ISSN 2005-8349 GRI연구논총 2020년 제22권 제4호

Assessment of Flooding Impact on Housing Value : A HAZUS-MH application*

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Extreme weather events have been increasing dramatically, destroying the security of places due to climate change. Natural disasters are difficult to prevent, given the limited abilities of human beings. However, people can prepare to mitigate various hazards through their efforts. The New York State (NYS) has been collecting historical weather data on several storms and their economic damage information. As a study area, the Village of Lancaster in NYS was chosen to evaluate the flood damages. This study deals with riverine flooding, focusing on the description how to apply HAZUS-MH (Hazards U.S.) for the flooding assessment, which is the software program released by FEMA in 1997. Therefore, this paper investigated and assessed how HAZUS could model an inundated area on the Village of Lancaster at level one using default data and generated the economic impacts estimated based on the price of each house combined with housing value available from the results of HAZUS analysis. Through the research process, this study is expected to deliver how local and central governments of Korea can prepare for the future economic losses to increase economic resilience, bring positive changes to the lives of the people in the community. Eventually, this study can provide a mechanism for safeguarding life and property from future flood hazards.

Key words _ Flooding, Economic Impact, GIS, HAZUS, Economic Resilience

* This research was supported by a grant(20TSRD-B151228-02) from Urban Declining Area Regenerative Capacity-Enhancing Technology Research Program funded by Ministry of Land, Infrastructure and Transport of Korean government.

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ISSN 2005-8349 GRI REVIEW Vol. 22, No. 4, November 2020

HAZUS를 활용한 홍수 피해의 주택가격 영향 분석*

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최근 기후 변화로 기상 이변이 증가하고 이에 따른 건축물 피해가 급속하게 증가하고 있다. 자연 재해는 인간 활동을 제한하고 억제하기 때문에, 이들 위험을 완화하고 적응하기 위한 정부의 대응과 준비가 절실하다. 뉴욕주는 여러 종류의 기후변화 관련 자연 재해 및 이로 인한 경제적 피해로 인해 과거 기상 및 관련 데이터를 수집하고 있다. 본 연구에서는 뉴욕주 랭커스터 마을의 홍수 위험 평가를 본 연구의 대상지로 선택하여 뉴욕주의 기후변화에 대한 사례 연구를 수행하였다. 이 연구는 강변 홍수를 다루며 FEMA에서 발표한 HAZUS-MH을 활용하여 홍수 피해 추정의 과정을 사례중심으로 설명하였다. 특히 HAZUS에서 제공하는 기본 자료를 사용하여 랭커스터 마을의 침수 지역을 모델링하고 HAZUS 분석 결과를 기반으로 주택 가치를 어떻게 평가하는 가에 대한 사례연구를 통해 한국에서 개발 중인 유사모형에 적용가능하여 추후 재난모형 개발에 상당한 시사점을 줄 것으로 기대한다. 일련의 적용 과정과 경제적 피해 추정과정의 활용을 통해, 한국에서 특히 심해지고 있는 집중호우와 이에 따른 홍수로 인한 미래의 위험으로부터 생명과 재산을 보호하기 위한 의사결정에 있어서 정책적 고려사항을 지원하여, 최종적으로 지역 사회가 필요로 하는 경제적 충격 완화에 기여할 수 있다.

주제어 _ 홍수, 경제파급효과, 지리정보시스템, HAZUS, 경제적 충격 완화

* 본 연구는 국토교통부/국토교통과학기술진흥원의 지원으로 수행되었음(과제번호 20TSRD-B151228-02)
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Ⅰ. Introduction

Natural disasters that include storms, hurricanes, and floods have doubled in frequency over the last three decades. The worst disaster in the United States was a convective storm, winter storm, in January 2016, but the eighth in the top 10 were storms and floods, as seen in Table 1 (EM-DAT, 2020). Although the National Flood Insurance Program (NFIP) focuses on the mitigation of flood damage from the early 1980s, the problem still needs to be managed (FEMA, 2006). To manage potential damages efficiently, weather history and historical flood damage data are crucial to modify the way of developing areas even though climate change impedes forecasting weather precisely (Pielke et al., 2002). As a precaution about the uncertainty of climate change, therefore, we need to prepare for unpredictable floods using historical weather records.

[Table 1] Top 10 Natural Disaster in the U.S. for the period 1900 to 2020

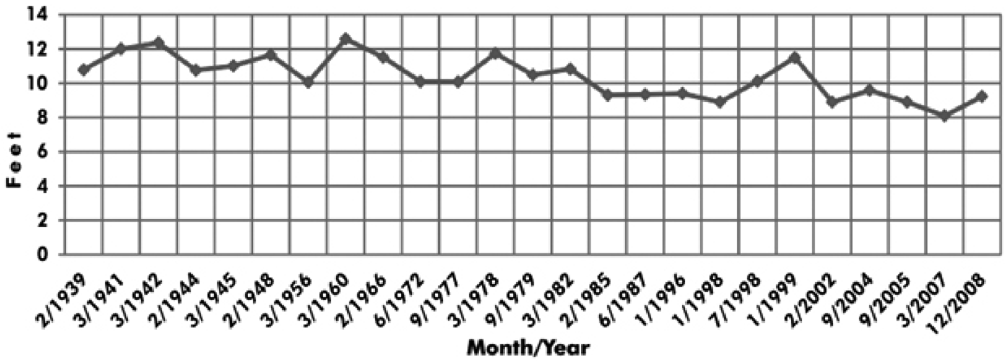
Disaster	Date	Numbers of total affected people
Storm	2016. 01. 23.–2016. 01. 26.	85,000,012
Flood	2008. 06. 09.–2008. 06. 30.	11,000,148
Storm	2004. 09. 05.–2004. 09. 05.	5,000,000
Storm	1999. 09. 13.–1999. 09. 17.	3,000,010
Storm	2008. 09. 01.–2008. 09. 01.	2,100,000
Storm	2018. 09. 12.–2018. 09. 18.	1,500,000
Storm	1985. 08. 30.–1985. 08. 30.	1,000,000
Wildfire	2007. 10. 21.–2007. 10. 24.	640,064
Storm	2017. 08. 25.–2017. 08. 29.	582,024
Storm	2005. 08. 29.–2005. 09. 19.	500,000

Source : EM-DAT(2020)

Increased land values and the need to accommodate population growth have required new land development near the significant floodplains. In 1979, the Federal Emergency Agency(FEMA) identified the areas of particular flood hazards for the Village of Lancaster to Flood Insurance Rate Map (FIRM). In addition, Cayuga Creek occasionally reaches the flood stage that represents the collected gauge data from 1939 to 2008 in the U.S. Geological

Survey (USGS) as seen in Figure 1 (USGS, 2010).

[Figure 1] Historical Crests for Cayuga Creek



Notes : For flood categories, refer to the followings.
1. Major Flood Stage is 12
2. Moderate Flood Stage is 10
3. Flood Stage is 8
4. Action Stage is 6
Source: USGS, 2010

In the importance of flood disasters, it is valuable to introduce newer assessment methodologies of flood losses. One of the major tools to measure the reduction of hazards exposed to residents is a risk assessment that allows conducting a productive risk assessment. When estimating the risk in the Village of Lancaster, this study applied HAZUS-MH(Hazards US-Multi Hazards) software for the estimation.

Ⅱ. Data and Scope

1. Flood Risks and Factors

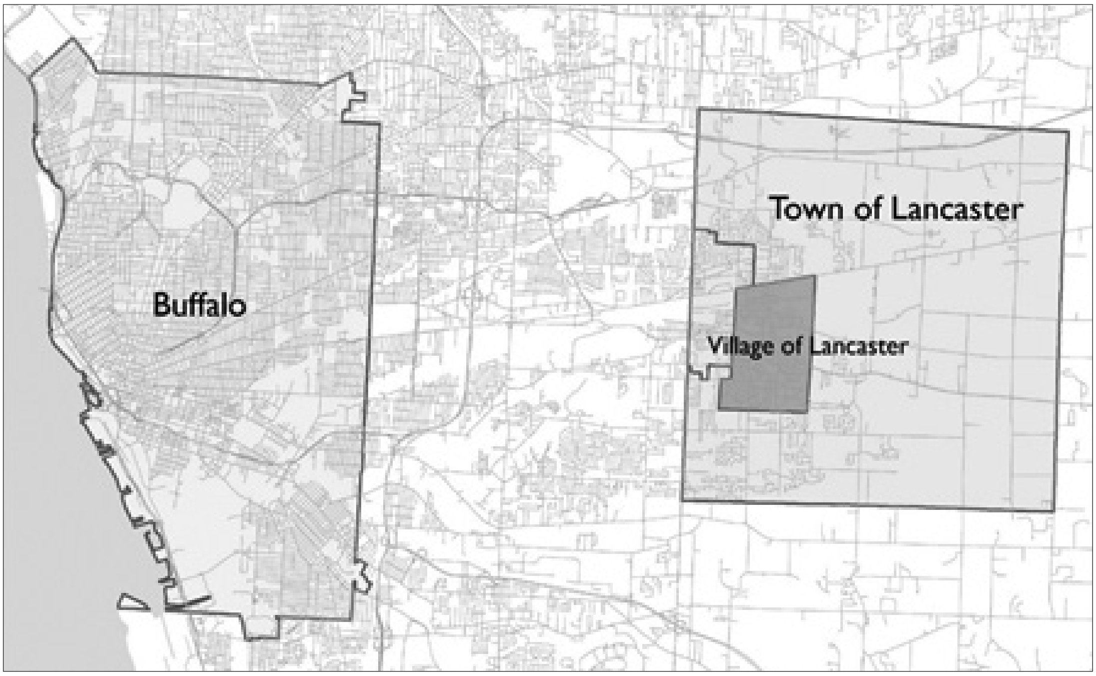
Climate is a distribution of weather events and entails the average range and variability of weather elements. Climate change involves the distribution of weather over a long period, and extreme weather events are extraordinary incidents linked to climate change (Milly et al., 2002).

As one of the extreme climatic events, flooding seamlessly threatens regions. NFIP has defined flooding as follows: "a general and temporary condition of partial or complete inundation of two or more acres of normally dry land area or of two or more properties (at least one of which is your property) from: overflow of inland or tidal waters, unusual and rapid accumulation or runoff of surface waters from any source, or a mudflow" (FEMA, 2010a). Also, according to the Federal Interagency Floodplain Management Task Force, flood types in the U.S. are categorized in the 'Hazard Identification and Risk Assessment' report of FEMA into six such as riverine flooding, local drainage or high groundwater levels, fluctuating lake levels, storm surges, debris flows, and subsidence (FEMA, 2007a). Especially, the factors of riverine flooding as a hydrologic hazard are overflow from river channels, flash floods, alluvial fan floods, ice-jam floods, and dam-break floods (FEMA, 2007a), which is the primary hazard in the area of this study. While the factors mainly depend on natural conditions, man-made artificial structures such as a levee, channel alteration, and impervious surfaces resulting from urbanization are also the factors affecting the riverine flooding.

2. Study Area: the Village of Lancaster

The study area, the Village of Lancaster, is located west of the Town of Lancaster and on the east side of the City of Buffalo in Erie County, Western New York State, as depicted in Figure 2. The area is about 7.1㎢ and consists of 179 census blocks. The center of the village developed in 1831, and in 1849 the Town of Lancaster became incorporated as the Village of Lancaster. Cayuga Creek and Plum Bottom Creek run through the village. Cayuga Creek, a major stream in the village, is a confluence as Buffalo Creek and Plum Bottom Creek join Cayuga creek. The diverging point of the Plum Bottom Creek is near the central business district of the village. (see Figures 3)

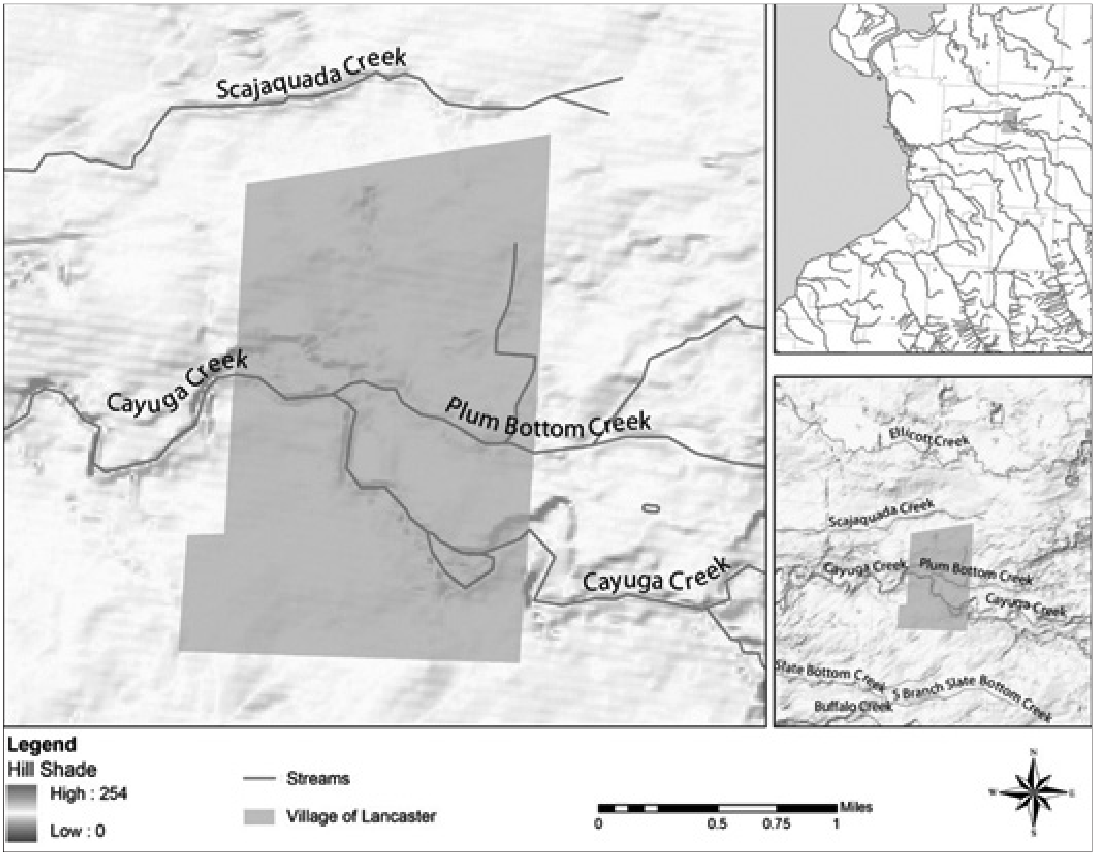
[Figure 2] Location of the Village of Lancaster



Source : Authors created by NYS GIS Clearing House

The entire population of the Village of Lancaster has steadily decreased by about 6.3% for the ten years between 1990 and 2000, estimating the population of 2009 as 11,065. Although the population is decreasing, total housing units and vacant houses have increased (see Table 2). This indicates that the possibility of physical damages exposed to a property is increasing. Therefore, it needs to examine the risk of a future disaster to protect the property from a disaster. In addition, as essential facilities, there are two fire stations, two police stations, two dams for provision against floods, and six schools. However, there is no emergency operation center (see Figure 4). The essential facilities are considered to provide community services when coping with an emergency (FEMA, 2007b). Essential facilities contain occupants who may not be sufficiently mobile to avoid death or injury and those who take part in flood response activities during a flood.

[Figure 3] Creeks on the Village of Lancaster



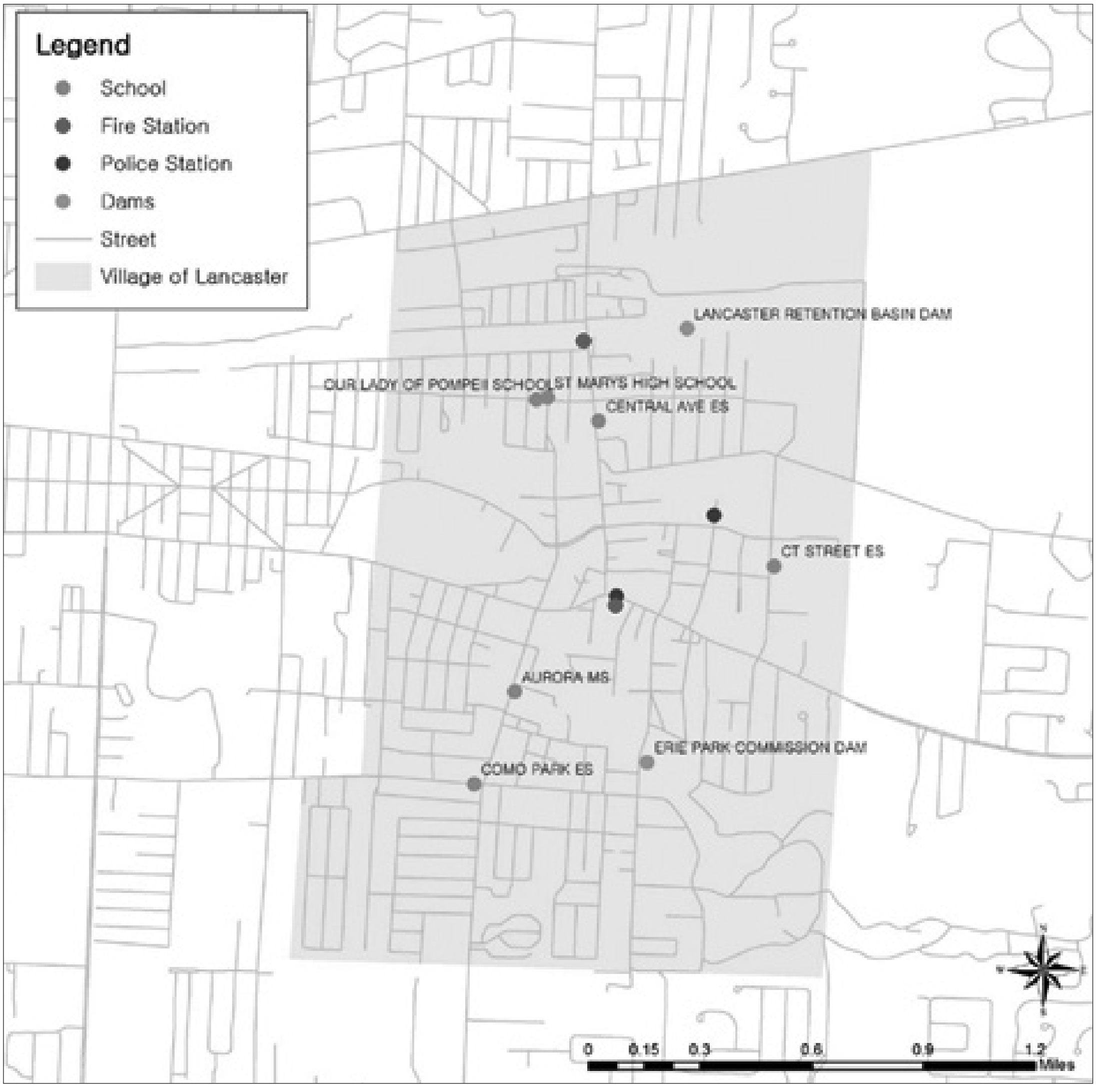
Source : Authors created by NYS GIS Clearing House

[Table 2] The number of population and housing units from 1990 to 2000

Year	Total population	Housing units	
		Total	Occupied
1990	11,940	4,885	4,760
2000	11,188	4,908	4,726

Source : U.S. Census Bureau

[Figure 4] Essential Facilities in the Village of Lancaster



Source : Authors created using HAZUS-MH software

3. Weather History of the Town of Lancaster and the Village of Lancaster

The Flood Insurance Study (FIS) for Erie County, New York, prepared by FEMA, provides various records as described in Table 3. Erie County has suffered severe storm impacts in the past, and most floods were generated by rapid melting snow and flash rainfall (FEMA, 2010b).

In the Town of Lancaster, the flood of March 1960 was estimated to have a recurrence interval of 20 years. The flood of August 1963, in addition, was estimated to have a recurrence interval of 40 years. Along Cayuga Creek, flooding occurs nearly annually, and significant storm events occurred in June 1937, and the flood was estimated to have a recurrence interval of 500 years (FEMA, 2009).

As an authorized project by the Flood Control Act in the village, in 1941, the project was started to clear and improve the Cayuga Creek channel. Earth dikes and floodwalls were constructed. Existing drainage facilities, besides, were improved for continuous running (NYS DEC, 2010).

[Table 3] Historical Storm Records

Year	Town of Lancaster	Scajaquada Creek	Cayuga Creek	Plum Bottom Creek	Slate Bottom Creek
1916	○				
1929	○				
1936	○				
1937	○		○	○	○
1940	○	○			
1942		○	○	○	○
1954	○	○	○	○	○
1955	○		○	○	○
1956			○	○	○
1959	○		○	○	○
1960	○	○	○	○	○
1963	○	○	○	○	○
1967		○			
1972			○	○	○
1975		○	○	○	○
1977		○			
1979			○		

Source : FIS in the Erie County, FEMA

4. 100-Year Floodplain in the Village of Lancaster

The 100-year floodplain is the 1% chance per year flood area mapped by FEMA. Therefore, "100-year floods" means that a flood may occur more frequently than once every 100 years.

The 100-year floodplain is the area regulated by local floodplain ordinances adopted by communities located in the NFIP (Holmes & Dinicola, 2010).

Technically, only the outer edge of the 100-year floodplain has a 1% risk of flooding. The risk rises for sites closer to the flooding source and at lower elevations. There are areas within the mapped 100-year floodplain that may flood more frequently and to greater depths than others, even though people think of the entire 100-year floodplain as having the same risk. In FIRM, the Village of Lancaster can be recognized as the one with the 100-year floodplain (Zone AE) about 0.56㎢, and the updated FIRM is available at the Erie County On-Line Mapping System website as illustrated in Figure 5.

[Figure 5] Captured FIRM of the Village of Lancaster

Source : Erie County On-Line Mapping System

Ⅲ. Analysis

In order to provide a systematic assessment of the impact on housing stock damage and loss, we used HAZUS–MH software developed by FEMA, which uses GIS software. HAZUS–MH contains substantial geo–referenced data, allowing anyone to obtain it free. This might help increase the accessibility to community directors or the public.

1. Flood Model in HAZUS–MH

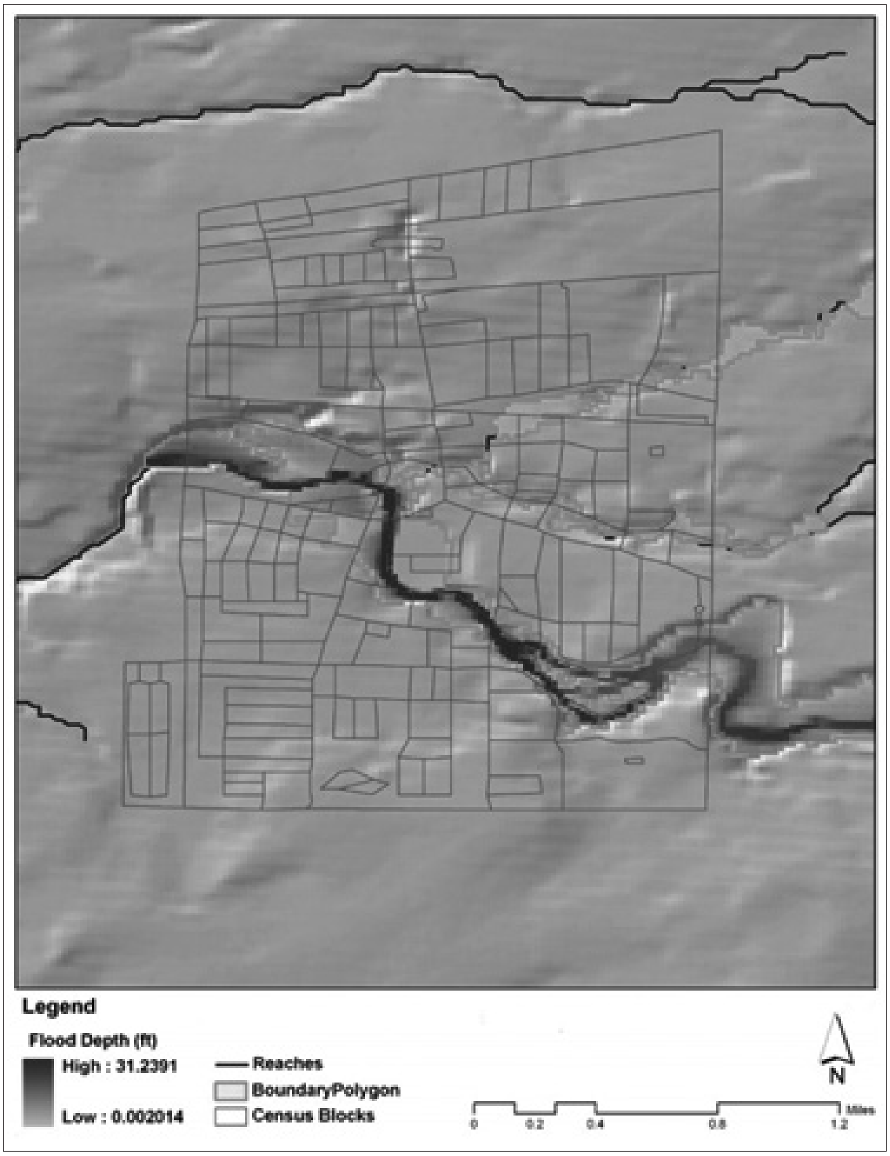
To perform the flood risk analysis using HAZUS–MH, datasets needed are provided by FEMA on the HAZUS distribution data disks and by the USGS. Specifically, Level 1 flood analysis requires block–level census data containing building stock, employment profiles, population counts, stream gauge locations and flow volumes, and lifeline locations; all provided on the data disks that accompany the HAZUS–MH software. In HAZUS, aggregated data is combined with inventory data, which are grouped by census block for the Flood model. In other words, the location of the inventory data is aggregated to the defined area. Further, we obtained the resolution of 1 arc–second (30–meter) Digital Elevation Model (DEM) from USGS. The DEM is a seamless raster dataset that has a continuous elevation layer. As a next step analysis with ArcGIS, from the NYS GIS Clearinghouse website, we could obtain shapefiles about streets, census boundary, address points, and orthoimage files.

2. Process

DEM layer and generated the stream network. Streamlines were, finally, computed on the village. Based on the scenario, which was selected for all streamlines following "100–year return period," a floodplain with flood depths was created (See Figure 6).

The floodplain was mostly found along Cayuga Creek, which is a representatively challenging area in mitigating damages. The flood depths as a raster format were converted to flood damage depths based on foundation type and first–floor height percentages for each specific occupancy type. Estimation of direct damage to the general building stock, which is expressed as percent damage to structures and their contents, is accomplished through the use of readily-available depth-damage curves, compiled from various sources including the Federal Insurance and Mitigation Administration (FIMA) "credibility weighted" depth-damage curves.

[Figure 6] Flood Depths



Source : Authors created using HAZUS-MH software

For each grid cell and associated flood depth as raster format, the HAZUS–MH software is identified as the percent damage per occupancy. Multiplying the percent damage and the percent of the census block with the estimated inventory gives an estimate of the damage at that flood depth. Summing over the flood depths within the block by occupancy creates the estimate of damages. The estimate is possibly calculated because damages at a given depth will vary by occupancy and the aforementioned parameters. Therefore, overall damage for the census block must be summed by both depth and occupancy. In the report, 'Building Damage Count by General Occupancy', consequently, percentage damage was categorized (FEMA, 2007b).

Building damage cost models within HAZUS is conducted by industry–standard cost–estimation models that were released in Means Square Foot Costs by R.S. Means Company. Also, replacement cost data are stored within HAZUS at the census block level for each occupancy class. For each HAZUS occupancy class, a basic default structure full replacement cost model (as cost per square foot) has been determined, provided in Tables 4 and 5 (FEMA, 2007b).

[Table 4] Default Full Replacement Cost Models

HAZUS Occupancy Class Description		Sub category	Means Model Description (Means Model Number)	Means Type Size	Means Cost/SF (2006)
OCC Code	OCC Description	OCC subclass			
RES1	Single Family Dwelling	Table 5	Table 5	Table 5	Table 5
RES2	Manufactured Housing	Manufactured Housing	Manufactured Housing Institute, 2004 average sales price and size data for new manufactured home (latest data available)	1,625	35.75
RES3A	Multi Family Dwell–ing–small	Duplex	SFR Avg 2 St., MF adj, 3000 SF	3,000	79.48
RES3B		Triplex/Quads	SFR Avg 2 St., MF adj, 3000 SF	3,000	86.6
RES3C	Multi Family Dwelling–me–dium	5–9 units	Apt, 1–3 st, 8,000 SF (M.010)	8,000	154.31
RES3D		10–19 units	Apt., 1–3 st., 12,000 SF (M.010)	12,000	137.67
RES3E	Multi Family Dwelling–large	20–49 units	Apt., 4–7 st., 40,000 SF (M.020)	40,000	135.39
RES3F		50+ units	Apt., 4–7 st., 60,000 SF (M.020)	60,000	131.93
RES4	Temp. Lodging	Hotel, medium	Hotel, 4–7 st., 135,000 SF (M.350)	135,000	132.52
RES5	Institutional Dormitory	Dorm, medium	College Dorm, 2–3 st, 25,000 SF (M.130)	25,000	150.96
RES6	Nursing Home	Nursing home	Nursing Home, 2 st., 25,000 SF (M.450)	25,000	126.95

Source : HAZUS Manual, FEMA

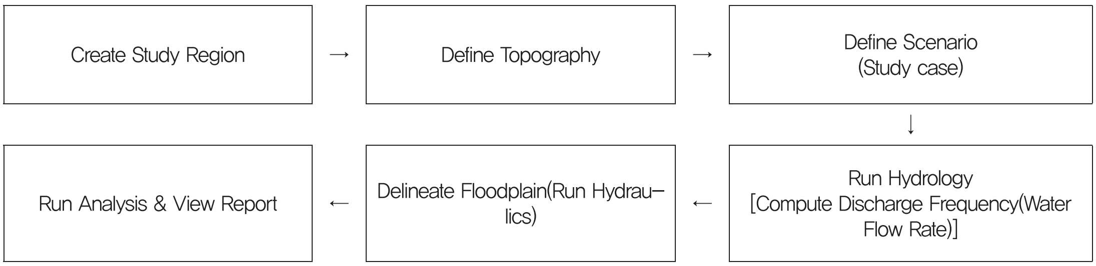
[Table 5] Replacement Costs (and Basement Adjustment) for RES1 Structures by Means Constructions Class

	Height Class	Average Base cost per square foot	Adjustment for Finished Basement (cost per SF of main str.)	Adjustment for Unfinished Basement (cost per SF of main str.)
Economy	1 story	65.91	19.3	7.1
	2 story	70.13	11.1	4.65
	3 story	N/A–use 2 st	N/A–use 2 st	N/A–use 2 st
	Split level	64.46	13.9	5.5
Average	1 story	92.84	24.05	8.45
	2 story	90.15	15.55	5.45
	3 story	94.49	12.35	4.25
	Split level	84.96	18.45	6.5
Custom	1 story	114.91	39.55	5.45
	2 story	112.91	22.9	9.2
	3 story	116.99	16.8	6.85
	Split level	105.25	28.55	11.35
Luxury	1 story	139.76	43.75	16.75
	2 story	133.09	25.75	10.1
	3 story	137.08	19	7.6
	Split level	124.81	31.9	12.45

Source : HAZUS Manual, FEMA

Through the process described in Figure 7, comprehensive analysis reports could be generated where the number of damaged buildings could be obtained. Especially, the reports contain data with high numbers on the residential type that has a range of damage percentage. It should be noted that HAZUS reports do not contain location information at the parcel level but the census block level.

[Figure 7] Steps of HAZUS Process



Source : HAZUS Manual, FEMA

Accordingly, we analyzed housing impacts for each house cost within the inundated area, allowing HAZUS to create the damaged percentage. Records of two reports were used to calculate the impacts: 1) Building Damage Count by General Occupancy and 2) Direct Economic Losses for Buildings. The ratio of distributed numbers of residential buildings to the total cost of building damage yielded $16,824,000. This is the number for the 'direct economic losses for buildings' in the report. The ratio multiplied the median value of each range of damage percentage (see Table 6).

[Table 6] Weighted Damage Value from the HAZUS results

	Range of Damage					
	5%	15%	25%	35%	45%	75%
Weighted Damage	0	289,593.4	206,852.5	1,641,030	1,985,784	3,723,344

Source : HAZUS Manual, FEMA

To earn the valid loss value, we divided the flood damage depth layer into 6 categories, depending on the cell value of depth used to recalculate the damage percentage. Flood losses depend on depth-related percent damage. Based on the categorized layer, we manually selected the address points by each area defined 15%, 25%, 35%, 45%, and 75% ranges. By investigating 186 house values from Zillow real estate website, we created the data and added up all house prices, grouping the data. The price of housing can be re-graded as a minimum value in the trend of depressed home prices. The number was divided by individual housing value, where the ratio value was multiplied to the weighed damage value.

For instance, the total hosing value in the 15% flood damaged area is $1,961,480, while a certain home value is only $84,500. The ratio of housing value between $84,500 and $1,961,480 is 0.043. As the final step, the ratio value of 0.043 was multiplied by 289,593.4, that is, the 15% weighted damage value. The yielded value of $8,858.78 represents the certain housing impact value from a flood.

Ⅳ. Result

The result data, consequently, collected to one excel table, exported to '.dbfIV' file format to join at ArcGIS. The point layer was classified by 5-quantile, and the grouped housing value was mapped (see Table 5).

Each point symbol representing the impact cost was visualized to a map on remotely sensed images (see Figure 8). Houses of highly ranked loss values are located in the Cayuga Creek and the west side of the village near the border. The calculated data shows a large amount of impacts for 186 houses and damaged loss.

[Figure 8] The Map of Housing Value Impact

Source: Authors created using HAZUS-MH software

[Table 7] The number of Houses and the range of Housing impact Value

Range of Housing Impact ($)	The number of houses
4,140.07 ~ 13,582.91	45
13,582.91 ~ 24,633.04	29
24,633.04 ~ 41,758.87	37
41,758.87 ~ 72,635.54	37
72,635.54 ~ 115,135.06	38

Ⅴ. Conclusion and limitation

From this analysis, some recommendations were made to recover the losses and develop resilient strategies. When residential structures are destroyed in a dense region, people's lives are threatened, where survivors keep suffering from recovering the cost for their residential properties and sustaining inconveniences as their way of living has been interrupted.

Still, many houses are located in floodplains, which are vulnerable to flood risk. Floodplain mapping for land use regulations could help prevent potential flood damages. To reduce flood damages, resilient plans and strategies should be included for floodplain management that relies on land–use decisions when managing activities needed to accommodate floodwater without disrupting safety and property.

As a convenient planning tool supporting disaster damages, HAZUS–MH is widely recommended because it provides a methodological convenience and superiority by containing all the historical data needed to assess flood damages and provides a guideline for whether or not a new flood planning technology can be beneficial. Further, it can contribute to policy– and decision–making process for the public.

During the research of this process, however, there were some limitations that could not be met for a better investigation of this study. To use the flood model in HAZUS, we could not reach the advanced level, i.e., the Level 2 analysis, because of the unavailability of data for the level, which requires the flood elevation information. In the current Q3 flood data, no information for Digital Flood Insurance Rate Maps (DFIRMs) for the Erie County was available when processing the status. We could find only five areas for the availability of the information: the Village of Angola, the Village of E. Aurora, the Town of Evans, the Town of Hamburg, and the Town of Sardinia. When DFIRMs of the Village of Lancaster are available, we will expand our study to be more detailed, estimating more accurate results with the updated data. This is expected to be conducted in the future.

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원 고 접 수 일 | 2020년 10월 10일
심 사 완 료 일 | 2020년 11월 6일
최종원고채택일 | 2020년 11월 9일

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2007년 한양대학교 도시공학과에서 학사학위를 받았으며, 2011년 University at Buffalo에서 도시계획 석사학위를 받았다. 현재는 프리랜서 연구원으로 있으며, 주요 관심분야는 도시재난 및 재생, 정보분석 등이다.

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박지영 교수는 뉴욕주립 버팔로대학교의 도시 및 지역계획학과 종신부교수 및 서울대학교 지역정보전공 겸임부교수로서, Asian Journal of Innovation and Policy의 편집위원장을 맡고 있다. 주요연구관심분야는 미래경제구조변화 추정과 이에 따른 토지이용모형 및 교통모형의 구축에 있으며, 이러한 정량적 시뮬레이션 모형을 활용하여 기후변화에서부터 4차산업혁명에 이르는 다양한 사회적 이슈들을 정량적으로 평가 측정하는 데에 있다.

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2012년 연세대학교에서 도시공학 박사학위를 받았다. 미국 University at Buffalo, the State University of New York에서 Research Scientist와, 서울대학교 농경제사회학부 지역정보전공 BK조교수를 역임 하였으며, 현재는 한국건설기술연구원 남북한인프라특별위원회 특화기술연구팀에서 수석연구원으로 재직 중이다. 주요 관심 연구 분야는 지속가능한 국토/지역 계획, 가치평가, 환경 및 재난 영향 평가 등이다.