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The Extent and Nature of Potential Flood Damage to Commercial Property Structures in the Midwestern United States

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Abstract: Prior research on the extent of potential flood damage in the U.S. has focused on single-family residential structures, whereas this study evaluates the extent and nature of potential flood damage to commercial structures in two locations. Commercial buildings represent 13% of all structures in the 100-year floodplain in Sarpy County (Omaha, NE) and 16% in Fargo/Moorhead (ND and MN), yet account for half of total potential flood damage exposure as represented by depreciated structural replacement values (DSRVs). The most frequent commercial structures are special use, warehouse, and industrial properties, which are all well suited to DSRVs estimation. Commercial building characteristics are highly heterogeneous, making the extrapolation of their potential flood damage based on sample observations problematic. Commercial floodplain structures are older and/or less maintained and less valuable than non-floodplain structures, which, combined with the fact that higher valued multiple family, retail, and office structures were relatively rare in the 100-year floodplain, indicates that commercial property owners in general exhibit rational flood risk avoidance.

Keywords: *flooding, flood damage exposure, building replacement cost, commercial properties*

Research on the extent and nature of buildings susceptible to flood damage in the United States has focused almost exclusively on single-family residential (SFR) properties. However, reliable data on the potential damage to building structures (i.e., building damage exposure) is frequently for all (residential and commercial) properties required for a variety of flood mitigation planning activities including Flood Damage Analyses (FDA) by the U.S. Army Corps of Engineers (USACE 2012) and multi-hazard analyses through the HAZUS-MH program created by FEMA (Scawthorn et al. 2006). However, these prior studies have focused mostly on indirect intangible flood damage, and a thorough review of both the published and 'grey' (unpublished) literature indicates a stark absence of analyses regarding the flood risk exposure to commercial (retail, industrial, office, multiple-family residential, and special use) buildings.

This paper addresses this information shortfall by quantifying the extent and nature of potential flood damage, defined as monetary damage exposure of single-family residential and commercial buildings in two Midwestern U.S. locations. The first location: Sarpy County (Omaha, NE), is a suburban area with recent development growth that has not yet experienced significant flooding. The second study site location: Fargo/Moorhead (ND/MN) incorporates two adjacent cities on the Red River of the North with older development patterns (as compared to Sarpy County) and which have experienced significant flooding, both historically and in recent years. In each location, building values exposed to flooding are represented by the cost of replacing (i.e., rebuilding) existing structures while taking into consideration current building conditions which are formally defined as depreciated structural replacement values (DSRVs). Damage exposure values are calculated for all structures within the regulatory 100-year floodplain (areas mapped by FEMA that have an estimated probability of flooding once every 100 years or 1% in any single year and where building development is highly regulated and/or where flood insurance is required).

It is hypothesized that commercial building damage exposure is a major component of total flood damage potential across typical (mid-sized) U.S. cities based on the frequency, extensive sizes, and relatively higher construction costs of commercial structures, as well as reported average national flood insurance payout values for residential and commercial properties (Floodsmart 2016). If confirmed, increased research into the nature and extent of commercial floodplain damage is warranted in order to facilitate the numerous flood mitigation efforts across the country. It is also hypothesized that, due to the highly heterogeneous nature of commercial structures, it is not possible to extrapolate potential flood damage based on a sample of commercial structures to the entire population, as is often possible with more homogenous SFR structures. Finally, it is suspected that commercial structures located in the 100-year floodplain are older, not as well maintained, and less valuable than otherwise similar non-floodplain commercial structures. If confirmed, this may indicate that commercial floodplain property owners are cognizant of floodplain risk in that they invest less in the construction and/or maintenance of buildings with relatively higher flood risks, and this may also imply that the use of non-floodplain structural inventory data may not be appropriate for quantifying the value of commercial structures within floodplains.

Literature Review: The Extent and Nature of U.S. Flood Damage

Quantifying Flood Damage

Potential flood damage, whether potential or actual, can be classified as either direct tangible damage (or building damage exposure, the focus of this research), direct intangible damage, indirect tangible damage, or indirect intangible damage (Merz et al. 2010). The dominant research on flood damage issues in the U.S. has historically focused on indirect intangible damages, by measuring the impact of flood risk on resale values, understanding property owners perceptions and decisions regarding flood insurance, and evaluating the efficiency and resiliency of the national flood insurance program.

Related to the focus of this research (direct tangible damage to buildings), both actual and potential flood building exposure damage estimates are compiled nationally by the National Weather Service (NWS), but these estimates have been determined to be inconsistent, inaccurate, and lacking in specificity with regards to types of flood damage in specific areas (Pielke et al. 2002; Cartwright 2005). Improved estimates of flood damage have relied on claims data from the Federal Emergency Management Agency Flood Insurance Program (FEMA/NFIP) (Kunreuther and Michel-Kerjan 2013; Kousky and Michel-Kerjan 2015). However, the majority of NFIP claims are focused on SFR structures and small business structures and generally exclude larger commercial structures that are only required to have flood insurance when financed using federally subsidized mortgages, which is relatively rare. Another reason why many commercial structures are not likely to participate in the NFIP is that coverages are limited to $500,000 for structures and $500,000 for contents. Detailed information on NFIP commercial claim payouts could not be found (via internet searches) but FEMA (2015) publicly reports that from 2010 to 2013 the average commercial flood claim amounted to nearly $89,000, substantially higher than the average SFR claim of $39,000 (Floodsmart 2016). Flood damage estimates can potentially be obtained from empirical data of past (historical) flood events and from private insurance loss data. In the few known (published) cases when this has been undertaken, estimates have either focused only on residential losses (CNT 2014) or total losses not aggregated by property types (Mohlejo and Pielke 2014).

The U.S. Army Corps of Engineers (USACE) estimates potential flood damage to all types of structures when conducting feasibility studies of flood mitigation projects (USACE 2012). These studies require structural building inventories where DSRVs (defined as new replacement cost minus depreciation) are calculated for all structures within a study area. Depreciation is applied to replacement costs to account for the fact that buildings wear over time and need repair and/or refurbishments. Not accounting for depreciation would over-estimate actual sustained damage due to flooding. These structural damage data are incorporated into the USACE FDA program to estimate the likely flood damage to each structure under a full range of possible flood events (USACE 2011). The USACE structural inventories are often conducted by contractors and based on cost replacement data supplied by national vendors (typically Marshall and Swift or RS Means) in conjunction with site visits and ancillary data from county tax assessors. The resulting DSRVs are very likely the most accurate available estimates of potential flood damage, but these data usually are only collected for a limited number of USACE project site locations nationally. The nature and extent of the potential flood damage summarized by property sub-types is rarely described in detail within USACE project reports. Finally, raw (non-summarized) DSRV data are often difficult to locate and obtain from USACE contractors, particularly when feasibility studies were completed many years prior. However, such detailed DSRV data were obtained from the USACE for this research.

A second potential source of flood damage data decomposed by structure types is the general building stock (GBS) of the FEMA Multi-hazard Loss Estimation Program (HAZUS), first developed in the 1990's in conjunction with the National Institute of Building Sciences (Scawthorn et al. 2006; Schneider and Schauer 2006; HAZUS 2009). The HAZUS GBS is closely tied to decennial census data and was first released in 2004 using year 2000 census data and recently re-released in the fall of 2015 based on 2010 census data. A particular concern with GBS methodologies used to calculate DSRVs is that building type data (styles, stories, existence of basements and garages) are both dated and based on regional and hence, greatly generalized data. Of even greater concern is that in 2000 the contractor Dunn and Bradstreet generated commercial GBS data using non-specified and unknown (i.e., proprietary) methodologies and data sources. The company did not update this commercial structural data for 2010 but rather FEMA used an unknown (not explained or publicly documented) approach to extrapolate commercial structural building data from 2000 to 2010. A few past studies have analyzed actual structural building data for comparisons with HAZUS GBS but they all focused only on SFR damage. The HAZUS-MH program provides a suite of flood depth damage curves for different building types, which, when combined with flood probability, modelling, and building replacement costs, can be used to generate estimates of potential flood damage exposure to buildings.

A third potential source of DSRV data for commercial floodplain structures is county tax assessors, who frequently rely on the cost replacement approach to value special use, industrial, and warehouse properties (Dornfest et al. 2010). In rare cases, assessors utilize the cost approach for all property types. Such a comprehensive dataset of DSRVs from the Sarpy County Assessor, NE is used in this study.

The Lack of Prior Research on the Extent of Commercial Flood Damage Exposure

There is an extensive quantity of published research dealing with flood risk management policy issues in the U.S. but these have focused on residential structures and can be generalized within three categories: 1) Quantifying the impact of flood risk on sale prices, 2) Evaluating the demand for flood insurance; and 3) Strategies to improve the efficiency and effectiveness of the NFIP. Almost none of this research has focused on commercial properties, likely because most have relied on real estate transaction databases and/or flood insurance premium and payout data that are almost exclusively associated with single-family residential properties. Considering the potentially large impact of commercial flood risk on total flood damage nationally, research specific to commercial structures is warranted. The scarcity of published information on commercial flood damage in the U.S. might be because site-specific flood damage inventories conducted by FEMA, USACE, local floodplain managers, and others are contained in unpublished project reports. The lack of other researchers' citations of such studies or reports suggest that they may not be very common, justifying the focus of this study: to quantify the nature and extent of potential commercial flood damage in two Midwestern study locations.

Methods and Data Collection

The extent of potential commercial flood damage in Sarpy County (Omaha, NE) and Fargo/Moorhead (ND/MN) was quantified by classifying the structure types and related DSRVs both within and outside the regulatory FEMA 100-year floodplain. DSRVs for structures were obtained from two alternative data sources: The Sarpy County Assessor, and the USACE Fargo/Moorhead Structural Inventory (part of the Flood Diversion Feasibility Study). Each of the data sources estimate DSRVs of structures using Marshall and Swift (M&S) cost estimation software. Both potential flood damage areas were classified by property sub-types and floodplain status based on GIS analyses to identify whether structures and related DSRV were within the 100-year floodplain. It is important to note that this potential flood damage does not attempt to account for the relative elevation of individual structures, possible existence of flood proofing measures, interior content damage, or losses associated with clean-up costs, disrupted living conditions, and lost business opportunities. Instead, this DSRV based data should be considered to represent a generalized indicator of potential flood damage.

For the Sarpy County (Omaha, NE) analyses, DSRVs were obtained from the County Tax Assessors parcel level database that contains 47,157 SFR structures within 47,000 parcels, and 4,742 commercial structures within 1,783 parcels. Most of the real estate development in the County has occurred in the last 15 years due to accelerated suburban growth trends. FEMA d-firm regulatory floodplain polygons exist for the county and they are mostly associated with the potential flooding of the Papillion Creek system. No recent major flooding events in the county have occurred, but flood risk is increasing as the City of Omaha to the north continues to urbanize, increasing urban run-off into the Papillion drainage system. For that reason, a series of upstream reservoirs are being built by local agencies to control future flooding.

The quality or reliability of this DSRV data is considered high because the Sarpy County Assessor relies heavily on the cost replacement approach to assess all classes of properties, in contrast to many other assessors around the country who rely on the cost approach only for newer SFR, industrial, and special use properties. The assessor uses M&S cost estimation software (Marshall and Swift 2017) in conjunction with detailed structural characteristics and condition data collected by the assessor's office through both building permit reviews and site visits. Depreciation rates are calculated using a market extraction approach where sale prices of properties with varying conditions and improvements are compared. The county assessment data were supplemented by GIS-based spatial overlays (intersects) of building footprint polygons and 100-year FEMA d-firm floodplain boundary polygons. When more than 15% of a structure footprint was located in the 100-year floodplain the entire structure was classified as being in the floodplain.

Corresponding DSRVs for commercial properties were obtained for Fargo/Moorhead (ND/MN) from a USACE contractor (URS 2009) who collected the data as part of the 2011 USACE (St. Paul District) feasibility study to evaluate a diversion-based flood mitigation project (the Fargo/Moorhead Diversion). Although the population of this metro-area is less than 220,000, it has a very large 100-year floodplain and has experienced both historical and recent significant flooding and damage, although a catastrophic (i.e., 500-year) flood event has not yet occurred.

As part of the feasibility study, the USACE contractor (URS, 2009) conducted a structural inventory of most of the two cities (both 100- and 500-year floodplain areas). The inventory was based on structural characteristic data obtained from local tax assessors combined with on-site inspections of structures to collect data on structure types and uses, foundations, exterior materials, roofing systems, first floor elevation, construction quality, and current condition. Cost estimates were generated using the M&S estimation software, while depreciation was calculated by dividing effective age, representing age adjusted for current building condition based on contractor assessments of building condition, by the expected typical life of structures.

The resulting DSRV database obtained from the contractor for this current research effort contained DSRV estimates and a limited amount of structural information for 40,128 SFR structures and 8,956 commercial structures. Parcel identification numbers, addresses, M&S occupancy codes, structure style/type, foundation height, and effective age data were provided. Key missing data were actual age, building life expectancy, size dimensions, condition and quality measures, floodplain status, and tax assessment values. Of particular importance, the provided dataset did not contain depreciation value, nor were non-depreciated structural values included, making the calculation of depreciation rates by comparing non-depreciated and depreciated building values impossible.

Missing information was supplemented by relational joins with tax assessor data and GIS overlays of building footprints within the regulatory (d-firm) 100-year and 500-year floodplain boundaries. For both study locations, the data on building damage exposure, represented by DSRVs within the 100-year floodplain, were first compared across SFR and commercial structures and then by six commercial structure sub-types (industrial, multiple-family, office, retail, and special use). These classifications follow owner occupancy classes (OCC's) developed by M&S that were adopted by both the Sarpy County Assessor and the USACE/URS when compiling DSRV data. Such detailed commercial structural classifications were not available for Moorhead, MN so the comparisons by property sub-types were only undertaken using the Fargo data. DSRVs are compared in terms of absolute values (totals) and on a size-adjusted basis (DSRV per square foot of structure).

Methodologies to compare commercial structure characteristics and DSRVs by floodplain status varied slightly across the two study site locations: In Sarpy County, where only 100-year floodplain areas are mapped, comparisons of 100-year versus non-100-year floodplain areas were made only within neighborhoods (census blocks) close to the 100-year floodplain. In Fargo/Moorhead, where the 500-year floodplain has been mapped, the 100-year floodplain was compared to nearby 500-year floodplain structures.

Finally, measures of central tendency (means, medians, and standard deviations) of structural characteristics and values of commercial structures are compared across floodplain status, and paired t-tests at the 90% confidence level are used to evaluate whether noted differences are statistically significant.

Results

Single Family Residential Versus Commercial Potential Flood Damage

In Sarpy County, 3.6% of all structures were located in the 100-year floodplain versus 5% in Fargo/Moorhead. The proportion of these floodplain structures by property type (SFR versus commercial) and their respective cumulative (total) DSRVs are summarized in Table 1 and Figure 1. Commercial structures only represent 13% to 16% of all floodplain structures (Sarpy and Fargo/Moorhead, respectively) yet commercial damage accounts for 54% of all potential damage in Sarpy County and 50% in Fargo/Moorhead, assuming that all residential and commercial buildings are equally susceptible to flood damage. The discrepancy between structure numbers and damage exposure is likely a result of most commercial structures being larger and more expensive to construct than typical SFR structures. However, it should be noted that these potential commercial flood damage estimates might be exaggerated since some valuable commercial floodplain properties may have higher levels of flood proofing (i.e., raised elevations, special building materials) than exist with SFR structures. Unfortunately, the databases relied on for this study did not have any details regarding the level of flood proofing for individual structures to confirm this hypothesis. Still, the implications from these findings are clear: Commercial flood damage is likely a major component of total flood damage in each of these two Midwestern communities, and not accounting for the predominance of potential commercial damage when evaluating and/or designing flood mitigation/management activities could lead to economically infeasible public policy decisions.

The Characteristics of Potential Commercial Flood Damage

The number and value of commercial 100-year floodplain structures categorized by six property sub-type classifications in Sarpy County and Fargo,

Table 1. Structure frequency versus Depreciated Structural Replacement Values (DSRVs) in the 100-Year floodplain.

	-----------Sarpy County-----------		----------Fargo/Moorhead----------	
Structure Type	**# Structures**	**DSRV (Millions)**	**# Structures**	**DSRV (Millions)**
All	1,239	$369	2,503	$818
Single-family Residential	1,079	$167	2,152	$411
Commercial	160 (13%)	$197 (54%)	351 (14%)	$407 (50%)

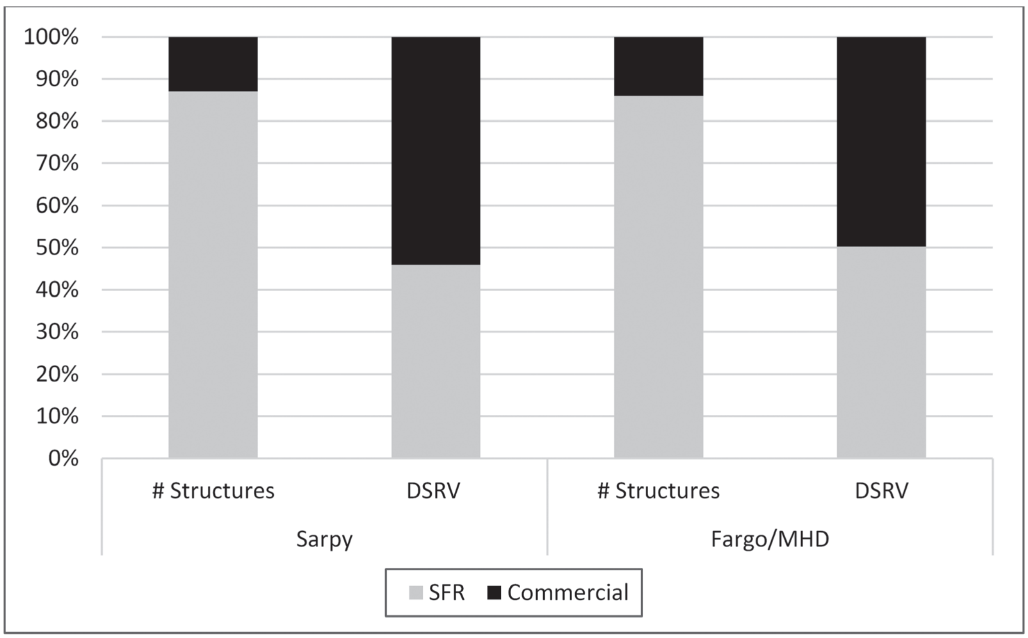

Figure 1. Structure frequency versus DSRVs in the 100-year floodplain. DSRV = Depreciated Structural Replacement Value. SFR = Single-family Residential.

ND are summarized in Table 2 and Figure 2. The types of commercial structures within the 100-year floodplain across the two locations are not identical; the majority (82%) of commercial structures in the Fargo floodplain are special use properties, whereas Sarpy County has a wider variety of commercial property types present. This is likely because the Fargo 100-year floodplain has been well established for many years and the community has been subject to several recent, large flood events, in contrast to the Sarpy County floodplain which was recently re-mapped (i.e., much of it was previously not designated as floodplain) and the area has not had any major flood events in the recent past.

In both study site locations, special use, industrial, and warehouse/storage structures are the most common and correspondingly generate the largest amount of potential flood damage. This bodes well for the use of the cost approach to value potential flood damage for floodplain properties since it is considered a reliable approach to value these types of structures which often do not have income rental revenue streams (used for the income valuation approach), and often do not sell frequently enough to utilize the comparable sales valuation approach. Finally, the finding that the highest valued commercial properties (multiple family residential, office, and retail structures) are

Table 2. Commercial structures and values by structure type in the 100-year floodplain.

	------------Sarpy County------------		----------------Fargo*----------------	
Structure Type	**# Structures**	**DSRV** (Millions)**	**# Structures**	**DSRV (Millions)**
All Commercial	160	$197	289	$357
Industrial	43 (27%)	$13 (6.5%)	5 (2%)	$6.9 (1.9%)
Multi-family Residential	5 (3%)	$26 (13%)	30 (10%)	$3.7 (1%)
Office	16 (10%)	$34 (17%)	0 (0%)	$0 (0%)
Retail	35 (22%)	$32 (16%)	14 (5%)	$8.2 (2.3%)
Special Use	27 (17%)	$83 (42%)	238 (82%)	$337 (94%)
Warehouse/Storage	34 (21%)	$9 (5%)	2 (<1%)	$1.5 (<1%)

*These calculations do not include Moorhead structures, which were not classified by property sub-type.
**DSRV = Depreciated Structural Replacement Value.

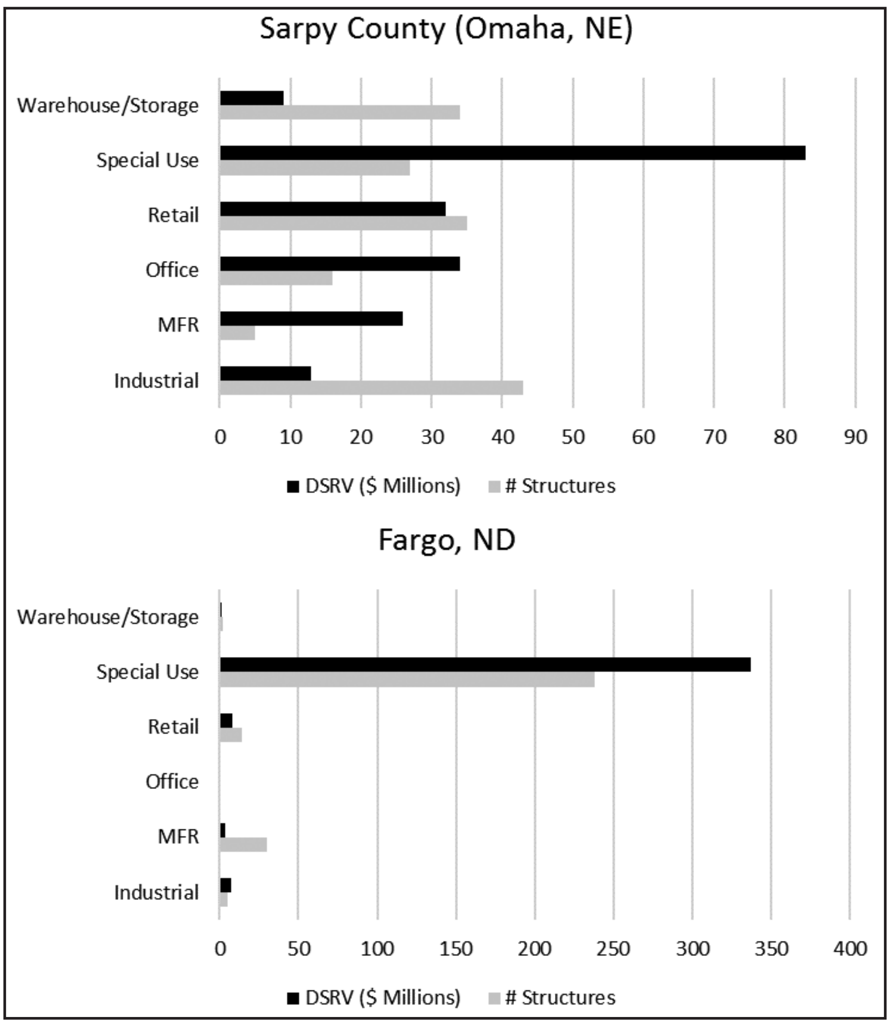

Figure 2. Commercial structures and values by structure type in the 100-year floodplain. DSRV = Depreciated Structural Replacement Value. MFR = Multi-family Residential.

relatively absent from the 100-year floodplain may indicate rational risk avoidance among commercial property owners.

The characteristics and values of commercial floodplain structures by detailed property subtypes (Table 3) indicate a high degree of variation (heterogeneity) in the age and value of structures across each of the six commercial sub-property type classifications. In Sarpy County, office, retail, and special use properties have the highest size adjusted potential flood damage, whereas in Fargo/Moorhead multiple-family and special use structures have the highest damage potential. There are many sub-classes of structure types for industrial, office, retail, and particularly special use categories in both locations and these property types also have a high degree of heterogeneity with regard to average size adjusted prices (as measured by standard deviations). In particular, office, multi-family residential, and special use properties have widely varying potential flood damage costs on a per square foot basis. This indicates that estimating commercial flood damage based on average values and/or sample observations is problematic, particularly when commercial property sub-types differ across areas where estimates and

Table 3. Characteristics of floodplain commercial structures by property sub-types.

	# Sub-Property Types	Most Common Sub-Types	Mean Age (Yrs.)	DSRV*/Sq. Ft. Mean	DSRV/Sq. Ft. Std. Dev.
Sarpy County					
Industrial (n=44)	5	Equip. Shop Service Repair/Garage	25	$24	$15
Multi-family Residential (n=6)	2	High Rise Low Rise	31	$38	$22
Office (n=16)	5	Office (general) Medical Office	26	$65	$44
Retail (n=35)	4	Shopping Restaurants	23	$63	$34
Special Use (n=29)	14	Auto Dealerships Lt. Commercial Utility	14	$56	$51
Warehouse/Storage (n=37)	3	Warehouse Storage Mini-Storage	22	$27	$10
Fargo/Moorhead					
Industrial (n=5)	5	Repair Shop Light Manuf.	38	$72	$19
Multi-family Residential (n=30)	4	Low Rise High Rise	23	$256	$341
Office (n=0)	NA	NA	NA	NA	NA
Retail (n=11)	3	Shopping Restaurants	8	$101	$59
Special Use (n=219)	12	Mixed Use Utilities	91	$168	$82
Warehouse/Storage (n=2)	2	Warehouse Storage	7	$86	$18

*DSRV = Depreciated Structural Replacement Value.

extrapolations are made. It is likely that future efforts to estimate the DSRVs of commercial floodplain properties will have to continue to rely on complete inventories of all structures.

Commercial Structure Characteristics and Potential Flood Damage by Floodplain Status

Commercial floodplain structures in Sarpy County are 26% smaller and 16% more depreciated than nearby non-floodplain properties, but they have similar values, both in absolute and size-adjusted terms (Table 4). Fargo/Moorhead 100-year floodplain buildings were older and 44% less valuable than 500-year floodplain structures (Table 5) but actual depreciation rates were not available for comparison – although it should be noted that mean quality/condition measures were identical across floodplain status. Therefore, the hypothesis that commercial structures in the 100-year floodplain are markedly inferior in construction quality and maintenance as compared to nearby non-floodplain properties appears to hold but the hypothesis that floodplain properties are less valuable than non-floodplain properties

Table 4. Commercial structures by floodplain status (Sarpy County, NE).

	100-Year Floodplain (n=167)		Non-Floodplain (n=1,016)		Difference
	Mean	Std. Dev.	Mean	Std. Dev.	(Floodplain - Non)
DSRV[1] ($)	1,211,133	5,471,387	1,138,961	3,180,360	6%
Total Sq. Ft.	17,495	37,934	23,502	50,876	-26%*
DSRV per Sq. Ft. ($ / Sq. Ft.)	43	36	44	29	-2%
Age (years)	24	18	26	22	-10%*
Quality (M&S[2], 10-60)	20	3	20	2	-1%
Condition (M&S, 10-50)	30	2	30	6	-1%
Depreciation (Assessor Estimate)	36%	30%	31%	28%	16%*

*Statistically significant difference at the 90% confidence level or higher.
[1]DSRV = Depreciated Structural Replacement Value.
[2]M&S = Marshall and Swift cost estimation.

Table 5. Commercial structures by floodplain status (Fargo/Moorhead, ND/MN).

	100-Year Floodplain (n=778)		500-Year Floodplain (n=3,964)		Difference
	Mean	Std. Dev.	Mean	Std. Dev.	(100-Yr - 500-Yr)
DSRV[1] ($)	1,577,205	3,526,660	794,710	1,651,971	98%*
AGSF[2]	25,681	42,493	15,868	31,007	62%*
DSRV per AGSF ($ / Sq. Ft.)	82	42	147	2,106	-44%*
Age (years)	61	28	45	39	36%*
Effective Age	13	8	22	74	-40%*
Quality (M&S[3], 10-60)	30	10	30	20	0%ef
Condition (M&S, 10-50)	30	20	30	30	0%

*Statistically significant difference at the 90% confidence level or higher.
[1]DSRV = Depreciated Structural Replacement Value.
[2]AGSF = Above Grade Square Footage; differs from total square foot values as it exludes below grade (i.e., basement) square footage, and is a more appropriate metric for comparing floodplain versus non-floodplain properties since many floodplain properties do not have basements.
[3]M&S = Marshall and Swift cost estimation.

only appears to hold in Fargo/Moorhead where the floodplain is more established and flood events are more common.

Conclusion

This research has identified a lack of previous studies and reports on the extent of potential commercial damage exposure in the U.S. It has also demonstrated that in at least two medium sized Midwestern urban areas, commercial structures make up a large share of building exposure to flood hazards. It is proposed that this research be replicated in other geographical locations across the U.S., particularly in non-urbanized areas, which may contain relatively smaller frequencies of commercial structures (even though such areas are likely to have fewer structures and hence relatively less potential flood damage). If it is confirmed that commercial flood damage is a major part of total flood damage exposure in other regions of the U.S., it is recommended that these values be more explicitly quantified and reported by Federal agencies (NWS, NFIP, and USACE) as well as by state and local governments and/or floodplain managers.

Since this present research focused only on potential flood damage exposure, it is recommended that future research efforts attempt to quantify the relative amounts of commercial versus SFR flood damage associated with actual flood events. This would likely involve detailed reviews of local, state, and federal flood damage inventories and classifications combined with reviews of NFIP and private insurer claim payouts and Small Business Association disaster lending. It may be the case that actual commercial flood damage is less than potential flood damage due to the hypothesis that many commercial structures at risk of flooding (i.e., in the 100-year floodplain) have been subject to certain degrees of flood-proofing measures.

This research indicates that the owners of commercial structures appear to recognize the risk of flooding in that commercial structures are older, less well maintained, and less valuable than nearby and similar structures (i.e., same property types) that are not in the floodplain. This finding should be supplemented by additional research that quantifies both spatial trends in commercial damage exposure, and the extent to which commercial floodplain properties are flood-proofed and/or have flood insurance coverage through either the NFIP or private insurance. If commercial property owners are under-insured for flood risk and instead rely on government disaster recover support such as Small Business Administration (SBA) disaster recover loans or SBA disaster lending, this may demonstrate a public policy inefficiency.

Finally, additional research is recommended to develop approaches to more efficiently estimate potential flood damage to commercial structures in light of the fact that structural inventory databases analyzed in this study are very time consuming and expensive to create. New approaches for classifying different types of commercial structures with relatively heterogeneous structural characteristics and DSRVs is likely required. Such research would also facilitate the development of more accurate depth damage curves for different types of building structures. Future research could potentially be facilitated through the continued use of actual USACE inventories, collaborations with county tax assessors who utilized the cost approach for assessing commercial properties, and/or through collaborations with cost estimation companies. Optimally, this research could facilitate the correction of commercial flood damage estimates generated by the FEMA-HAZUS data set of potential flood damage, so widely utilized by flood mitigation professionals around the nation.

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