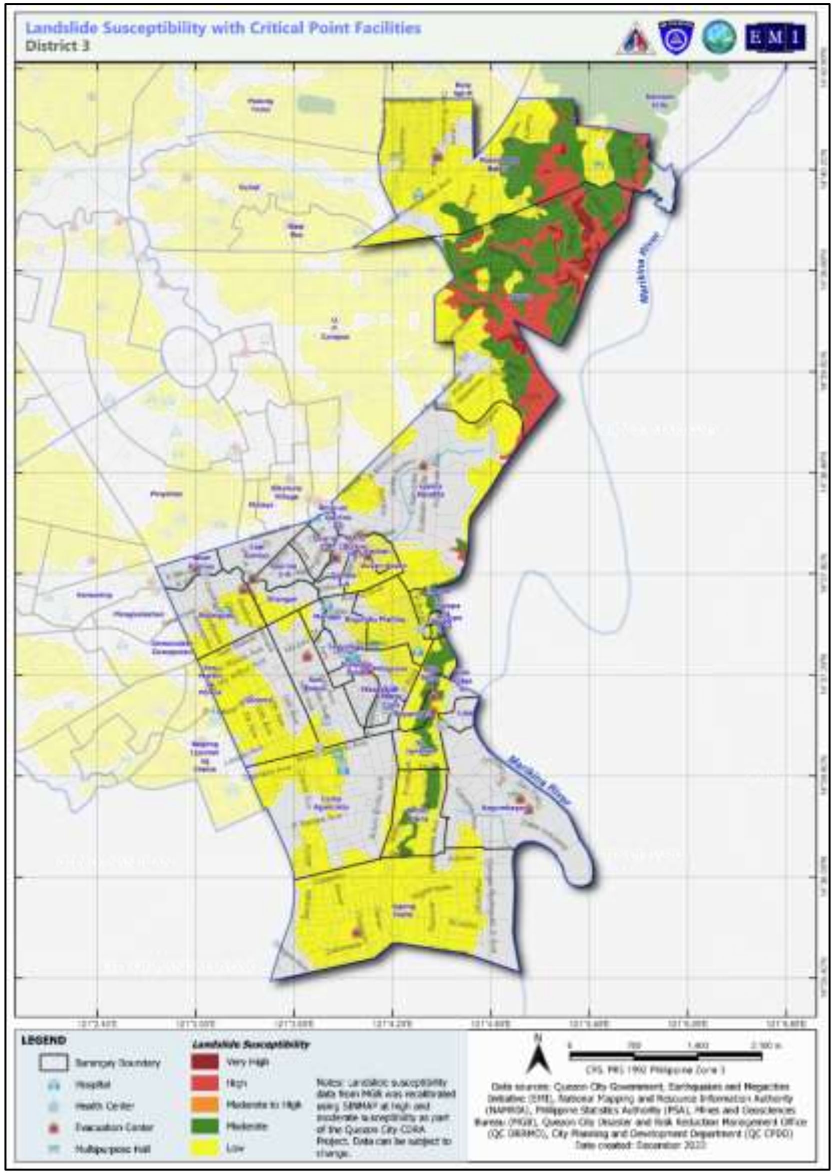


Figure 104. Landslide susceptibility map with hospitals, health center, and multi-purpose halls for District 3

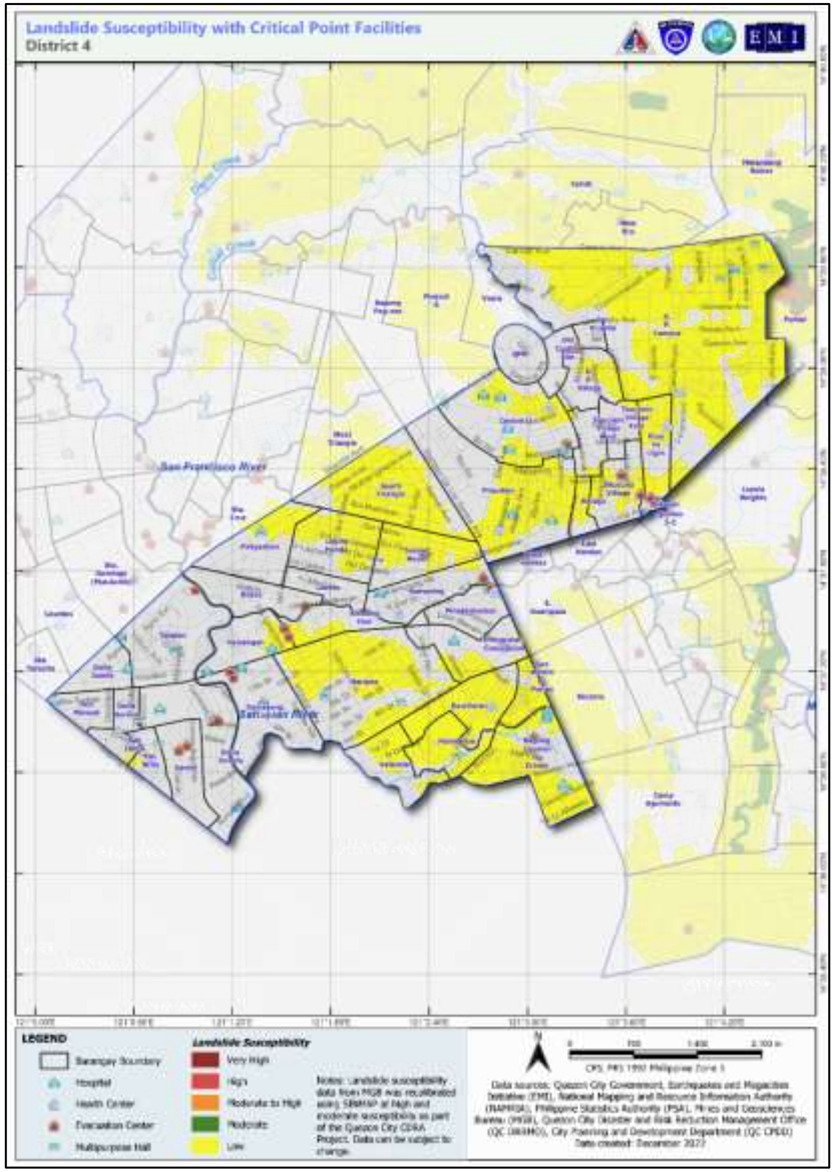


Figure 105. Landslide susceptibility map with hospitals, health center, evacuation centers and multi-purpose halls for District 4

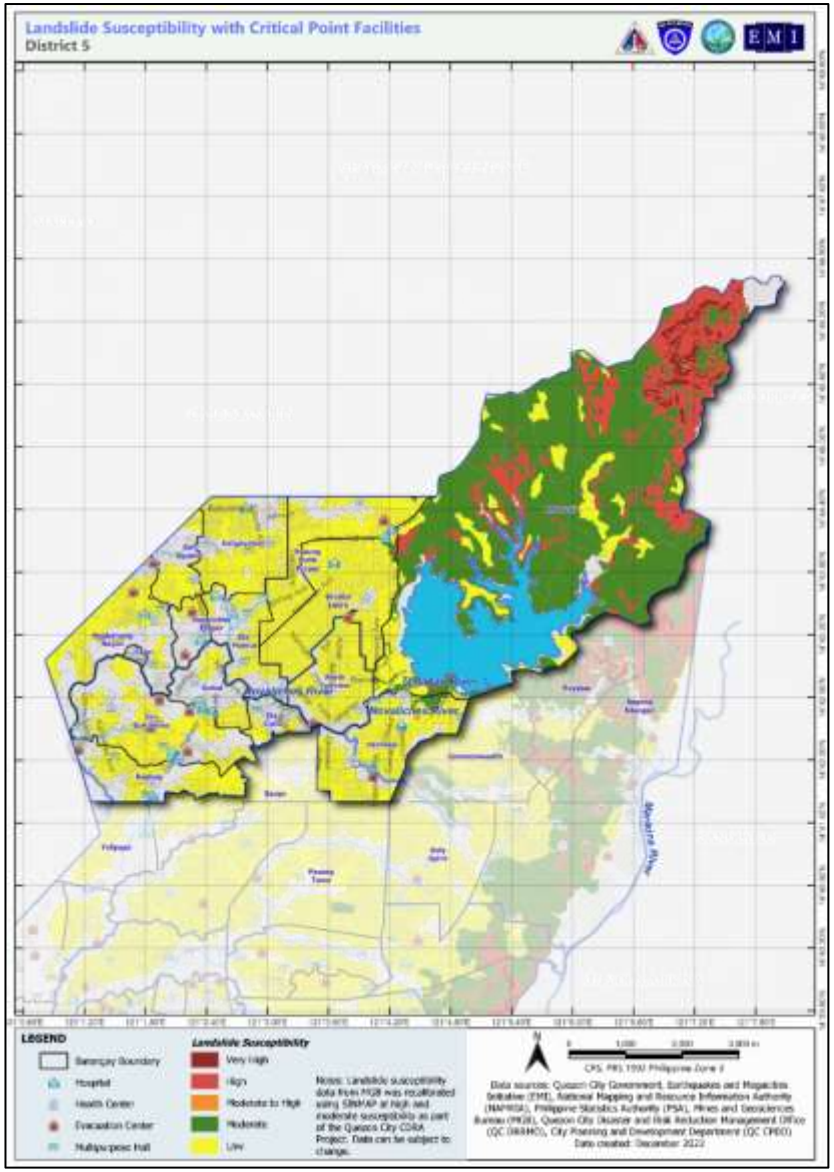


Figure 106. Landslide susceptibility map with hospitals, health center, evacuation centers and multi-purpose halls for District 5

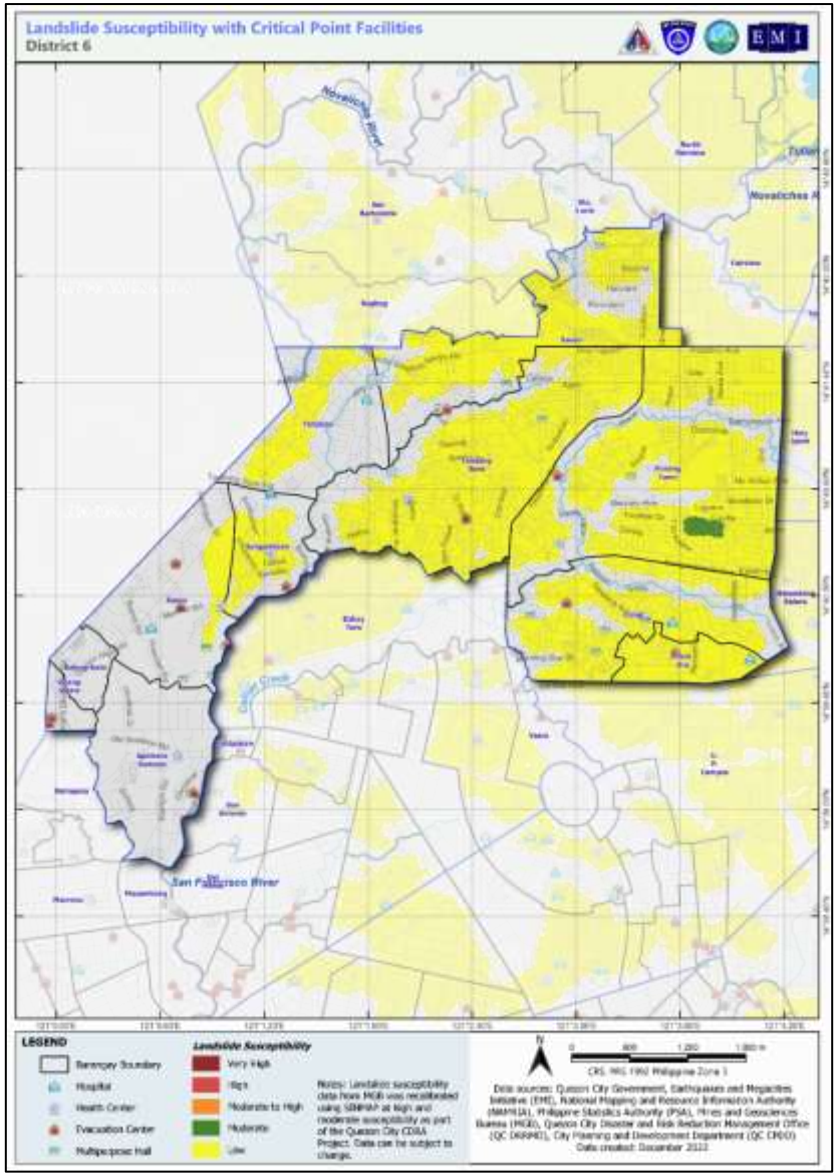


Figure 107. Landslide susceptibility map with hospitals, health center, evacuation centers and multi-purpose halls for District 6

5.4.3. Facilities for Safety and Security

Police, fire stations and barangay halls are critical in response and maintaining order during and after an emergency. Identifying facilities that are in risk of landslides would be crucial to provide uninterrupted and effective services. Figure 108 to Figure 113 show the location of police and fire stations, and barangay halls with an overlay of landslide susceptible areas.

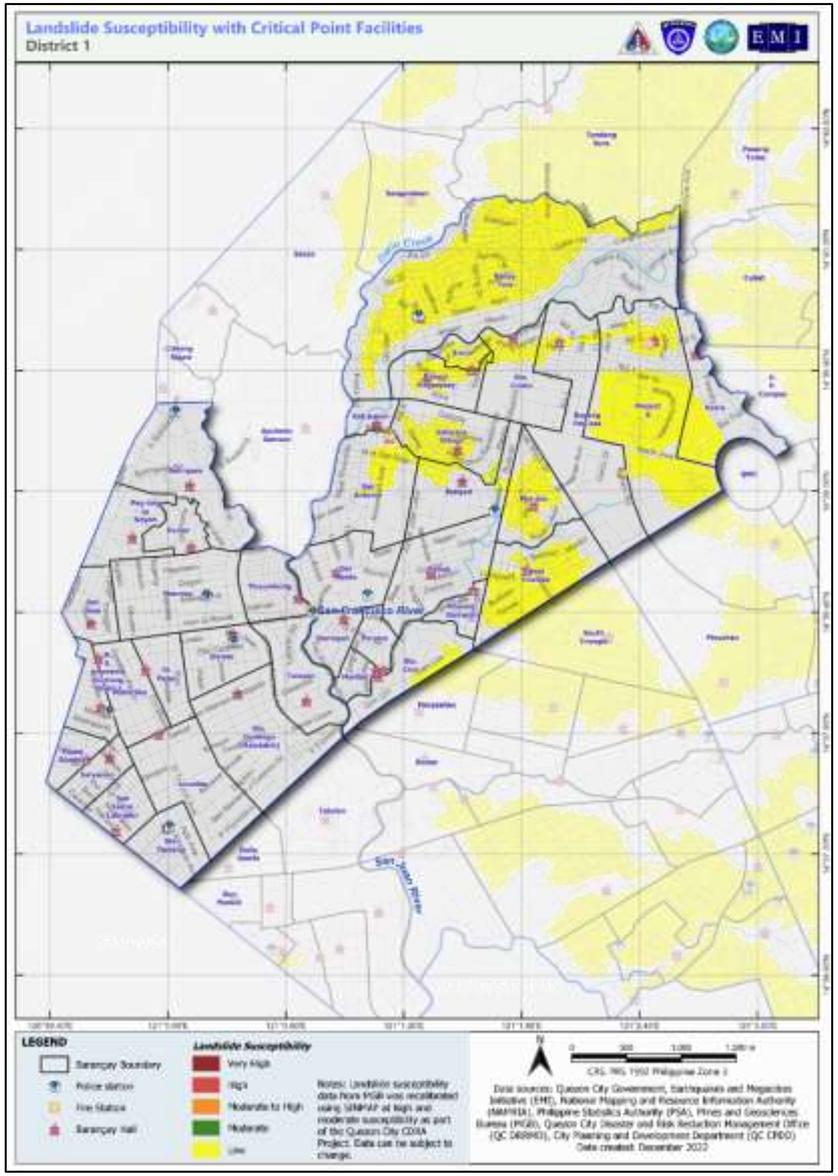


Figure 108. Landslide susceptibility map with police and fire stations, and barangay halls for District 1

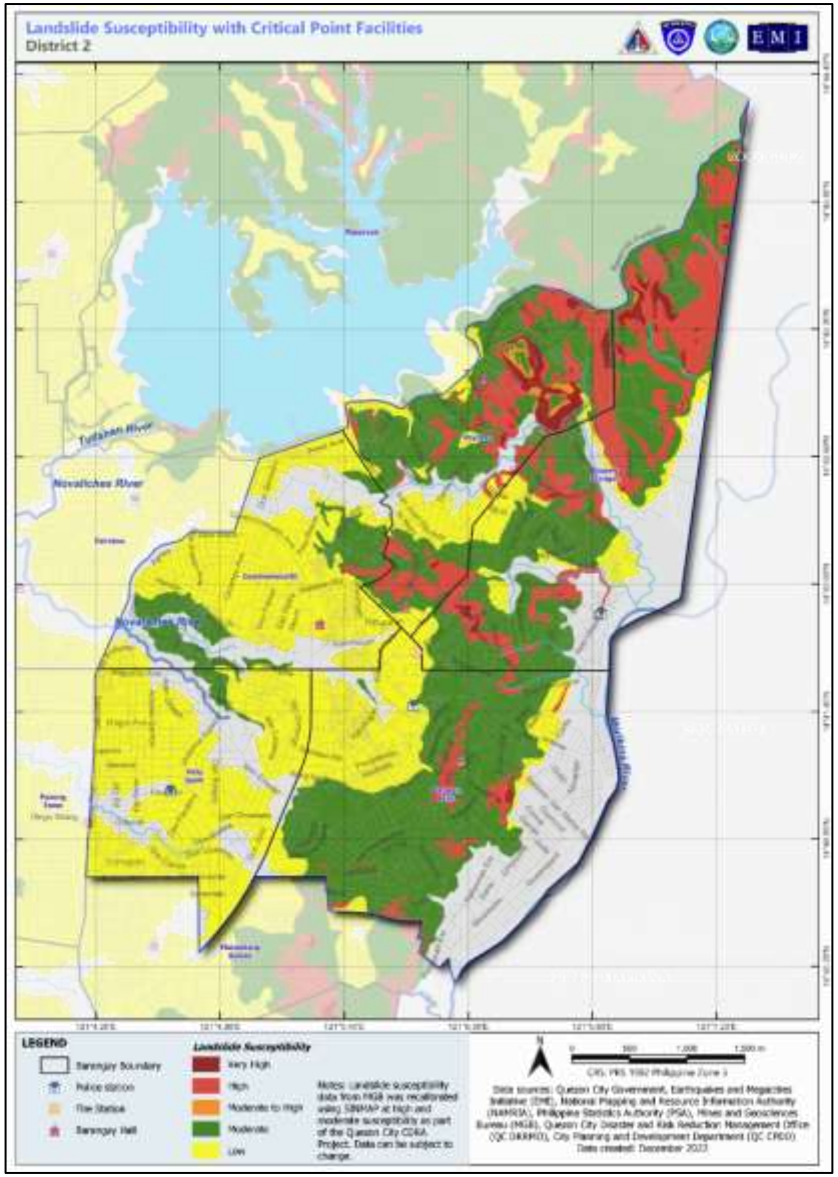


Figure 109. Landslide susceptibility map with police and fire stations, and barangay halls for District 2

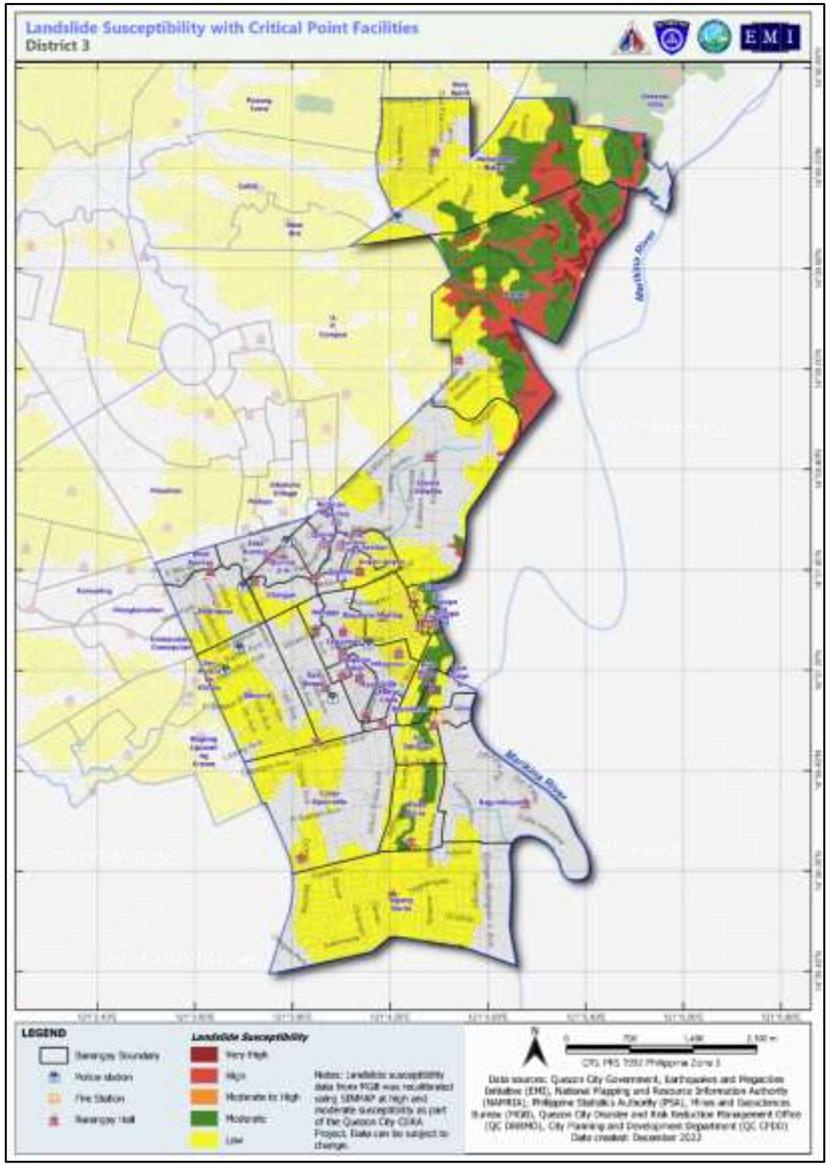


Figure 110. Landslide susceptibility map with police and fire stations, and barangay halls for District 3

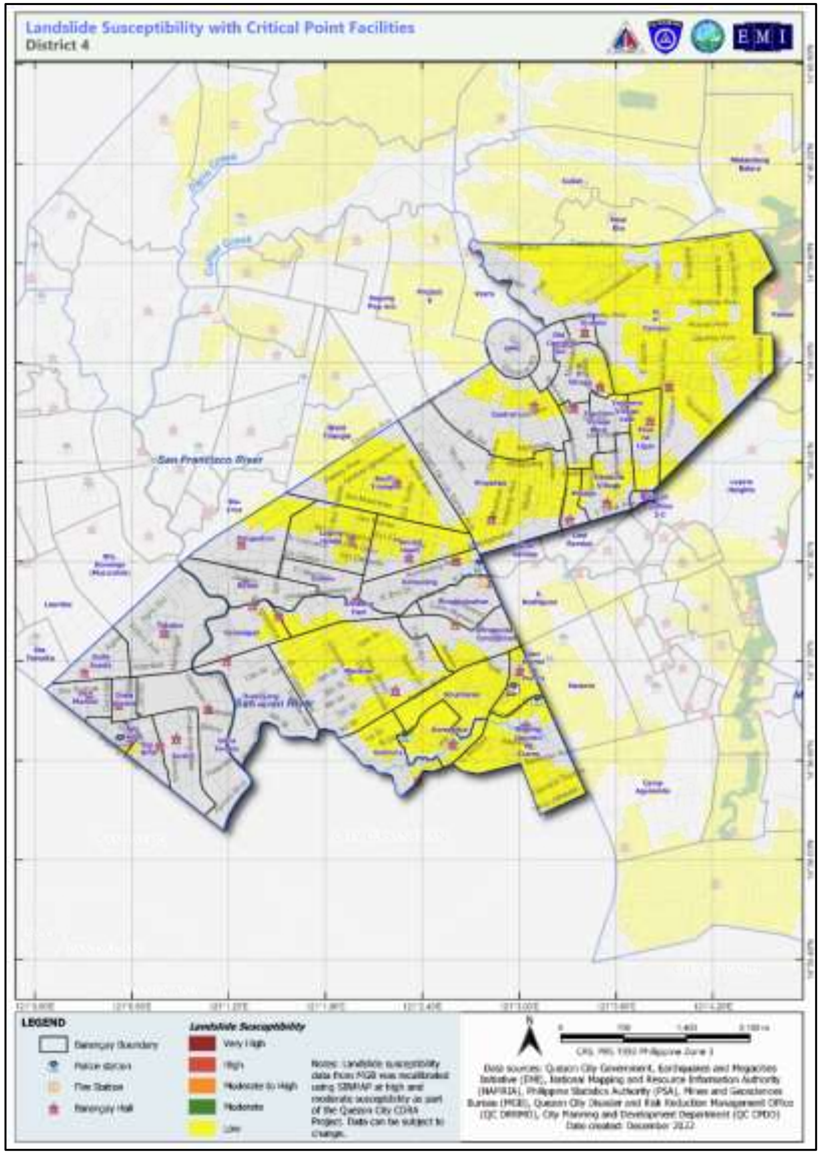


Figure 111. Landslide susceptibility map with police and fire stations, and barangay halls for District 4

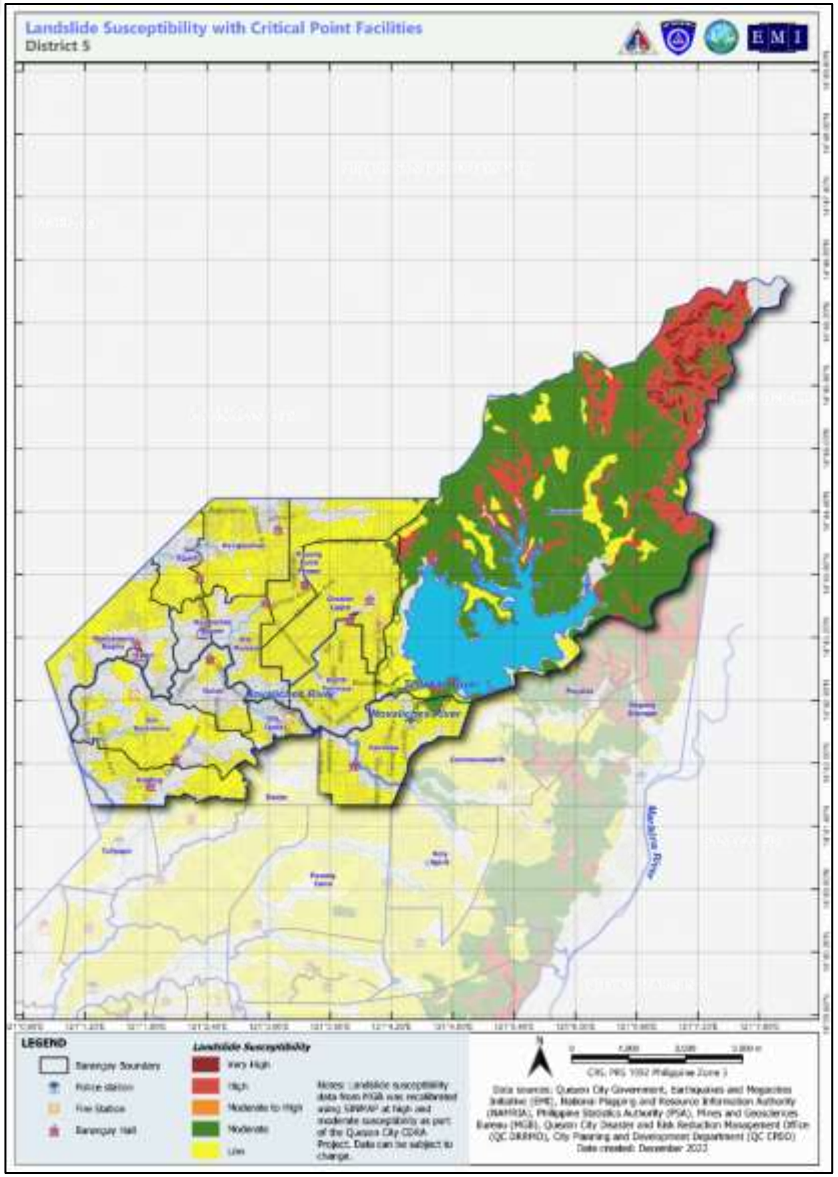


Figure 112. Landslide susceptibility map with police and fire stations, and barangay halls for District 5

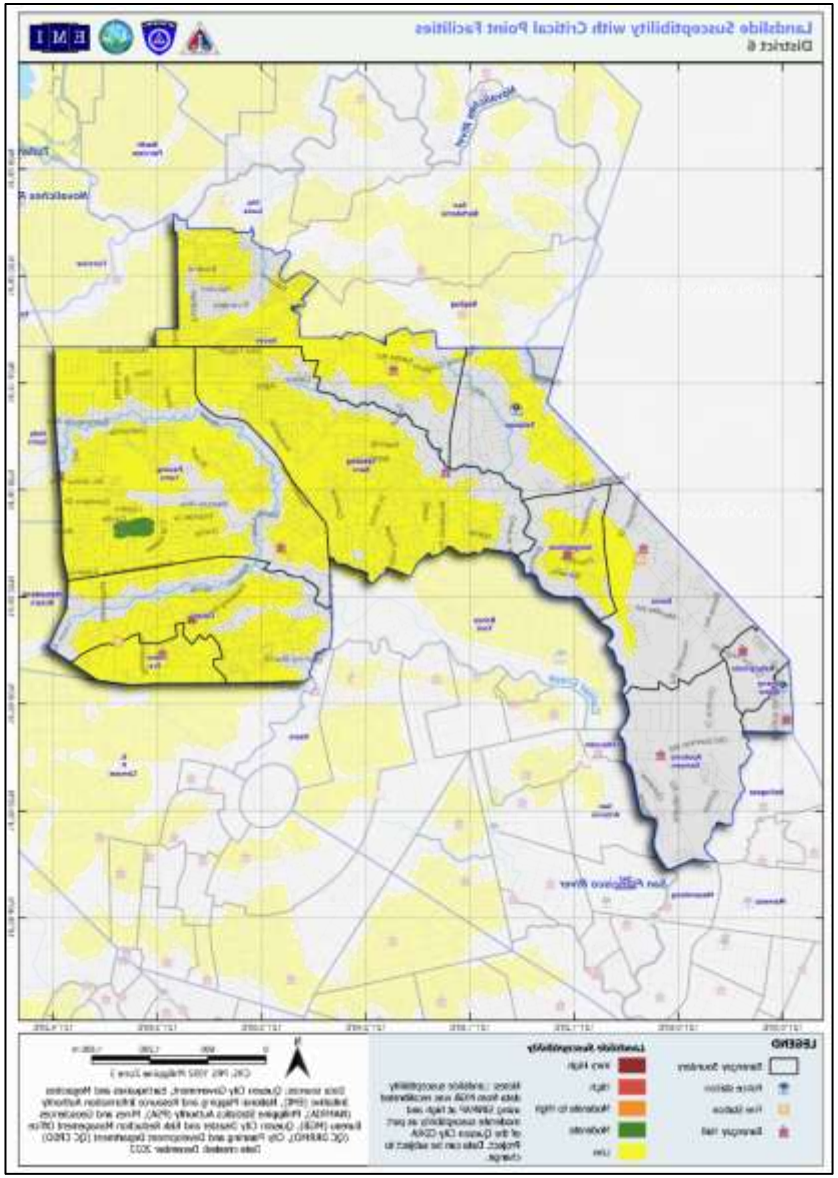


Figure 113. Landslide susceptibility map with police and fire stations, and barangay halls for District 6

5.5. Impact on Transportation Systems and Mobility

5.5.1. Road Network

One of the impacts of landslides to infrastructure is the possibility of impassable road segments due to movement of the ground. Road networks at high to very high landslide susceptibility could be an indicator of possible roadblock, limit in access and potential need for reconstruction to deliver services during and after disaster. Table 66 shows the length of road segments within the high to very high landslide susceptibility in the affected area barangays. It is worth noting that barangay Bagong Silangan will have more than 13km of road impassable. Mobility will be severely impacted for several days if not weeks. Similarly, barangay Pansol will have close to 9km of roads impassable making it very difficult to access.

Table 66. Length of road segments of barangays in Quezon City within high to very high landslide susceptibility

Barangay	Length of Road on High to Very High Landslide Susceptibility (km)
Bagong Silangan	13.26
Pansol	8.95
Batasan Hills	2.59
Matandang Balara	2.02
Greater Lagro	0.39
Commonwealth	0.08
Loyola Heights	0.04

5.5.2. Population Affected by Landslide Hazard

Using an overlay of the recalibrated landslide susceptibility map and residential buildings, population on different landslide susceptibility levels can be estimated. Figure 114 to Figure 119 present the percentage of population for each barangay in Quezon City in moderate to very high susceptibility levels. To narrow down the most susceptible barangays, Figure 120 to Figure 125 show percent population in high to very high susceptibility.

Barangays with population on high to very high susceptibility are Payatas, Bagong Silangan, Pansol, Batasan Hills, Commonwealth, Matandang Balara, Greater Lagro, Loyola Heights. Around 20-40% of the population of barangay Payatas, Bagong Silangan and Pansol are located in high to very high susceptible areas.

In addition to the barangays mentioned above, the following barangays are in moderate to moderate to high susceptibility: Pasong Tamo, Holy Spirit, Escopa 3, Fairview, Escopa 2, Escopa 4, Blue Ridge A, Sta. Cruz, and Blue Ridge B.

The rest of Quezon City falls under no to low susceptibility based on the MGB data.

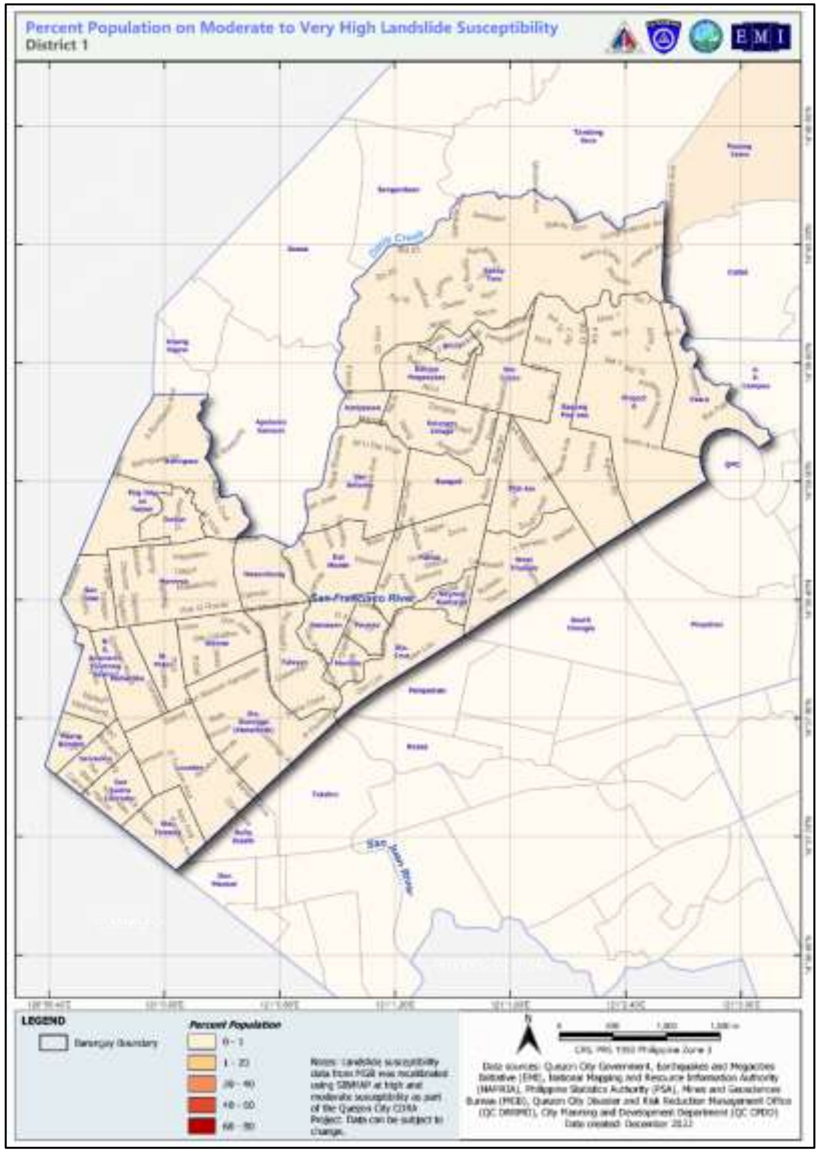


Figure 114. Percent population per barangay in moderate to very high susceptibility to landslide for District 1

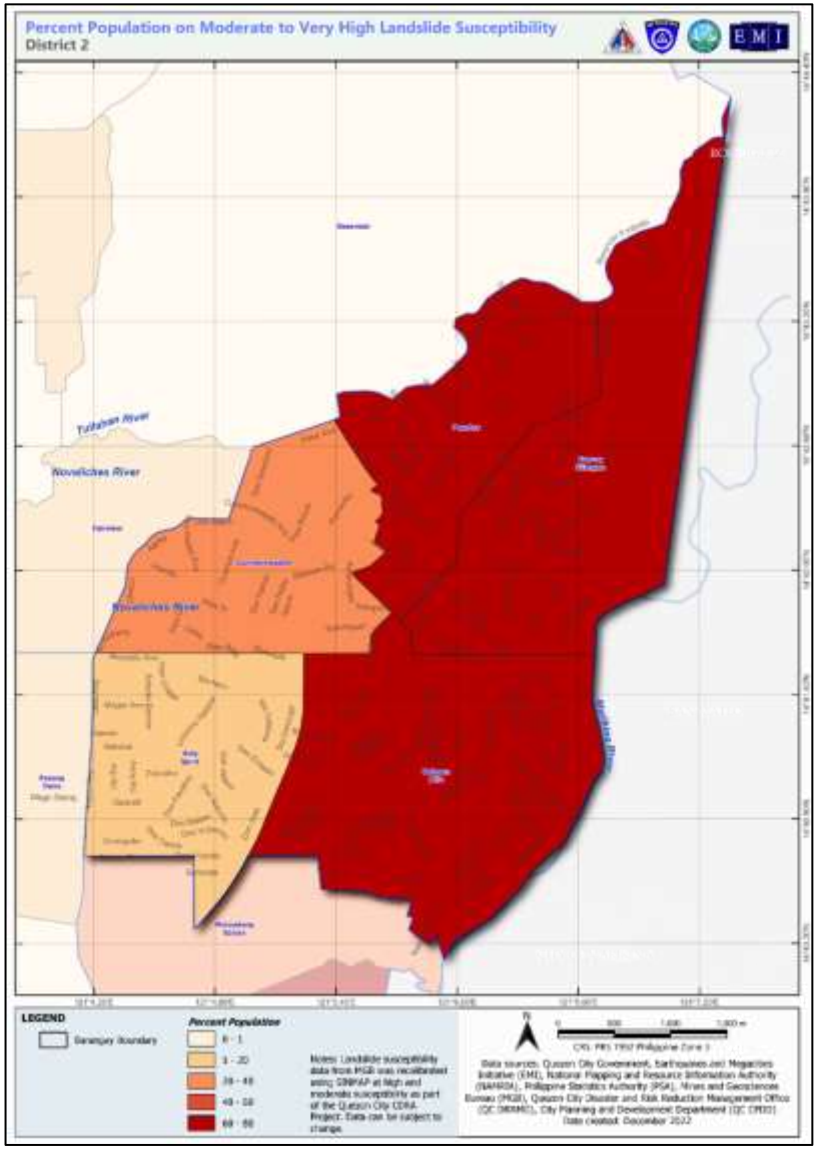


Figure 115. Percent population per barangay in moderate to very high susceptibility to landslide for District 2

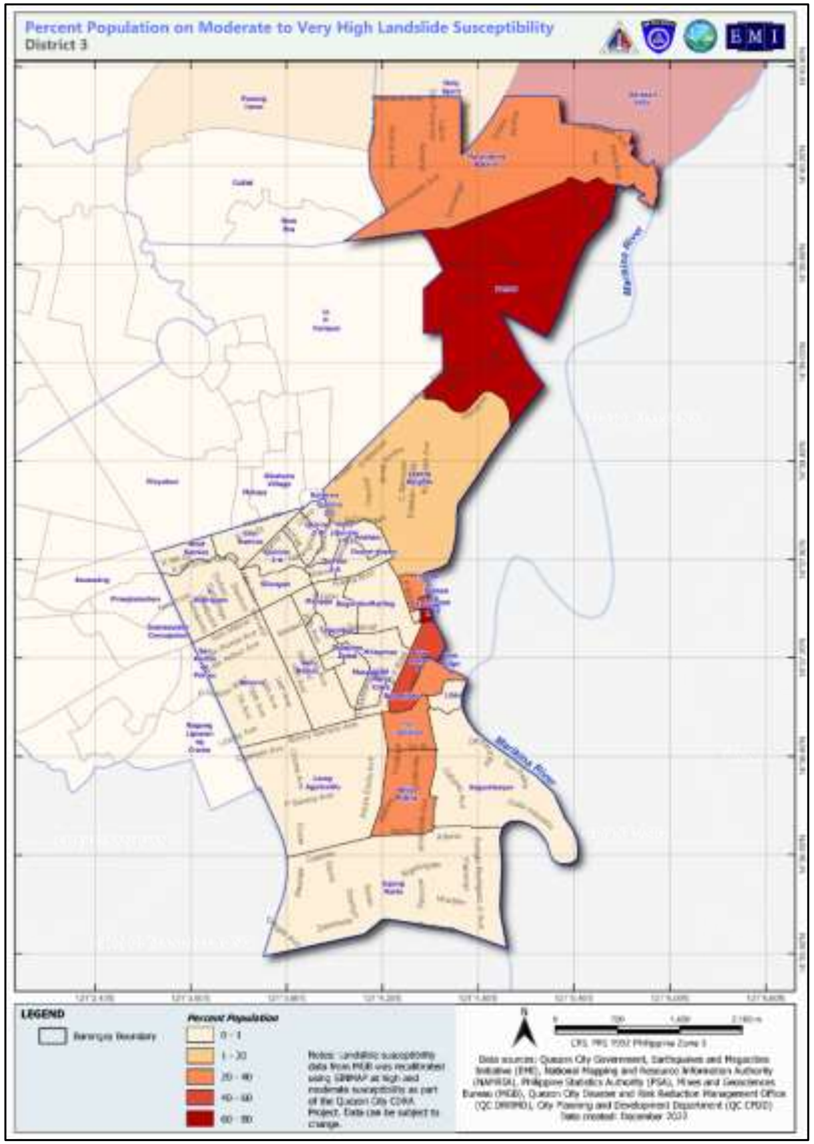


Figure 116. Percent population per barangay in moderate to very high susceptibility to landslide for District 3

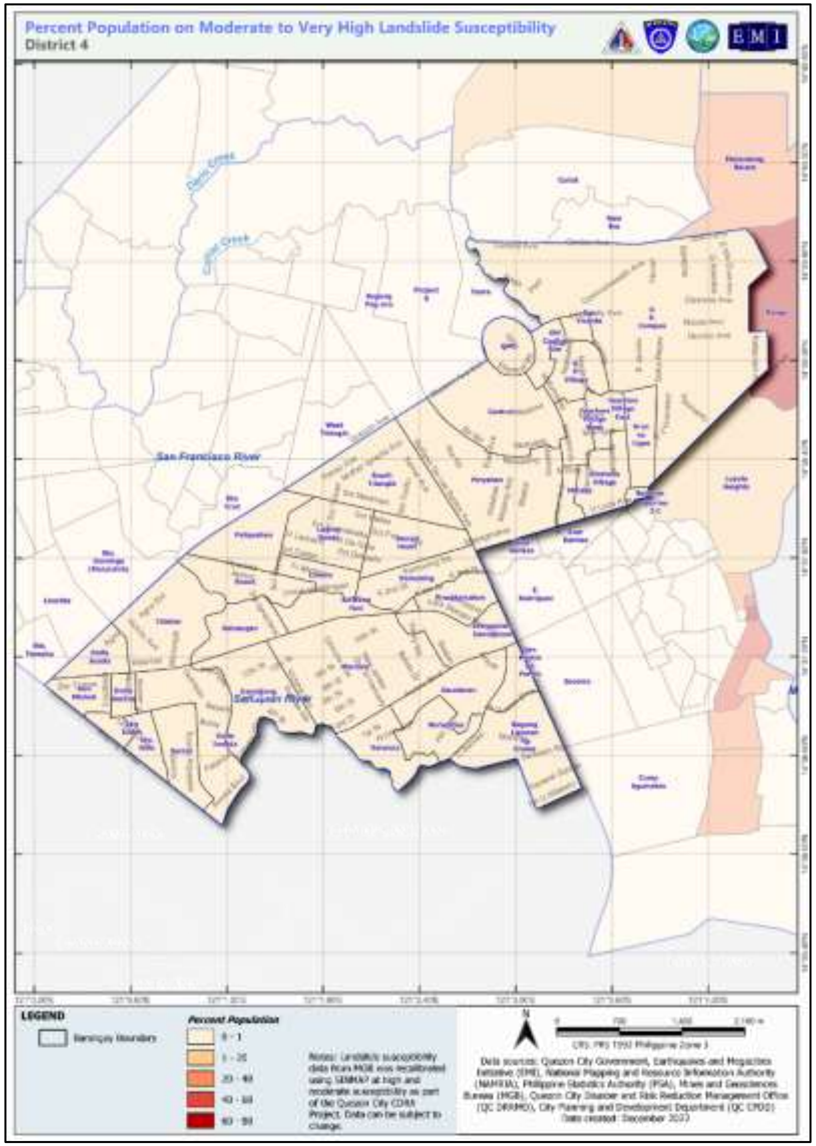


Figure 117. Percent population per barangay in moderate to very high susceptibility to landslide for District 4

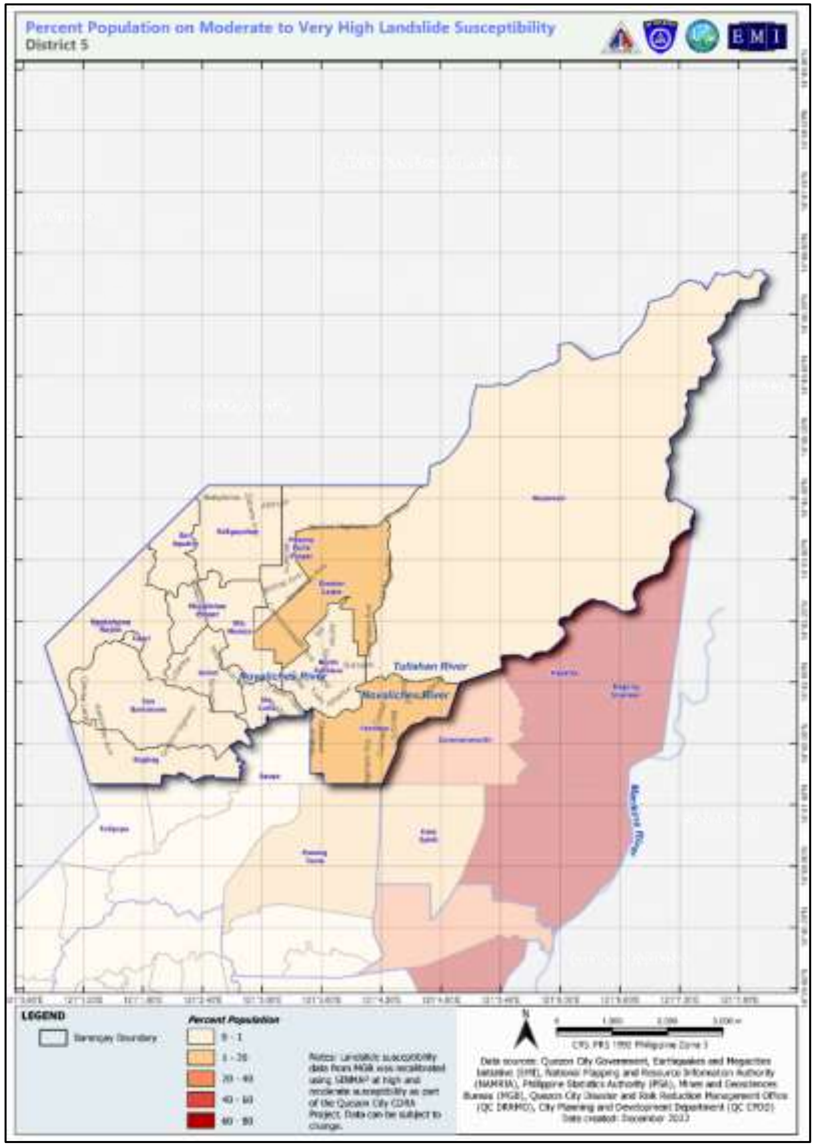


Figure 118. Percent population per barangay in moderate to very high susceptibility to landslide for District 5

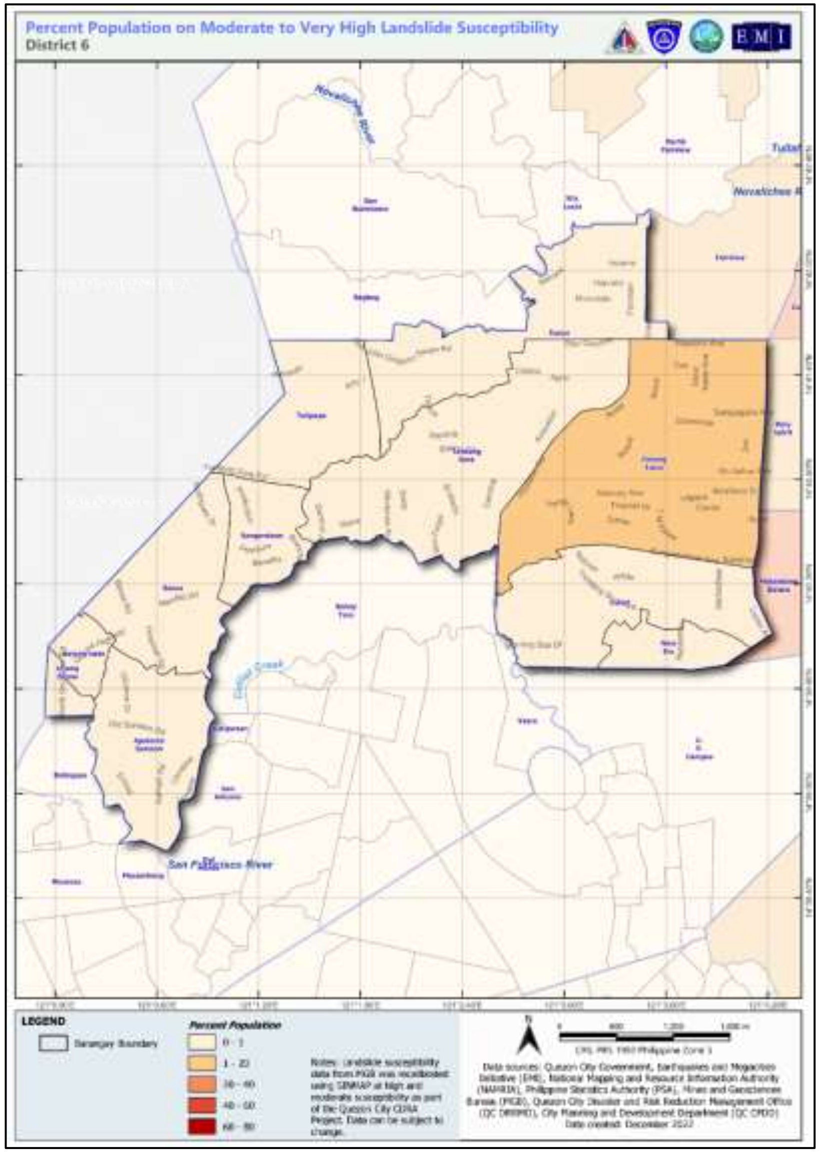


Figure 119. Percent population per barangay in moderate to very high susceptibility to landslide for District 6

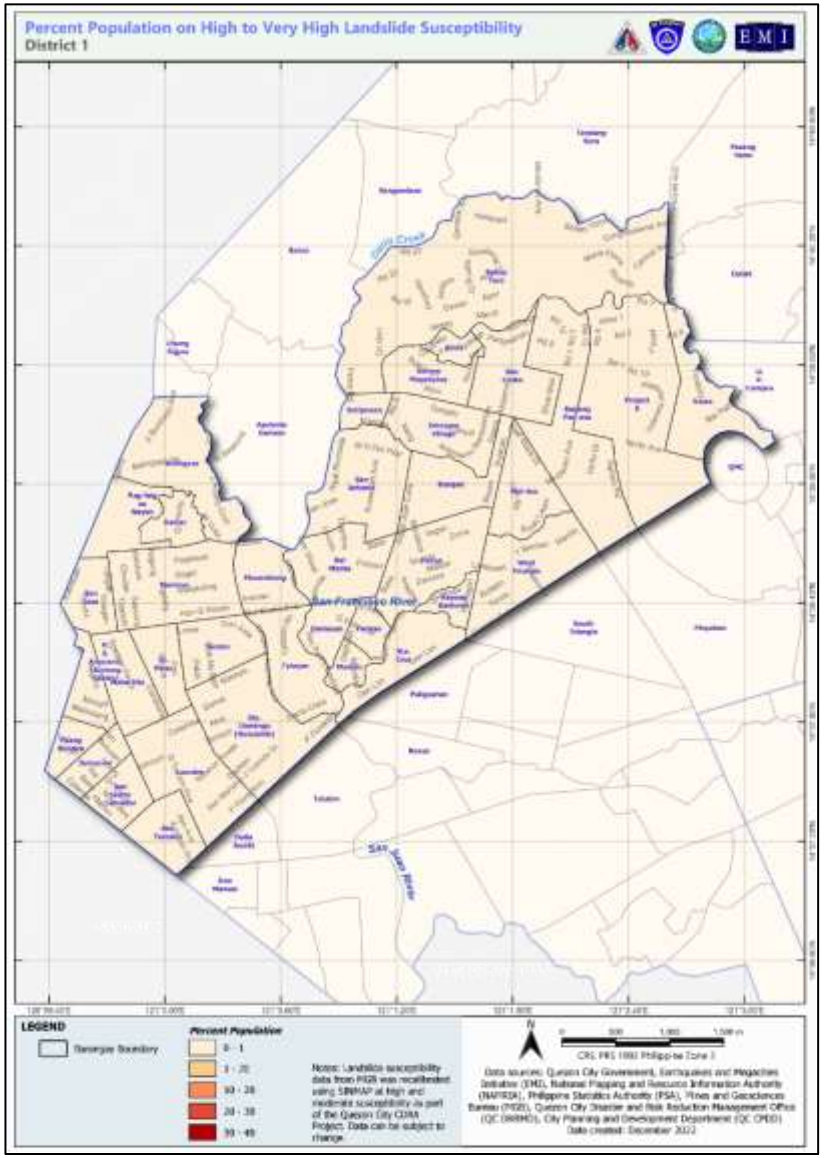


Figure 120. Percent population per barangay in high to very high susceptibility to landslide for District 1

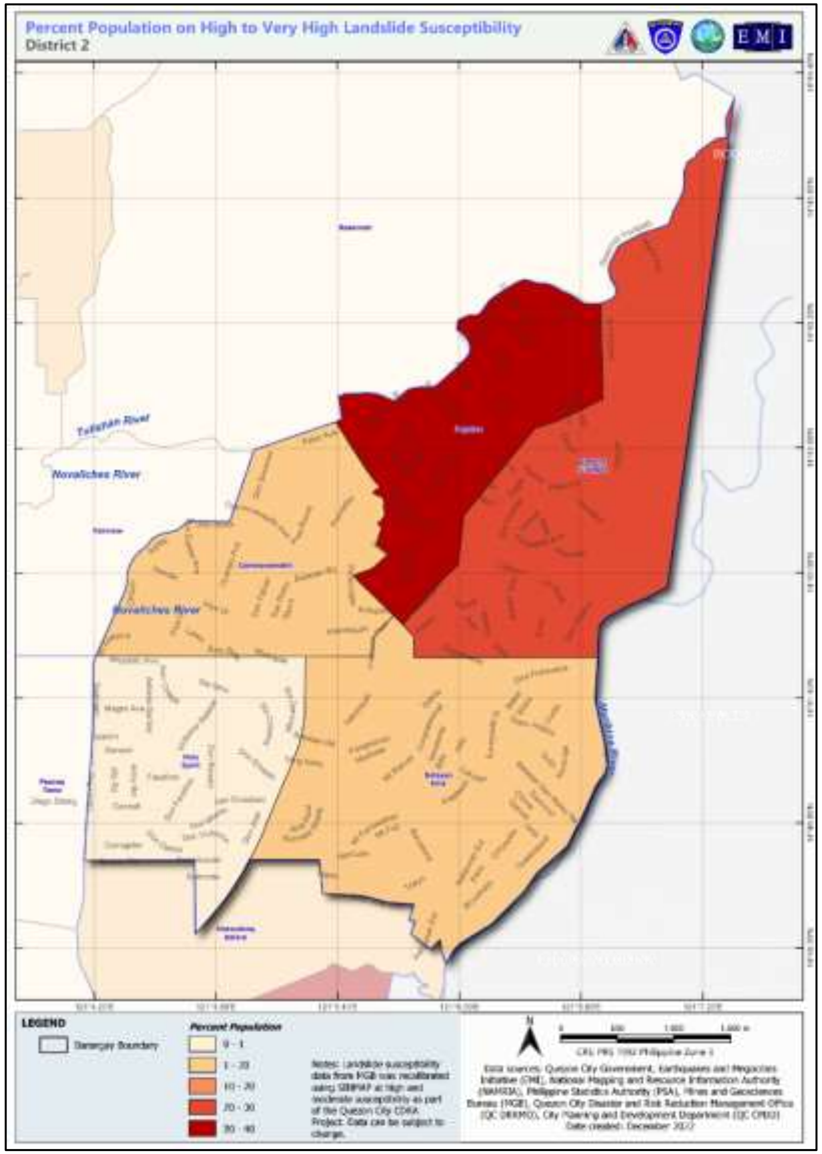


Figure 121. Percent population per barangay in high to very high susceptibility to landslide for District 2

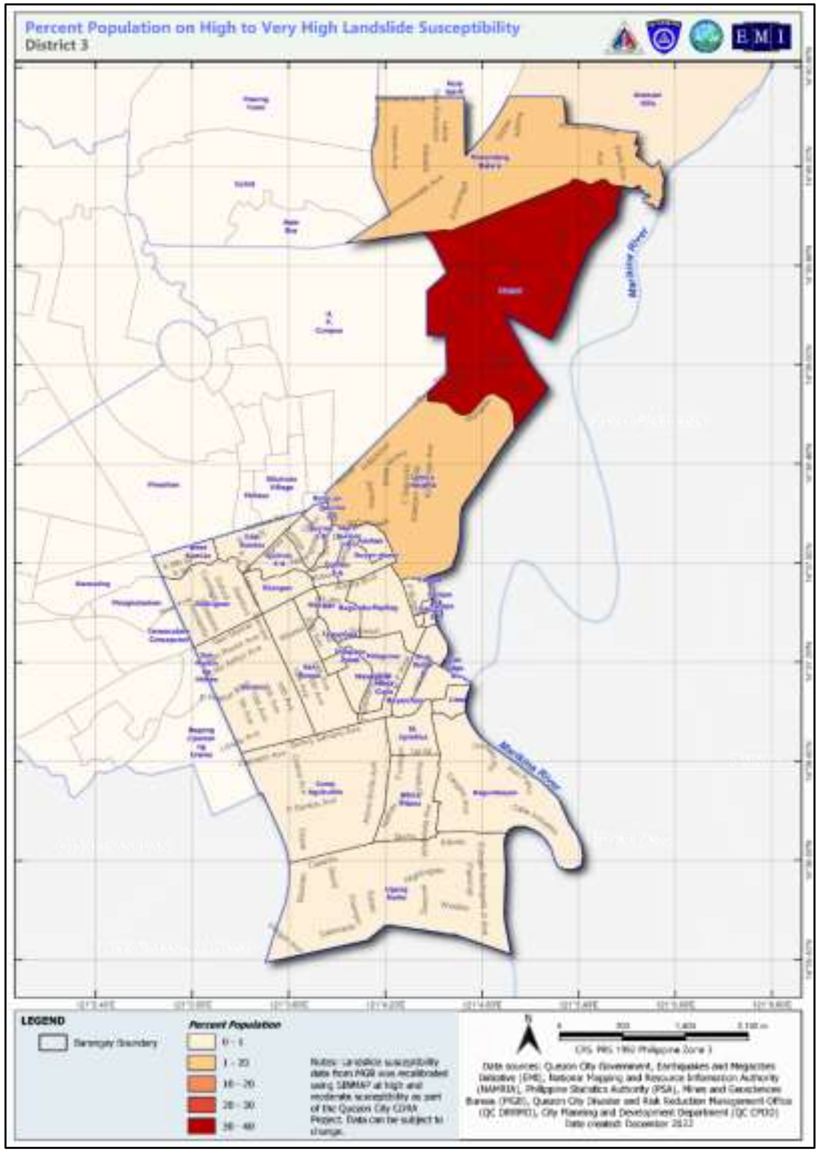


Figure 122. Percent population per barangay in high to very high susceptibility to landslide for District 3

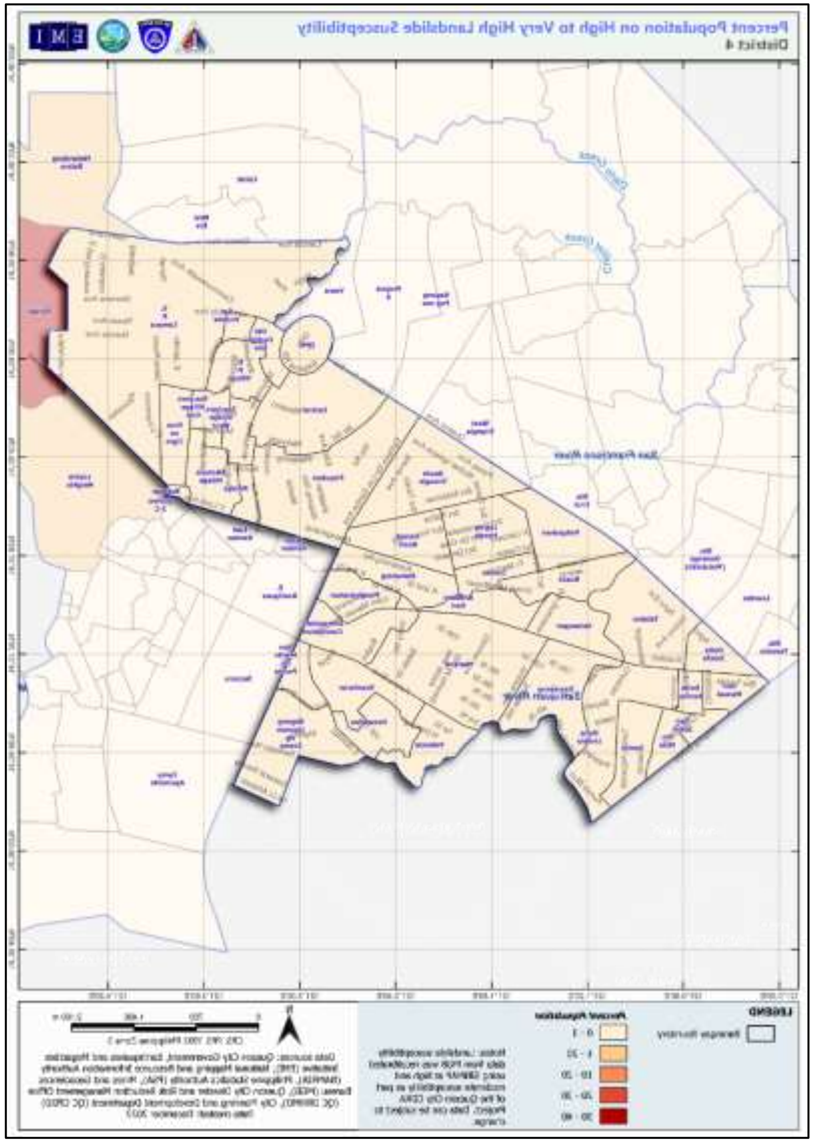


Figure 123. Percent population per barangay in high to very high susceptibility to landslide for District 4

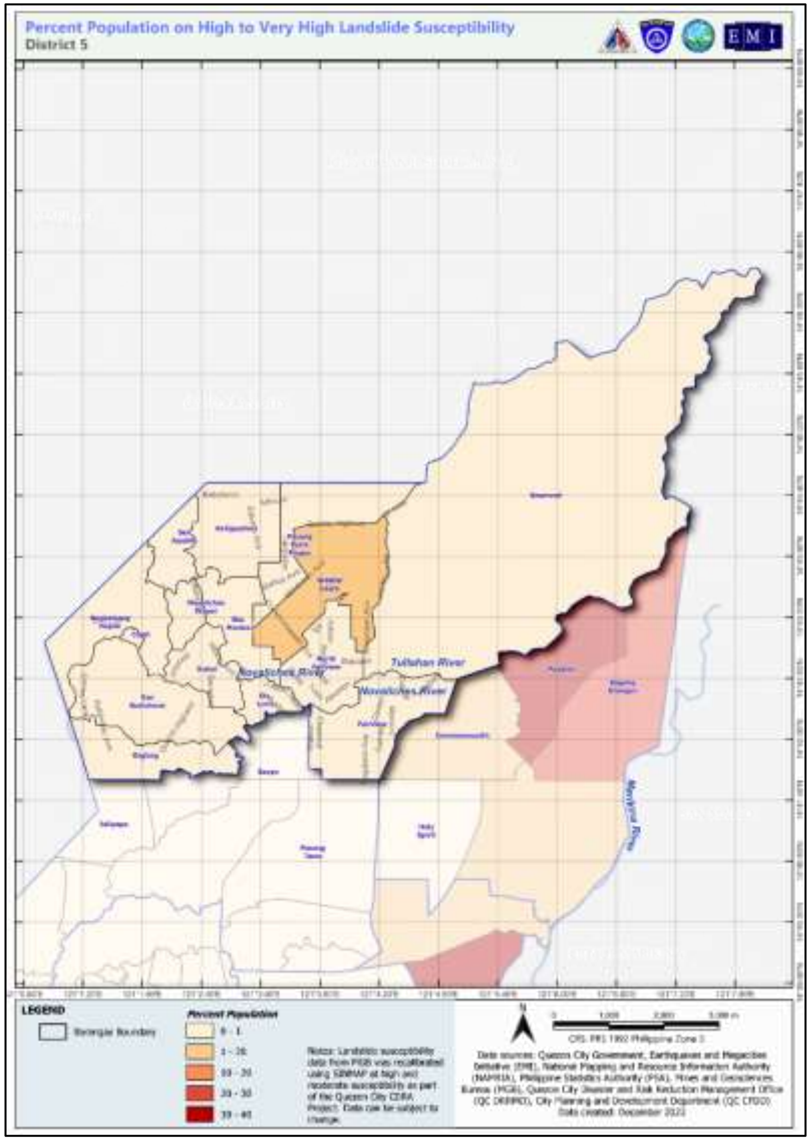


Figure 124. Percent population per barangay in high to very high susceptibility to landslide for District 5

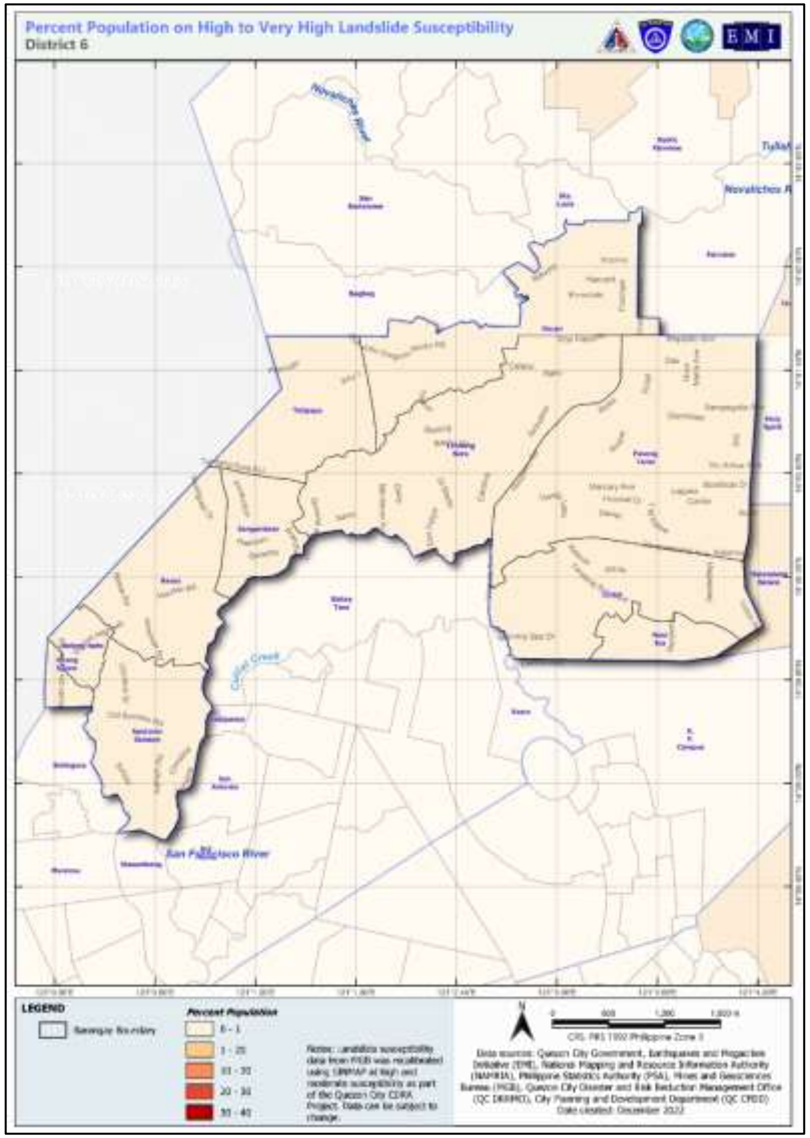


Figure 125. Percent population per barangay in high to very high susceptibility to landslide for District 6

Part 6:

Hotspot Barangays

Part 6: Hotspot Barangays

6.1. Introduction: Hotspots and Indicators

6.1.1. What are hotspot barangays and related indicators?

Hotpot barangays are barangays that represent the highest potential vulnerability for one or multiple hazards. The assessment of vulnerability is measured by an "**Index**", which is calculated based on a combination of relevant vulnerability indicators. To understand the relevance of hotspots, it is important to understand the related **indicators** that are used to identify the hotspots.

Indicators are quantitative parameters intended to best represent the core characteristics of a system's performance (or lack thereof), which in this case is a measure of barangay vulnerability.
Combining these indicators analytically and applying relative weights will produce a single **vulnerability index** that can be used to rank the barangays to determine the hotspot barangays. Identifying hotspot barangays helps inform decision making in terms of disaster risk reduction investment, build consensus on prioritization of action, and provide a way to measure progress over time. Indicators are also a powerful tool to raise awareness and to advocate for investment in DRR.

Indicators' based indices are widely used for consistent relative ranking of countries or any other process or system to enable decision making and to measure progress. Among some of the most widely known indicators are the World Poverty Index, the World Risk Index but also indices such as the Dow-Jones or countries credit ratings. It is important to note that indices are only relevant to a relative ranking. An index by itself is often a dimensionless quantity that has relevance relative to a ranking scale. For example, in the World Poverty Index, the index itself is not objective. However, what is objective and coherent is the ranking of countries relative to the index. Similarly, for the Dow-Jones the index of the day only takes relevance when compared to the previous days. Thus, one has to only focus on the relative ranking to benefit from the value of the indicators.

6.1.2. Defining the Barangay Vulnerability Index for Quezon City

In the development of the Quezon City Risk Profile and Atlas, four hazards were considered, namely: Earthquakes, Floods, Landslides and Climate Change. As explained in Chapter 3, the impact of climate change is incorporated in the assessment of the flood hazard and flood risk. Hence, the indicators selected for the flood hazard, explicitly integrate the effects of climate change.

The index used to determine the hotspot barangays is termed as the Barangay Vulnerability Index (BVI). The BVI was developed by EMI and is tailored to the particular geographical, physical and social considerations of Quezon City. A selection of barangays with the highest BVIs are identified as hotspot barangays. A special algorithm is used to perform sensitivity analysis to understand the variability of each indicator and its related weight on the BVI values. This is done to ensure that the outcome in terms of determining the hotspot barangays is coherent, consistent and reliable. The final determination shows that the BVI is a stable and robust index for the determination of the hotspot barangays of Quezon City.

Flood and earthquake hazards affect wide areas of Quezon City spanning a multitude, and in the case of the earthquake hazard, all of the barangays. Each barangay within the city is impacted with varying levels of physical and social severity. Thus, it is of interest to also develop the list of barangay hotspots that represent the combined impact of both the flood and earthquake hazards.

The hotspot barangays for combined hazards can be determined by making the indicators dimensionless quantities and developing a single BVI for the combined hazards. The combined hotspot barangays indicate barangays where the impacts from multiple hazards cumulate to increase vulnerability. It must be noted that a barangay can have a very high BVI for one hazard, but that is not sufficient for that barangay to be represented in the combined hazard hotspot. The exposures and vulnerabilities from multiple hazards must intersect and compound each other to represent a combined higher vulnerability, i.e., a large combined BVI number.

This observation has implications on the consideration of landslide hazard. The landslide hazard concerns only a limited number of barangays that do not intersect with the flood and earthquake hazards in a significant way. Thus, in Quezon City the landslide hazard does not impact the combined BVIs for flood and earthquake and can be considered separately. For these last two hazards, several barangays with high impact for both flood and earthquake hazards intersect and compound to define the combined hotspot barangays.

6.1.3. Selection of earthquake and flood indicators to identify hotspot barangays

Seven indicators are selected for each of the flood hazard and the earthquake hazard and combined with appropriate weights to develop the Barangay Vulnerability Index (BVI) for each hazard. The selected indicators that comprise the BVI represent three separate characteristics of vulnerability to the hazards of flood and earthquake. They are defined by the following hazard and risk quantities:

The selected indicators that comprise the BVI represent three separate characteristics of vulnerability to the hazards of flood and earthquake, namely they represent the following risk quantities:

a. The expected **severity of the hazard** of each barangay for flood and earthquake
b. **Impact on population** either in terms of loss of life, displaced populations and/or disease
c. Aggravating **land use constraints** such as population density or road congestion

This is represented schematically in Figure 126.

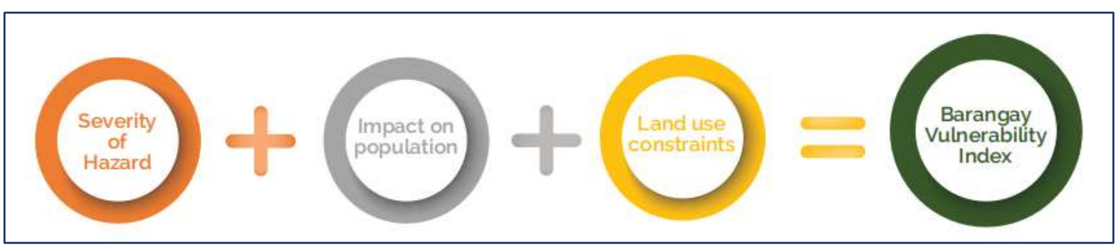


Figure 126.. Hazard and Risk Quantities Reflecting the Indicators that are Incorporated in the BVI.

The severity of hazard drives the impact and the evidence of physical vulnerability (e.g., the greater the severity of the hazard, the more damage is sustained by buildings, critical point facilities and infrastructure).

This is valid for both the flood hazard and the earthquake hazard. Thus, the indicator reflecting the severity of hazard of each barangay is essential to the definition of the BVI.

Impact on population as measured by loss of life and/or displaced populations and/or hazard-induced diseases is a good measure of social vulnerability that implicitly incorporates vulnerable populations since the latter are likely to be more affected by the hazards. The demographics of the population is taken from Quezon City's latest demographic data (2022).

Land use constraints provide aggravating factors related to both physical and social vulnerability and to fragilities associated with coping capacity and recovery. These indicators are also strongly correlated with vulnerable populations and lack of social inclusion. For example, low-income communities tend to live in the most congested area where mobility and access to services and facilities are the most difficult.

By aggregating the seven indicators representing these quantities, the BVI takes a comprehensive view to the representation of both social and physical vulnerability for each hazard. The combined flood and earthquake index considers all 14 indicators. In the following section, each of the indicators for flood and earthquake hazards is provided and explained.

6.2. Flood and Earthquake Indicators

The seven indicators used in the calculation of the BVI and determining the flood hotspot barangays are presented in Table 67 below.

Table 67. Indicators Used in the Calculations of the Flood BVI

ID	Flood Indicator	Description
1	**Flooded Area Susceptibility**	Reflects the ranking in the flood hazard as measured by the percent area of the barangay that is flooded with flood depth of 0.5m and greater. The reference flood event used for this indicator is the 2021 MGM Flood Susceptibility Map.
2	**Flooded Area (Climate Adjusted)**	Reflects the ranking in the flood hazard as measured by the percent area of the barangay that is flooded with flood depth of 0.5m and greater. The reference flood event used for this indicator is the RCP 8.5 100-year Rain Return Flood Scenario as established by the Quezon City Drainage Master Plan project.
3	**Risk of Infection to Gastroenteritis**	Indicates the risk to life during the flood. It made use of flood depth and other criteria such as mode of infection, duration of flood, depth of flood, population density, ingestion of contaminated water, and number of fecal coliforms per 100 ml. The reference flood event used for this indicator is the RCP 8.5 100-year Rain Return Flood Scenario as established by the Quezon City Drainage Master Plan project.
4	**Flooded Road Intersections**	Indicates ease or difficulty of moving from node to node of connected road links. Flood depth is assigned to each node. A cluster of contiguous flooded nodes can be used to define intensity of flood along network segments. It also reveals passable or non-passable links for different vehicle types. Roads are expected to be at lower

		elevations than building ground elevations. The reference flood event used for this indicator is the RCP 8.5 100-year Rain Return Flood Scenario as established by the Quezon City Drainage Master Plan project.
5	**Flooded One or Two-story buildings**	Using max flood depth found by intersecting the building footprint area with the flood data, the level of water depth compared to the height of the building provides a proxy for the threat to life for people trapped in the buildings as well as physical damage to contents and structures. The threat is predominant in one and two-story buildings. The reference flood event used for this indicator is the RCP 8.5 100-year Rain Return Flood Scenario as established by the Quezon City Drainage Master Plan project.
6	**Displaced Populations**	This indicator represents the percent of the population compared to the total population of the barangay that is expected to be displaced by the flood. The reference flood event used for this indicator is the RCP 8.5 100-year Rain Return Flood Scenario as established by the Quezon City Drainage Master Plan project.
7	**Number of barangay Facilities and Evacuation Centers Made Inoperable by Flood**	This indicator represents the number of evacuation centers and official barangay facilities that are made inoperable because they are flooded, thus impairing response, relief and recovery. The reference flood event used for this indicator is the RCP 8.5 100-year Rain Return Flood Scenario as established by the Quezon City Drainage Master Plan project.

The seven indicators used in the calculation of the BVI and determining the earthquake hotspot barangays are presented in Table 68 below.

Table 68. Indicators Used in the Calculations of the Earthquake BVI.

Earthquake Indicator	Description
Earthquake Intensity	This indicator represents the severity of the earthquake shaking for each barangay as measured by the value of intensity (in MMI) from the M7.2 earthquake on the West Valley Fault.
Liquefaction Susceptibility	This indicator measures the percent area for different liquefaction susceptibility levels under M7.2 earthquake for each barangay in Quezon City.
Injuries that Need Hospitalization	This indicator measures the percent of people who would require medical attention due to injuries sustained from the M7.2 earthquake on the West Valley Fault compared to the total population of the barangay. The larger the indicator, the more strain the health system will sustain.
Loss of Life	This indicator measures the percent of expected fatalities from a M7.2 West Valley Fault earthquake scenario compared to the total population of the barangay Large fatality ratios will pose significant social disturbance and socio-economic issues. Experience has also

	shown that mortality is higher among women and children in earthquakes and other disasters.
Displaced Population	Measures the potential ratio of population that could be displaced and would need shelter as percent of the total population of the barangay. Populations are displaced because the buildings where they reside have either collapsed or sustained extensive damage under the M7.2 earthquake scenario. Experience has also shown that women, children and PWDs suffer the blunt of the impact from displacement and need special arrangements.
Lack of Open Spaces	This indicator is a proxy measure for the difficulty in the organization of the response and relief operations. It also reflects potential aggravation of the social impact of the disaster. It is represented by the average open space area per 1000 people in the barangay. This quantity is calculated for each barangay.
Road Density and Distance to Hospitals and Fire Stations	Indicates accessibility during and after an earthquake to and from essential facilities such as hospitals and fire stations. Road density assumed to be proportional to possible blockage due to debris and limited width of the road. Proximity to hospitals and fire stations for each building indicates the relative length of travel and increase in potential blockage along the way. This indicator measures the difficulty for response and relief operations after the M7.2 for each barangay in terms of access and mobility. It could impair search and rescue, access of ambulances and other emergency vehicles and access to hospitals and fire stations. It impacts relief operations and long term recovery. This quantity is calculated for each barangay.

6.3. The Barangay Vulnerability Index

6.3.1 Analytical Approach

All barangays are ranked relative to each indicator, the ranking being 1 to 142 where rank 1 is the barangay with the highest value of the indicator (for example highest earthquake intensity) and rank 142 is the lowest value of the indicator. Weights are assigned to each indicator. The relative ranking of the weights is established by experience and by undertaking sensitivity analyses.

Using the ranking, the Barangay Vulnerability Index (BVI) is calculated by combining a term that represents the frequency of each indicator and a second term that represents the severity of each indicator. In essence, the BVI represents how often in time a barangay is among the worse impacted barangays and, if it is among the worse, how high is its value compared to the other barangays. If a barangay is highly ranked several times, it means it is highly susceptible to intense values of hazard. In addition, if the barangay impact (in terms of seven the physical and social indicators) is among the worse, then both the social and physical vulnerability of that barangay is among the worse compared to other barangays. In short, the BVI reflects the severity of the impact of the hazard on each barangay's infrastructure and population and how the response, relief and recovery will be aggravated by land use constraints. Implicitly, the BVI also reflects long-term socioeconomic impact, particularly on the most vulnerable populations, women and children with indicators such as displaced populations, fatalities and risks of infections.

From an analytical standpoint, the BVI provides a fairly spread-out prediction by which the barangays can easily be ranked. In fact, the larger the standard deviation, the higher is the predictivity of the indicator. The BVI is an objective index since all indicators can be consistently and accurately calculated from the hazard, risk or exposure data. It is stable as the calculation will always result in a discrete number by which the rank of that barangay can be obtained compared to the other barangays.

6.3.2. Criteria for determining the hotspot barangays

The hotspot barangays are identified based on statistical criteria of the BVI values of the concerned barangays. The BVIs are first normalized to 100 and then the barangays are ranked according to the normalized BVI value. The mean and standard deviation are calculated and a distribution is fit on the data to find the percentile of each value relative to the data. The hotspot barangays are identified on the basis of the criteria indicated in Table 69.

Table 69. Criteria for Hotspot Barangays in Three Tiers Based on the BVI Percentile Distribution.

Barangay Vulnerability Index (BVI)	
Tier 1: Very High BVI These barangays are on the Top First Tier Hotspot. The vulnerability is very high.	These barangays are in the top 90th percentile of the BVIs for all barangays.
Tier 2: High BVI These barangays are on the Second Tier Hotspot. The vulnerability is high but not as high as in Tier 1.	These barangays are in the top 80th to 90th percentile of the BVIs for all barangays.
Tier 3: Moderate BVI These barangays are still part of the hotspot barangays but represent a moderate to high vulnerability.	These barangays are from the 50th to the 80th percentile of all the BVIs.

The above criteria can vary slightly depending on the statistics for each hazard and the variability in the risk parameters between barangays as calculated in the climate and disaster risk assessment (CDRA). Note that the hotspot barangays for earthquake, flood and landslide are different since they are linked to different hazards. Barangays falling lower than 50th percentile are not considered to be hotspot barangays, which means that relative to the other barangays, they have a lower vulnerability compared to the first three tiers.

As explained earlier, the combined hotspot barangays (e.g., for both earthquake and flood) reflect both hazards, meaning that they have high vulnerability for both earthquake hazard and flood hazard.

6.4. Hotspot Barangays in Quezon City

Using the criteria in Table 69, the barangays are grouped into Three (3) Tiers for the earthquake hazard, flood hazard and flood and earthquake combined. The barangays in Tier 1 represent the highest vulnerability as measured by the BVI. Tier 2 lists the barangays that follow Tier 1 and can be considered as high vulnerability. Tier 3 follows Tier 2 and these barangays are considered to be of moderate vulnerability compared to the previous two tiers. The BVI value (normalized to 100) is provided for each barangay to have a better appreciation of the ranking between the barangays.

A few important points should be noted:

1. Barangays that are not listed **do not equate to no or low** vulnerability. Recall that the BVI is just an index that enables a rational relative ranking. It simply indicates that the **barangays that are not listed are less vulnerable than the ones that are listed** as hotspot barangays.
2. The BVI indicators are normalized relative to the population of each barangay. Thus, they emphasize the **density of loss** rather than the absolute value of loss. Consequently, many of the hotspot barangays are barangays with low geographical area and large density of population.
3. Had the BVI been calculated on the **absolute values**, the output in terms of the hotspot barangays would have been different. It would have emphasized the barangays with the largest populations.

The results for each hazard and the combined hazard are as provided and explained in the following paragraphs.

6.4.1. Earthquake Hotspot Barangays

The **earthquake** hotspot barangays are presented in Table 70 and graphically shown in Figure 127. Out of the 24 barangays that are considered as hotspot barangays, 20 are in District 3, two (2) are in District 2 and two (2) are in District 4.

- In **Tier 1**, four (4) out of the six (6) barangays are in District 3 whereas two (2) are in District 2. The latter two barangays are large size barangays. All the barangays are very close to or are transected by the West Valley Fault, have severe earthquake intensities (MMI>9.6) and rank high in terms of **lack** of open space, density of injuries, fatalities and displaced population compared to their total populations.

- Barangay Libis in **Tier 2** is expected to have the highest shaking severity with MMI close to 10 and ranked third in density of displaced population, but it is in Tier 2 because it has more open space and lower density of injuries and fatalities than the barangays in Tier 1. Most of the barangays in Tier 2 are very constrained by lack of open space, severely impairing their mobility and access to critical point facilities such as hospitals. Health care centers and shelters.

- Overall, the **lack of open space and lack of access to critical point facilities** are determinant factors in sorting the ranking of the hotspots. This is the case, for example, in Teachers Village East, which ranks 40th in terms of earthquake shaking severity, but it is constrained by lack of open space and mobility, making it part of Tier 3 of the hotspot barangays. Its ranking moved from 40 on the basis of intensity to 24 on the basis of all seven indicators.

- These findings are **consistent** with observations and experiences from urban earthquakes. Lack of mobility and open space can be major impediments to organizing the response and relief operations. They can cause dire situations for reaching the affected communities, for communication, for providing search and rescue or for dealing with injured individuals and providing for the needs of the survivors. These parameters in turn, delay the recovery process.

Table 70. Earthquake Hotspot Barangays as Established by the 3-tier Barangay Vulnerability Index (BVI).

Earthquake Hotspot Barangays				
Tier	Rank	Barangay	BVI	District
Tier 1 Very High Vulnerability	1	Blue Ridge B	100	3
	2	Batasan Hills	92	2
	3	Ugong Norte	90	3
	4	Bagong Silangan	89	2
	5	Escopa 4	88	3
	6	Blue Ridge A	88	3
Tier 2 High Vulnerability	7	Libis	85	3
	8	Villa Maria Clara	78	3
	9	White Plains	78	3
	10	Amihan	77	3
	11	Escopa 3	77	3
Tier 3 Moderate Vulnerability	12	Bagumbayan	72	3
	13	Escopa 2	71	3
	14	Teachers Village East	71	4
	15	Quirino 2-B	70	3
	16	Escopa 1	70	3
	17	Masagana	68	3
	18	Pansol	68	3
	29	Loyola Heights	67	3
	20	Quirino 2-C	67	3
	21	Marilag	63	3
	22	Milagrosa	63	3
	23	Claro (Quirino 3-B)	60	3
	24	Teachers Village West	60	4

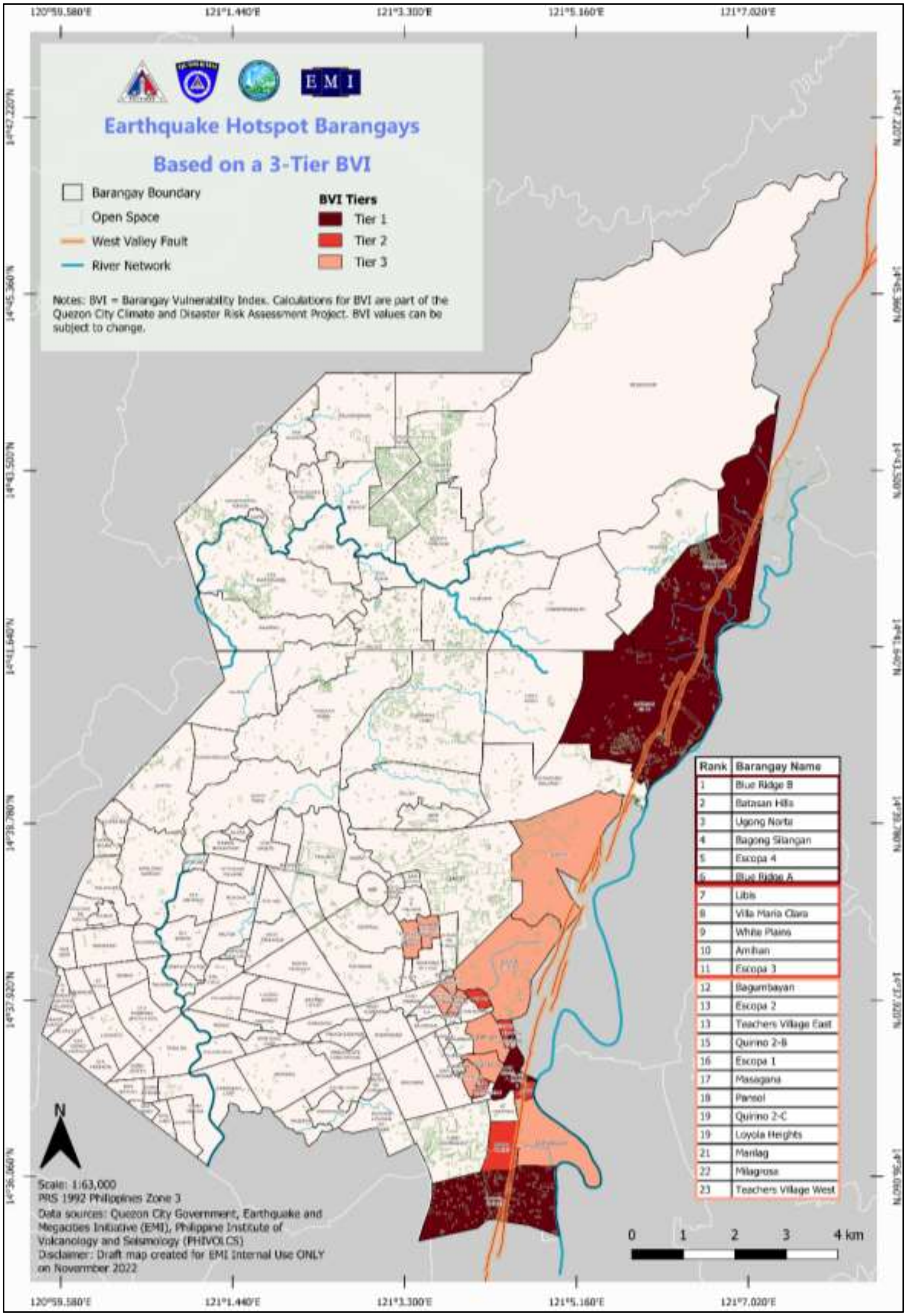


Figure 127. Earthquake Hotspot Barangays in Three Tiers.

6.4.2. Flood Hotspot Barangays

The **flood hotspot barangays** are presented in Table 71 and graphically shown in Figure 128.

- Out of the **21 barangays** that are considered as hotspot barangays, nine (9) are in District 1, five (5) are in District 3 and five (5) in District 4, one (1) is in District 5 and one (1) in District 6.

- In **Tier 1**, **six (6) out of the nine (9) barangays are in District 1,** whereas one (1) is in each of District 5, District 4, and District 3. The joining of the San Francisco River and the San Juan River drives the vulnerability of the barangays in District 1. Barangay Capri in District 5 is impacted by the Novaliches River.

- The top barangays in Tier 1 typically rank among the top five in each of the seven indicators including: risk of infections, flooded roads, flooded buildings, displaced populations and difficulty of access to critical point facilities.

- The barangays in **Tier 2** also exhibit BVIs in the mid and upper 80s, showing significant vulnerability.

- The flood hotspot barangay ranking is highly influenced by the RCP 8.5 100-year Return Period Flood depths. Thus, the impact of climate change is incorporated in the assessment of the flood hotspot. The above consideration takes a longer time perspective in terms of how the flood hazard and flood vulnerability will impact Quezon City.

- With the significant experience that Quezon City has had with dealing with flood hazard and flood risk, the indication of the flood hotspot barangays can further support that experience by providing a more holistic approach that not only integrates social and physical vulnerabilities but also provides an assessment of the impact of climate change.

Table 71. Flood Hotspot Barangays as Established by the 3-tier Barangay Vulnerability Index (BVI) .

Flood Hotspot Barangays				
Tier	**Rank**	**Barangay**	**BVI**	**District**
Tier 1 Very High Vulnerability	1	Katipunan	100	1
	2	Capri	98	5
	3	Talayan	97	1
	4	Masambong	97	1
	5	Mariblo	94	1
	6	Sto. Domingo (Matalahib)	94	1
	7	Tatalon	91	4
	8	St. Peter	90	1
	9	West Kamias	89	3
Tier 2 High Vulnerability	10	Doña Imelda	87	4
	11	Sienna	84	1
	12	Damayang Lagi	83	4
Tier 3 Moderate Vulnerability	13	Claro (Quirino 3-B)	78	3
	14	Maharlika	76	1
	15	San Antonio	73	1
	16	Santol	71	4
	17	Bagumbayan	71	3
	18	East Kamias	68	3
	19	Apolonio Samson	68	6
	20	San Vicente	64	4
	21	Quirino 2-B	63	3

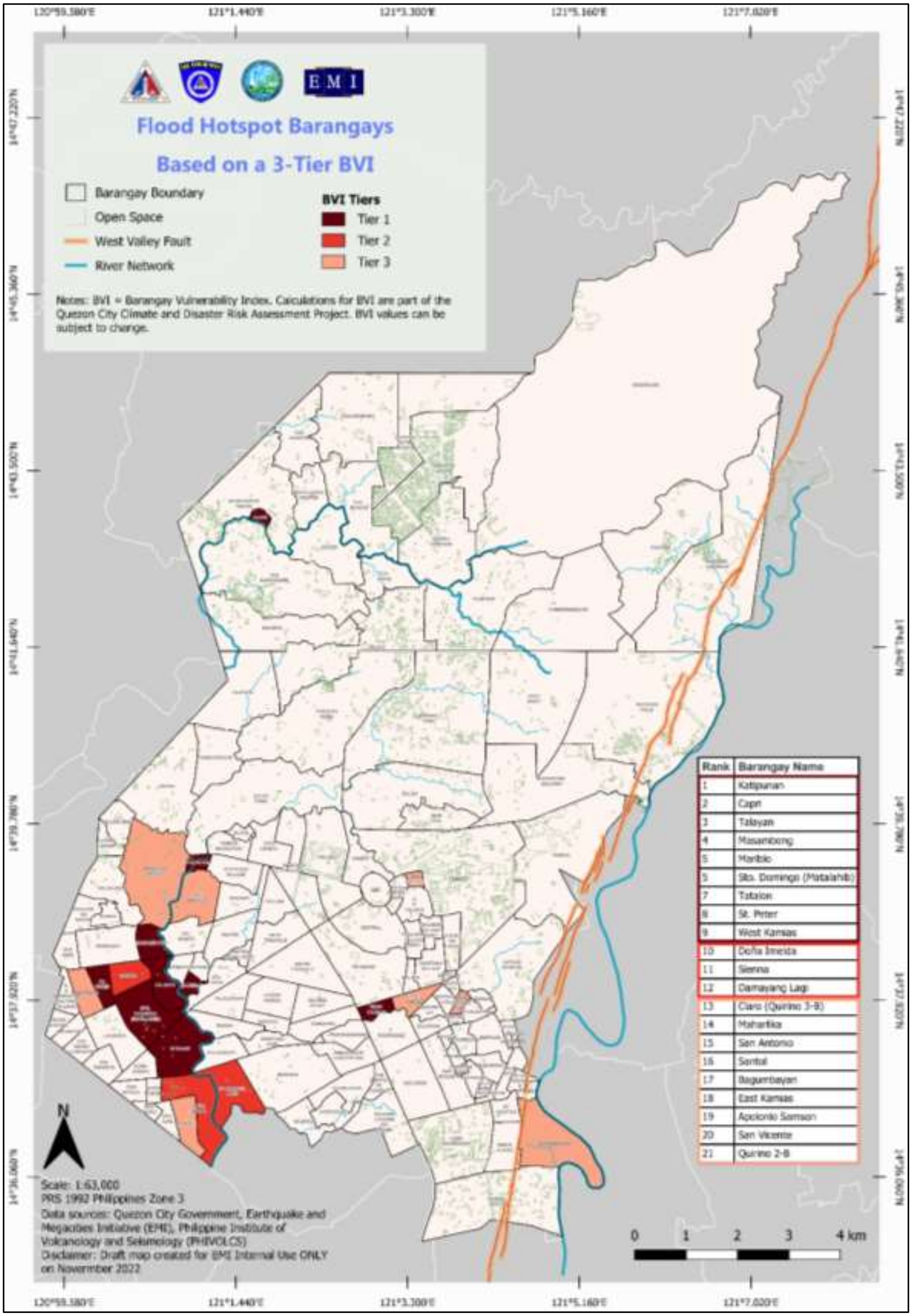


Figure 128. Flood Hotspot Barangays in Three Tiers.

6.4.3. Landslide Hotspot Barangays

The **landslide hazard** concerned only a limited number of barangays. In fact, only eight (8) barangays are indicated as having a **Very High or High** Susceptibility to Landslides (See Chapter 3). Undertaking a BVI calculation for such a limited number of barangays is not analytically viable. Thus, the classification in tiers is undertaken relative to only two indicators: 1) the susceptibility to landslides, and 2) the percent of the population exposed to landslides compared to the total population of the barangay. The eight hotspot barangays for landslides are classified into two tiers as indicated in Table 72. The barangay hotspots for landslides are shown in Figure 129.

Of the **eight hotspot barangays**, four are in District 2 and three are in District 3. Of the two Tier 1 barangays, two are in District 2 and one is in District 3.

Note that barangays Bagong Silangan, Pansol, Loyola Height and Barangay Batasan Hills overlap with the earthquake hotspot barangays. This increases the potential for earthquake-induced landslides for these four barangays.

Table 72. Landslide Hotspot Barangays in Two Tiers.

Landslide			
Tier	**Rank**	**Barangay**	**District**
Tier 1 Very High Vulnerability	1	Payatas	2
	2	Pansol	3
	3	Bagong Silangan	2
Tier 2 High Vulnerability	4	Batasan Hills	2
	5	Matandang Balara	3
	6	Greater Lagro	5
	7	Commonwealth	2
	8	Loyola Heights	3

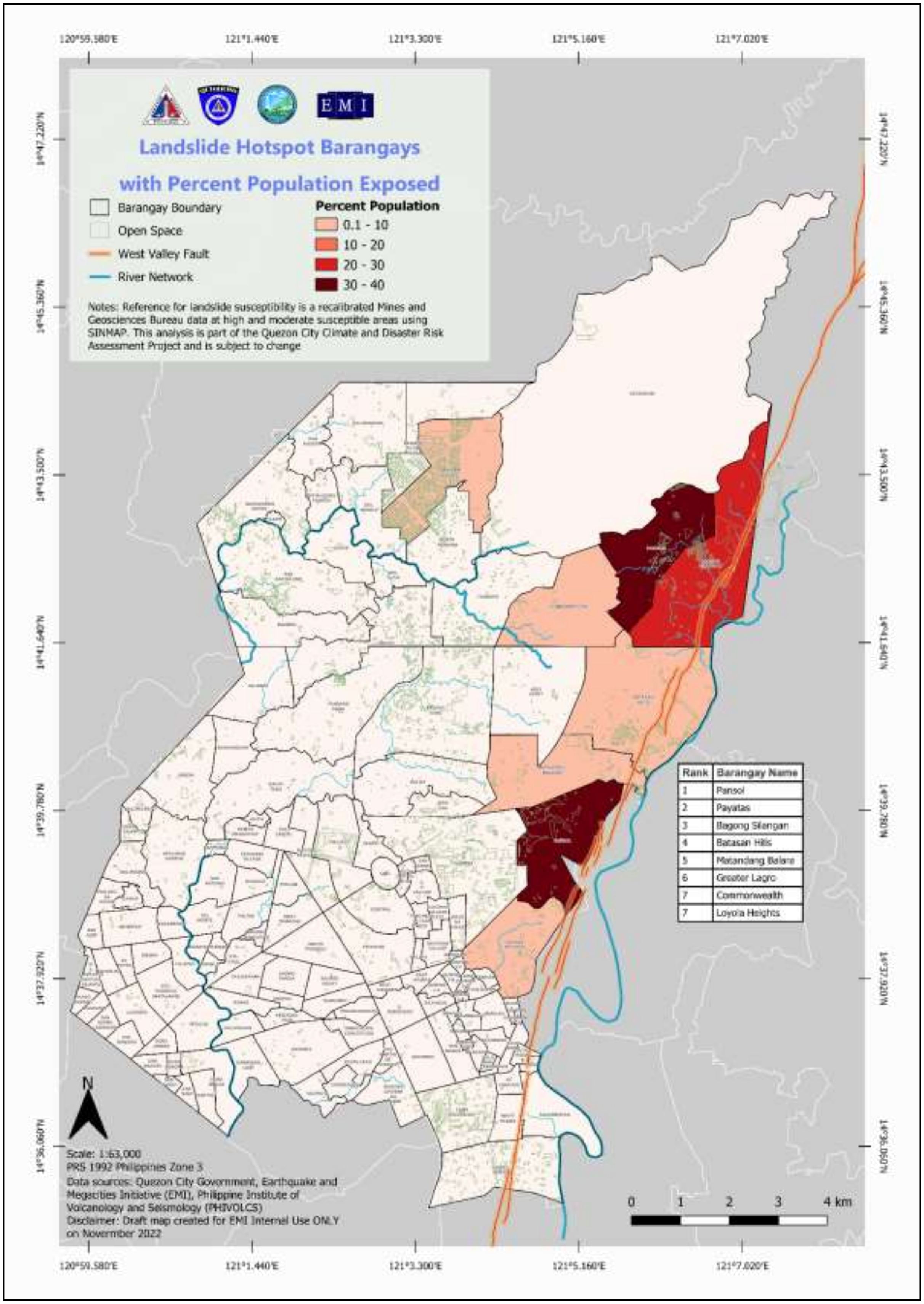


Figure 129. Landslide Hotspot Barangays.

6.4.4. Combined Hotspot Barangays for Earthquake and Flood Hazards

As explained earlier, the **combined hotspot barangays** indicate barangays where the impacts from multiple hazards **cumulate** to increase vulnerability. The exposures and vulnerabilities from multiple hazards must intersect and cumulate the value of the BVI to represent a combined high vulnerability. With this consideration, **14 barangays** interact between the earthquake hazard and the flood hazard in a combined increased vulnerability, resulting in the 14 highest combined BVIs. The results are shown in Table 73 and graphically in Figure 130.

- All the **14 hotspot barangays for Flood and Earthquake are** in District 3 except for one (St. Peter), which is in District 1. The reason for this concentration is that both physical and social vulnerabilities of floods **and** earthquakes accumulate and compound each other) in District 3 more so than any other district or location in Quezon City.
- Other barangays where the flood impact is high resulting in identification of several flood hotspot barangays such as District 1 and District 4 have lower impact from earthquake hazard and thus do not make it in the combined hotspot barangays. The same goes for the barangays where the earthquake BVIs are very high but the flood BVIs are low.
- Consequently, none of the Tier 1 or Tier 2 hotspot barangays for floods are included in the Tier 1 or Tier 2 of the Combined Hotspot barangays because their earthquake BVIs are low. Similarly, none of the Tier 1 hotspot barangays for earthquakes are included in the Tier 1 or Tier 2 of the Combined Hotspot barangays because their flood BVIs are low.
- Among the Tier 2 earthquake Hotspot barangays, Barangay Libis and Barangay Villa Maria Clara are included in the Tier 1 and Tier 2 of the Combined Hotspot Barangays, respectively.
- The Combined Hotspot Barangays for Flood and Earthquake should be seen as **target barangays where both earthquake risk and flood risk accumulate**. Thus, any investment for risk reduction would have an impact on reducing risks from both hazards.

Table 73. Hotspot Barangays for Combined Flood and Earthquake Hazards.

Combined Flood and Earthquake				
Tier	Rank	Barangay	BVI	District
Tier 1 Very High Vulnerability	1	Bagumbayan	100	3
	2	Claro (Quirino 3-B)	98	3
	3	St. Peter	97	1
	4	Quirino 2-B	93	3
	5	Libis	92	3
Tier 2 High Vulnerability	6	Masagana	86	3
	7	Quirino 2-C	81	3
	8	East Kamias	81	3
	9	Villa Maria Clara	80	3
Tier 3 Moderate Vulnerability	10	Silangan	80	3
	11	Quirino 3-A	61	3
	12	Bagumbuhay	60	3
	13	Mangga	57	3
	14	Quirino 2-A	55	3

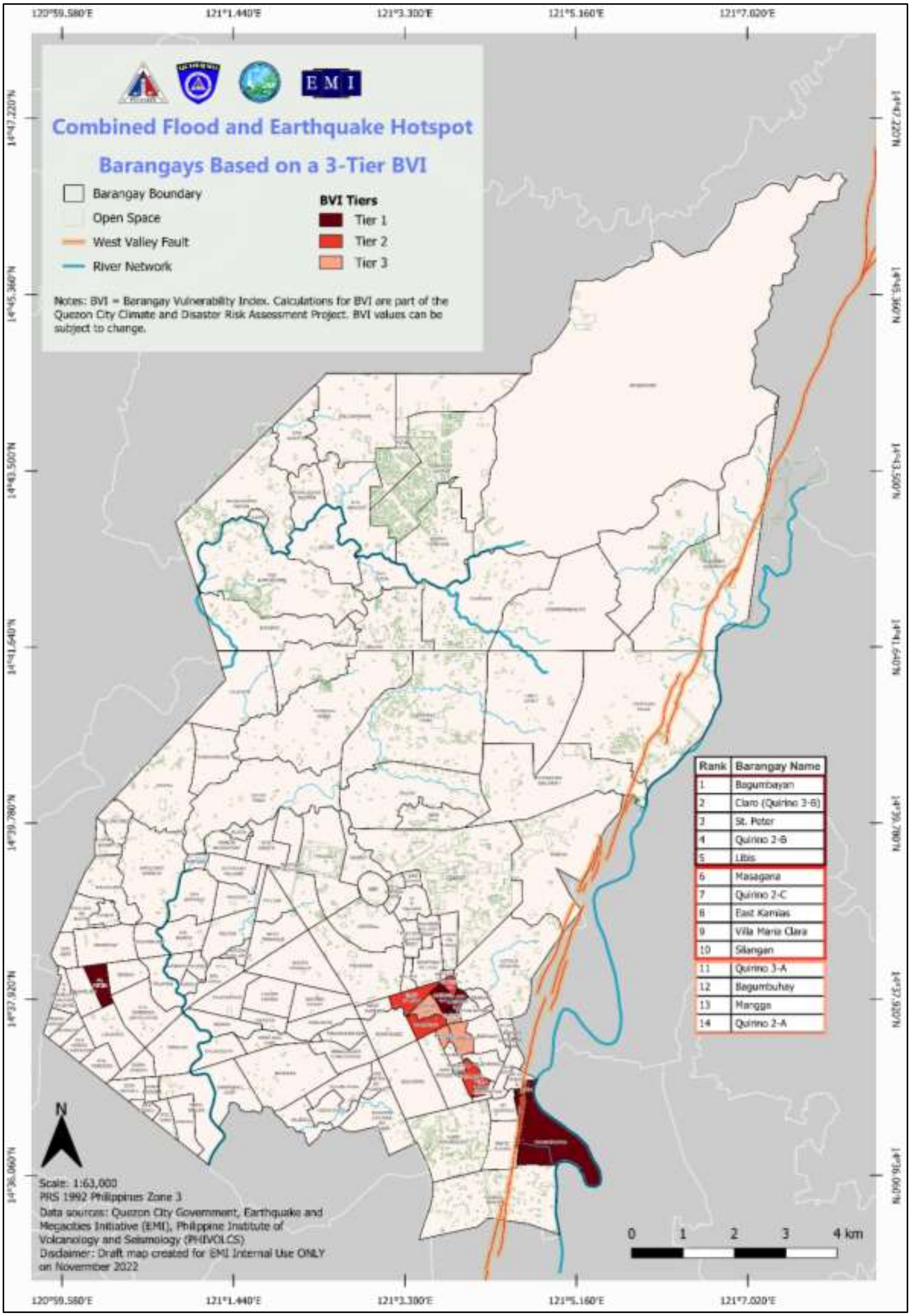


Figure 130. Combined Flood and Earthquake Hotspot Barangays.

6.5. Recommendations on the Use of Barangay Hotspot

As explained throughout this chapter, hotspot barangays are barangays where the combined social and vulnerabilities are high as represented by the indicators that define the BVI. This is very relevant to **establish priorities for investments** in disaster risk reduction as well as in efforts **to raise awareness** and **to secure engagement** of the relevant stakeholders. Reasonably, there is never an endless amount of resources available. Thus, priorities must be established in terms of where to push greater amounts of resources. The hotspot barangays are a reliable tool for making such decisions. This does not translate and should not be interpreted as barangays that are not hotspot barangays are not in need of investment. That consideration is **erroneous**. Disaster risk reduction is much more effective when undertaken comprehensively and holistically. The social, environmental and physical conditions of each and every barangay should be considered carefully in making such decisions. However, the identification of **hotspot barangays can facilitate policy and decision making** at the level of the city government.

The **hotspot barangays** linked to a single hazard shown in tables 70, 71 and 72 are relevant to each barangay and could be an additional tool for consideration in the development of the barangay DRRM plans, in the development of contingency plans as well as the development of simulation exercises for response, recovery and public service continuity planning.

The hotspot barangays for combined hazards (i.e., flood plus earthquake) are appropriate for **multi-hazard approach to risk management**. In this case, **the 14 barangays** listed in Table 73 should be considered as primary targets for an optimum return on multi-hazard risk reduction investment, starting with the five barangays in Tier 1.

Part 7: Towards a Resilient Quezon City

Part 7: Towards a Resilient Quezon City

7.1. A Model City for Urban Resilience

Quezon City has made great strides in achieving its vision of becoming a model for resilient urban development in the country by following transparent, responsive and proactive governance principles, adopting risk-informed policies, and devoting significant resources to disaster risk reduction. This is in line with its dynamic and globally competitive economy that is vital to the city's ability to provide world-class services and infrastructure. This progress is translating into communities of empowered, disciplined and resilient citizens.

Nonetheless, natural hazards continue to represent a significant threat to Quezon City's development and the well-being of its citizens due to inherent social, physical and environmental vulnerabilities. This requires that the city continuously and actively works to improve its capacities, increase its competencies and acquire the latest scientific knowledge and tools to manage the risks and reduce its vulnerabilities. Quezon City's enabling policies provide for higher awareness and shared responsibilities from everyone.

7.2. Utilizing Science to Manage and Reduce Risk

The **Updating of the Climate and Disaster Risk Assessment of Quezon City** project involved the assessment of the climate, earthquake, flood and landslide hazards and risks to the city, identifying hotspot barangays, and the development of a risk profile and atlas for the city. It also involves the creation of a roadmap for the management of complex emergencies, through a simulation exercise based on a realistic but complex disaster scenario. The project relies on the latest scientific data to develop a comprehensive understanding of the risks caused by these hazards, using an updated 2022 building-level exposure database and a high-resolution hazard and risk analysis.

The findings and outputs of the project have been designed not only inform the city's disaster risk reduction and management agenda but also provide essential data to other core planning processes such as the development of local disaster risk management and reduction plan, various contingency plans, the public service continuity plan (PSCP), the comprehensive land use plan (CLUP) and others plans and policies. The high resolution and accuracy of data and analysis enables the city to complete reliable science-based plans at the city level, barangay level and community level. This is a major accomplishment, which in EMI's opinion has not been reached by any other city in the Philippines.

7.3. Forward Looking Plans to Guide Policy and Investments

Other plans of the QCG within the last five years that are geared towards guiding planning, policy and investment to secure livelihoods, improve quality of life and build resilience of Quezon City residents are listed in Figure 131.

These plans and manuals represent the road map for policy, investment, and action to achieve a sustainable and resilient future and in bringing the city in full compliance with national government regulations. These elaborate plans together with the high resolution CDRA outputs, and risk communication guidebooks such as the RPA, the city government and the communities within Quezon City will be better prepared for disaster events through improved local-level planning and more effective preparedness. In turn, this will make them more capable of safeguarding their human, physical and economic assets from hazard impacts.

The effective development and implementation of these plans require not only a significant investment in human and financial resources, but most importantly the appropriate policies that engage and enable communities, institutions and city's partners to participate, contribute and take ownership. The challenges of managing disaster risks require orientation and outreach initiatives to various communities, regular trainings and capacity-building sessions, simulation exercises, and knowledge management activities for climate change adaptation and mitigation (CCA/M), disaster risk reduction (DRR) and disaster risk reduction and management (DRRM). It also requires building competencies at the barangay level for the development and implementation of comprehensive barangay DRRM and CCA/M plans.

Figure 131 Quezon City Government planning instruments from 2017-2022

7.4. Roadmap to Urban Resilience

The QCG's efforts to enhance its DRRM and CCA/M systems and capabilities over the years have been rewarded by numerous awards and recognitions. Some of the major awards received by the city in the last five years (2017-2022) are shown in Figure 132. Such recognition is the proof for QCG's commitment to good governance, safety and resilience. In particular, Quezon City received the award for having the Top Disaster and Risk Reduction and Management Council in the Philippines - Gawad KALASAG Award four times, including the one for 2019.

Nonetheless, climate change adaptation and mitigation and disaster risk reduction are continuous endeavors requiring consistent policies, sustained efforts and significant investments. Each disaster event is a learning experience, and each contribution towards the ultimate goal to reduce loss of life and property and to protect the environment is an additional building-block to realize a resilient city. There are certainly constant challenges to overcome along the way.

Among the challenges faced by complex urban agglomerations such as Quezon City is understanding and responding to the special needs of vulnerable populations, mainly the elderly, PWDs, women, children, the youth and the very poor. These segments of the population suffer the most during disasters and require most attention and deliberate policies to support them during emergencies and reduce their exposures to hazards. Reducing the vulnerability of the vulnerable populations to hazards and providing them with safe living conditions and livelihood will remain a formidable challenge and a long-term effort.

Another formidable challenge relates to preparing and managing for the "Big One". There is little on-the-ground experience from low frequency but high severity events such as earthquakes. Part 4 of this report indicates that large earthquakes such the M7.2 scenario could have devastating impacts on the city. Preparing for earthquake events requires a **novel approach** that may be different from one directed to the management of floods or other more frequent hazards. Earthquakes will cause widespread damage and will make mobility and access extremely difficult for days, if not weeks after the event. Critical utilities and lifelines may not be available for a prolonged period. Thus, preparedness and response planning for earthquake events call for a more **decentralized approach** that will enable localized decision-making, and mobilization and assignment of resources. This new approach will rely on barangay officials and community leaders to have a thorough understanding of their hazard, vulnerability and risk parameters, and to reflect these parameters adequately into their disaster risk reduction and management plans. It may also require establishing and evaluating a '**sheltering-in-place**" approach, which is the current trend in earthquake preparedness in other areas of high earthquake risk, such as in California. Quezon City has a robust capacity at the city level. The vision for the future will require **augmenting that capacity at the barangay level** and the community level to respond to more complex emergencies such as a major earthquake and supporting the barangays in developing effective, participatory and science-based DRRM plans.

Figure 132 Timeline of Quezon City awards and recognitions from 2017-2022

Despite these challenges, guided by the 14-Point Agenda (Figure 133), the future of Quezon City remains on a positive trajectory to achieve a resilient and sustainable economic and social development.

QUEZON CITY'S 14-POINT

- Deliver responsive, efficient and cost-effective social services
- Build more homes
- Provide better health care
- Ensure high-quality education
- Empower citizens of every gender and social class
- Build a safer and more resilient city
- Make Quezon City the preferred destination for businesses
- Create new jobs across more businesses
- Develop growth hubs
- Build a livable, green and sustainable city
- Build essential infrastructure
- Be a model of good governance
- Professionalize and strengthen the Quezon City workforce
- Listen to our citizens and understand what they need

Source: QC Economic Development and Investment Plan

Figure 133 Quezon City's 14-Point agenda

The QCG's focus on safeguarding development gains by effectively reducing and managing disaster risk, demonstrates its commitment to engage its own resources and to pro-actively seek the collaboration of the relevant stakeholders and community leaders in the long process of resilience building. The advancements and investments of the city for disaster risk reduction, particularly in the last five years, and its constant push to reach and implement sound international standards of practice, have built strong foundations for the achievement of its vision to become an exemplar of good governance, with a competitive and inclusive economy, an ecologically balanced environment, resilient and sustainable communities and institutions.

References

- Allen, T., Wald, D., & Worden, B. (2012). Intensity attenuation for active crustal regions. Journal of seismology 16.3, 409-433.
- Atkinson, G., & Adams, J. (2013). Ground motion prediction equations for application to the 2015 Canadian national seismic hazard maps. Canadian Journal of Civil Engineering 40.10, 988-998.
- Badilla, R., Barde, R., Davies, G., Duran, A., Felizardo, J., Hernandez, E., . . . Umali, R. (2013). Component 3 – Flood Risk Analysis, Enhancing Risk Analysis Capacities for Flood, Tropical Cyclone Severe Wind and Earthquake for the Greater Metro Manila Area' Project. Metro Manila, Philippines: Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA), Geoscience Australia.
- Boore, D., & Atkinson, G. (2008). Ground-motion prediction equations for the average horizontal component of PGA, PGV, and 5%-damped PSA at spectral periods between 0.01 s and 10.0 s. Earthquake spectra 24.1, 99-138.
- BSSC. (2004). NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures. Washington, D.C.: Building Seismic Safety Council, National Insitute of Building Sciences.
- BSWM. (1976). Soil and physiography map of Philippines. Bureau of Soils and Water Management. Retrieved from (BSWM) Map Library Platform. World Bank and Department of Agriculture: http://www.bswm.maps.da.gov.ph/maps-library
- CHD. (2022). Quezon City Age Group Distribution. Quezon City: Quezon City, City Health Department.
- Cinco, T. (2016). Observed trends and impacts of tropical cyclones in the Philippines. International Journal of Climatology, 36(14), 4638-4650.
- DOST-PAGASA, Manila Observatory and Ateneo de Manila University, (2021); Philippine Climate Extremes Report 2020: Observed and Projected Climate Extremes in the Philippines to Support Informed Decisions on Climate Change Adaptation and Risk Management. Philippine Atmospheric, Geophysical and Astronomical Services Administration, Quezon City, Philippines.145 pp
- DRRMO, (2022) Drainage Master Plan Flood Hazard Simulation: Climate Change Adjusted Scenario (January 2022) Quezon City Government, University of the Philippines, Resilience Institute and Nationwide Operational Assessment of Hazard(NOAH) Center
- DRRMO. (2020). Situational Report Typhoon Ulysses, 11-21 November 2020. Quezon City. Quezon City Government, EMI.
- GMMA-RAP. (2013). Enhancing Risk Analysis Capacities for Flood, Tropical Cyclone Severe Wind and Earthquake for Greater Metro Manila Area, Philippines. Metro Manila, Philippines: PHIVOLCS, Geoscience Australia, NAMRIA.
- Haas, C., Rose, J., & Gerba, C. (1999). Quantitative microbiological risk assessment. New York: John Wiley and Sons.
- IPCC, 2019: Summary for Policymakers. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–35. https://doi.org/10.1017/9781009157964.001.
- IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 3–32, doi:10.1017/9781009157896.001.
- Mines and Geosciences Bureau, 2021, initial Results of the MGB's Geohazard Assessment and Vulnerability and Risk Assessment Fieldwork, Quezon City, Metro Manila, Sept 2021

- Mines and Geosciences Bureau. (2010). Geology of the Phlippines, 2nd Edition.
- Mines and Geosciences Bureau. (2010). Guidebook for the Conduct of Landslide and Flood Susceptibility Assessment and Mapping (1:10,000).
- Mines and Geosciences Bureau. (2015). Preliminary Methodology in the Rain-induced Landslide and Flood Exposure Information Development for Vulnerability and Risk Assessment. Department of Environment and Natural Resources.
- Mines and Geosciences Bureau. (2021). Updated 1:10,000-scale Detailed Flood and Landslide Susceptibility Map. Quezon City, Metro Manila, Philippines.
- NAMRIA. (2020). IFSAR, Digital Terrain Model of Metro Manila and Province of Rizal.
- NAMRIA. (n.d.). Geoportal Philippines. Retrieved from https://www.geoportal.gov.ph/
- NAMRIA. (n.d.). Learn. Retrieved from Website of the National Mapping and Resource Information Authority: http://www.namria.gov.ph/learn.aspx
- NCRP. (2017). The Big One: Facts and Impacts. Retrieved from National Research Council of the Philippines. Retrieved from https://nrcp.dost.gov.ph/feature-articles/280-the-big-one-facts-and-impacts
- Nga, T. (1999). Water supply and its effect to public health in Ha Noi City. Asian Institute of Technology, Master's Thesis.
- NOAH. (n.d.). Nationwide Operational Assessment of Hazards. Retrieved from http://noah.up.edu.ph/#/
- PAGASA, 2018: Observed and Projected Climate Change in the Philippines. Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). Quezon City, Philippines. 36 pp
- PAGASA. (2021). Tropical Cyclone Information. Retrieved from Philippine Atmospheric, Geophysical and Astronomical Services Administration: http://bagong.pagasa.dost.gov.ph/climate/tropical-cyclone-information
- PEMSEA, 2012; Integrating climate change risk scenarios into coastal and sea use planning in Manila Bay. Partnerships in Environmental Management for the Seas of East Asia (PEMSEA), Quezon City, Philippines. ISBN 978-971-812- 029-3.
- Perez, R.T., L. A. Amadore and R.B. Feir,1999; Climate change impacts and responses in the Philippines coastal resource sector. Climate Research, Vol. 12: 97-107,1999. 11 pp.
- Philippine Bureau of Mines and Geo-sciences. (1983). Geological Map of Manila and Quezon City Quadrangle. Metropolitan Manila, Philippines.
- PHIVOLCS. (2018). Earthquake Hazards. Retrieved from Philippine Institute of Volcanology and Seismology: https://www.phivolcs.dost.gov.ph/index.php/earthquake/earthquake-hazards
- PSA. (2020). Total Population by Province, City, Municipality and Barangay (NCR) as of May 1, 2020. Philippine Statistics Authority.
- Quezon City LGU. (2016). Pasig City Profile 2015. Pasig City.
- Rimando, R., & Knuepfer, P. L. (2006). Neotectonics of the Marikina Valley fault system (MVFS) and tectonic framework of structures in northern and central Luzon, Philippines. Tectonophysics, 17-38.
- Sadigh, K., Chang, C., J, E., Makdisi, F., & Youngs, R. (1997). Attenuation Relations for Shallow Crustal Earthquakes Based on California String Motion Data. Seismological Research Letters 68.1, 180-189.
- UNDRR. (n.d.). Retrieved from United Nations Office for Disaster Risk Reduction: https://www.undrr.org/terminology/hazard
- US-EPA. (1999). Risk Assessment guidance for Superfund Vol.1. Human health evaluation manual (Part A) EPA/540/1-89/002. Washington: United States Environmental Protection Agency.
- USGS. (2001). United States Geological Survey. Retrieved from Measuring the size of an earthquake: https://earthquake.usgs.gov/learn/topics/measure.php
- USGS. (2002). United States Geological Survey. Retrieved from The science of earthquakes: https://earthquake.usgs.gov/learn/kids/eqscience.php

- USGS. (2016). The severity of an earthquake. Retrieved from United States Geological Survey: https://pubs.usgs.gov/gip/earthq4/severitygip.html
- Wood, H., & Neumann, F. (1931). Modified Mercalli intensity scale of 1931. Bulletin of the Seismological Society of America, 277-283.

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