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Phi-LiDAR 1**



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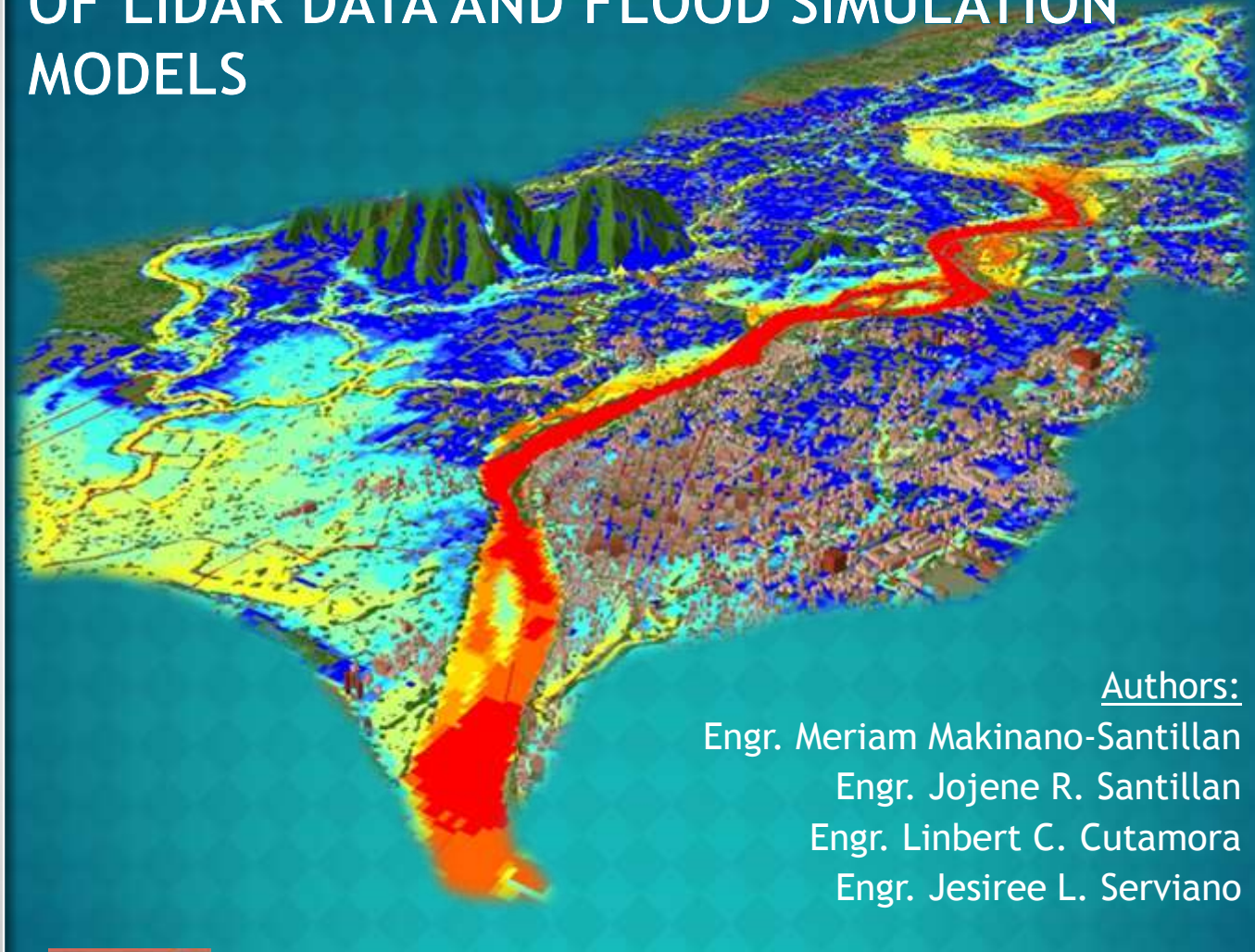
College of Engineering and
Information Technology
(CEIT)



Department of Science and Technology
(DOST)

Philippine Council for Industry, Energy
and Emerging Technology Research and
Development
PCIEERD)

FLOOD HAZARD EXPOSURE ASSESSMENT OF BUILDINGS THROUGH COMBINED USE OF LIDAR DATA AND FLOOD SIMULATION MODELS



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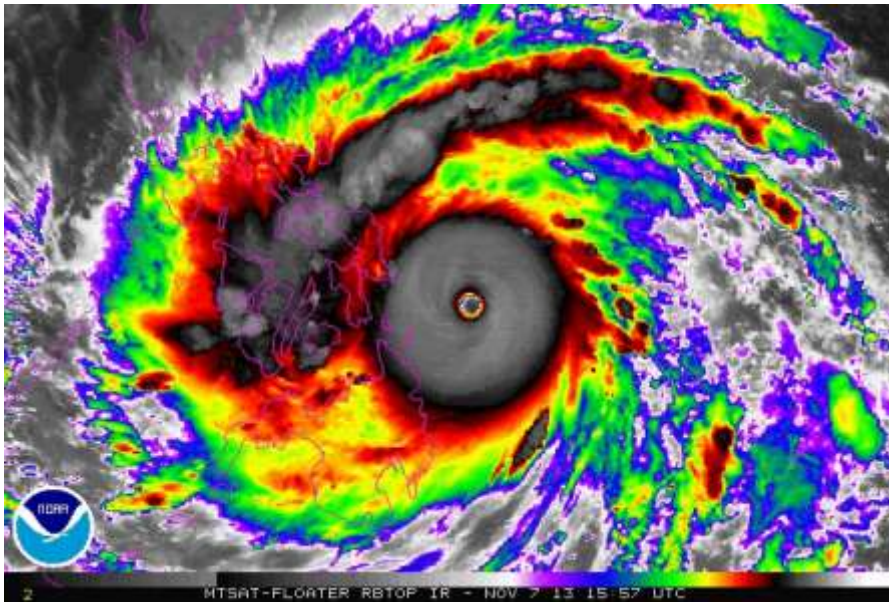
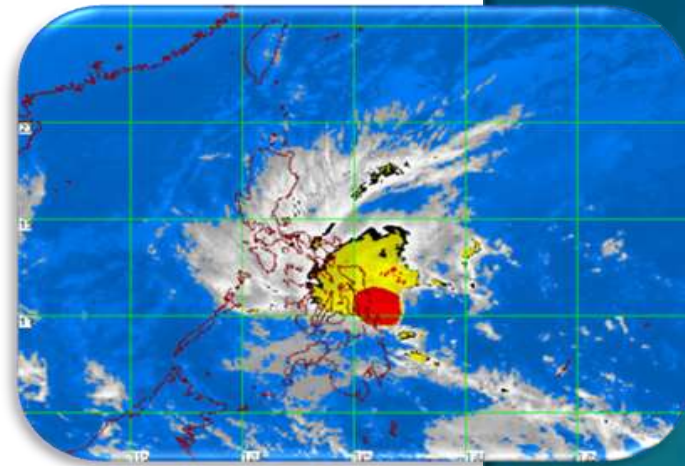
Putra World Trade Centre (PWTC)

Kuala Lumpur, Malaysia

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BACKGROUND

- Flooding is one of the most destructive natural disasters in the Philippines.
- It can cause loss of lives and damages to properties as well as to infrastructures like buildings, roads and bridges.
- Although the frequency of flood-related disasters has grown in recent years, the tools to model and understand flood risks have also increased in number, had become more sophisticated, and are readily available for use.



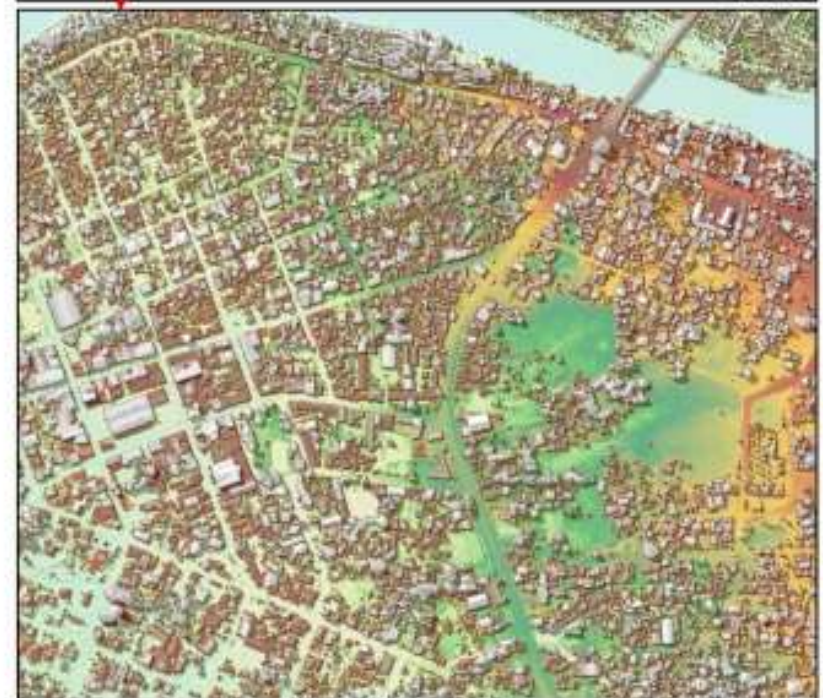
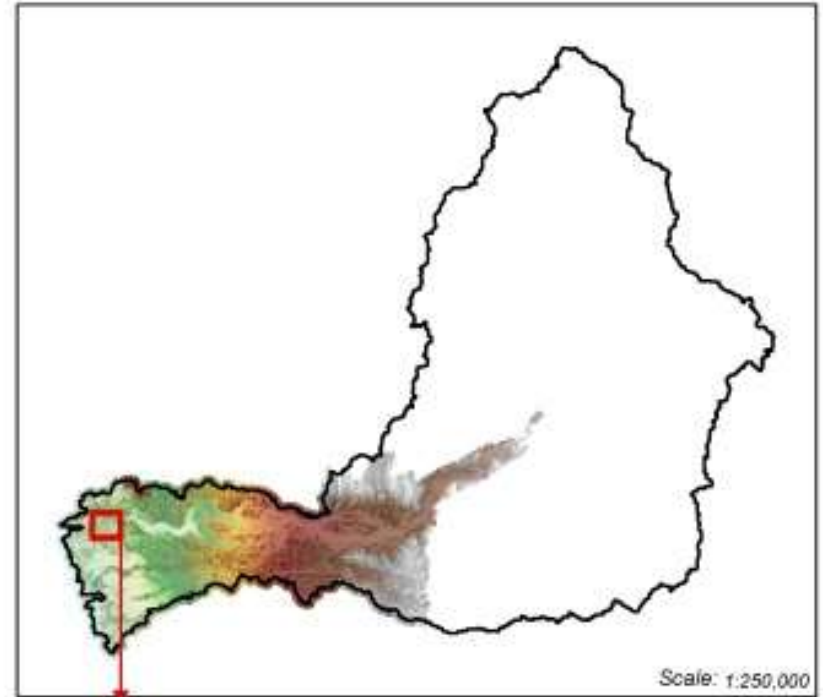
- Examples of these are flood models that allow hydrodynamic scenario simulation of flood water propagation, as well as in the assessment of flood damage.
- The hazard maps produced by these flood models are used as important inputs for assessing the exposure and vulnerability of localities to various flood scenarios usually conducted using Geographic Information System (GIS) tools and techniques.
- An important part of this GIS-based assessment is the identification of the type, location, and height of buildings that are exposed to various scenarios and levels of flood hazards.

OBJECTIVES

- In this paper, we generated a 3D GIS database of buildings in Cabadbaran River Basin, Mindanao, Philippines through analysis of various datasets that included 1-m resolution LiDAR DSM and Digital Terrain Model (DTM), high resolution images in Google Earth, and free online web maps such as Wikimapia.
 - Google Earth images and Wikimapia was used to address the limitation of using the DTM and DSM during the building type classification.
- We also present in this paper how the 3D buildings database was used as exposure datasets for the flood hazard assessment of the river basin that included assessment of the vulnerability of the buildings to the flooding.

THE STUDY AREA: Philippines CABADBARAN RIVER BASIN

- Covers major portion of Cabadbaran City
- Drainage area: 215 sq.km.
- Heavily affected by TS Lingling (*Agaton*) and TS Jangmi (*Seniang*) in 2014.

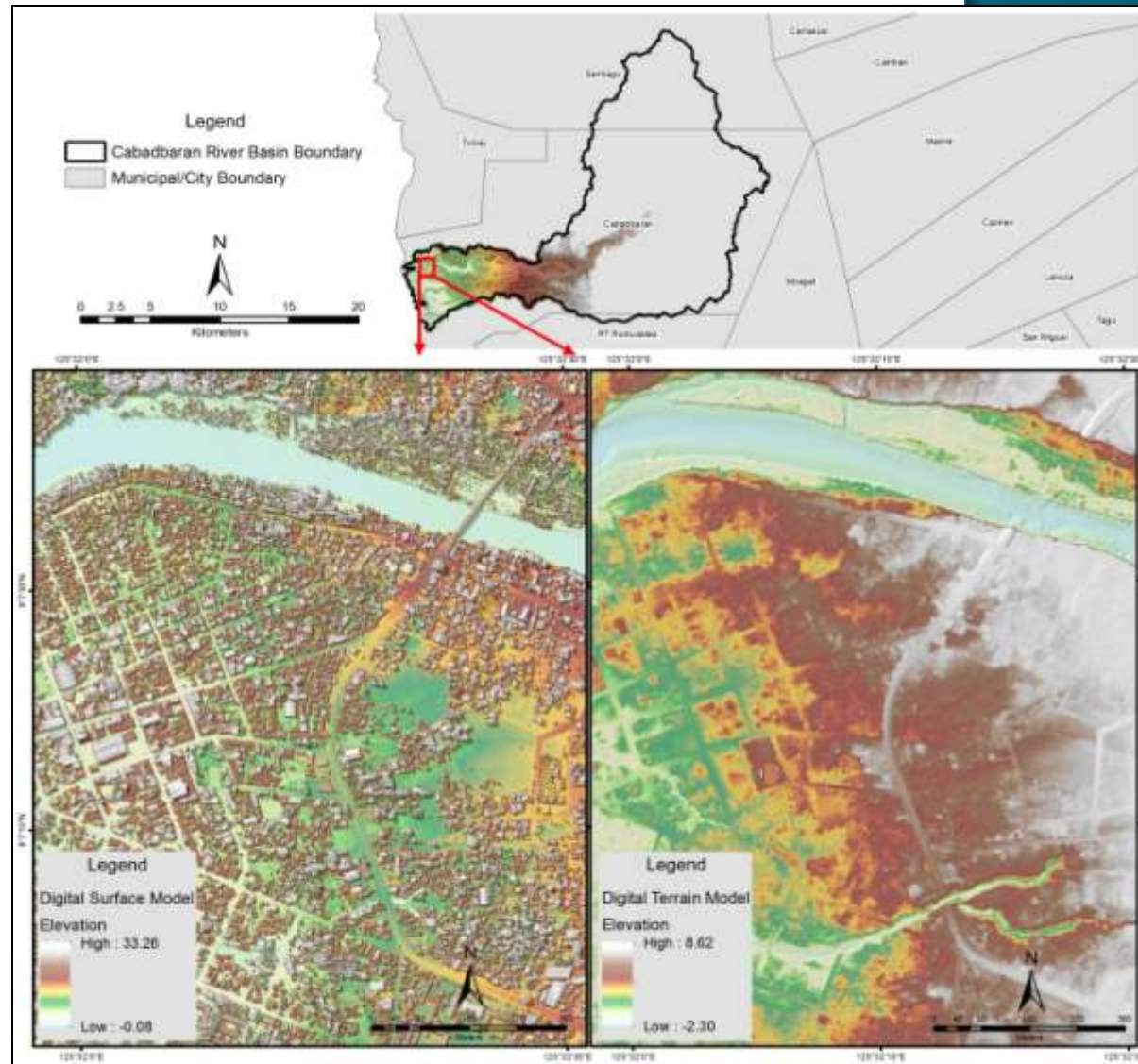


Portion of the DSM in Cabadbaran river basin

MATERIALS & METHODS

- 1-meter resolution LiDAR-derived Digital Surface Model (DSM) and Digital Terrain Model (DTM)

- for extracting the building features within the river basin
- acquired and processed by Data Pre-Processing Component of the University of the Philippines - Diliman Phil-LiDAR 1 project



MATERIALS & METHODS

○ Google Earth

- utilized to improve the precision in extracting the buildings

○ Wikimapia and Google Map

- used to gather information such as name and type of the buildings




MATERIALS & METHODS

○ Flood depth maps


- generated by Caraga State University through the CSU Phil-LiDAR 1 project were used as input in flood hazard and building vulnerability assessment
- These flood depth maps represent maximum depth of flooding due to rainfall events with varying intensity and duration (i.e., return periods of 2, 5, 10, 25, 50 and 100-year).

3D Map of the Simulated Flood Depth for 2-Year Rain Return in Cabadbaran City

LEGEND

 Barangay Boundary

Building Height (m)

 High : 15.40



 Low : 1.51

Flood Depth (m)

 0.11 - 0.20  1.51 - 2.00

 0.21 - 0.30  2.01 - 2.50

 0.31 - 0.40  2.51 - 3.00

 0.41 - 0.50  3.01 - 3.50

 0.51 - 1.00  3.51 - 4.00

 1.01 - 1.50  > 4.00




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3D Map of the Simulated Flood Depth for 5-Year Rain Return in Cabadbaran City

LEGEND

 Barangay Boundary

Building Height (m)

 High : 15.40





 Low : 1.51

Flood Depth (m)

 0.11 - 0.20  1.51 - 2.00

 0.21 - 0.30  2.01 - 2.50

 0.31 - 0.40  2.51 - 3.00

 0.41 - 0.50  3.01 - 3.50

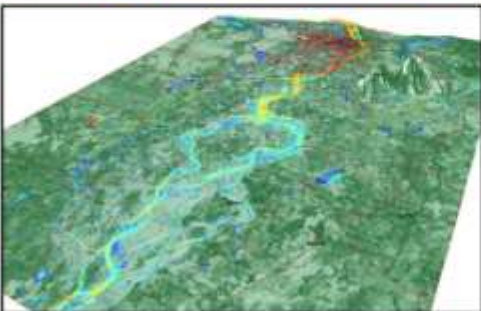
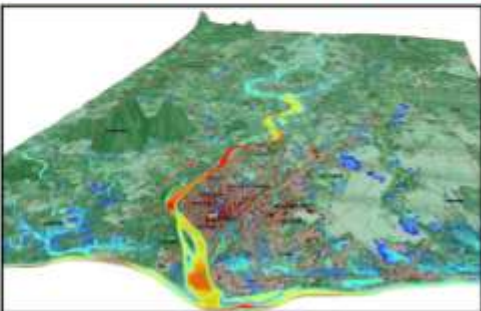
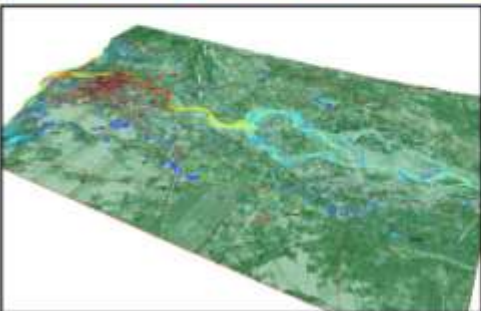
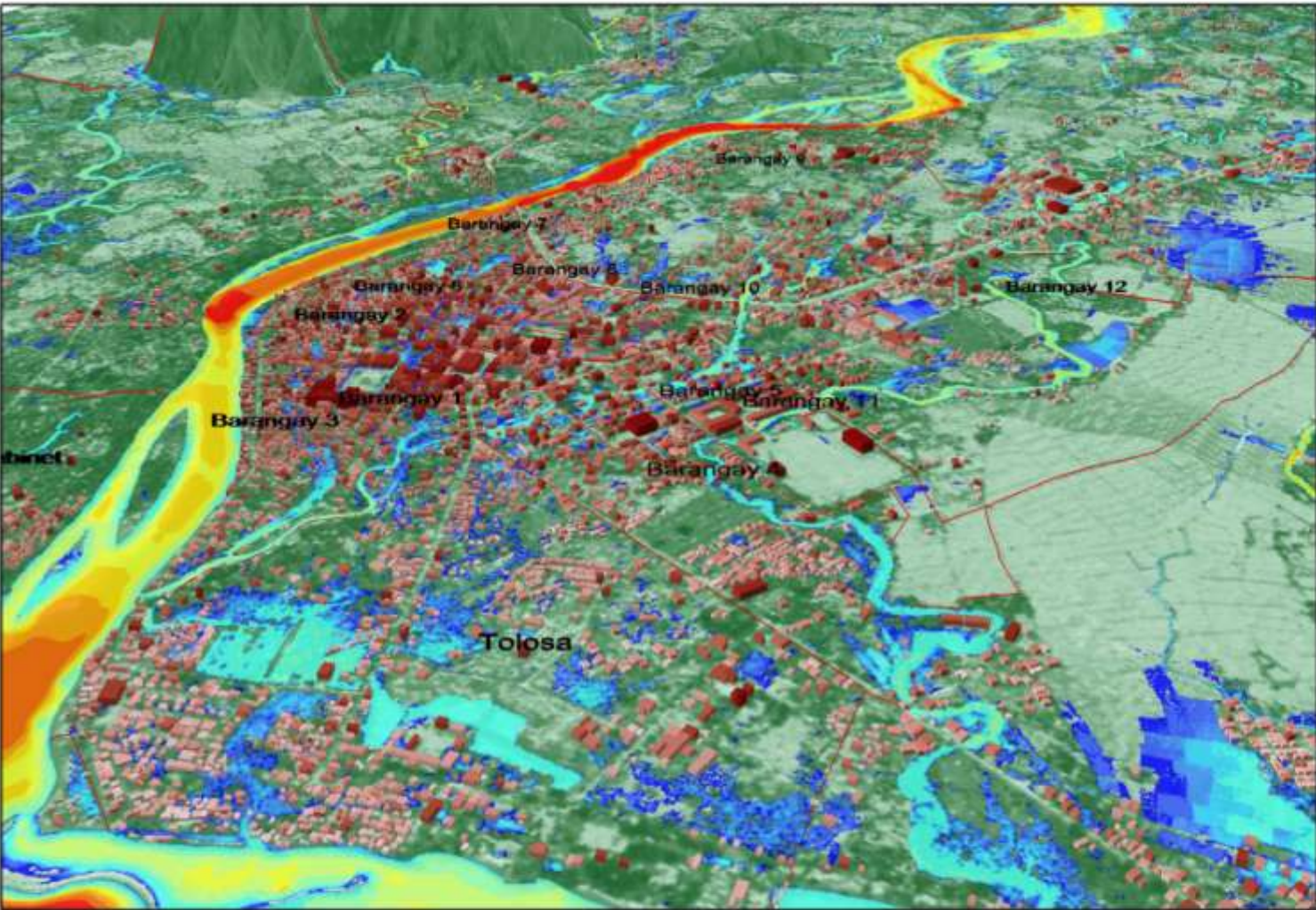
 0.51 - 1.00  3.51 - 4.00

 1.01 - 1.50  > 4.00



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3D Map of the Simulated Flood Depth for 10-Year Rain Return in Cabadbaran City


LEGEND

 Barangay Boundary

Building Height (m)

 High : 15.40



 Low : 1.51

Flood Depth (m)

 0.11 - 0.20  1.51 - 2.00

 0.21 - 0.30  2.01 - 2.50

 0.31 - 0.40  2.51 - 3.00

 0.41 - 0.50  3.01 - 3.50

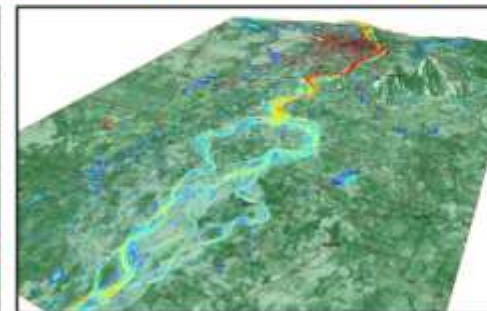
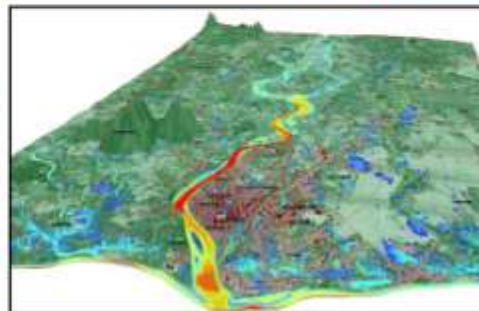
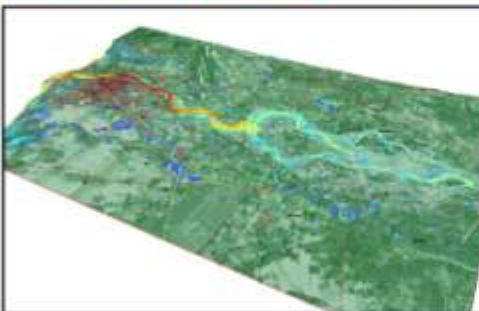
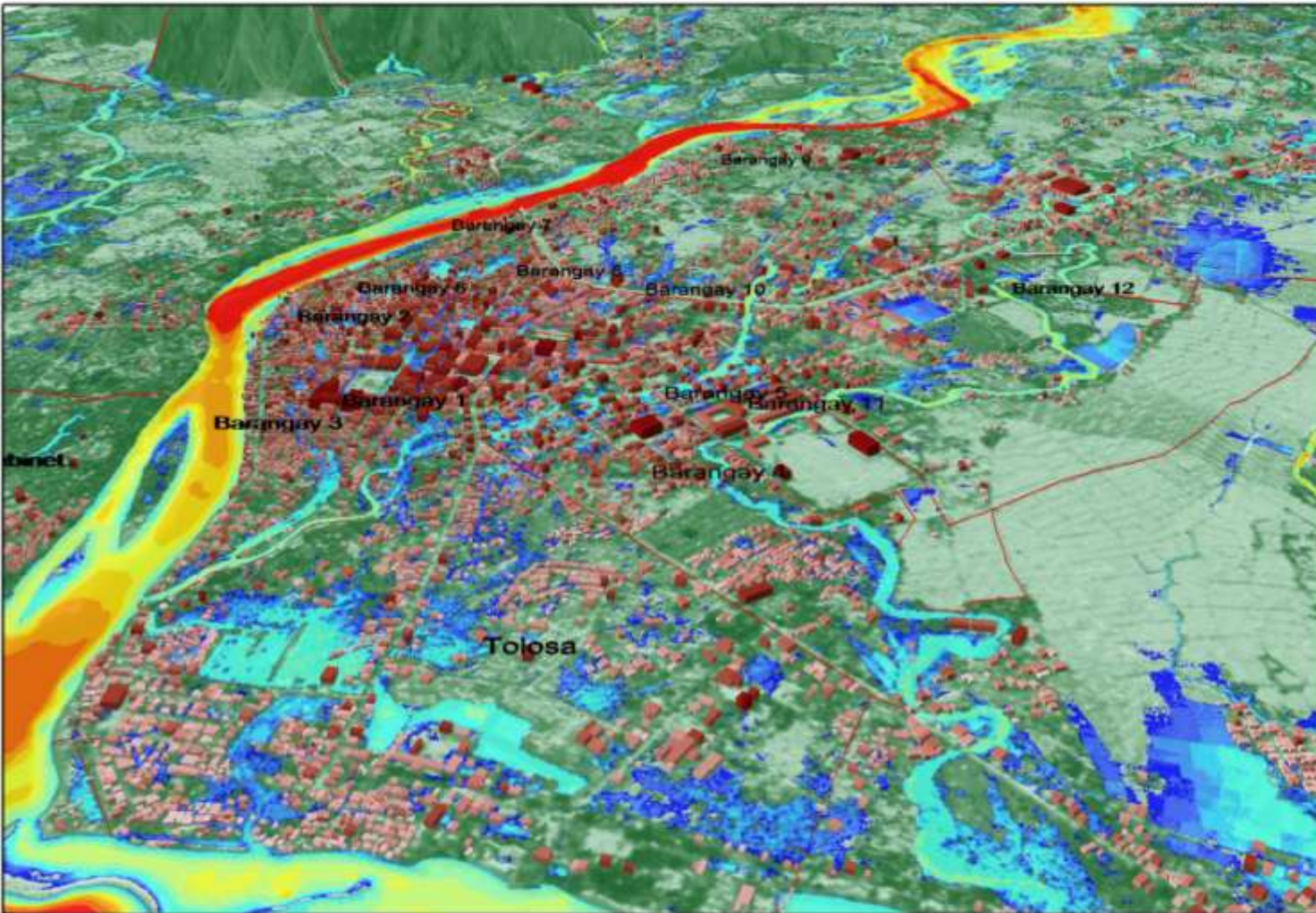
 0.51 - 1.00  3.51 - 4.00

 1.01 - 1.50  > 4.00



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3D Map of the Simulated Flood Depth for 25-Year Rain Return in Cabadbaran City

LEGEND

 Barangay Boundary

Building Height (m)

 High : 15.40



 Low : 1.51

Flood Depth (m)

 0.11 - 0.20  1.51 - 2.00

 0.21 - 0.30  2.01 - 2.50

 0.31 - 0.40  2.51 - 3.00

 0.41 - 0.50  3.01 - 3.50

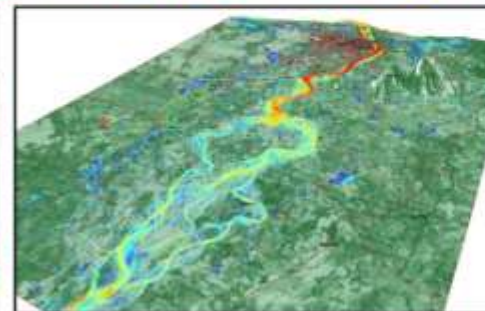
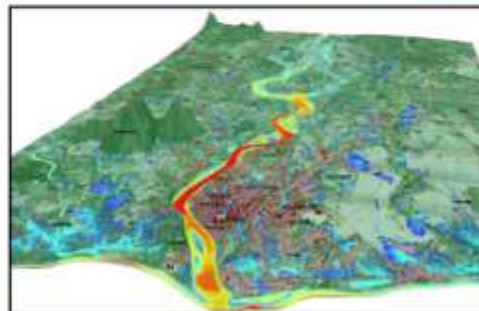
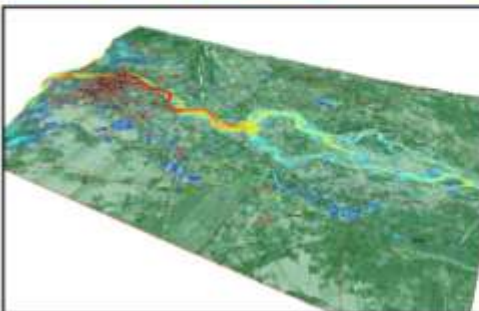
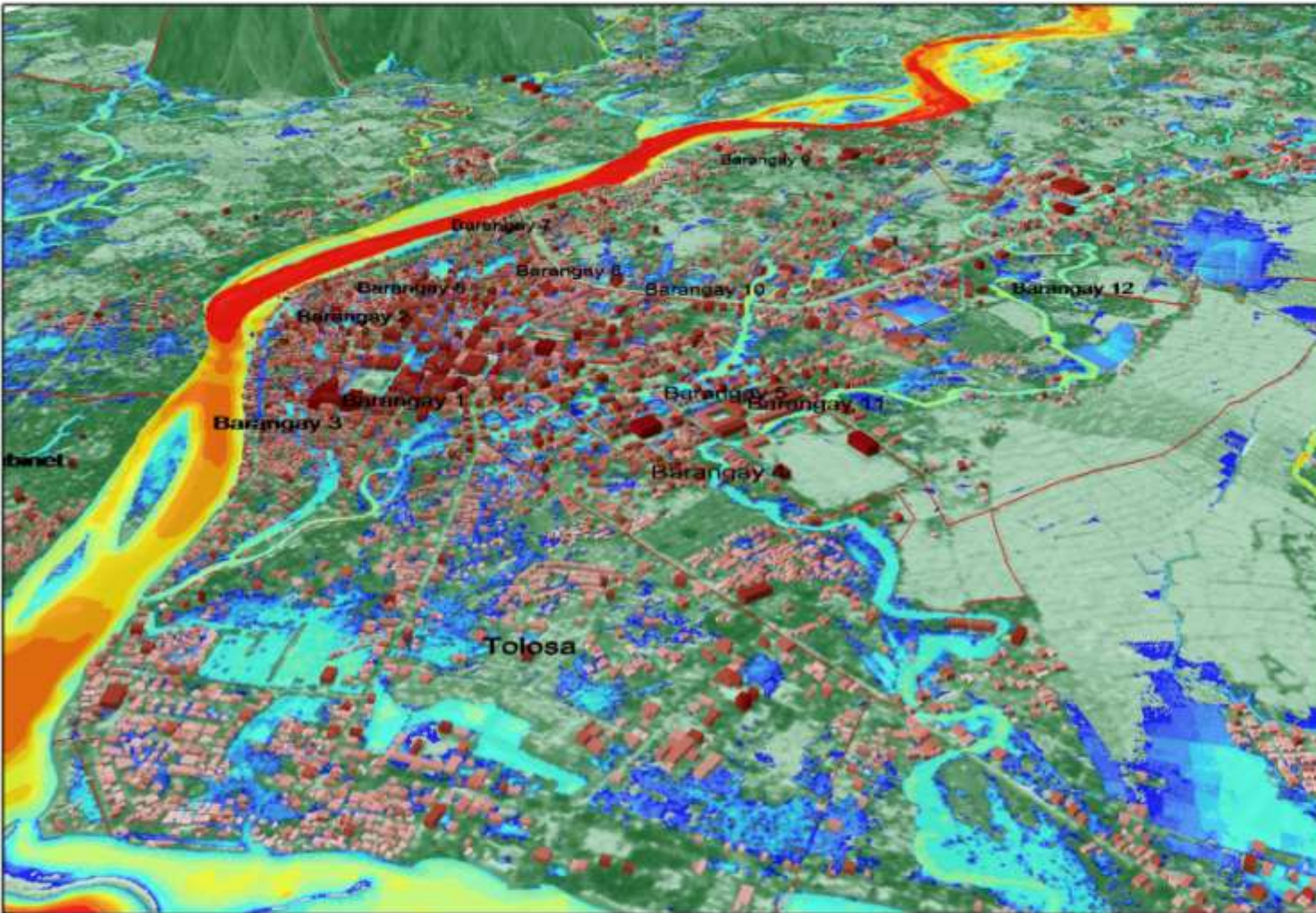
 0.51 - 1.00  3.51 - 4.00

 1.01 - 1.50  > 4.00



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3D Map of the Simulated Flood Depth for 50-Year Rain Return in Cabadbaran City

LEGEND

 Barangay Boundary

Building Height (m)

 High : 15.40



 Low : 1.51

Flood Depth (m)

 0.11 - 0.20  1.51 - 2.00

 0.21 - 0.30  2.01 - 2.50

 0.31 - 0.40  2.51 - 3.00

 0.41 - 0.50  3.01 - 3.50

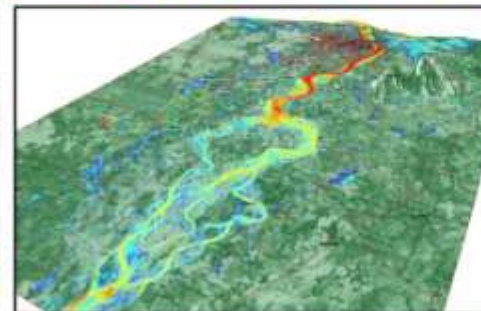
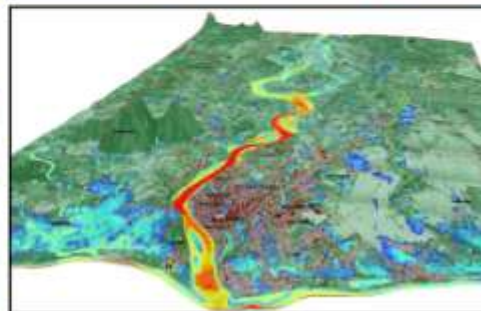
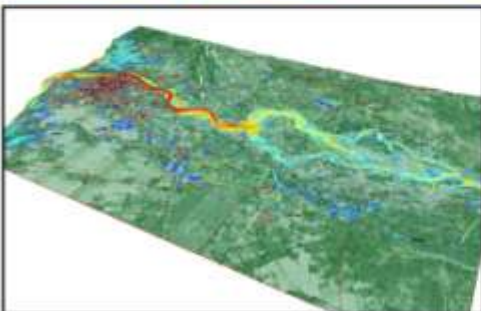
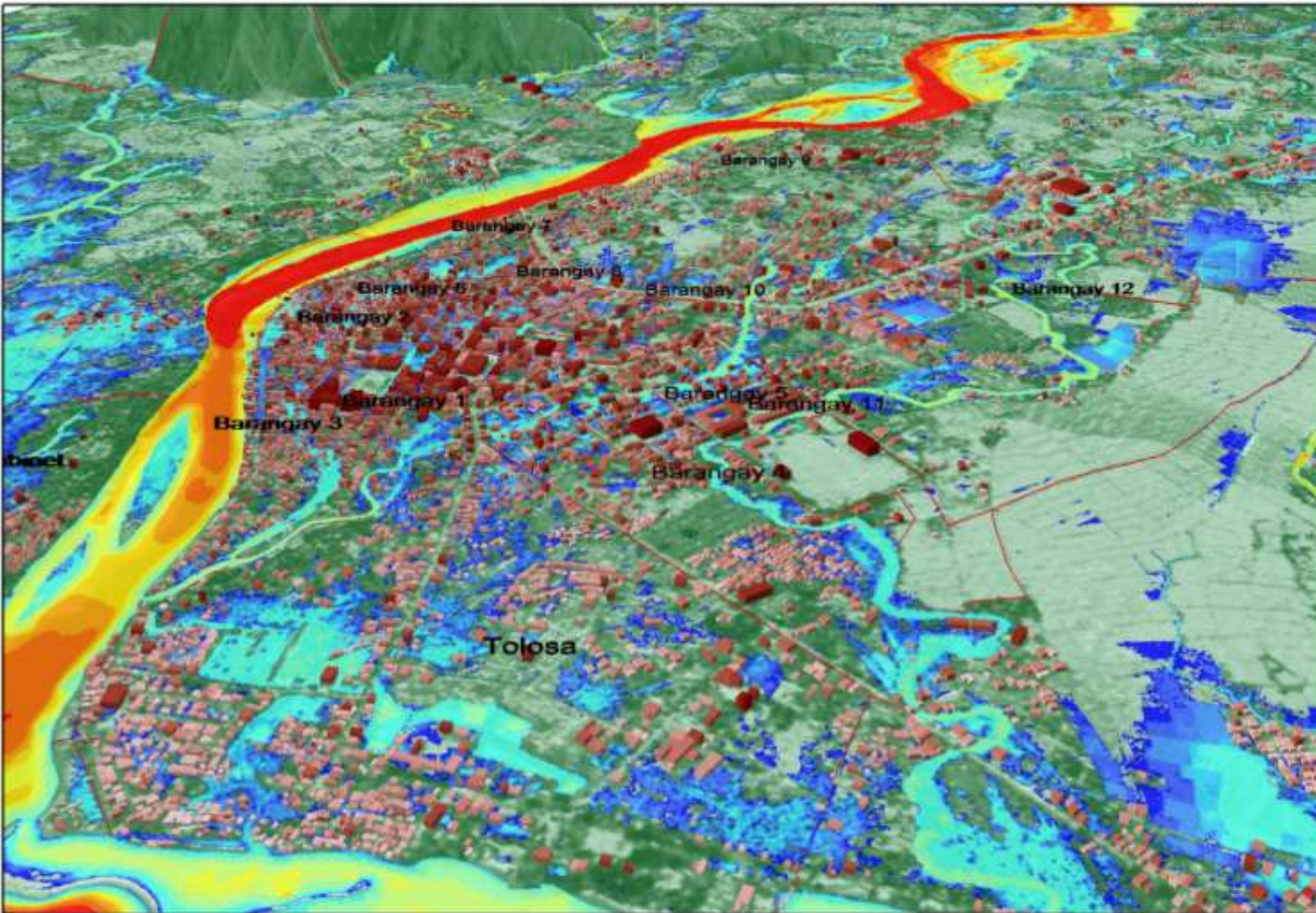
 0.51 - 1.00  3.51 - 4.00

 1.01 - 1.50  > 4.00



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3D Map of the Simulated Flood Depth for 100-Year Rain Return in Cabadbaran City


LEGEND

 Barangay Boundary

Building Height (m)

 High : 15.40



 Low : 1.51

Flood Depth (m)

 0.11 - 0.20  1.51 - 2.00

 0.21 - 0.30  2.01 - 2.50

 0.31 - 0.40  2.51 - 3.00

 0.41 - 0.50  3.01 - 3.50

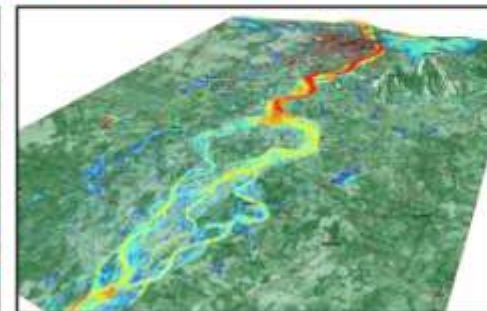
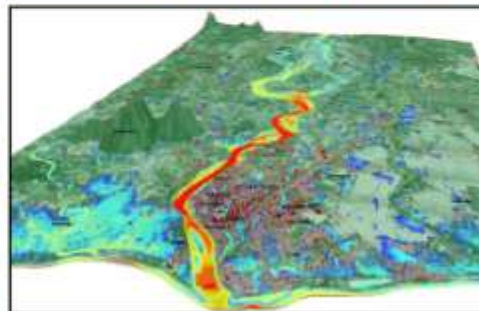
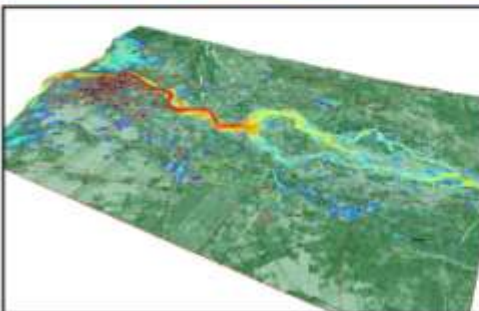
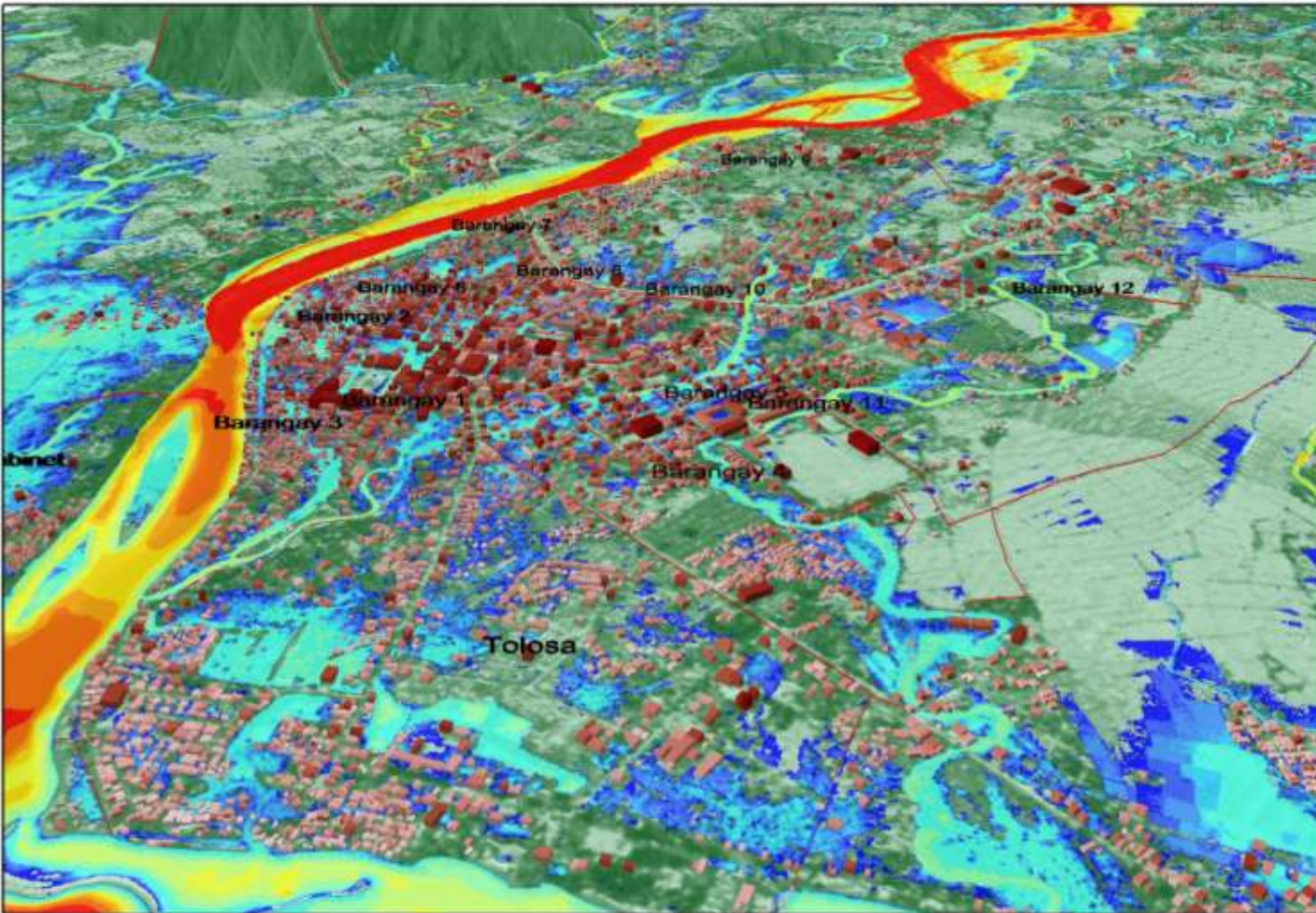
 0.51 - 1.00  3.51 - 4.00

 1.01 - 1.50  > 4.00



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MATERIALS & METHODS

○ Flood hazard maps

- The flood depth maps generated by the CSU Phil-Lidar 1 project were transformed into flood hazard maps by categorizing the flood depths into hazard levels as follows:
 - low (<0.50 m depth)
 - medium (0.50 m - 1.50 m depth), and
 - high (>1.5 m depth)

3D Flood Hazard Map of 2-Year Rain Return in Cabadbaran City

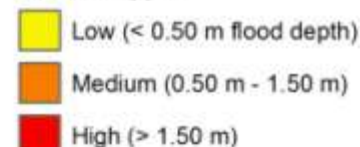
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 Barangay Boundary

Building Height (m)

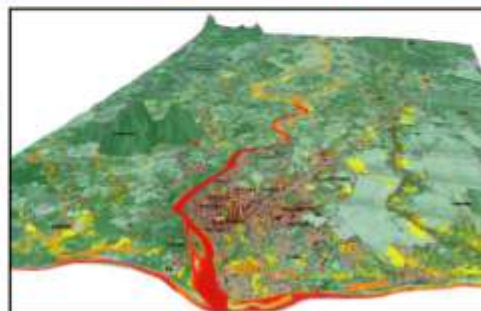
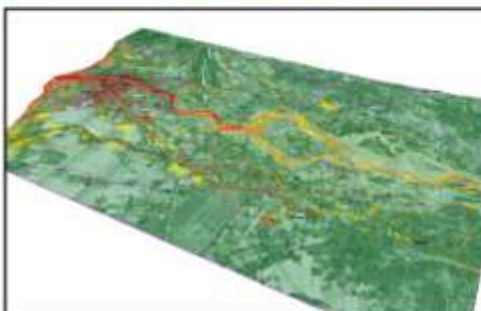
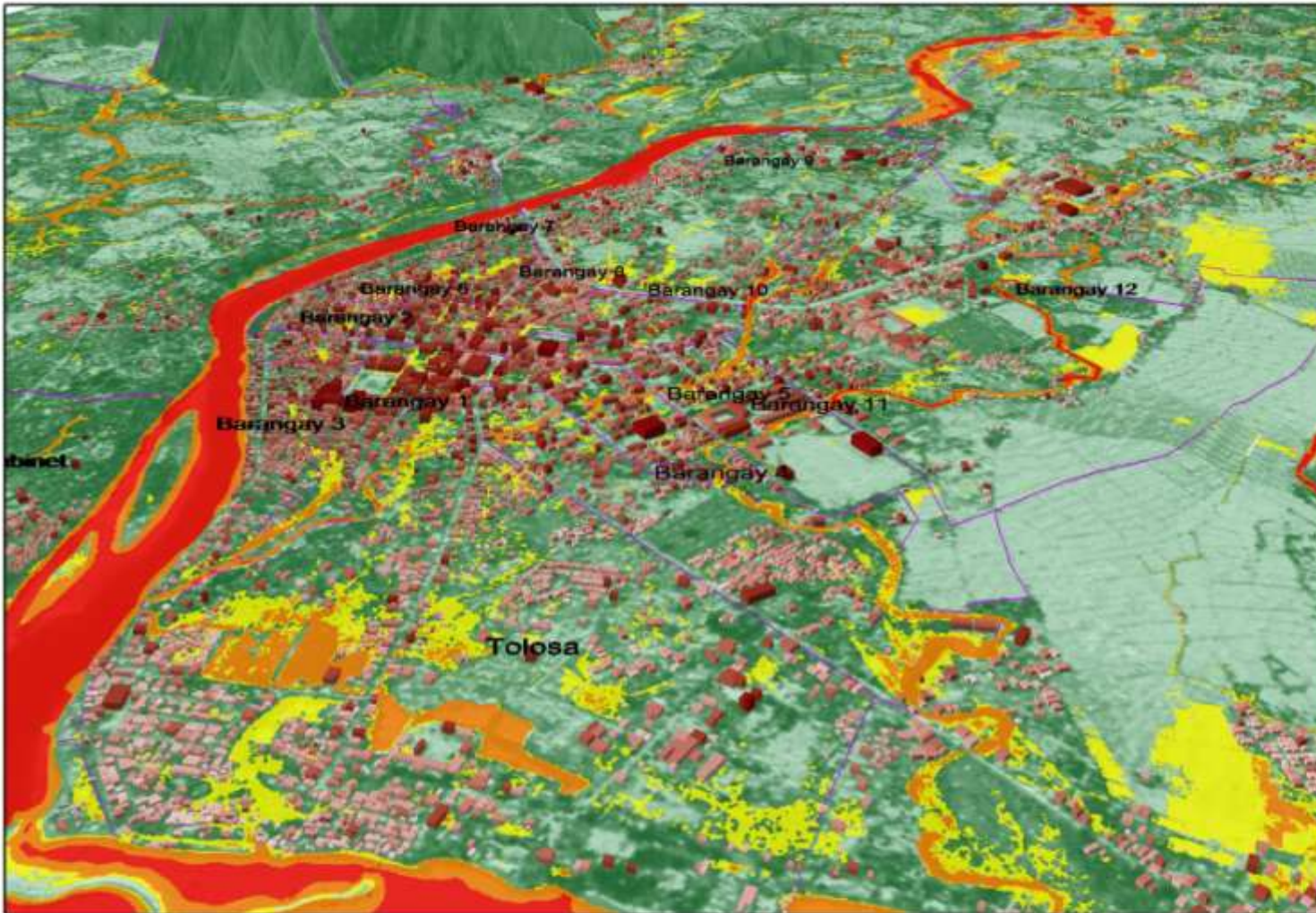


Hazard Type



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3D Flood Hazard Map of 5-Year Rain Return in Cabadbaran City

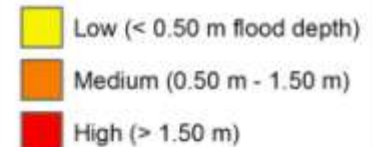
LEGEND

 Barangay Boundary

Building Height (m)

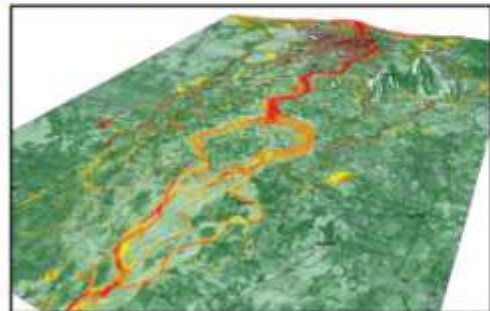
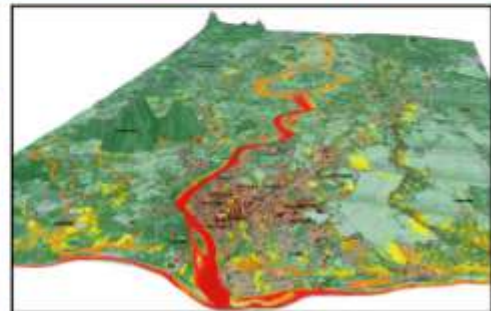
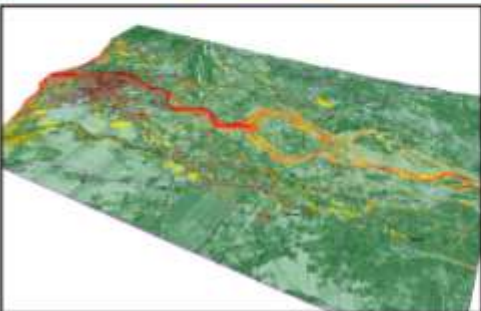
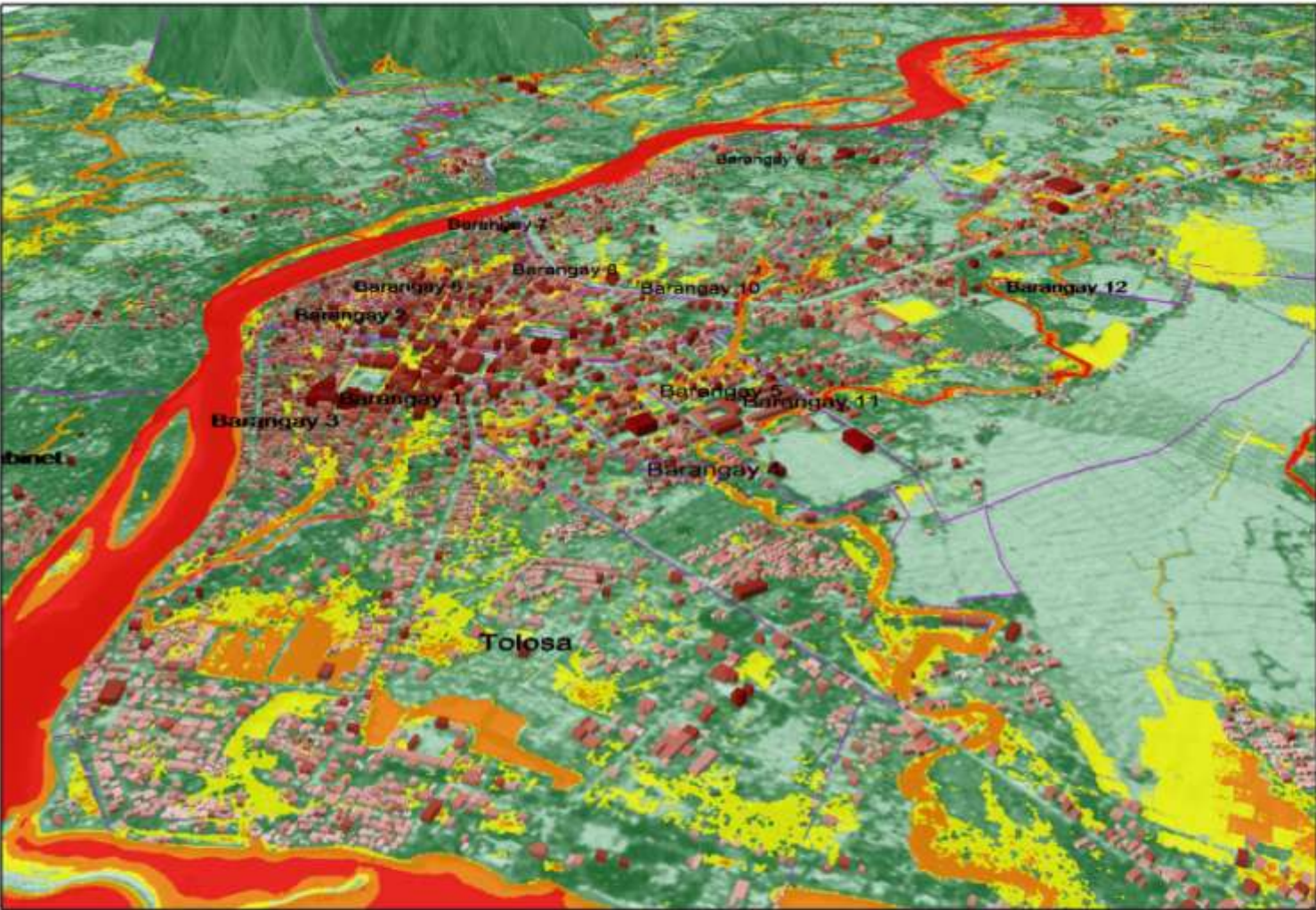


Hazard Type



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3D Flood Hazard Map of 10-Year Rain Return in Cabadbaran City

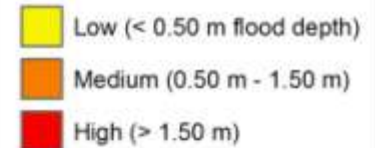
LEGEND

 Barangay Boundary

Building Height (m)

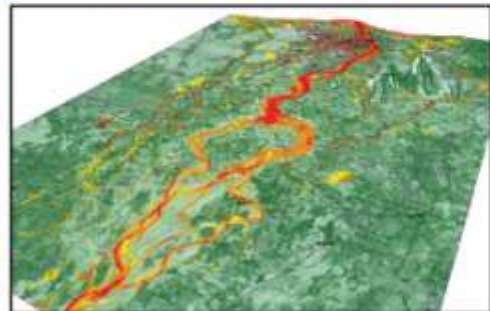
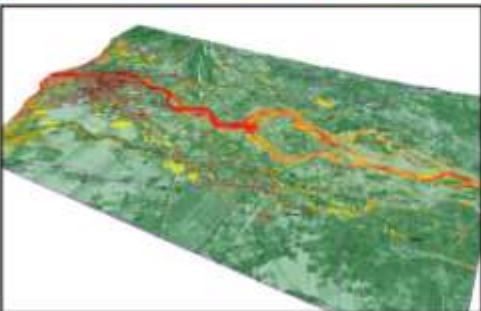
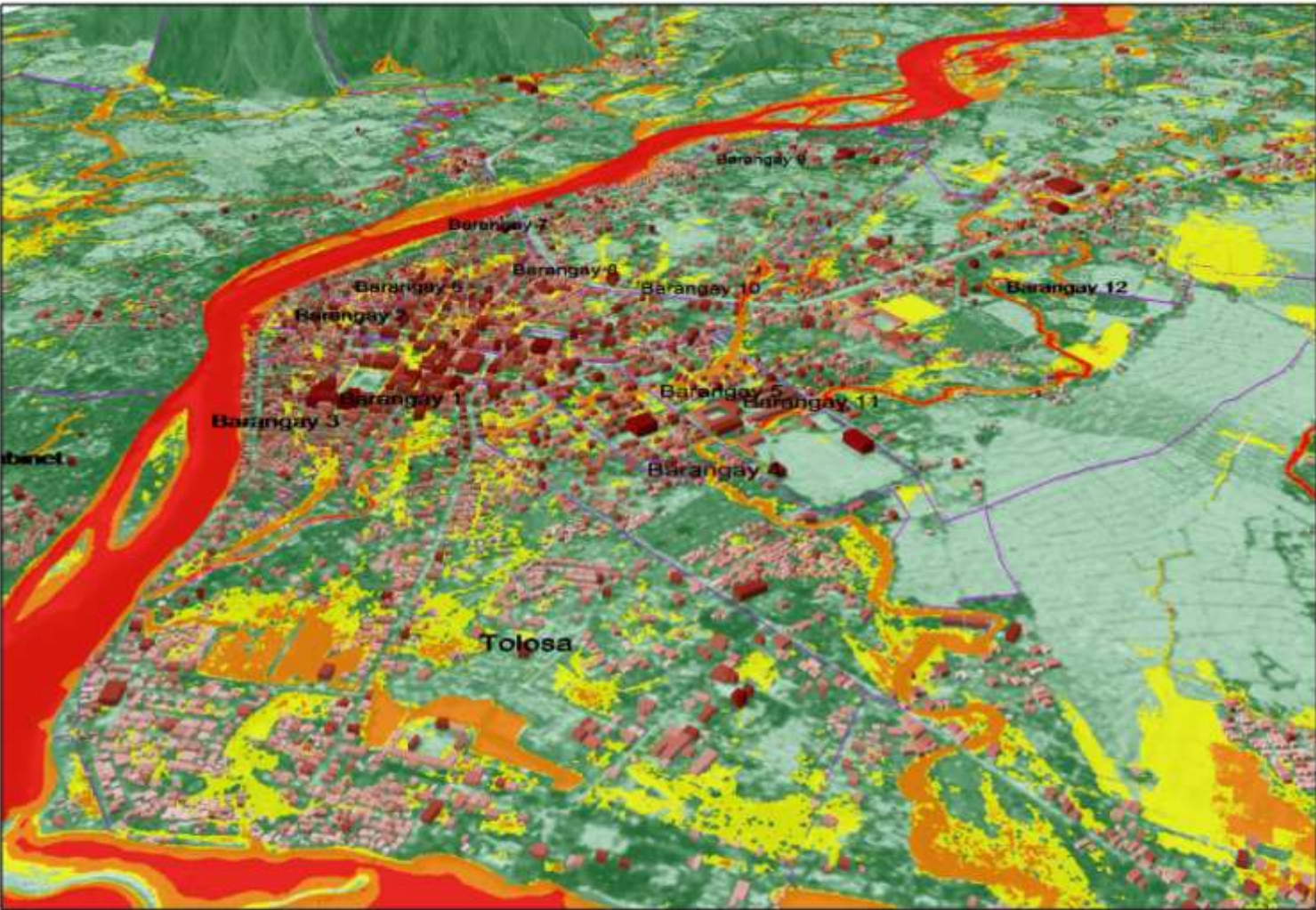


Hazard Type



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3D Flood Hazard Map of 25-Year Rain Return in Cabadbaran City

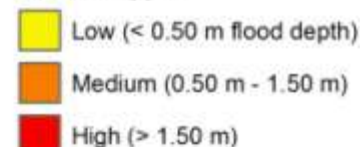
LEGEND

 Barangay Boundary

Building Height (m)

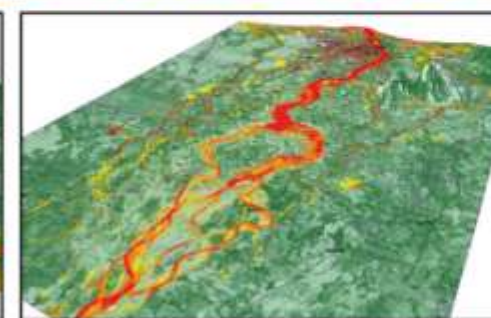
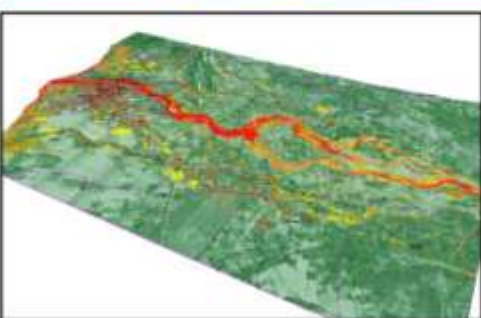
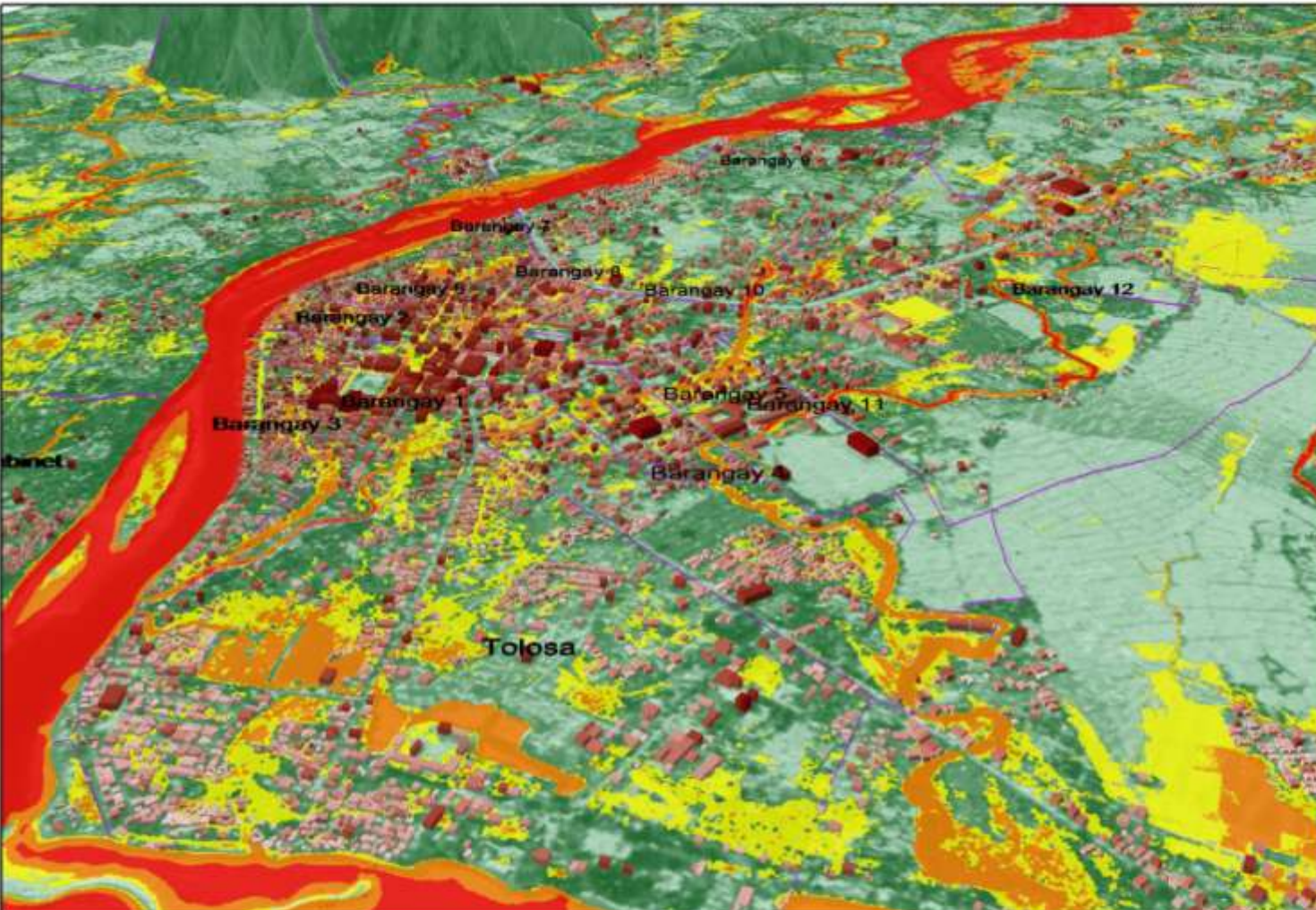


Hazard Type



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3D Flood Hazard Map of 50-Year Rain Return in Cabadbaran City

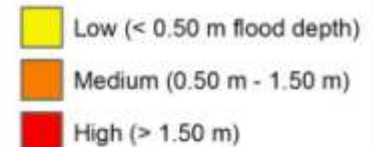
LEGEND

 Barangay Boundary

Building Height (m)



Hazard Type



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3D Flood Hazard Map of 100-Year Rain Return in Cabadbaran City

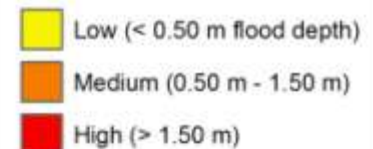
LEGEND

 Barangay Boundary

Building Height (m)

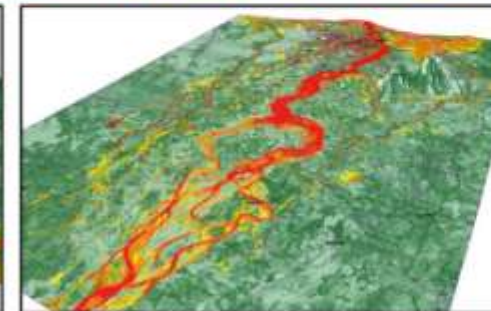
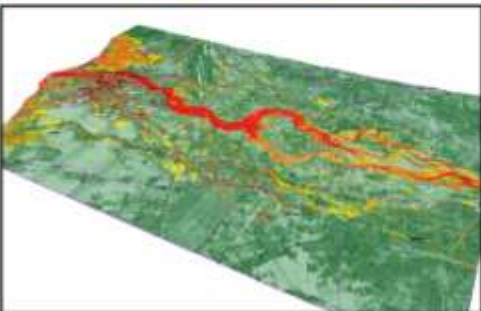
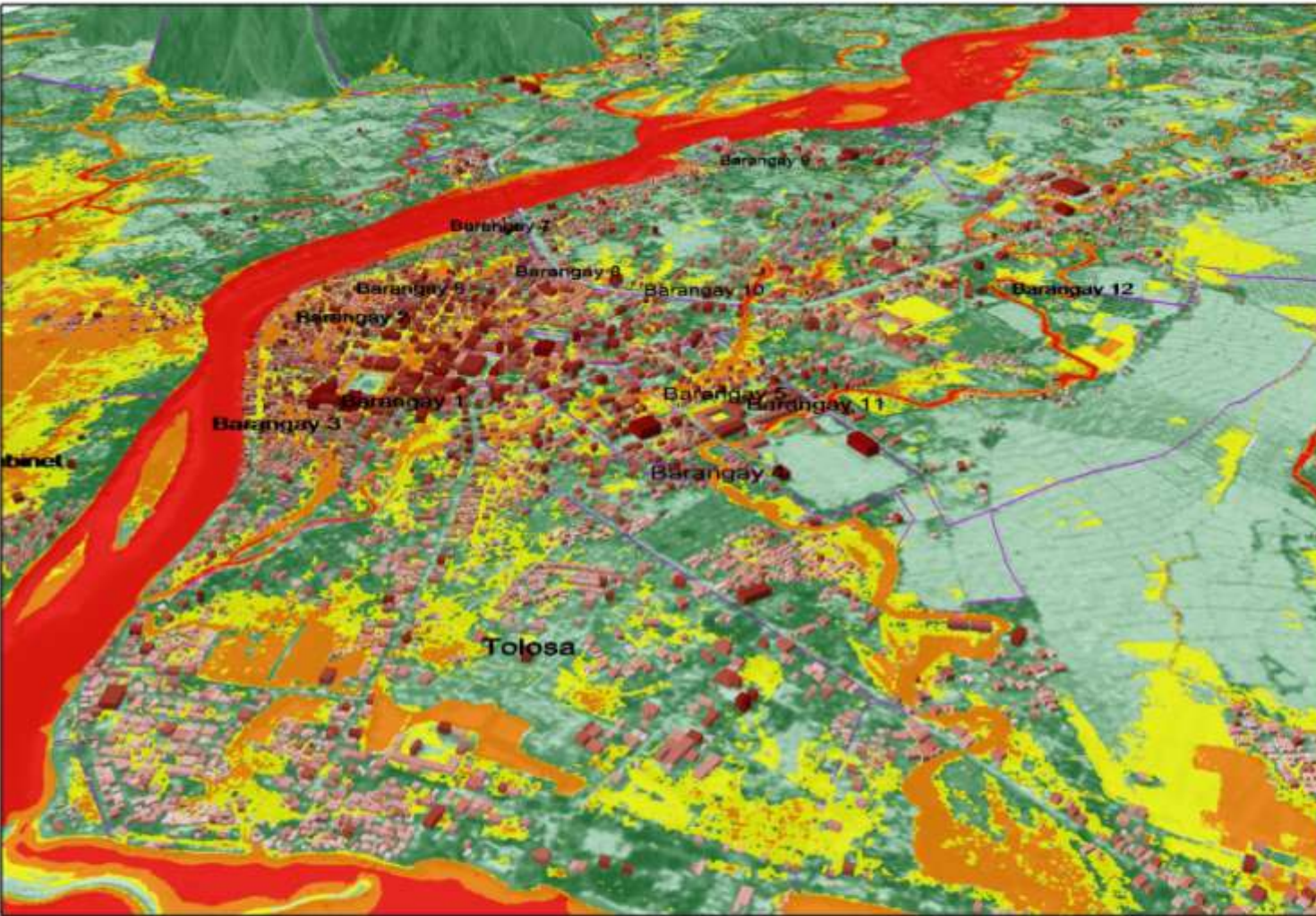


Hazard Type



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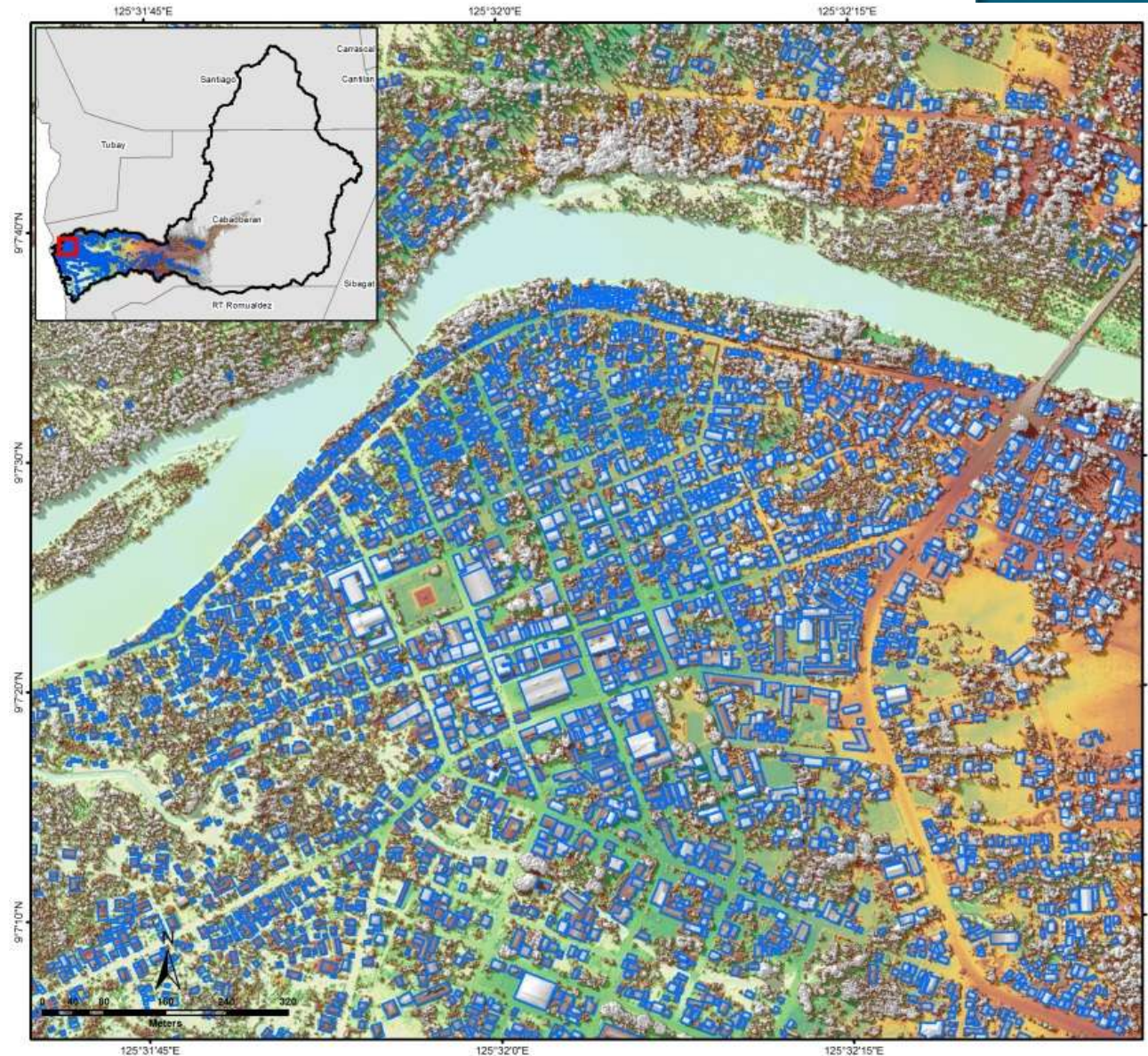
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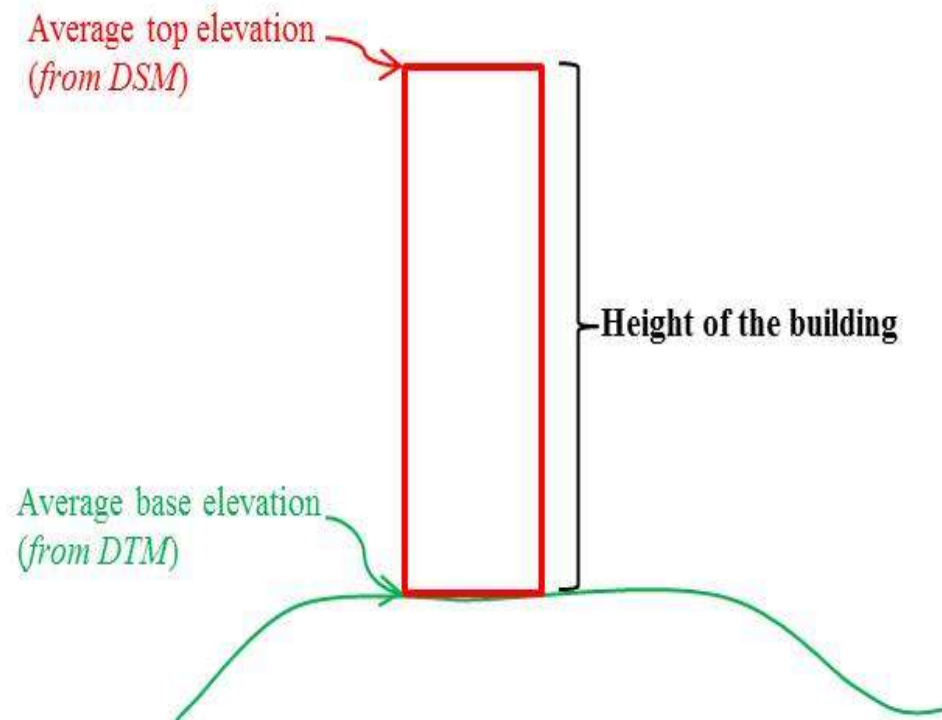
BUILDING EXTRACTION FROM LIDAR DATA

- Buildings were manually digitized from the LiDAR DSM.
- Google Earth was used as reference for checking and comparing the results of the extracted features.



HEIGHT ESTIMATION AND FEATURE ATTRIBUTION

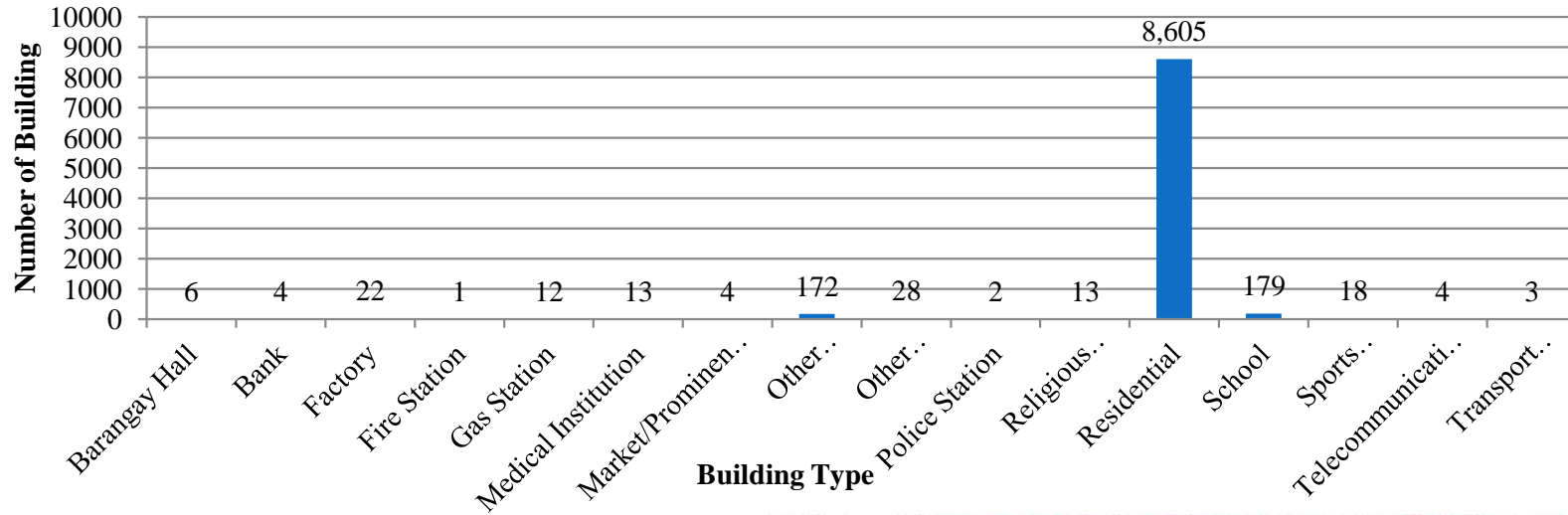
- Height of the buildings were calculated using the average of the base elevations and top elevations for each building footprint.
 - Base elevation values were extracted from DTM
 - Top elevation values were extracted from DSM
- Building attribute were obtained from Wikimapia and Google Map.



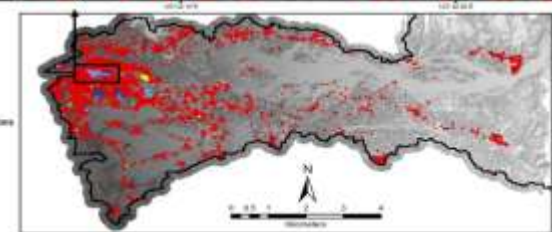
FLOOD HAZARD AND BUILDING'S VULNERABILITY EXPOSURE ASSESSMENT

- GIS overlay analysis of the building footprints and 3D flood hazard maps
 - To identify which buildings are exposed to various levels of flood hazard
- The degree of flood exposure of buildings was characterized by comparing their heights (h) with the simulated flood depths
 - Vulnerability of the buildings:
 - If the building is located in a location where flood depth is:
 - less than 0.10m → coded as “Not vulnerable”
 - 0.10 to less than $0.25 \cdot h$ → vulnerability is “Low”
 - $>0.25 \cdot h$ to less than or equal to $0.5 \cdot h$ → vulnerability is “Medium”
 - If flood depth is $>0.5 \cdot h$ → vulnerability is “High”

RESULTS: BUILDING DATABASE

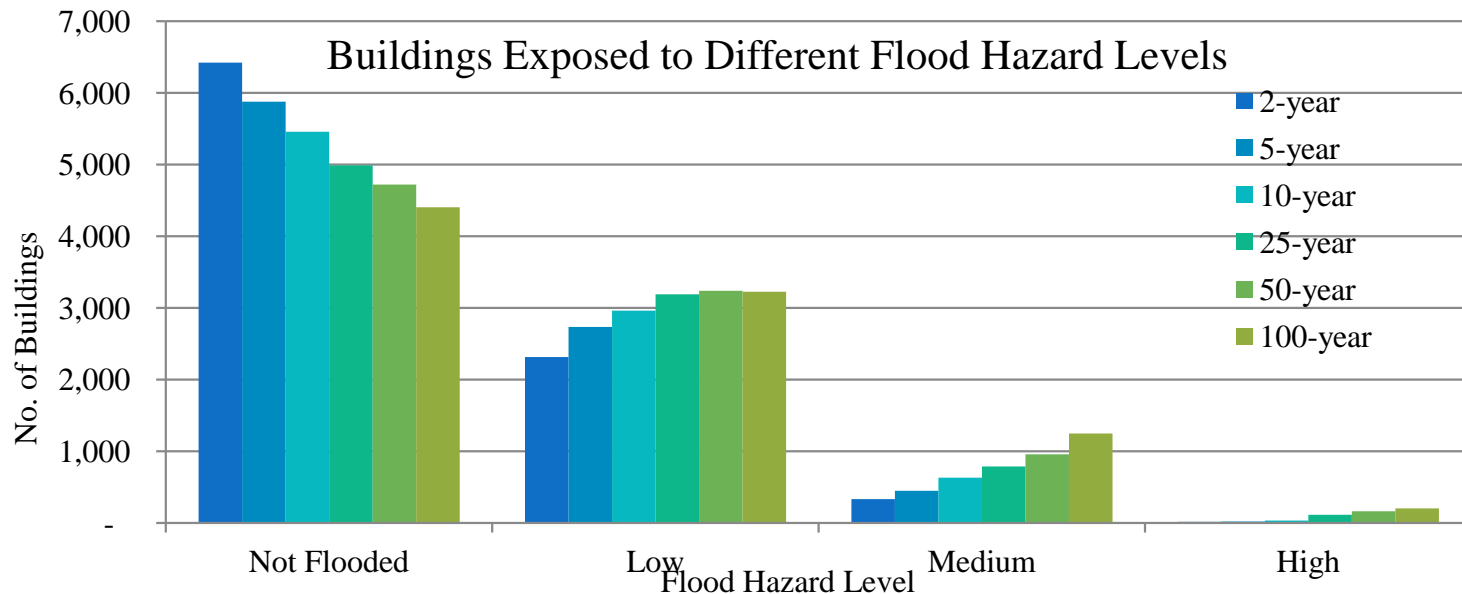


- Total of 9,086 identified buildings
- 95% are residential



RESULTS: EXPOSURE OF BUILDINGS TO FLOOD HAZARD

- Statistics show that as the rainfall return period increases, the number of buildings affected by flooding also increases. Consequently, the number of buildings that are not flooded decreases.
- In all rainfall scenarios considered, majority of the buildings appears to be not flooded.
- For flood-affected buildings, more buildings are exposed to 'low' flood hazard levels than those in 'medium' and 'high' hazard levels.
- This result means that majority of areas within the river basin where buildings are located are relatively not prone to flooding; and if there is flooding, the level of hazard is low.



3D BUILDINGS FLOOD HAZARD EXPOSURE MAPS

3D Building Flood Hazard Exposure Map of 2-Year Rain Return in Cabadbaran City

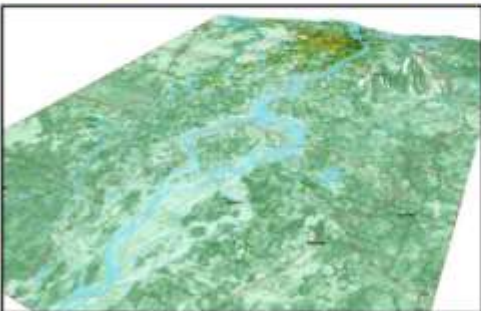
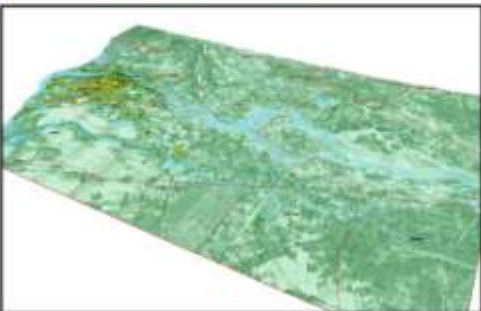
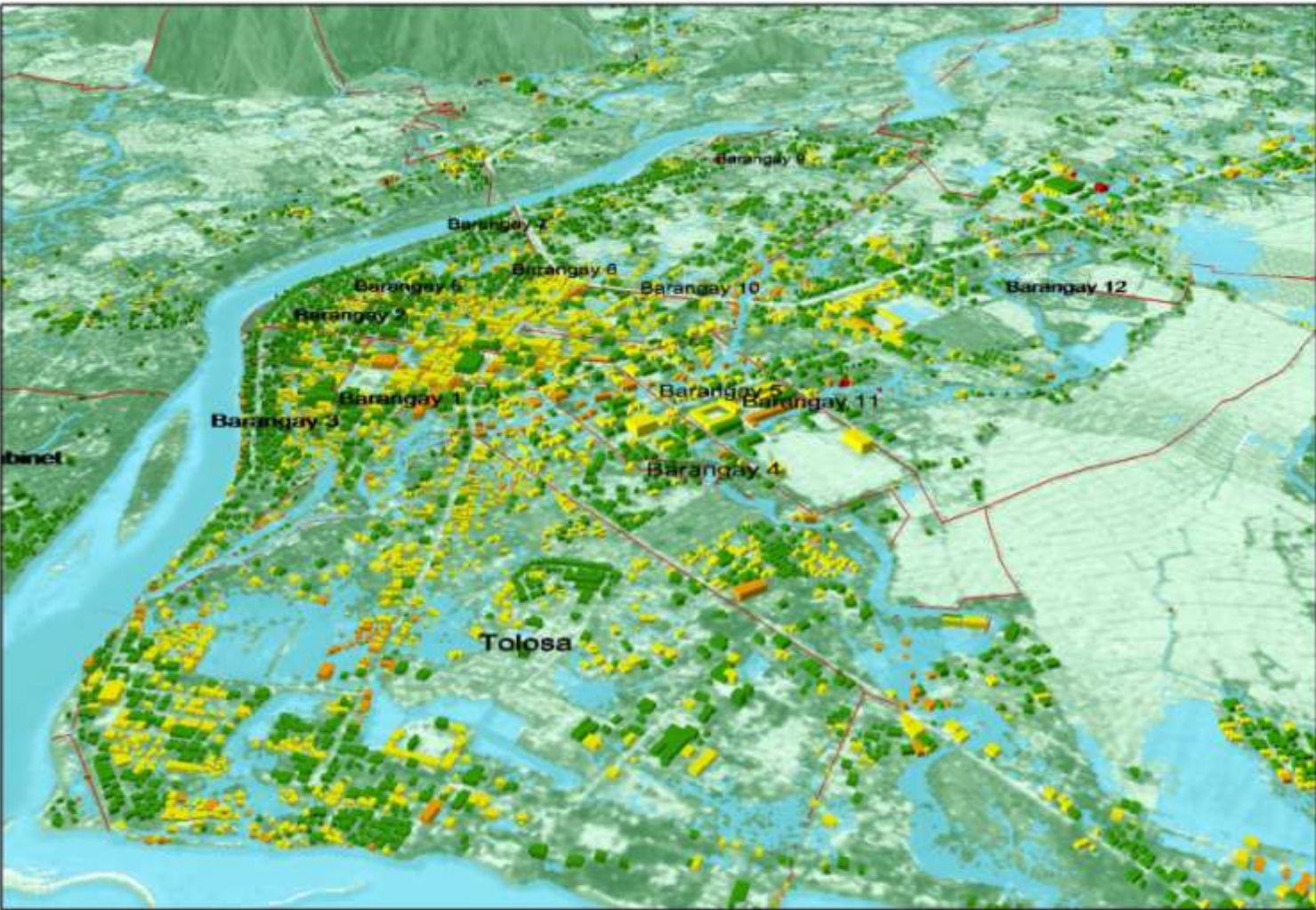
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Hazard**
-  Not Flooded
-  Low (< 0.50 m flood depth)
-  Medium (0.50 m - 1.50 m)
-  High (> 1.50 m)



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3D Building Flood Hazard Exposure Map of 5-Year Rain Return in Cabadbaran City

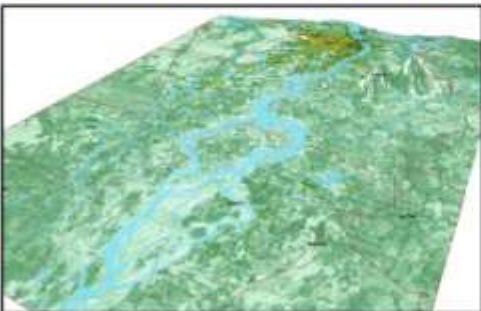
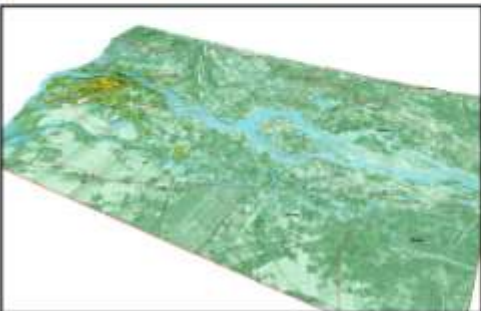
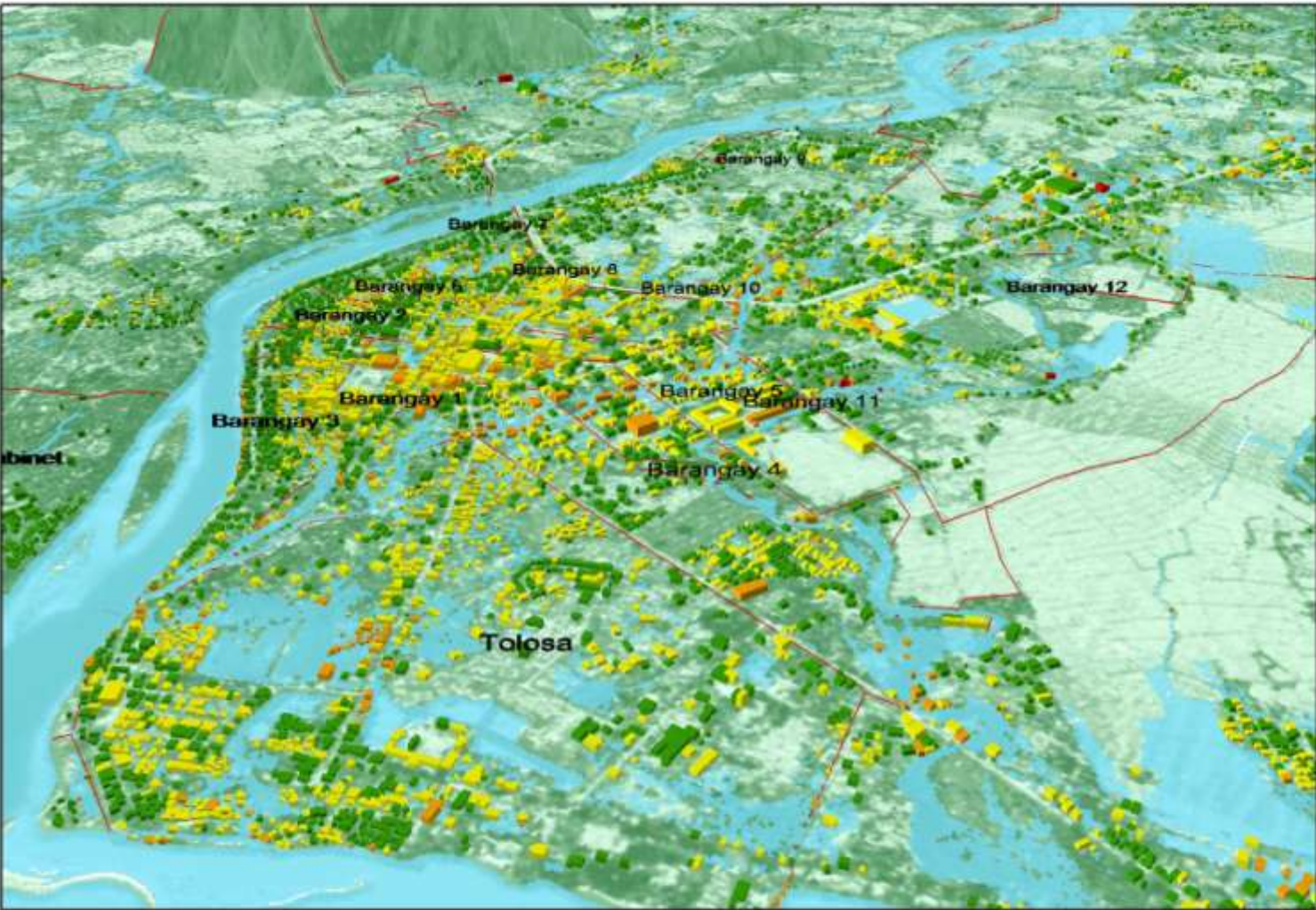
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Hazard**
-  Not Flooded
-  Low (< 0.50 m flood depth)
-  Medium (0.50 m - 1.50 m)
-  High (> 1.50 m)



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3D Building Flood Hazard Exposure Map of 10-Year Rain Return in Cabadbaran City

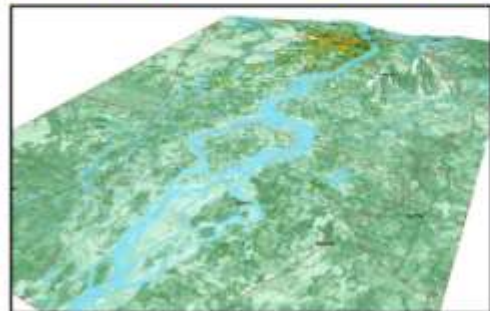
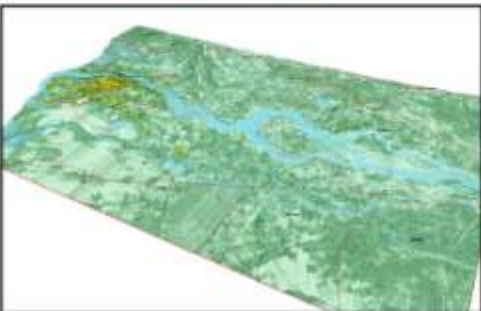
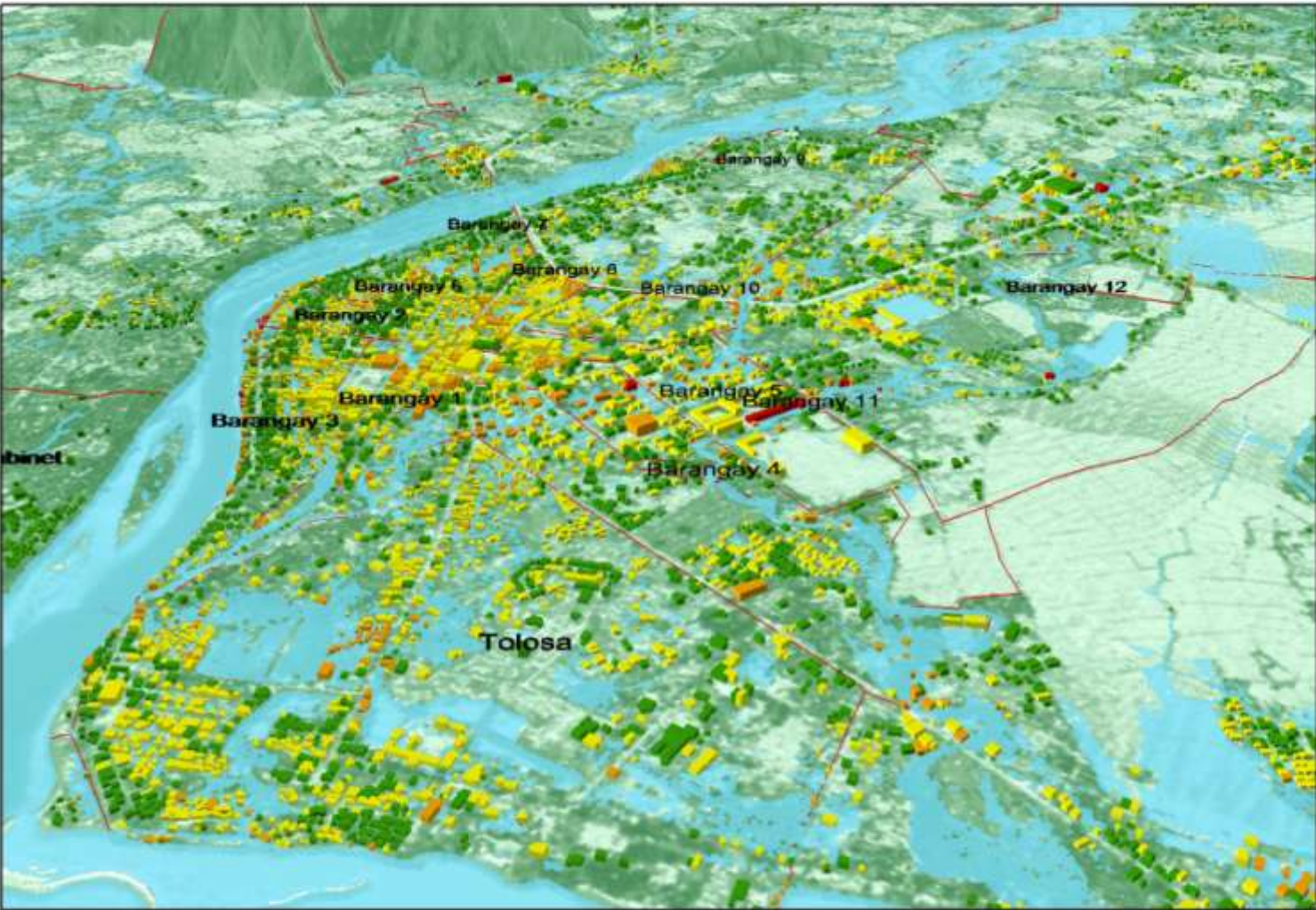
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Hazard**
-  Not Flooded
-  Low (< 0.50 m flood depth)
-  Medium (0.50 m - 1.50 m)
-  High (> 1.50 m)



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3D Building Flood Hazard Exposure Map of 25-Year Rain Return in Cabadbaran City

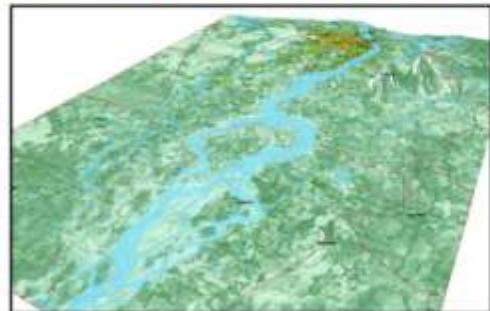
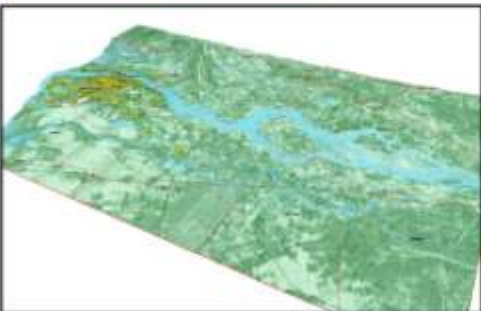
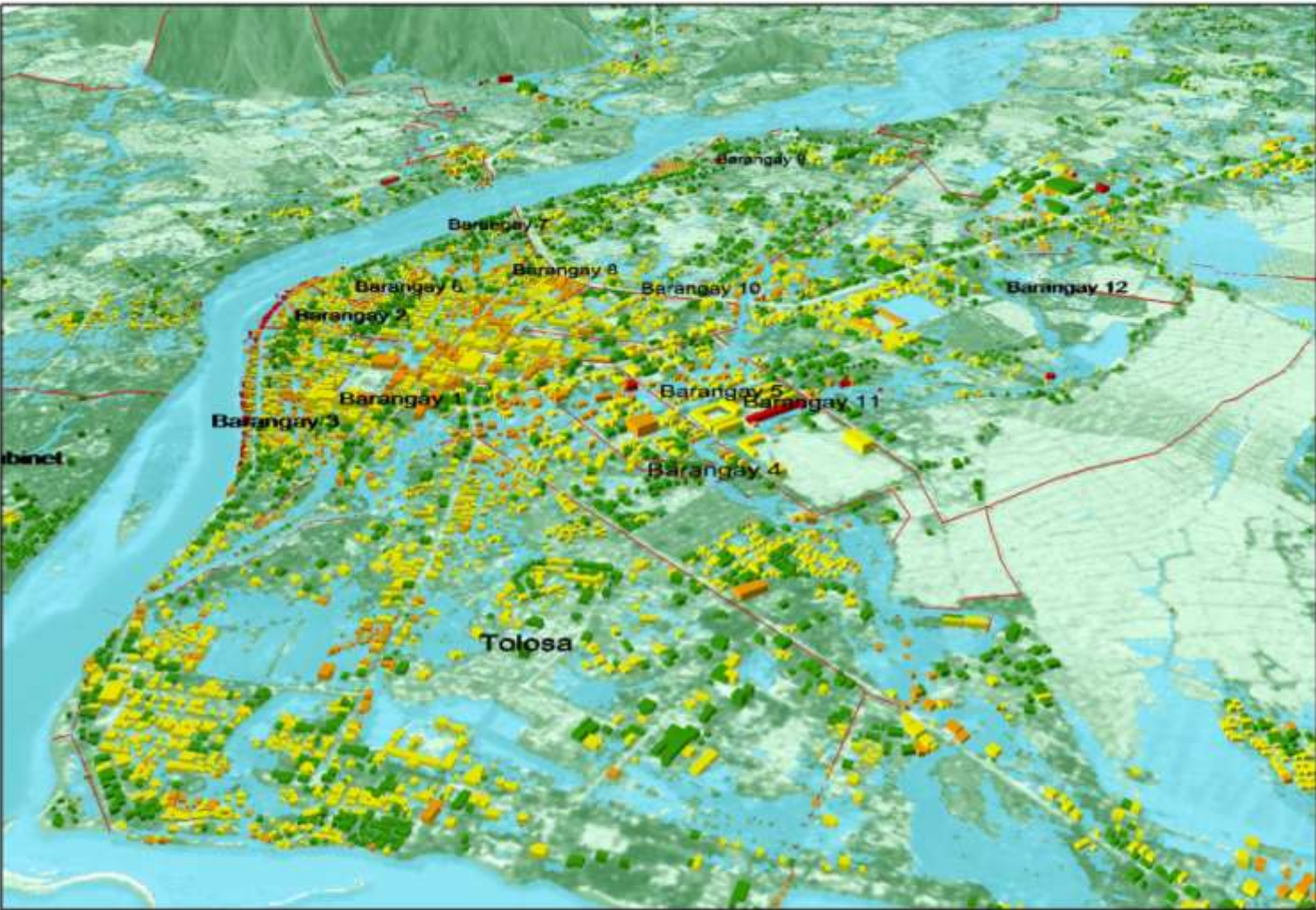
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Hazard**
-  Not Flooded
-  Low (< 0.50 m flood depth)
-  Medium (0.50 m - 1.50 m)
-  High (> 1.50 m)



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3D Building Flood Hazard Exposure Map of 50-Year Rain Return in Cabadbaran City

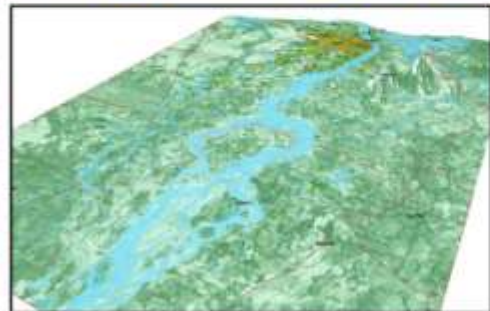
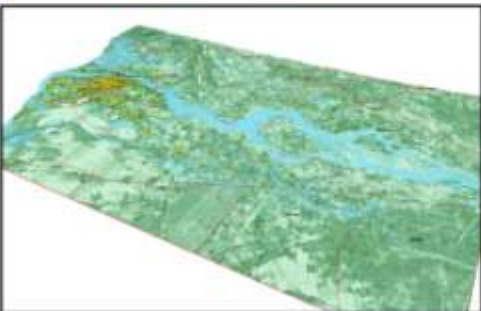
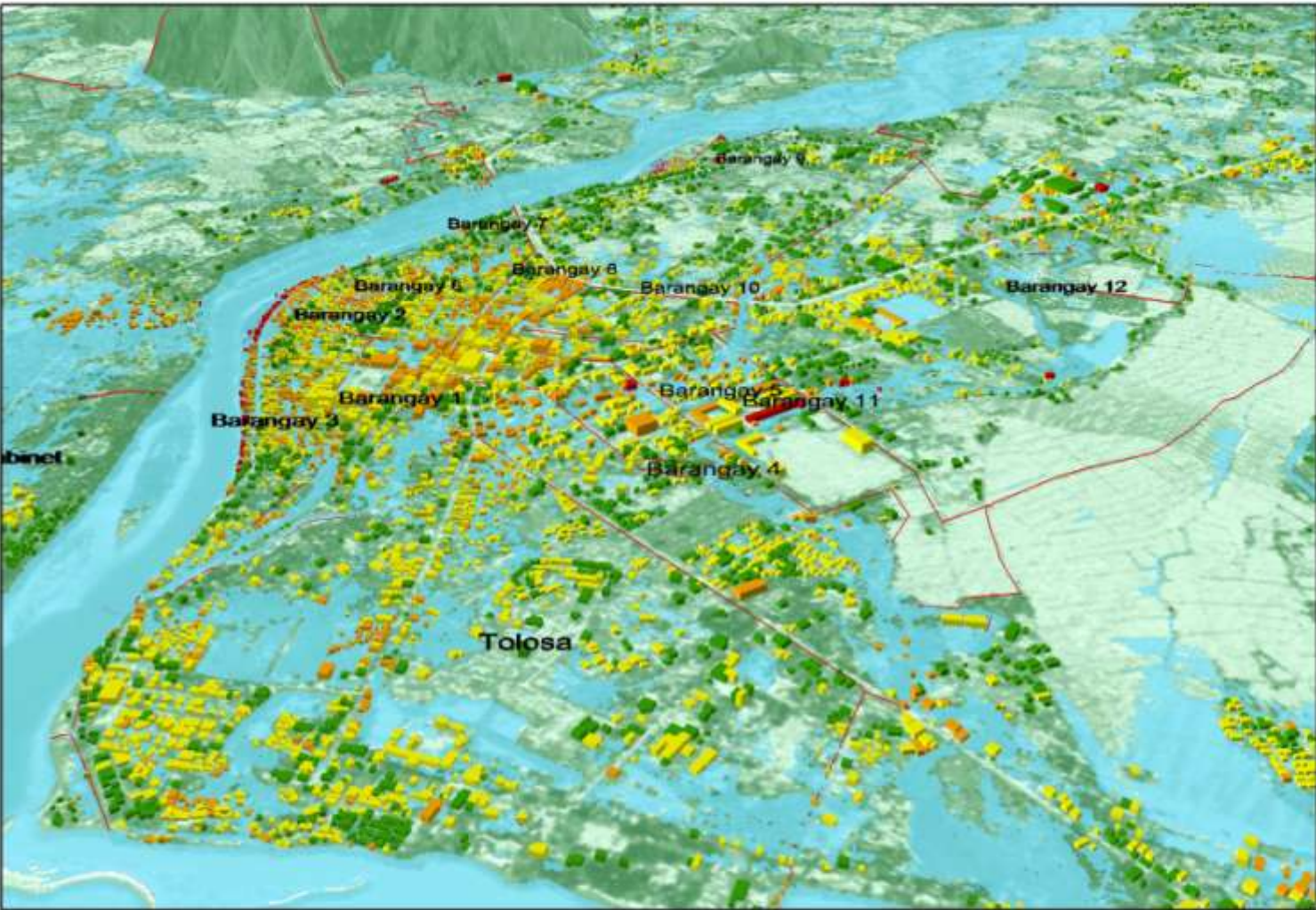
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Hazard**
-  Not Flooded
-  Low (< 0.50 m flood depth)
-  Medium (0.50 m - 1.50 m)
-  High (> 1.50 m)



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3D Building Flood Hazard Exposure Map of 100-Year Rain Return in Cabadbaran City

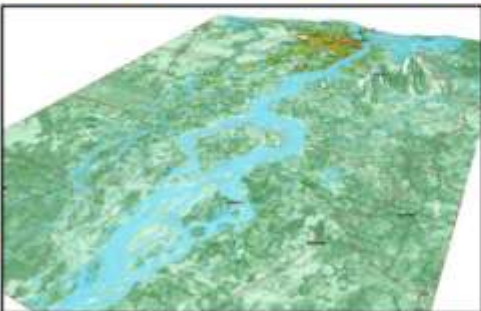
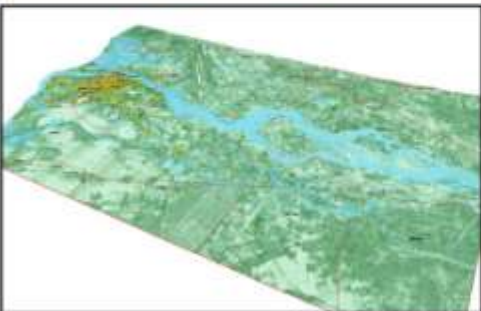
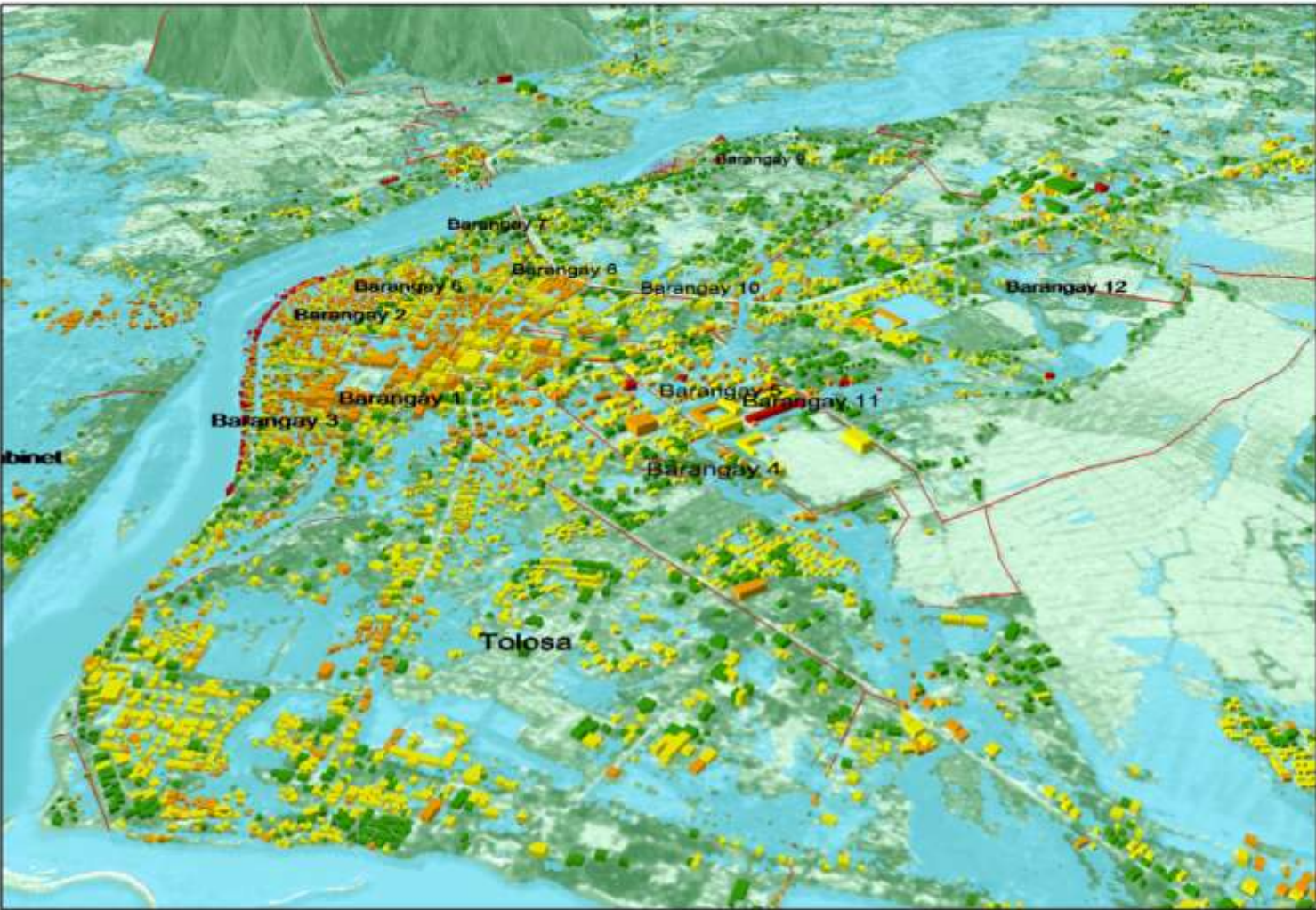
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Hazard**
-  Not Flooded
-  Low (< 0.50 m flood depth)
-  Medium (0.50 m - 1.50 m)
-  High (> 1.50 m)



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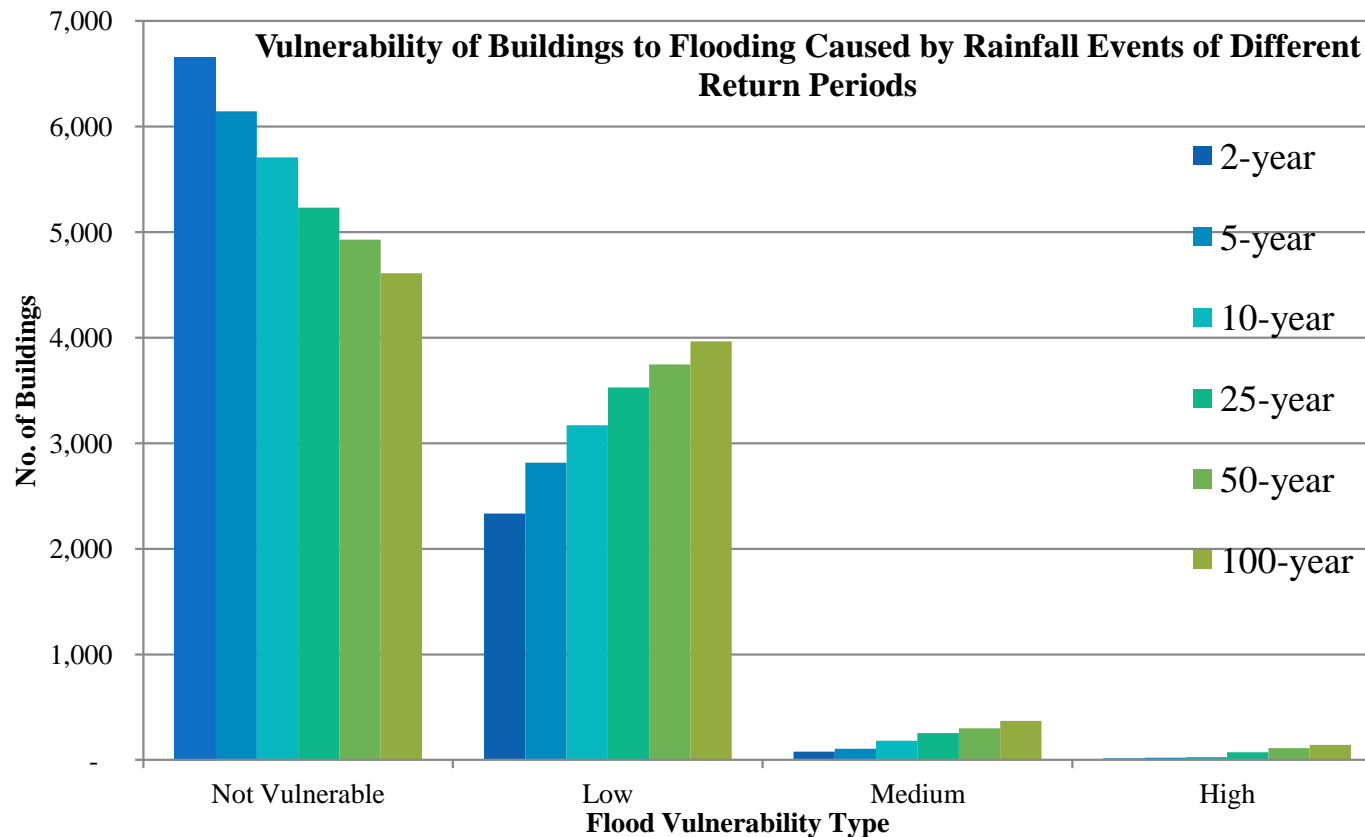
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RESULTS: VULNERABILITY OF BUILDINGS TO FLOOD HAZARDS

- Majority of the buildings are not vulnerable to flooding, especially for flooding due to rainfall events of 2, 5, 10, and 25 return periods. For flood affected buildings, more buildings are in 'low' vulnerabilities, with increasing number as the rainfall return period increases.



3D BUILDINGS VULNERABILITY MAPS

3D Buildings Vulnerability Map of 2-Year Rain Return in Cabadbaran City

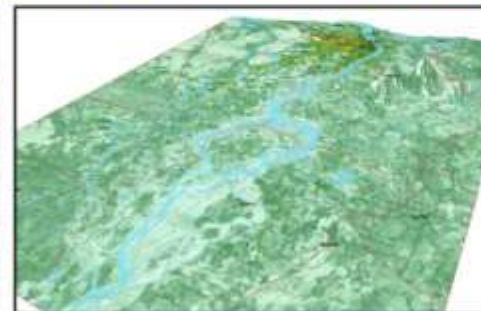
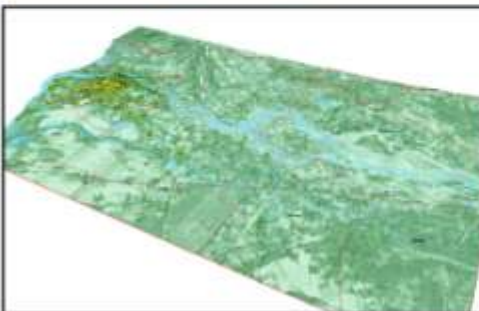
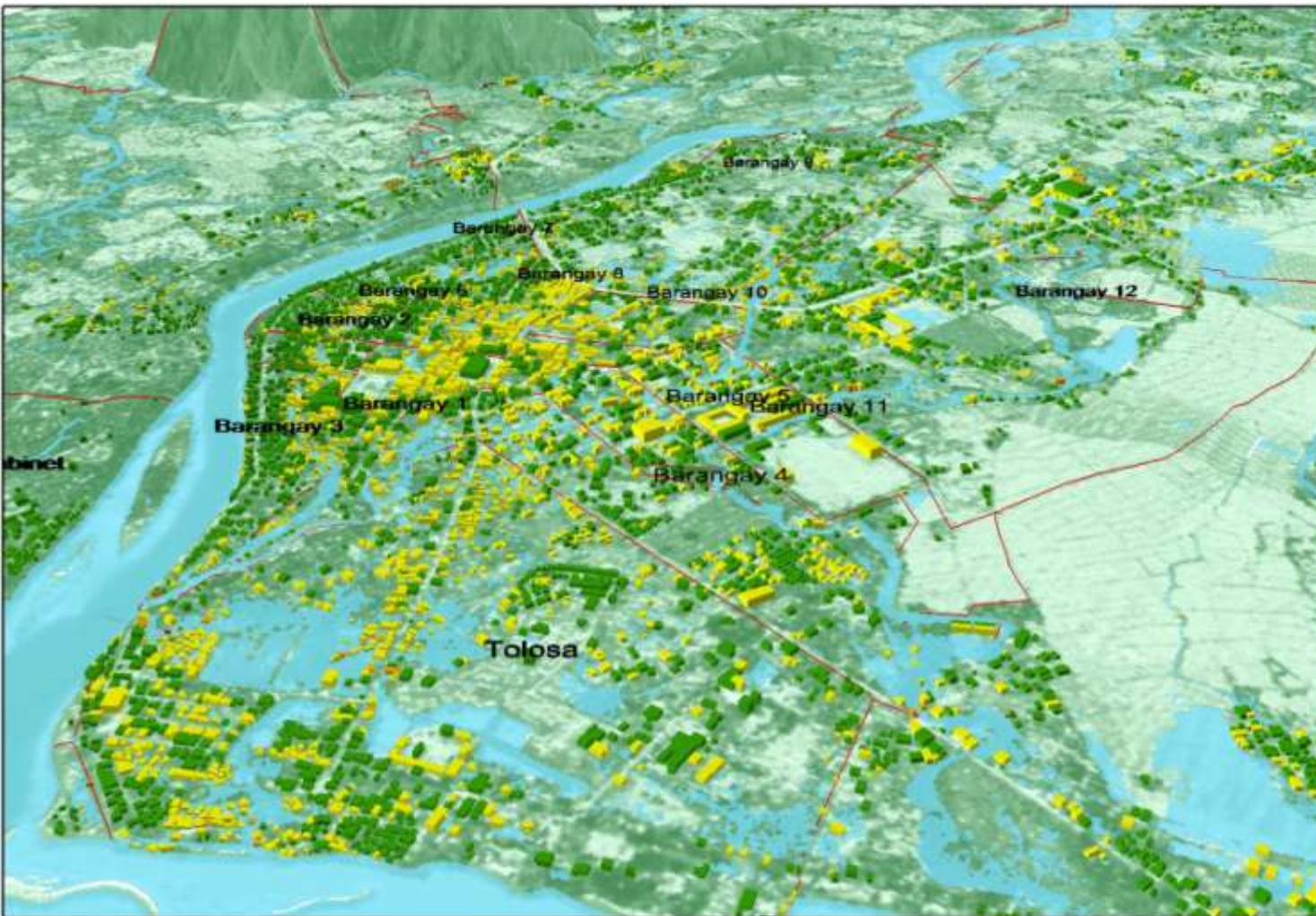
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Vulnerability**
-  Not Vulnerable
-  Low
-  Medium
-  High



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3D Buildings Vulnerability Map of 5-Year Rain Return in Cabadbaran City

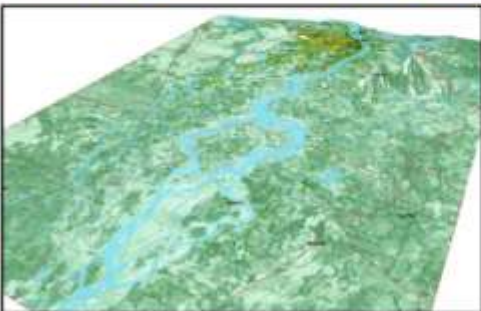
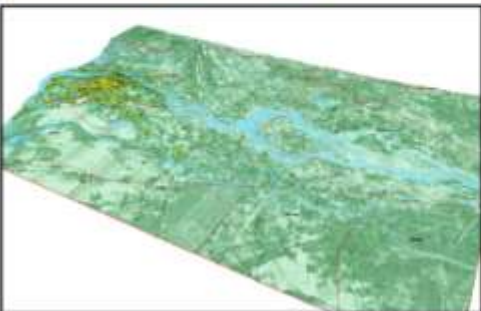
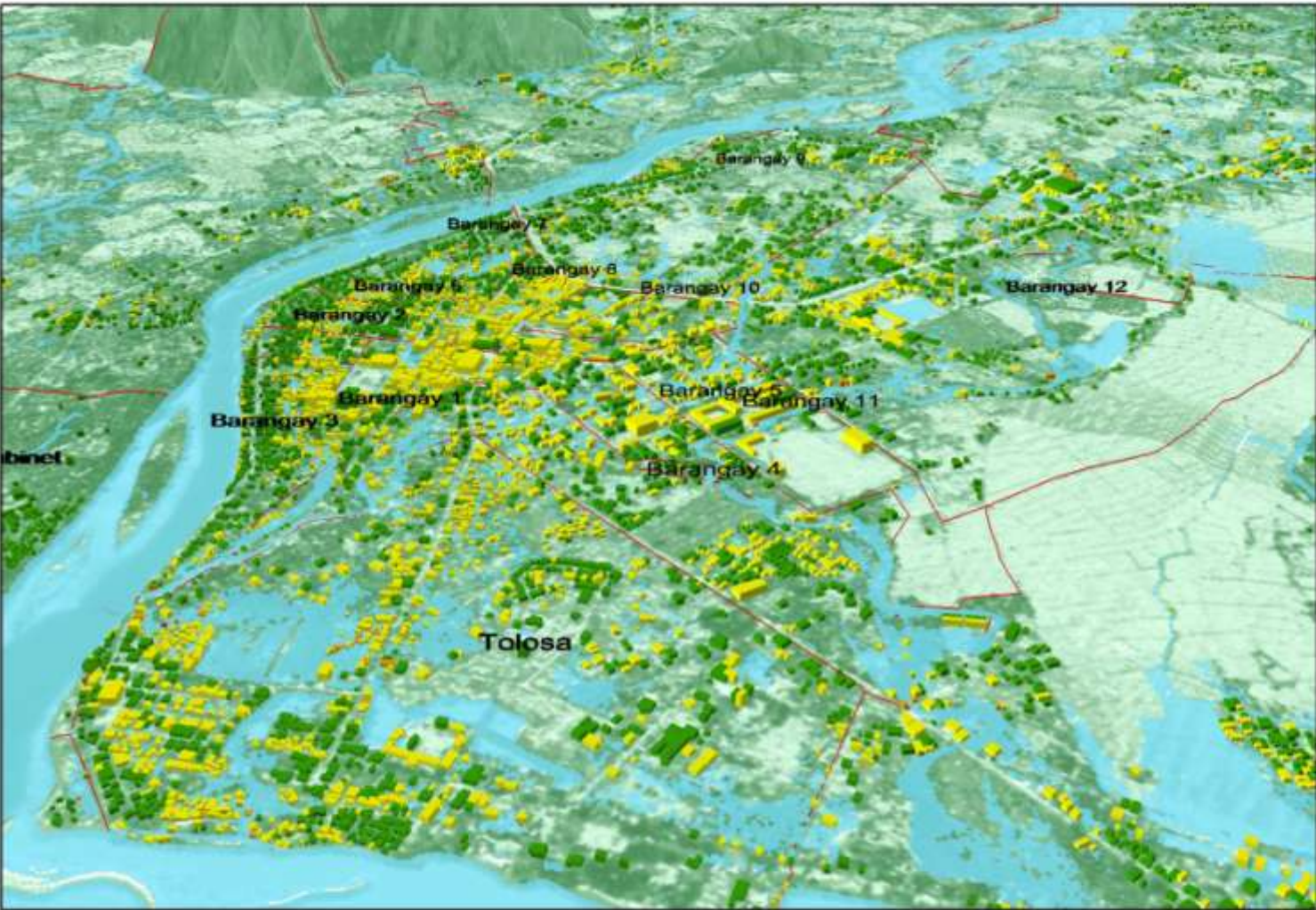
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Vulnerability**
-  Not Vulnerable
-  Low
-  Medium
-  High



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3D Buildings Vulnerability Map of 10-Year Rain Return in Cabadbaran City

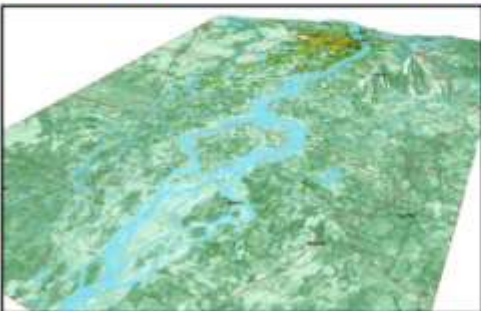
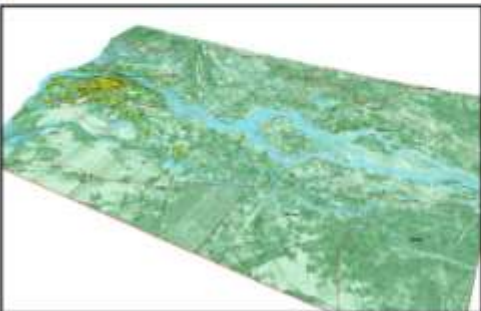
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Vulnerability**
-  Not Vulnerable
-  Low
-  Medium
-  High



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3D Buildings Vulnerability Map of 25-Year Rain Return in Cabadbaran City

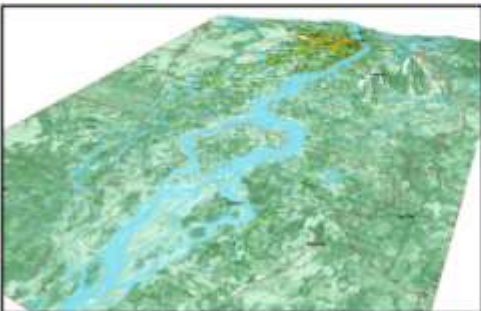
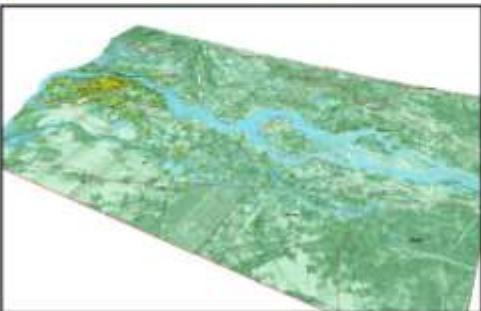
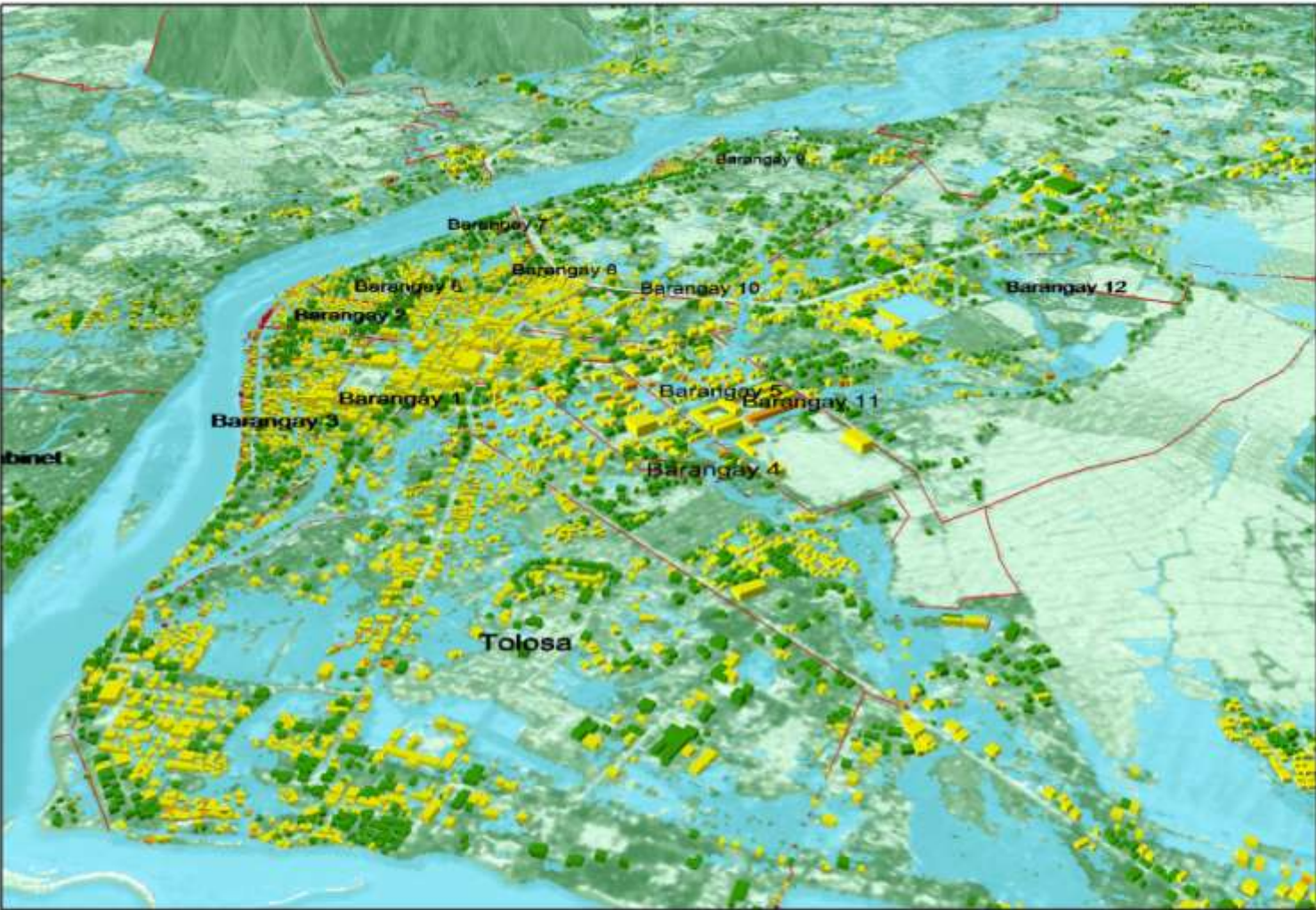
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Vulnerability**
-  Not Vulnerable
-  Low
-  Medium
-  High



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3D Buildings Vulnerability Map of 50-Year Rain Return in Cabadbaran City

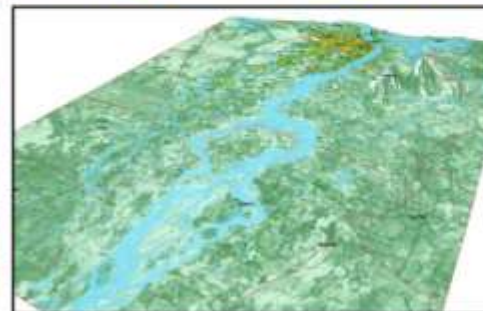
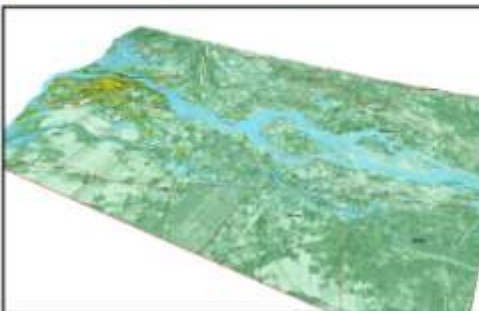
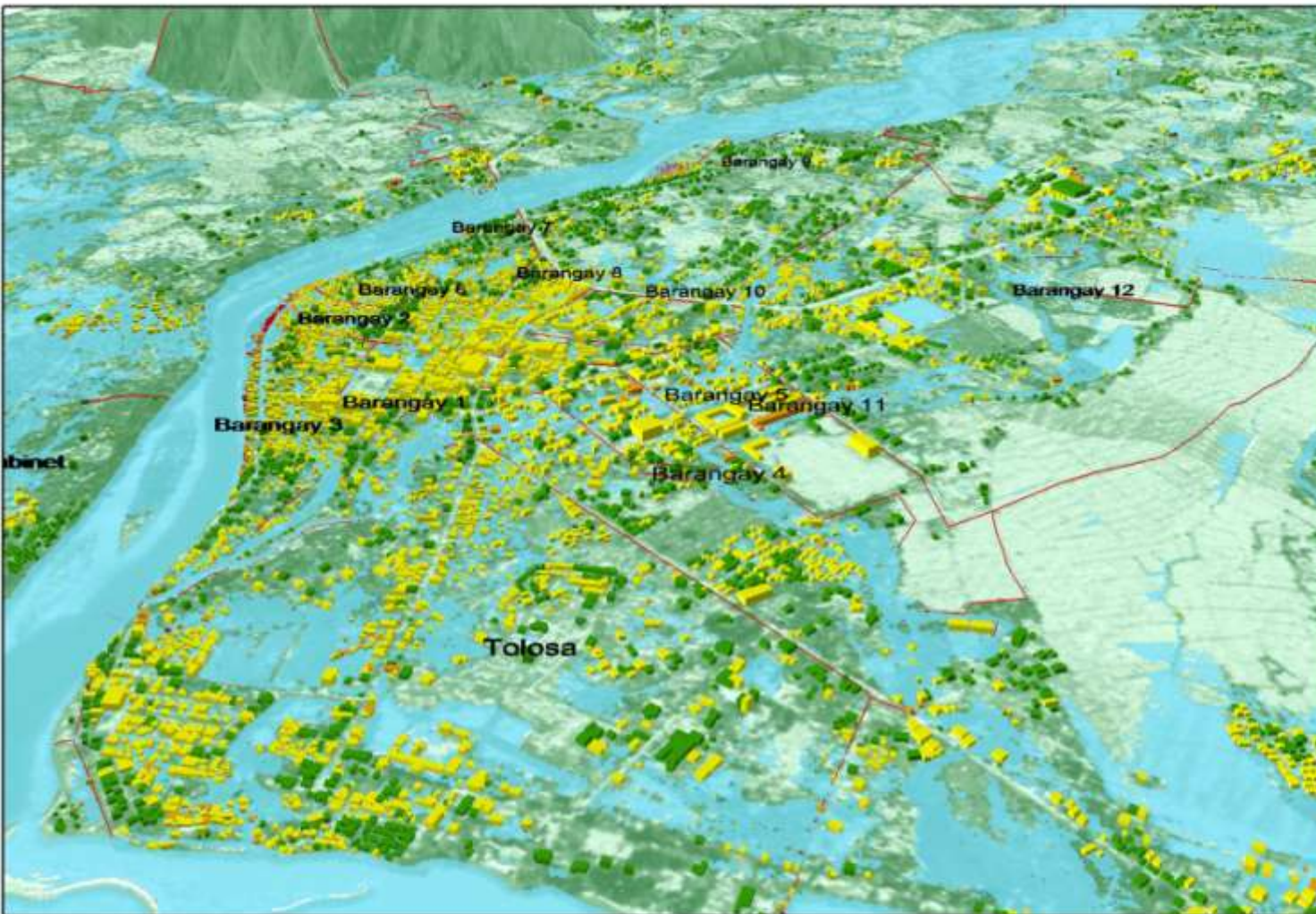
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Vulnerability**
-  Not Vulnerable
-  Low
-  Medium
-  High



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3D Buildings Vulnerability Map of 100-Year Rain Return in Cabadbaran City

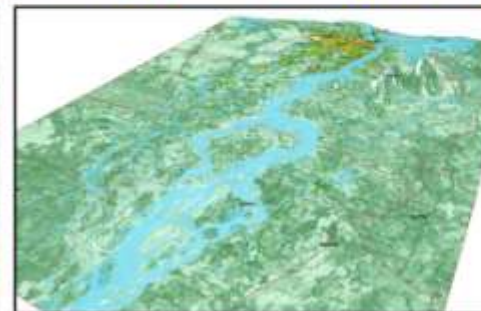
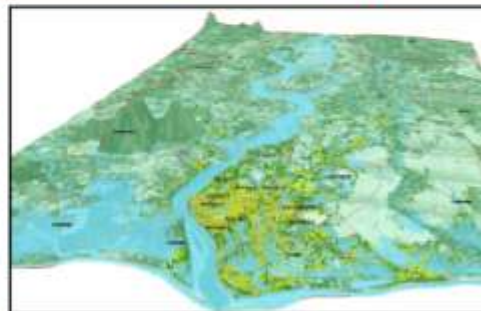
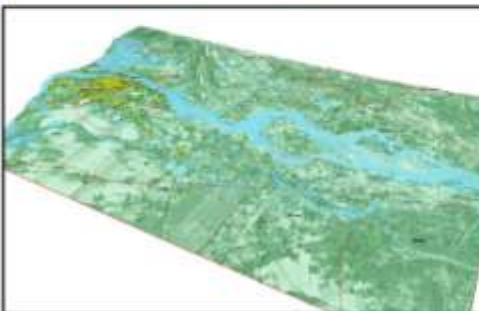
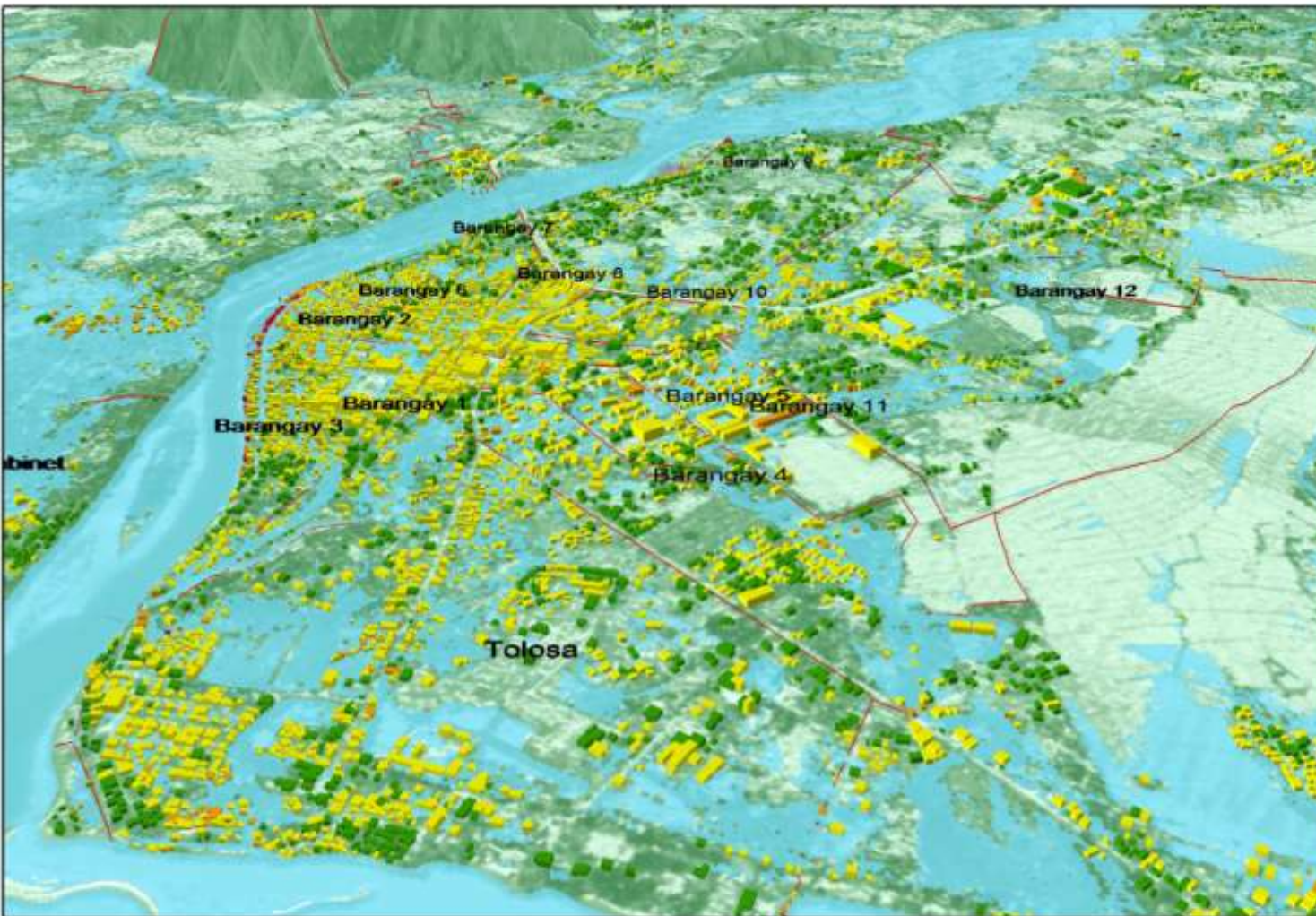
LEGEND

-  Flood Extent
-  Barangay Boundary
- Building Vulnerability**
-  Not Vulnerable
-  Low
-  Medium
-  High



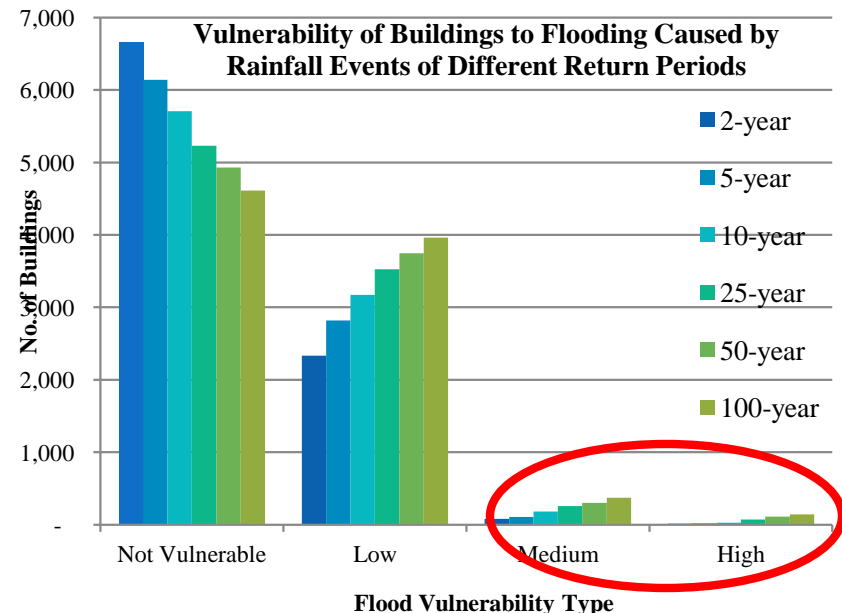
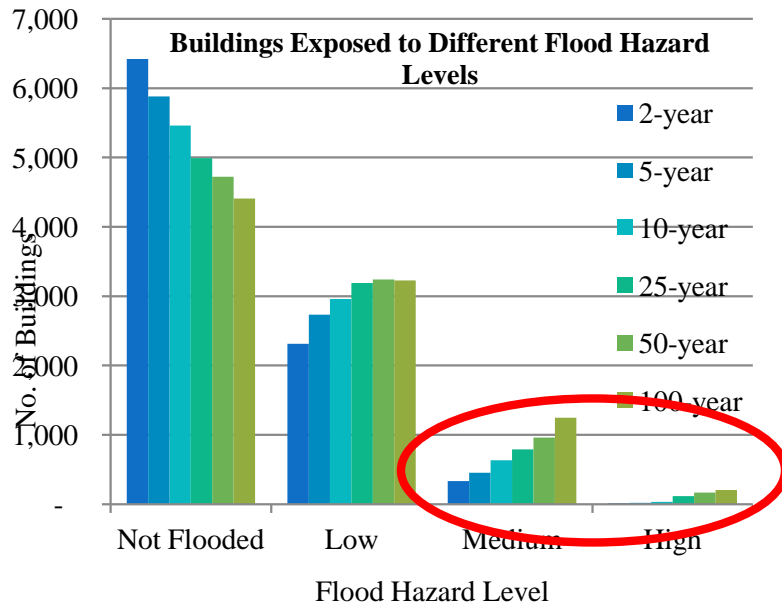
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EXPOSURE VS VULNERABILITY

- The generated statistics also show that buildings exposed to medium and high flood hazard levels does not necessarily mean they will also have medium and high vulnerability.
 - Looking at the graphs the total number of buildings under medium and high hazard exposure are higher than the total number of buildings in medium and high vulnerabilities.
- This implies that even if a building's location has medium or high flood hazard levels, a building's vulnerability can be lesser if its height is much higher than the depth of flooding.
- All of these results, however, only used height as basis for assessing a building's vulnerability. The type of building material and other factors were not considered.



CONCLUSIONS AND FUTURE WORKS

- ◉ In this paper we showed that a 3D building database extracted from LiDAR data (with each building attributed in terms of type and height) can be a valuable dataset in assessing the exposure and vulnerability of buildings to flooding.
- ◉ The results of this case study made for Cabadbaran River Basin highlights the use of this database to generate statistics as well as in creating maps that can show the spatial distribution of buildings exposed to low, medium and high hazard levels of flooding caused by rainfall events.
- ◉ The height information derived for each building also allowed fast generation of statistics and maps showing the building's vulnerability to flooding.
- ◉ The next phase of this study is to expand the analysis where the type and material of buildings will be considered in the exposure and vulnerability assessment.
- ◉ Also, we will improve and consider physical basis in computing a building's vulnerability level.
 - Currently, the vulnerability levels adopted in the analysis were only based on building height and flood depth, and the criteria used were only assumed due to absence of proper reference material during the conduct of this study.

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